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AUTHOR	Pella, Milton O.; And Others
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ABSTRACT

This document presents the lesson plans and tests used in the research study reported in Technical Report 173 (ED 070 658), together with descriptions of models and films developed for the teaching program. Thirty-one lessons are included, covering the topics of matter and energy; making interferences; particles; a model for matter; particles and spaces; particle size; motion of particles; expansion and contraction; solid, liquid, and gas structures; boiling and condensation; melting and freezing; pressure; elements, compounds, and mixtures; atoms and subatomic particles; electric charges and forces; isotopes; and molecules. Each lesson provides the teacher with background information on the topic covered and on suggested teaching procedures, lists the materials needed for the lesson, and outlines the procedures to be followed. Material for a series of 54 transparencies and test questions for evaluating student achievement are included. (DT)

CLASSROOM MATERIALS FOR TEACHING "THE PARTICLE NATURE OF MATTER"

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CENTER FOR
COGNITIVE LEARNING

ED 094958

Practical Paper No. 173

(Issued in conjunction with Technical Report No. 173)

CLASSROOM MATERIALS FOR TEACHING "THE PARTICLE NATURE OF MATTER"

by

Milton O. Pella, Richard A. Green, Rodney L. Doran, and Robert Roy

Report from the Project on
Prototypic Instructional Systems: Science
Milton O. Pella, Principal Investigator

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
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Statement of Focus

The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This Practical Paper and Technical Report are from the Prototypic Instructional Systems in Elementary Science Project in Program 2. General objectives of the Program are to establish rationale and strategy for developing instructional systems, to identify sequences of concepts and cognitive skills, to develop assessment procedures for those concepts and skills, to identify or develop instructional materials associated with the concepts and cognitive skills, and to generate new knowledge about instructional procedures.

Contents

Abstract

This Practical Paper, published in conjunction with Technical Report 173, presents the lesson plans and tests used in the research study, together with descriptions of models and films developed for the teaching program.

I
Introduction

The following lesson plans and tests, together with the descriptive models and films, are discussed at length in the accompanying paper, Technical Report No. 173. They were revised many times based on the results of their use in pilot projects with individual pupils, small groups, and entire populations of elementary schools. The teaching materials included in this practical paper are slight modifications of those used in the study.

The lessons, tests, and visual aids that follow are published as a practical paper for the convenience of the teacher who may wish to use these materials; it is urged, however, that the research basis for these materials be thoroughly examined before utilizing the lessons in the classroom.

II
Lessons

The lessons in this unit are designed to provide opportunities for young children to learn more about how problems resolved by theory development are attacked. The first lesson aims at the development of classificational concepts where the learner forms operational definitions of matter and energy. In the following lessons the learner is assisted in evolving a model for matter that enables him to explain natural phenomena.

Throughout the lessons the rules for theory formation are followed. The learner is reminded that theoretical models must be useful in explaining specific natural phenomena if they are to be retained and that there are no general models of matter separate from a natural phenomenon involving matter. As the learner proceeds he finds that a model that is useful in explaining a change in the phase of matter from liguid to gas is not necessarily adequate to help explain chemical changes. To the learner, the adequacy of the model must always be judged from the frame of reference of the phenomenon to be explained.

In the lessons the student experiences a natural phenomenon, judges some models, and suggests or judges modifications of a model. Opinions concerned with concept teaching in science are somewhat confused; hence, you are alerted at this point. There are some teachers who believe that the students should discover the theory and there are others who say that discovery of a theory is impossible since theories are inventions of the human mind. The procedure followed here is based on the opinion that theories evolve as more facts are accumulated and as more ideas are invented by people; theories in science are invented by people and not discovered in nature. If you wish to believe that the processes involved in making inferences are discovery you may say that some discovery takes place here.

The lessons that describe the teaching procedure include extensive use of mechanical models and films for suggesting ideas to the learners. The learner judges the reasonableness of adding each inferred idea to the model to be used in explaining the phenomena. Some ideas he accepts, some he rejects, and some he modifies. The factors used in modifying an existing concept to meet the requirements of a new situation are introduced singly so the learner is protected from confusion that is consequent to "too many factors" at one time.

Pupil activity, in addition to manipulating apparatus, witnessing demonstrations, and viewing films, involves the building of models on an overhead projector. The overhead projector activity appears to help the pupils to build mental models involving the idea of particles.

Lesson 1
Matter and Energy

Prerequisite Concepts

1. All objects and phenomena are classified as matter or energy.

2. Anything that has weight and occupies space is classified as matter.

3. Anything that causes changes in matter is classified as energy.

Teacher Orientation

Since (a) the scientific study of natural objects and phenomena begins with assumptions and definitions and progresses in a semiorderly manner to concepts related to the natural world and (b) learning proceeds, generally, in a sequential manner from simple to complex concepts, the teaching procedure begins with the development of two working or operational definitions. These definitions are based on the fundamental assumptions in science; however, the assumptions are not discussed with the class. The teacher should recognize the basic assumptions to be the reality of time, matter, and space. Only when these assumptions are accepted can useful definition making proceed.

Classification utilizing the procedure of forming operational definitions includes the description of an object or phenomenon in terms of mutually inclusive and mutually exclusive factors. Most definitions begin with gross observations and evolve from more detailed data.

Observations made by a mature individual are restricted, since they are based upon purpose. However, the observations of small children appear to be erratic; if they have a purpose it is not communicated. In the teaching process the strategy employed to cause the desired observations to be made must, therefore, vary with the maturity of the learner. The procedure employed here is that of directing the attention of the child to changes.

It is recognized that this lesson involves use of the concept of conservation of matter; however, if the lesson is conducted as directed, the lack of formal experience with this concept does not appear to be a problem. The concept of conservation of matter essentially is "Matter can be neither created nor destroyed." This concept is credible throughout the universe if you accept the universe as a "closed system."

In this lesson the children are to be assisted in generating operational definitions of matter and energy that are based upon gross observations. Some of the activities suggested may be used as demonstrations in grades 2 and 3 and as laboratory activities in grades 4, 5, and 6. The number of pieces of apparatus needed depends upon how the activity is utilized in teaching.

Materials

Spring balance or beam balance and weights

Beaker—500 ml

Ice—about 300 gm

Stirring rod

Heat source—Propane burner

Ring stand or tripod

Inflated football or basketball

Transparencies: 1, "WATER HEAT MATTER ENERGY"

2, "Matter can be weighed on our scale. Energy cannot be weighed on our scale."

Procedure

The fact that ice melts or that ice changes to water is commonly accepted by children in nearly all of the elementary grades. Most children in these grades, however, cannot explain melting in terms of energy. Ice is selected for use in this lesson because it is readily available and is easily handled. The teacher will introduce the lesson with a demonstration that leads to discussion and some possible cooperative planning of an experiment.

Demonstration. Add a quantity of ice to a beaker and place this on a support within the view of pupils. Tell the pupils the material in the beaker is ordinary ice.

Teacher: "How much ice do we have in the beaker?" (Answer: 4 chunks, half-full, 1 pound, 4 pieces each 1 1/2 inches square, etc.)

Teacher: "How can we find out how much ice we have so that we could tell someone else? (How is ice sold in markets?)" (Answer: Weigh it or measure it. A reasonable answer is to weigh it.)

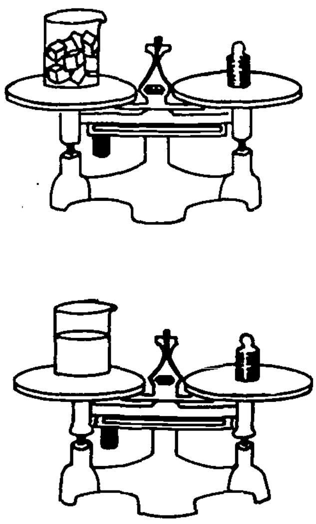

Figure 1.1. Melting ice

The teacher places the beaker and ice on a balance. If the desire is to follow more of the suggestions of the class members or in case they express the quantity in other ways, have additional quantities of ice available. After the ice is weighed the number is recorded.

Teacher: "How can the ice be changed?" Or if the ice is melting the question will be "What is happening to the ice?" (Answer: Make the ice melt. The ice is melting. Heat the ice.)

Teacher: "If heat is added to the ice what will happen?" (Answer: The ice will melt. The ice will change to water.)

Teacher: "If the ice melts will the water weigh more than the ice, less than the ice, or the same as the ice?" (Answer: All will be picked by some.) "How can we find out?" (Answer: Weigh a beaker of ice, melt the ice by heating, and weigh the beaker and contents again.) Teacher and pupils together will carry out the experiment.

Place about 300 grams of ice in a 500 ml beaker and weigh it with a beam or spring balance (kitchen scale will work). Be sure the exterior of the beaker remains dry. The heating of the beaker and contents must be carried on carefully so water does not splash out or boil away. Gentle stirring is of some help. When nearly all of the ice is melted, remove the heat and weigh the beaker and contents again. Record the weight.

Teacher: "Compare the weight before melting with the weight after melting." (Answer: They are the same.) "What did we add to the ice?" (Answer: Heat.) "Does it appear that we can weigh heat?" (Answer: No.)

[You may wish to extend this idea to light. Place a flashlight on the balance when the bulb is not lighted. Reweigh it when the bulb is lighted. Weigh an electric bell not ringing and ringing. Heat, light, and sound are called forms of energy. Does it appear that we can weigh energy?]

Teacher: "What can we weigh?" (Answer: Water and ice.) "How do water and ice differ from heat?" (Answer: Water and ice can be touched and weighed; heat cannot.)

Use Transparency No. 1. Show "water—heat," then uncover "matter—energy."

Use Transparency No. 2. Emphasize matter can be weighed on our balance and energy cannot be weighed on our balance.

Teacher: "What other things are matter." (Answer: Chair, desk, chalk, people, etc.) "Is air matter or energy?" (Answer: Varies.) "How can we tell?" (Answer: See if we can weigh it.)

Activity. Weigh an inflated football. Allow the air to escape and weigh it again. Have some members of the class witness the escape of the air.

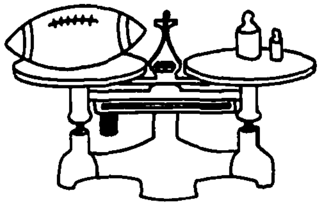

Figure 1.2. Weighing air in a football

Teacher: "Is air matter or energy?" (Answer: Matter.) "Why do you say this?" (Answer: It can be weighed.)

Use Transparency No. 2, "Matter can be weighed on our scale. Energy cannot be weighed on our scale."

Teacher: "We are going to spend most of our time working on matter. We must, however, also be able to tell matter from energy. You have seen energy do something to ice. What was that?" (Answer: Melt it.) "You saw what happened to the bell when it was connected to the battery. Tell us." (Answer: It rang.) "What happened to the light bulb when the switch was turned on?" (Answer: Gave off light.) "We saw that the matter was changed every time. Ice was changed to water, no sound to giving off sound, no light to giving off light. Energy can change matter. Matter we can weigh. Energy we cannot weigh."

Lesson 2
Making Inferences

Process Concepts

1. Evidence in science may be gathered by indirect means.

2. In science theoretical models are developed that help in explaining observations made in nature.

Teacher Orientation

The nature or structure of matter has been the subject of interest, study, and speculation for many centuries. There have been the ideas that "matter is continuous" and that "matter is made up of particles." The appearance of a vessel of water or piece of iron causes one to think of matter as being continuous. If the disappearance of water by evaporation is contemplated very carefully, the particle idea becomes preferred. To some ancient scientists like Aristotle (384-322 B.C.) the smallest particle of matter was determined by the method employed in cutting the matter. He believed that matter could be cut into smaller and smaller pieces. To other scientists there was a smallest particle of matter; a particle that was not cutable was called an atom. (Democritus, 460-370 B.C. & Dalton, 1766-1844).

It is not always possible to make direct observations of natural phenomena by smelling, seeing, tasting, hearing, or feeling. Sometimes it is necessary to employ man-made devices and sometimes it is necessary to make inferences.

Inferences made in science are usually of two types: inferences from part to whole and inferences of fact translation. In both types there is complete dependence upon facts, that is, on observations. If you see a large antenna on a house, you infer that the occupants also have a T.V. set. If you see a doghouse in a yard, you infer that there is a dog. If you see one part of an animal, you may infer that the other parts are present. These inferences of whole from part are the result of past experience. The facts you observe are compared with the whole experiences you have had in the past. Your thoughts go something like this when you observe the furry tail of an animal while walking in the woods. What do I know from the past that has a tail like that? Dog, cat, fox, skunk, raccoon, monkey, cow, horse, etc. You then compare what you see with what you know. It is probably not a monkey if the observation was made in the upper temperate zone. It cannot be a horse or a cow if it is small. If it has a plume-like tail, it is probably not a cat. If the fur forms rings of dark and light colors, it could be a raccoon but not a skunk and probably not a dog. If the tail is a solid color, it is probably not a raccoon. It could be a dog or a fox. If the animal waved the tail back and forth in a leisurely manner, it could be a dog. No matter what your inference is concerning the rest of the animal, there is a probability that you are wrong. Your probability of predicting precisely depends upon how many facts you have from the present and how many related facts you can recall from the past. The inferences that involve the translation of fact from one situation to another are similar to the part-to-whole inferences.

Have you heard a sound caused by the wind during the night and thought it was someone walking into your house? When you did this you translated one fact to another. In the box activity in this lesson, the pupils are asked to transfer facts they have collected from a variety of sources to a new situation and to develop a composite by placing the facts together. The pupils will build a model of an unknown by observing facts indirectly and then making inferences.

The model to be developed here is not a replica of something. The model here is an idea of what something may be like. A model of a railroad train is a replica and a model of an atom is an idea. Models may be in the mechanical, mathematical, or verbal form.

Model formation is very important to all parts of our society and not just to science. Bioengineers are able to form models of the spread of disease and thus plan the distribution of vaccines or other therapeutic activity. The models bioengineers develop are based upon related facts gathered over a period in history and from them inferences are made.

Whenever inferences are to be made the most useful question is, "What do I know from my experience that acts like what I see, hear, taste, feel, or smell?"

Materials

Overhead projector

One large sealed box that contains an object. (The object should be one with properties that may be inferred from indirect observation—hard cylindrical, spherical, vibrates, has a flat side, etc.)

Small sealed boxes that contain one or more objects with properties similar to those of the object in the big box. (It is advisable to have as many boxes as pupils in the class.)

Transparency No. 3 "Many things can be learned about objects without really seeing them."

Procedure

Demonstration. Hold the large sealed box so all pupils can see it; be careful not to shake or tip it to give clues.

Teacher: "What does the box contain?" (Answer: Air, matter, energy, nothing, etc.) "How can we get a hint of what is in the box?" (Answer: Shake it.) "Why would I want to shake the box?" (Answer: To see what kind of a noise it makes.) "What kind of noise are you looking for?" (Answer: If it thumps in the box, the something could be hard. If it gives a ringing sound, it could be glass

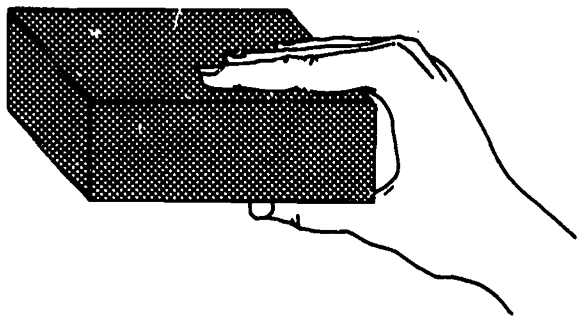

Figure 2.1. The black box

or metal. If there are two sounds, there may be two objects. If it goes "wosh wosh," it may be a soft object.) "Do these noises really tell you what is in the box?" (Answer: No, but we can guess what there is in the box from the noise.) You are doing what scientists, engineers, and people who study natural objects in the universe do. You make observations and then you try to remember when you noted that before. You guess about what you now see by recalling your past.

Step two is concerned with forming a model of the object in the box. The model is to be an idea and not a replica.

Teacher: "Let us see how many things we can learn about this object without opening the box. We have shaken the box and found that the object was a solid. What do we do next?" (Answer: Tip the box so the bottom is at a slant.) "What is the purpose of this?" (Answer: If the object is round, it will roll to the low side.) "Does this tell us it is round like a ball or round like a piece of chalk?" (Answer: You have to tip the box several ways to find this out.)

The teacher, with the help of the pupils, will perform each experiment as it is requested. The pupil should always know why the teacher is making a request and what kinds of data he will collect. The information gained will be the facts. The inferences made by the pupils become the facts related to the unknown. The data are tabulated for all to observe.

Teacher: "Now let us see if we can draw a picture or describe what the object seems to be like. We want to know what is your idea about the object?"

Each child will contribute to this activity or each child may write or draw his own description. Remember that the model is just an idea. The box is never to be opened so the nature of the contents is never known.

Laboratory Activity. Each child will use a separate sealed box and will try to describe the contents. The teacher should help the pupils to start the investigation and then move around the room so each child can operate independently.

Following the activity the class discussion will consist of having individual pupils describe the contents of the box and the nature of the evidence they used.

This activity may be followed by another in which each child is allowed to make up an "unknown box" and bring it to school where the children may exchange them and describe the contents.

Close the lesson with Transparency No. 3, "Many things can be learned about objects without really seeing them."

Teacher: "This lesson was to help you understand how we are going to study matter. We want to build a model for matter and we cannot get inside it to learn exactly what it is like. I think you will be able to build a model anyway."

Lessons 3-4
Matter and Particles

Concept 1: All matter is made up of particles.

Background Information

This information is presented to the teacher with no intent that it is to be passed on to the students. The desire is to provide the teacher with the opportunity to gain a more complete understanding of the development of the concepts included.

Historically, matter has been looked upon in two ways; it is continuous or it is discontinuous. Those who looked upon matter as continuous thought there were no discrete particles of matter and the size of the smallest particle of matter was determined by the skills of the person or machine doing the cutting. Aristotle believed that matter was continuous and he said that the size of the smallest particle was "determined by the keenness of the blade." When you look at a piece of glass, iron, or rock or test these materials in a variety of ways, it looks as if they are continuous. The continuous model for matter is not a very useful one.

To those who look upon matter as being discontinuous, matter is made up of particles. The particles of each material have a precise size. You may think of matter first as made of many particles, like a box of buckshot. The idea of particles is very useful. The particle theory of matter has been the one that has been most popular for the last 150 years.

In 1803 John Dalton, an English school teacher, consolidated the historical information related to the structure of matter while working on the problem of gases dissolving in liguids and thereby formulated what has become the atomic theory. This theory was useful to him in explaining what he had observed. In the theory, Dalton assumed that all matter is made up of little particles called atoms, that these particles cannot be subdivided or changed into one another, and that atoms can be neither created nor destroyed. He further assumed that atoms of a particular element are identical in shape, size, mass, and all other properties and different from other elements in these properties. He also proposed that a chemical change involves the joining together or separating of atoms.

Dalton's theory has remained very useful to scientists through the years, even though it has been periodically modified. Today we believe that atoms can be divided into even smaller particles: namely, protons, neutrons, and electrons. We also believe that atoms can be changed to other atoms and matter can be changed into energy in nuclear reactions. However, for the purposes of these lessons one can think of atoms as the fundamental particles of matter.

When teaching these lessons it will be better not to mention the terms "atom" or "molecule," but instead to talk about "particles of matter" or "little pieces of matter." The particles will be discussed and given their proper names later on in the unit.

Studies of the structure of matter have led to the formulation of ideas related to the shapes of molecules of many materials. For example, water molecules are made up of hydrogen and oxygen and it seems the atoms have a definite geometric relationship. Figure 3.1 represents a molecule of water, two atoms of hydrogen and one atom of oxygen arranged in a particular way. To deal with a particle of water as complicated as this at this stage of instruction leads to confusion; hence, a "particle" of matter will simply be represented by a single particle in the models we build.

The solutions formed in these lessons are

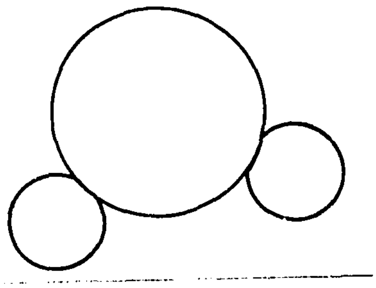

Figure 3.1. A model for a water molecule

considered to be homogeneous mixtures of two or more components. Therefore when they are explained via the particle theory of matter, they are considered to be two or more kinds of particles mixed together. Figure 3.2 is one way of representing a solution of water and potassium permanganate. Figure 3.3 is a means of representing sugar dissolving in water.

The main concern in these lessons is to develop the idea that matter is made up of many small particles. In addition, you are developing the idea that a scientific model is an idea or a construct to help explain observed phenomena. Thus, it is not a model of what matter looks like, but rather a bridge between the real world of people and the concept of the particulate nature of matter. A model is a good model only as long as it is useful in explaining something.

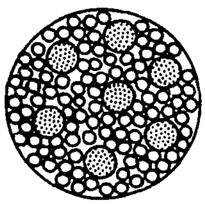

Figure 3.2. A model for $KMnO_4$ dissolved in water

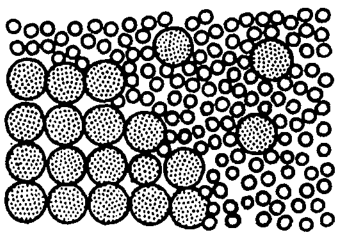

Figure 3.3. A model for sugar dissolving in water

Lesson 3
A First Model for Matter

Teacher Orientation

Inference is an important but complex process in science. In the experiment with the sealed box the attempts were: (a) to collect facts, (b) to find like facts from experiences in our background which could serve to relate the observed facts as an important frame of reference, and (c) to construct a model of the unknown (object in the box) studied in the experiment. In the process of model building, the one who makes the inferences as a result of correlating observed facts in an experiment with facts from past experiences assigns what he believes to be logical properties to the model he builds. The model is developed in the mind of the builder but he never sees if his model is correct. All he knows is that the model he constructs helps him to explain what he wants to explain.

Imagine that the following tests were performed on the box you had.

Question: What are the properties of the contents of the box?

Experiment Activity	Result	Past Experience	Inference
1. Shake box (fact).	Thumping sound (fact).	When a solid object is in a box and the box is shaken, thumping noise is produced.	Because the facts of the experiment are the same as the facts of past experience, we say the object in the box is solid.

Question: What is the shape of the object?

Experiment Activity	Result	Past Experience	Inference
2. Tip box so bottom surface is tilted from right to left.	Sounds as if the object rolls to the lower level.	When objects roll down a slanted surface, they are round like a cylinder or round like a ball.	Because the facts of the experiment are the same as facts related to spherical objects and facts related to cylindrical objects, we say the object is either round like a ball or round like a cylinder.

Question: Is the object spherical or cylindrical?

Experiment Activity	Result	Past Experience	Inference
3. With the box tipped from right to left, also tip the box from back to front.	Sounds as if the object slides to the front of the box.	A cylindrical object in a V-shaped track, such as the corner of a box, will slide when the track is slanted. A spherical object will roll.	Because the facts of the experiment are the same as the facts from experience related to cylindrical objects, we say the object is cylindrical in shape.

If all you wanted to explain is the thumping noise, you could have stopped your inferences with Step 1. If you wanted to explain Question 2 only, you could go through Steps 1 and 2. If you wanted Question 3 explained, you would go through Steps 1, 2, and 3.

The nature and extent of the experimenting and inferring depend upon the question that is to be answered. Because the function of science here is to explain natural phenomena, the investigator must be careful to ask questions that can be answered. It is obvious that asking questions is the most important part of investigating any part of nature. The quality of the answer to a question is never better than the quality of the question.

The process of forming ideas or models involves inferring and inventing and each model includes many inferences and probably a variety of inventions. In this project the models of matter to be formed will help us to explain several things. The model will have to start out to be very simple and gradually evolve as more demands must be met. Remember that the model to be developed here is to be an idea, not a replica. Theoretical models are not replicas; however, they are representatives. As the theoretical model "the Particle Nature of Matter" is developed, you must be sure that two requirements are satisfied: (a) Does the model agree with the facts observed? and (b) Is the model useful in explaining what you want to explain? In the practice of science only the facts are discovered. Very few if any authorities would classify the collection of facts as science. Science results in the way the collected facts are treated.

Materials

Overhead projector

Transparencies

4, "Can we determine some of the characteristics of an object we cannot see?"

5, "What has happened to the sugar?"

6, Diagram of a beaker

7, "Matter is made up of particles."

Teacher demonstrations:

3 1000-ml beakers

1 50-ml beaker

30 gm sugar

1 stirring rod

750 ml water

200 gm sand (dry)

150 gm small glass beads

food coloring

transparent colored disks

solid blue cellophane

transparent material the same size as the blue cellophane

Student kit (one per student)
- 1 50-ml plastic beaker
- 1 teaspoon of salt
- 1 medicine dropper
- 1 paper towel

Procedure

Project Transparency No. 4, "Can we determine some of the characteristics of an object we cannot see?" Review the sealed box experiment with emphasis upon the following ideas: (a) We compared some sounds we got by moving the box with other sounds we knew. (b) We made a model of the object in the box. (c) We never really knew what was in the box.

Teacher: "Today we are going to try the idea of building a model of some water and sugar to see if we can develop an idea that will (a) fit the facts and (b) help us explain what we observe. Are we working on matter or energy here?" (Answer: Matter.)

Teacher: "What was the first thing we did with the sealed box?" (Answer: Shook it, tipped it, moved it around, etc.) "What were we trying to do?" (Answer: Find out as much as we could about what was in the box.) "We made some observations; we collected some facts."

Demonstration. To about 750 ml of water add about 30 gm sugar and stir the mixture until the sugar is dissolved. Each pupil should be sure to observe what the sugar looked like and what the water looked like before and after mixing. The question, "Can you see the sugar in the beaker?" should be asked often.

Project Transparency No. 5, "What has happened to the sugar?" (Answer: Dissolved in the water.) (Pupils use and attach some meaning to the term "dissolve"; however, the intent seems to be to name rather than to explain.) It is well to discuss the term if it is given.

Teacher: "How can you find out if the sugar is still in the beaker?" (Answer: Taste it, evaporate the water, etc.) Note: Tasting is a very poor method for detecting the presence of chemicals, hence it should not generally be used.

Pupil Activity. (The pupils may carry out the following activity if desired.) Add one half teaspoon of sugar to about 30 ml of water in the beaker. Stir until the sugar is dissolved.

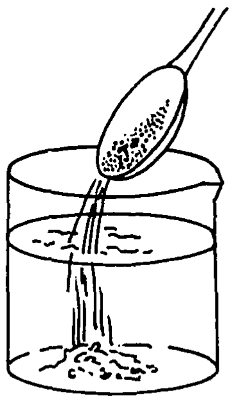

Figure 3.4. Dissolving sugar in water

Teacher: "What has happened to the sugar?" (Answer: Dissolved.) "Where would we find the sugar?" (Answer: In the beaker with the water.) "Would it be near the top, bottom, middle, or some other place." (Answers will vary.) "How can we find out where the sugar is in the beaker?" (Note: The desire is to assist the pupils in finding that the sugar is distributed throughout the water and is not concentrated in one place.) (Answer: Take a small amount of liquid from different parts of the beaker; if the samples taste sweet, we know that sugar is present.)

(Note: The teacher will demonstrate how a sample of the mixture may be taken from different locations in the beaker. Later, if desired, the individual pupils may perform the activity. Depress the bulb of the dropper and insert the glass part so the open end is at the location from which you wish to draw a sample. Release the bulb. When the bulb is fully expanded, remove the dropper and place a drop of the solution on your finger. Taste the mixture. If this is to be a class activity have different parts of the class take samples from different parts of the beaker. If this is a demonstration, the testing can be performed by moving around the class with the samples so different pupils may participate.)

The results are tabulated on the chalkboard or on a transparency.

Teacher: "What do we learn from the results?" (Answer: The sugar is all over in the water.) "Could we see the sugar?" (Answer: No.) "Water?" (Answer: Yes.) "We have used only one observation — tasting. Let us try out something else to see if we can see the other material."

Demonstration. To about 500 ml of water add about five drops of food coloring. Stir the mixture.

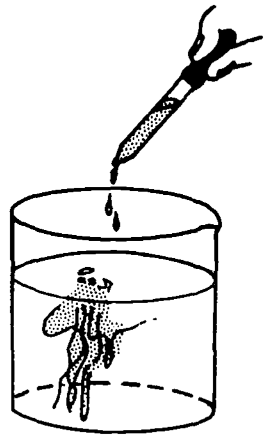

Figure 3.5. Food coloring being added to water

Teacher: "Can you see the food color?" (Answer: Yes.) "Where is it located?" (Answer: All over the beaker.) "What could water be like and what could sugar and food coloring be like for this to happen? We are now going to try out our sealed box idea of study." (Answers: None may be given because this is new procedure.)

Teacher: "You may not remember examples so we can try to refresh your memory. Have you ever seen sand and stones together?"

Demonstration. Place 200 gm of sand in a beaker and to this add 150 gm of glass beads. Stir the sand and beads. Teacher: "If we believe that this is like our sugar and water, which would be the water and which the sugar?" (Answer: Water is like sand, sugar is like beads.) "Can you see the beads?" (Answer: Some next to the side.) "How can we find out if the beads are all through the sand?" (Answer: Take samples of the sand out to see if there are beads in it.) (Note: The teacher, assisted by the pupils, will remove different samples of the mixture to see if there are beads present.) "How is this like the sugar and water?" (Answer: The beads are mixed in with the sand. Each part of the beaker includes sand and beads just like the beaker of sugar

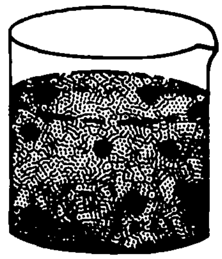

Figure 3.6. A model for sugar water

and water.) "If we use these materials how can we make this into a model for sugar and water?" (Answer: The sand is the water, the beads are the sugar, and the beads are distributed throughout the sand.) "What kind of a model for water have you formed?"

Teacher: "In this model you have decided what water could be like. Is it sensible to believe that the water in the beaker is made up of little particles? Is it sensible to believe that the sugar and the food coloring consist of particles? Before we answer let us remember

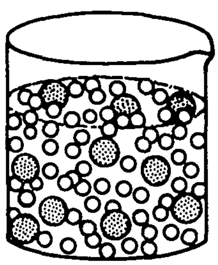

Figure 3.7. Model for sugar and water

what these ideas must help us to do. Repeat — The ideas must help us explain what we see and the ideas must fit what we see."

Place Transparency No. 6, the diagram of a beaker, on the projector. Add colored disks to the transparency so they appear to be in the beaker.

Teacher: "If these dots are water where would they be placed?" (Answer: All over inside the beaker.) "If these smaller dots are the sugar where would they be placed?" (Answer: In between the water particles but all over the beaker.) Is this a good model?" (Answer: It does help us to explain what we see.) "In this model we said that water is made up of particles and that sugar is made up of particles. Let us try another idea for the water and sugar."

Demonstration. Place a piece of solid blue cellophane on the projector. Have available another piece of transparent material the same size and shape as the blue and also some of the colored dots to use as sugar. Teacher: "If we let the blue be the water, what would we use for sugar?" (Answer: Something in the blue.) (Try by placing another color over the blue.) "Does this help us explain anything?" (Answer: No.) (Try placing the dots on the blue.) "Does this help us explain anything?" (Answer: It could.) "What is wrong with this model?" (Answer: The water looks solid and we make believe that the sugar is on the water. We know that the sugar is in the water.) "Which of the models we have formed so far is the best?" (Answer: The one with the two kinds of dots mixed together.) "In the model we selected, we agreed that we would say that matter is made up of particles."

Project Transparency No. 7, "Matter is made up of particles." It is a good model because it helps us to explain the sugar and water.

Lesson 4
Testing the Model

Teacher Orientation

Models that are useful in only one situation are not as valuable as those that are useful in more than one. The desire is to develop a model that is simple and with wide applicability.

The student is here asked to apply the model he used to explain a natural phenomenon.

Materials

Overhead projector

Transparency No. 6, Diagram of a beaker

Transparent colored disks (red and white)

Crystal of potassium permanganate

2 petri dishes

1 forceps

1 stirring rod

Procedure

Project Transparency No. 6, the diagram of a beaker. Teacher: "If we wished to show that there is water in the beaker, what could we do?" (Answer: Draw a line alone at any level. Place a color over the bottom part of the drawing. Place some dots in the beaker.) "Why is any one of these methods satisfactory?" (Answer: All we want to do is show that there is something in the beaker. We do not have to explain anything.) "What kind of a model did we talk about yesterday?" (Answer: Matter is made up of particles.) "Why did we use this model?" (Answer: We wanted to explain sugar in water. The sugar was all over the water.) "Is water really made up of particles?" (Answer: It could be. It seems as if it is. No one really knows.) "What other idea could we have about what water is like?" (Answer: It is not made up of particles.)

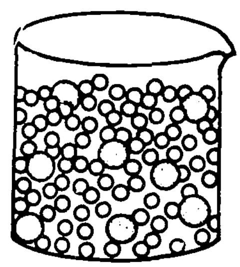

Figure 4.1. Model for a beaker of sugar water

Teacher: "Today we are going to try to explain another thing."

Demonstration. Place one petri dish containing water on the overhead projector. Place an empty petri dish near the first so that both are projected.

Teacher: "What do we observe at present?" (Answer: One dish contains water and the other does not.) "How could we show this by using the idea of a model?" (Answer: Place anything that could represent water in a circle.)

Add the crystal of potassium permanganate to the water in the petri dish and stir. Teacher: "What do you notice?" (Answer: The color of the water changes.) "Are you sure you changed the color of the water? When we added beads to sand, did we change the color of the sand? The sand and glass bead mixture did look different from the sand or glass beads alone." (Answer: We could have added materials of another color. We couldn't really see the water anyway so it is possible that we are seeing the other stuff.) "Let us review the things we have seen." (Answer: Water in the dish. When other material is added we notice a color change.) "What do we want to explain?" (Answer: The color being all over in the water.) "What materials do we have?" (Answer: Water and the colored material.)

Figure 4.2. Dissolving $KMnO_4$ in water

Either draw a circle on the overhead projector or use the empty dish to develop a model. This is the cooperative task of the teacher and pupils.

Teacher: "If we wish to explain how this color is distributed in the water, what kind of model for matter could we use?" (Answer: Put in a red disk.) "If a red disk is put in do we have water and the other material or do we just show what it looks like?" (Answer: Just shows what it looks like.) "We want both the water and the color." (Answer: Place some white dots and red dots mixed together.) This is performed by one of the pupils and the class will judge the adequacy of the model in terms of the requirements: (a) Water and colored material are both present. Two kinds of matter are present. (b) The color and water are equally distributed throughout the sample.

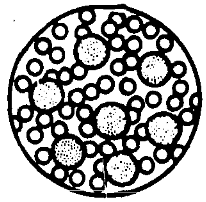

Figure 4.3. A model for $KMnO_4$ dissolved in water

Teacher: "What model for matter is useful here?" (Answer: The idea that matter is made up of particles.) "How many kinds of matter did we have?" (Answer: Two.) "How many kinds of particles did we show in the model?" (Answer: Two.) "Were the particles of each kind of matter in one place or spread out?" (Answer: Spread out.) Is this model useful? If it is, someone must explain the colored water using the model." (Answer: The particles of colored material represented by the colored dots are spread out between the particles of water represented by the clear dots. It looks red because of the colored dots.)

Lesson 5
Particles and Spaces

Concept 2: Particles of matter have spaces between them.

Background Information

A statement of high obvious credibility is "Before a phenomenon can be explained that phenomenon must be established." This means that before you explain something, that something to be explained must be known. Such a generalization is of great importance in teaching the concepts in the particle theory of matter. The concepts have no value to the learner unless he has knowledge of what they are used to explain. In this procedure you should follow the learning principle "Begin with the concrete and go to the abstract"; begin with the observations and progress to the theories.

In this lesson the inadequacy of the concept "matter is made up of particles" becomes evident; the concept does not help us explain what we see. The choices now available become: "Discard the idea that matter is made up of particles and form a new theory" or "Modify the theory we now have so that it fits the past experiences and this new experience." In science this is a continuous option so the scientists have decided on a way to deal with the decision-making process. Their rule is to modify an existing theory rather than create a new one whenever possible.

When we approach the problem in this lesson, the options should be open to the learners because the desire is to teach the process concept as well as the product concept. It is important to have knowledge of the ideas of how nature seems to operate and also of how man has come to understand nature.

When salt and water or alcohol and water are mixed together, the volume after mixing is not equal to the sum of the two volumes before mixing. This observation was not made in the lessons thus far, because it would have led to confusion. Now that observation will be made and there will be an attempt to explain the observation. The explanation to be developed is that the particles of matter have spaces between them.

It is not difficult, at first, to think of liquids or gases as being made up of particles with spaces between them but it is difficult to accept this idea about solids. The pupils will encounter this kind of misgiving and only gradually come to accept the ideas as they appear to help in some explanations.

As you progress in teaching this scheme you will come to teach that the "spaces" become the means for explaining the differences between the solid, liquid, and gas phases of matter. In gases the particles account for only about .04% of the space occupied by the gas. In liquids the free space between particles is much less; about 33% of a volume is occupied by the particles and 67% is free space. In solids the space occupied by the particles is greater depending upon how the particles are packed. Alcohol molecules:

```
  H H
H-C-C-OH
  H H
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are larger than water molecules: H-O-H, and thus probably have larger spaces between them. No matter what phase matter is in—solid, liquid, or gas—the space between the particles is greater than the space occupied by the particles themselves.

Teacher Orientation

The desire in Lesson 5 is to develop the concept "matter is made up of particles that have spaces between them" by utilizing the existing concept "matter is made up of particles" and another analogous mechanical model. The procedure in the use of the analogous model is to involve the pupils to a maximum and will again include the making of inferences. The reasonableness to the pupils of the inferences made will depend upon the nature of the pupils' past experiences.

The lesson is to begin with two volumes of liquids that are to be mixed together. The situation to be explained is: The total volume after the two liquids are mixed does not equal the sum of the two separate volumes. It is obvious that the model for matter developed thus far does not provide the explanation. A three-dimensional analogous model consisting of a large tube, BB shot, and marbles is used as the source of the pupil inferences (BB shot represents one liquid; marbles, the other liquid). As the tube with the BB shot and marbles is tipped back and forth the total volume occupied by the two materials appears to decrease; a situation analogous to the mixing of alcohol and water.

During the teaching, the pupils should observe that the particles are not of the same size and that one kind of particle occupies space between the other particles. It is wise to keep reminding yourself that this particle idea is a theoretical model and is not a replica. We do not know that matter is like this. We do know that this idea of matter is very useful.

Materials

Overhead projector

Transparency No. 8, "Particles of matter have spaces between them"

1 10-mm x 48-inch glass tube

2 corks to fit 10-mm tube

100 ml alcohol

100 ml water

Food coloring

Wax pencil

2 32-mm x 200-mm test tubes

Corks to fit 32-mm test tube

BB shot enough to half fill the test tube

Marbles enough to half fill the test tube

Procedure

Demonstration. Place a cork in one end of the glass tube 48" long. Fill the tube half full of water. Carefully add colored alcohol to the tube until it is about 1 1/2" below the top. Stopper the tube. (The desire is not to mix the alcohol and water during the filling procedure.)

Figure 5.1. Water and alcohol in glass tube

Have a pupil mark the top level of the liquid in the tube with a wax pencil. Turn the tube over so the air bubble at the bottom end moves to the top. Again invert the tube. When the bubble is again at the original end, have a pupil mark the level of the liquid. "What happened to the level of the liquid?" (Answer: It seems that some liquid disappeared.) Repeat the inverting process and note the level of the liquid each time. "How do we know the two liquids are mixed together?" (Answer: The color is all over the tube.)

Teacher: "What happened?" (Answer: Some of the liquid seemed to disappear because the level of the liquid went down.) "How can we explain this?" (The students will try many kinds of answers such as: the water dissolved the alcohol; the alcohol evaporated.) If the pupils use such terms as evaporate, dissolve, etc., they should explain what they mean. The important factor is that the liquids are still in the tube.

Demonstration. Add BB shot to the large test tube until it is about half filled. Add marbles to the test tube until it is nearly filled. Stopper the tube and mark the level of the contents with the wax pencil. This is to serve as the analogous model: the shot is the water and the marbles the alcohol. The pupils are to make the observation that we have an analogous model here.

Teacher: "Which could be the water?"

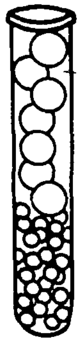

Figure 5.2. A model for water and alcohol

(Answer: Shot.) "Which could be the alcohol?" (Answer: Marbles.) "Now let us mix them as we did before."

The teacher will turn the tube over and over, and each time the pupils will mark the level of the marbles.

Teacher: "How do the results with our model compare with the other results?" (Answer: Look the same.) "How can we use this model to explain what we want to?" (Answer: One kind of particle goes into the spaces between the other particles.) "How must we change our model for matter so it is useful here?" (Answer: We must say that matter is made up of particles that have spaces between them.)

Project Transparency No. 8, "Particles of matter have spaces between them." Discuss this in terms of the demonstration and the model.

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Lesson 6
Particle Size

Concept 3: Particles of matter are very small.

Background Information

According to the particle theory, all kinds of matter are made up of certain kinds of particles called atoms or molecules, and each kind of particle has a specific size. Since you have looked at solids, liquids, and gases with the idea that they are all particulate in nature, you must have come to the conclusion that, "if the particles do exist, they must be very small." In order to explain some observations made by scientists studying the make-up of matter it has been necessary to give each particle a rather precise size. Because the sizes of atoms are very small a new unit of measure has been employed: it is the Angstrom. An Angstrom (Å) is .00000001 cm, or 10^{-8} cm, or one one-hundred millionth of a centimeter, or one ten millionth of a millimeter. A water molecule is given the length of about 2 Å, a sugar molecule is about 10 Å, and a molecule of oil of wintergreen is about 6 Å long.

So far you have talked about particles with spaces between them, so the logical next belief, since we have not seen one of the particles, is to say they are very small. The "very small" description is not precise since there is no frame of reference. Do you classify as "very small" those things you are unable to see with the naked eye, with a hand lens, with an optical microscope, or with an electron microscope?

There are photographs taken with electron microscopes that have been called pictures of molecules. These are somewhat less than precise labels for the photographs because the procedure employed is indirect. Hence, the evidence is inferred rather than direct. Care must be exercised in using and interpreting such designs on photographic plates.

Teacher Orientation

The frame of reference for smallness of particles in this case will be the optical microscope or the hand lens. The pupil begins by observing crystals (aggregates of particles) and later by noting that the crystals seem to disappear as they dissolve. Another experience that is useful in teaching this concept is the sensing of odors that are not visible.

Pupils experience difficulty in accepting the idea that some matter touches part of the nose when they have the sensation of smell. In order to use this phenomenon in the teaching process the pupil must come to accept the idea that matter does enter the nose. Only then can he accept the inference that since he is unable to see the particles, the particles are very small.

Materials

Overhead projector and screen

Microprojector or microscope

Transparencies:

9, Floor plan of classroom

10, "Particles of matter are very small"

11, "Particles of matter have spaces between them and are very small" (The first three concepts)

Demonstration or laboratory activity
Salt crystals

Watch glasses
Hand lens

Oil of wintergreen

Cotton

Mortar and pestle

Blue and red transparent disks of the same size, about 1/2 inch in diameter

Small red and blue disks, about 1/4 inch in diameter.

Procedure

Demonstration or laboratory activity. Project an image of some salt crystals on a screen or have pupils examine a few salt crystals on a watch glass with a hand lens.

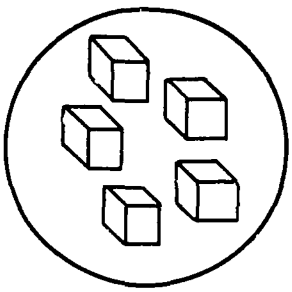

Figure 6.1. Salt crystals

Teacher: "What is the shape of the crystals?" (Answer: Roughly square.) "How large do they appear to be when you look at them through the glass?" (Answer: Varies.) "Place salt crystals in the mortar and crush them with the pestle. Place the pieces on the watch glass and examine them again. What did you notice?" (Answer: The pieces are much smaller.) "While you are looking at the crystals place a few drops of water on the crystals. What happens?" (Answer: The salt dissolves.) "Can you see it with the lens?" (Answer: No.) "Can you see it with a microscope?" (Answer: No.) "Is the salt still present?" (Answer: Yes.) "What would a model of salt in water look like?" (Answer: Salt particles mixed with water particles.)

Construct a model of salt in water on the overhead projector using the colored dots. The pupils may be given a choice, large dots or small dots. Their choice should be the small dots because the pieces of salt and water are small. They may select dots of two different sizes to indicate that the particles are not the same size.

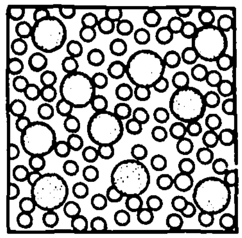

Figure 6.2. A model for salt water

Teacher: "Why are you unable to see them with the microscope?" (Answer: The particles are too small to be seen with any microscope.)

Project Transparency No. 10, "Particles of matter are very small." You may wish to refer to the size as being so small that it would take about 50,000,000 water particles to form a line less than 1/2 inch long (1 cm). Water molecules are given the length of 2 Å.

Uncover the bottom half of the transparency that represents three models for matter.

Teacher: "Which would be the better model if you wanted to explain what happened to the salt in water?" (Answer: Smallest particles.) "Why are each of the other models rejected?" (Answer: The particles are large in A, and C shows nothing.)

Demonstration. Project a floor plan of the classroom, Transparency No. 9. Locate a few pupil positions on the floor map. Soak a quantity of cotton with oil of wintergreen or perfume and expose this near the center of the room. Each pupil will raise his hand as he detects the odor. When a pupil reports that he detects the odor his position on the map is marked as 1, 2, 3, etc. After a number of pupils have reported noting the odor, the teacher asks: "What must have occurred in order for you to have noted the odor?" (Answer: Some of the small particles of the material must have reached the nose.) "Could you see the particles?" (Answer: No.) "Why not?" (Answer: The particles are probably very small.) "The fact that we cannot see them can be explained by saying that the particles are very small."

Project Transparencies No. 10, "Particles of matter are very small," and No. 11, "Particles of matter have spaces between them and are very small."

Our model for matter now includes:

Matter is made up of particles.

The particles have spaces between them.

The particles are very small.

Lessons 7-8
Motion of Particles

Concept 4: Particles of matter are in motion.

Background Information

A lump of sugar seems to disappear in a glass of water, and after the apparent disappearance the water tastes sweet. A drop of ink or food coloring in a glass of water soon loses its identity as a drop and becomes distributed throughout. If a bar of gold is placed next to a bar of lead for a period of time and the lead is later analyzed, gold particles will be found in the lead. When a bottle of perfume is opened in a room, the odor is soon detected throughout the room.

These phenomena are known to occur without any mixing being carried on by man or machine; it just seems to happen. The person who believes that effects have causes, however, rejects the supernatural and the unexplained. In these studies of matter we will reject the supernatural and try to explain the phenomena. The choice we have is the same as before—discard the old theory and form a new one, or modify the old theory to make it useful in the new situation.

The model "matter is made up of small particles with spaces between them" is to become "matter is made up of small moving particles with spaces between them."

The addition of the quality of motion to the particles is logical since it fits everyday experience—it is based on facts. If the location or position of an object is changed, the object has moved. There is no possible explanation for the change of position of a body other than motion.

Later this idea of motion of particles must be qualified since matter exists in three phases: solid, liquid, and gas. It does not make sense to say that a particle of water, when it is a part of a solid, is different from a particle of water when it is part of a vapor or liquid. A particle of water is a particle of water, regardless of the phase it is in. It is possible, however, to explain the differences between solids, liquids, and gases by means of the motion of the particles. The motion of the particles in a solid is generally described as vibrating within a limited space; in a liquid the motion is random but in a straight line with one particle moving past another; and in a gas the motion is similar to that in a liquid but the distance traveled by each particle is greater. Speeds of more than 1000 miles per hour have been used in describing the motion of some gas molecules.

The factor of motion in a straight line leads logically to the question "Do the particles strike each other, and if so what happens?"

As you view the short films it will appear that the particles do strike each other and then bounce away. This is really not considered to be a part of the model. A more precise description is that the particles approach each other (but never actually touch) and bounce away. Each particle is given the property of perfect elasticity; hence, the kinetic energy of each particle is conserved and the collision of particles does not result in a loss of kinetic energy by the particle.

The solution of a solid in a liquid is described by using the impact of particles of the solvent as well as the motion of the particles of the solute. It may be said that the molecules of solvent strike the solid knocking particles into the liquid. This process continues until the number of particles of solute knocked off equals the number of particles that join the solid. When this occurs, the solution is said to be saturated.

As the process of dissolving is observed, it is noted that the diffusion always moves away from the saturated region around the crystal. The general direction of diffusion of all substances is from the region of greater concentration to the region of lesser concentration. Apparent diffusion stops when the concentration of the solute and solvent within a closed system is uniform.

Motion of the particles is necessary to explain diffusion in solids, liquids, and gases; change of phase; and chemical change.

Lesson 7
Motion of Particles I

Teacher Orientation

The need for teaching theoretical concepts is based upon the desire to explain natural phenomena; therefore it is only reasonable that the strategy should begin with the phenomenon to be explained. The second factor to be considered is recognition by the learner that his present knowledge is not adequate.

The diffusion of a solid in a liquid is a phenomenon that cannot be explained with the idea that matter is made up of small particles with spaces between them. In order to have a useful explanation, the particle must have the property of motion.

Introduction of the factor of motion is not as simple as it appears. Pupils of this age tend to omit the idea that the change in position of an object implies motion. The use of the overhead projector in modeling the movement of particles from one place to another is helpful. Involving the individual pupils in modifying the existing model serves to stimulate pupil interest.

Materials

Colored transparent disks for use on the overhead projector—two colors

Overhead projector

Transparency No. 12, "Particles of matter are in motion"

Demonstration
- 1 petri dish
- 1 crystal of potassium permanganate
- 1 forceps
- water

Film
- $KMnO_4$ diffusing in H_2O

Super 8 mm cartridge projector

Procedure

Demonstration. Place a petri dish of cold water on the stage of the overhead projector. When the water has stopped churning about, place one small crystal of potassium permanganate in the water near the center of the disk. The pupils are to make observations of the phenomenon.

Figure 7.1. Potassium permanganate dissolving in water

Teacher: "What do you see happening?" (Answer: A pink area is forming around the crystal.) "What is causing the pink color?" (Answer: Some parts of the crystal are going into the water—dissolving.) "Does this mean that parts of the crystal have moved away from the crystal into the water?" (Answer: Yes.) "When we used these materials before, what did we do to get the pink color to spread out in the liquid?" (Answer: We stirred the liquid.) "Would this color have spread out without mixing?" (Answer: It looks as if this would happen.) "What could our model for matter look like if it is to help us to explain this?"

The overhead projector should be used here unless you wish to have the individual pupils work with materials such as small felt or magnetic boards. The overhead projector is suggested.

Teacher: "We should now try to construct a model for the crystal in the water before we saw the pink color in the water."

Construct a model on the overhead projector or stage. Pupils should participate in the activity. The clustered red dots are the $KMnO_4$ prior to going into solution.

Teacher: "Now we must use the model to show what happens to cause the water to become pink."

The pupils will now modify this model showing that the red particles become distributed in the water. Be sure to show that the particles on the edge escape first; that is, the entire solid does not break up at once.

Teacher: "What did you do to the red dots to show that they could cause the red color?" (Answer: Moved them from the crystal to between the water particles.)

Be sure that the following acts are considered in forming the model:

1. The dots representing water are spread out evenly in the circle representing the petri dish.

2. The particles representing $KMnO_4$ are mixed with the water.

3. The crystal does not dissolve all at once.

Teacher: "What did we add to our model for matter 'matter is made up of particles with spaces between them'?" (Answer: The particles are in motion.) "Why was this necessary?" (Answer: Motion of the particles is necessary if we are to explain the diffusion of the solid in the liquid.)

Project the film loop showing the diffusion of $KMnO_4$. The teacher narration should include the factors of motion and change of position of particles.

Project Transparency No. 12, "Particles of matter are in motion."

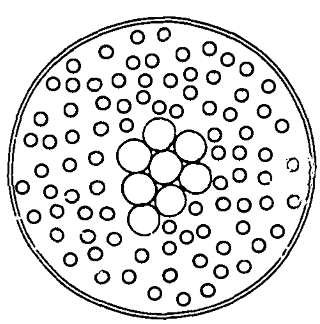

Figure 7.2. A model for a crystal in water

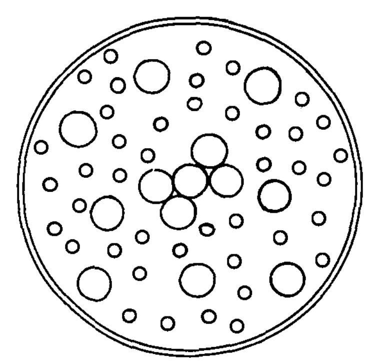

Figure 7.3. A model for a crystal dissolving in water

Lesson 8
Motion of Particles II

Teacher Orientation

The value of theories, in addition to that of making explanation possible, is that of making prediction possible. It is important to point out that one of the tests of credibility of a theory is its use in making predictions.

The procedure used in this lesson is to make a prediction and then to see how credible the prediction is. The test to be used depends upon identifying whether or not motion has occurred. Here the reaction between HCl (hydrogen chloride) and NH_3 (ammonia) will be used. When these gases react a white visible cloud, NH_4Cl (ammonium chloride), forms.

Care should be exercised in handling the chemicals since they are corrosive and may burn the skin. If either chemical comes in contact with the skin, immediately flush the area with water. It is not wise to breathe the vapor of either chemical for long periods of time.

Materials

Transparencies:

12, "Particles of matter are in motion"

13, "CHEMICAL A CHEMICAL B"

Glass tube, 10 mm x 25 cm

Dropping bottle of hydrochloric acid (Chemical A)

Dropping bottle of ammonium hydroxide (Chemical B)

Cotton

Swab sticks

Transparent dots (red, blue, and white)

Procedure

Teacher: "Yesterday we formed a new model for matter. What was the new one?" (Answer: Matter is made up of moving particles that have spaces between them.) "If you accept this idea let us try to use it in guessing what might happen."

Demonstration. This activity is going to involve the use of two chemicals. Open Bottle A. Teacher: "Is there anything visible at the opening?" (Answer: No.) Open Bottle B. "Is there anything visible at the opening here?" (Answer: No.) Hold the open mouth of Bottle A near the open mouth of Bottle B. "What happens?" (Answer: A white cloud forms.) "There seems to be something at the open mouths of both bottles. This white cloud is the result of chemical A and chemical B coming together. This was performed only so you could make your guesses."

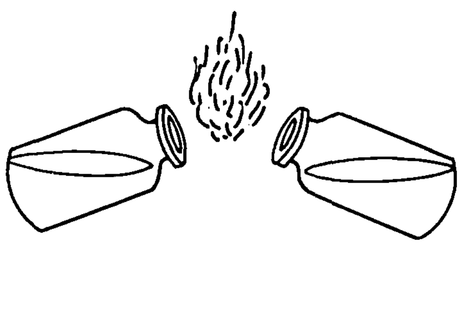

Figure 8.1. Formation of white cloud by interaction of chemicals A and B

Place the glass tube on Transparency No. 13, "Chemical A   Chemical B," on the projector.

Teacher: "If some of chemical A is placed in one end of the tube and some of chemical B is placed in the other end of the tube and the two ends are closed, what do you think will happen?" (Answer: Some of chemical A will go toward B and some of B will go toward A.) "How could we tell if this happens?" (Answer: Where the two chemicals meet a white cloud should form.)

Make two swabs by wrapping cotton onto the sticks. Add four or five drops of A to one swab and four or five drops of B to the second swab. Hold the swabs near to each other so pupils can see the cloud.

Insert swabs A and B into the respective ends of the glass tube. Observe what happens. (The cloud will appear after several minutes in the form of a ring. This will not be in the center; it will be a bit toward the HCl end.)

Teacher: "Was our guess a good one?" (Answer: Yes.) "What idea did we use in making the guess?" (Answer: The particles move.)

Draw two lines on the transparency to form the tube between A and B. This will be used to form a model. The pupils are to assist the teacher in constructing a model. The model will look like "1" at first, "2" next, and "3" at the end. It is well to go through these steps. (See Figure 8.3.)

You may wish to explain why the cloud formed at a location nearer to the HCl end than at the center. This is done using the idea of rate of motion of the particles; HCl is heavier than NH_3 and has the same amount of energy as NH_3 (at same temperature), and thus it will move more slowly than NH_3.

The slow movement of the molecules through the tube is explained as follows: The particles of the gases strike other particles that make up air, thus the total drift of the gases is slowed down.

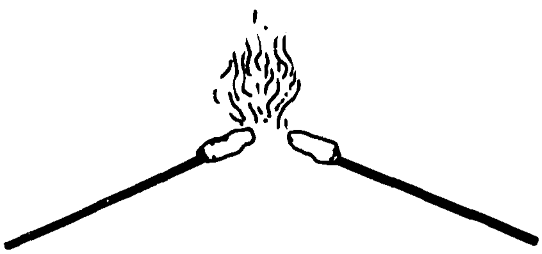

Figure 8.2. Formation of white cloud

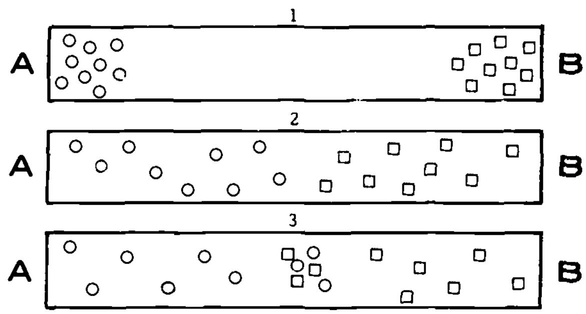

Figure 8.3. A model for the formation of ammonium chloride, NH_4Cl

Lesson 9
Heat and Particle Motion

Concept 5: Particles of matter move faster when the matter is heated.

Background Information

Our model for matter thus far has, in effect, ignored any relationship between matter and energy. The odor of wintergreen was caused to move from one location to another—that is, the particles were caused to move by something. Now there is to be a slight introduction to energy and its relation to matter.

Temperature may be stated in a quantitative way. The temperature of a quantity of matter is a measure of the rate of motion of the molecules. The greater the rate of molecular motion, the higher the temperature. Hence, at a temperature of 25° F, the same particles are moving faster than they would move at 20° F. This can lead to the development of the idea that if the temperature can be reduced enough the motion of the particles will cease. The temperature at which molecular motion theoretically ceases is called absolute zero. This temperature is defined as 273° below zero Celsius.

There are some observations that support this extension of the idea of temperature and motion. If an iron rod is heated on one end, it soon becomes hot on the other. This can be explained by using the idea that as the rod is heated in one place the particles increase speed. As they move faster, their collisions cause the particles next to them to move faster. This continues until all the particles are moving faster and the iron rod becomes hot throughout. Other ideas inherent in this explanation include energy transmission from particle to particle and the property of particle elasticity. The energy of the moving particle is called kinetic energy. It may further be stated that the heat content of a sample of matter increases as the total kinetic energy of the molecules increases, and that the temperature of a given sample of matter is also directly proportional to the average kinetic energy of the molecules. Thus a gallon of water at a temperature of 50° F will have a greater heat content than a cup of water at 50° F, yet both will have the same average kinetic energy of the molecules.

In this lesson the phenomenon observed can be explained by using the particle model we have at present only when it is modified to include the idea that the rate of motion of the particles is increased by adding heat.

Teacher Orientation

The phenomenon to be explained here is an inference that is made from the comparison of two observations. The pupils will observe the rate of spread of the red color in two dishes of water, one containing hot water and the other cold. They will use the past knowledge that the red color obtained when $KMnO_4$ was dissolved was explained in terms of particles of $KMnO_4$ mixed with particles of H_2O. The inference will be that since the $KMnO_4$ spreads out more rapidly in warm H_2O than in cold, the particles were moving faster—the particles moved farther in the same time, so the rate of motion must have been greater.

A question that follows is "How do we explain why one moved faster than the other?" One simple way is to add to our model. We can easily say that as heat is added the rate of motion of the particles increases. This makes the theory now satisfy our need. We more specifically say that the rate of motion of the particles is proportional to the temperature. The higher the temperature the greater the rate of motion. Now we can explain changes in temperature in terms of the motion of particles. We can also infer relative temperature from observing some phenomena in nature. The theory as modified is good—it helps us to explain and it helps us in making predictions.

Materials

Overhead projector and screen

Super 8 mm cartridge projector

Transparencies:

12, "Particles of matter are in motion"

14, "HOT COLD"

15, "Particles of matter move faster when the matter is heated"

Film

The diffusion of $KMnO_4$ in water

Demonstration

Potassium permanganate, $KMnO_4$ (2 crystals)

2 petri dishes

1 forceps

2 600-ml beakers

1 propane burner

1 tripod

1 wire gauze

Water

Ice

Procedure

Project Transparency No. 12, "Particles of matter are in motion."

Teacher: "What does this statement mean to you?"

(Answer: Matter is made up of particles. The particles of matter are small. The particles of matter have spaces between them. The particles of matter are moving.)

Examples: The dissolving of sugar in water, the reduction of the total volume when water is mixed with alcohol, the spread of the smell of wintergreen, the spread of the red when we put that chemical in water.

"Today we are going to make some more observations and we will again use the chemical that makes the water appear red. What happened when we placed the chemical in the water before?" (Answer: A red spot formed and the spot got bigger as time passed.) "Today in our experiment we will use one dish of hot water and one dish of cold water. We want to compare the rate of formation of the red areas in cold and warm water. What observations should we make?" (Answer: To see if one area is larger at any specific time. If one is bigger, it is forming faster.)

Demonstration. Place Transparency No. 14, "HOT COLD" on the overhead projector. Place a petri dish on each space on the transparency. Add very hot water to the dish marked hot and ice water to the dish marked cold. (Water may be heated in a beaker. If this is done, take great care not to drop the beaker so that hot water will strike the pupils. You may wish to handle the hot beaker with a towel.) When the water is no longer sloshing around in the dishes add one crystal of $KMnO_4$ to each dish. (It is wise to add the crystal to the cold water first if the crystals cannot be added to both at the same time. Pick up the crystals with a forceps.)

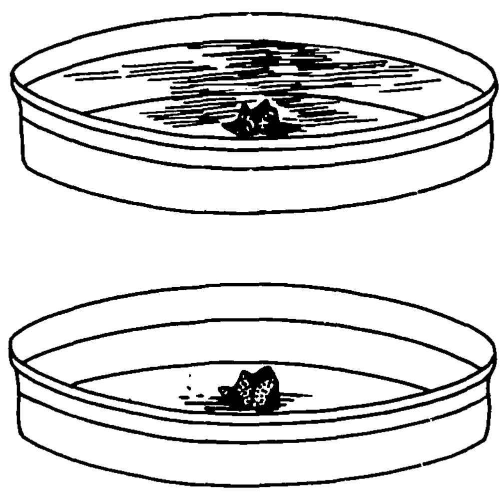

Figure 9.1. Dissolving $KMnO_4$ in hot and cold water

Teacher: "What do you observe?" (Answer: The red color is spreading.) "Is it the same in both dishes?" (Answer: The red color is spreading faster in the hot water than in the cold.) "What is present wherever the water appears to be red?" (Answer: Some red particles.) "In which case are the red particles moving faster?" (Answer: In the warm one.) "Why can you say this?" (Answer: Where the dot is larger the particles move farther in the same time.) "What have we added to our model for matter?" The model is: (a) Matter is made up of particles, (b) The particles have spaces between them, (c) The particles are small, (d) The particles are moving. (Answer: The particles move faster when heated.)

For a summary, project the film of the solution and the diffusion of $KMnO_4$ in water. Project Transparency No. 15, "Particles of matter move faster when the matter is heated."

Lesson 10
Expansion and Contraction

Concept 6: Particles of matter usually move farther apart when the matter is heated.

Background Information

To say that solids, liquids, and gases expand when heated and contract when cooled is to describe what happens. Contraction and expansion are natural phenomena that are to be explained through the use of a model for matter. Expansion and contraction, when using the logic and the model for matter we have developed thus far, may be explained in two ways: (a) the particles get bigger, or (b) the spaces between the particles get bigger.

The use of the idea that "the particles get bigger" would only rely on the same phenomena we are trying to explain. If the particles get bigger, how do we explain their increase in size? The idea that the spaces get larger is a more reasonable inference since this is a part of our experience. Automobiles parked far apart take up more area than when parked close together.

The method of logical inference used here is valuable but when used alone is not very productive. Science depends upon logic but logic alone is not science. The scientist must have some facts that enter into his application of logic. Why does he accept the idea that as energy is added to matter and the matter expands, it is more logical to say that the particles move farther apart? There is evidence to indicate that the particles move faster and farther apart. The demonstration in which mercury is changed to a vapor that causes a pith ball to move is of some help; the pith ball acts as if it is struck by particles.

You may now be thinking about water as a typical material and recall that when water freezes it expands. In fact, water contracts as it is cooled until it reaches 39.2° F (4° C) and then expands until it freezes at 32° F (0° C). When the ice is cooled, it contracts; ice acts as a typical solid. The change in the density of water as it changes to ice is explained by using a concept of an ice crystal. In the formation of crystals the water particles become arranged in such a way that they take up more space; this makes the ice less dense.

Teacher Orientation

The development of a more comprehensive model for matter continues to be the theme in this lesson, and the procedure is to modify the present model if possible. The model—matter is made up of small particles that move at different rates at different temperatures and that have spaces between them—is not adequate in explaining the expansion and contraction of solids, liquids, and gases. The needed modification is: the size of the spaces between particles increases as the rate of motion of the particles increases. The requirement that the particles do not change size must be included; this becomes more important later. It is also more reasonable to use the "increase in space between particles" idea rather than "increase in size of particle" idea because of its simplicity.

In the development of knowledge in science there is a rule that when there are two or more ideas that will help in explaining natural phenomena equally well, the simplest of those available will be selected.

Materials

Overhead projector and screen

Transparencies:

16, "Particles of matter usually move farther apart when the matter is heated"

17, Review of first six concepts

18, Sketch of flask and tube

19, Sketch of thermometer

Demonstration:

Ball and ring apparatus

Propane burner

600-ml beaker

Water

Demonstration:

Mercury and pith ball apparatus

Different colored dots

Thermometer

Demonstration:

Small and large embroidery hoops

Marbles enough to fill smaller hoop

Demonstration: Expansion of air

1 24-in. x 8-mm glass tube

1 1-hole rubber stopper to fit

Wax pencil

1 500- to 600-ml flask

1-ring stand and clamp

Procedure

Common phenomena, yet not often consciously observed by children, are the expansion and contraction of solids, liquids, and gases when they undergo a change in temperature. Because of this, the lesson will begin with one of these phenomena at a time.

Demonstration. With the ball and ring at room temperature note that the ball passes through the ring. Heat the ball. Note that the heated ball does not pass through the ring.

Teacher: "The first task we have is to

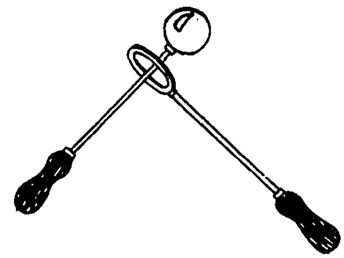

Figure 10.1. The ball and ring apparatus

describe what happened." (Answer: When the ball and ring were cool, the ball passed through the ring. When the ball was heated, the ball did not pass through the ring.) "You could then guess that something happened to the ball when it was heated." (Answer: The ball got bigger.) "How is this change in the ball explained using our model for matter? The model so far is:" (Show Transparency No. 17, "Review of first six concepts"; use first five concepts.)

Pupils may now try to use the idea of small particles moving at different rates at different temperatures but none helps to explain an increase in size. Pupils may also suggest that the particles get bigger when heated. This response is really no better than saying the ball got bigger; however, it must be considered as an alternative. Pupils may also propose the idea that the particles move farther apart. This is the idea that is wanted. However, the acceptance must follow the rules of science. Is there any evidence to support either one of these ideas?

Teacher: "Which of these two ideas is better since both help us with explanations?" (Answer: The discussions will vary and the teacher will have to judge the rationality of the arguments.) "Is there anything that you know about that would support one idea over the other?" (Answer: Pupils will probably have no contribution here.)

Demonstration. (If the apparatus used here is not available, the procedure is to use the idea of particles of one size moving farther apart since it is more simple than the expanding particle.)

Describe the apparatus as an airless glass vessel containing a pith ball and mercury. Note that the pith ball does not move and that if it did move the only matter present to strike it would be the mercury. Carefully apply heat to the bulb containing the mercury and note what happens. Soon the pith ball is bouncing up in

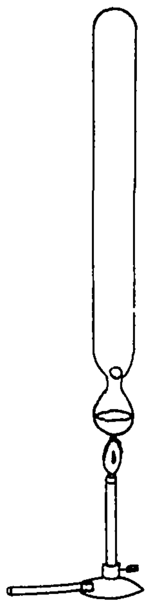

Figure 10.2. Mercury and pith ball apparatus

the tube but there is nothing visible touching it. Have the pupils note the mercury condensed on the upper walls of the tube.

Teacher: "What seems to have happened?" (Answer: The hot mercury particles hit the ball and pushed it up.) "If the particles of mercury struck the ball what must have happened?" (Answer: The particles of mercury moved faster and farther apart when heated.) "This bit of evidence supports which of our two ideas for use in explaining expansion?" (Answer: Particles move apart when heated.)

The next task is to see if we can build a model to help us explain the expansion of the brass ball in the ball and ring apparatus.

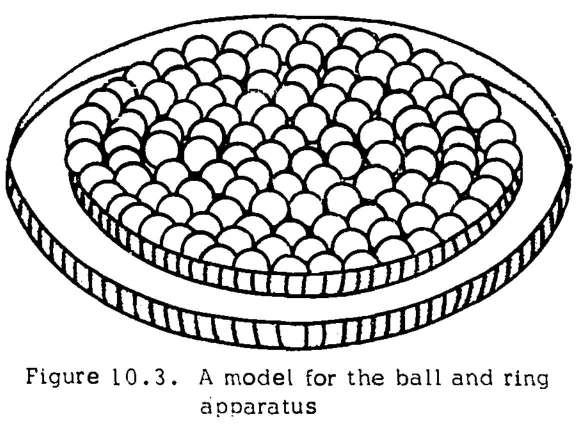

Figure 10.3. A model for the ball and ring apparatus

Demonstration. Place the smaller of two embroidery hoops on the overhead projector. Fill the hoop with marbles.

Teacher: "What are we representing with the marbles?" (Answer: The particles of matter that made up the ball.) Place the larger hoop over the smaller one and then remove the smaller. Spread the marbles around in the larger hoop to show the spaces being increased in size.

Teacher: "Which hoop shows the ball at room temperature?" (Answer: Smaller.) "The larger hoop was the ball after heating. Did the particles increase in size?" (Answer: No.) "Did we add particles by heating." (Answer: No.) "What did we do to our model to help us explain expansion?" (Answer: Moved the particles farther apart to show what happened when it was heated.) Project Transparency No. 16, "Particles of matter usually move farther apart when the matter is heated."

We have now changed our model again by adding another idea. It is that the particles can move farther apart when heat is added. Project Transparency No. 17, "Review of the first six concepts." Read the six concepts.

One way to judge the value of theoretical models in science is to see if they help in a large number of places. Next we are to see if this model will work with a liquid.

Demonstration. Have a pupil read the temperature indicated on a thermometer immersed in cool water. Apply heat to the water and note what happens to the level of the liquid in the thermometer.

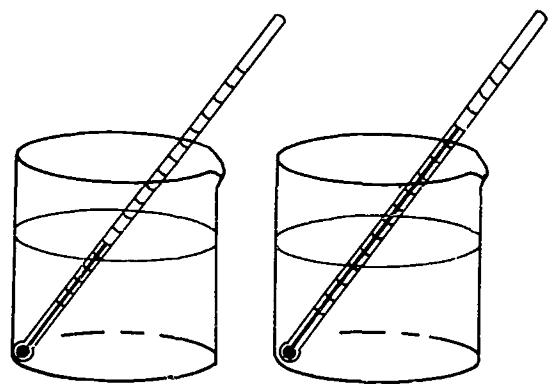

Figure 10.4. Expansion of liquid in a thermometer

Teacher: "What caused the level of the liquid to go up?" (Answer: The liquid expanded when heated.) "Why is this a reasonable answer?" (Answer: Because no one added any more liquid to the thermometer. All we did was add heat, just like with the ball and ring.)

Place Transparency No. 19, a sketch of

a thermometer, on the projector. Place a pile of small dots on the stage.

Teacher: "We want to construct a model of the matter in the thermometer when it was cool and later when it was heated." (The pupils will cooperate in constructing a model. Be sure to keep the number of particles in each the same.)

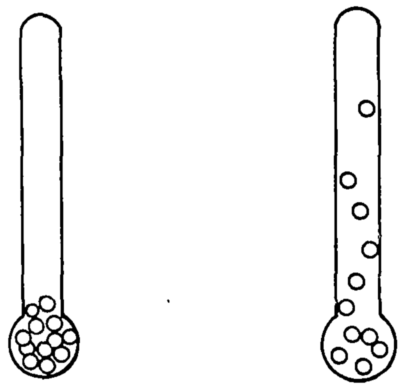

Figure 10.5. A model for a thermometer

Our next task is to see if we can use the ideas we have so far to tell what might happen if we do certain things.

Demonstration. Assemble the flask, tube, and beaker as in the sketch.

Teacher: "This flask and tube are full of air. We want to guess what will happen if the air is heated. The way we will attack this problem is to construct a model of what we have here." (Project the transparency of the flask, No. 18.) Have the pupils place dots of different colors and shapes in the flask and tube to show what the model for the cool air would be. Now let us guess what would happen if heat is added to the air by heating the flask. "What would happen to the gas?" (Answer: It would get bigger.) "What would happen to the particles?" (Answer: They would move farther apart.) "The flask is already full, so where would the air go?" (Answer:

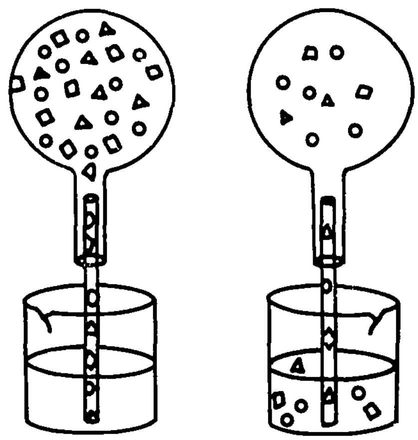

Figure 10.6. A model for explaining the heating of a flask of air

Some may go out the tube.) "What would happen if after the flask is heated it would be cooled again? Would the flask and tube still be full of air?" (The speculations would vary.)

Heat the flask with a burner or with the hands. Note the results. (Bubbles should escape from the tube.) Compare this observation with the model. Cool the flask with ice and note the results. (Water rises in the tube.)

Teacher: "Can we explain the last result by using our new model?" (Answer: The motion of the particles is slowed and the spaces between them is reduced, so the water takes up some of the space.)

Project Transparency No. 17, "A review of the first six concepts."

The model for matter we have so far includes six parts. These additions have been necessary in order to explain what we have seen.

Lesson 11
Solid Structure

Concept 7: In the solid state, the particles of matter are packed together in a pattern and move within a small space.

Background Information

Reference has been made during several of the lessons thus far to the three phases or states of matter, and to some extent, the explanation of differences between them has involved motion of the particles. In a liquid the motion is random and the particles move past each other. In a gas the motion of the particles is random and the distance apart is great. These theoretical descriptions provide only a limited explanation of the difference between solids, liquids, and gases: the change from solid to liquid to gas with the addition of energy. This does not help us to explain some other phenomena such as:

1. Solids are nearly incompressible.

2. Solids have a relatively constant volume.

3. Solids have definite shapes.

4. Solids exist as crystals. (Amorphous solids like rubber and plastics have a crystalline structure, but it is difficult to observe.)

5. Solids diffuse very slowly.

From certain of these properties and experiences in nature some structural characteristics of solids may be inferred: the particles must be relatively close together, the particles are arranged in an orderly manner, and the particles are held to each other. Experiences in life help us to infer that it is difficult to move between two objects that are close together, that patterns may result from the orderly arrangement of matter, and that two things fastened together are separated only with difficulty. Objects called solids do not change shape even after the passage of extensive periods of time.

The existence of cleavage surfaces in crystals can be easily explained only if the particles of matter are described as being arranged in a consistent and regular geometric manner. As you cleave crystals you will find that each one has definite cleavage planes which occur at specific angles. This reflects the orderly internal arrangement of the particles reflecting the crystal structure. Calcite and alum can be cleaved easily with the stroke of a hammer. Mica can be cleaved by pulling the planes apart with the fingers. Other crystals can be cleaved by methods that require different amounts of skill.

In addition to cleavage there is another crystal phenomenon that should be known, the formation or growth of crystals. If a small salt crystal is examined it will be found to be generally cubic and there will be pieces broken off from the corners. When this crystal is suspended in a saturated solution of salt water the crystal will appear to grow. The first growth will be noticed as the broken-off pieces are replaced. As days pass the water evaporates and the crystal grows; it will increase in size and regularity, retaining the general cubic shape. Growth of crystals of copper sulfate, alum, and salt is often demonstrated by pupils in the elementary grades. (See Alan Holden, Crystals and Crystal

Growing.)

Teacher Orientation

The present level of the concept of matter involves small, moving particles separated by spaces that may vary in size. Is this conceptual level adequate to explain the regularities noted in crystalline solids? There is a factor missing—it is "In a solid the particles are packed together in a pattern and they move only in a small space." With this modification the formation of crystals of salt, sugar, iron, brass, etc., can be explained. In this lesson the phenomena to be used to illustrate the inadequacy of the present concept will be crystal cleavage. You may also plan to grow some crystals or have the pupils grow some. Those of sugar are easily grown and you can produce rock candy. If you plan to show the pupils a crystal you have grown, it is well to start this about 2 months ahead of time.

The formation of crystals, the structure of crystals, and the cleavage of crystals are easily explained by using styrofoam models.

Materials

Overhead projector and screen

Super 8 mm cartridge projector

Transparencies:

20, Identification key (three crystal shapes)

21, "In the solid state, the particles of matter are packed together in a pattern and move within a small space"

Film: The Solid State

Pupil activity

Small vials containing crystals of copper sulfate, potassium aluminum sulfate, and sodium chloride

Hand lenses

Crystal identification sheet

Demonstration: Crystal of galena

Demonstration:

Mica

Alum or calcite crystal

Single-edged razor blade

Hammer or piece of wood

Demonstration:

64 styrofoam balls, each about 2" in diameter

24 pipe cleaners or pieces of wire (used to hold balls together)

Procedure

Today we are going to examine some pieces of common matter with a magnifying glass. You have probably seen these materials without a magnifying glass. Today we want to see if we can find out how the three samples are alike and how you can tell one sample from another.

Pupil activity. Each pupil is to have (a) crystals of copper sulfate ($CuSO_4$), potassium aluminum sulfate ($Al_2(SO_4)_3K_2SO_4$), and sodium chloride (NaCl); (b) hand lens; and (c) crystal identification sheet.

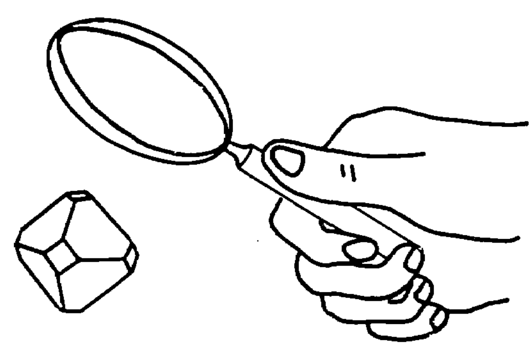

Figure 11.1. Viewing crystals

The pupils will examine each type of crystal for the purpose of classifying it according to shape, color, and size. (Each crystal of a kind of matter has a definite shape and color.)

Project Transparency No. 20, the identification key (three crystal shapes).

Teacher: "How are the three samples

alike?" (Answer: They all have corners and have definite shapes.) "How can you tell one sample from another?" (Answer: Each has a little different shape.)

Demonstration. Secure a large cleavage fragment of galena and place it on the stage of an overhead projector so that the angular corners show. Teacher: "Describe the shape of the galena fragment. What do you see?" Remove the crystal from the stage of the overhead projector and place it on a table. Cause the crystal to cleave by striking it gently with a hammer. Place both the crystal and the cleaved pieces on the overhead projector stage. Repeat the previous question.

Teacher: "How do the corners formed when the crystal was broken compare with the corners that existed before it was broken?" (Answer: They are the same.)

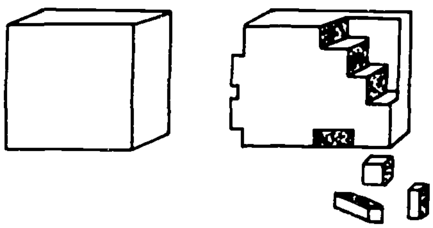

Figure 11.2. Crystals of galena

Teacher: "What properties do we have in our model for matter so far?" (Answer: (a) Made up of particles, (b) spaces between the particles, (c) particles are in motion, (d) rate of motion of the particles is related to temperature, and (e) the distances the particles are apart depend on temperature.)

Teacher: "How have we used each of these ideas?" (Answer: (a) One was used to explain sugar dissolved in water, (b) two was used to explain the decrease in total volume when alcohol and water were mixed, (c) three was used to explain diffusion, (d) four was used to explain the more rapid diffusion when the substance was heated, and (e) five helped us to explain expansion and contraction.)

Teacher: "Can we use only these ideas to explain the shape of crystals and the fact that when crystals cleave they form angles?" (Answer: The particles could be formed into layers like sheets.)

If this idea of layers is good we should be able to use it to predict something about crystals. We should be able to form layers of a crystal.

Demonstration. Hold a piece of mica edgewise on the overhead projector. Peel a layer of mica off so pupils can see the paperlike form. Place a large crystal of alum or calcite on the overhead projector so pupils can see the shape of the crystal. Hold a single-edged razor blade with the sharp edge parallel with the edge of the crystal. Strike the blunt side of the blade with a piece of wood or hammer. Note the shape of the piece that cleaves off.

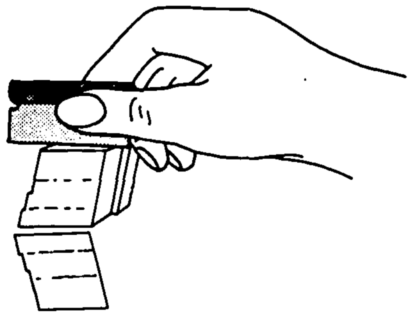

Figure 11.3. Cleavage of calcite

Teacher: "How would you judge the results? Is this what should be expected if the particles are arranged in layers?" (Answer: Yes.) This mental model of a crystal is difficult to imagine so let us build a model that is not so difficult to accept.

Demonstration. Use about 64 styrofoam balls, each about 2 inches in diameter and pipe cleaners or small pieces of wire to build the model. It should look like Figure 11.4. The top layer of balls should be attached to the layer below by only one piece of pipe cleaner. This will make it possible for you to remove the layer by giving it a push.

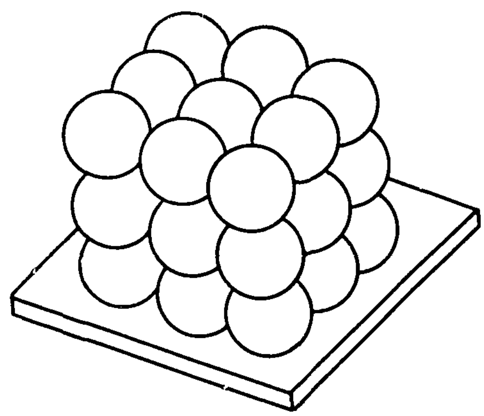

Figure 11.4. A model for a crystal

After the model is completed, show how

one layer will slide off from the others and form an independent layer of the substance. Also, show that the form that remains has the same shape.

Teacher: "How have we changed our model of matter to explain the formation of crystals?" (Answer: The particles are arranged in a regular pattern.) They are solid materials and most solids are crystals. Hence, we can say that solids are composed of particles, that they are arranged in a pattern, and that the particles are closely packed together. Project Transparency No. 21, "In the solid state, the particles of matter are packed together in a pattern and move within a small space."

Project the film, The Solid State. The teacher will narrate. The following points are important:

1. The particles in a solid are packed closely together.

2. The particles in a solid are in a pattern; they are orderly.

3. The motion of particles in the solid state is vibratory (i.e., they move back and forth in place in the solid pattern).

Lesson 12
Liquid Structure

Concept 8: In the liquid state, the particles of matter are loosely clustered together and move about.

Background Information

The difference between a solid and a liquid is easily described in terms of measurable quantities; solids have a definite shape but liquids do not. Shape is described in terms of length measurements. To go beyond these easy-to-make observations, it is necessary to use a theory that involves particles. In the previous lesson the model consisted of particles arranged in a definite pattern. It is obvious that since a liquid does not have a fixed shape, the model of a liquid, if it consists of particles, must not include the factor of a fixed pattern. Further, since a liquid has a fixed volume, it must involve the factor of particles close together.

According to the particle theory of matter the motion of the particles is related to temperature; the higher the temperature the greater the speed of the particles. The use of this idea permits us to explain the change from a solid to a liquid and also the difference between a solid and a liquid.

When a solid is heated the particles of the substance move faster and faster; this is described as adding energy. When the energy level of the particles is great enough to partially overcome the forces of attraction between the particles, the substance turns from a solid to a liquid. The forces of attraction cause the particles to be arranged in a definite form. When the particles move past each other the solid has become a liquid.

This model is consistent with facts that can be observed: (a) liquids have a definite volume, (b) liquids are essentially not compressible, and (c) liquids have no definite shape.

Explaining the properties of liquids using the idea of particles must also include the ideas that (a) the particles are very close together—nearly as close together as in solids—and (b) the particles are moving in a random manner and move past each other. (There is no fixed structure.)

Teacher Orientation

When using the "particle idea of matter," the gross difference between solids and liquids is that of arrangement of the particles; therefore, crystals were used as the phenomenon to be explained when considering solids. Unfortunately there is no comparable phenomenon that involves liquids.

The inferences made or the factors of the model must satisfy three observable facts: (a) a cubic inch of a solid has nearly the same weight as a cubic inch of the same substance as a liquid, (b) liquids are nearly incompressible, (c) liquids have no specific shape, and (d) liquids have a definite volume. (The concept of volume is not easily developed with young children. If this term is the source of difficulty you may wish to substitute "takes up same amount of space.")

The model to be developed must, therefore, have the ideas: (a) particles are close together, (b) particles move past each other with ease, (c) particles have no fixed pattern.

Materials

Styrofoam model of a solid

Overhead projector and screen

Super 8 mm cartridge projector

Transparencies:

21, "In the solid state, the particles of matter are packed together in a pattern and move within a small space"

22, Beaker, flask, and cylinder; overlays 1 and 2

23, "In the liquid state, the particles of matter are loosely clustered together and move about"

Film: The Liquid State

Demonstration:

2 600-ml beakers

Erlenmeyer flask, 600-1000 ml

Florence flask, 600-1000 ml

Graduated cylinder, 600-1000 ml

Ice

Water

Heat source (propane burner)

50 dots

Petri dish

Glass beads

Procedure

Display the styrofoam model for a solid developed in the previous lesson and project Transparency No. 21, "In the solid state, the particles of matter are packed together in a pattern and move within a small space."

Teacher: "So far we have a model for matter that includes particles that move, and the rate of motion increases with temperature. What would happen to this model if we added more energy to the particles?" (Answer: The particles would move faster and may be farther apart.)

Demonstration. Show pupils a beaker of liquid water and a beaker of ice cubes. Transfer the ice cubes to the graduated cylinder. Transfer the liquid water from the beaker to the Erlenmeyer flask and back again.

Teacher: "What did you observe?" (Answer: The ice was in chunks in the beaker and in chunks in the cylinder. You could pick up pieces of ice from either container. The water was in the shape of the beaker when in the beaker and the shape of the flask when in the flask.) Project Transparency No. 22, the beaker, flask, and cylinder. Point out how a liquid can have different shapes but still have the same volume.

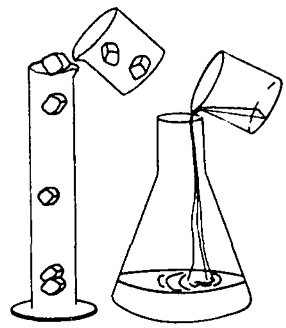

Figure 12.1. Comparing solids and liquids

Place the ice in the beaker and apply heat. Note the results. (The ice changes to water.)

Teacher: "Let us see if we can construct a model first of the solid and then try to change it to a liquid." (Pupils will assist the teacher in forming a dot model on the overhead.) "Now

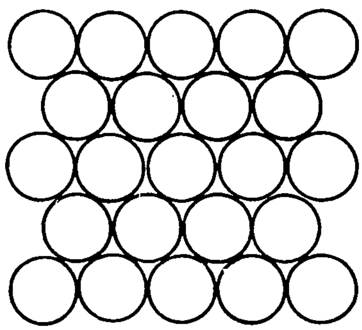

Figure 12.2. Model for a solid

we will imagine that we heat the substance. How will the model be changed?" (Answer: The regular arrangement of the particles will disappear.) Project Transparency 22, overlay 1, then overlay 2. It will look like Figure 12.3. Note that the pieces will not have such a regular order and will move more.

Demonstration. Place some glass beads in a petri dish on the overhead projector. Form a cluster of beads. This is a solid. Shake the dish so the beads move around in a random order. This is a little better model.

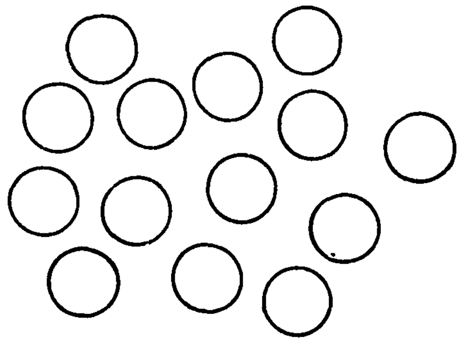

Figure 12.3. Model for a liquid

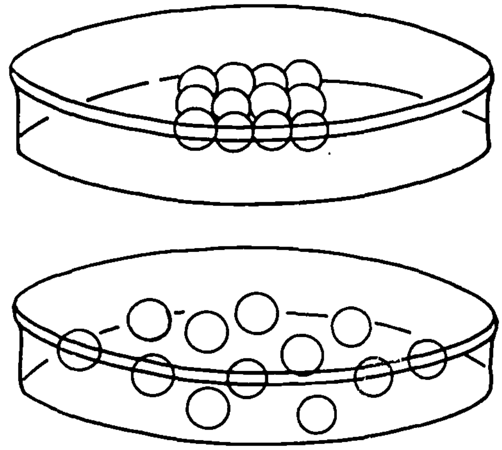

Figure 12.4. Model for a liquid

Project the film, The Liquid State. Teacher will narrate. It is important to point out that:

1. The arrangement of particles in a liquid is random.

2. Adding energy causes the particles to increase in speed.

3. The particles are close together.

4. The motion is random.

Follow the red dot in the film. It helps with 1, 2, 3, and 4.

Project Transparency No. 23, "In the liquid state, the particles of matter are loosely clustered together and move about."

Lesson 13
Gas Structure

Concept 9: In the gas state, the particles of matter are far apart and move freely.

Background Information

Gases have the general properties of matter—they have weight and occupy space. You may have inflated pneumatic tires or footballs and still not have thought of the space inside the tire or ball as being filled with air. Would you consider an inflated tire to weigh more than one not inflated? The fact is, the inflated tire does weigh more.

Most gases are colorless, therefore they are not very visible. The visible gases often cause some people to be afraid, and properly so, since many are poisonous. There would be more people protected if at least a few more gases were visible. Carbon monoxide is a colorless, odorless gas that is very toxic to people. Even the illuminating gas used for cooking is not visible.

Gases have some specific properties that come to be understandable after you are able to use the particle idea of matter in explaining natural phenomena.

Gases do not have a constant volume; that is, a given mass of gas may occupy almost any volume. If the pressure exerted is great, the volume occupied will be small. If the pressure exerted is very small, the volume occupied will be very great. A gas may be changed to a liquid if it is compressed enough. Air, which is a mixture of gases, is changed to a liquid by cooling and compressing. The volume occupied by a mass of gas when it is liquified is extremely small when compared to the volume occupied by that gas under the pressure of just the atmosphere. This fact makes it possible to consider the particles of a gas as separated by a great deal of space. Also accepted is the belief that the particles of a gas move in a random fashion and at high speeds.

Gases also expand when heated and contract when cooled. These facts are not surprising since gases are matter. We discovered the same thing previously when we tried to explain the action of the air thermometer. These

Solid	Liquid	Gas
Particles vibrate	Particles move past each other	Particles move past each other
Particles move slowly	Particles move rapidly	Particles move very rapidly
Particles are very close together	Particles are close together	Particles are very far apart
Particles remain in one region	Particle motion is random	Particle motion is random

facts, however, help us in forming a model for a gas.

In forming a model for a gas we do not have to make any changes in our theory. All that is necessary is to put the parts together.

Particles—far apart—moving fast. The particles are farther apart and move faster in a gas than in a liquid. Our model will be merely for a phase of matter.

Teacher Orientation

It is easy to arrive at a model for a gas if one merely extends the difference between a liquid and a solid. All of the extensions of the liquid idea are logical since they are based upon our common experiences. We know a gas has no shape. We know that it is easy to move through a gas. We know that a gas can be compressed and that it will expand when the outside force is removed. We also know that there can be several gases present at one time (perfume odor in air, cooking odors in air).

Materials

Overhead projector and screen

Super 8 mm cartridge projector

Transparencies:

21, "In the solid state the particles of matter are packed together in a pattern and move within a small space"

23, "In the liquid state, the particles of matter are loosely clustered together and move about"

24, "In the gas state, the particles of matter are far apart and move freely"

Film: The Gaseous State

25 1/2" or 1/4" transparent dots, two different colors or shapes

Demonstration:

Oil of wintergreen

Beaker, 600 ml

Ice

Propane burner

Support—tripod or ring stand

Procedure

Using the dots, form a model for a solid on the stage of the overhead projector.

Teacher: "How can we change this so it could be a model for a liquid?" (Answer: Move them about. Do not have them in such good order.) The pupils and teacher together will change the model. "Why did we accept this model for a liquid?" (Answer: Because liquids do not have a shape and liquids flow.) "What are the qualities of a good model?" (Answer: The model helps us to explain what we see.)

Project Transparencies 21, "In the solid state the particles of matter are packed together in a pattern and move within a small space," and 24, "In the gas state, the particles of matter are far apart and move freely," and review the concepts.

Demonstration. Place a quantity of ice in a beaker. Have the pupils list the properties of ice: it is solid, it has shape.

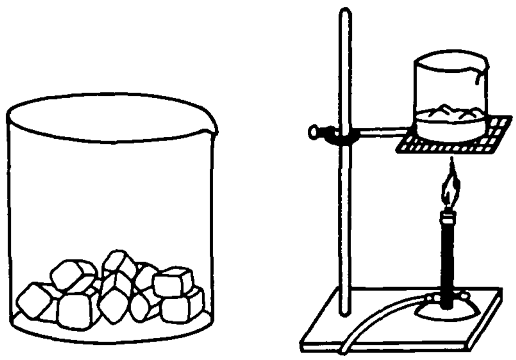

Figure 13.1. A change of phase

Heat the beaker. Pupils will list the changes they observe. Note the properties of water vapor (steam). It has no shape. Objects can move through it easily. It seems to weigh very little.

List the properties of a gas as indicated by the observations. It has no shape. It has no volume. Objects seem to move through it easily.

Demonstration. Open a jar of oil of wintergreen and have pupils indicate when they detect the odor.

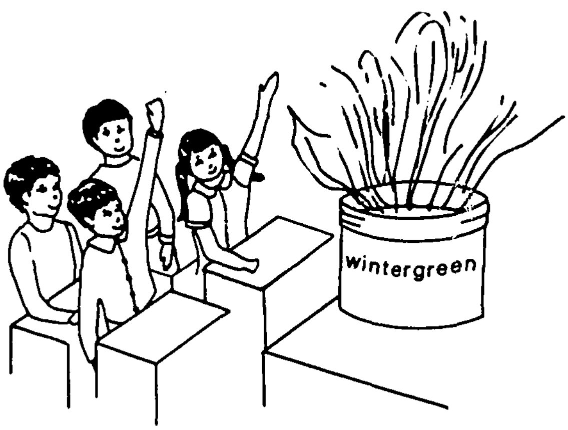

Figure 13.2. Diffusion of a gas

The observations to be made here are: (a) we cannot see the gas, (b) the gas mixed easily with other parts of air, (c) the gas was spread out all over the room, and (d) the gas seemed to get all over by itself.

Develop a model of a gas on the projector using the colored dots. First show the change from solid to liquid to gas using water. The pupils will assist the teacher.

Develop a model showing the oil of wintergreen in the other gases.

Teacher: "Are the particles arranged in a pattern?" (Answer: No.)

Project the film The Gaseous State.

Describe particles in gases.

1. Particles do not exist in a pattern.

2. They move past each other but in a random manner.

3. They are far apart.

4. As energy is added the particles move more rapidly.

Project Transparency No. 24, "In the gas state, the particles of matter are far apart and move freely."

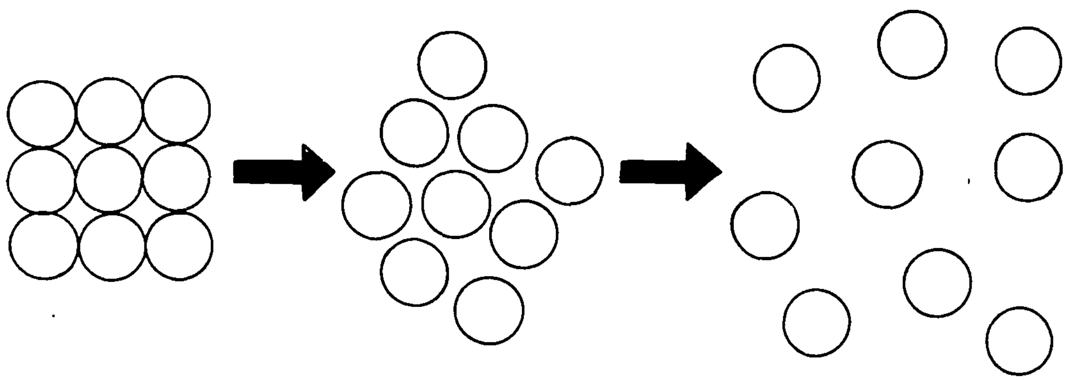

Figure 13.3. Three phases of matter

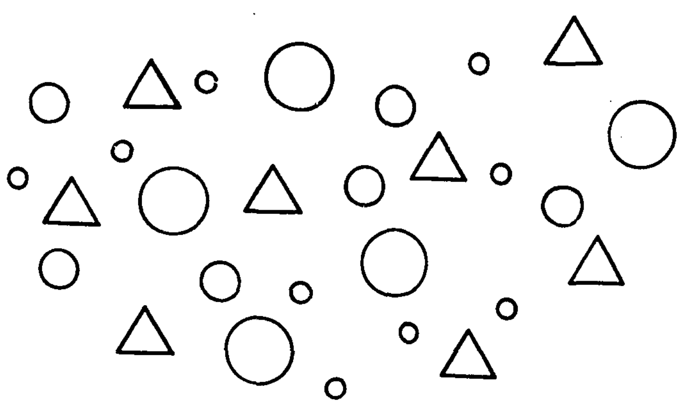

Figure 13.4. A model for the odor of wintergreen in air

Lesson 14
Boiling and Condensation

Concept 10: The state of matter can be changed from solid to liquid and from liquid to solid.

Background Information

Changes in the phase of matter are commonly known. In fact, in Lesson 13 you demonstrated changes of phase; you melted ice and boiled water. In the lessons thus far the pupils have learned that in solids the particles are ordered, in liquids the particles have no order, and in gases the particles have no order and are far apart. The changes in properties have been brought about by adding energy. The idea of relative order or disorder of particles is used to explain differences between states of matter. If we are to use this idea we must recognize that the particles attract each other when they are close together. The attraction between particles has been used to explain the form of solids. The attraction between particles in the liquid phase has not been used, so far, to explain surface tension. If you place a drop of water on wax paper it forms into a drop that seems to be surrounded by a membrane. This surface is explained as the result of particles attracting each other.

When the substance in a liquid phase receives more energy, the particles increase in kinetic energy and move farther apart. The force of attraction between two particles decreases as the distance apart increases. It is now possible to briefly explain the change in the phase of matter using the ideas of kinetic energy and the attraction of particles.

As heat is added to a solid, the vibration rate and distance between the particles increases. As the distance apart increases, the attractive force between particles decreases. As more energy is added there comes a time when the motion of the particles no longer involves a pattern; that is, the particles break out of the pattern and they no longer are attracted very strongly to each other. When this occurs the phase is called liquid.

As energy is added to the particles in the liquid phase they move farther apart until they are so far apart that the attraction between the particles is very, very small. When this occurs, the liquid has changed to a gas. It has no specific volume unless the pressure is designated, and it has no specific shape other than the entire container.

When energy is subtracted from a gas, the gas will condense and become a liquid. Further removal of energy will cause the particles to slow down even more and a solid will form.

Teacher Orientation

Essentially, the concept is not new to the pupils since it has been included in past lessons. The organization of the concept through the ordering of existing knowledge will be the essential strategy employed. The change in phase rather than the properties of a phase of matter becomes the phenomenon of nature to be explained.

The explanation begins with the properties of solids and liquids, and is extended to how the transition occurs.

Although the concept of energy has not been developed extensively, it can be successfully used at the level "energy is what changes things." If the speed of a piece of matter is increased, energy has been added. If the speed of a piece of matter is reduced, energy has been subtracted. If a body is lifted, moved against gravity, energy is added. If a body moves with gravity, energy is released.

Kinetic energy is a class of energy that is associated with motion. Any object that is moving possesses a given amount of kinetic energy.

A second factor to consider is that a force is needed to cause any particle of matter to change its rate of motion. This is true whether the rate is increased or decreased.

You may now be concerned with the relationship between force and energy. Without this relationship the ideas of rate of motion and kinetic energy make no sense. Energy is defined as the capacity to do work. That means that to change the rate of motion, work must be done. To the scientist the idea is correct because work is defined as force times distance: F x d = work. Now you have a direct tie between the motion of particles and energy.

You may now say that the difference between a solid and a liquid is the average kinetic energy of the particles. You may also say that when the phase of matter is changed from solid to liquid the average kinetic energy of the particles is increased. At a more elemental level you may say:

1. The particles move more slowly in a solid than in a liquid.

2. The particles are closer together in a solid than in a liquid.

Materials

Overhead projector and screen

Super 8 mm cartridge projector

Transparencies:

21, "In the solid state, the particles of matter are packed together in a pattern and move within a small space"

23, "In the liquid state, the particles of matter are loosely clustered together and move about"

25, "The state of matter can be changed from solid to liquid and from liquid to solid"

Films: Melting (animated)

Transparent dots, about 4 dozen

Demonstration:

Beaker, 600 ml

Tripod or ring stand

Propane burner

Ice

Procedure

With the cooperation of the pupils, construct a dot model for a solid on one half of the stage of the projector. It would look like this:

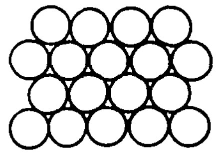

Figure 14.1. A dot model for a solid

Teacher: "Would the particles be standing still or would they be moving?" (Answer: They vibrate back and forth but usually do not move from their position.) "Why is this a good model?" (Answer: Because it helps us to explain the facts: solids have a definite shape and a definite volume.) Project Transparency No. 21, "In the solid state the particles of matter are packed together in a pattern and move within a small space."

With the cooperation of the pupils construct a dot model of a liquid on the second half of the stage of the projector. It would look like this:

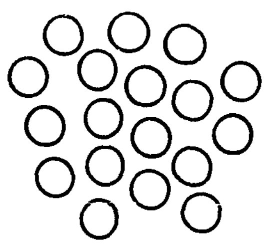

Figure 14.2. A dot model for a liquid

Teacher: "Would the particles be standing still or would they be moving?" (Answer:

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They move past each other and bounce around a great deal.) "Why is this a good model?" (Answer: Because it will help us to explain the following facts: (a) liquids have a definite volume, (b) liquids have no definite shape, (c) liquids can be poured, etc.) Project Transparency No. 23, "In the liquid state, the particles of matter are loosely clustered together and move about."

Demonstration. Place a number of ice cubes in a beaker. Have the pupils state which of the models on the overhead is best for this phase of matter. Gently heat the beaker so that the ice will melt. Note the water at the bottom of the beaker. Have the pupils state which of the models on the overhead is best for this phase of matter.

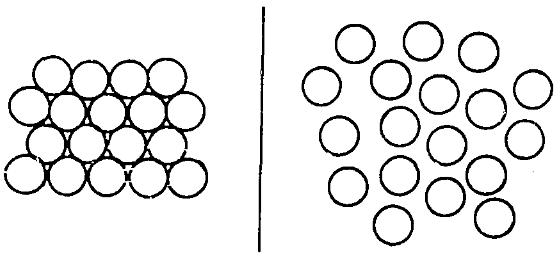

Figure 14.3. A model for two phases of matter

Teacher: "Where did the water come from?" (Answer: The ice melted. Water that was in the solid state became water in the liquid state.) "Are the water particles in the solid different from the water particles in the liquid?" (Answer: They are the same particles but they move more in the liquid.) "With the aid of our two models, can you explain what happened when the solid was heated?" (Answer: The speed of the particles was increased by adding heat. The particles were vibrating as a solid. As heat was added the vibrations increased until the particles moved out of position. When the particles moved past each other, the material became a liquid. Particles, when a part of a liquid, have more energy than when they are part of a solid.

Show the film, Melting. The narration should call attention to:

1. the vibration of the particles when in a solid state,

2. the increased rate of vibration until the liquid forms, at which time the motion becomes random.

The change in state is explained in terms of a change in the motion of the particles. The film has a good summary statement. This should be emphasized and even repeated.

Project Transparency No. 25, "The state of matter can be changed from solid to liquid and from liquid to solid." Pupils may be concerned with the temperatures at which substances melt. The answer is that each kind of solid requires a different amount of energy to cause the particles to move out of the vibrating state into the random motion state. Some kinds of particles attract each other with greater force than others.

Teacher: "How can the change from a liquid to a solid be explained?" (Answer: Remove energy so the particles move slower until the force of attraction between the particles is greater than the force that is the result of their motion.)

Lesson 15
Melting and Freezing

Concept 11: The state of matter can be changed from liquid to gas and from gas to liquid.

Background Information

The change from a liquid to a vapor or gas has been witnessed by nearly every individual. Also witnessed has been the boiling of water. The cloud that forms at the spout of a teakettle is often called steam, however, this is truly condensed water vapor. The real water vapor is not visible.

Not so common is the fact that both of these changes are explained in the same manner. In both cases, enough energy must be added to the water particles so that they can "break away" from the molecules around them. When water evaporates from your body, you feel cool because the heat energy needed for evaporation of the water comes from your body. In the explanation that involves the particle theory of matter, there must be a source of energy if matter is to undergo a change of phase.

The change from a solid to a gas is called sublimation. Examples of this change are found in "freezing dry," a term used in describing such phenomena as clothing hung outside during very cold weather that freezes but also dries. The water in the form of ice changes to a gas without becoming a liquid. Dry ice is solid CO_2, and it changes from a solid directly to a gas. In both cases mentioned, energy must be added to the particles. To change the phase of matter from vapor or gas to liquid, energy must be removed. The particles must be slowed down enough so that they can influence each other and form a liquid.

Teacher Orientation

This is an extension of Lesson 14 and hence should employ a similar teaching strategy. The extension of theory involves assigning the property of increased randomness to the particles when energy is added and vice versa.

Make use of the film Boiling and the film Bromine. The latter exposes the pupils to a phenomenon without extensive theory building, while the Boiling film provides a theoretical explanation. The teacher should narrate the two films, paying special attention to change of phase in Bromine and to the particle motion and energy in Boiling.

Materials

Super 8 mm cartridge projector

Overhead projector and screen

Transparency:

26, "The state of matter can be changed from liquid to gas and from gas to liquid"

Films: Boiling

Bromine

Demonstration:

Tea kettle or beaker

Tripod or ring stand

Propane burner

Metal pan supported on ring stands

Ice

Water

Procedure

Demonstration. Assemble the apparatus as in the sketch. The tea kettle or glass container holds water that is boiling. The shallow pan that includes ice cubes is used to cool the vapor and make it appear to rain. The changes from liquid to vapor and vapor to liquid are visible.

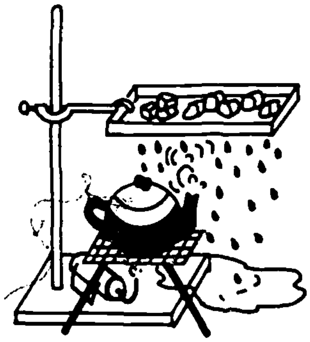

Figure 15.1. Changes of phase in water

Pupils will note the changes: (a) In the container—heat is added to water changing it to steam. (b) On the bottom of the pan—heat is absorbed by the ice cooling the steam, changing it back to water.

List these changes on the overhead or chalkboard.

Teacher: "Can we use the idea of matter we have so far in explaining these changes?" (Answer: When heat is added to the particles of water they move faster and escape from the surface of the liquid. When they do this they are called a gas. When heat is removed from the particles [cooled] they move more slowly and come closer together and form a liquid.)

Teacher: "Do we have to change our model for matter to explain the change from liquid to gas and gas to liquid?" (Answer: No. We have everything we need.)

Project the film, Bromine. Note the changes and forms of matter as well as the conditions:

warm—gas

cool—liquid

cold—solid

Have pupils explain the observation.

As a summary, project the film, Boiling.

Write summary statements on the overhead projector or chalkboard.

1. Heat is added to particles, so particles move faster.
2. When the particles move fast enough, they escape from the surface and become a gas.
3. When the rate of motion of the particles is decreased, the matter is changed from a gas to a liquid.

Project Transparency No. 26, "The state of matter can be changed from liquid to gas and from gas to liquid," as the final generalization.

Lessons 16-17
Pressure

Concept 12: The push against a surface by a gas depends upon the number and rate of motion of the particles of the gas.

Background Information

The interrelationship between matter and energy is used to explain changes in the phase of matter and rates of diffusion and also many of the mechanical effects of one form of matter on another. One of these mechanical effects is gas pressure. When the attendant at the service station inflates the tires on an automobile, he uses a gauge to be sure the pressure is correct. He is measuring the force that the air is exerting on the tire; he is not measuring the amount of air in the tire. You may ask, "Why does he add air to increase the pressure?" This question will be answered in these lessons.

If you accept the concept that matter is composed of particles, you can answer the question now. When the particles that make up air strike a surface, they exert a force. When more particles strike the same surface, the total force exerted on the surface is increased. This is described as an increase in pressure.

In this explanation we have used the terms surface, force, and pressure. In science it is important to develop definitions in terms of measurable quantities. The amount of surface is described as area. The units used in describing an amount of area are square inches, square feet, square centimeters, etc. Length is the unit from which the area unit is derived. When two lengths are multiplied, the product is area; inches x inches = square inches, etc. The definition of force is based on a result that can be measured. A force is exerted when the rate of motion of a particle of matter is changed. Forces are measured in pounds, dynes, tons, etc. These units are now used in giving us the definition of pressure.

If a box of water 1 foot long, 1 foot wide, and 1 foot deep is resting on a surface, the total force on the 1 square foot bottom is 62.4 pounds. (This is the weight of a cubic foot of water.) We can also say that the pressure on the square foot is 62.4 pounds. Notice that in this case the pressure is 62.4 pounds per square foot. It is easy to determine the pressure per square inch by dividing, since there are 144 square inches in a square foot. The pressure per square inch is

$$\frac{\text{Force}}{\text{Area}} = \text{Pressure}$$

$$\frac{62.4 \text{ pounds}}{144 \text{ sq. inches}} = .43 \text{ pounds per sq. inch}$$

Pressure is defined as force per unit of area.

Now to return to the idea of gas pressure. A football without much air in it is not expanded; only a relatively small number of moving gas particles strike each square inch of the inner surface. Each gas particle is moving quite fast but only a few strike the surface. When more air is added to the football, the number of particles of gas striking the surface is increased. The increase in number of particles increases the force acting on each square inch; this is described as an increase in pressure. Adding air did not increase the rate of motion of the particles; the increase in pressure was the result of more particles striking the surface. The pressure is equal to the sum of the forces exerted by the individual gas particles on a unit of area.

There is a second way of changing gas pressure—changing temperature. A basketball may be very firm when inside a warm building on a cold day, and be soft when outside where the temperature is low. A balloon tied over a bottle will become inflated if the air is heated.

These phenomena are explained in terms of the rate of particle motion rather than number of particles. Again it is wise to return to individual experiences. For example: It is easy to catch a ball that is thrown gently. This is because the force caused by the mass and rate of motion of the ball is small. If the ball is thrown more rapidly, it is more difficult to catch and often stings the hands. The force exerted by the fast ball is greater.

In our model for matter we have already explained temperature in terms of rate of motion of particles; the higher the temperature the more rapidly the particles move. When this is applied to gases, pressure changes due to heating are also explained. In a balloon that is cool there are X number of particles striking the surface with a small force. When the temperature is increased, the balloon becomes inflated due to the same X number of particles striking the surface, but this time each particle exerts a greater force. The combined individual forces cause the balloon to be inflated.

Materials

Overhead projector and screen

Super 8 mm film cartridge projector

Transparencies:

27, Diagram of the dynamic model

28, "The push against the surface by a gas depends upon the number and rate of motion of the particles of the gas";
Overlays 1, 2, and 3

Films: Pressure

The Gaseous State

Transparent dots

Dynamic gas model

500-ml flask

Propane burner

Balloons

Cold water

Shot

Marbles

Lesson 16
Pressure and Number of Particles

Teacher Orientation

The natural phenomenon explained is that of pressure exerted by gases, and the exemplification will be via an inflated balloon. The desire is to explain how gases exert a force on the inside of the balloon.

In this case there are no needed modifications to the theory we have—matter in the form of a gas is made up of particles that are far apart and moving. The new factor, however, is that when a moving object strikes a stationary object a force is exerted. The force is transmitted from the moving object to the second object. You may recognize this as the transfer of kinetic energy from the particles to another quantity of matter.

You may wish to investigate this idea for yourself by performing an analogous experiment.

Extend a rubber band between two nails stuck in a board so the band is taut but not too tight. Support another board at a slant about 1 foot from the stretched band (see Figure 16.1). Release a steel marble from a marked level on the slanted board so that it strikes the rubber band when the ball is allowed to roll down the board. Note the amount of bend in the band. Repeat this with three or more steel marbles of the same size at the same time. In which case did the band bend more? The three marbles may be thought of as more particles of gas pushing on a surface.

On occasion a pupil may ask why a basketball is more firm when it is warm than when it is cold even though no air is added or taken away. You can answer this using the particle idea already formulated, remembering that the rate of motion of the particle increases when energy is added. (Temperature is increased.)

When air is added the pressure is increased because more particles strike a unit area. When

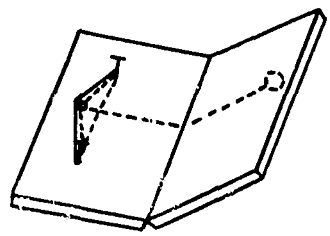

Figure 16.1. An analogy for pressure

air is heated the pressure is increased because the same number of particles strike a unit of area with a greater force.

It is very important that the teacher not confuse the students by using the terms force and pressure as equivalents.

Procedure

Display one fully inflated and one partially inflated toy balloon and have the pupils list observed differences (size, firmness, etc.).

Teacher: "If both balloons were the same before they were blown up, what else can we say?" (Answer: One has more air blown in it than the other.) "Why can we say this?" (Answer: Because we have blown up balloons before. When you blow in more air, the balloon gets bigger.) "What must happen to cause the balloon to stretch?" (Answer: Something has to push on the inside.) "What pushes on the inside of the blown-up balloon?" (Answer: The air.) "How is the push on the inside of the balloon with the air explained?" (Answer: The moving particles that make up the air push on the inside of the balloon.) [In the event that the pupils have difficulty, you may wish to review what we know about gases: particles—particles move—moving particles strike surface—striking surface exerts force on balloon.]

In either instance, show the film, The Gaseous State. The teacher will narrate the film. Attention of the pupils may be directed to the desired observations by asking some questions. "What happens when one particle

Figure 16.2. Inflating a balloon

strikes another?" (Answer: They bounce.) [The particles essentially strike each other, but in the strict sense in the theory they do not. This is not important for the pupils.] "What kind of a path do the particles follow between collisions?" (Answer: Straight.) "When two particles collide, which one changes its rate of motion?" (Answer: Both do.) It is important to note that the force from one particle is transmitted to another.

If the apparatus to demonstrate the dynamic model of a gas is available, demonstrate the effect of particles striking the piston. First place one piece of shot in the cylinder and run the motor. Note how high the piston is pushed up.

Teacher: "How can we make the piston go higher?" (Answer: Increase the number of particles striking the piston.) Add a few more shot and observe the result. The piston moves higher.

Show the film, Pressure.

Call the attention of the pupils to the analogy. The shot represent the particles of gas.

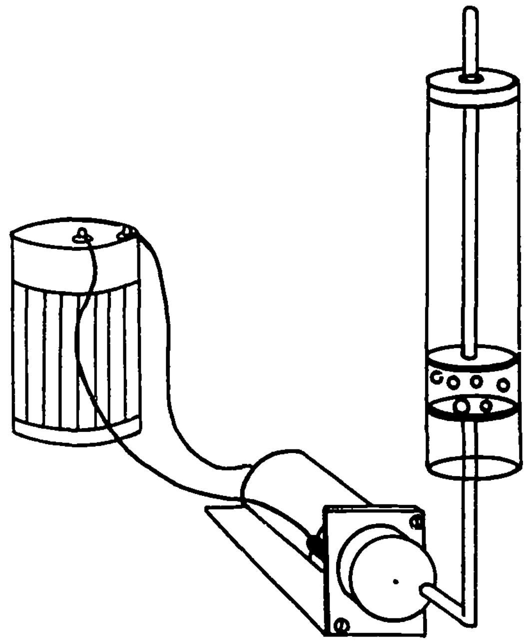

Figure 16.3. A dynamic model for a gas

Teacher: "Where does the force come from that causes the piston to move up?" (Answer: The moving particles.)

Construct a model for the gas and piston on the projector from the dots and Transparency No. 27, the diagram of a dynamic model.

Teacher: "What factor is missing in this model?" (Answer: Motion of the particles.)

Project Transparency No. 28, "The push against the surface by a gas depends upon the number and rate of motion of the particles of the gas," and discuss it to explain the difference between the two balloons. Add the first overlay and explain that the gauge indicates the pressure, the amount of the force the particles are exerting on each unit area of the box. Add overlay dots to show a few particles in the boxes.

Teacher: "What should be added to the second box to help explain the difference in pressure in the two boxes?" (Answer: Add more dots to represent more particles striking the walls.) Add the third overlay.

Lesson 17
Pressure and Particle Rate of Motion

Teacher Orientation

In the first lesson related to this concept, the emphasis was on pressure due to more particles. The second lesson relates to explaining changes in pressure in terms of changing the rate of motion of the particles present. The change in rate amounts to changing the kinetic energy, the capacity of each particle to do work. It must be accepted as a useful concept only when the particles remain the same.

If you wish to set up another simple analogous situation, you may use the stretched rubber band and marble equipment. (See Figure 16.1.) Note that the faster the marble is caused to move the more the rubber band is stretched. This will help clarify the idea of speed of particle and force exerted. It is obvious that a force is needed to change the rate of motion of an object. When the marble was caused to move faster, the force had to be increased. When the marble struck the rubber band, a greater force was needed to slow it down; the rubber band therefore was bent more.

Procedure

Review the explanation for gas pressure due to increasing the amount of gas in a given volume. Construct a model on the overhead using the dots and Transparency No. 28, "The push against the surface by a gas depends upon the number and rate of motion of the particles of the gas." Emphasize the idea of number of particles striking an area. It may be necessary to review the meaning of the terms area, force, and pressure.

Demonstration. Stretch a balloon over the mouth of a 500-ml flask. Have the pupils note the degree to which it is inflated. Heat the flask. Note what happens to the balloon. (The balloon becomes inflated.) Place the flask in cold water. Note what happens to the balloon. (The balloon is deflated.)

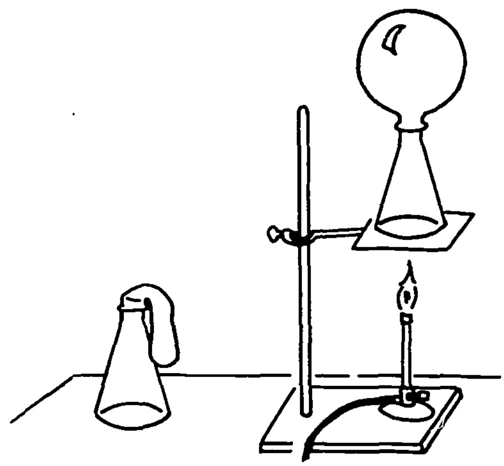

Figure 17.1. Inflating a balloon by expansion of gas through heating

Teacher: "We now want to see if we can explain what we see." [Begin with some obvious facts.] "Did we add any more air to the flask?" (Answer: No.) "What was added to the flask?" (Answer: Heat.) "Is heat matter or energy?" (Answer: Energy.) "What happens to the particles if energy is added?" (Answer: They move faster.) "Is this true when the form of matter is a gas?" (Answer: Yes.) "If one particle is moving slowly and another particle of the same size is moving rapidly, which will strike a surface with a greater force?" (Answer:

The faster moving particle.)

Show the film, Pressure. In this narration, pay special attention to the rate of motion of the particles and the distance the piston is moved.

Teacher: [Apply this idea, in summary, to the balloon.] "How is the change in pressure by heating explained?" (Answer: The particles are caused to move at a higher rate so they strike the balloon harder. This causes an increase in pressure. Because the balloon is elastic it stretches out and gets bigger.)

You may wish to summarize the lesson using the dots and Transparency No. 28, "The push against the surface by a gas depends upon the number and rate of motion of the particles of the gas."

Lessons 18-19
Particles Are Made Up of Particles

Concept 13: Some particles of matter (molecules) are made up of simpler particles (atoms).

Background Information

The particle concept of matter developed thus far relates to single indivisible particles. If one were to date this level of the concept, it would probably be about 1810-1830, and the summary of many of the factors it includes would be credited to Dalton. Dalton was not the first man to think of matter as made up of particles; however, he did a great deal in pulling some older ideas together to form some new ideas.

In the lessons so far, some of the particles used in explaining certain phenomena have been atoms and some have been molecules although no differentiation has been made. The next step can ultimately lead to a concept of fundamental particles. The concept for this level will be "atoms are fundamental building blocks of matter." "Atoms are combined to form molecules" is a common idea that is slightly in error since by definition some molecules are made up of only *one* atom. Monatomic molecules will not be treated here.

At this time the idea that some particles (molecules) are made up of other particles (atoms) is adequate. Later the idea of the electrical nature of matter will be developed.

The surprises that appear as the chemical nature of matter is studied fascinate most pupils. For example: hydrogen is a colorless, odorless gas that burns in another odorless, colorless gas—oxygen—to form water. Another example is the very active metal, sodium, that reacts with a yellowish-green poisonous gas, chlorine, to form sodium chloride which is common table salt. Salt and water are both necessary for the human body.

Models of molecules of the space-filling kind are used here because they can be easily manipulated and taken apart. In this type of model, the hydrogen can be separated from the oxygen in water, and carbon and oxygen can be separated in carbon dioxide.

As the growth of this concept proceeds, there will be increasing need for use of the terms molecule, atom, element, and compound because of their relationship. An element is made up of one kind of atom. A compound is made up of two or more kinds of atoms. It is evident that molecules of elements are made up of one kind of atom and molecules of compounds are made up of more than one kind of atom. A molecule of an element is possible, but there can be no such thing as an atom of a compound.

Care must be taken so that the pupils use the examples of atoms and molecules as ideas; little emphasis should be placed on properties of selected elements. The need is for a general concept related only to the idea that particles are made up of particles.

Lesson 18

Teacher Orientation

This lesson is to be initiated with a demonstration probably never seen before by the pupils. It is also a first for the pupils to witness the disassociation of a compound, so they may really not believe what they see. The pupils may have talked about oxygen but it is probably considered to be air, and hydrogen is an unknown. Hydrogen can't be seen or smelled but it does burn, so the students may think that what they see is "magic."

The use of the space-filling type of model is helpful here. One source of confusion may be the volumes occupied by the two gases because the space-filling hydrogen atom is smaller than the oxygen. Remember that these models are only models and are much expanded; this should not become an issue.

The names "element," "compound," "atom," and "molecule" must be introduced slowly and carefully. They should be used only when the other terms are no longer satisfactory.

Materials

Overhead projector and screen

Super 8 mm film cartridge projector

Wax pencil

Transparencies:

- 29, Electrolysis apparatus
- 30, "Some particles of matter (molecules) are made up of simpler particles (atoms)"

Red transparent dots, 8-10

Blue transparent dots, 8-10

Film: Electrolysis of Water

Demonstration:

- Electrolysis apparatus
- Direct current source
- 2 test tubes
- Wood splinters
- Matches
- Water
- 10 drops of sulfuric acid (H_2SO_4)
- 2 stoppers to fit the test tubes

Models:

- Water molecule, styrofoam
- H_2

Procedure

Mention that today we are going to see if our particle idea of matter can be used to explain another observation.

Demonstration. Add about 10 drops of sulfuric acid to enough water to fill the electrolysis apparatus. Be sure the two arms with the electric wires connected to it are filled. The air can be allowed to escape through the stopcocks on the top. Connect the source of electricity to the wires. (Use about four dry cells connected in series or another source of direct current.)

Have the pupils note that the tubes contain only water. (The sulfuric acid is added only to make the water a good conductor of electricity.) The observations to be made relate to what happens at each wire end and collects in the tubes.

Project Transparency No. 29, the diagram of electrolysis apparatus, so the pupils can see the details of the apparatus.

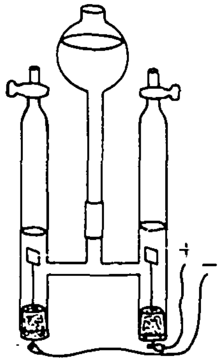

Figure 18.1. Diagram of electrolysis apparatus

While waiting for the results of the demonstration, it is well to review the concept of water used so far:

1. It is made up of particles.

2. The particles are in motion.

3. The particles move past each other.

You may wish to form a dot model for water on the overhead projector.

As the demonstration proceeds, the pupils should note:

1. Bubbles form at the ends of the wires in the tube.

2. The gases in the bubbles collect in the tubes.

3. The gas accumulates twice as fast in one tube as in the other.

Project film, Electrolysis of Water.

Write the terms oxygen and hydrogen in the proper places on Transparency No. 29, the diagram of electrolysis apparatus. The tube with the greater volume of gas contains hydrogen and the one with the smaller volume contains oxygen.

[It is usually necessary to tell the students that the gases are hydrogen and oxygen.]

If the demonstration is in operation long enough, each gas may be collected so some of the properties of each gas can be demonstrated. Transfer each gas to a separate test tube by inverting one test tube over each stopcock. Open one stopcock at a time until the gas enters the test tube. When all of the gas has entered the tube, close the stopcock and stopper the test tube.

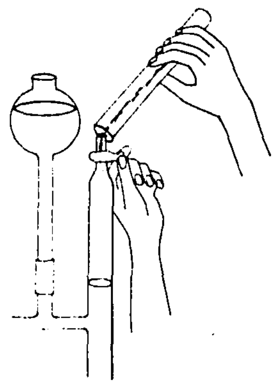

Figure 18.2. Releasing gas from electrolysis apparatus

To test for hydrogen hold a burning splinter at the mouth of the test tube after removing the stopper. If a "pop" is heard, hydrogen is present.

To test for oxygen open the tube and insert a glowing splinter. If the glowing splinter glows brighter or begins to burn, oxygen is present.

Teacher: "Where did the two different gases come from?" The pupils probably will be unable to answer. It will be necessary to tell them that the electric current breaks the water apart into hydrogen and oxygen. "How can we explain the fact that when water is broken apart we get hydrogen and oxygen? Is our idea that water is made up of particles useful in explaining this?" (Answer: No.) "How can we modify our model so that we can explain the fact that water can be broken down into hydrogen and oxygen? What two facts must we consider in our model?" (Answer: (a) oxygen and hydrogen are formed, (b) twice as much hydrogen as oxygen is formed.) List these on the overhead or chalkboard.

Have the pupils try to make such logical inferences as: (a) Since we got hydrogen and oxygen, maybe the electricity changed water into the two gases; and (b) Water could be made up of hydrogen and oxygen, and the electricity only separates them. If the pupils do not mention (b), you may suggest that hydrogen and oxygen are both matter. This means that they are also made up of particles. Call the red dots oxygen and the blue dots hydrogen. Have pupils put the colored dots together to form a ratio of two hydrogens to one oxygen. They can put the dots together in many different ways. No matter what geometric figure they use, the only requirement is two hydrogens for one oxygen.

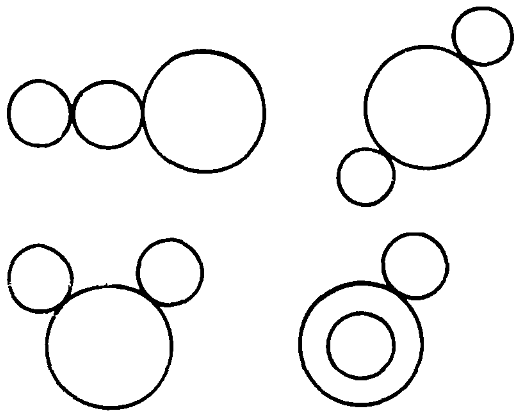

Figure 18.3. Models for water molecules

Explain that each of these particles has a name. When there are one oxygen and two hydrogen particles together, we have a molecule of water. The hydrogen parts are called atoms and the oxygen part is called an atom.

Display a styrofoam model of water showing what scientists think is a reasonable structure for water. Use the terms atoms and molecules and be sure they are modeled as particles.

You may now form some models on the overhead projector to show how the two gases were formed. The pupils should participate in this formulation.

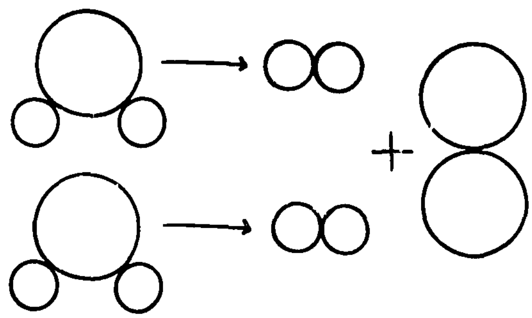

Figure 18.4. Model for decomposition of water

Our model for forming oxygen and hydrogen can be reviewed by using styrofoam models.

Use the styrofoam models to define atom and molecule.

Project Transparency No. 30, "Some particles of matter (molecules) are made up of simpler particles (atoms)."

Use the electrolysis of water as the frame of reference for use of the model.

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Lesson 19

Teacher Orientation

In the process of developing knowledge in science, great care is exercised to make the outcome as credible as possible. Notice that the word credible and not truth or proof is used. This is done because there is really only temporary truth in science. If the term truth is used, it is not considered to say anything is absolute, it is always at this time, or under these conditions, or some other relativistic idea.

In this lesson we will check a model and a chemical formula to see if we can tell what is in a compound from it's formula. Some individuals may think this is a wrong approach since formulas for compounds are developed only when the composition is known. Here one of our concerns is to help the pupil learn that these formulas tell us what elements the compound is made up of. The other concern is more important; some particles are made up of particles, i.e., molecules are made up of atoms.

The demonstration in this case becomes a means of testing a prediction. If the prediction is proper, the idea is probably a good one. One criterion of a good theory is its use in making predictions.

Materials

Overhead projector and screen

Transparencies:

30, "Some particles of matter (molecules) are made up of simpler particles (atoms)"

31, A model for a sugar molecule

Demonstration:

6-in. test tube

30 gm sugar

Propane burner

Matches

Test tube holder

1000-ml flask

Water

Models, styrofoam:

Water

Carbon dioxide

Procedure

Teacher: "What was the model for water that we developed yesterday?" (Answer: It is made up of two kinds of particles: hydrogen and oxygen.) "How many of each kind of particle did we say there were?" (Answer: 2 hydrogen and 1 oxygen.) "What was the reason for making our model include these numbers?" (Answer: Because when water was taken apart, there was twice as much hydrogen as oxygen collected.) "What did we call the particle that was made up of two pieces of hydrogen and one piece of oxygen?" (Answer: A molecule of water.) "What did we call the particles of hydrogen and oxygen?" (Answer: Atoms.)

Display the model for water.

Teacher: "There is an easy and precise way of representing a molecule of water." Write the formula H_2O on the overhead or chalkboard. "The letter H is the short way of writing one atom of hydrogen. The letter O stands for one atom of oxygen. If we wrote HO, this would tell us that there was one atom of hydrogen and one atom of oxygen present in water, and this would be incorrect. This is why we place the little number 2 at the bottom of the hydrogen. The H_2O tells us this is a molecule of water that is made up of two atoms of hydrogen and one atom of oxygen."

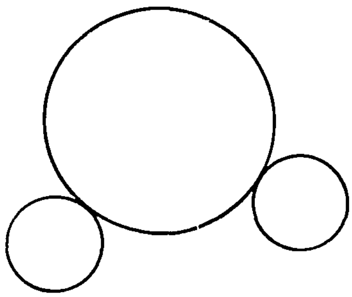


Figure 19.1. A model for a water molecule

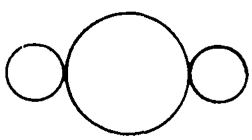


Figure 19.2. A model for a carbon dioxide molecule

Display the model for carbon dioxide.

Teacher: "This is a model of a carbon dioxide molecule. Carbon dioxide is one of the gases we breathe out. The black ball represents carbon and the white balls represent oxygen. How many atoms of carbon are present?" (Answer: One.) "How many atoms of oxygen are present?" (Answer: Two.) "How can we write the symbols for carbon dioxide?" (Answer: One C and O_2 in the form of CO_2.)

Project Transparency No. 31, a model for a sugar molecule.

Teacher: "This is a sketch of a model for a molecule of sugar. It is not a crystal of sugar. It is one of the tiny particles of sugar you looked for when you dissolved sugar in water. Each shade represents a different kind of atom. How many kinds of atoms are there in a molecule of sugar?" (Answer: Three: hydrogen, oxygen, carbon.) "Although you cannot see all of the atoms present, you can see most. You can see all of the carbon (black dots) and all the oxygen (gray dots). Some of the hydrogen atoms (white dots) are underneath so you cannot see them. How many carbon atoms do you see?" (Answer: 12.) "How many oxygen atoms?" (Answer: 11.) "There are also 22 hydrogen atoms. How can we write the symbol for a molecule of sugar?" (Answer: $C_{12}H_{22}O_{11}$.) "If we could take sugar apart what would you expect to find?" (Answer: Carbon, hydrogen, and oxygen.) "This is what we can predict from the formula. We can also see how accurate our predictions are by performing an experiment."

Demonstration. Add about 20 gms of sugar to the test tube and hold the tube with a test tube holder. Add about 750 ml of cold water to the flask. (If you do not have a flask, use a shiny aluminum pan or sheet or a mirror. The purpose of the cold shiny object is to detect the presence of water vapor. If the surface becomes clouded when it is held above test tube, this is evidence that water is being given off.)

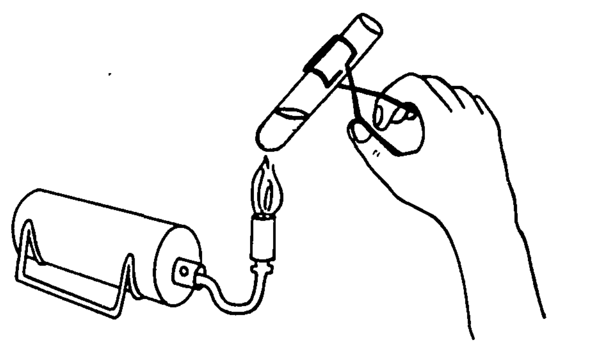


Figure 19.3. Heating sugar in a test tube

Hold the test tube containing the sugar in the burner flame. When some change takes place in the test tube, hold the cold flask or shiny sheet above the mouth of the tube. Note what changes occur. The pupils should make observations and report the changes.

Teacher: "What has happened?" (Answer: Contents of the tube turn brown and then black. The cold surface is fogged.)

Teacher: "What do you think these materials are?" (Answer: Black material is carbon and the stuff on the glass is water.) "Is our prediction correct so far?" (Answer: Yes, we got carbon.) "Did we also get hydrogen and oxygen?" (Answer: We got water and water is made up of hydrogen and oxygen.)

It is important to emphasize to the pupils that here is another example of a very complicated substance, but it is made up of simpler substances; the molecule is made up of different kinds of atoms.

Project Transparency No. 30, "Some particles of matter (molecules) are made up of simple particles (atoms)."

Lesson 20
Elements

Concept 14: Some molecules are made up of only one kind of atom (elements).

Background Information

All matter may be classified as either a pure substance or a mixture. Pure substances may be further divided into two classes, elements and compounds. The definition of an element is given as a substance that is made up of one kind of atom. A compound is defined as a substance made up of more than one kind of atom and in which the number of each kind of atom is definite and specific. The smallest part of an element is, therefore, an atom and the smallest part of a compound is a molecule.

The development of classificational schemes is one of the ways developed by scientists that make it possible to deal with large numbers of facts. In forming classifications of facts, definitions must be developed that make each class mutually inclusive and exclusive. This means that all factors included in any classificational scheme must be based upon measurable quantities. In classifying elements and compounds it is possible to measure the factors used.

There are a number of ways of classifying atoms: how easily they become parts of compounds; weight; number of electrons, protons, and neutrons, etc. At this level the only factors to be considered are weight (density) and appearance.

Teacher Orientation

This lesson is essentially an application to elements of the previous theory of atoms and molecules. It could also be the application of the theory to explain the nature of a material that was made up of only one kind of substance that could not be broken up by simple physical or chemical means. The concern is not for the difference between elements and compounds. It is somewhat easier if an element is described as a substance that cannot be separated into simpler substances by chemical means. It is thus apparent that atoms are not divisible by chemical means. This definition includes the molecules that are made up of one atom (molecule) like mercury, iron, copper, etc.; diatomic molecules like hydrogen, oxygen, chlorine, etc.; and polyatomic molecules like ozone.

The idea of different structural models of the same element may cause some concern. Diamond, soot, and graphite are all made up of the same element, carbon. However, in the model for each there is a noted difference in the arrangement of the atoms. The atoms are in layers for graphite; this accounts for its slippery feeling. The atoms are arranged in the form of pyramids in diamond, accounting for its hardness. As the study of matter is pursued you will find more attention being directed to the arrangement of the atoms. The nature of the arrangement helps us to explain some of the properties of matter.

Materials

Overhead projector and screen

Transparency No. 32, "Some molecules are made up of only one kind of atom. ELEMENT"

Styrofoam models:

Water

Carbon dioxide

Oxygen

Hydrogen

Diamond

Graphite

Small quantities of a variety of elements as:

carbon	copper	gold
aluminum	iron	silver
lead	zinc	neon
	mercury	

Procedure

Display several styrofoam models of molecules—hydrogen, water, carbon dioxide, etc.—and tell the pupils all are molecules.

Teacher: "How are these molecules different?" (Answer: Hydrogen has only hydrogen atoms, and water and carbon dioxide have two kinds of atoms.) Identify the atoms in the molecules and emphasize the difference between those with one kind of atom and those with more than one kind. Project Transparency No. 32, "Some molecules are made up of only one kind of atom. ELEMENT." Stress the word element. Display models of molecules of hydrogen and oxygen. These are elements because they are made up of only one kind of atom.

Display several samples of carbon but be sure to include graphite and mention diamond. (If you have a problem obtaining graphite you may use pencil lead because it is a mixture of graphite and clay.) Compare the properties of graphite and diamond. Emphasize the hardness and rigidity of diamond and the slipperiness of graphite.

Teacher: "How can we make a model for graphite that would help us to explain that it is slippery?" Display the styrofoam model for graphite and show how the layer arrangement of the atoms allows for one atom to slide over another.

Display the styrofoam model for diamond. Emphasize the pyramid arrangement and the way the atoms are attached to each other. Note that both graphite and diamond are made up of the same kind of atom; the difference is due to the arrangement of the atoms.

Display samples of as many kinds of elements as available.

Teacher: "How many kinds of atoms are known so far?" (Answer: 103 to date.) All of the substances known in the universe are made up of one or some combination of these 103 kinds of atoms. The 103 kinds of atoms are the building blocks of all matter. Some of the elements are solid, some are liquids, and some are gases at room temperature: iron, copper, etc., are solid; mercury is a liquid; and oxygen, hydrogen, nitrogen, etc. are gases.

Write the terms element and atom on the overhead or chalkboard. Review the ideas of atom and element using models of molecules of oxygen and hydrogen.

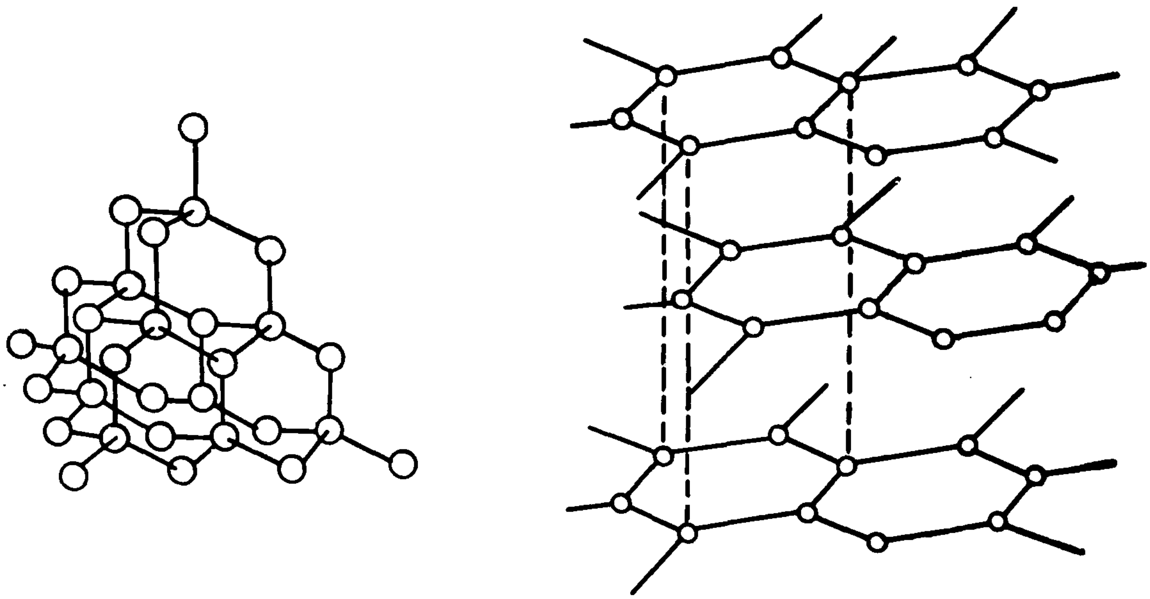


Figure 20.1. Diamond and graphite models

Lesson 21
Compounds

Concept 15: Some molecules are made up of two or more kinds of atoms (compounds).

Background Information

Atoms combine chemically to form molecules. The atoms of elements lose their general identity when they become a part of a molecule. Hydrogen is a flammable gas and oxygen is a gas that supports burning. When two atoms of hydrogen combine with one atom of oxygen water is formed. The water has none of the chemical properties of hydrogen or oxygen. When two or more kinds of atoms unite chemically a compound is formed. A compound has chemical and physical properties that are different from the elements that make it up.

Compounds are pure substances, because the composition in terms of kinds of atoms and number of atoms in a molecule of a given compound is always the same. In a mixture, the composition may vary but the composition of a compound never varies. This statement may be challenged by some, because some compounds are believed to be aggregations of ions. Ions are atoms with an electric charge. Salt is an ionic compound; however, it is not especially serious if the pupils refer to the combination of sodium and chlorine, $NaCl$, as a molecule of salt.

Mercuric oxide (HgO) is an ionic compound that we will use. When the HgO is heated in a test tube, care must be exercised to prevent the escape of mercury vapor; it is necessary to insert a cotton plug in the test tube. Do not allow the pupils to play with the mercury because this metal is toxic.

The purpose of this lesson is to develop a low-level concept of a compound. In this, as in other cases, the concept formed is the means of explaining the structure of a type of matter. A compound can be explained using the idea of particles if we say that there are different kinds of particles.

Teacher Orientation

This lesson will involve the formation of a compound from two elements and the analysis of a compound into its elements. The models used will essentially be applications of the particle idea. The particles join together in forming a compound. The particles are taken apart in the analysis of the compound.

It is desirable to point out the use of the particle idea in describing the make-up of matter. You will do this with wood—carbon, hydrogen, and oxygen; salt—sodium and chlorine; mercuric oxide—mercury and oxygen; rubber—carbon, hydrogen, and oxygen; and gasoline—carbon and hydrogen; etc.

Materials

Super 8 mm cartridge projector and screen

Overhead projector and screen

Transparency No. 33, "Some molecules are made up of two or more kinds of atoms. COMPOUNDS"

Colored disks

Film: Decomposition of Mercuric Oxide

3" strip of magnesium ribbon

Forceps

Asbestos pad

Black paper

Propane torch

Magnesium oxide

1/4 oz. mercuric oxide

8" test tube

Cotton plug

Test tube holder

Wood splinters

Styrofoam models:

- Oxygen
- Magnesium oxide
- Mercuric oxide
- Water
- Hydrogen
- Carbon dioxide
- Magnesium

Procedure

Display the molecular models of water and oxygen.

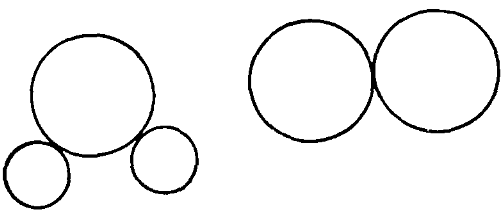


Figure 21.1. Models for water and oxygen

Teacher: "How are these two models alike?" (Answer: They are made up of more than one atom. They both probably represent molecules.) "These are models of molecules; one is water and the other is oxygen. How are the two molecules different?" (Answer: Oxygen is made up of one kind of atom and water is made up of two kinds of atoms.)

Display a strip of magnesium. Teacher: "This is a sample of an element that is called magnesium. What does the word element tell you about the molecules of magnesium?" (Answer: It is made up of only one kind of atom.)

Construct a dot model of magnesium on the overhead projector. Have the pupils participate in the activity. Be sure to note:

1. There is only one kind of particle.
2. Particles are arranged in a pattern (solid).

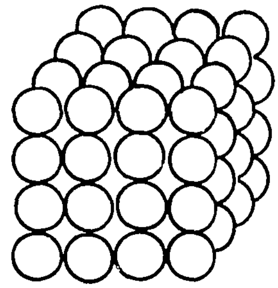


Figure 21.2. A model for magnesium

Display a three-dimensional styrofoam model of magnesium, so pupils can visualize the collection of particles. Note that there is only one kind of particle present.

Demonstration. (A very bright light will be produced when the magnesium burns in this demonstration. Pupils should be warned not to look at it directly.)

Teacher: "Today we are going to put two elements together and then see if we can form a model that can help us explain the result. The two elements are magnesium and oxygen. The oxygen will come out of the air. There will be a bright light formed. Do not look at it directly." (You may hold a piece of colored plexiglass between the light and the pupils.) Hold a piece of magnesium ribbon in the flame of a propane burner. Allow the ash to be deposited on a piece of black paper or in a dish.

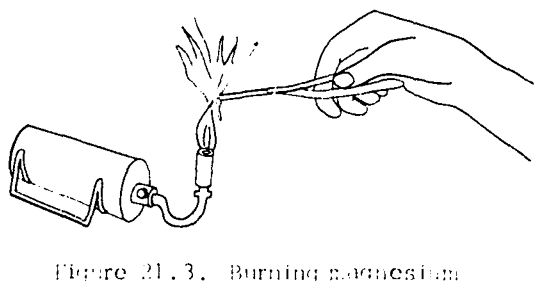


Figure 21.3. Burning magnesium

Teacher: "What has happened?" (Answer: The magnesium burned.) "Does the product formed look like the ribbon?" (Answer: No.) "If the magnesium combined with oxygen, what kinds of particles would we have to include in any model we make for the white powder?" (Answer: Magnesium and oxygen.) "If one atom of magnesium combined with one atom of oxygen, what would our model for the powder look like?" (Answer: One magnesium dot and one oxygen dot.)

Construct a molecule of magnesium oxide (MgO) on the overhead projector. (Use dots of two colors and two sizes and have pupils participate.) Add several more molecules to form a bigger quantity on the projector.

Figure 21.4. A model for magnesium oxide

Display the styrofoam model of MgO so pupils can see the arrangement of the atoms.

Project Transparency No. 33, "Some molecules are made up of two or more kinds of atoms. COMPOUNDS."

Display several other models and have the pupils identify the atoms in the compound.

Demonstration. We are now going to take a compound apart, see if we can identify the parts, and construct a model for both the original compound and the parts. (If the materials are not available show the film on mercuric oxide. If the visibility of the demonstration is limited, the film is a useful supplement.)

Place a quantity of mercuric oxide (HgO) about the size of a pea in a test tube. Describe its appearance (red-yellow powder). Insert the tube in a clamp.

Teacher: "As we go on with this experiment we will want to see what changes occur, and one of these possible changes will be to see if oxygen is given off. We also want to make any other reasonable observation. We should, therefore, see if the powder gives off oxygen before it is heated."

Insert a glowing splinter into the test tube. (Result: Nothing happens.) Heat the powder by holding the test tube in the flame of a burner. Periodically insert a glowing splinter into the tube and observe the results. (Result: After heating for a short time, the splinter will burst into flame.) "What do we infer from these observations?" (Answer: Oxygen is given off.) "Examine the side of the test tube. What has happened?" (Answer: Small silver drops have formed on the side of the test tube.) "Where do you think they came from?" (Answer: The material we heated.)

"These drops are mercury. It is the silver material often used in thermometers. It is a metal that is liquid at room temperature. What two elements were present in the compound we heated?" (Answer: Mercury and oxygen.) "Was the mercury like the powder we heated?" (Answer: No.) "How would you classify the red powder, as an element or a compound?" (Answer: Compound.) "Why?" (Answer: Compounds have properties different from the elements that make them up.)

With the help of the pupils construct a model for HgO and the elements yielded when it was heated. Be sure to count the number of atoms on each side of the arrow; these must be the same. The number of atoms is conserved in a chemical change.

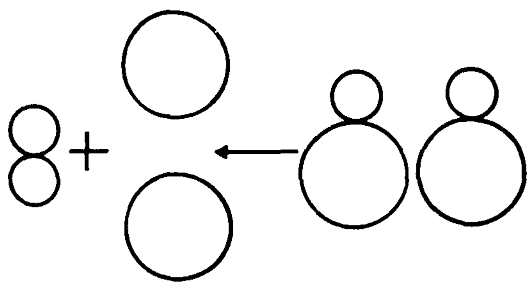


Figure 21.5. A model for the decomposition of mercuric oxide

Project Transparency 33, "Some molecules are made up of two or more kinds of atoms. COMPOUNDS," and compare and contrast the concept of element with the concept of compound.

Lesson 22
Mixtures

Concept 16: Some samples of matter contain more than one kind of molecule (mixtures).

Background Information

Matter has been classified in terms of its phase as solid, liquid, or gas. It can also be classified according to its composition as an element, compound, or mixture. Elements and compounds have already been defined and described in terms of the number and kinds of particles present. Elements have a single kind of atom present per unit particle (molecule). Compounds have more than one kind of atom present per molecule, and in any type of molecule the number of individual atoms is always uniform.

There are some substances that are not pure, that is, they do not have a constant composition. Sugar and water can be mixed together in an infinite number of proportions. There can be one grain of sugar in a cup of water or there can be much more. There can be stones, sand, and water all together with no specific numbers of any of the parts required. It is possible to have pennies and nickels in the same container. These substances are called mixtures. Mixtures are characterized by their composition—what elements or compounds they include. Mixtures cannot be described by means of a chemical formula because the proportions of each part are not constant.

Another characteristic of mixtures is that the parts (elements or compounds) retain their individual identities and do not react chemically to form a new substance. This means that mixtures can be separated by mechanical means.

If a mixture of sugar and sand is to be separated, the fact that sugar dissolves in water can be used. The water can be evaporated and the sugar recovered. An alcohol-water mixture can be separated by distillation because the boiling points of water and alcohol are different.

The important concept of a mixture is that it consists of two or more substances and has no definite composition.

Solutions are a type of mixture. Solutions are defined as particles of solute of molecular size dispersed uniformly throughout a solvent. When dissolving sugar in water, as in the case above, the sugar is the solute and the water is the solvent. The special characteristic of a solution is that some chemical change does occur since an energy change occurs when solution takes place. At this level of sophistication this idea of a solution should not be of concern.

The idea that in solutions the solute is of molecular size in the solvent can be used to separate some mixtures. If a mixture with one soluble part is to be separated, the soluble part and the solvent will pass through a filter. The part of the mixture that does not dissolve is separated from that which does in the filter. The two mechanical methods of separating mixtures to be used in this lesson are boiling and filtering.

Teacher Orientation

Mixtures can be made up of elements, compounds, and mixtures of mixtures, and the proportions of each component can vary. The amount of each part of a mixture compared to the total of all present may be referred to as concentration. If a mixture that weighs 150 grams includes 50 grams of sugar, the concentration of sugar is 33 1/3%.

Air is a very common mixture. It includes oxygen, nitrogen, carbon dioxide, water vapor, and some other gases. Soil is a common mixture of rock particles, humus, water, and air. The mechanical separation of both of these mixtures has been witnessed often. The "sweat" water on the outside of a glass containing ice water on a humid day comes from the air. This causes the composition of the air to vary. Evaporation of liquids into the air results in a change in the composition of air. When soil dries out, there is also a change in composition of a mixture.

The three substances to be used in this lesson are salt, sand, and water. The simple separation of the mixture is the phenomenon to be explained via the development of a model for a mixture.

You will find the use of styrofoam balls, sand, and marbles useful in forming the model. If possible, you can make a model of the filter from a piece of window screen. The small particles pass through and the larger ones remain on top. The overhead projector is also helpful in forming models for mixtures.

In this lesson the pupils should be able to construct a model for a mixture with little difficulty.

Materials

Overhead projector and screen

Transparency No. 34, "Some samples of matter contain more than one kind of molecule. MIXTURES"

Styrofoam models

Water, H_2O

Carbon dioxide, CO_2

Oxygen, O_2

Hydrogen, H_2

Silicon dioxide, SiO_2

Nitrogen, N_2

Plastic bag

Demonstration:

100 ml sand

2 300-ml beakers

2 tablespoons salt

Water

Filter paper and funnel

Evaporating dish

Tripod

Source of heat

Model for a mixture:

2 1000-ml beakers

Marbles

Small glass beads

BB shot

Wire screen

Procedure

Teacher: "What are the characteristics of our model for matter so far?" (Answer: Made up of particles, the particles move, there are spaces between the particles, when energy is added the particles move faster, some particles are made up of particles.) "What are some of the names for the particles that are made up of one kind of particle?" (Answer: Atom, element.) "What are the names of the particles made up of more than one kind of particle?" (Answer: Molecule, compound.)

Display some styrofoam models of water, carbon dioxide, oxygen, hydrogen, and silicon dioxide. The class will identify the elements and compounds.

Place several models of CO_2, O_2, N_2, and H_2O in a plastic bag.

Teacher: "What do you think this bag of molecules would be called?" (Answer: Pupils may not be able to respond.) "Today we are going to do something that can make this bag have some meaning. Now you should know that this is a model for matter and that it will be useful."

Demonstration. Add about 100 ml of sand (SiO_2) to a 300-ml beaker. Identify the compound as sand. Add 2 tablespoons of salt and stir. Identify the salt. "What have we formed?" (Answer: The salt and sand are mixed.) "Have the sand and salt changed or do we still have sand and salt?" (Answer: They are still the same.) "How can we separate the two?" (Answer: Pick the salt out of the sand.)

Place some of the mixture on the overhead projector so that the similarity of the pieces can be observed.

Teacher: "Is there an easier way to separate the two?" (Answer: There may be none or some may say, pour water in so the salt will dissolve.) If there is no response, you should recall, with the pupils, that they have previously mixed salt and water. Add water to the salt-sand mixture and mix thoroughly.

"We must next separate the sand and salt water. We will use a very fine sieve called a filter." Filter the mixture through filter paper or paper towel and collect the liquid in another beaker. "How can we determine if the salt is in the water?" (Answer: Evaporate the water.) Evaporate some of the liquid in an evaporating dish. [Heat this very carefully or it will spatter.] Have the pupils identify the salt residue that remains. "When we mixed the sand and salt did we change the substances?" (Answer: No.)

"Can we use our model for matter to make a model of a mixture?" (Answer: Place marbles and BB shot in a beaker. Add small glass beads to the beaker. Mix all the parts together [the marbles representing the sand; the glass beads, the salt; and the BB shot, the water].)

Place a piece of wire screen with holes slightly larger than the BB shot and glass beads over the opening of another beaker. Pour the contents over the screen. [The screen is the filter.]

"How could you now separate beads and BB shot?" (Answer: Pick them out.)

"Is this a good model?" (Answer: Yes.) "Why?" (Answer: Because we can use it to explain the separation of the mixture into its parts. It also shows that the particles in a mixture do not change to a different kind of particle.)

"Examine the bag of models. What does

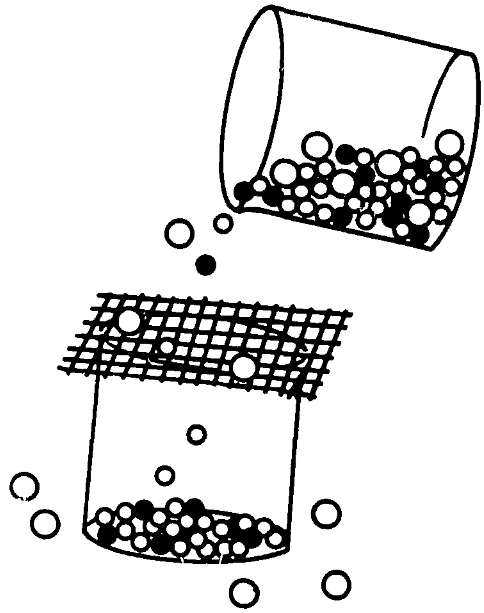


Figure 22.1. A model for filtering sand from salt water

this represent?" (Answer: A mixture.) "This is a fair model of air. What would it be if we added more water particles?" (Answer: There may be no response.) "Where does the water come from when it rains? Where does water go when it dries from the streets?" (Answer: Air.) "If water is added to air and we still have air, is air a compound?" (Answer: No.) "Why not?" (Answer: The amount of each part is not always the same.) "Mixtures are not elements or compounds. Mixtures are made up of elements and compounds."

Project Transparency No. 34, "Some samples of matter contain more than one kind of molecule. MIXTURES," and review the concept.

Lesson 23
Number of Atoms in Molecules

Concept 17: Each type of molecule is formed from definite numbers and kinds of atoms.

Background Information

Thus far the concept of a molecule is that it has a definite composition which does not vary. This idea may have created the idea that whenever elements combine they combine in only one way; i.e., hydrogen and oxygen, when combined, always form water. This idea is basically adequate, yet it is not always credible. Hydrogen and oxygen can combine to form water (H_2O) or hydrogen peroxide (H_2O_2). Experience with peroxide is enough to convince anyone that water and hydrogen peroxide have different properties. They are both colorless, odorless liquids, but one is unstable. H_2O_2 will easily break down into H_2O and O_2 if a catalyst is used. In the case of H_2O_2 the catalyst to be used is manganese dioxide (MnO_2). A catalyst is defined as a material that increases the rate of a chemical reaction without itself being changed. It is often compared to a minister at a wedding; he is necessary for the marriage to take place but really is not part of the marriage.

When H_2O_2 breaks down, water is one of the products.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

Here there are two different kinds of molecules made up of the same kinds of atoms. The difference is the number of each kind of atom involved.

There are many molecules made up of carbon, hydrogen, and oxygen and each is different from the other. The differences are not due to the kinds of atoms present, but rather the number of each kind of atom present.

The particle idea of matter includes a couple of other ideas that are useful.

1. Each kind of molecule is made up of definite kinds of atoms.
2. Each kind of molecule is made up of a definite number of each kind of atom.

If you continue your study of matter, you will add still another qualification; that is—each molecule has a particular structure in terms of the arrangement of the atoms in the molecule.

Teacher Orientation

Concept 17 is an extension or continuation in depth of the concept of a molecule. You may wish to review the lessons concerned with Concepts 13, 14, and 15. In addition to the kinds of atoms in a molecule, the factor of the number of each kind of atom is included.

The model-forming activity will apply the idea of a model in explaining the chemical and physical property differences between two compounds made up of the same kinds of atoms. The sequence will be from observed phenomena to model building or theory formation.

The composition of water has already been discussed and is given as H_2O. You will tell the pupils that the hydrogen peroxide molecule is made up of hydrogen and oxygen. When the MnO_2 (manganese dioxide) is added and O_2 is given off, the pupils must again be told that what remains in the test tube is H_2O. The logic to be applied by the pupils in developing a model will approximate the following: Since the substance in the test tube was made up of hydrogen and oxygen, and some of the oxygen was set free leaving water behind, the original composition must have included more than one atom of oxygen per molecule. This could be modeled as O-H-O-H or H-O-O-H. The arrangement of the atoms in the water and peroxide molecules is generally quite specific.

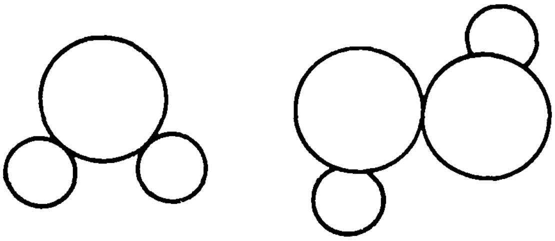


Figure 23.1. Models for water and hydrogen peroxide

Remember that the new part of the concept is that a molecule is made up of a specific number of each kind of atom.

Materials

Super 8 mm cartridge projector

Overhead projector and screen

Transparency No. 35, "Each type of molecule is formed from definite kinds and numbers of atoms"

Demonstration:

2 8-inch test tubes

100 ml hydrogen peroxide, 3% (H_2O_2)

Water

Wood splinter

1 gm manganese dioxide (MnO_2)

Film: Electrolysis of Water

Procedure

Teacher: "Today we are going to return to our study of molecules. We are going to try to construct a model of a molecule based on what we know already and what we can observe here in class."

Demonstration. Secure two 8-inch test tubes. Half fill one with hydrogen peroxide (H_2O_2) and the other with water (H_2O).

Teacher: "These two tubes contain different compounds but both are made up of the same kinds of atoms. Both of these compounds are made up of hydrogen and oxygen."

Insert a glowing splinter into each of the test tubes. Note no result in either. Review the results of the electrolysis experiment. "What happened when the glowing splinter was inserted into the tube containing the hydrogen?" (Answer: A "pop" was heard.) "What happened when the glowing splinter was inserted into the tube containing the oxygen?" (Answer: The glowing splinter burst into flame.) "What is this a test for?" (Answer: Oxygen.)

Add a pinch of manganese dioxide (MnO_2 powder) to both test tubes. Insert a glowing splinter into each tube. Result: Bubbles form in the H_2O_2. The splinter bursts into flame when inserted in the tube of H_2O_2.

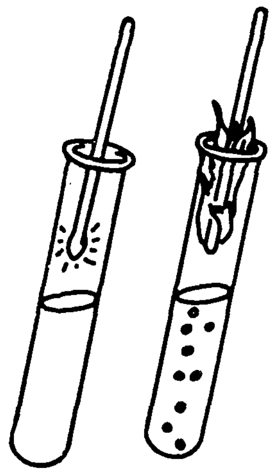
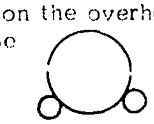


Figure 23.2. Testing for oxygen

Teacher: "What do you think is given off in this tube?" (Answer: Oxygen.) "Why?" (Answer: The glowing splinter burst into flame. This is one test for oxygen.) "Was oxygen given off in the water?" (Answer: No.)

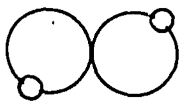
Teacher: "The material remaining in the tube after the bubbles of oxygen escape is water. What do you remember to be the composition of water?" (Answer: Hydrogen and oxygen. Two atoms of hydrogen and one atom of oxygen in each molecule.) [If it is deemed necessary you may project the film, Electrolysis of Water.]

Teacher: "Our first task is to think about what we have given as our model for water. Let us build a model on the overhead projector." [The model will be  .]

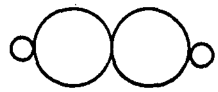
GPO 828-145-7

Label the atoms as oxygen and hydrogen. "What was given off by the other material when we caused it to break apart?" (Answer: Oxygen.) "Was there oxygen remaining in the molecules of water that were left?" (Answer: Yes.) "We started with the molecules in the one test tube and caused them to break apart. We got substance $\longrightarrow$ H_2O and oxygen. What could the substance be like?" (Answer: It must have more oxygen than water.) "What will a model for this substance be like?" (Answer: More than one oxygen atom.)

Construct a model for hydrogen peroxide on the overhead projector. There are several varieties that can be structured. The one that is accepted is



The pupils could form



and the difference is not serious. [If you have a styrofoam model, you may display this. You may also show that one oxygen atom came out of the molecule, leaving water behind.]

Teacher: "How can we explain that water is different from hydrogen peroxide?" (Answer: It has more oxygen atoms in a molecule than water does.)

Project Transparency No. 35, "Each type of molecule is formed from definite kinds and numbers of atoms." Discuss this statement with reference to some kinds of sugars, such as $C_6H_{12}O_6$, $C_{12}H_{22}O_{11}$, and starch $C_6H_{10}O_5$; carbon dioxide, CO_2; carbon monoxide, CO; etc.

The number of atoms is a factor used in describing the different kinds of matter known.

Lesson 24
Particles Are Real

Concept 18: Particles of matter have mass and occupy space.

Background Information

Knowledge in science moves ahead as a series of what may be called temporarily credible concepts. Every concept is temporary because to know everything about anything does not seem to be a possibility. In this study of matter, some assumptions were made—space is real, matter is real, and time is real. Matter was described as anything that occupied space and had weight. Next, matter was divided into particles with spaces between them; however, nothing has been said about the mass of the individual particles.

Your ability to make inferences from your experience causes you to say that "Of course, it is only the particles that have weight, and not the space." The implications of this are many, since we know that all substances do not have the same density—the weight of a cubic foot of lead is greater than a cubic foot of aluminum. This could be the result of the distance between particles, if we assume that all particles have the same weight. This could also be the result of the weight of the particles, if we assume that the distance between particles is the same. Or this could be the result of both variation in the weight of the particles and variation in the space between them.

When the particle concept of matter is accepted and other measurements are made to the level of precision possible with present instruments, it is found that the particles of matter must be extremely small when compared to the space between them. It may be said that matter is mostly space. It is also found that the particles of different kinds of matter must have different weights, must be of different sizes, and must be different distances apart. Important here are the ideas of particle mass and interparticle space.

Teacher Orientation

This lesson is an extension of the introduction to the concept of matter. In the initial lesson, the concern was for the whole of a piece of matter, as a rock, or piece of iron, or quantity of air. This lesson is designed to form the concept that the weight of a large piece of matter is the sum of the weights of the individual particles. There is no simple way of getting to this concept except through analogy. A matchbox full of lead shot can be compared to a matchbox full of glass beads of similar size. The volume occupied by the two is the same. The weights for the two are different. Without opening the boxes the pupils may try to explain why these two boxes that are the same size have different weights. They can say that one includes more particles. They can say that the spaces between the particles in one are greater than in the other. They can say that the particles in one are heavier than those in another. To explain this observation the model for matter must include the factor of mass (weight) of the particles. Since the particle is the unit of matter it must therefore occupy space.

A comparison of the weights of gases can also be made by comparing the weight of a bag of CO_2 with the weight of a bag of air. The bags can be expanded plastic or paper. You may also substitute any type of container for a bag.

The weight of the individual particles can be compared since it may be said that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.

Materials

Overhead projector and screen

Transparencies:

2, "Matter can be weighed on our scale. Energy cannot be weighed on our scale."

36, "Particles of matter have mass and occupy space."

Demonstration:

3 small boxes (matchboxes work well)

BB shot

Glass beads

Steel marbles or ball bearings

Demonstration:

Meter stick balance

2 paper sacks

Sand

Dry ice

Pail or bucket

Procedure

Project Transparency No. 2, "Matter can be weighed on our scale. Energy cannot be weighed on our scale." Review the two properties of matter: it occupies space and has weight. Classify examples of the three phases of matter and describe the physical properties of each. Be sure to include air as matter.

Teacher: "Since we have defined matter as the stuff that has weight and occupies space, how would we classify an atom or molecule? Do atoms and molecules occupy space and have weight?" (Answer: Yes. Because they are what make up matter.) [The pupils may have difficulty with this answer.] "Do all of the particles—molecules and atoms--weigh the same?" (Answer: Will vary.)

Demonstration or Exercise. Fill one small box (matchbox) with BB shot, a second with glass or aluminum beads of about the same size, and a third with larger and fewer steel marbles. One box is called a block of lead, the other a block of aluminum, and the third a block of iron. The number of particles in the lead and aluminum boxes should be about the same. The number of particles in the iron box must be fewer.

Teacher: "How can we explain the difference between the weight of the aluminum box and the lead box, and the aluminum box and iron box?" (Answer: Several comments are possible. The lead molecules might be heavier than the aluminum molecules.) "In order for this answer to be an acceptable one what must we assume?" (Answer: The molecules are about the same size.) "Is that a fair thing to assume?" (Answer: We have no reason to believe that molecules are of different sizes.) "How could we explain this if we did not think the molecules are the same size?" (Answer: Some could be larger and take up the same space as the small one but they could also be heavier.)

Open the boxes so pupils can see if their model agrees with the constructed model.

Teacher: "Is it possible that different molecules could take up different amounts of space?" (Answer: Yes.) "Is it possible that different atoms could have different weights?" (Answer: Yes.) "So far we have used solids and those are easy to handle. How about gases? Could they have different weights?"

We will do an experiment to see if we can get some information. As we do this we must remember that in our model of a gas, the gas particles are very small when compared to the space between them. We will, therefore, say that the two containers we use will contain the same number of gas particles. Our problem is to see if the gas molecules that make up air have the same weight as the other gas we use for comparison. What will we look for if we use a balance?" (Answer: To see if the two quantities weigh the same.)

Demonstration. Balance a stick at its center and fasten one grocery sack open side up to each end. (If the two sides are not in balance add grains of sand until they balance.)

Teacher: "The two bags are now filled with air." [Prior to this, have the class place a piece of dry ice about 10 inches square and 1 inch thick in a laundry pail. Allow the dry ice to sublimate for about 30 minutes or until the pail is full of CO_2.] "Bag A will stay full of air. Into Bag B we will add the other gas so that the air will be forced out. It will then be filled with a gas that is not air." [Pour the CO_2 from the pail into the bag just as you would pour water.] "What happens?" (Answer: The new gas is heavier.) "If we say that both bags contain the same number of particles, what can we say about the weight of the particles?" (Answer: They are different.) "What can we say about the mass of matter?" (Answer: It is the total of the mass of the individual particles.) "Are they all the same weight?" (Answer: No.) "Are they all the same size?" (Answer. No.)

Project Transparency No. 36, "Particles of matter have mass and occupy space."

Teacher: "Why is this a good addition to our model for matter?" (Answer: It helps us explain why some things are heavier than others.) "How would you use this idea to explain why a full piece of chalk is heavier than a half a piece of chalk?" (Answer: In the full piece of chalk, there are more molecules of whatever chalk is made of.) "How do you explain that the greater number of particles makes a bigger piece of chalk?" (Answer: Because the molecules take up space.)

"How can we use this idea to explain the difference between the weight of a piece of chalk and a piece of iron the same size?" (Answer: The molecules of iron are heavier.)

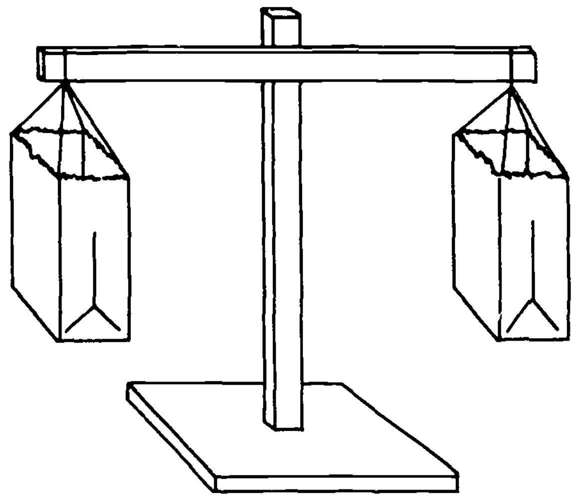


Figure 24.1. A stick balance

Lesson 25
Atoms and Physical and Chemical Changes

Concept 19: The average size and mass of the atoms of each element do not vary.

Background Information

Recall Concept 6, "Particles of matter usually move farther apart when the matter is heated." This lesson left open the speculation that changes in size could be explained by using the concept that the particles got bigger when heated. This is going to come up again for consideration.

The addition of energy to matter, in the accepted theory, does not influence the size or the mass of the particle. We will try to help pupils infer this idea. We will also try to help them see the function of the idea. It is important that the pupils see the need for accepting the most reasonable or logical of many possible inferences. Remember that inferences may be made up of the parts of many experiences in life put together in an infinite variety of ways. The concept of the constancy of the mass and size of atoms as a part of the particle scheme is an inference that is based on very remote and "indirect" evidence.

The phenomenon of the falling of BB shot in warm and cold syrup could have a variety of explanations. One bit of confusion could come from the apparent total reduction in volume when the syrup is cooled, hence, the explanation of this reduction is omitted here. The change is very small.

The expected interpretation is that: (a) if the molecules got smaller when cooled and the total volume remained the same, the spaces between the molecules should be greater and the shot should fall more rapidly than when the syrup is warm; and (b) if the molecules go larger when warmed and the volume remained the same, the spaces between the molecules should be smaller and the shot should fall more slowly.

What happens in each case is just the opposite; in cold syrup the shot falls slowly, and it falls rapidly in warm syrup. These observations must then be compared to the fact that the matter expands when heated and contracts when cooled. The best logical answer then becomes: the size of the particle does not change, whereas the space between the particles does.

The problem of change of mass of the particles must be considered (at this level of sophistication) in a similar manner. The pupils have had experience with melting ice and no change in mass. Now the extension will be to the molecules of ice. If the total mass did not change, then the mass of the individual particles should not change, for no particles were added or removed. Essentially, this lesson is concerned with the principles of conservation.

Teacher Orientation

The introduction of this lesson should have as its basis the expansion and contraction of solids, liquids, and gases. These were observed early in the unit.

There must be more than an average amount of teacher leadership here, because of the very remote kinds of data used. Have the pupils make predictions and point out the conditions of the situation. Clarity of understanding of these conditions is important. Cold—small particles—distance between particles large, hence easy movement through substance. Warm—large particles—distance between particles small, hence difficulty of movement through substance. The observations deny these predictions, hence, the assumptions are judged not to be credible.

Materials

Super 8 mm cartridge projector

Overhead projector and screen

Transparencies:

37, "There is no change in the mass of the atoms of an element when the temperature or phase changes"

38, "The average size and mass of the atoms of each element do not vary"

Demonstration:

500-ml flask with water in it

Kitchen scale

Tripod and asbestos screen

Propane burner

Thermometer

Demonstration:

6 steel balls

Aluminum pan

Paraffin wax

500-ml beaker

Student Activity:

1 vial of syrup for each student

2 lead shot for each student

Film: Ammonia Gas in Water

Procedure

In the previous lesson the idea that atoms had mass and occupied space was developed. Review these parts of the concept with the class. Here we are going to look for more facts that are useful in supporting the idea that the mass of and the space occupied by the individual particles do not change when energy is added or subtracted.

Teacher: "What happened to the mass of the matter we used during one of our first lessons about matter? Remember that we used a beaker of ice. We weighed the beaker of ice, caused it to melt, and weighed it again." [You may repeat this demonstration for the class.] "Did the mass of the substance change?" (Answer: No.) "This seems to give some hint to an idea about what could be happening to the particles (molecules) of water. Would it seem reasonable that the particles always weigh the same?" (Answer: Variable, but is yes.) "In this experiment all we found was that the change in state did not have an associated change in mass. Is there a change in mass when energy is added to matter and the state of matter does not change?"

Demonstration. Place a 500-ml flask partly filled with H_2O on a kitchen balance to determine the mass. Record the data. Place the flask on a tripod, and gently heat it with a propane burner. (Do not bring it to a boil.) You may wish to place a thermometer in the water to indicate the temperature. After the water is heated, place it on the balance.

Teacher: "Has there been a change?" (Answer: No.) "Does it appear that the molecules of water increase in mass as a result of heating?" (Answer: No.) "Do solids change in mass when heated and cooled?" Place several steel balls in an aluminum pan and weigh. Heat by directing the torch on the balls in the container on the balance. (Result: No change in mass.)

If you have some paraffin wax that melts at a low temperature, you may place it in a beaker and melt it. Have the pupils predict what will happen to the mass as it changes state. The beaker can remain on the balance and the pupils can observe that no change in mass occurs. It is well to have the pupils give some predictions based on their past experience.

Project Transparency No. 37, "There is no change in the mass of the atoms of an element when the temperature or phase changes." Discuss this concept with the pupils.

What happens to the size of the particles as the temperature changes? Explain that a change in particle size is even more difficult to support. When we were looking for a model to use in explaining the expansion of matter, we said it was more reasonable to assume that the distance between the particles changed, rather than the size of the particles, when matter was heated and cooled. Now we want to see if we can support our decision.

Student Activity. Let us begin with a situation that we will use in making inferences:

Teacher: "Each of you will be given a small bottle of syrup. It will be cold when you get it and will warm up with time. We are going to place one BB-shot on the top surface of the syrup when it is cold and another BB shot on the surface when it is warm. We are going to try to make some predictions based on two different ideas.

"Let us begin when the matter is cold.

"If the particles got smaller when cooled would a shot fall fast or slow through the syrup? We will find out, but what do you think would happen?" (Answer: Since the particles would get smaller, the spaces between could be greater or stay the same. Then the shot should fall fast in the cold syrup.)

"If the particles get larger when heated, then what will you guess will happen?" (Answer: The shot should fall slowly because the particles will take up more space.)

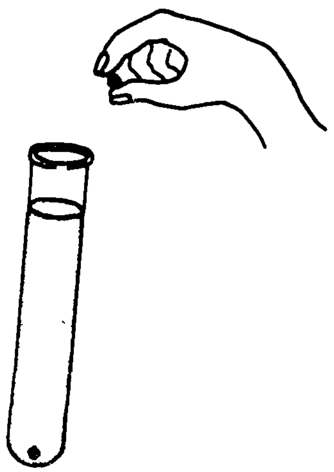


Figure 25.1. Dropping lead shot in syrup

Perform the activity. Each pupil will be supplied with a vial of cold syrup and two shot. He will place the first shot in the vial immediately and note how long a time is required for it to fall. This is repeated after the syrup is warmed.

Teacher: "What happens?" (Answer: The shot falls slowly in the cold syrup and rapidly in the warm syrup.) "Do these results support the idea we had?" (Answer: No.) "It seems that the size does not change, or at least not in the way we guessed."

Project the film, Ammonia Gas in Water. The first showing could be without much narrative. Repeat the showing. Point out the rate of movement of the NH_3 through the water, both hot and cold. Discuss the results in terms of changes in the sizes of the particles with changes in temperature.

When cold, the particles would be small and the rate of diffusion would be rapid. When warm, the particles would be larger and the rate of diffusion would be slower. In the film the reverse occurs. The indicator helps us keep track of the movement of the ammonia through the water. The results of the NH_3 experiment deny the idea of the change in the size of the molecules with a change in temperature.

Project Transparency No. 38, "The average size and mass of the atoms of each element do not vary." The size and mass of an atom or molecule are independent of the temperature.

Lesson 26
Protons, Neutrons, and Electrons

Concept 20: Atoms are made up of particles: protons, neutrons, and electrons.

Background Information

This series of lessons began with the concept of a particle of matter as if it were not divisible. In a later lesson the concept was modified to "the particles are made up of particles." The particles were called molecules, and the particles making up the molecules were called atoms. This lesson is the first of several devoted to the concept that atoms are made up of particles.

Although there are many kinds of atomic particles referred to, we shall be interested only in electrons, protons, and neutrons. One model of an atom is that the nucleus is made up of protons and neutrons and the electrons move around the nucleus. Electrons are characterized as having a very small mass and a negative electrical charge. The protons have a relatively large mass and a positive electrical charge. The neutrons have about the mass of a proton but no electrical charge. The neutrons and protons are packed together and make up the small and dense nucleus. One difficult part of this atom concept is that the nucleus is very small. Another is that the atom is mostly space. If it were possible to expand an atom to the size of a football field, the outermost electron could be on either goal line and the nucleus would be near the center. The nucleus would then be about the size of a BB shot.

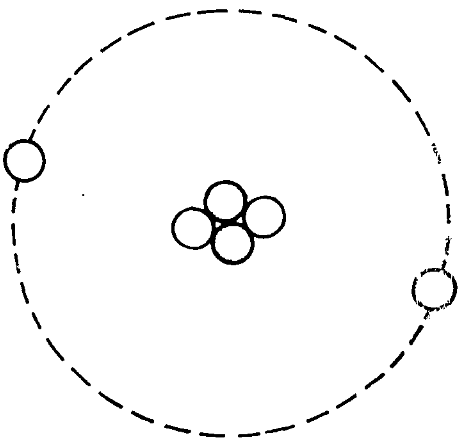


Figure 26.1. A model for an atom of helium

As you continue to study this particle concept of matter, you will find that the differences between the known elements are explained in terms of differences in the numbers of electrons, protons, and neutrons. In the explanations that include the idea that matter is electrical in nature, the fundamental part is that only the electrons move. The flow of electric charges in a conductor is explained as the movement of electrons.

A simple electrolytic cell used here is fascinating and gets lots of attention. You must be careful not to spill the sulfuric acid. If you do spill any on your skin, be sure to flush the area with water. If you spill it on clothing, you may expect a spot or a hole to appear. Most chemicals are harmless if properly handled.

When immersed in the acid, the magnesium ribbon and copper form an electrolytic cell. The ribbon will be consumed in the process of changing chemical energy to electrical energy. The challenge is to change our model for matter to account for these observations. The answer is that part of the atom moves and the other does not. This means that we have to have parts to the atoms.

The teacher may have to do more instructing here than in the previous cases because the facts are so remote. Be sure you accept the models of atoms as only models. They are acceptable models because they are useful in making certain explanations.

The history of the atom concept is long and very interesting. Do not expect to arrive at the full acceptance all at once; it will take time.

Teacher Orientation

Particles are made up of particles. The problem here is not the idea of particles but rather the introduction of the idea of particles with electric charges. Each atom is electrically neutral; it has the same number of positive and negative electric charges. Although atoms are relatively stable, some atoms can be caused to release their electrons.

In the structure of the atom we use there are some rules to follow.

1. The electrons exist at different levels from the nucleus.
2. At the first level there are never more than 2 electrons. (There can be 1 or 2.)
3. At the second level there are never more than 8 electrons.
4. At the third level there are never more than 18 electrons.

The desire is to help the pupils think of matter as electrical in nature. It is model forming. You should use all possible opportunities for inferences.

Materials

Overhead projector and screen

Transparency No. 39, "Atoms are made up of particles: protons, neutrons, and electrons."

Demonstration:

6" magnesium ribbon

Sheet copper, 1 x 3 inches

2 alligator clamps

Flashlight bulb mounted in socket

Wire to connect clamps and bulb

500-ml beaker

25 ml concentrated sulfuric acid, H_2SO_4

Water

Procedure

Review Concept 13, "Molecules are made up of atoms."

Teacher: "Today we are going to see if we can use this idea in explaining several other observations. If we cannot use the idea we have, what must we do?" (Answer: Change our idea or invent a new one.)

Demonstration. Fold about 6 inches of magnesium ribbon so there are several layers, each about 3 inches long. Fasten one end in an alligator clamp. Place a piece of sheet copper about 1 inch wide and 3 inches long in a second alligator clamp. Add about 200 ml of water to a 500-ml beaker. Add about 25 ml of sulfuric acid to the water.

[BE SURE TO ADD THE ACID TO THE WATER. NEVER ADD THE WATER TO THE ACID.]

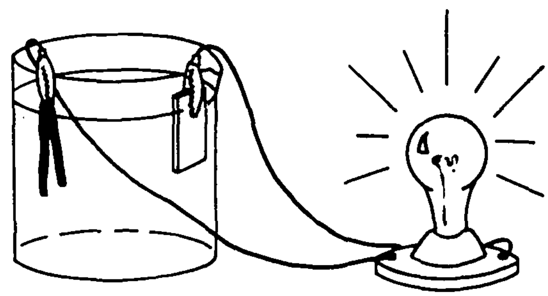


Figure 26.2. Apparatus for producing electricity

Connect a wire from the clip with magnesium to one contact of a flashlight bulb and a second wire from the copper-holding clip to the other contact of the bulb. Insert the copper plate in the water-acid mixture. Insert the magnesium ribbon in the mixture. (Result: The light bulb was lighted.) "Where did the electricity come from?" (Answer: The liquid and the metals.) "Can we explain this by using the idea of atoms?" (Answer: No. Where does the electricity come from?) "We must now change or expand our idea of an atom. We will begin by forming a model for electricity in a wire. We will imagine that there are little things called electrons moving along the wire. They will be something like water flowing in a hose. We need to have some source of these particles called electrons. Now we are at the atom again.

"The model of the atom that is useful here includes three types of particles—electrons, protons, and neutrons."

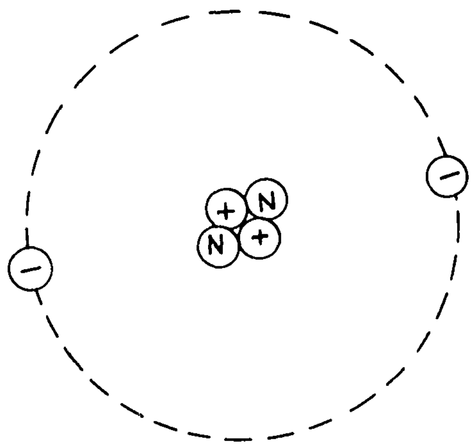


Figure 26.3. A model for an atom of helium

Draw sketches on the overhead projector or chalkboard.

Most of the mass of the atom of any element is concentrated in the nucleus (protons and neutrons). The protons have a positive electrical charge, the electrons have a negative electrical charge, and the neutrons have no electrical charge.

We can now say that the electrons from the acid or the magnesium or the copper get to the wire and to the light. The resistance of the filament in the light bulb to the flow of electrons through it results in the heating up and glowing of the filament and the light is given off. Now we have changed our model for matter so that the atom is made up of particles. [You may wish to relate the analogy of the football field and the size of the nucleus.]

Distribute diagrams to the class of models of three atoms: helium, hydrogen, and carbon. Try to make up models of other atoms. Be sure the pupils can place the particles in the proper places.

Project Transparency No. 39, "Atoms are made up of particles: protons, neutrons, and electrons."

Review the particles and placement of each.

Lesson 27
Electric Charges and Forces

Concept 21: Electric charges are associated with the particles of matter.

Background Information

The concept of the electrical nature of matter did not evolve along with the particle concept in parallel steps. There were many ideas used to explain how atoms were fastened together before the idea of electrical charges was used. One was that there were hooks on the outside of each atom and the hooks caught on each other.

You will not be concerned with the formation of compounds in this lesson. You will merely be extending Lesson 24 on the electrical nature of matter. You already know the usefulness of the electrical property of matter in explaining the flow of charge in a conductor.

According to the theory that is now accepted, all matter is made up of the same fundamental particles: electrons, protons, and neutrons. These particles, regardless of the atom of which they are a part, always have the same properties. The numbers of electrons and protons are useful in describing the chemical properties of the atoms. The numbers of protons and neutrons determine the mass of the atom.

Remember that the nucleus is made up of protons and neutrons and always has a positive charge. The electrons always have a negative electrical charge and always occupy space away from the nucleus.

As you proceed you will note that the fact that opposite electrical charges attract each other makes it possible for us to explain what holds an atom together, and also what holds two or more atoms together to form a molecule. The attraction between + and - charges is a key in explaining chemical changes as well as many physical phenomena. Charges and the fact that like charges repel each other (+ repel +, and - repel -) are also useful ideas. Since one positive charge can attract only one negative charge, all atoms are electrically neutral when they are alone. If the atoms are in the presence of other atoms, it is possible that some kinds can add or give up electrons. If an atom adds electrons, the result is a particle with a negative charge. If an atom gives up electrons, the result is a particle with positive charge.

Static electricity is explained by using the concept, "matter is electrical in nature." When some materials are rubbed by other materials, a difference in electrical charge is generated. The experience of getting a shock on a dry day after walking on a wool or nylon rug with leather or plastic soled shoes is common. The explanation is that the electrons accumulate on the shoe soles and since there are so many they spread to the surface of your body. When you touch an electrical conductor that does not have a large number of electrons stored on its surface, a number will jump from your body to the other surface. The tendency always is to end up with two neutral bodies.

Static electricity is generated by rubbing. It is the mechanical energy of rubbing that causes the electrons to be moved from one place to another. The potential energy that enables them to jump is their stored mechanical energy.

As you use the idea, you will come to think of the electrical nature of matter as a very imaginative concept.

Teacher Orientation

The electrical nature of matter is to be extended from use in explaining the flow of electric charge in a wire to explaining the accumulation of static electrical charges. In the explanation for static charges the electrons are believed to come from the surface of one material and be attracted to the surface of another. The nature of the charge is difficult to determine since there are no absolutes here. The standard or frame of reference that is used is the nature of the charge that accumulates on glass when it is rubbed with silk. This charge is defined as positive (+) and is always the same. When glass is rubbed with silk the electrons move from the glass to the silk. The silk thus has a negative charge (many electrons) and the glass has a positive charge (fewer electrons). In this lesson you will use a plastic ruler and a piece of wool or flannel. The ruler will have a negative charge and the wool will have a positive charge. If you perform the demonstration on a dry day you will be able to detect the repulsion of like charges and the attraction of unlike charges.

The charges come from the matter of the ruler and the cloth. The terms we use—generate a charge—do not refer to creating an electrical charge from nothing. They mean that some form of energy is used to bring about the accumulation of electrons (particles) in one place and a deficiency of electrons in another. When the charges flow from where there are many to where there are few, work is done. This is as valid for the spark from your finger as it is for the turning of an electric motor.

As you present this lesson keep in mind that the structure of the atom is developed so that natural phenomena can be explained.

Materials

Overhead projector and screen

Transparencies:

- 39, "Atoms are made up of particles: protons, neutrons, and electrons"
- 40, A model for a lithium atom
- 41, "Exercise Sheet"
- 42, "Electric charges are associated with the particles of matter"

Demonstration:

- Rubber stopper
- 3 feet of string

Experiment (for each 2 students):

- 2 plastic 6-inch rulers
- Piece of wool or felt
- Piece of thread

Transparent colored dots with + and - on them

Transparency marking pencil

Exercise sheets (one for each student)

Procedure

Project Transparencies No. 39, "Atoms are made up of particles: protons, neutrons, and electrons," and No. 40, a model for a lithium atom, so pupils can review the theoretical structure of atoms. They should be able to use the terms electron, proton, and neutron in describing the structure.

Teacher: "If the electrons move around the nucleus very rapidly, what would you expect to happen?" (Answer: The electrons would fly away from the nucleus.) [If this answer does not appear, you may tie an object like a rubber stopper or rubber ball on the end of a string. Slowly whirl the object on the string and then release the string. Be careful not to strike one of the pupils. Note what happens to the ball.]

Teacher: "Today we are going to perform an experiment that may help us to explain why the electrons do not fly away from the nucleus."

Experiment. Provide each two pupils with two plastic rulers, a piece of wool or felt, and a piece of thread. The pupils or the teacher will tie the thread in order to suspend one ruler.

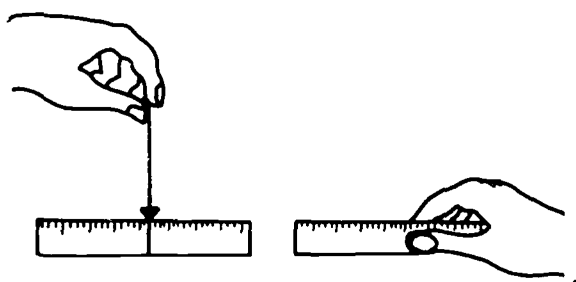


Figure 27.1. Testing the plastic rulers for electrical charge

One pupil will hold the end of the string to support one ruler. The second pupil will

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bring one end of the second ruler near one end of the suspended ruler. Note that nothing happens. [If they do repel each other, touch the rulers to a steam radiator or other metal object. You want both rulers to be neutral to begin. This will usually be the case. If the pupil rubs the ruler, a charge may be formed.] Rub the suspended ruler four or five times with the cloth. Do not touch it with the fingers. Rub the second ruler with the cloth. Bring one end of the second ruler near one end of the suspended ruler. (Result: The two rulers should repel each other.) Bring the cloth near the suspended ruler. (Result: The ruler and cloth should attract each other.)

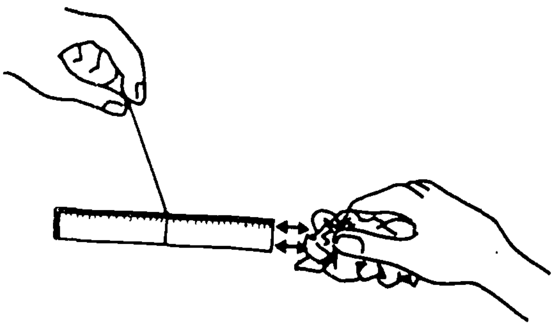

Figure 27.2. Showing attraction

Teacher: "Can we use our model for an atom in explaining what we see here? First let us try to tell what we saw." (Answer: When the two rulers were not rubbed, they did not affect each other. When they were rubbed, they repelled each other. After rubbing, the cloth attracted the suspended ruler.) "Our first task is to explain this pushing apart and pulling together. We can easily see that the rubbing could have had some connection with the results. If we accept the idea that only the electrons move easily from the atom, can we make a model of what happened?" (Answer: When the rulers were rubbed, electrons could be rubbed from the cloth to the ruler.) "If this occurs, then how can you explain that the rulers moved away from each other?" (Answer: We must say that electrons repel electrons.) "What evidence is there to support this idea?" (Answer: The cloth attracted the ruler. This could mean that the cloth gave away electrons and the ruler received them.)

Construct a model on the overhead projector with some dots to represent + and − charges.

The model shows what could happen, but we cannot see the electrons. There is one more thing we must accept at this point or the model is not useful. We must accept the ideas that electrons influence other electrons at a distance, and that electrons and protons influence each other at a distance.

Now it may be stated that since we have used the idea of electrical particles successfully in explaining what we saw with the rulers, matter may be electrical in nature. Also, we may say that there are forces associated with the electric charges.

Distribute the exercise sheet so pupils can complete the sketches. Project Transparencies No. 41, "Exercise Sheet," and No. 42, "Electric charges are associated with the particles of matter."

Teacher: "How can we now explain what keeps the electrons around the nucleus?" (Answer: The two unlike electric charges attract each other.)

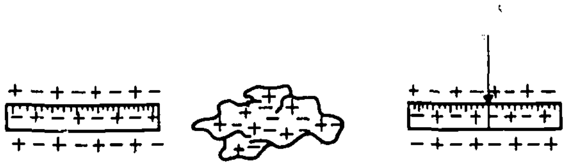

Figure 27.3. A model for showing neutral objects

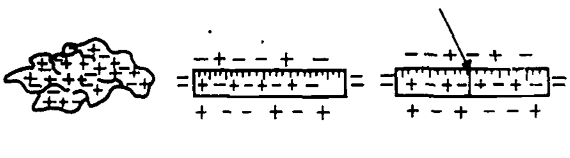

Figure 27.4. A model for showing attraction

Lesson 28
Electrical Forces

Concept 22: The particles of matter attract each other.

Background Information

A glass can be filled over the full mark, and a drop of water is nearly spherical when placed on the surface of waxed paper. A needle or razor blade may float on the surface of water. A duck will easily float on the water when its feathers are covered with a natural oil formed by certain glands of the animal. The same duck will sink in the water if there is enough detergent to cut the oil film on the feathers. When the corner of a blotter or a soft t[illegible] is [illegible]sed in water the water seems to climb into and up the material.

Some of these phenomena appear to be supernatural. In science, supernatural explanations are not accepted. The desire is to explain what can be observed in a reasonable way. This is why the model for matter we have been developing has been modified so many times. The model must fit what we see.

There are forces between atoms and forces between molecules. Some of these may be electrical and some gravitational in nature. Gravitational force depends upon the masses of the particles involved and the distance between them. The greater the particle mass, the greater is the force between them. Furthermore, the smaller the distance between particles, the greater is the force between them. Your weight, for example, is a measure of the gravitational force between you and the earth. It is a function of your mass, the earth's mass, and the distance between the two.

Although both gravitational and electrical forces exist, forces between molecules are best explained on the basis of electrical attraction. This is because attractive forces in matter are much greater than gravitational forces. Like gravitational force, electrical force varies with distance; here the distance is between unlike charges. The closer together the charges become, the greater becomes the force of molecular attraction. Scientists have classified matter, in part, on the basis of the attractive forces between particles. Objects having a fixed form with the particles vibrating yet packed close together are called solids. In liquids the particles move about more rapidly so they move past each other. In gases the particles move even more rapidly, and hence the distances between them are greater than those in liquids. Thus, gases are free to bounce and fly about.

Adhesion and cohesion are terms applied to the kinds of attractive forces existing between charged particles. If the two or more particles of matter that attract each other are of the same substance, the attractive force is called cohesive. If, however, the attractive force is between two different kinds of substances, the attractive force is called adhesive. You can remember this by thinking of the use of adhesive tape. Here there are two kinds of substances that attract each other, cloth and glue particles.

The term used to describe the over-filled water glass is surface tension. Surface tension is also used in describing the nearly spherical water drop placed on the surface of waxed paper and the skin-like surface of water on which a needle floats. This is a reasonable term because it acts like a tight membrane over the surface and a force is necessary to puncture it. Yet, to name a phenomenon or a force does not help much in explaining the cause.

Surface tension in liquids like water can be explained by using the idea that in a water molecule there are concentrations of different electrical charges positioned at different places about the molecule. This means that the electrical properties have been noted and that the

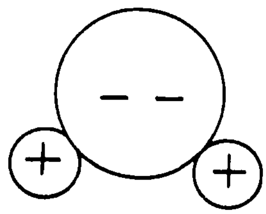

Figure 28.1. A model for a water molecule

best explanation is to say that the water molecule has these charge concentrations.

Figure 28.1 represents a water molecule. Note that the hydrogen atoms are placed in a definite way. This placement is not accidental but is a function of the charge configurations of the molecular parts, the hydrogens and oxygen. We can see from Figure 28.1 that each molecule of water has a negative and positive end. When the positive end of one molecule of water attracts the negative end of another water molecule, they hang together. The attraction of one water molecule for another forms the skin-like surface of water and the cohesive force is great enough to support a needle. In order for the needle to enter the water, the force of electrical attraction must be overcome.

Adhesive forces, such as those existing between water and glass particles, can also be explained by electrical forces in much the same way as cohesive forces. The difference is due only to the nature of the particles attracted.

Teacher Orientation

In the previous lesson the idea of the electrical nature of matter was expanded. The pupils should now think of many forces between particles as being electrical in origin. This lesson is an application of these electrical forces in explaining some rather interesting phenomena. You may use the terms cohesion and adhesion, but this is not necessary. Merely say like molecules and unlike molecules.

If you think it is necessary, you may start the lesson by blowing some soap bubbles. The film of soap can be used as the introduction. What holds this thin layer together? It is described as the result of the unequal distribution of electrical charges on the molecules.

Materials

Overhead projector and screen

Transparencies:

43, "Exercise Sheet—Cohesion and Adhesion"

44, "Particles of matter attract each other"

Demonstrations:

Medicine dropper
Large crystal
Tumbler
Water
Dish
Sewing needle
Metal-edged ruler

Experiments:

Waxed paper
Water
Dropper
Paper towel
Petri dish
Glass microscope slide

Procedure

Review the particle model for an atom noting the following:

1. Atoms are made up of protons, electrons, and neutrons.

2. A negative electrical charge is associated with an electron.

3. A positive electrical charge is associated with a proton.

4. Opposite electrical charges attract each other and like electrical charges repel each other.

5. Electric charges are helpful in explaining how solids are held together, static electricity, conduction of electricity, etc.

6. Some negative charges (electrons) can be removed from atoms and caused to accumulate in certain places.

Display a solid like a large crystal or support a weight on a wire.

Teacher: "What holds the molecules together in these solids? Note how nicely the crystal is formed." (Answer: Something must be holding the particles together.) "What is the force we know about so far that holds particles together?" (Answer: Electricity.) "Let us move along to look at some other things and then see if we can make up a model to help us explain what we see."

Demonstration. Fill a tumbler with water as full as possible. After it appears to be full add more water to the glass with a dropper or syringe. Have the pupils note that the surface is curved. You may even take a ruler with a metal edge and scrape the extra water off.

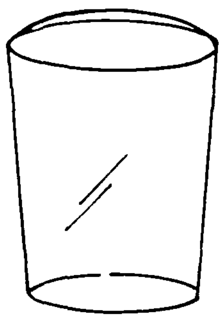

Figure 28.2. A glass of water filled beyond the rim

Teacher: "What was observed?" (Answer: The water extended above the top of the glass.)

Demonstration. Add water to a petri dish until it is about 1 inch deep. Pass a sewing needle through your hair to give it a coating of oil. Carefully place the needle on the water surface. It will float if you are careful not to break the surface. (Result: The water surface was bent down, but the needle floated.) [This activity may be performed as a pupil experiment with the older children.]

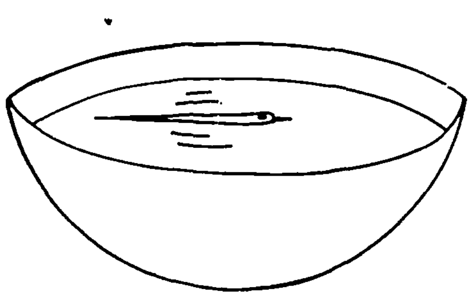

Figure 28.3. Floating a needle on water

Experiment. Provide each pupil with a piece of waxed paper, a small container of water, and a dropper. The pupils will place a drop of water on the waxed paper. (Result: The drops form into little round lumps like balls of water.) Place two drops close together. By using the dropper push one drop close to the other. (Result: The two drops combine to form one drop. It is still somewhat rounded on the surface.)

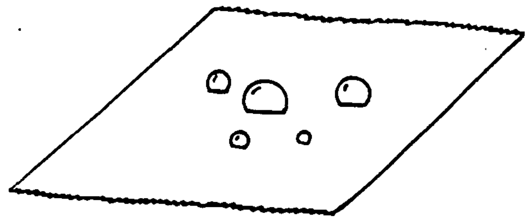

Figure 28.4. Drops of water on wax paper

Experiment. Provide each pupil with a small container of water and a piece of paper towel. The corner of one end of a strip of the towel is dipped into the water. (Result: The water moves up the towel.)

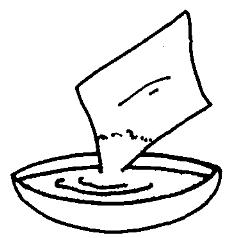

Figure 28.5. Water being absorbed by a paper towel

Experiment. Provide each pupil with a petri dish, a microscope slide, and a dropper of water. Place the slide in the petri dish. Place several drops of water some distance from the slide. (The water may form a drop or may spread out. Try to have it form a drop.) Move the slide along the bottom of the dish until it touches the water. (Result: The water creeps between the microscope slide and the dish.)

Teacher: "We now have a number of observations we want to explain." List the observations with the pupils:

1. Solids hang together.

2. Water seems to have a skin-like layer over the surface—we over-filled a water tumbler and we floated a needle on the surface of water.

3. Water forms little balls when placed on waxed paper. Two drops can become one and form a new unbroken layer.

4. Water seems to crawl into small places, lifting other drops as it moves.

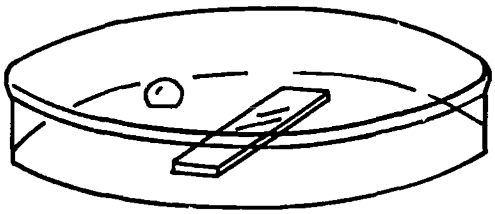

Figure 28.6. Glass slide and water drop

Teacher: "Is there a factor that exists in observations 1, 2, 3, and 4 that is the same?" (Answer: Solids are held together by a force. Water in liquid form has a skin-like surface caused by a force. Drops of water are held in that form by a force. Water is caused to move up the towel and between the slide and the dish by a force. The common factor is force.)

Teacher: "What part of our model helps us find the origin of this force?" (Answer: Unlike electric charges attract each other.) "If we are to have these charges attract each other, then the particles of matter must have more electrons than protons or more protons than electrons. Is this really the only way?" (Answer: No. The charges could be unevenly distributed over the particle. On some parts of a molecule there could be more electrons than protons and on other parts of the same molecule there could be more protons than electrons.)

"Form a model of a particle with the charges unevenly distributed on the surface. How will this help?" (Answer: Other particles could also have an unequal distribution, and thus pull the particles together.) "This can help us with like materials. Can it be used with unlike materials like the towel?" (Answer: Yes. The other material could also have an unequal distribution of charges.)

Project Transparency No. 43, "Exercise Sheet—Cohesion and Adhesion." Have the pupils draw lines to show the forces pulling on the particles.

Project Transparency No. 44, "Particles of matter attract each other." Be sure to end with the electrical attraction of particles.

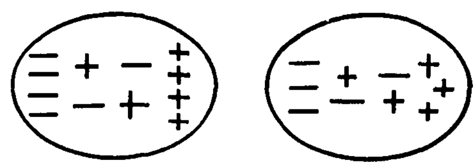

Figure 28.7. A model for particles with uneven charge distribution

Lesson 29
Particle Mass

Concept 23: The mass of an atom is determined by the number and kinds of particles that it contains.

Element	Approximate Atomic Mass	Number of Protons in Nucleus	Number of Neutrons in Nucleus
Hydrogen	1	1	0
Helium	4	2	2
Lithium	7	3	4
Beryllium	9	4	5
Boron	11	5	6
Carbon	12	6	6
Lawrencium	257	103	154

Background Information

The weight per unit of volume of any substance is usually defined as density. The idea of different densities for different materials is known to most adults, although the term may not be used; a cubic foot of lead is much heavier than a cubic foot of aluminum. The difference in density can be accounted for in two different ways: there could be more molecules present per cubic foot of lead than per cubic foot of aluminum, or the individual molecules of lead could be heavier than the individual molecules of aluminum.

The idea that there are more molecules per unit of volume of lead has been rejected as the result of carrying out some weight measurements. A more useful explanation is that individual atoms of different elements have different weights.

As a result of careful study, it is now possible to arrange the known 103 different elements in a table based upon the numbers of protons in the nucleus. It is also possible to arrange the elements in a table based upon their individual atomic weights. The fact that the arrangement by number of protons in the nucleus is very similar to the arrangement by atomic weight is easily explained using the theory that matter is made up of particles. This is because the weight (mass) of an individual atom is explained in terms of the number of particles, mainly protons and neutrons, that make it up. Let us examine a few examples in the table which follows. Note that the number of protons in the nucleus is always a whole number and it extends from 1 to 103. The atomic mass also increases in a generally regular manner. The mass of a given atom may be described in terms of the sum of the number of protons and neutrons in the nucleus. However, this would be slightly in error, because the mass of the electrons is not included. The mass of an electron is only 1/1837 that of one proton, so the error would not be great.

The important part of the particle concept here is that the differences in atomic mass can be explained in terms of the mass of separate particles.

In science there are no absolutes, hence there are no absolute units of mass to begin with. In addition, the desire of the scientist is to be as consistent and precise as possible. The scientist, therefore, accepts a unit of measure that he feels is as constant as possible and that is also usable; here he has chosen the atomic mass of carbon-12. In his study of the other atoms he compares the mass of other elements to carbon-12 and says that carbon weighs 12 atomic mass units. With this standard all scientists can use the same measuring unit.

Two ideas will be pointed out in this lesson:

1. The atoms of different elements have different masses.

2. The mass of an atom is described in terms of the number of electrons, protons, and neutrons that make it up.

Teacher Orientation

The lesson is initiated by having the pupils experience the same volumes of two different elements. You may use a small volume of mercury and an equal volume of magnesium powder, or a cube of iron and a cube of aluminum, or a cube of lead and a cube of iron. The important factor is that the volumes are equal.

The move may then be: if we keep dividing these blocks what would be the smallest particle we could get? This would be an atom. Would the atom of aluminum (total of 27 protons and neutrons) have the same mass as the atom of lead (total of 207 protons and neutrons)?

How can we explain the difference in mass? You may wish to use a sensitive balance or two and some other apparatus in the lesson.

The following directions for constructing a model for an atom will prove useful in this lesson. Cut two pieces of clear plastic the same size, about 1 1/2 feet square. Form a circle about 3 inches in diameter and place it at the center of the plastic sheet. Place each plastic sheet on a separate kitchen balance. Secure about one dozen steel marbles of the same size and one dozen colored plastic dots. Paint one half of the steel marbles a different color. (The steel marbles are to be protons and neutrons—the plain ones protons, and the colored ones neutrons. The plastic dots will represent the electrons.)

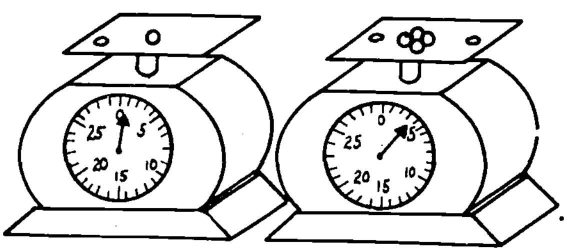

Figure 29.1. A model for showing the difference in mass between two atoms

The hydrogen atom can be formed first—it is light and it has only one proton and one electron. Pupils can note the reading on the balance. Helium is next—two electrons, two protons, and two neutrons. Notice the two protons and the mass of four. This can be continued. (You may wish to calibrate the balance in units of one nuclear particle. This would make it possible to develop the concept of an atomic mass unit.)

This lesson is concerned with explaining differences in atomic mass in terms of atomic particles—electrons, neutrons, and protons.

Materials

Overhead projector and screen

Transparencies:

45, Models for magnesium and mercury atoms

46, "The mass of an atom is determined by the number and kinds of particles that it contains"

Demonstrations:

2 metal blocks with the same volume but different mass; i.e., aluminum and steel, or lead and steel, etc.

OR

2 identical small bottles with mercury in one and magnesium powder in the other.

2 balances or kitchen scales

2 sheets of plastic about 1 1/2 feet square

2 paper circles—4 inches in diameter

12 steel marbles, half of them painted a different color

12 plastic circles, about 1 inch in diameter

Procedure

Review the level of development of the concept of the atom to date:

1. Atoms are different.

2. Atoms are made up of electrons, protons, and neutrons.

Demonstration. [If you use blocks of iron and aluminum, several of these pairs may be passed around the class. If you use bottles of mercury and magnesium, the samples should be carried by the teacher and the bottles should be in another container (like a plastic pail).] Pupils will lift each sample or the samples may be weighed on a balance.

Teacher: "What difference is noted?" (Answer: One is heavier than the other.) "Are the amounts (volume) the same?" (Answer: Yes.)

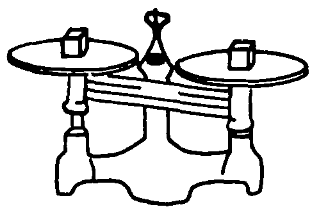

Figure 29.2. Showing the difference in mass between two elements

Teacher: "How can we explain the difference in weight?" (Answer: The atoms of lead are heavier than the atoms of aluminum; or, the atoms of lead are nearer together than the atoms of aluminum, so there are more atoms of lead than aluminum in the block.) [Write the two ideas on the overhead projector or chalkboard.] "If we decide that the number of atoms in both blocks are the same, which of these decisions do we accept?" (Answer: The atoms of lead are heavier.) "Measurements of the mass of particles indicates that a mass of 207 can be assigned to lead and a mass of 27 to aluminum. We can say that the mass of an atom of lead is 207 and the mass of an atom of aluminum is 27. Our problem is to explain this difference in mass. What can we say? Can we build a model from what we say about an atom so far?" (Answer: We now say that the nucleus is made of protons and neutrons, and that these are heavy. We also say that there are different numbers of particles in atoms.) "How does this knowledge help?" (Answer: Some atoms may have more particles than others.)

Demonstration. Place a plastic sheet on each of two balances. Place a cardboard or paper circle in the center of the sheet. (This center will be the nucleus.) Start by forming a model for hydrogen. Place one shiny steel marble in the center (Proton). Place a plastic dot somewhere outside the circle (Electron). On the second balance place two shiny steel marbles and two painted marbles in the center. Place two dots outside the circle. This second model is helium. The models will look like Figure 29.3.

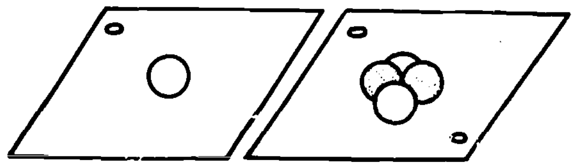

Figure 29.3. Models for hydrogen and helium

Note the balance reading for each of the model atoms. The mass of hydrogen is 1 and helium is 4. Form other atoms like those listed in the teacher orientation. In each case note the increase in mass.

Teacher: "Is this a good model to explain the difference in weight of the different atoms?" (Answer: Yes. It shows us that the difference in mass can be explained in terms of the number of nuclear particles.)

Project Transparency No. 45, the models for magnesium and mercury atoms, and note the number of nuclear particles in each.

Project Transparency No. 46, "The mass of an atom is determined by the number and kinds of particles it contains," as the summary.

Lesson 30
Isotopes

Concept 24: All atoms of a given element are made up of the same numbers of electrons and protons.

Background Information

As the study of matter progressed, it was found that all phenomena could not be explained using the idea that the nucleus of an atom always had the same number of nuclear particles. It was found that some hydrogen would act like hydrogen—combine with oxygen and form water—but was heavier than other hydrogen. It was called heavy hydrogen. This same observation was found naturally or made to occur with all elements. Gold was found to have an atomic mass from 188 to 2ul. In spite of this difference, all the gold had the same chemical properties. Atoms of any element that have atomic masses different from the most common form are called isotopes of the element. The only difference is the mass. How can we explain this?

We have said that the numbers of protons and electrons determine the chemical properties of an atom. Because of this part of our model, all hydrogen atoms must have one proton and one electron. The number of neutrons in an atom contributes to its mass but not to its chemical properties.

The number of neutrons in a nucleus is used in explaining radioactivity. When the number of neutrons becomes too large or too small in relation to the number of protons, the nucleus tends to break up. When this occurs, it is said to undergo radioactive decay. Many radioactive isotopes are used in medicine and industry.

In this lesson the important ideas are: (a) The number of electrons and protons in a given type of atom is always the same. The number of neutrons can be different; and (b) The number of electrons always equals the number of protons when the atom exists alone.

Teacher Orientation

This lesson adds to the preceding one but is concerned with the equivalence of the number of protons and electrons and with differences in atomic mass. Constant attention should be given to the concepts of electrical neutrality when the element is in the form of an atom and that all atoms are made of the same kinds of particles. The differences between atoms are explained by using different numbers of the three types of particles.

The problem in this lesson is: Some atoms of a given element have different atomic masses. How can this be explained?

Since our model is "atoms are made up of electrons, protons, and neutrons," we must try to explain the mass difference in these terms. We have also said that the number of protons must equal the number of electrons. The chemical nature of an element is determined by the number of electrons and protons. The only factor in our model that gives us an opportunity to explain the difference is the neutrons. This is adequate, so we explain isotopes in terms of nuclear stability and number of neutrons. [Neutrons and protons have the same mass.]

The following table lists some common elements and the mass numbers of their known isotopes. The underlined ones are stable and occur naturally. The others are radioactive and are produced artificially.

Materials

Overhead projector and screen

Element	Mass Number of Isotopes					
Hydrogen	1	2	3			
Carbon	10	11	12	13	14	15
Nitrogen	12	13	14	15	16	17
Oxygen	14	15	16	17	18	19
Neon	19	20	21	22	23	
Aluminum	25	26	27	28	29	

Transparencies:

40, Model for lithium atom

42, "Electric charges are associated with the particles of matter"

46, "The mass of an atom is determined by the number and kinds of particles that it contains"

47, "All atoms of a given element are made up of equal numbers of electrons and protons"

Demonstration:

Kitchen balance

Sheet of plastic, 1.5 x 1.5 feet

Paper circle, 4-inch diameter

4 steel balls, 3 painted a different color

1 plastic circle, 1-inch diameter

Procedure

Project Transparencies No. 40, a model for a lithium atom, and No. 42, "Electric charges are associated with the particles of matter." From these the pupils should review:

1. The atom is made up of electrons, protons, and neutrons.
2. The atom has as many electrons as protons.
3. The chemical properties—difference between lead and gold—of an element are explained in terms of numbers of electrons and protons.
4. The protons and neutrons are in the nucleus.
5. The electrons are nearly weightless.
6. The electrons and protons attract each other due to electrical forces.

Teacher: "Today I am going to tell you about something that was a sort of mystery in about 1931. Dr. Harold Urey was studying hydrogen and he found some hydrogen that acted like ordinary hydrogen, that is, it would combine with oxygen to form water and react in other ways just like hydrogen is expected to react. There was, however, one property of this sample of hydrogen that was different; it weighed twice as much. Here we had an element that was hydrogen but its atomic weight was 2 rather than 1. Later, after this hydrogen-2 was reported, a hydrogen with an atomic mass of 3 was found. Can we explain this difference in mass with our present model?" (Answer: Yes.) "Let us construct a model that satisfies our requirements; these are:" (Answer:

1. The atom must remain the same kind of element.
2. The atoms have different masses.)

"How do we satisfy these requirements?" (Answer: Change the number of neutrons in the nucleus.)

Demonstration. Place the plastic sheet on the sensitive kitchen balance. The circle in the center is to be the nucleus.

Teacher: "If the element is hydrogen, how many protons do we have?" (Answer: One.) "Where is it placed?" (Answer: Nucleus.) "How many electrons are there?" (Answer: One.) "Where is it placed?" (Answer: Outside the nucleus.) "What is the mass of this atom?" (Answer: One.) "Why?" (Answer: It has one

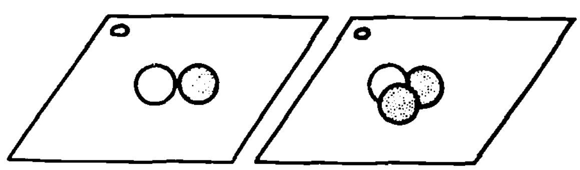

Figure 30.1. Two isotopes of hydrogen

nuclear particle.) "What would we change to make hydrogen with a mass of 2?" (Answer: The nucleus.) "How would it be changed?" (Answer: Add one neutron.) Add one steel marble and note the change in mass. "Is this a good model?" (Answer: Yes.) "Why?" (Answer: It meets our requirements. We still have hydrogen and the weight is twice as much.) "How can you make a model for hydrogen 3?" (Answer: Add another steel marble.) Note the reading of the balance.

"These atoms with different weights from the ordinary are called isotopes."

Sketch a model of an atom of carbon and its many isotopes.

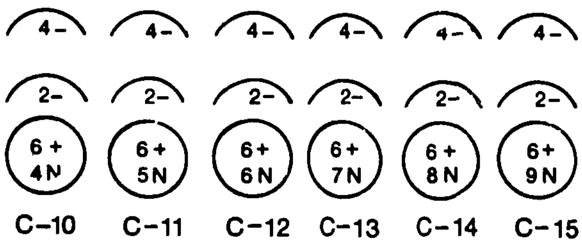

Figure 30.2. Isotopes of carbon

Note the following:

1. All have the same number of protons and electrons. (This means they are all carbon.)
2. Each has a different number of neutrons. (This means each has a different mass.)

Repeat this with sketches of gold.

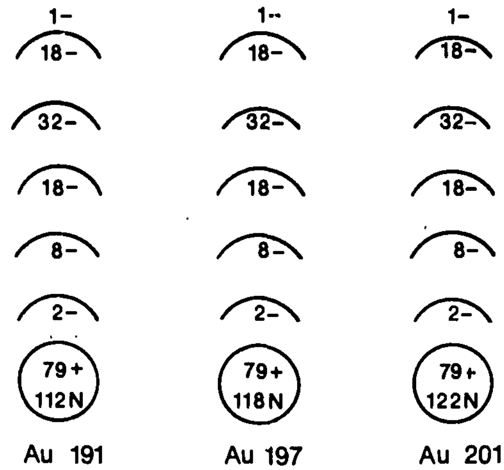

Figure 30.3. Isotopes of gold

Project Transparencies No. 46, "The mass of an atom is determined by the number and kinds of particles that it contains," and No. 47, "All atoms of a given element are made up of equal numbers of electrons and protons."

Lesson 31
Molecules

Concept 25: Molecules are made up of atoms that are held together by electrical forces.

Background Information

A molecule may be defined as an electrically neutral combination of atoms that acts as a single unit. This means that a molecule of water is not merely hydrogen and oxygen side by side, but rather a new unit that is made up of hydrogen and oxygen. A molecule is not a mixture with the parts easily noted and separated. The atoms are said to be bonded together. The question asked for many years was "What kind of a bond is this that exists between atoms as a result of a chemical change?" Now we have a model that satisfies this question: "The bond between atoms is an electrical force." To explain this electrical force requires some invention because metals are different from metallic compounds and these are different from nonmetallic compounds. There is no reason to go into metallic, ionic, or covalent bonding at this level, since the desire is to develop the idea that a bonding force is explained in terms of the idea of electricity.

The electrical conductivity of some solutions sets up the idea of electrical bonds. There is no reason to go beyond the idea that the attraction is due to the sharing of electrical forces.

Recall the electrolysis of water experiment to support the idea of an electrical attraction. There are some materials that cannot be broken down electrically and also that do not conduct electricity. It is difficult to establish the electrical nature of the bond here. At this level, it may be necessary to take it on faith.

The theoretical base, though not of concern for the pupils, is that an outer shell of eight electrons is the ideal stable state for all atoms except hydrogen and helium; for these it is two.

Teacher Orientation

This concept follows the many concepts presented so far because it is quite sophisticated. It is based upon many previous concepts.

1. Matter is made up of atoms.
2. Atoms are made up of electrically-charged particles.
3. Electrical charges (-) can be caused to move, resulting in particles that are negatively charged and positively charged.
4. Like charges repel and unlike charges attract each other.

In this lesson you will use these ideas, but not stress how the particles get the charge. You are merely concerned with the explanation of molecules being held together.

Materials

Overhead projector and screen

Transparencies:

48, "Model for a water molecule"

49, "Molecules are made up of atoms that are held together by electrical forces"

50, Listing of Concepts 1-6

51, Listing of Concepts 7-11

52, Listing of Concepts 12-16

53, Listing of Concepts 17-21

54, Listing of Concepts 22-25

Procedure

Review the ideas listed in the teacher orientation statement. Place these on the overhead projector or chalkboard.

Teacher: "We have come a long way in forming our model for matter. Now we want to go one step farther. How can we explain what holds the atoms together in molecules?" Pupils are asked to speculate some. [Possible ideas are: Electrons move from one atom to another causing the atoms to have different electrical charges and, thus, attract each other. In some way the atoms share electrons so both are attracted to the electron.]

Project Transparency No. 48, "Model for a water molecule." Note the sharing of electrons. The electron from each hydrogen atom got into the orbit of the oxygen electrons, so this holds them together.

There are many ways these electrical forces can be developed.

Project Transparency No. 49, "Molecules are made up of atoms that are held together by electrical forces."

Teacher: "Let us review the ideas we have developed so far. We have constructed each of these models for matter for a reason. What is that reason?" (Answer: To help us explain what we see happen.) "When is a model a good one?" (Answer: When the model includes what we know and helps us to explain what we want explained.)

Project Transparencies No. 50, 51, 52, 53, and 54 that list all the concepts.

The teacher will point out why we used each model and, as often as possible, why and to what extent it was changed. The review should be the history of an idea about matter.

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III
Transparencies 1-54

WATER HEAT

MATTER ENERGY

Transparency No. 2

MATTER CAN BE WEIGHED ON OUR SCALE.

ENERGY CANNOT BE WEIGHED ON OUR SCALE.

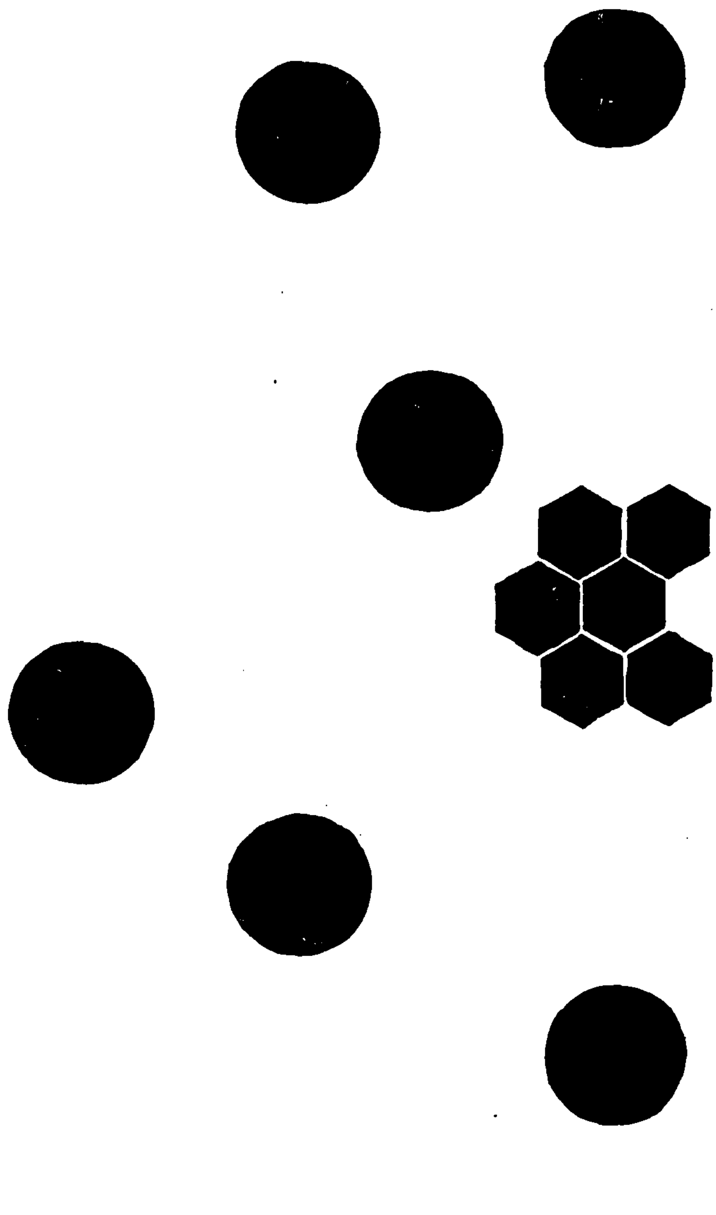
Transparency No. 3

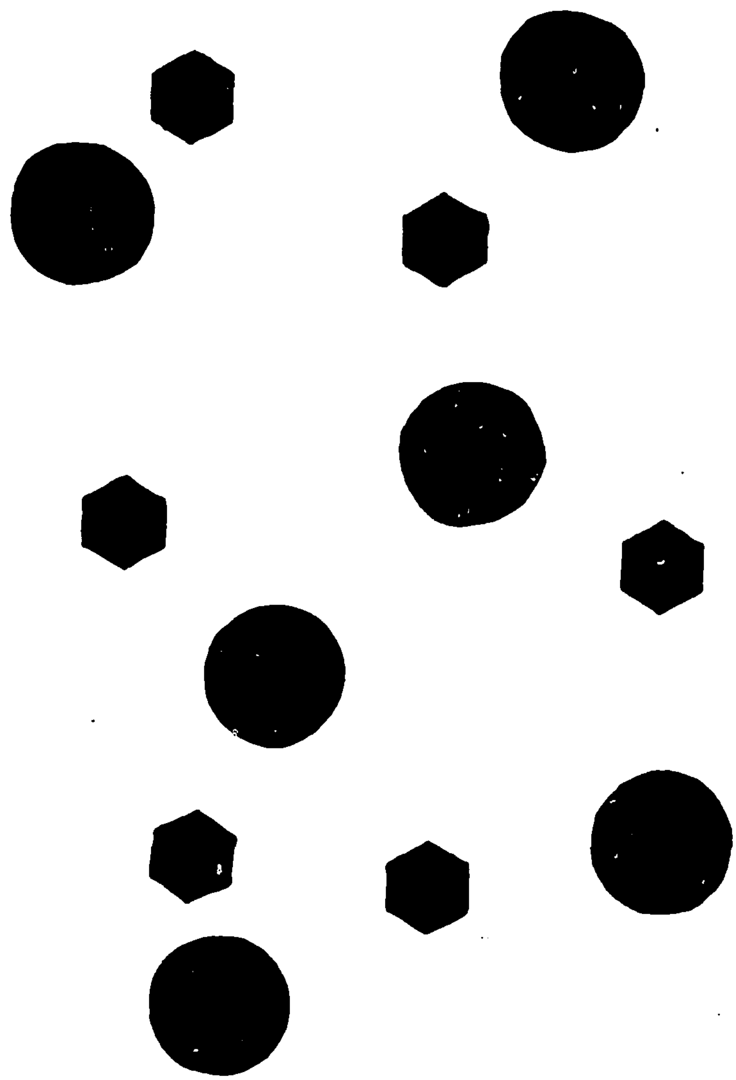
MANY THINGS CAN BE
LEARNED ABOUT OBJECTS
WITHOUT REALLY SEEING THEM

Transparency No. 4

CAN WE DETERMINE SOME
OF THE CHARACTERISTICS
OF AN OBJECT
WE CANNOT SEE ?

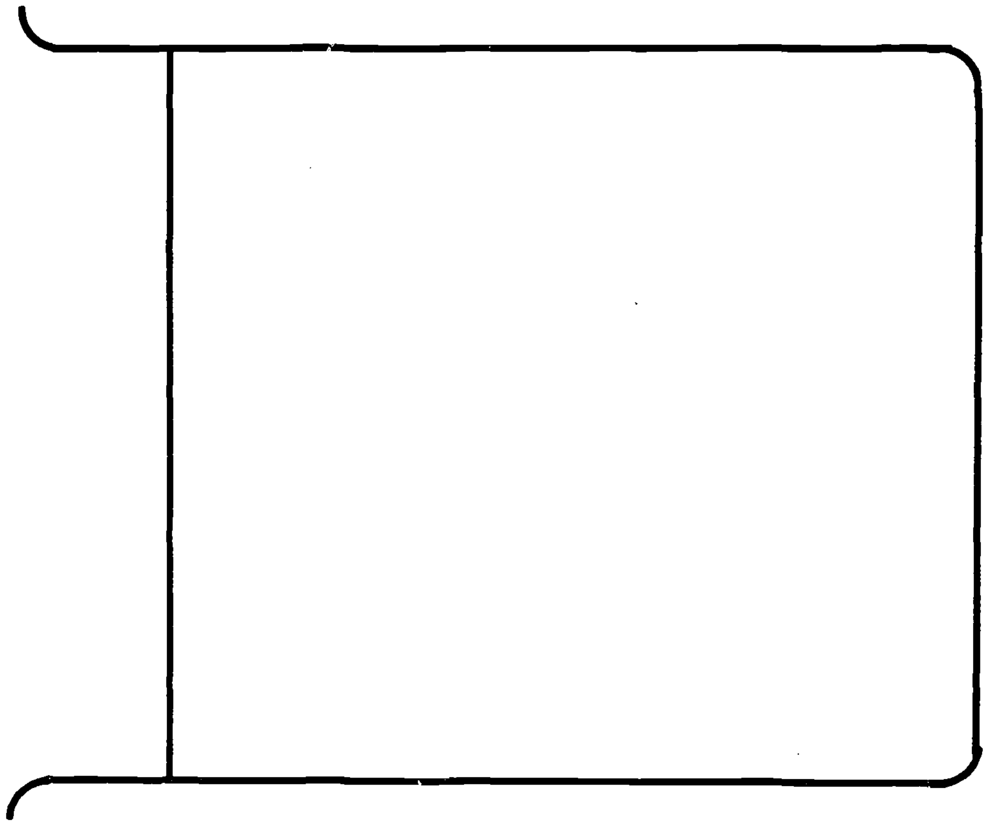
Transparency No. 5 Overlay No. 1



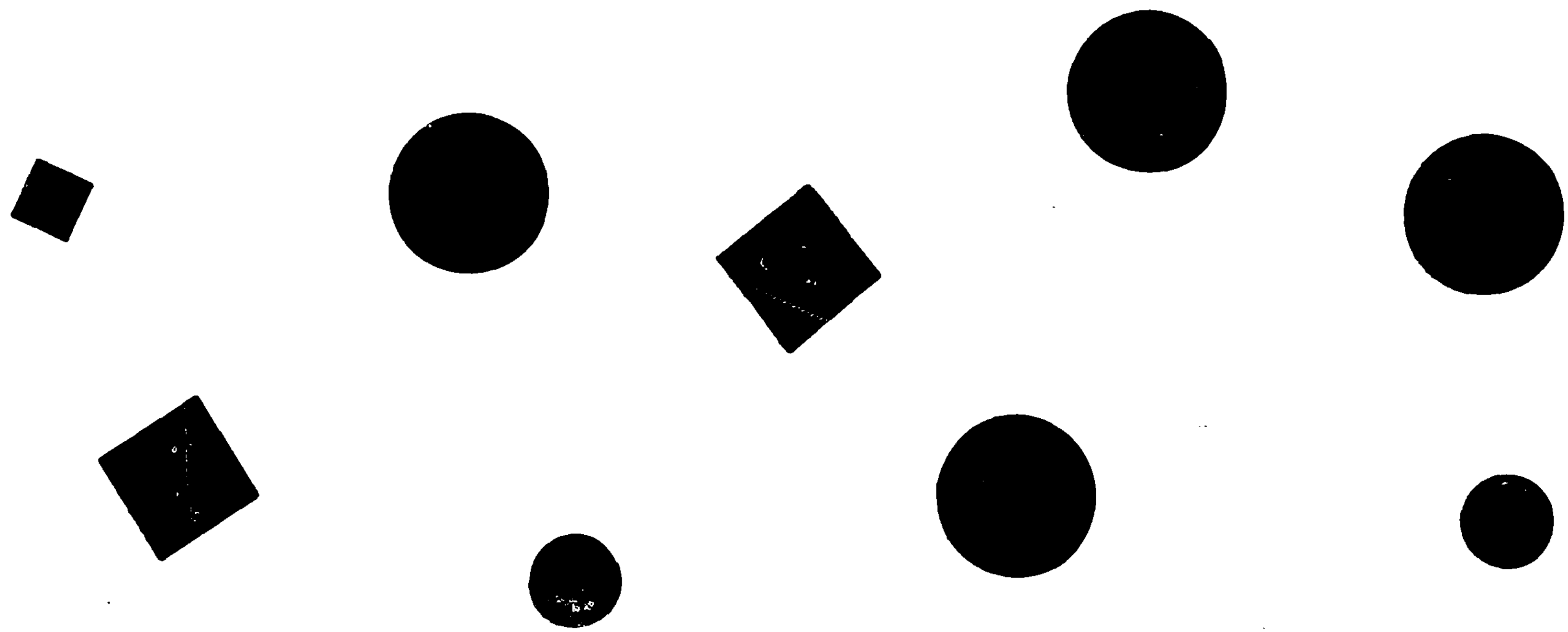


WHAT HAS HAPPENED TO THE SUGAR?

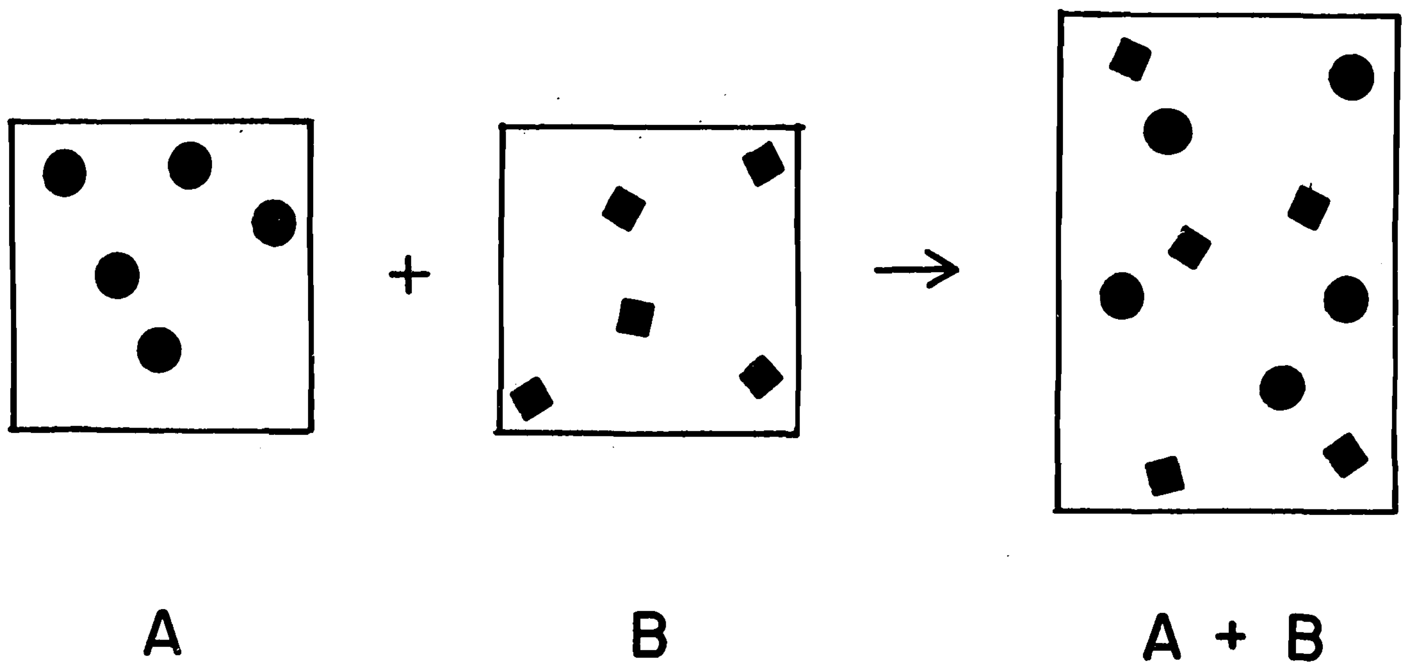
Transparency No. 6



MATTER IS MADE UP OF PARTICLES

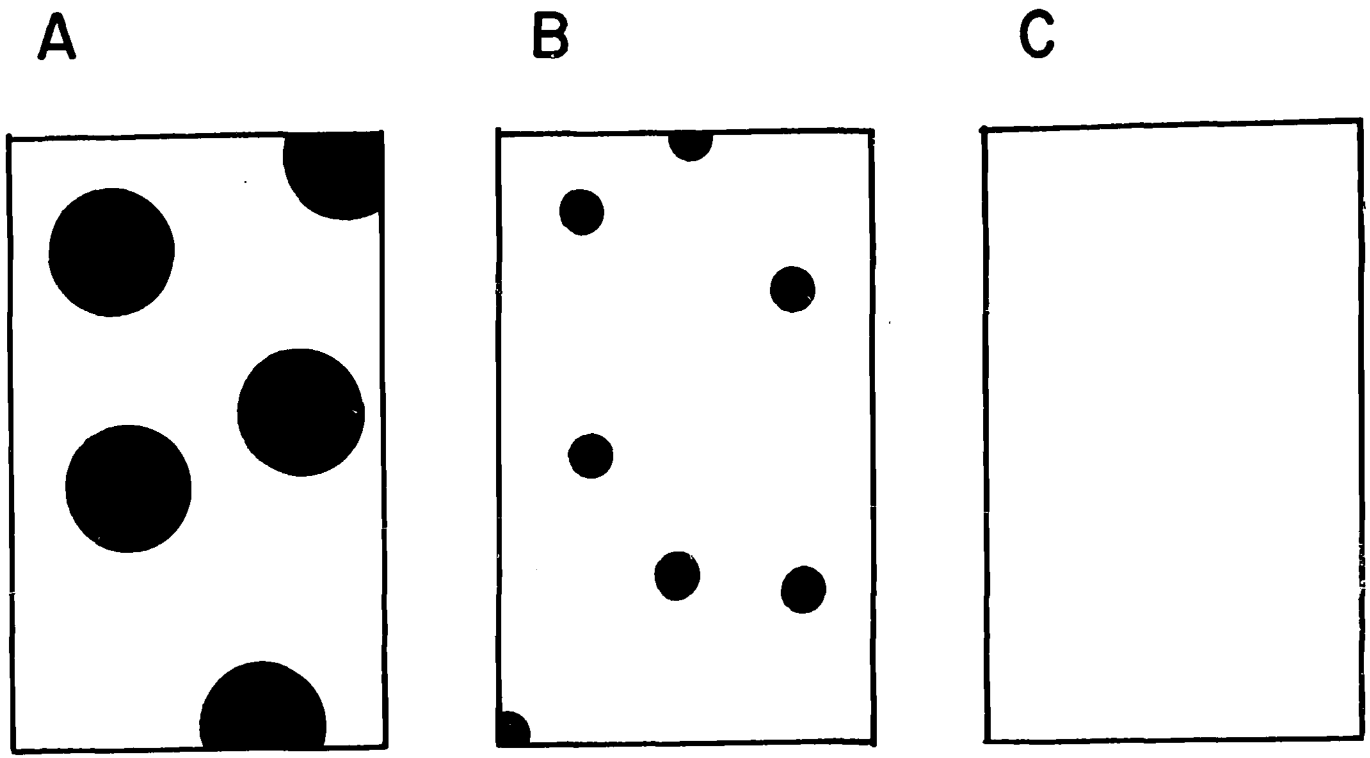


PARTICLES OF MATTER HAVE SPACES BETWEEN THEM



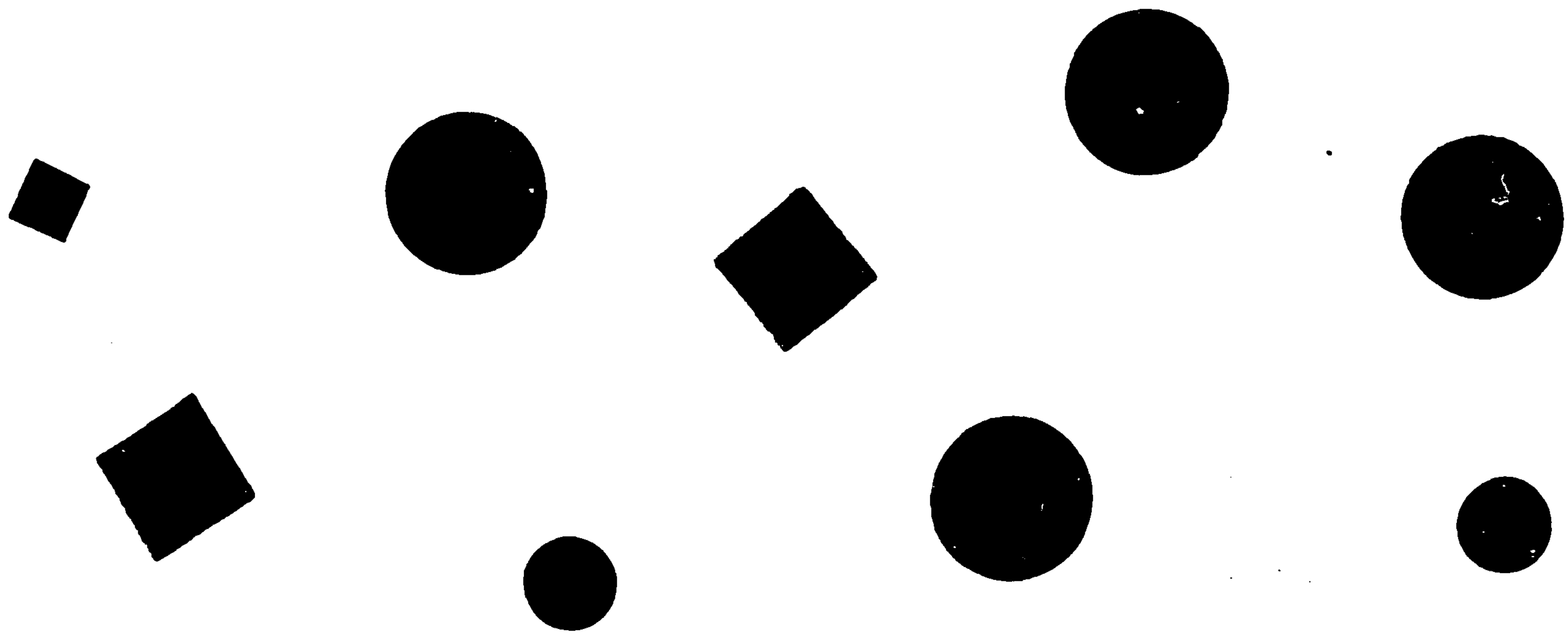
GENERALIZED FLOORPLAN OF YOUR CLASSROOM

PARTICLES OF MATTER ARE VERY SMALL

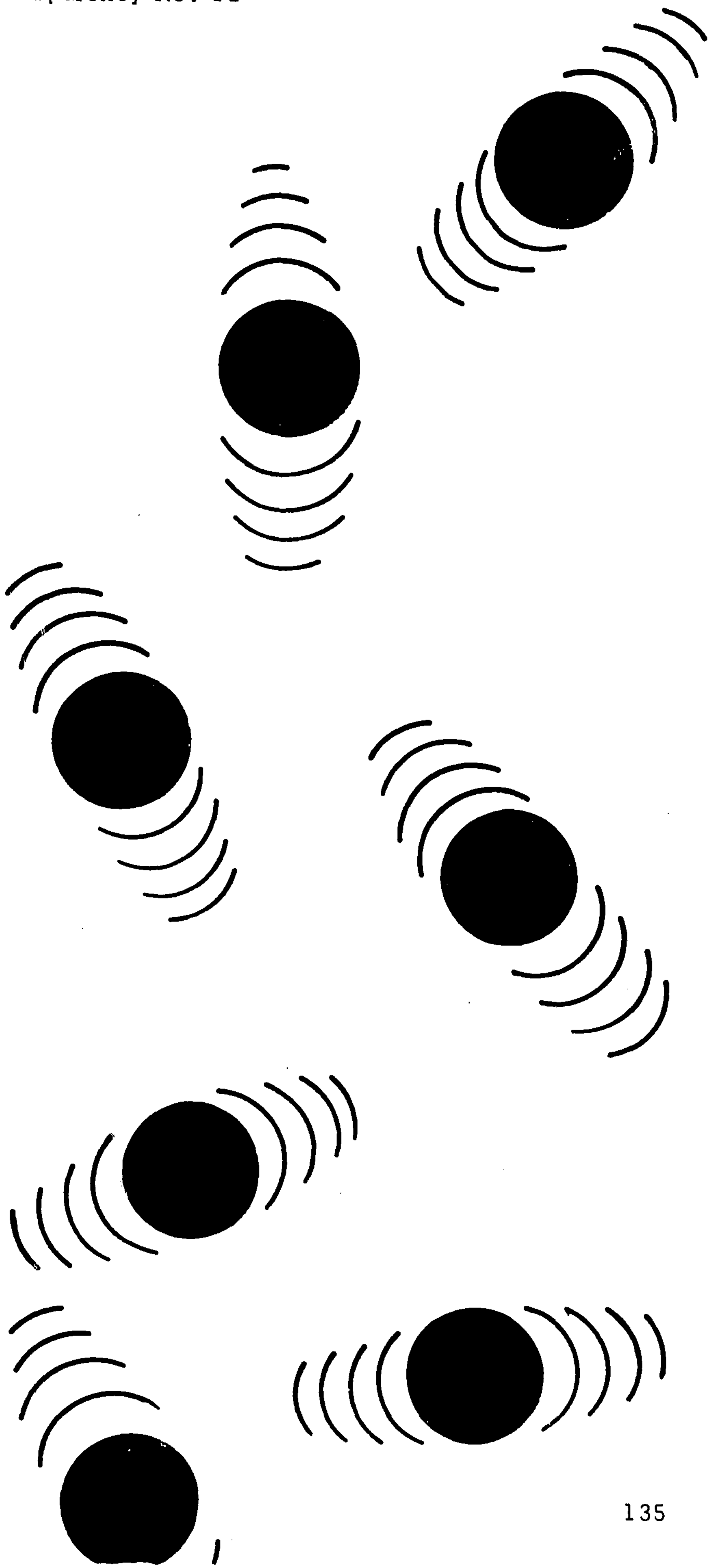


PARTICLES OF MATTER

- HAVE SPACES BETWEEN THEM
- ARE VERY SMALL



PARTICLES OF MATTER ARE IN MOTION



Chemical B

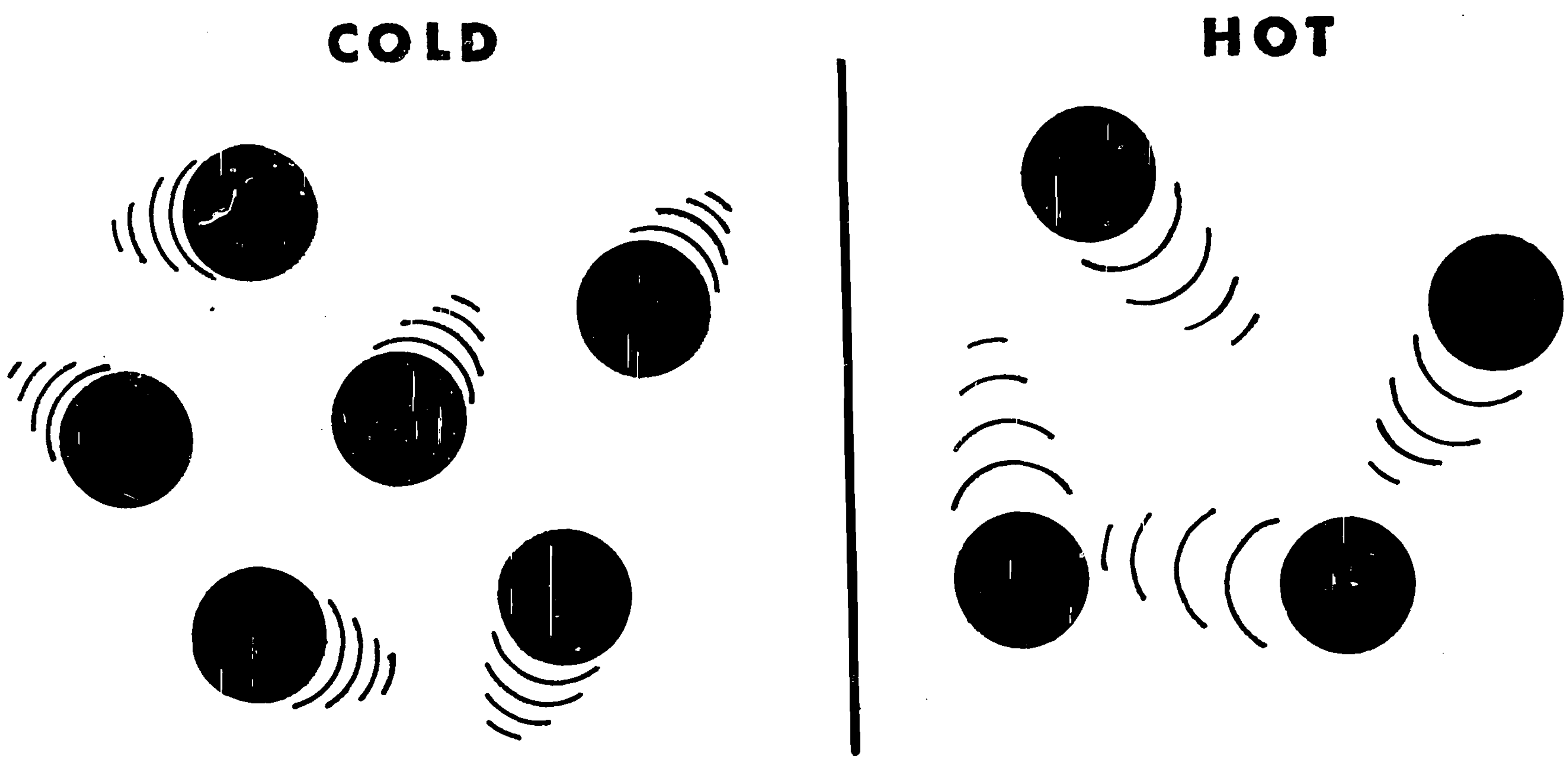
Chemical A

GPO 828-145-10

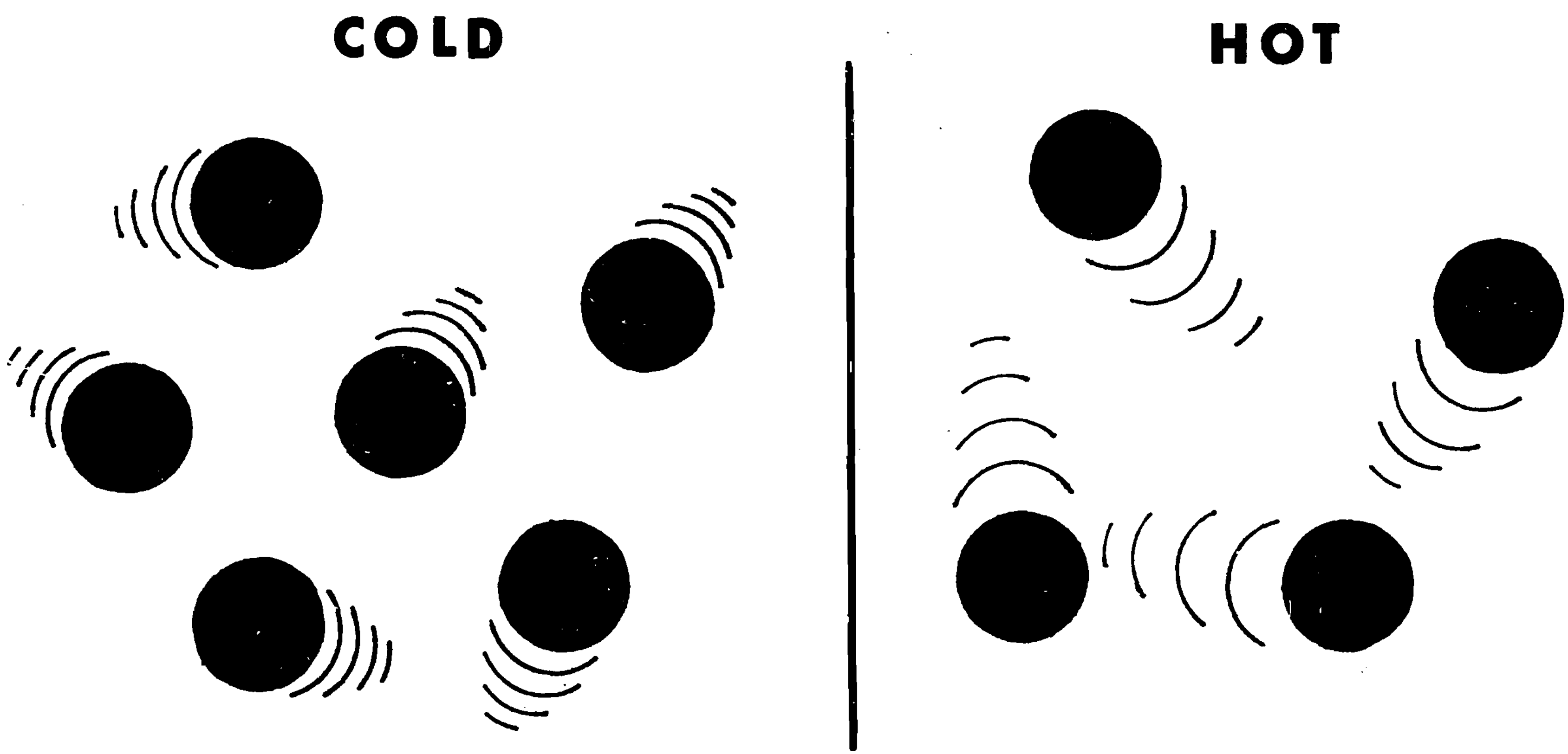
HOT COLD

Transparency No. 15

PARTICLES OF MATTER MOVE FASTER WHEN THE MATTER IS HEATED



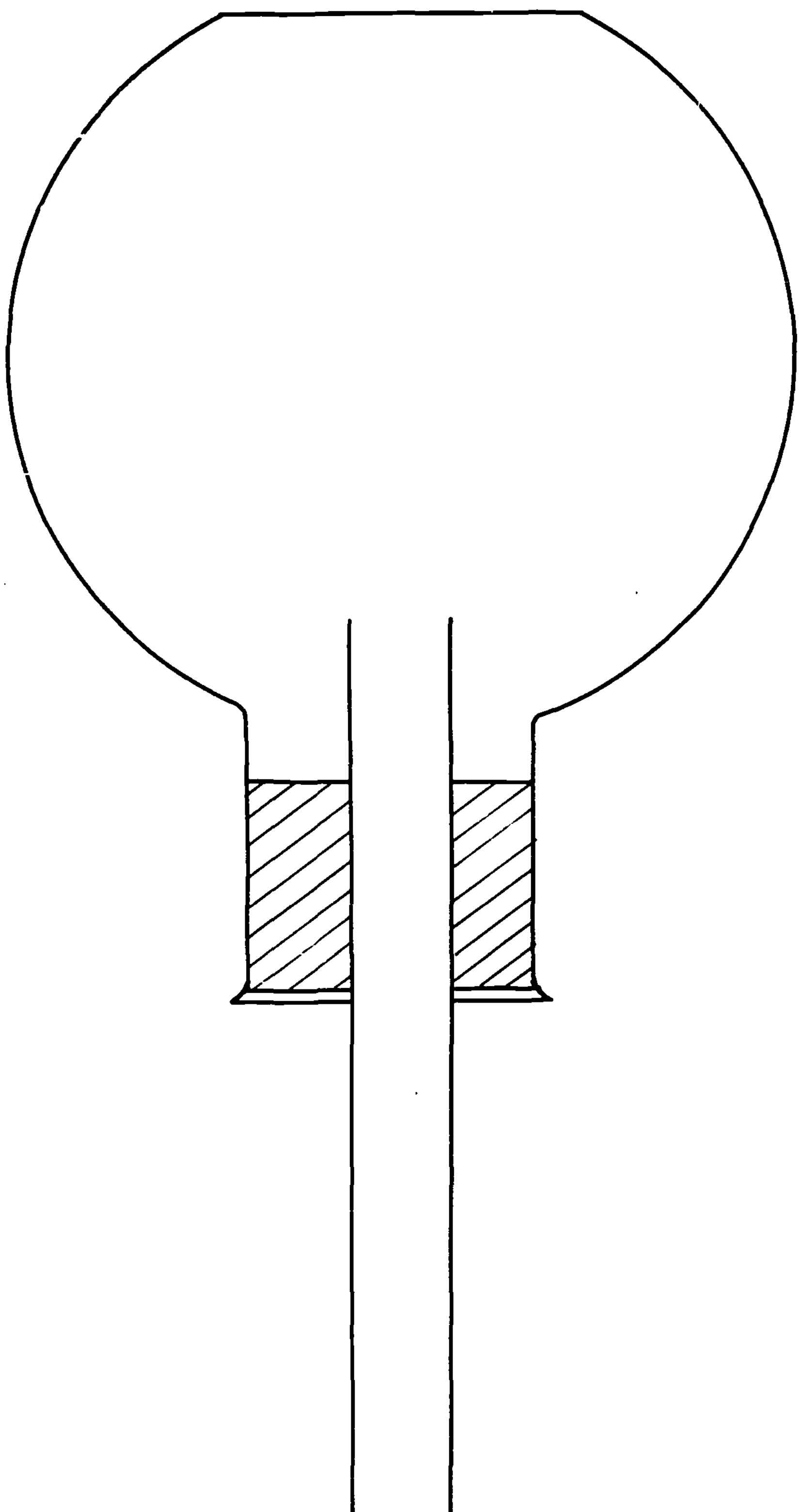
PARTICLES OF MATTER USUALLY MOVE FARTHER APART WHEN THE MATTER IS HEATED



PARTICLES OF MATTER...

- HAVE SPACES BETWEEN THEM
- ARE VERY SMALL
- ARE IN MOTION
- MOVE FASTER WHEN HEATED
- USUALLY MOVE FARTHER APART WHEN HEATED

Transparency No. 18



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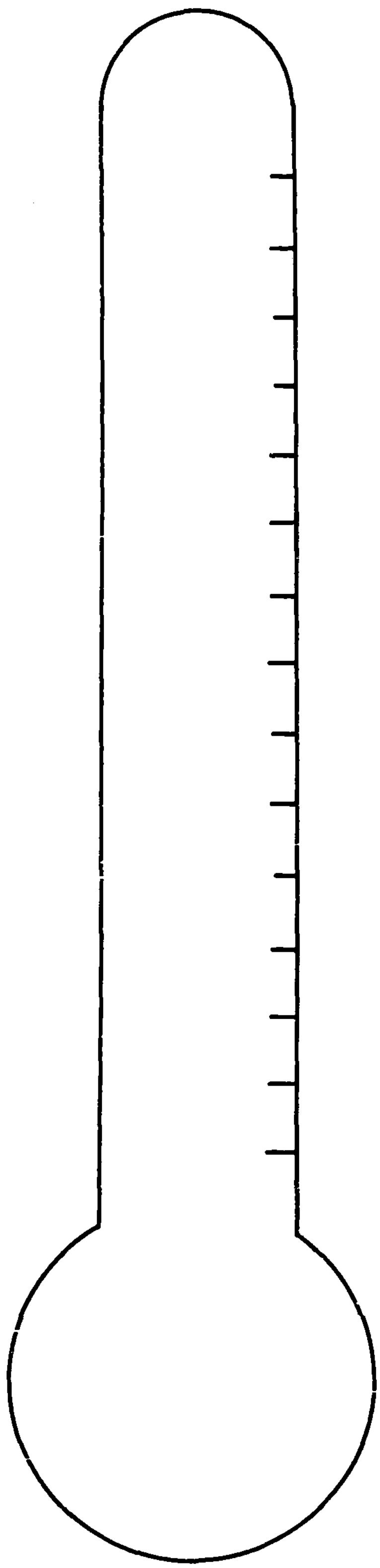
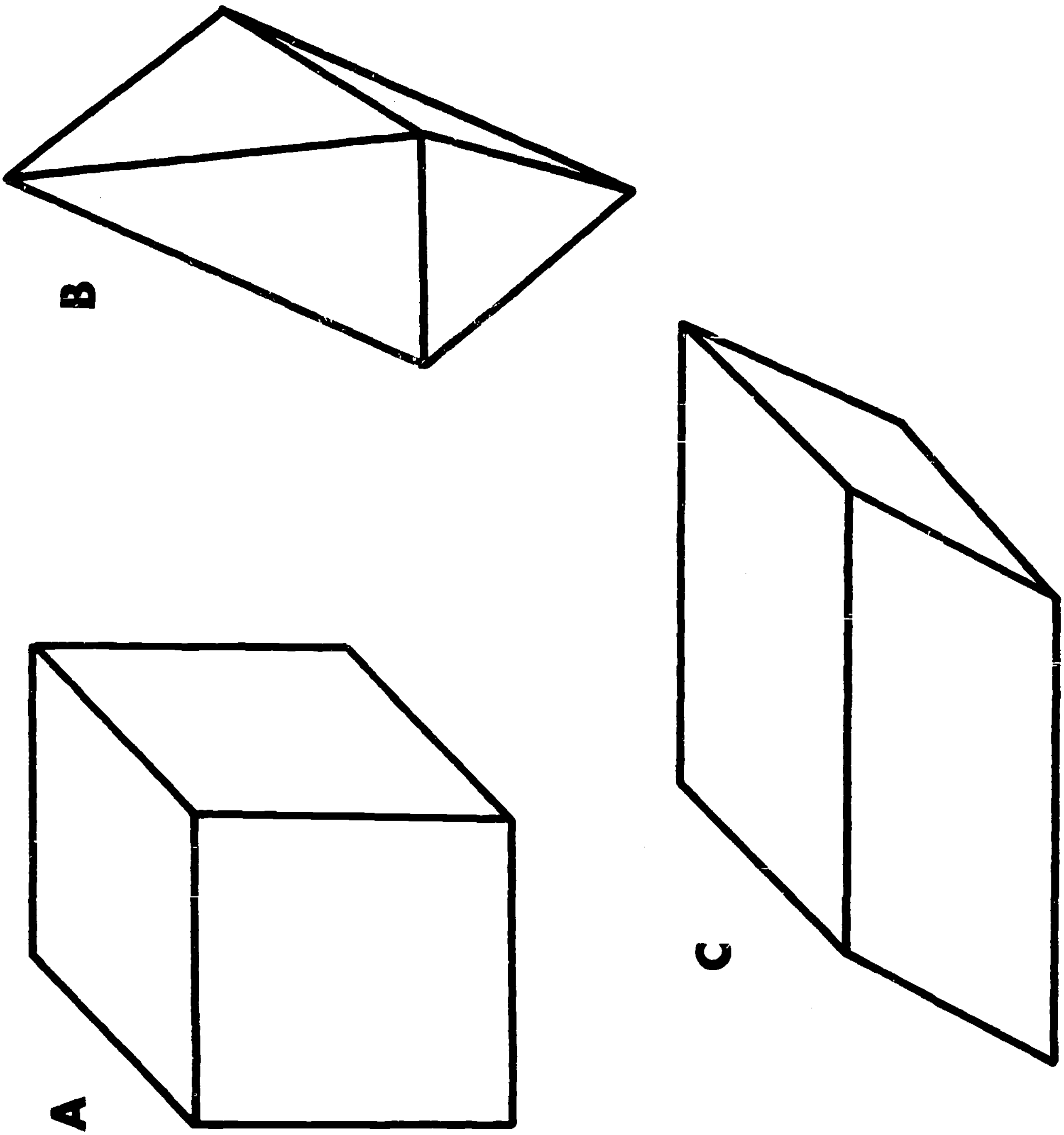
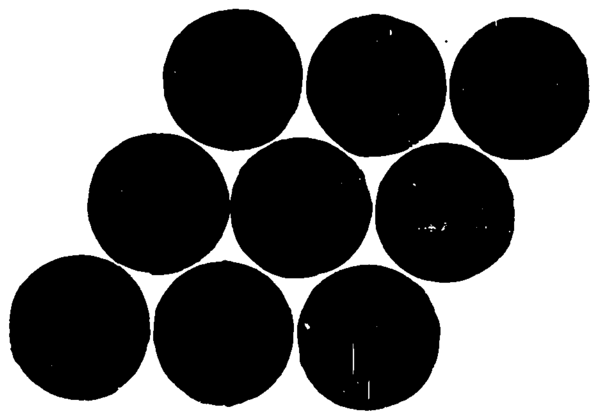
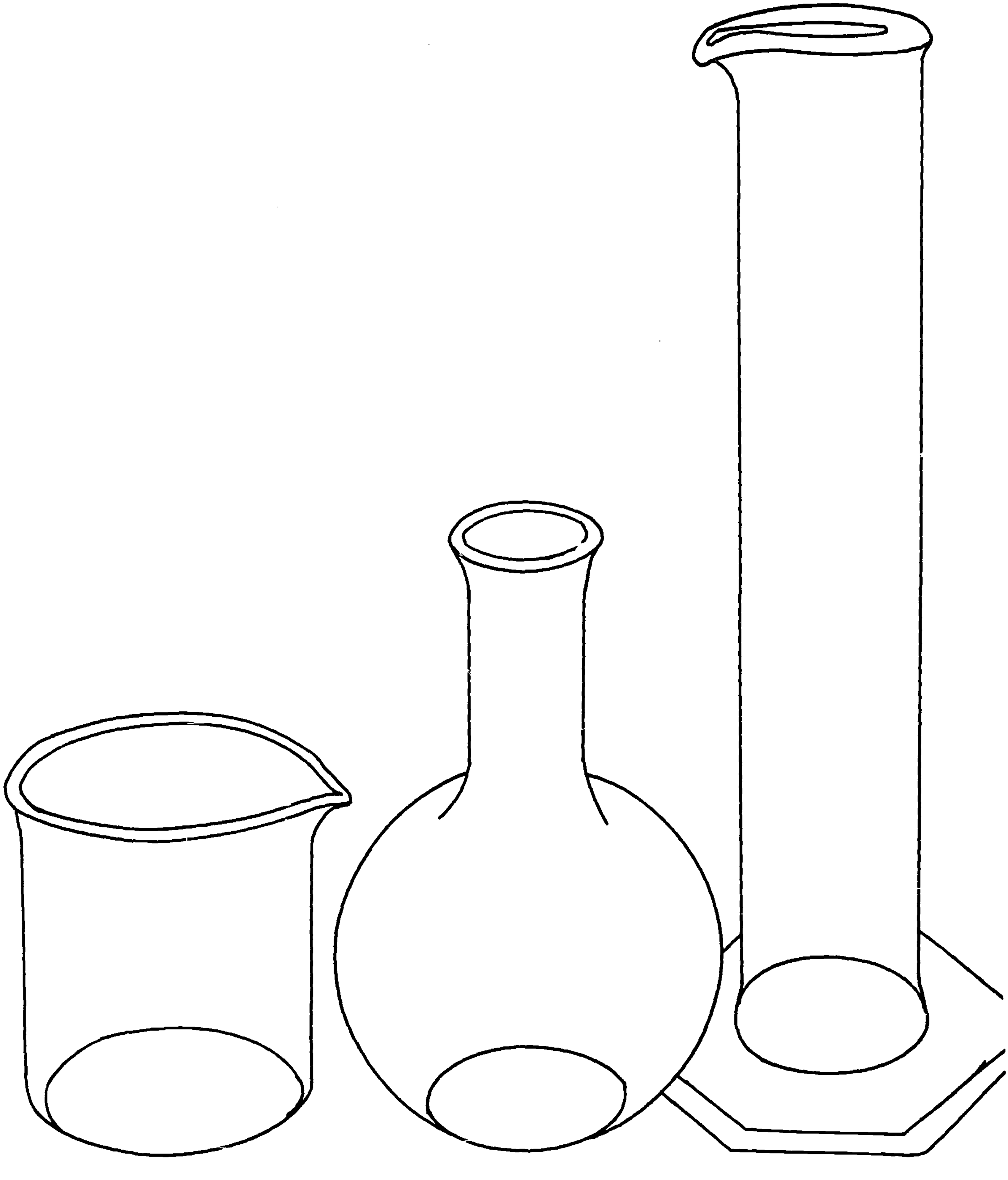



B
A
C

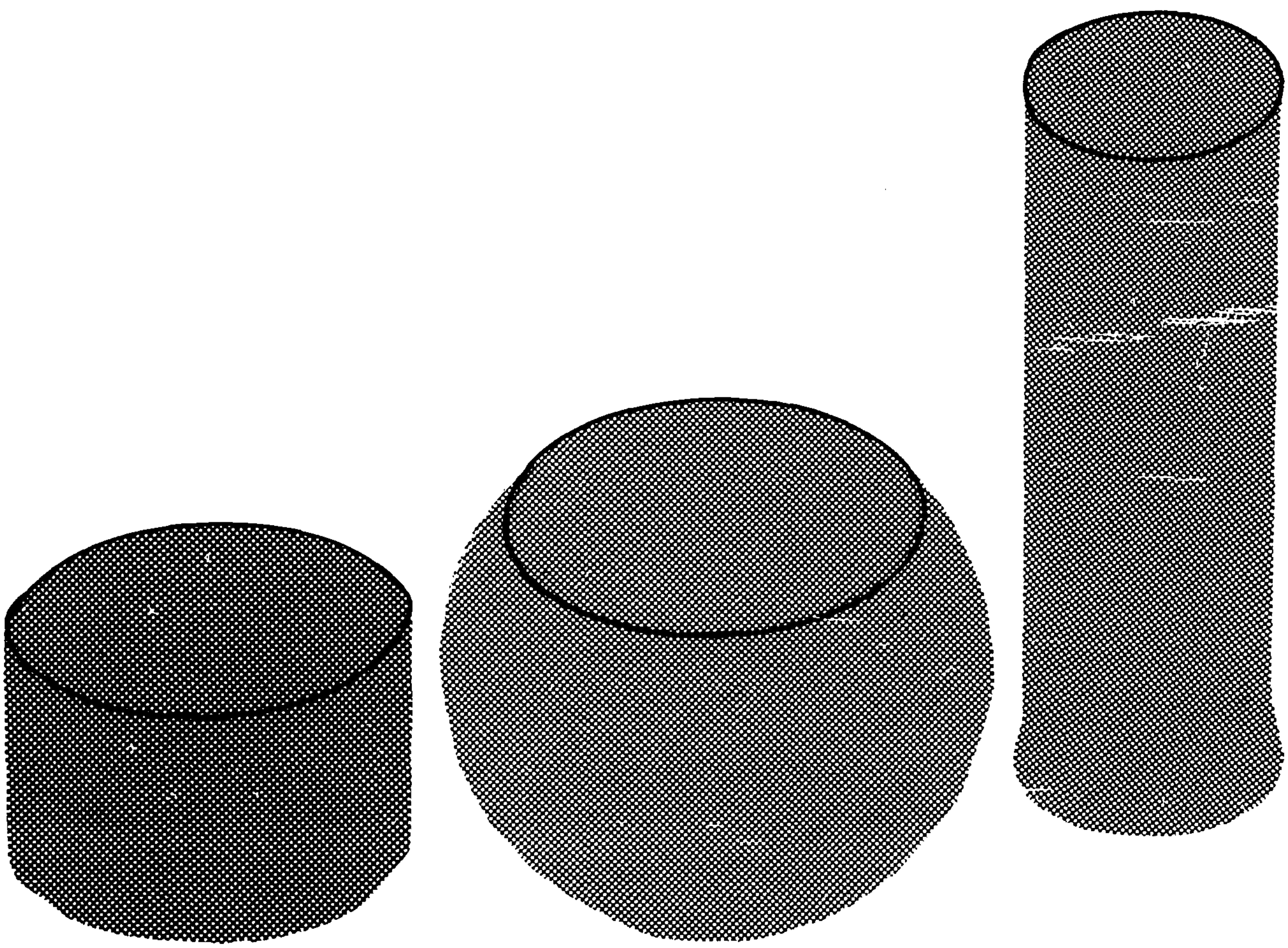
IN THE SOLID STATE, THE PARTICLES OF MATTER ARE PACKED TOGETHER IN A PATTERN AND MOVE WITHIN A SMALL SPACE

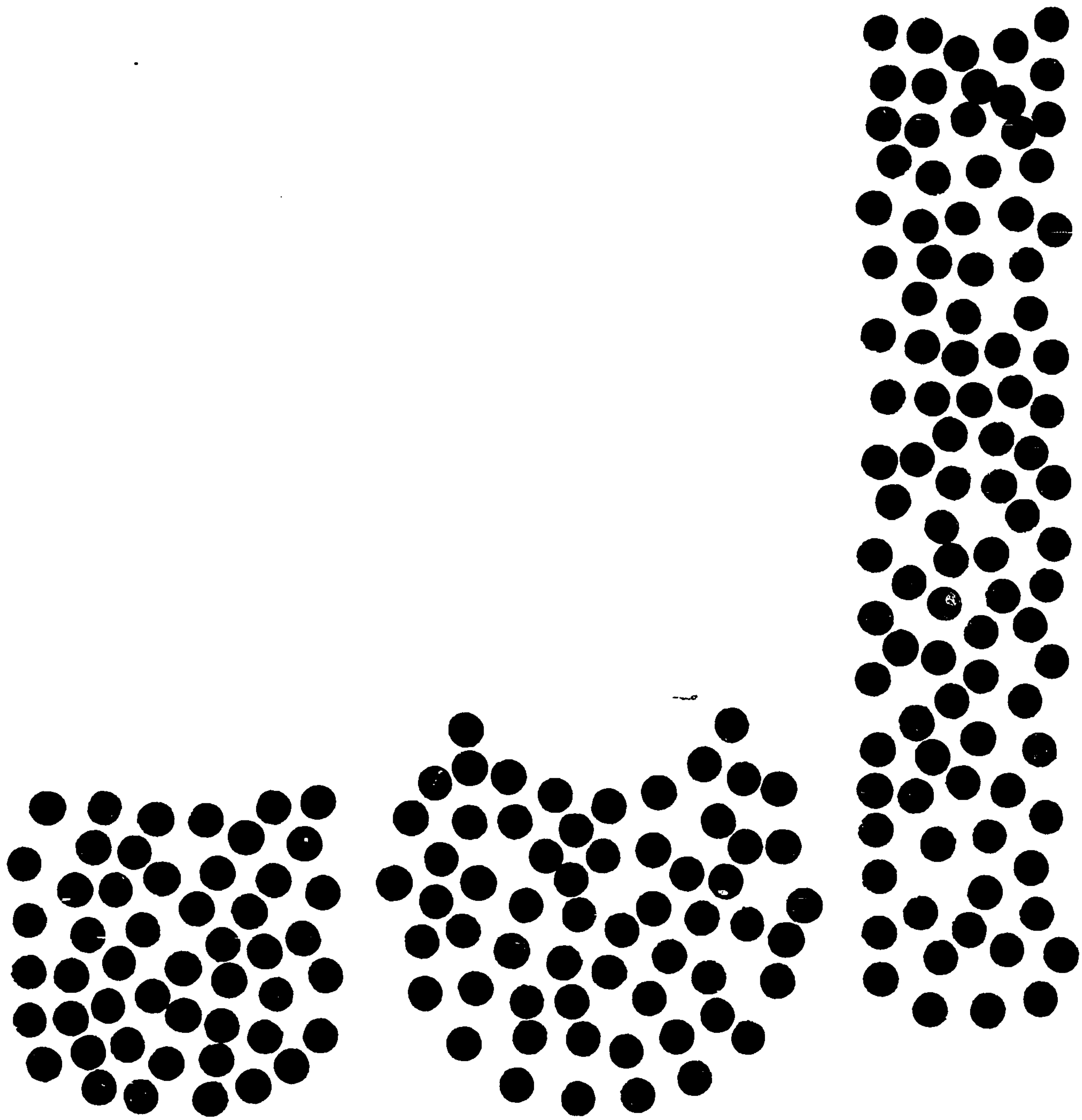


Transparency No. 22

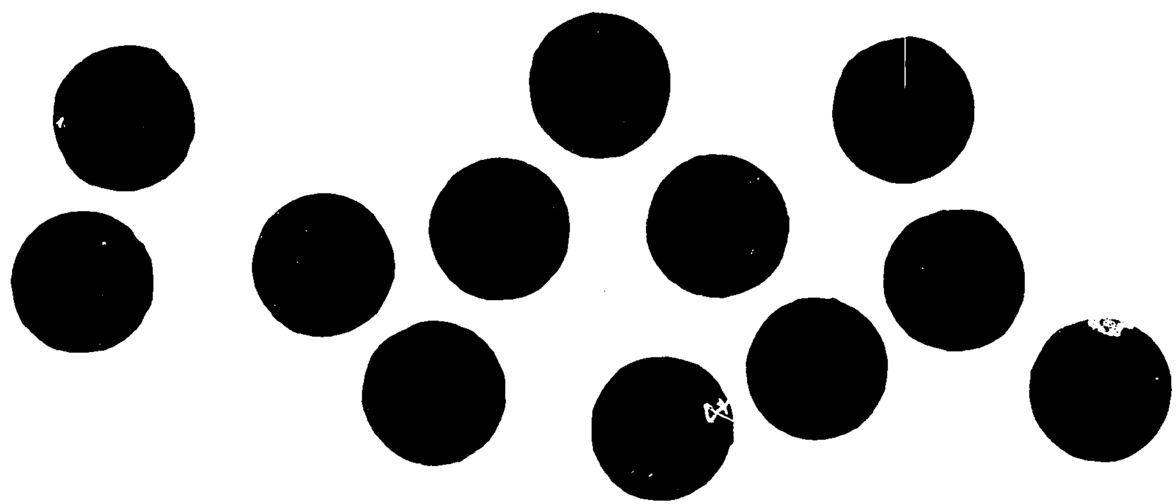


Transparency No. 22 Overlay No. 1

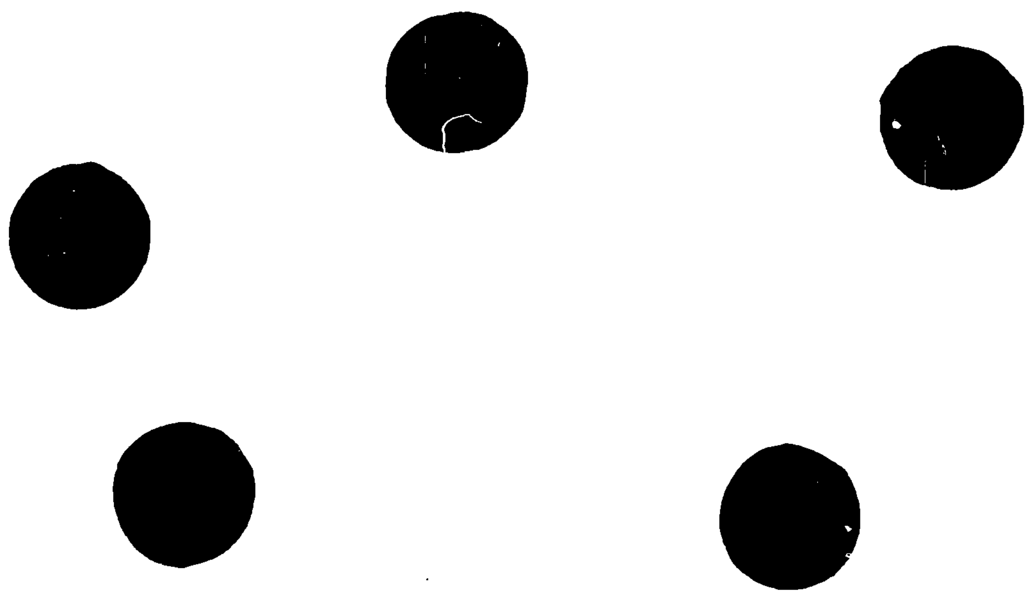




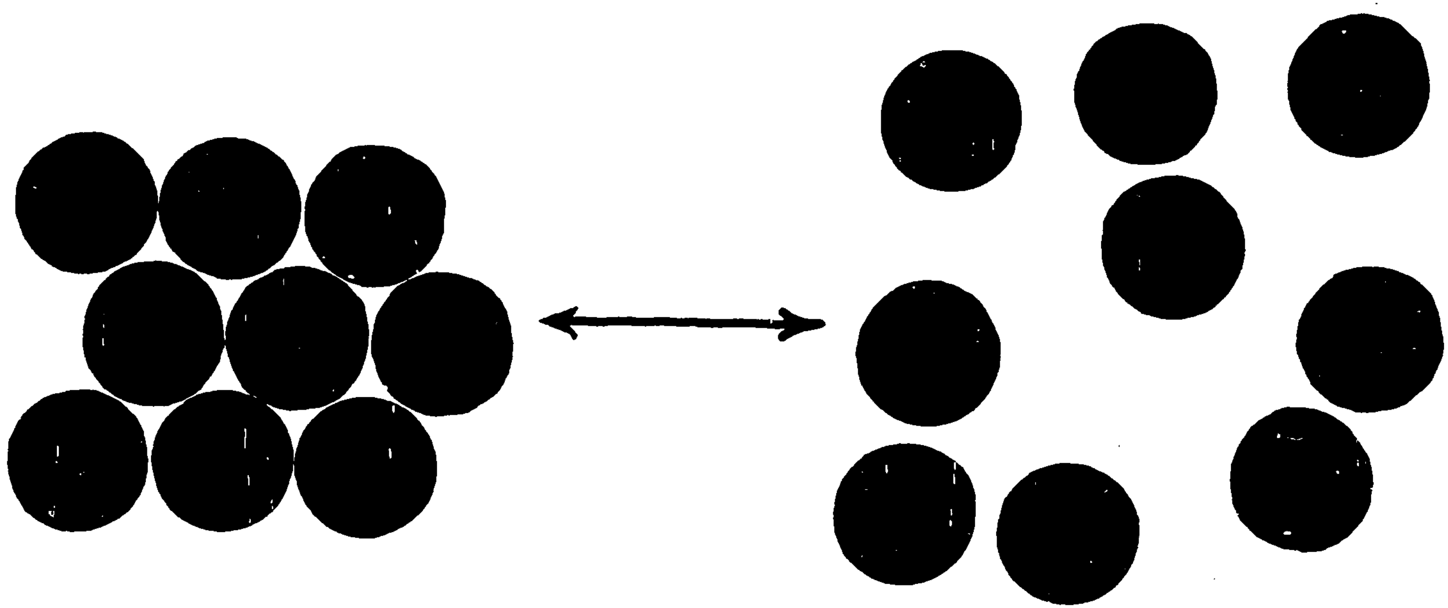
IN THE LIQUID STATE, THE PARTICLES OF MATTER ARE LOOSELY CLUSTERED TOGETHER AND MOVE ABOUT



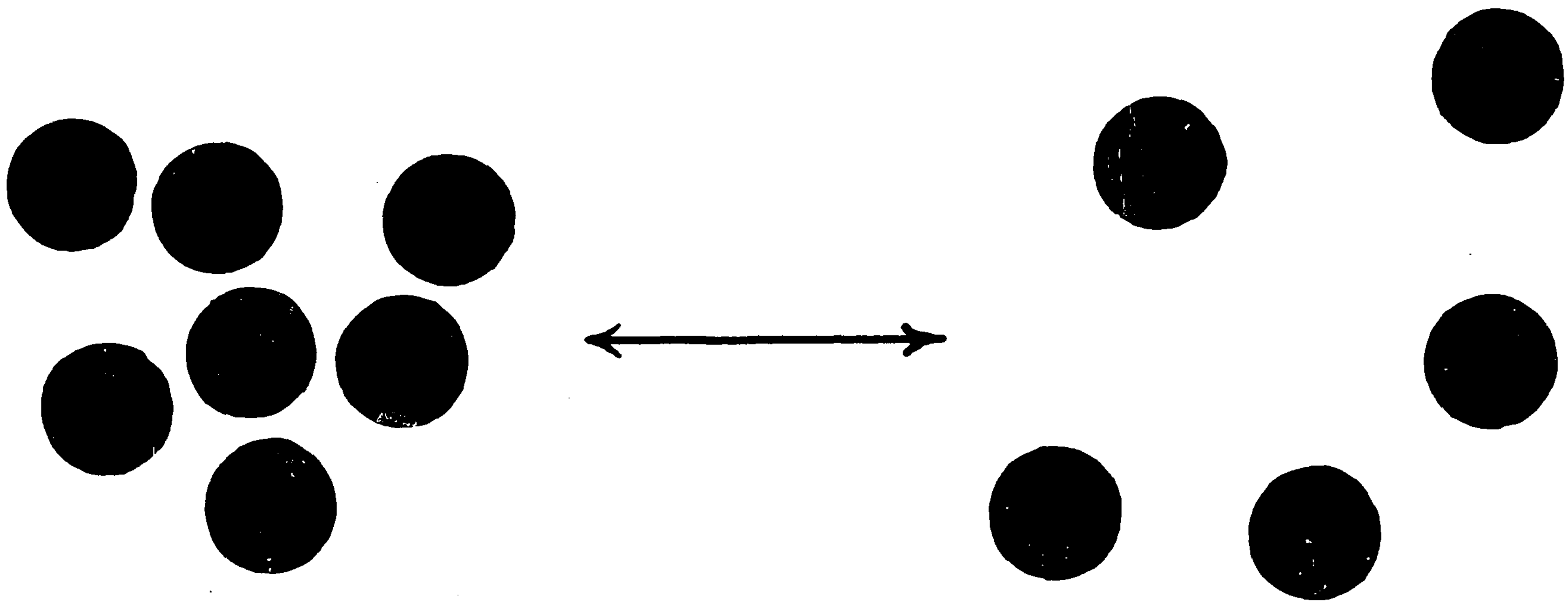
IN THE GAS STATE, THE PARTICLES OF MATTER ARE FAR APART AND MOVE FREELY



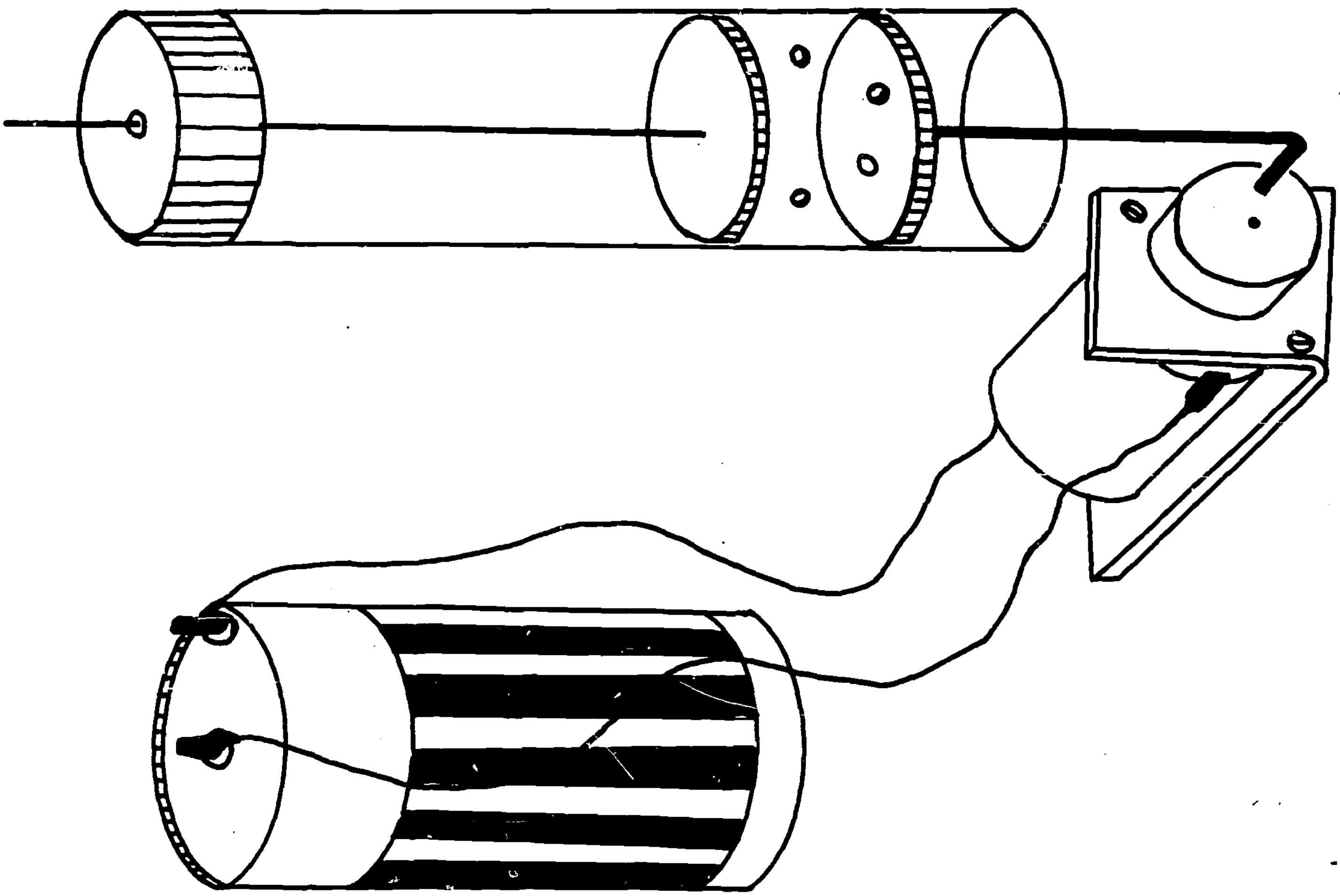
THE STATE OF MATTER CAN BE CHANGED FROM SOLID TO LIQUID AND FROM LIQUID TO SOLID



THE STATE OF MATTER CAN BE CHANGED FROM LIQUID TO GAS AND FROM GAS TO LIQUID



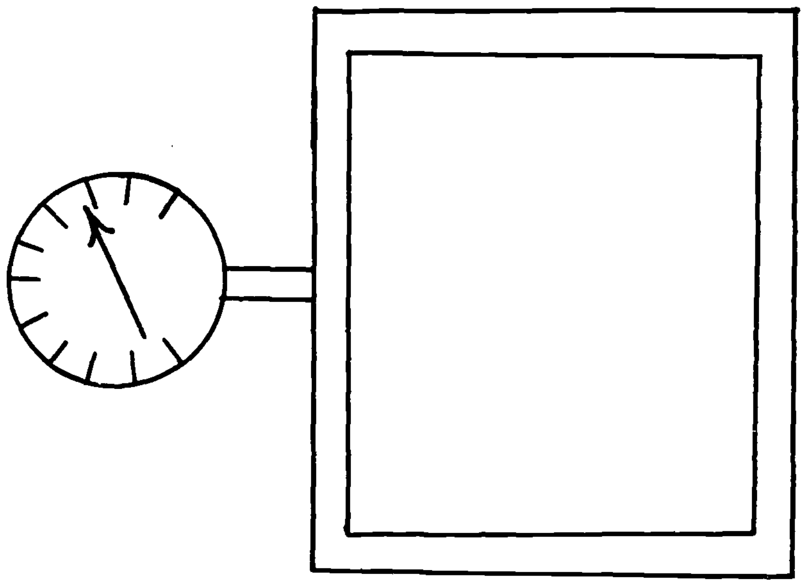
Transparency No. 27

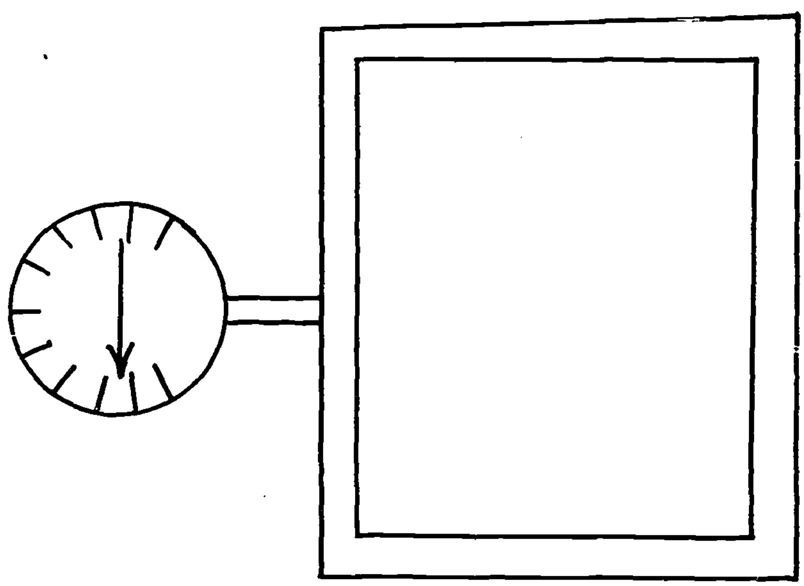


GPO 828-145-11

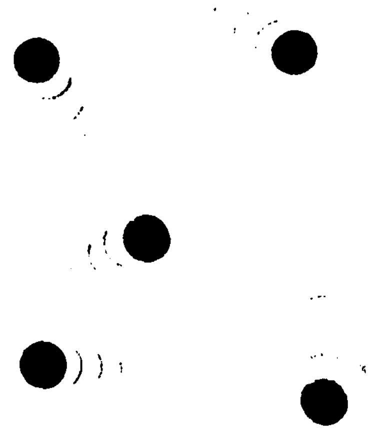
'HE PUSH AGAINST THE SURFACE BY A GAS DEPENDS UPON THE NUMBER AND RATE OF MOTION OF THE PARTICLES OF THE GAS

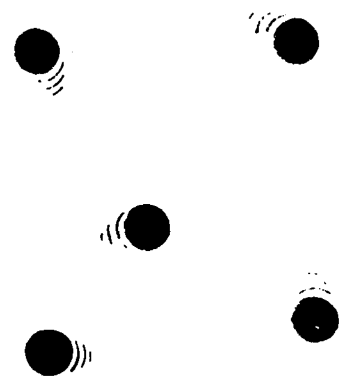
Transparency No. 28 Overlay No. 1



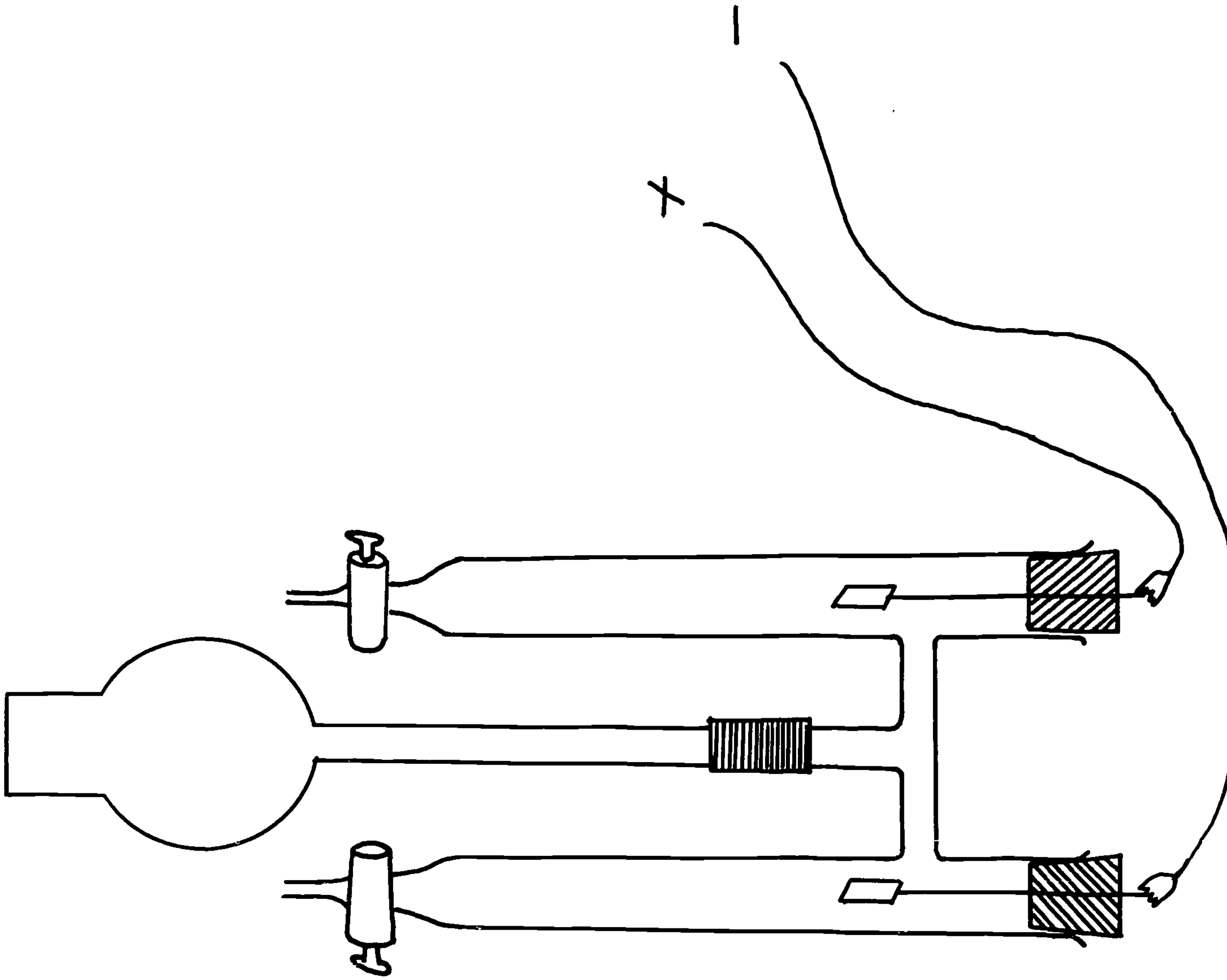


Transparency No. 28 Overlay No. 2





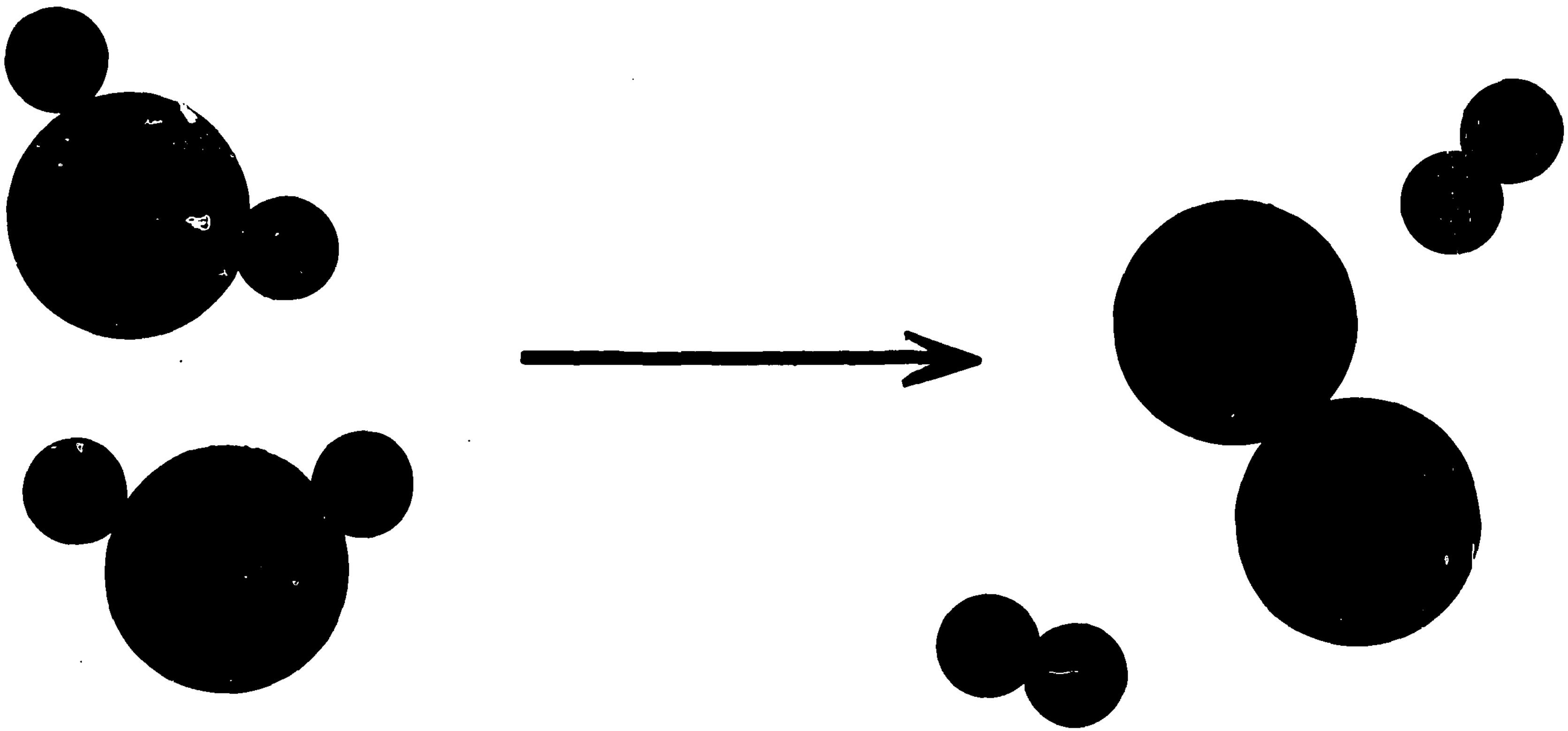
Transparency No. 28 Overlay No. 3

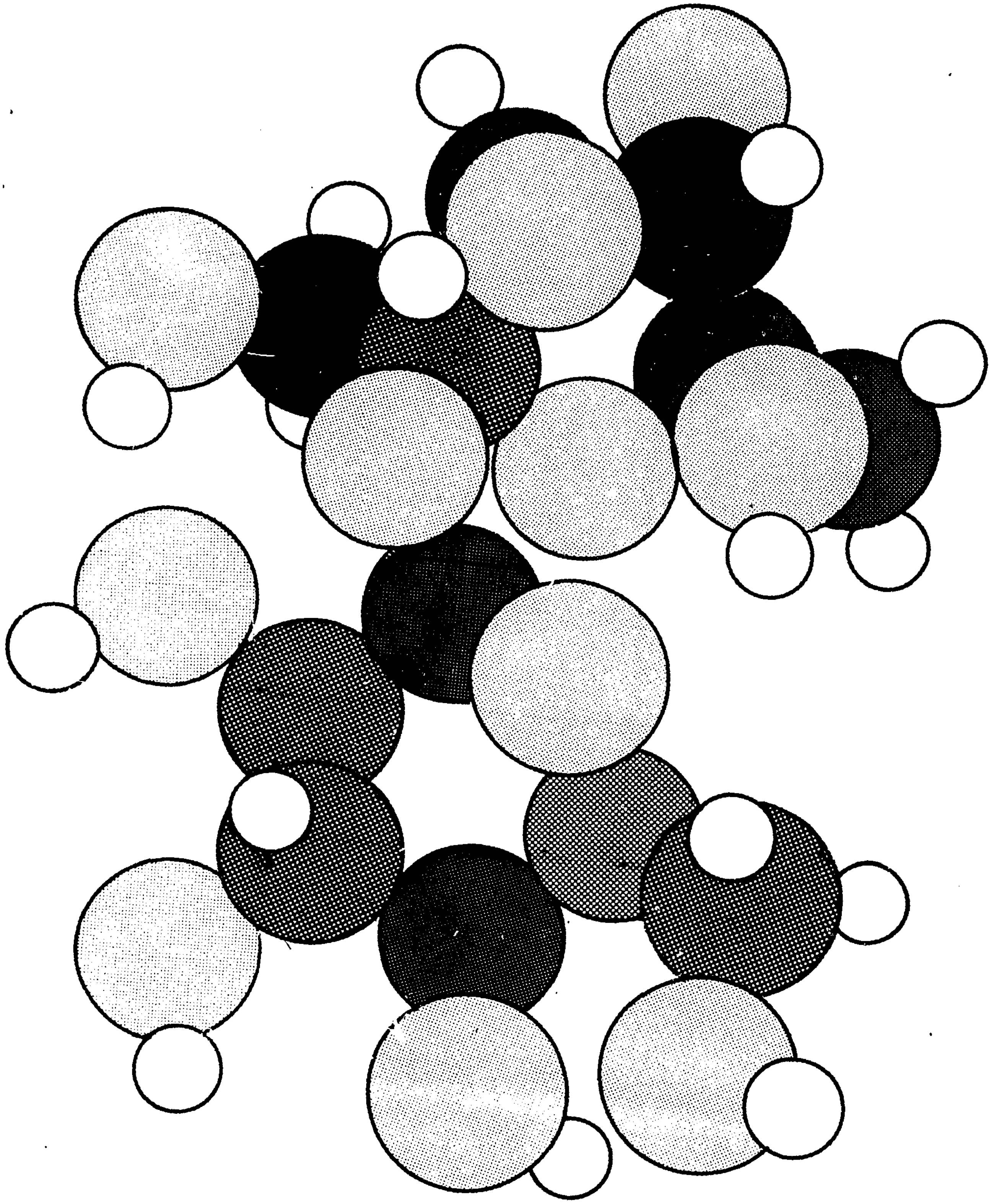


SOME PARTICLES OF MATTER (MOLECULES)

ARE MADE UP OF

SIMPLER PARTICLES (ATOMS)





SOME MOLECULES ARE MADE UP OF
ONLY ONE KIND OF ATOM

ELEMENT

SOME MOLECULES ARE MADE UP OF

TWO OR MORE KINDS OF ATOMS

COMPOUNDS

SOME SAMPLES OF MATTER CONTAIN MORE THAN ONE KIND OF MOLECULE

MIXTURES

Transparency No. 35

EACH TYPE OF MOLECULE IS FORMED FROM DEFINITE KINDS AND NUMBERS OF ATOMS

PARTICLES OF MATTER HAVE MASS AND OCCUPY SPACE

Transparency No. 37

THERE IS NO CHANGE IN

THE MASS OF THE ATOMS

OF AN ELEMENT WHEN

THE TEMPERATURE OR

PHASE CHANGES

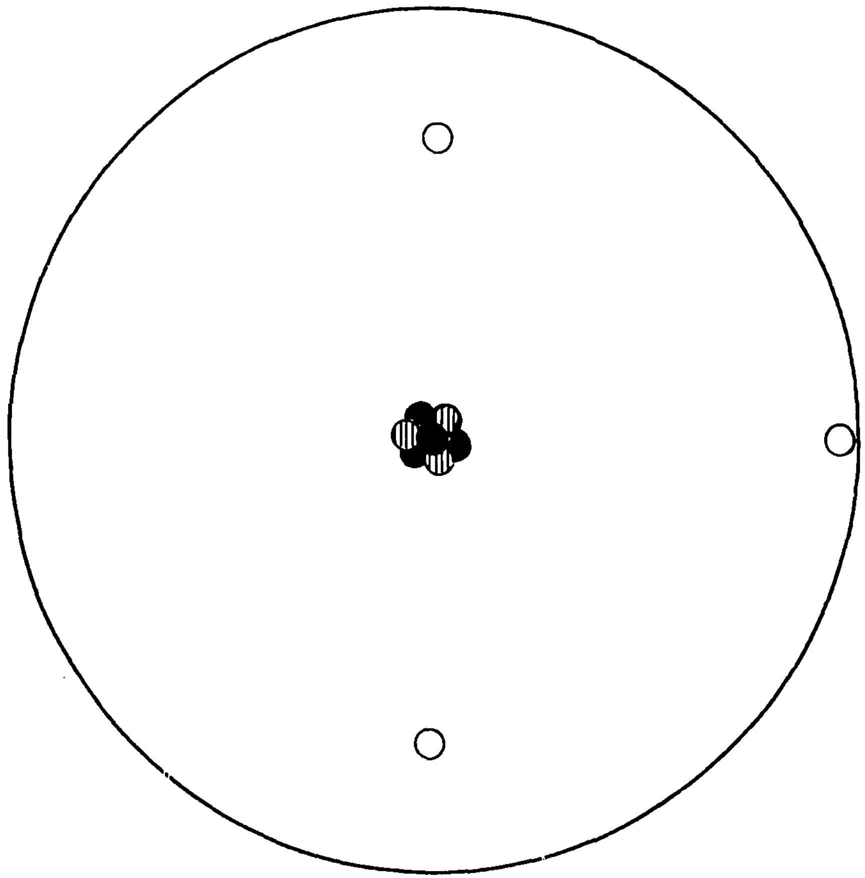
THE AVERAGE SIZE AND

MASS OF THE ATOMS

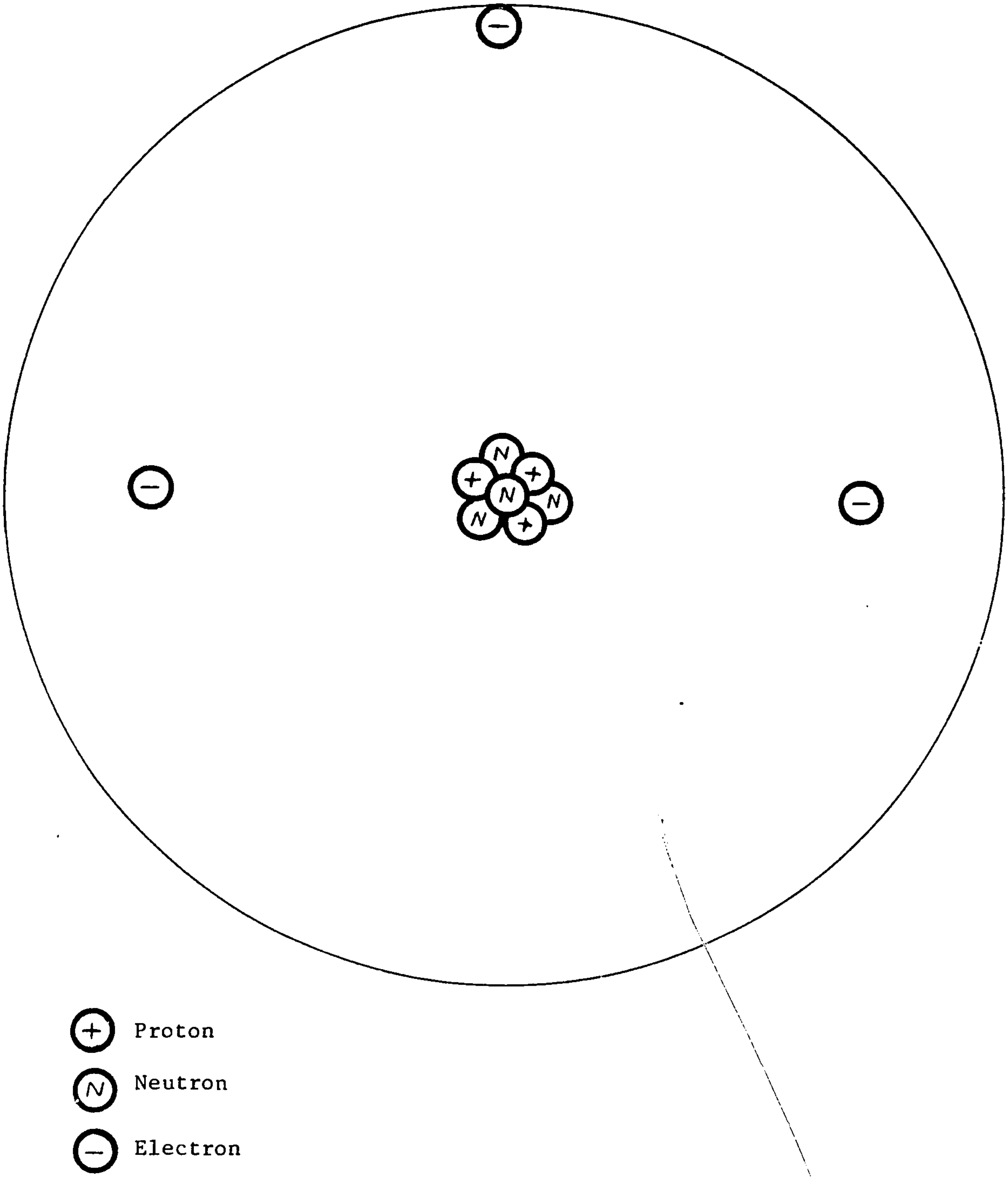
OF EACH ELEMENT

DO NOT VARY

ATOMS ARE MADE UP OF PARTICLES: PROTONS, NEUTRONS, AND ELECTRONS



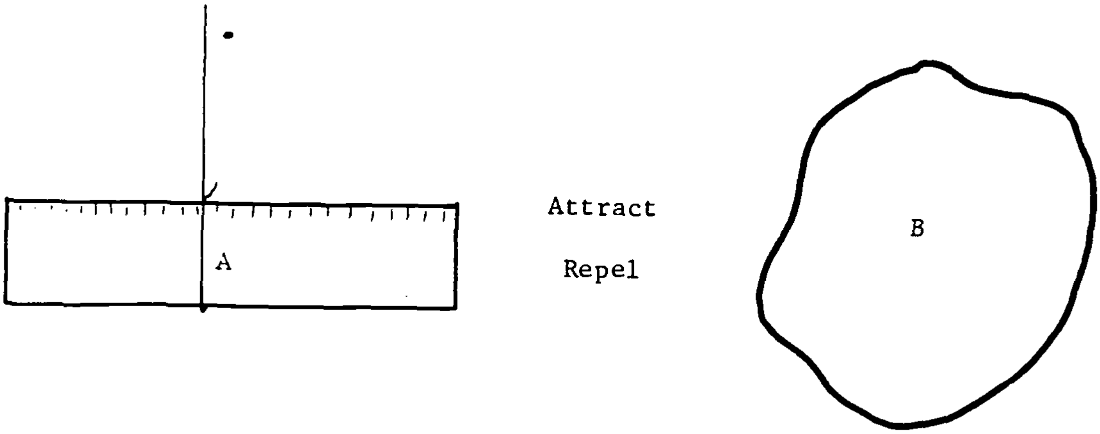
Transparency No. 40



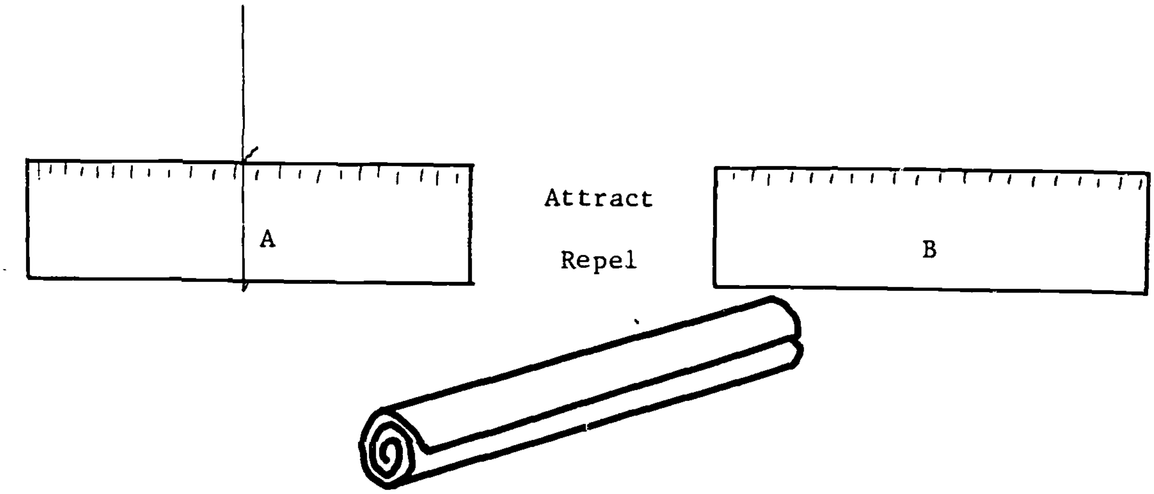
EXERCISE SHEET

In each case, if the felt cloth were rubbed on the plastic ruler indicate the electrical charge on "A" and "B" and indicate if they would <u>attract</u> or <u>repel</u> by circling the answer you think is correct.

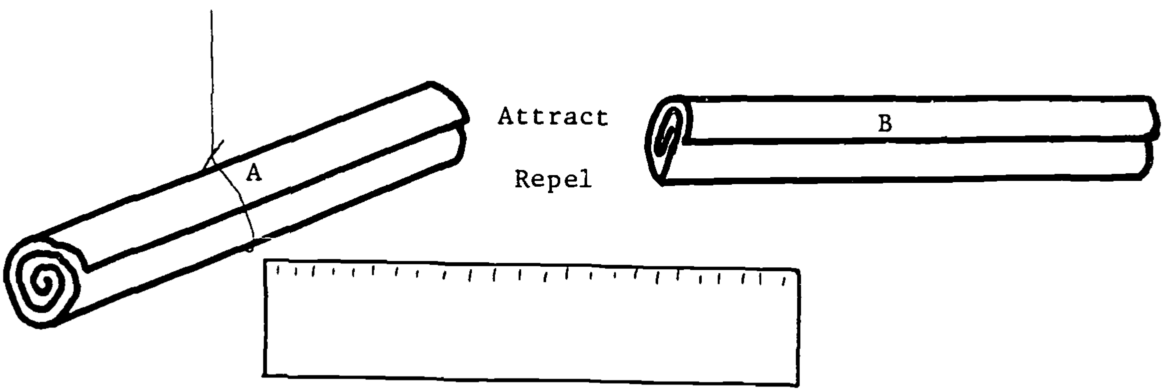
1.



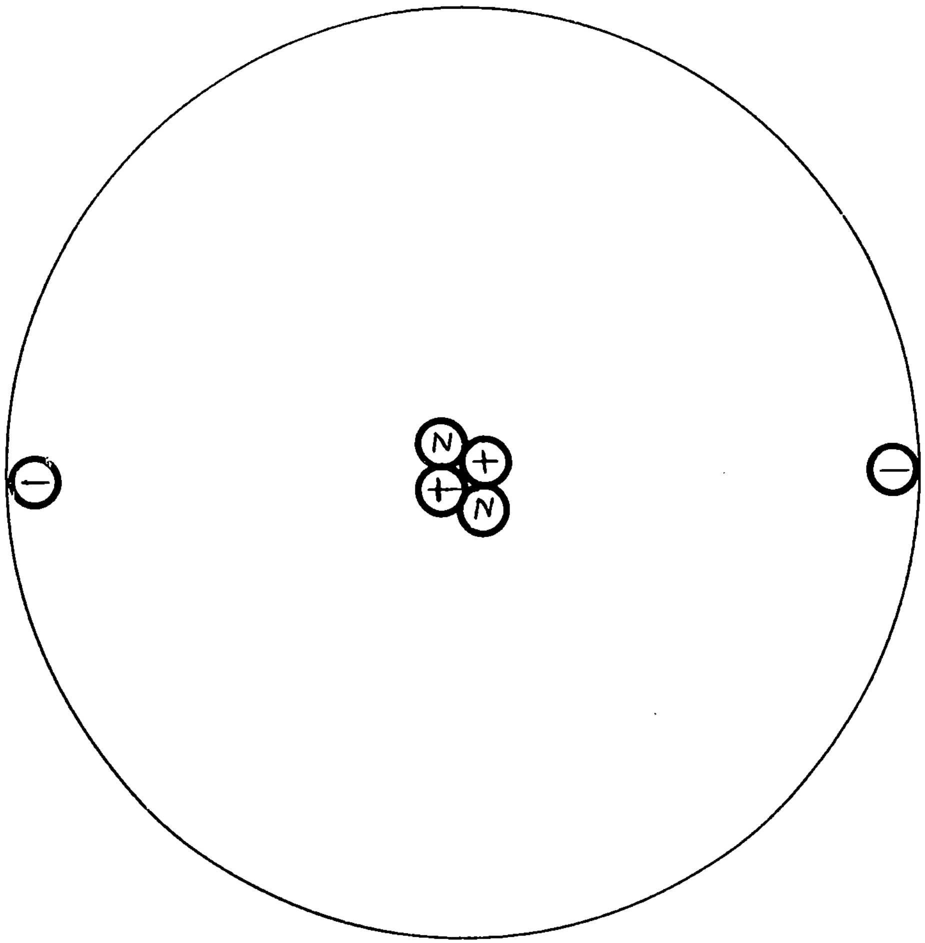
2.



3.

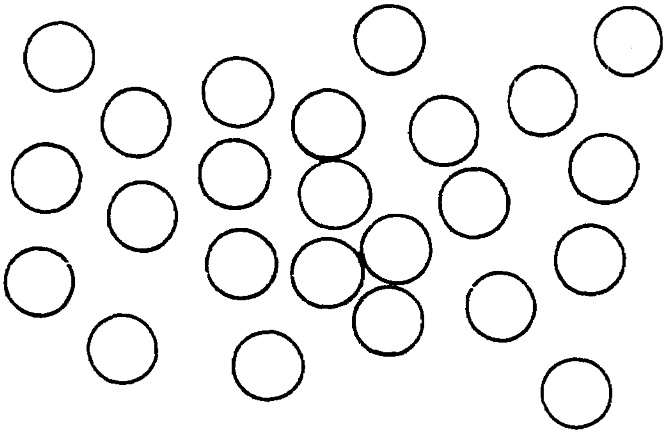


ELECTRIC CHARGES ARE ASSOCIATED WITH THE PARTICLES OF MATTER



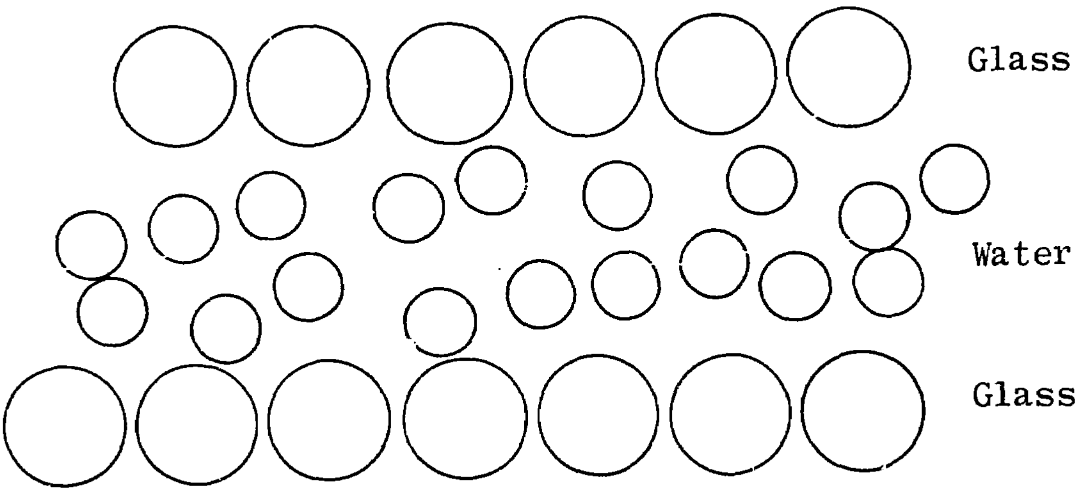
EXERCISE SHEET

I.



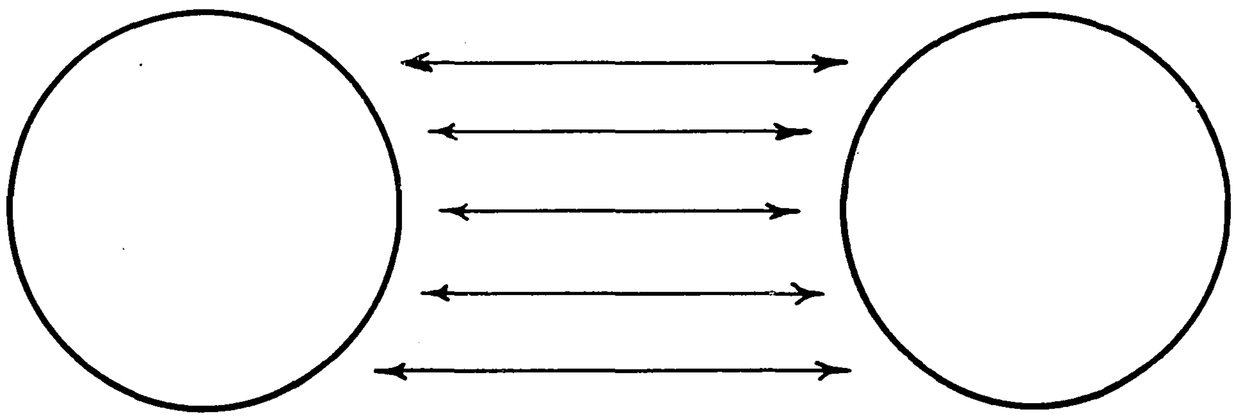
Cohesion of Water

II.

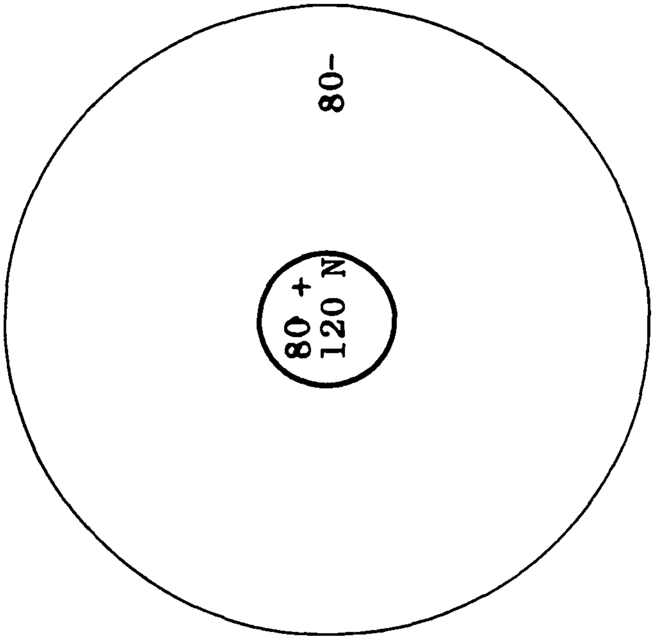


Adhesion of Water and Glass

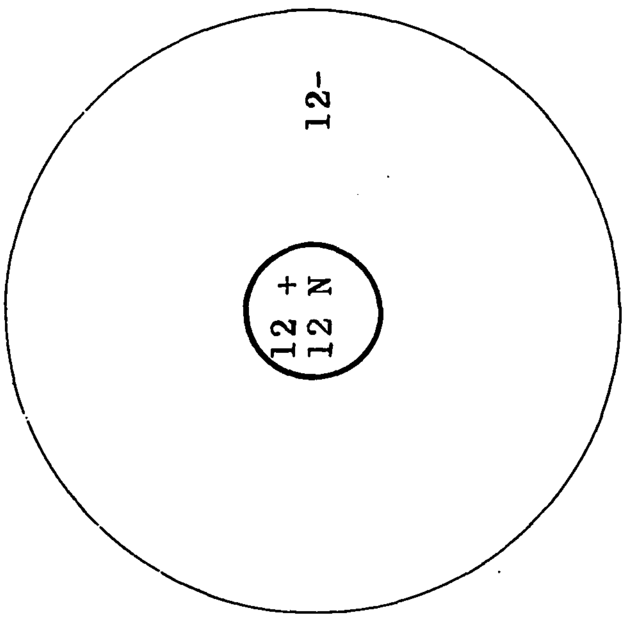
PARTICLES OF MATTER ATTRACT EACH OTHER



Transparency No. 45



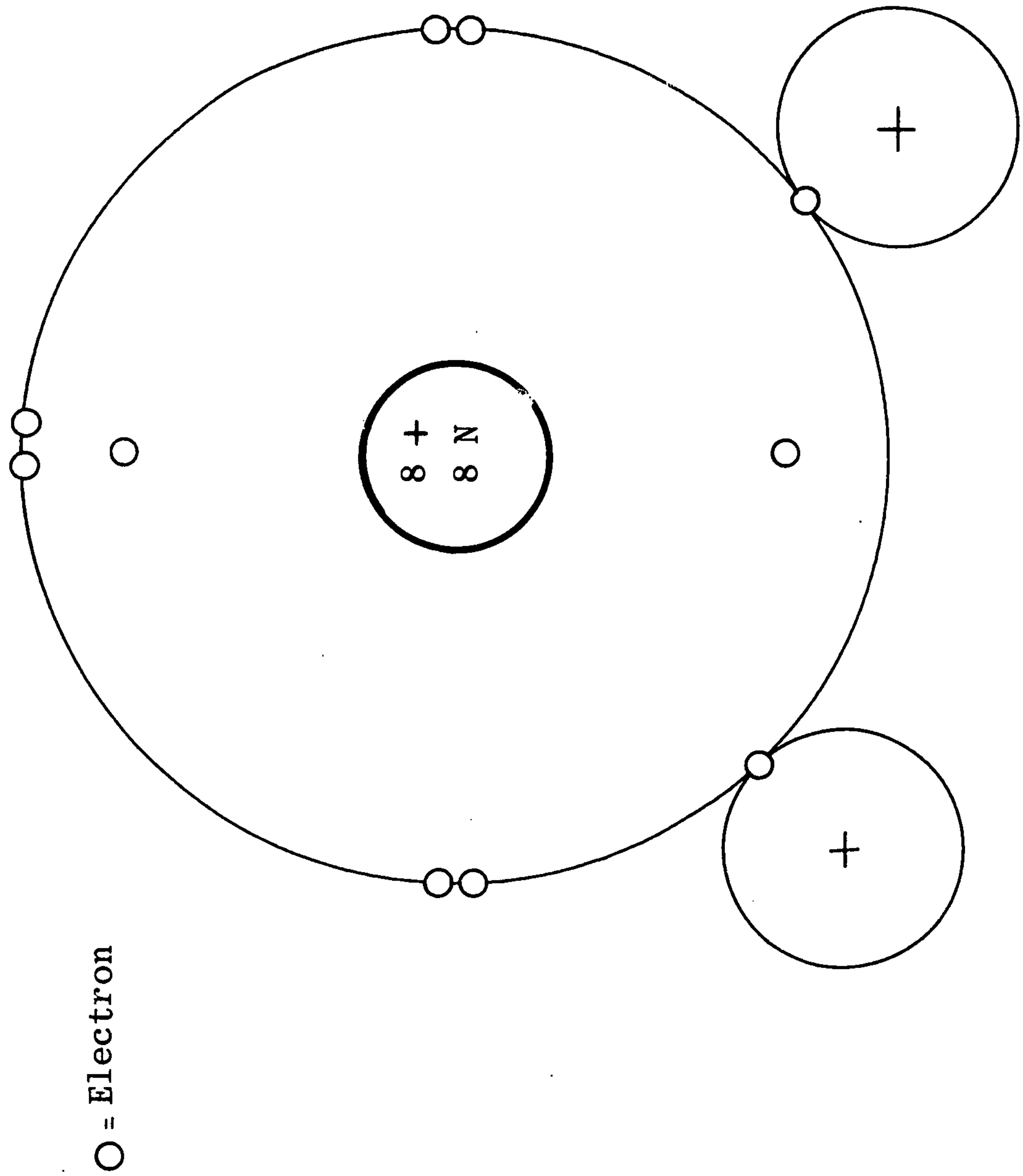
Mercury



Magnesium

THE MASS OF AN ATOM
IS DETERMINED BY THE
NUMBER AND KINDS OF
PARTICLES THAT IT
CONTAINS

ALL ATOMS OF A GIVEN ELEMENT ARE MADE UP OF EQUAL NUMBERS OF ELECTRONS AND PROTONS

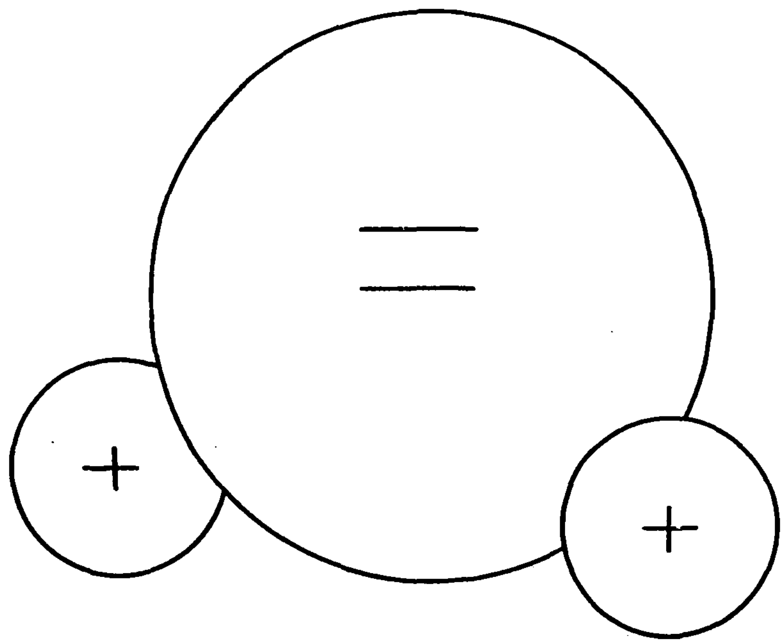


Model for a Water Molecule

MOLECULES ARE MADE UP OF ATOMS

THAT ARE HELD TOGETHER BY

ELECTRICAL FORCES



1. All matter is made up of particles.

2. Particles of matter have spaces between them.

3. Particles of matter are very small.

4. Particles of matter are in motion.

5. Particles of matter move faster when the matter is heated.

6. Particles of matter usually move farther apart when the matter is heated.

7. In the solid state, the particles of matter are packed together in a pattern and move within a small space.

8. In the liquid state, the particles of matter are loosely clustered together and move about.

9. In the gas state, the particles of matter are far apart and move freely.

10. The state of matter can be changed from solid to liquid and from liquid to solid.

11. The state of matter can be changed from liquid to gas and from gas to liquid.

12. The push against the surface by a gas depends upon the number and rate of motion of particles of the gas.

13. Some particles of matter (molecules) are made up of simpler particles (atoms).

14. Some molecules are made up of only one kind of atom (element).

15. Some molecules are made up of two or more kinds of atoms (compounds).

16. Some samples of matter contain more than one kind of molecule (mixtures).

17. Each type of molecule is formed from definite numbers and kinds of atoms.

18. Particles of matter have mass and occupy space.

19. The average size and mass of the atoms of each element do not vary.

20. Atoms are made up of particles: protons, neutrons, and electrons.

21. Electric charges are associated with the particles of matter.

22. The particles of matter attract each other.

23. The mass of an atom is determined by the number and kind of particles that it contains.

24. All atoms of a given element are made up of the same number of electrons and protons.

25. Molecules are made up of atoms that are held together by electrical forces.

IV
Tests

The evaluation instruments are in the form of motion picture films with each test item identified in terms of the associated concept. The administration and assessment of the results of the test are simple in that the number answered in an acceptable manner per concept is the important indicator. The key and concept identification are included for your reference.

The orientation of the concepts and the teaching strategy employed in this unit placed very little emphasis on reading as a tool for learning. Consistent with this idea, the development of the evaluation procedures employed also minimized reading. Basic to the plan to minimize reading in this unit was the belief that the conceptual background development possibilities of an individual are not limited to the reading level of the individual; the conceptual level of the individual may exceed his technical reading vocabulary. The evaluation instruments developed for this unit of study, therefore, had to meet the criterion of "demanding minimal reading skills and vocabulary."

Item Criteria

All items used in the tests were expected to satisfy at least six of the eight criteria that follow:

1. The item is concerned with the selected concept. (Each item must be specific to a given concept.)

2. The proportion of the population selecting the accepted response when the instrument was administered following instruction is greater than 0.50, the level attributable to random guessing.

3. The proportion of the population selecting the accepted response to each item is greater when the instrument is administered as a posttest than when it is administered as a pretest.

4. The proportion of the instructed population is greater than the proportion of the noninstructed population choosing the accepted response to each item when the instrument is administered as a posttest.

5. The proportion of the instructed population at each class level selecting the accepted response to each item increases progressively with grade level when the instrument is administered as a posttest.

6. The items are not of extreme difficulty when included as a posttest for the instructed population ($-2\sigma \leq X_{50} \leq +2\sigma$).

7. The items are positive discriminators when included as a posttest for the instructed population ($\beta \leq +0.30$).

8. The items are usable with groups in a classroom.

In addition to minimal reading the following characterize the evaluation instruments:

1. The items are stated in an objective form.

2. There are five individual items related to each concept.

3. Each test item involves a natural phenomenon and the theoretical concept

useful in explaining the phenomenon.

4. All items are in the media of colored still or motion pictures and sketches.

5. Written captions are included so the teacher may read them to the pupils.

6. The five items related to an individual concept in a given test are sequenced at random.

7. Sample items are included to serve in giving directions to the pupils.

8. The total evaluation instrument consists of five parts and five items per concept: 1. Concepts 1-6, 2. Concepts 7-11, 3. Concepts 12-16, 4. Concepts 17-21, and 5. Concepts 22-25.

9. The pupils indicate their responses on separate answer sheets.

The Test

The items included in each of the five test parts are indicated for your information. It is impossible to show the several colors used to avoid the development of student clues and for you to observe the motion; however, each sketch includes shading and an indication that the sketch is dynamic or static.

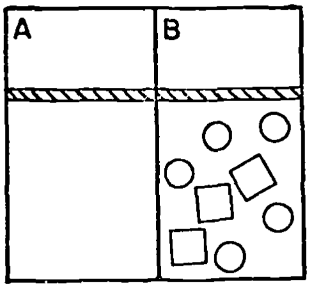
The five items related to each concept and the position of each item relative to other items are indicated. For example, Test Part C includes Concepts 1-6 and item C-5 is the fifth item on the test, Test Part M includes Concepts 7-11 and M-15 is the 15th item on the test, Test Part S includes Concepts 12-16, Test Part U includes Concepts 17-21, and Test Part X includes Concepts 22-25.

GPO 828-145-13

CONCEPT NO. 1: All matter is made up of particles.

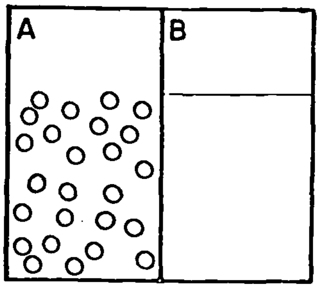
Which model is more useful for explaining the make-up of air?

C-1



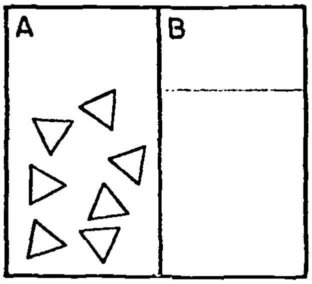
Which model is more useful for explaining the make-up of oil?

C-4



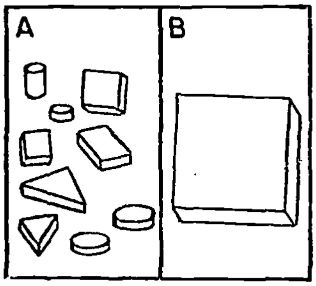
Which model is more useful for explaining the make-up of water?

C-12



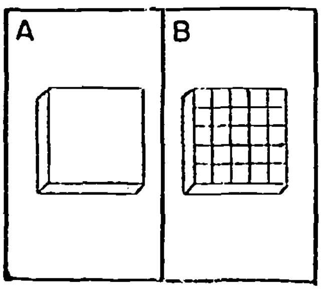
Which model is more useful for explaining the make-up of the blackboard?

C-20



Which model is more useful for explaining the make-up of iron?

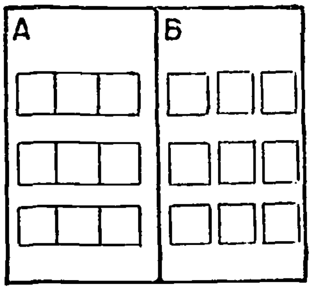
C-26



CONCEPT NO. 2: Particles of matter have spaces between them.

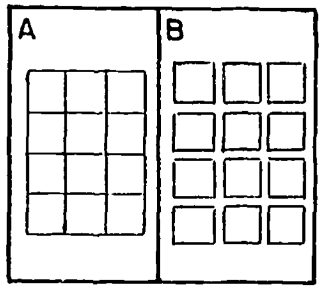
Which model of water is more useful in explaining that water can dissolve sugar?

C-2



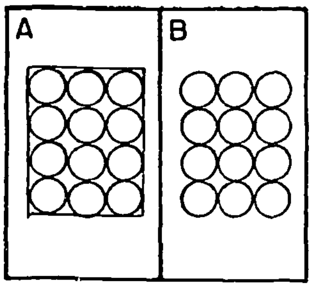
Which model is more useful in explaining the make-up of iron?

C-7



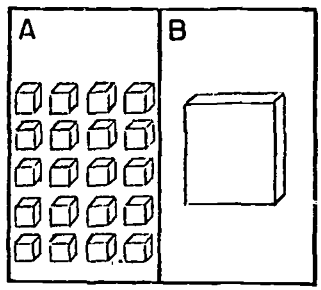
Which model of water is more useful in explaining that water can dissolve ink?

C-11



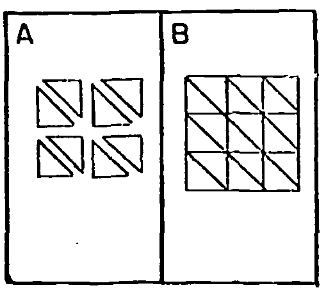
Which model of water is more useful in explaining that water can dissolve salt?

C-16



Which model is more useful in explaining the make-up of water?

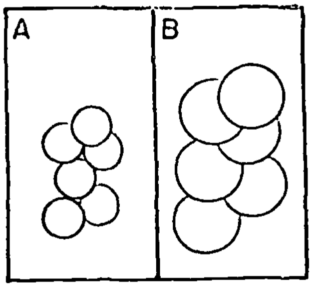
C-27



CONCEPT NO. 3: Particles of matter are very small.

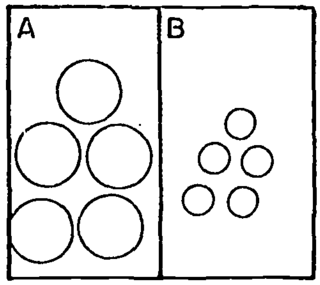
Which model of perfume is more useful for explaining the fact that you can smell perfume in the air but you cannot see it?

C-5



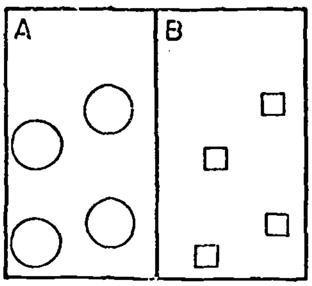
Sugar that is dissolved cannot be seen. Which model of sugar is more useful in explaining this?

C-17



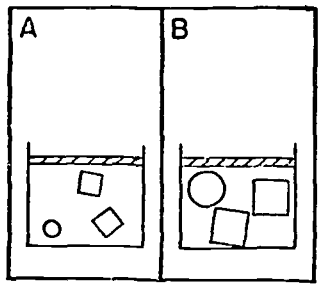
Which model is more useful for explaining the fact that you cannot see the particles of water even with the aid of a microscope?

C-19



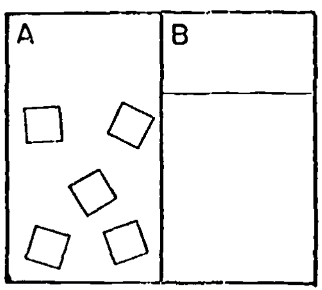
Which model is more useful in explaining the make-up of air?

C-23



Which model is more useful in explaining the make-up of water?

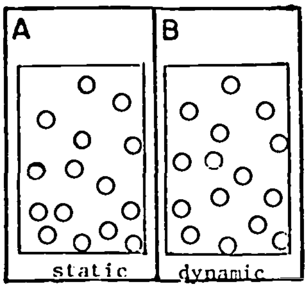
C-30



CONCEPT NO. 4: Particles of matter are in motion.

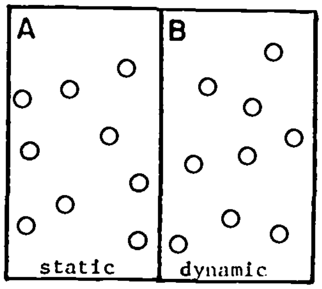
Which model is more useful for explaining how an odor spreads throughout an entire room?

C-9



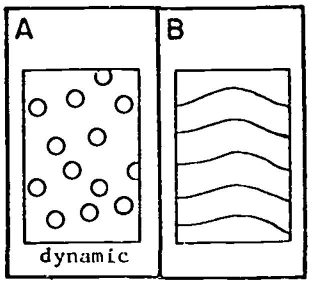
Which model is more useful in explaining the make-up of air?

C-14



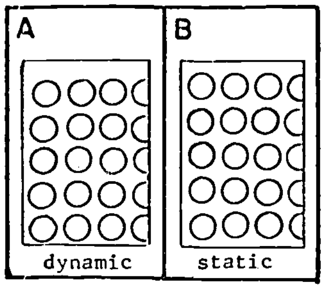
Which model of water is more useful for explaining how sugar seems to disappear when placed in water?

C-21



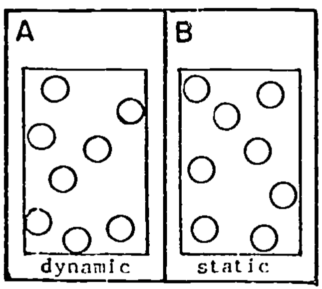
Which model is more useful for explaining that dry ice seems to disappear?

C-25



Which model of water is more useful for explaining how ink spreads out in water?

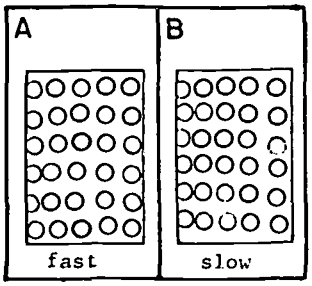
C-29



CONCEPT NO. 5: Particles of matter move faster when the matter is heated.

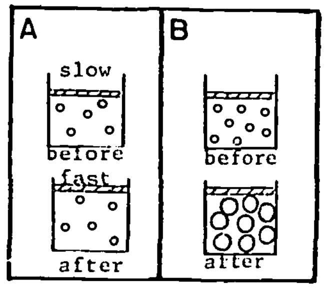
Which model is more useful in explaining matter at a higher temperature?

C-8



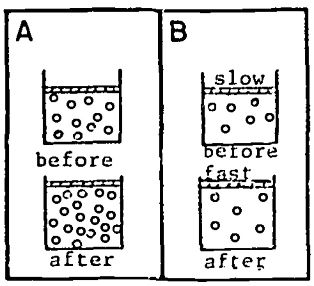
Which model is more useful in explaining what happens to matter when it is heated?

C-15



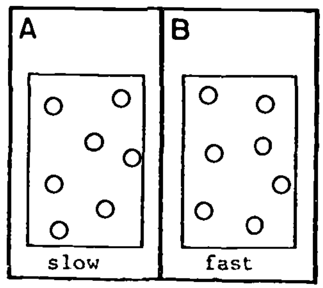
Which model is more useful in explaining what happens to matter when it is heated?

C-18



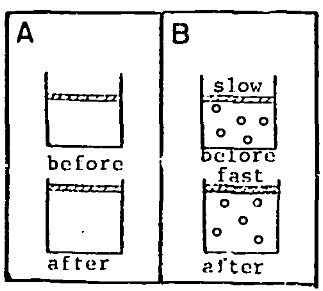
Which model is more useful in explaining matter at a lower temperature?

C-22



Which model is more useful in explaining what happens to matter when it is heated?

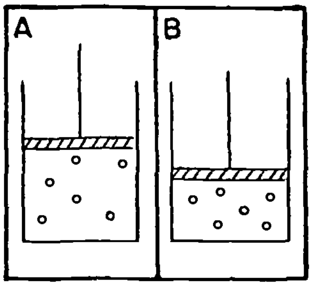
C-24



CONCEPT NO. 6: Particles of matter usually move farther apart when the matter is heated.

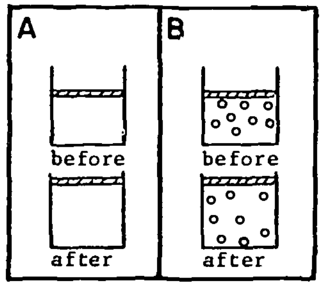
Which model is more useful in explaining matter at a higher temperature?

C-3



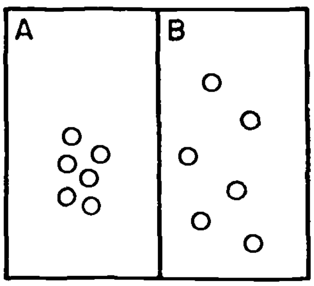
Which model is more useful in explaining what happens to matter when it is heated?

C-6



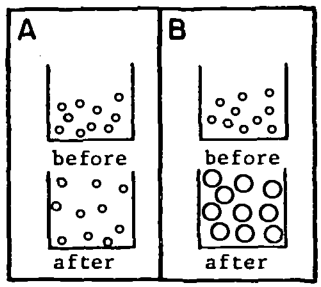
Which model is more useful in explaining matter at a lower temperature?

C-10



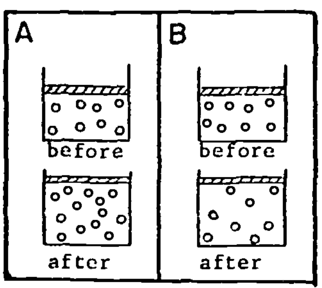
Which model is more useful in explaining what happens to matter when it is heated?

C-13



Which model is more useful in explaining what happens to matter when it is heated?

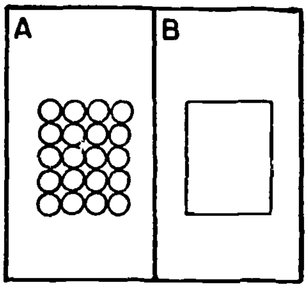
C-28



CONCEPT NO. 7: In the solid state, the particles of matter are packed together in a pattern and move within a small space.

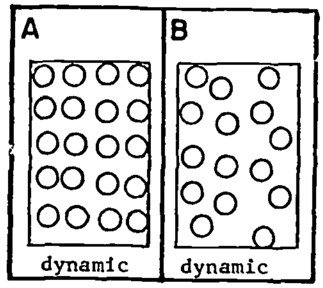
Which model is more useful in explaining the make-up of solids?

M-1



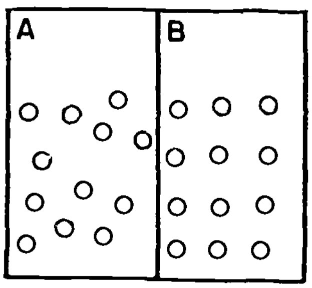
Which model is more useful in explaining that solids keep their shape?

M-6



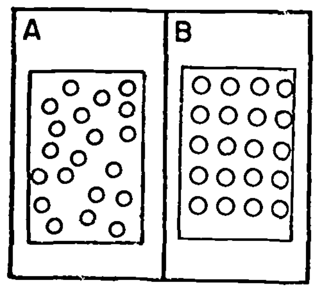
Which model is more useful in explaining that solids keep their shape?

M-10



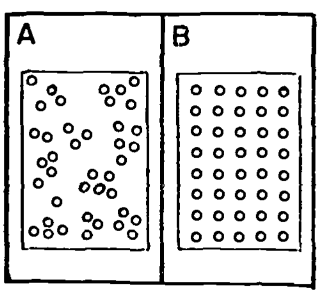
Which model is more useful for explaining that solids keep their shape?

M-12



Which model is more useful in explaining the make-up of solids?

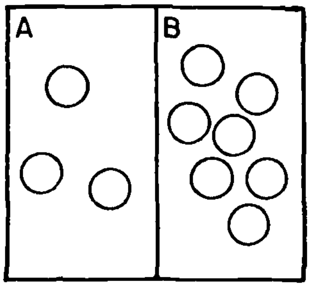
M-17



CONCEPT NO. 8: In the liquid state, the particles of matter are loosely clustered together and move about.

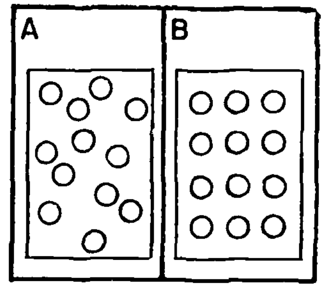
Which model is more useful in explaining the make-up of liquids?

M-2



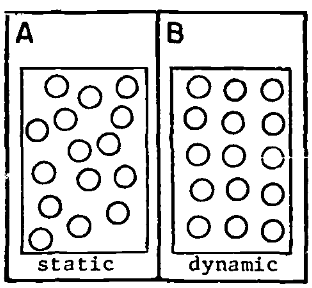
Which model of liquids is more useful in explaining that liquids have no definite shape?

M-8



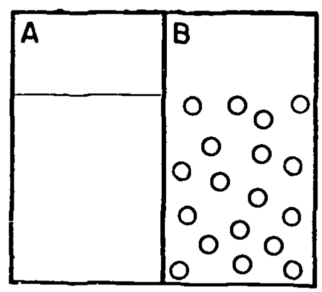
Which model is more useful in explaining the make-up of liquids?

M-13



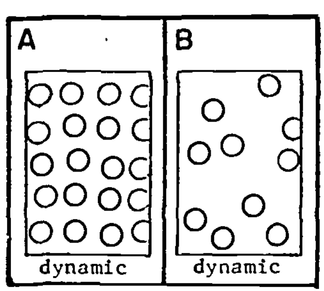
Which model of a liquid is more useful in explaining that liquids take the shape of their container?

M-19



Which model is more useful in explaining that liquids flow?

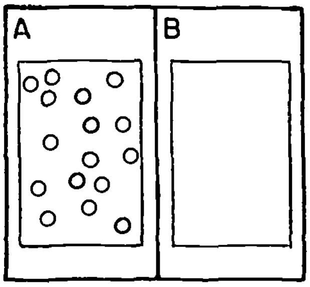
M-22



CONCEPT NO. 9: In the gas state, the particles of matter are far apart and move freely.

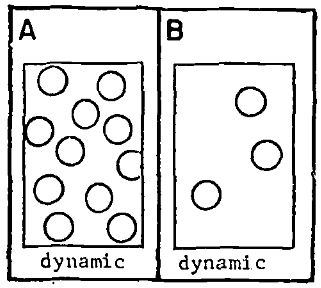
Which model is more useful in explaining that gases expand and fill any container?

M-4



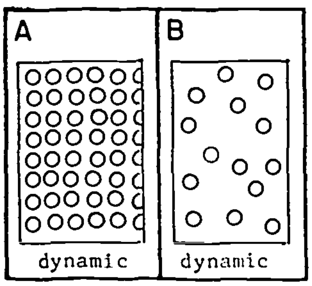
Which model is more useful in explaining that gases can be compressed?

M-7



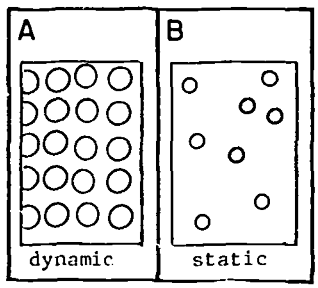
Which model is more useful in explaining that gases have no definite shape?

M-15



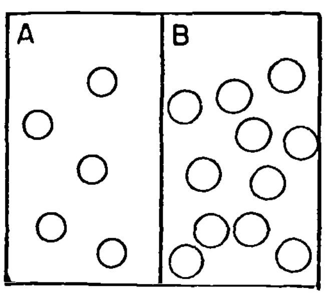
Which model is more useful in explaining that gases mix easily with each other?

M-21



Which model is more useful in explaining the make-up of gases?

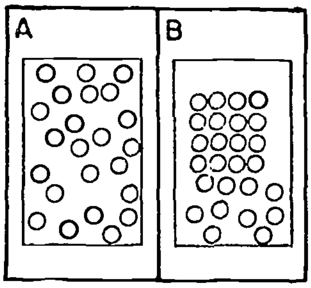
M-24



CONCEPT NO. 10: The state of matter can be changed from solid to liquid and from liquid to solid.

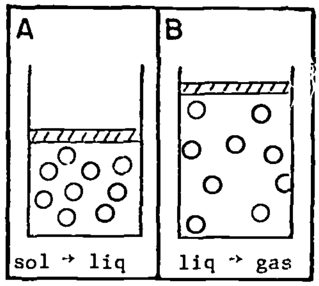
Which model is more useful in explaining melting?

M-5



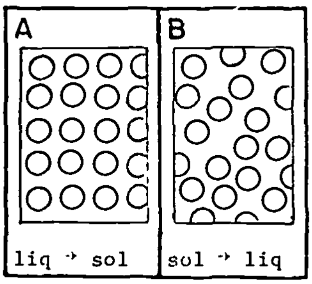
Which model is more useful in explaining melting?

M-14



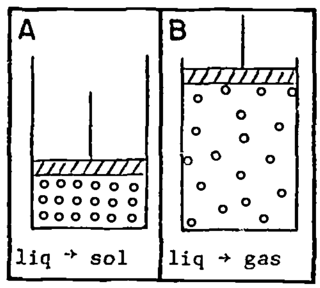
Which model is more useful in explaining what happens when a liquid is cooled until it freezes?

M-16



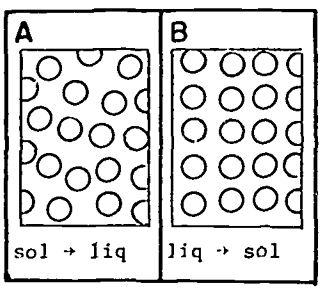
Which model is more useful in explaining freezing?

M-23



Which model is more useful in explaining what happens when matter changes from a solid to a liquid?

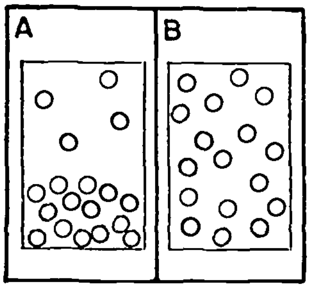
M-25



CONCEPT NO. 11: The state of matter can be changed from liquid to gas and from gas to liquid.

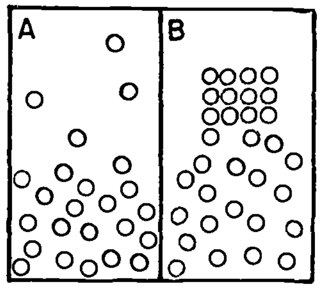
Which model is more useful in explaining boiling?

M-3



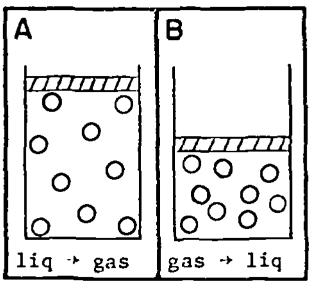
Which model is more useful in explaining a liquid changing to a gas?

M-9



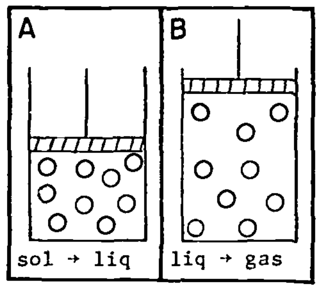
Which model is more useful in explaining a gas changing to a liquid?

M-11



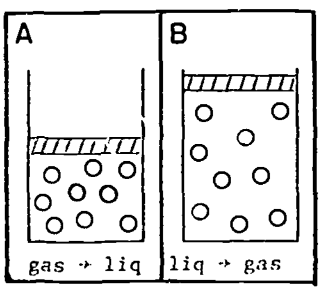
Which model is more useful in explaining what happens after a liquid is heated until it becomes a gas?

M-18



Which model is more useful in explaining what happens when a gas is cooled until it becomes a liquid?

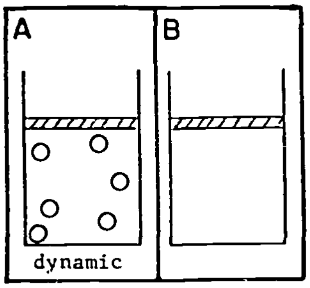
M-20



CONCEPT NO. 12: The push against the surface by a gas depends upon the number and rate of motion of particles of the gas.

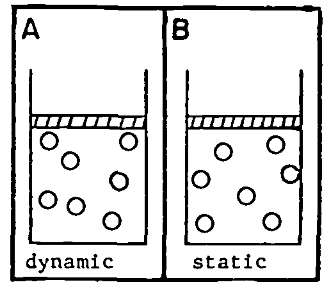
Which model is more useful in explaining how a gas pushes on its container?

S-1



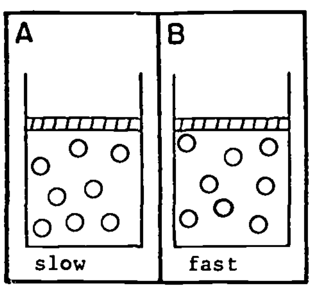
Which model is more useful in explaining how a gas pushes on its container?

S-6



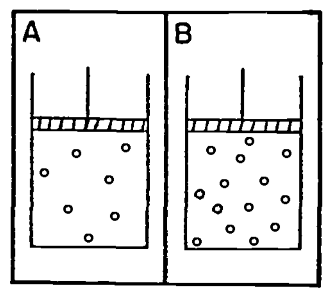
In which model is the gas pushing the hardest on the inside of the container?

S-10



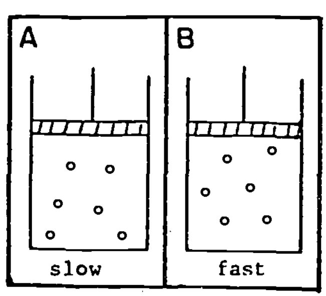
In which model is the gas pushing the hardest on the inside of the container?

S-20



In which model is the gas pushing the hardest on the inside of the container?

S-22



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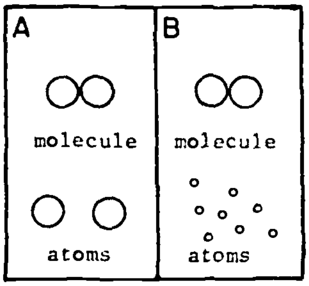
CONCEPT NO. 13: Some particles of matter (molecules) are made up of simpler particles (atoms).

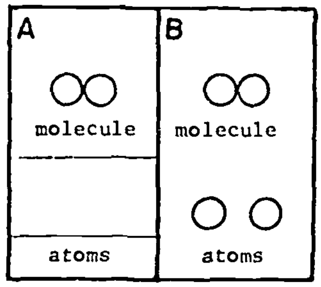
Which model is more useful in explaining the difference between a hydrogen molecule and hydrogen atoms?

S-5



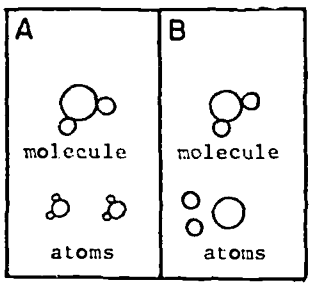
Which model is more useful in explaining the differences between a nitrogen molecule and nitrogen atoms?

S-8



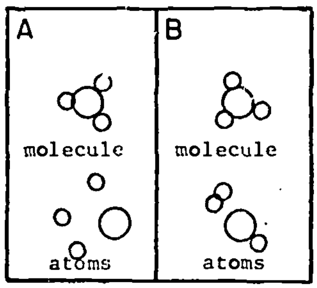
Which model is more useful in explaining the differences between the atoms that make up the water molecules and the water molecules?

S-12



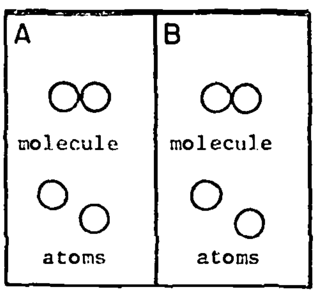
Which model is more useful in explaining the differences between the atoms that make up ammonia molecules and the ammonia molecules?

S-19



Which model is more useful in explaining the differences between the atoms that make up carbon monoxide molecules and the carbon monoxide molecules?

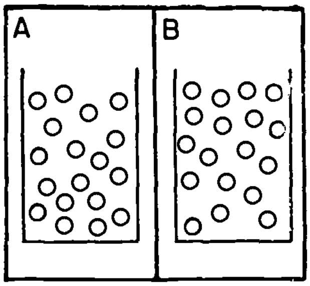
S-23



CONCEPT NO. 14: Some molecules are made up of only one kind of atom (element).

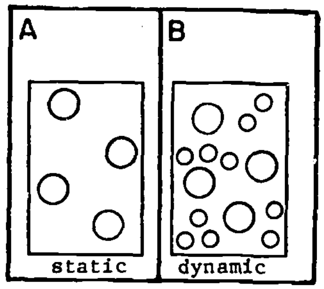
Which model is more useful in explaining the make-up of the element mercury?

S-2



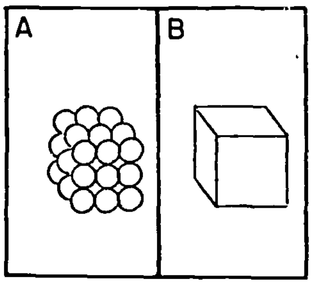
Neon is an element. Which model is more useful in explaining the make-up of the neon molecules?

S-9



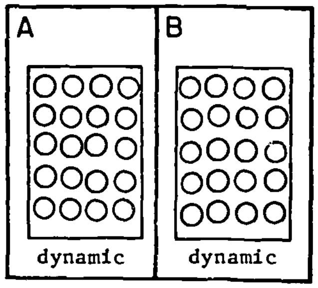
Which model is the more useful in explaining the make-up of the element silver?

S-14



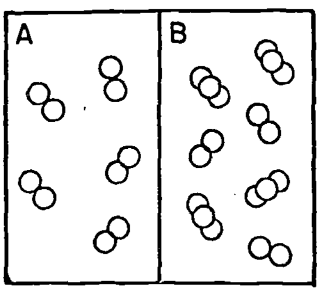
Which model is more useful in explaining the make-up of the element gold?

S-17



Oxygen is an element. Which model is more useful in explaining the make-up of oxygen molecules?

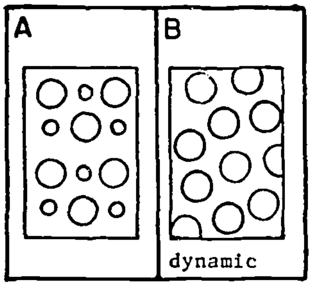
S-25



CONCEPT NO. 15: Some molecules are made up of two or more kinds of atoms (compounds).

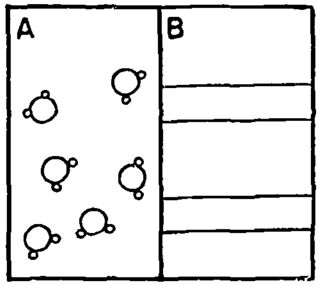
Which model is more useful in explaining the make-up of table salt? (NaCl)

S-3



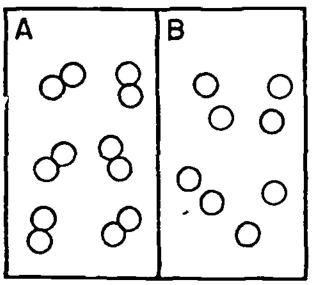
Which model is more useful in explaining the make-up of water? (H_2O)

S-7



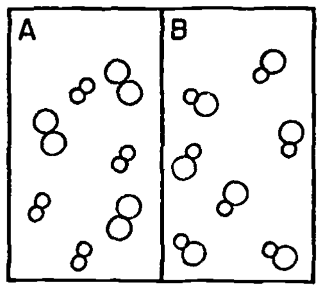
Which model is more useful in explaining the make-up of carbon monoxide? (CO)

S-13



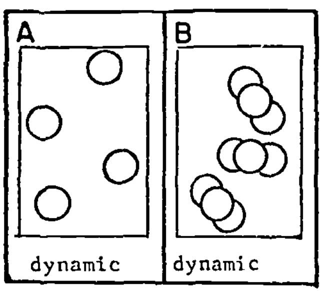
Which model is more useful in explaining the make-up of hydrogen chloride molecules? (HCl)

S-15



Which model is more useful in explaining the make-up of carbon dioxide? (CO_2)

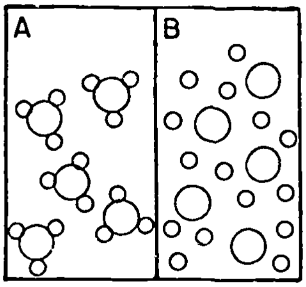
S-18



CONCEPT NO. 16: Some samples of matter contain more than one kind of molecule (mixtures).

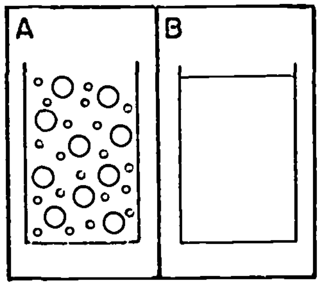
Which model is more useful in explaining the make-up of a mixture of water and air?

S-4



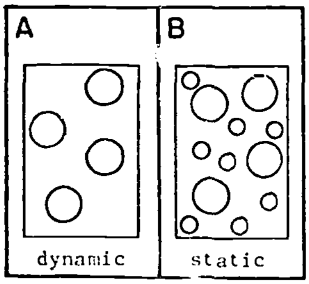
Which model is more useful in explaining the make-up of a mixture of sugar and tea?

S-11



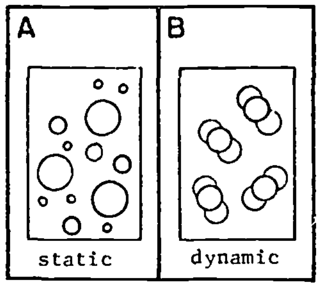
Which model is more useful in explaining the make-up of a mixture of salt and water?

S-16



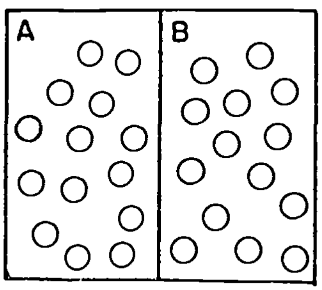
Which model is more useful in explaining the make-up of a mixture of perfume and air?

S-21



Which model is more useful in explaining the make-up of ink in water?

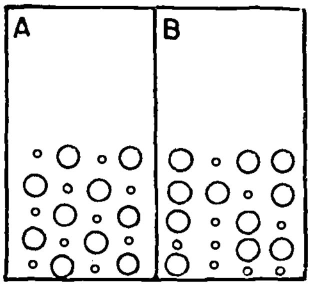
S-24



CONCEPT NO. 17: Each type of molecule is formed from definite numbers and kinds of atoms.

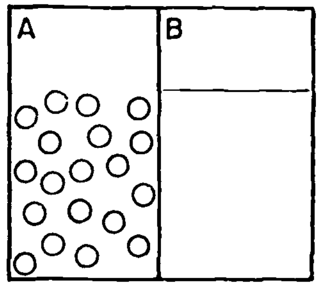
Salt is a compound.
Which model better describes the scientist's idea of the nature of salt?

U-3



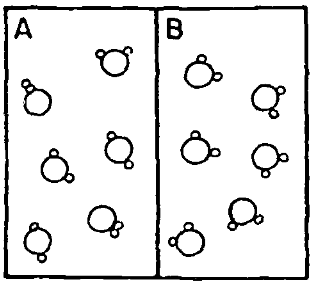
Mercury is an element.
Which model better describes the scientist's idea of the nature of mercury molecules?

U-5



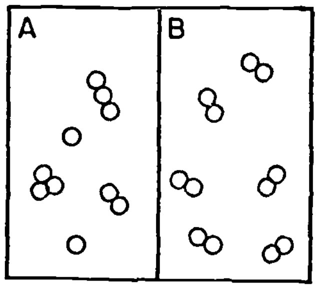
Water is a compound.
Which model better describes the scientist's idea of the nature of water molecules?

U-13



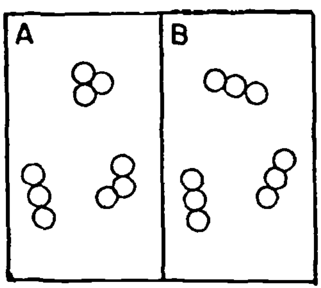
Oxygen is an element.
Which model better describes the scientist's idea of the nature of oxygen molecules?

U-19



Carbon dioxide is a compound.
Which model better describes the scientist's idea of the nature of carbon dioxide molecules?

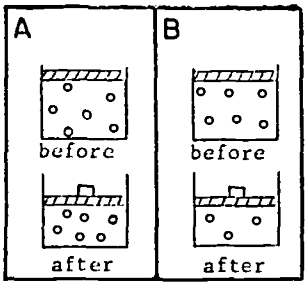
U-24



CONCEPT NO. 18: Particles of matter have mass and occupy space.

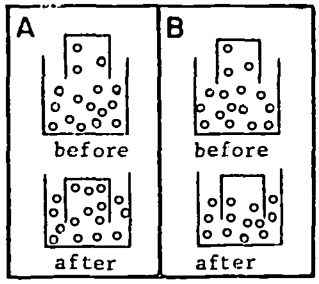
A sample of gas is compressed by adding weights to the piston. Which model is more useful in explaining what happens?

U-4



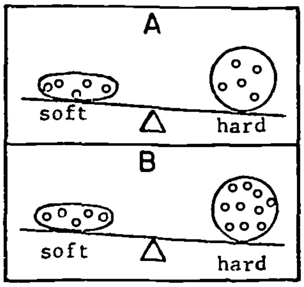
Which model is more useful in explaining what happens when a glass full of air is lowered open end down into the water?

U-8



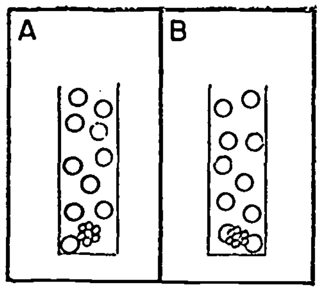
Which is more useful in explaining the difference in mass between the balloons?

U-10



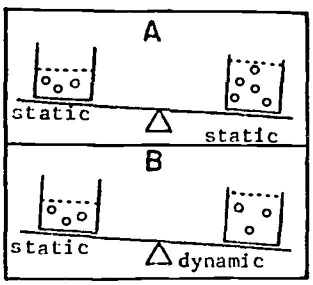
When a steel ball is dropped into a glass of water, the level of the water rises. Which model is more useful in explaining what happens?

U-21



Which model is more useful in explaining the difference in mass?

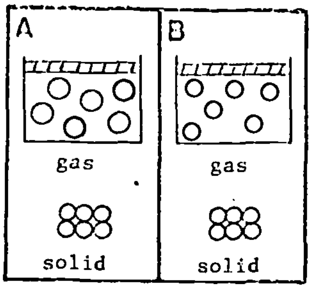
U-23



CONCEPT NO. 19: The average size and mass of the atoms of each element do not vary.

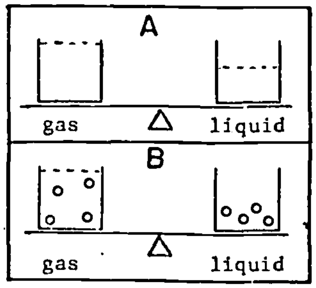
Dry ice changes from a solid to a gas. Which model is more useful in explaining this increase in volume?

U-2



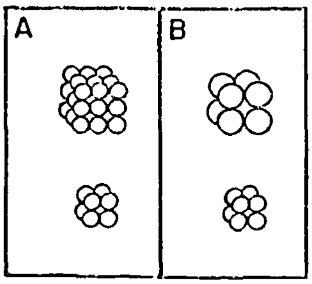
Which model is more useful in explaining how a substance occupies different volumes when in the gas or liquid states?

U-12



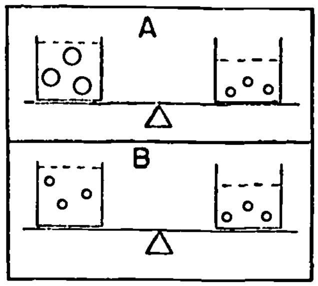
A block of iron is larger in size and mass than another block of iron. Which model is more useful in explaining how this is possible?

U-14



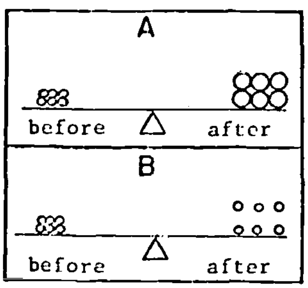
Which model is more useful in explaining that two samples of the same gas can have the same mass, yet different volumes?

U-16



Which model is more useful in explaining the change in volume without a change in mass?

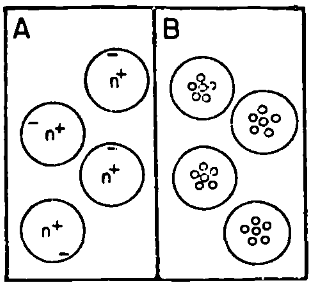
U-18



CONCEPT NO. 20: Atoms are made up of particles: protons, neutrons, and electrons.

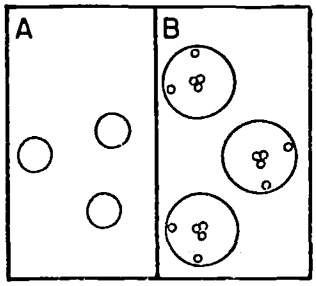
Which model is more useful in explaining the make-up of atoms?

U-1



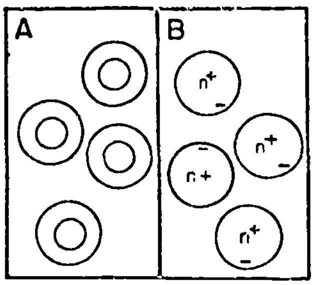
Which model is more useful in explaining the make-up of atoms?

U-6



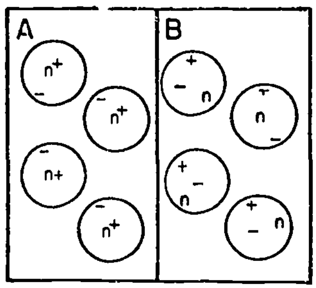
Which model is more useful in explaining the make-up of atoms?

U-9



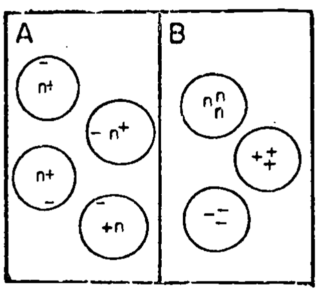
Which model is more useful in explaining the make-up of atoms?

U-15



Which model is more useful in explaining the make-up of atoms?

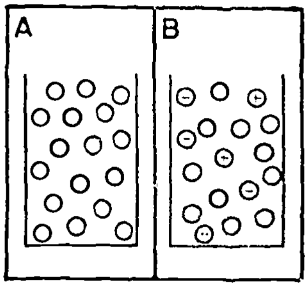
U-20



CONCEPT NO. 21: Electric charges are associated with the particles of matter.

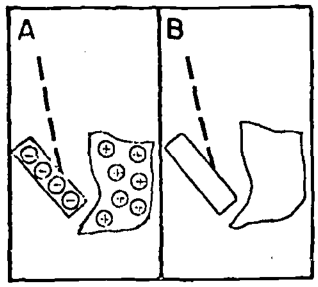
Which model is more useful in explaining why some liquids conduct electricity?

U-7



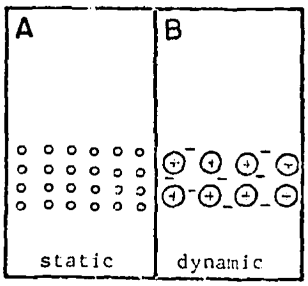
Which model helps us more to explain this?

U-11



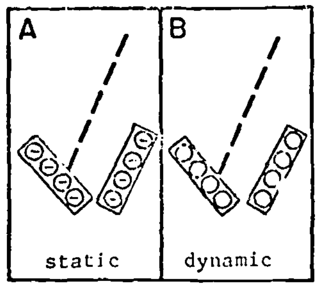
Which model is more useful in explaining why some solids conduct electricity?

U-17



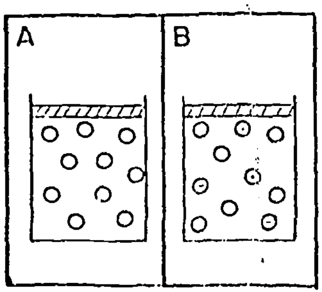
Which model is more useful in explaining what happens?

U-22



Which model is more useful in explaining why some gases conduct electricity?

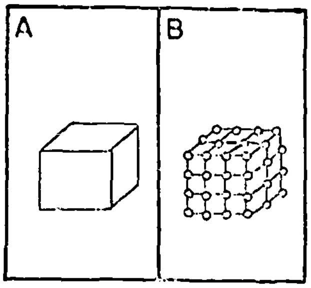
U-25



CONCEPT NO. 22: The particles of matter attract each other.

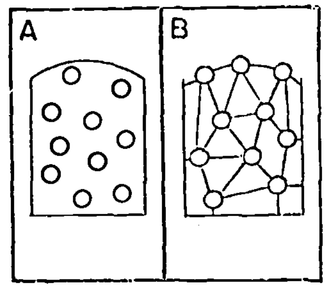
Crystals have regular shapes. Which model is more useful in explaining the make-up of crystals?

X-2



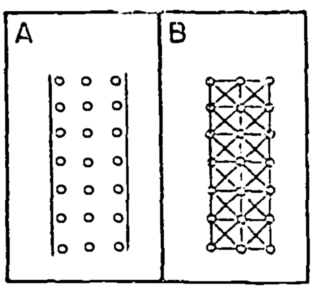
Which model is more useful in explaining how a glass of water may be made to be "heaping full"?

X-6



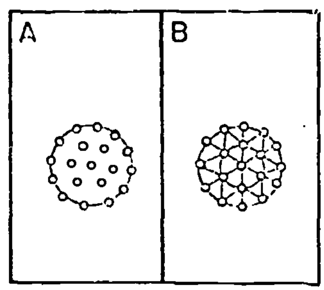
A slim copper wire can hold a weight of many pounds. Which model is more useful in explaining the strength of the wire?

X-12



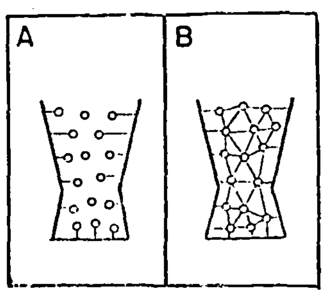
Which model is more useful in explaining how the steel ball keeps its shape?

X-17



Which model of water is more useful in explaining how water takes the shape of the glass?

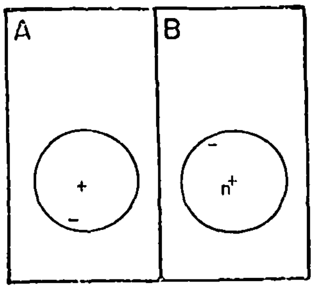
X-19



CONCEPT NO. 23: The mass of an atom is determined by the number and kinds of particles that it contains.

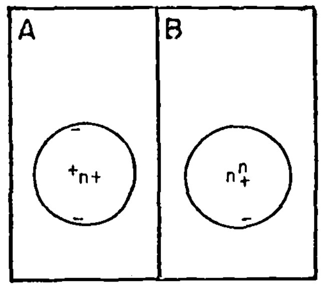
Which model represents the atom with the smaller mass?

X-1



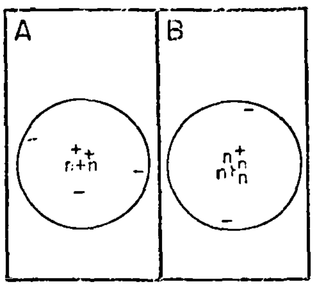
Which model represents the atom with the greater mass?

X-7



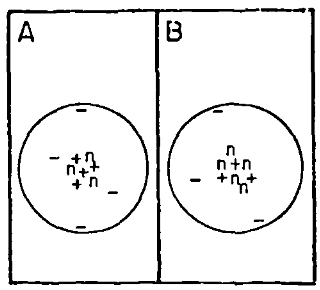
Which model represents the atom with the smaller mass?

X-9



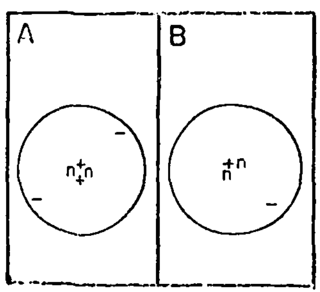
Which model represents the atom with the greater mass?

X-14



Which model represents the atom with the greater mass?

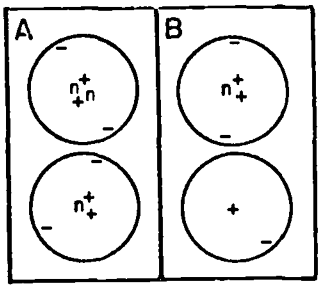
X-18



CONCEPT NO. 24: All atoms of a given element are made up of the same number of electrons and protons.

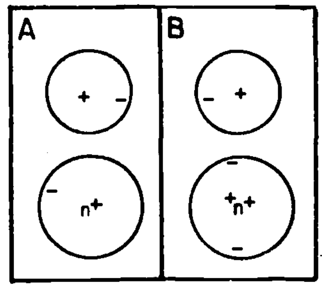
Which of the models represents atoms of the same element?

X-4



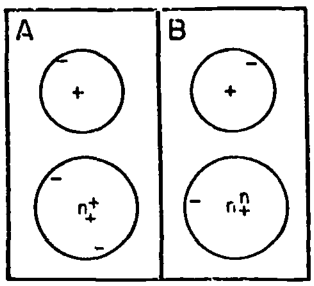
Which of the models represents atoms of the same element?

X-8



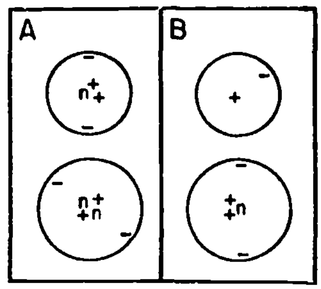
Which of the models represents atoms of the same element?

X-11



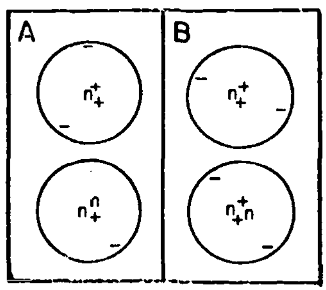
Which of the models represents atoms of the same element?

X-16



Which of the models represents atoms of the same element?

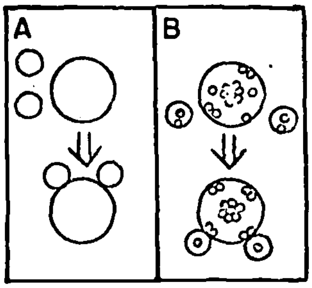
X-20



CONCEPT NO. 25: Molecules are made up of atoms that are held together by electrical forces.

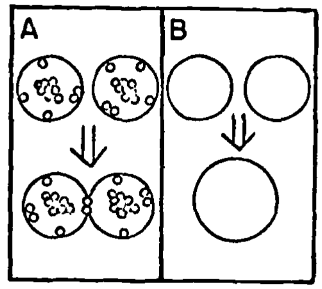
Which model is more useful in explaining the formation of a water molecule?

X-3



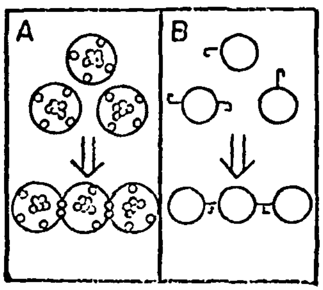
Which model is more useful in explaining the formation of a carbon monoxide molecule?

X-5



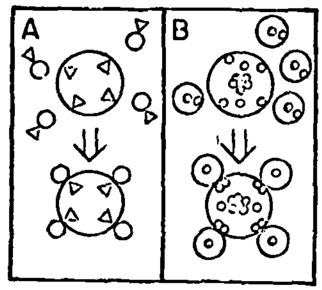
Which model is more useful in explaining the formation of a carbon dioxide molecule?

X-10



Which model is more useful in explaining the formation of a methane molecule?

X-13



Which model is more useful in explaining the formation of a hydrogen molecule?

X-15