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ABSTRACT
This instructional guide, intended for student use, develops the concept of matter through a series of sequential activities. A technical development of the subject is pursued with examples stressing practical aspects of the concepts. Included in the minicourse are: (1) the rationale, (2) terminal behavioral objectives, (3) enabling behavioral objectives, (4) activities, (5) resource packages, and (6) evaluation materials. A series of mini-experiments are described, providing explanations of density and changes of state. This unit is one of twelve intended for use in the second year of a two year vocationally oriented physics program. (CP)

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CAREER ORIENTED PRE-TECHNICAL PHYSICS

Matter: A First Approach

Minicourse

ESEA Title III Project

1974

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This Minicourse is a result of hard work, dedication, and a comprehensive program of testing and improvement by members of the staff, college professors, teachers, and others.

The Minicourse contains classroom activities designed for use in the regular teaching program in the Dallas Independent School District. Through minicourse activities, students work independently with close teacher supervision and aid. This work is a fine example of the excellent efforts for which the Dallas Independent School District is known. May I commend all of those who had a part in designing, testing, and improving this Minicourse.

I commend it to your use.

Sincerely yours,

Nolan Estes

General Superintendent

NE:mag

CAREER ORIENTED PRE-TECHNICAL PHYSICS

MATTER: A FIRST APPROACH

MINICOURSE

<u>RATIONALE (What this minicourse is about)</u>:

How does one explain why ice melts, why water boils, why a pressure cooker can explode, or how jars are vacuum-sealed? Such explanations are based upon a knowledge of certain fundamental properties of matter. Matter, simply speaking, is the "real stuff" the world is made of: chairs, atmosphere, oceans, rocks, and the like.

Here's an answer to the question, How are jars vacuum-sealed? When a jar lid is screwed onto a hot jar, there is a small amount of steam trapped between the lid and the jar's contents. As the jar and its contents cool, the steam condenses to water. This cooling of the fixed volume of atmosphere trapped beneath the lid results in a drop in the pressure of the confined atmosphere. Any decrease in pressure is known as a vacuum. But <u>why</u> does the cooling of a relatively fixed volume of a gas cause a pressure decrease? <u>Why</u>? is always a difficult question; but once you start understanding it, you can answer many other related questions.

To start understanding "why?" a simple approach is to first look closely at the structure of matter. If one can figure out how matter is "put together" (its structure), then one can better understand how matter behaves under various conditions, such as temperature change, volume change, or pressure change.

Interested? That's good, because you are made up of matter, and everything tangible around you is made up of matter. (The only "non-matter" thing in our universe is <u>energy</u>.)

This minicourse consists mostly of laboratory investigations. You might well ask, why mostly laboratory investigations? The answer is because a first step in understanding the properties of matter is to see how matter behaves under different conditions. This may not be as much fun as going to the beach, but (a) you can't spend all of your time at the beach; (b) the only person on the beach who makes a living there is the life guard; and (c) understanding can be fun. You may be the first on your block to know that there are four "states of matter"!

In addition to RATIONALE, this minicourse contains the following sections:

1) TERMINAL BEHAVIORAL OBJECTIVES (Specific things you are expected to learn from this minicourse)

2) ENABLING BEHAVIORAL OBJECTIVES (Learning "steps" which will enable you to eventually reach the terminal behavioral objectives)

3) ACTIVITIES (Specific "<u>things to do</u>" to help you learn)

4) RESOURCE PACKAGES (Instructions for carrying out the activities, such as procedures, references, laboratory materials, etc.)

5) EVALUATION (Tests to help you learn and to determine whether or not you satisfactorily reach the terminal behavioral objectives)

   a) Self-test(s) with answers, to help you learn more.

   b) Final tests, to measure your overall achievement.

TERMINAL BEHAVIORAL OBJECTIVE:

Upon the completion of this minicourse, you will be able to:

- correctly answer ten (10) questions out of twelve (12) relating to "states" and general properties of matter.

ENABLING BEHAVIORAL OBJECTIVE #1:	ACTIVITY 1	RESOURCE PACKAGE 1
Determine differences between states of matter experimentally and define the properties which account for these differences.	Complete Resource Package 1.	"Investigating States of Matter"
ENABLING BEHAVIORAL OBJECTIVE #2:	ACTIVITY 2	RESOURCE PACKAGE 2
Learn how to solve simple density problems.	Complete Resource Package 2.	"Density"
ENABLING BEHAVIORAL OBJECTIVE #3:	ACTIVITY 3	RESOURCE PACKAGE 3
Be able to define the 21 terms related to states of matter found in Resource Package 3.	Complete Resource Package 3.	"Some Definitions" (States of Matter)
ENABLING BEHAVIORAL OBJECTIVE #4:	ACTIVITY 4	RESOURCE PACKAGE 4
Relate changes of state to appropriate laboratory investigations.	Complete Resource Package 4.	"Mini-experiments"
ENABLING BEHAVIORAL OBJECTIVE #5:	ACTIVITY 5	RESOURCE PACKAGE 5
Diagram a model of the change from solid matter to liquid matter and explain how movement of particles is important in changes of state.	Complete Resource Package 5.	"Changes of State Explained by Models"

ENABLING BEHAVIORAL OBJECTIVE #6:	ACTIVITY 6	RESOURCE PACKAGE 6
Define the terms related to models of matter found in Resource Package 6.	Complete Resource Package 6.	"Ideas for Use With Models of States of Matter"

RESOURCE PACKAGE 1

INVESTIGATING STATES OF MATTER

Equipment Needed: 2 beakers of different size, balance, 2 balloons, pressure gauge, stopcock, 2 rubber bands, 3 liquids, 3 solids, 2 gases (include air as one of these gases), Bunsen burner, ringstand, evaporating disk, magnifying glass, and graduated cylinder.

Note: One of the materials studied should be an alum; one of the liquids should be water.

Procedure:

(1) Look at the samples given to you and describe the properties of each; list these properties in your lab notebook.

(2) List the properties which the liquids seem to have in common.

(3) List the properties which the solids seem to have in common.

(4) What properties do the gases seem to have in common? List these.

(5) Again, using a magnifying glass, look at each of the samples. Are there any properties that you can add to your previous lists?

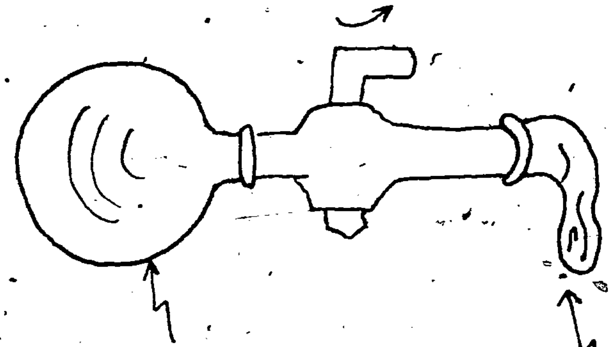
(6) Determine the volume and weight of the solids and the liquids.

(7) Separately, heat each of the solids and liquids. Then allow them to cool. Are there any additional properties that you can add to your lists?

(8) Blow up a balloon. Check its pressure with the pressure gauge. Allow the balloon to deflate. What caused it to deflate?

(9) Follow the steps 1 through 3 as illustrated on page 6. Blow up the balloon again and attach this inflated balloon to the stopcock (closed). Attach a deflated balloon to the other end

of the stopcock. Open the stopcock. Record any properties of a pressurized gas which you have inferred from this activity. (Hint: consider volume and pressure relationships.)



(10) Examine the solubility of each of the 3 solids in each of the 3 liquids. List common, observable properties of each of the states of matter, as derived by you from this investigation.

RESOURCE PACKAGE 2

DENSITY

Now that you have investigated some of the general, observable properties of solids, liquids, and gases, consider the next statement. Some properties of matter are not obvious or easily observable. Density is an example of such a property. In physics we talk about two kinds of density--weight density and mass density. Density is mathematically expressed by the ratio, $\frac{\text{weight}}{\text{volume}}$; mass density is expressed by the ratio, $\frac{\text{mass}}{\text{volume}}$. This may look complicated; but after you have worked with these ratios for awhile, you will find that they are really very simple.

Consider the question, "Which is heavier, lead or water?" "Lead," some might say. But if you have a gallon of water and a lead disc the size of a nickel, which is heavier? The water, obviously. No trick is intended here. What you need to see is that to compare lead to water (or any one kind of matter to another kind), it is necessary to state questions precisely.

Two things follow from this: (1) the two density ratios discussed above define density; and (2) the definition of volume, weight, and mass must be precise.

DENSITY COMPARISONS

Comparison #1:

A 3,000 lb car occupies a garage. A 30 lb bicycle occupies a garage of equal volume. Which combination of garage plus vehicle has the greater weight density?

Solution: Weight Density = $\frac{\text{Weight}}{\text{Volume}}$

$$\frac{3{,}000 \text{ lbs}}{\text{Parking space volume}} = \text{Car and garage weight density}$$

$$\frac{30 \text{ lbs}}{\text{Parking space volume}} = \text{Bicycle and garage weight density}$$

Therefore, the car plus garage is more dense.

Comparison #2:

A piece of metal of 10 gm mass displaces a 2 ml volume of water. A second piece of metal has a mass of 20 gm and displaces 5 ml of water. Which metal is the denser?

Solution: Mass Density = $\frac{\text{Mass}}{\text{Volume}}$

$$\frac{10 \text{ gm}}{2 \text{ ml}} = 5 = \text{Mass density of first piece}$$

$\frac{20 \text{ gm}}{5 \text{ ml}} = 4$ = Mass density of second piece

Therefore, the metal with the 10 gm mass property has the greater mass density.

RESOURCE PACKAGE 3

SOME DEFINITIONS (STATES OF MATTER)

Definitions are just like good friends; they will help you when you need them. The following are some definitions for you to become familiar with and, if possible, to learn:

atmosphere - one atmosphere (1 atm), or standard atmospheric pressure - This is the "average" pressure of the earth's atmosphere at sea level. Atmospheric pressure can be measured in several ways. One common way is related to the height of a column of fluid which the air pressure can support; i.e., 1 atmosphere supports 76 cm of mercury (Hg), 34 ft of water, etc. Of course, atmospheric pressure is also expressed in pressure units; 14.7 lb/in^2 equals 1 atmosphere, for example.

calorie - a unit of heat energy; the amount of heat energy required to raise the temperature of 1 gram of pure water at standard pressure from 15.5^o C. to 16.5^o C. This "scientific calorie" is <u>NOT</u> the same as the food industry's calorie. The food calorie, used by dieticians, home economists, weight watchers, Galloping Gourmet, etc., is equivalent to a scientific <u>kilocalorie</u>; in other words, a "food calorie" is 1,000 times greater than a "science calorie."

Celsius degree (C^o) - $\frac{1}{100}$ of the temperature measurement between the boiling point and the freezing point of water at one atmosphere (1 atm) of pressure.

crystal - a solid state of matter characterized by an orderly arrangement of the atoms (molecules) making up the crystal.

deposition - the change of state from a gas (vapor) directly to a solid, skipping the liquid state (phase) entirely.

evaporation - the change of state of a liquid to a gas or vapor.

gas - a state (phase) of matter characterized by randomly moving, rapidly moving, widely spaced particles. A gas fills its container and lacks definite shape or fixed volume. Gases have no fixed shape or volume because their molecules are in a constant bombarding, flying motion. They are restrained to a fixed space (volume) only by some kind of "container."

heat of condensation* - the heat energy released by a standard amount of a material when it changes from a gas to a liquid without changing the material's temperature.

heat of crystallization* - the heat energy released by a standard amount of a liquid when it changes to a solid without changing its temperature. For example, this would be the <u>freezing point</u> for water.

heat of fusion* - the heat energy required to melt a standard amount of a solid without changing its temperature; this occurs at the temperature called its <u>melting point</u>.

heat of vaporization* - the amount of heat energy required to boil a standard amount of a material without changing its temperature; this occurs at its <u>boiling point</u>.

Kelvin degree (K^o) - a unit on a temperature scale whose zero point is equal to -273^o Celsius. In other words, Kelvin temperature equals 273 plus Celsius temperature ($^oK = 273 + {}^oC$). The Kelvin temperature scale is sometimes referred to as the Absolute temperature scale.

liquid - a state of matter having a definite volume but no definite shape. In other words, a liquid assumes the shape of its container because its molecules are not bound together strongly enough to hold a fixed shape; but a liquid has a definite volume (size) because its molecules are bound to each other strongly enough that they do not "voluntarily" separate.

plasma - the so-called fourth state of matter; a collection of high temperature gaseous <u>ions</u> (electrically charged atoms or molecules) under high pressure. For example, the sun's surface has plasmas (hot, charged "gases"); and the burning off of the surface of an atmospheric re-entry vehicle (or a meteor) results in plasma production. If you've seen a "shooting star," you have seen a plasma.

STP - the acronym for the conditions of "standard temperature and pressure"; for example, 1 atmosphere of pressure and 0^o Celsius temperature constitute standard conditions of pressure and temperature in the metric system.

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* These "heats" are referred to in science as <u>latent heats</u> of fusion, of sublimation, of condensation, of vaporization, etc., because during such state (phase) changes, no change of temperature occurs.

solid - a state of matter having a definite shape and volume. A solid's molecules are strongly bound to one another.

sublimation - the change of state from a solid directly to a gas, skipping the liquid state entirely.

temperature - a comparison of the "hotness" or "coldness" of something to the "hotness" or "coldness" of such standard conditions as the boiling point of water, the freezing point of water, etc. Often, non-science people use the term, Centigrade, instead of the more internationally recognized and more scientific term, Celsius.

thermometer - measuring device for temperature (for comparing the "hotness" or "coldness" of things).

0^o C - the freezing point of pure water at standard pressure.

0^o K - the theoretical zero temperature point; the lowest possible temperature; the absolute zero of temperature.

Now that you have examined these definitions, you probably could use some practice with them to good advantage. We could let you use each of these definitions in a sentence, as English teachers might do. But since physics is laboratory oriented, the "mini-experiments" which constitute the rest of this minicourse will provide you with opportunities to use these definitions to help explain what you have done while "mini-experimenting."

SELF-TEST

1) Define: temperature, "scientific" calorie, "food" calorie, C^o, K^o, standard atmosphere, solid, liquid, gas, and heat of vaporization.

2) The latent heat of fusion of water is approximately 80 cal/g. How much heat energy will be used to melt 10 grams of pure water at the boiling point temperature and at standard pressure?

3) The latent heat of fusion of water is approximately 80 cal/g. What is the heat of crystallization of pure water?

ANSWERS TO SELF TEST

1) See preceding definitions.

2) 800 calories

3) 80 calories/gram

RESOURCE PACKAGE 4

MINI-EXPERIMENTS

MINI-EXPERIMENT: BOILING WATER

Vacuum distillation is a process used in the purification of many materials without getting them so hot that they chemically decompose. Simply put, it is possible to boil liquids without having them break down chemically. This is done by lowering the boiling point of the liquids before heating them. The way to lower the boiling point of a liquid is to reduce the pressure on the liquid's surface. This surface pressure is called vapor pressure, and it is the pressure exerted by the molecules of the liquid which have evaporated from that very same liquid.

Procedure:

Boil some water in a beaker. First, describe what you see happening. Second, look back at the Resource Package on definitions and then rewrite your first description, using as many of the definitions as possible. Compare your two descriptions.

Report:

Now write up this mini-experiment, using the following as a guide:

1) Purpose of the mini-experiment

2) Equipment used

3) Procedures followed

4) Recorded data or observations

5) Results and/or conclusions

Hint for observations: What was the general pattern of bubble activity? first bubbles? bubbles during first boiling? etc.

Hint for conclusions: Can you relate what was happening to the water molecules in terms of change from the liquid to vapor (gas) state?

MINI-EXPERIMENT: MELTING ICE

Procedure:

First, put three ice cubes in a beaker, allow them to melt, and then let the ice water warm to room temperature. Second, go on to another mini-experiment while the ice changes to water at room temperature. Third, return to the ice water which has warmed to room temperature; bring this water to a boil. Observe the ice, ice water, warm water, and steam and record such data as the time it took the ice to melt, the time for the ice water to warm to room temperature, and the time for the water to boil.

Report:

Describe the various changes of state you saw the water go through; i.e., from ice to ice water, from ice water to warm water, and from warm water to steam, using as many of the terms in Resource Package 3 (definitions) as possible.

MINI-EXPERIMENT: EVAPORATION-CONDENSATION-EQUILIBRIUM

Procedure:

Fill a dry jar or bottle (a mason jar should do nicely) half full of water and seal it.

Report:

Describe the changes that you observe over a three-day period. Again, use as many terms from Resource Package 3 as possible.

MINI-EXPERIMENT: STATES OF MATTER
(Optional)

Plan your own mini-experiment (with your instructor's approval), including even more of the terms from Resource Package 3 than any you have done previously.

SOMETHING TO THINK ABOUT

Think about the mini-experiments you have performed. What did you learn from this unit that you did not know before and that might help you to understand better the real world (perhaps some things that you did or saw recently outside of school)? Write down some of these and discuss them with your teacher.

RESOURCE PACKAGE 5

CHANGES OF STATE EXPLAINED BY MODELS

Models are used in science and technology to more easily explain something. A model 747 airplaine is not the real thing, but it can closely resemble a real 747. A model of an atom is not an atom; and it need not be nearly as close to the real thing as, say, a 747 model, to be extremely useful. This section deals with models of some of the properties of the states of matter.

If we assume that matter is made up of particles (atoms or molecules), what might happen to matter when it changes state because its temperature is raised? Consider that most materials are most dense when in the solid state. It would thus seem obvious that a solid's particles are as close to one another as they can be.

SELF-HELP TEST

1) If the above is a valid model (description) of the solid state of matter, diagram what change would take place as a solid is changed, first to a liquid and then to a gas?

   Answer: Any diagram showing the particles moving farther apart is correct.

   If you don't agree with the answer above, talk with your teacher about it. Then push on.

2) What causes the particles of the solid to move farther apart?

   Answer: Heat energy

Was your answer, "heat energy"? If so, then you're right again.

3) How does one melt (fuse) something?

Answer: Heat it.

4) How does one boil something?

Answer: Heat it.

5) Heating something sometimes raises its ______________ but always increases its __________.

Answer: temperature, energy

Temperature can be related to particle motion. So let's add another characteristic to our model. Let's assume that a material's particles are always moving; and if we consider the various states, we might expect our model to have different amounts of motion for each state: the least motion for a solid, more for a liquid, and the most motion for a gas. Evidence for motion is given by observation of Brownian motion of tiny particles, such as smoke particles suspended in air or certain particles suspended in a liquid. When viewed through a microscope, these tiny particles are seen to move constantly in both a gas or a liquid. They move randomly (in no particular direction), and the smaller ones move faster than the larger ones.

If we assume that the tiny particles of smoke or other suspended material are being bumped around randomly by the even <u>tinier</u> particles (atoms/molecules) of the gas or liquid, then write down your ideas about what Brownian motion tells about the tinier particles that can't be seen but are causing it. Draw pictures and/or graphs to illustrate your ideas. Discuss these with your teacher and ask for some appropriate reading references for further study.

SELF-HELP TEST

Do you know that if a piece of gold is pressed against a piece of lead, left pressed for several months, and then the two materials are separated, there will be some gold in the lead and some lead in the gold? Write down how you might account for this mixture of lead and gold. Use the model concepts discussed above.

MINI-EXPERIMENT

Another evidence for the movement of the particles in matter is phenomenon ("happening") called <u>diffusion</u>. Consider what happens if you open a bottle of perfume, or break a rotten egg, in one corner of a room, or what happens if you have a "No Pest Strip" hung in a corner of a room.

Drop one crystal of $KMnO_4$ (potassium permanganate) into a test tube full of water and leave it for a day. Observe the results. At the same time, try the $KMnO_4$ experiment with a drop of food coloring replacing the $KMnO_4$. Observe the results. Consider your observations and diagram what you think happens on a molecular level. As an example, look at Fig. 2, below.

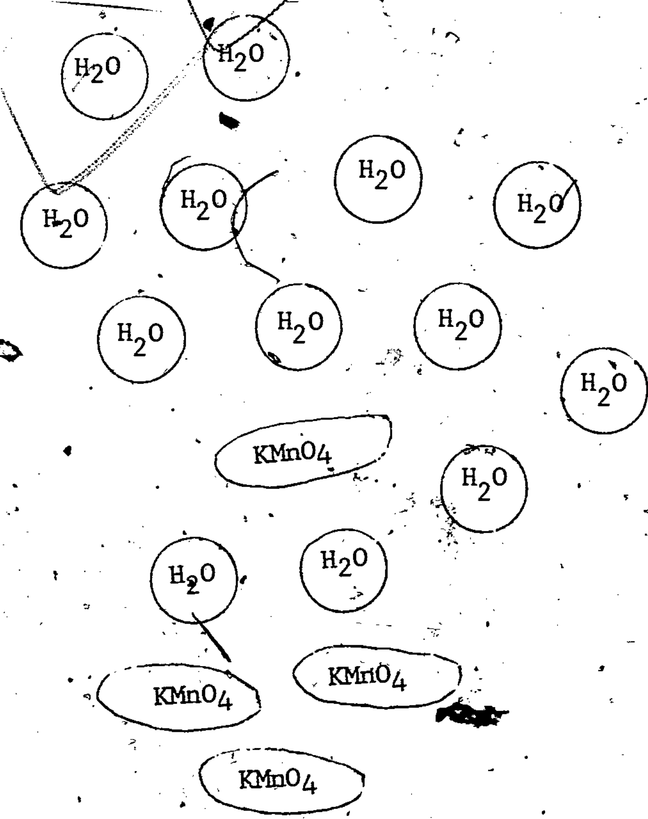


Fig. 2

MINI-EXPERIMENT

Equipment Needed: Erlenmeyer Pyrex flask, 250 ml, with rubber stopper
ring stand
Bunsen burner

Procedure: Put 100 ml of H_2O in the flask. Do not stopper the flask. Boil the water. Remove the flask from the burner, stopper the flask, and quickly put the inverted flask under a stream of cold water (see Fig. 3, below), being very careful not to touch the hot flask with your bare hands! Observe the behavior of the water in the flask when the flask is placed under the cold water stream.

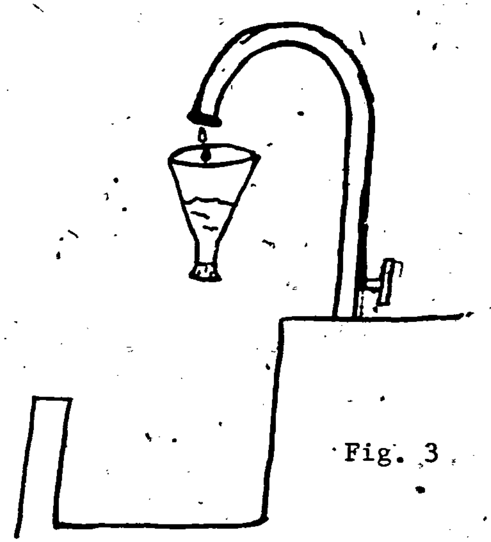


Fig. 3

<u>Report</u>: Write a report on your observations. Consider such things as: What happens to the pressure inside the flask? Is a vacuum ever produced above the water? What gas was in the flask when it was stoppered?

RESOURCE PACKAGE 6

IDEAS FOR USE WITH MODELS OF STATES OF MATTER

Kinetic Theory - The kinetic theory states that matter is composed of very small particles that are in constant motion and that if the particles of matter are free to collide (as in a gas), they do not lose motional energy on collision with one another.

Hard Sphere Model - The hard sphere model pictures the particles of matter as very small solid spheres.

Hole Theory - If particles are pictured as hard spheres, even in their closest packed arrangement, there will be at least 24% of the space that is empty between the spheres.

Consider these statements:

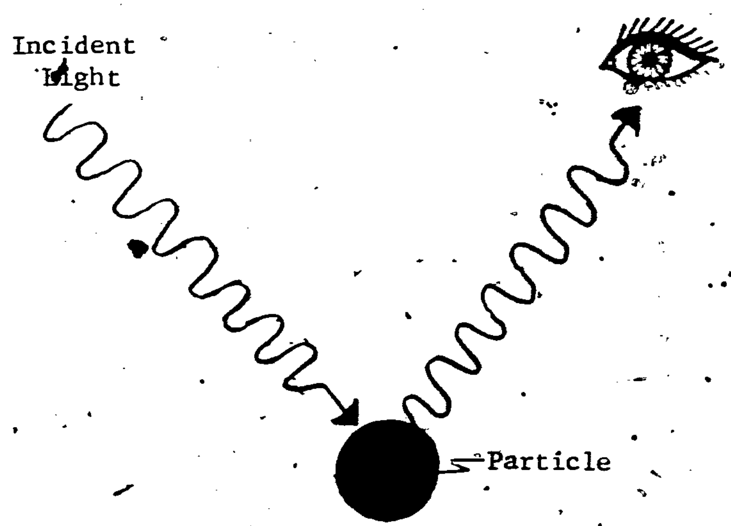
1) Most solids other than water expand when they melt. This expansion can be explained by the kinetic theory.

2) If the particles in a solid are made to move (dance back and forth) by heating, they will tend to take up more space than when they are not moving. A theory which helps explain the increase in volume of a heated solid is the Hole Theory.

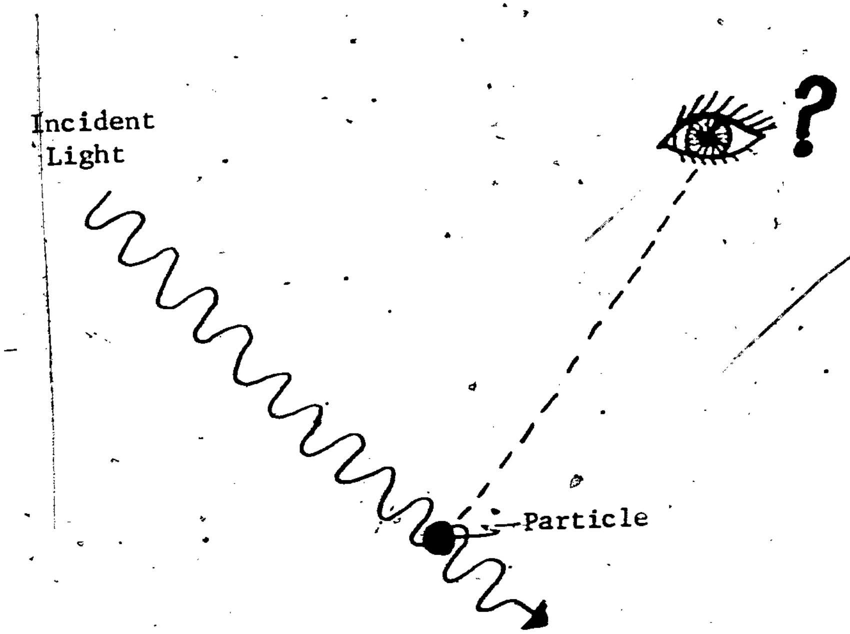
Now look up some pictures of models of matter. Sketch at least three (3) such models and submit them for evaluation.

Seeing Atoms

This title, as most of you know, is an untruth. One cannot see atoms. Why? Because they are just too small. "Well," some of you might say, "Let's look through a microscope." Again, the answer is that they are just too small. What does "too small" mean? It means that the light that we must bounce off the atoms to be able to see them has a much larger wavelength than the space between the atoms. Since seeing must be done by the reflection of visible light off the atoms, each atom is invisible because light reflects from a group of atoms as though they were an unbroken surface. A model of why we cannot see atoms is shown below.



a. Incoming light is "Smaller" than particle size; can see the particle because reflected light reaches eye.



b. Incoming light is "Bigger" than particle size; cannot see the particle because no light is reflected to eye.

Fig. 4
SEEING PARTICLES

After looking at Fig. 4, above, which of the following might permit seeing at atom?

A. Using better microscope.

B. Using shorter wavelength light.

C. Using longer wavelength light.

Read some simple material on X-ray diffraction and try to diagram this and to relate it to your answer to the question above.