R E P O R T   R E S U M E S

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NUCLEAR SCIENCE CURRICULUM PROJECT. INSTRUCTIONAL RESOURCES SUPPLEMENT.

CULVER CITY UNIFIED SCHOOL DISTRICT, CALIF.

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DESIGNED AS AN ADJUNCT TO MATERIALS DEVELOPED BY THE NUCLEAR SCIENCE CURRICULUM PROJECT, THIS DOCUMENT PROVIDES RESOURCE MATERIAL WITH WHICH THE NUCLEAR SCIENCE CURRICULUM MAY BE ENRICHED, AND ADDRESSES ITSELF TO (1) INSTRUCTIONAL AIDS PRESENTLY AVAILABLE, (2) USE OF INSTRUCTIONAL AIDS TO SUPPLEMENT THE CURRENT SCIENCE CURRICULA, (3) FACILITIES NEEDED FOR THIS CURRICULUM, (4) LEGAL AND PRACTICAL RESTRAINTS ON THE USE OF RADIOACTIVE MATERIALS, AND (5) TEACHER TRAINING NEEDED FOR TEACHING AN INSTRUCTIONAL UNIT ON NUCLEAR SCIENCE. INSTRUCTIONAL AIDS LISTED IN SECTION I, SURVEY OF INSTRUCTIONAL AIDS, WERE SELECTED ON THE BASIS OF THE FOLLOWING CRITERIA--(1) COST, (2) SOPHISTICATION, BASED UPON APPROPRIATENESS, DEGREE OF TRAINING REQUIRED FOR USE, AND UTILITY AS AN INSTRUCTIONAL TOOL, (3) AVAILABILITY, AND (4) MAINTENANCE REQUIREMENTS. CATEGORIES ARE (1) WALL CHARTS, (2) OVERHEAD TRANSPARENCIES, (3) FILMSTRIPS, (4) FILM CARTRIDGES, (5) FILMS, (6) RADIOISOTOPES, (7) AUTORADIOGRAPHY MATERIALS, (8) INSTRUMENTATION, (9) MISCELLANEOUS KITS AND MATERIALS, AND (10) BIBLIOGRAPHIC REFERENCES. SECTION II, CORRELATION OF INSTRUCTIONAL AIDS WITH SECONDARY SCIENCE CURRICULA, RELATES CURRICULUM SUBJECT TO PARTICULAR MEDIA, AND INDICATES INSTRUCTIONAL METHODS WHERE APPROPRIATE. DISCUSSED ARE FACILITIES AND RADIOISOTOPES, INCLUDING LEGAL ASPECTS, REGULATIONS, HARZARDS, PROCEDURES, AND INSURANCE REQUIREMENTS. TEACHER TRAINING IN THE USE OF RADIOACTIVE MATERIALS AS A TEACHING TOOL IS CONSIDERED BRIEFLY. (DH)

ED018374

# NUCLEAR SCIENCE CURRICULUM PROJECT



DPSC-66-1824
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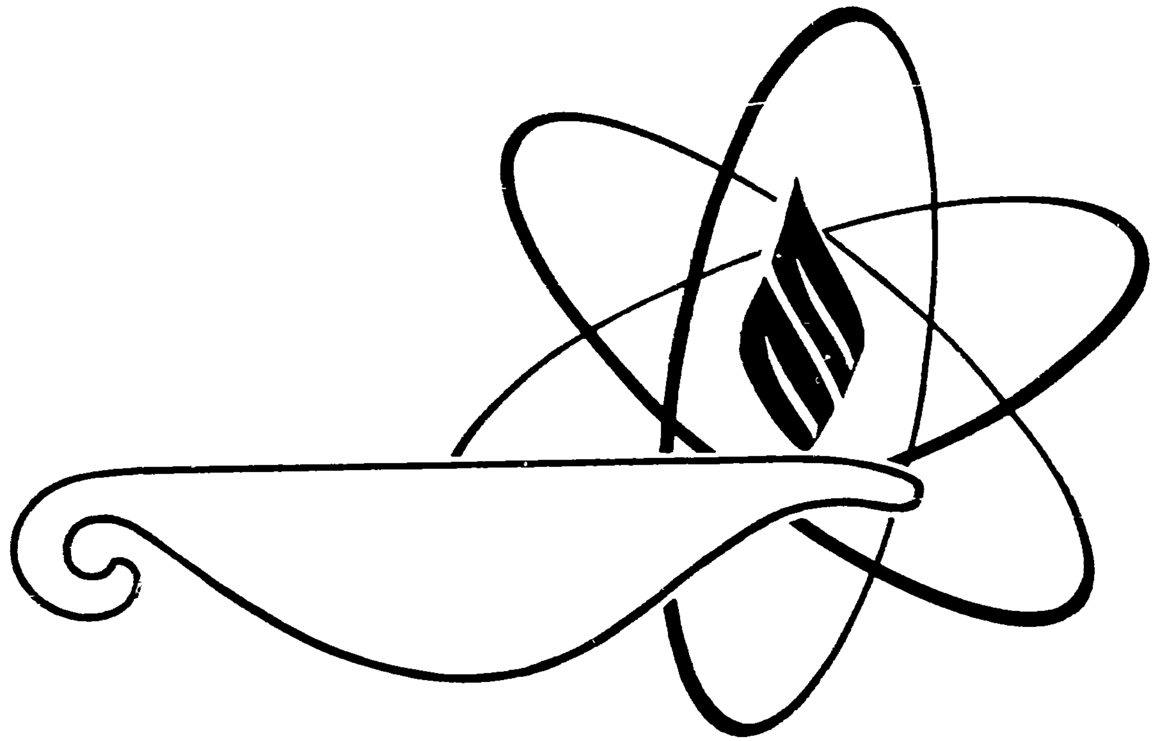
## INSTRUCTIONAL RESOURCES SUPPLEMENT



CULVER CITY UNIFIED SCHOOL DISTRICT
CULVER CITY, CALIFORNIA

DR. EARL D. PATTON, SUPERINTENDENT
DR. JAMES CAMAREN, PROJECT DIRECTOR

SE004 363

# A SURVEY OF INSTRUCTIONAL AIDS AND OTHER FACTORS AFFECTING THE IMPLEMENTATION OF A NUCLEAR SUPPLEMENT TO HIGH SCHOOL SCIENCE CURRICULA

Prepared For Submission To
The Culver City Unified School District
Culver City, California

By
The Bio-Atomic Research Foundation
North Hollywood, California

CULVER CITY UNIFIED SCHOOL DISTRICT

BOARD OF EDUCATION



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Appreciation is extended to the members of the Academic Task Force who graciously accepted and met the responsibility and challenge of identifying the need-to-know knowledges and attitudes regarding the social-scientific implications of nuclear development, and to the teacher consultants from Beverly Hills, Burbank and Culver City Unified School Districts, upon whom the Project relied heavily with respect to matters of content relevancy and organization.

To Betty Hatch and Eva Brosseau of the Project secretarial staff, a special debt of gratitude is due for their pleasing manner in meeting routine and crisis situations and for efficiently attending to many Project tasks which enabled scheduled activities to be accomplished.

Finally, additional thanks are owed to the many researchers whose efforts have contributed to the background of pertinent data from which this study benefits, and to the teachers who through their efforts endeavored to provide learning opportunities for students based on "real-world" needs.

James Cameren
Project Director

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# TABLE OF CONTENTS

# INTRODUCTION

## INTRODUCTION

This document is designed as an adjunct to the developments made by the Nuclear Science Curriculum Project under the direction of Dr. James Camaren of the Culver City Unified School District, Culver City, California.

An important aspect of such developments is the selection of supporting instructional media which, in the case of this project particularly, should be based on the stated objectives. At the time a complete analysis is made of the objectives identified in Phase I of the Nuclear Science Curriculum Project the curriculum designers can then consider available materials in the light of their effectiveness toward achieving the desired goals. Based on the review contained in this report decisions regarding the development of additional materials can be knowledgeably made.

The implementation of a curriculum as a vehicle for meaningful instruction must include classroom demonstrations or, better still, laboratory experimentation by the student (where applicable). Although this can be stated as a generality, it can be applied as a specific in the field of nuclear science instruction. Fears, apprehensions, misconceptions, can be dispelled only by thorough familiarity with a medium or process or, at the very least, through the exposure of an individual or group to the facts concerning a medium or process by a personal involvement in its practical application.

In order to effectuate such application certain considerations must be made prior to any implementation. For example:

1. What instructional aids are currently available to a teacher, department or district?

2. Where could the instructional aids be used to supplement the current science curricula?

3. What educational plant facilities would it be desirable to have for this area?

4. Since we are to be concerned with the possible use of radioactive material which is regulated by either state or federal authority, what are the legal and practical constraints?

5. What teacher training might be required prior to the implementation of an active program of science instruction containing a nuclear supplement?

This report then, will concern itself with a consideration of the above questions.

# SURVEY OF INSTRUCTIONAL AIDS

The following criteria have been established for the organization of the material contained in this section of the report: (In order to retain greater objectivity, no reference will be made here as to where any particular item can be used as an aid. Such information will be found as a reference in Section 3 - Correlation of Instructional Aids).

1. Following are the major criteria established for the selection of instructional aids:

   a. Cost - This item is sometimes of prime interest and is most certainly a factor which can have a bearing in the selection of any piece of capital equipment. It is assumed that in selecting the media of instruction consideration must be given to the kinds of learning in addition to the cost effectiveness of the material selected. Thus if cost becomes a major factor the curriculum designer is given the option of making a choice based on his individual situation.

   b. Sophistication - Instructional aids are designed with varying degrees of sophistication. Judgement regarding the degree of sophistication is, by its nature, an arbitrary one. The bases upon which selection decisions were made were the following:
      1. Appropriateness for use in a classroom situation.
      2. Degree of training required.
      3. Utility as an investigative or instructional tool.

   The grade coding is as follows:
   A- Lowest level of sophistication.
   B- Intermediate - Useful at the High School level.
   C- Higher intermediate - Probably too complex for use at the High School level.

   c. Availability - It must be assumed that if an item is listed as a stock item by a reputable supplier, it is available for purchase and delivery on order. It would be far beyond the scope of this study to attempt to estimate the stock situation of any supplier or the production capability of any manufacturer. It is known that occasionally a supplier will have a stock deficiency and delivery of a specific item may be delayed. This however, cannot be foretold in any case and no account of this is taken in the tabulation.

d. Maintenance - This also cannot be foretold with any degree of accuracy. Suffice it to say that any piece of equipment is generally sold with some performance guarantee which can be exercised by the purchaser. It can be said however, that any instrument suitable for classroom use can be serviced by the same personnel which care for the school's sound and projection equipment. It should be necessary for them to familiarize themselves with the peculiarities of the acquired instrumentation so that routine maintenance can be handled easily. Major repairs or rework should be left to the manufacturer.
Where a special feature or problem is known to exist mention of it will be made in the general comment column.

2. The instructional aids considered here are tabulated by categories and are segregated as follows:

    1. Wall charts
    2. Overhead Projector Transparencies
    3. Film Strips
    4. Film cartridges--Single concept films (2-4 min.)
    5. Films
    6. Radioisotopes
    7. Autoradiography materials
    8. Instrumentation
    9. Miscellaneous kits and materials
    10. Bibliographic references

# 1. Wall Charts

## 1.1 Denoyer-Geppert Company, Chicago, Illinois

### Atomic Theory Charts

| | | |
|---|---|---|
| 1.1.1 | TNAT-1 | Structure of Atoms |
| 1.1.2 | TNAT-2 | Natural Disintegration of Atoms |
| 1.1.3 | TNAT-3 | Artificial Transmutation of Atoms |
| 1.1.4 | TNAT-4 | Fission of the Atomic Nucleus |
| 1.1.5 | TNAT-5 | Nuclear Reactor and Atomic Power Plant |
| 1.1.6 | TNAT-6 | Electromagnetic Radiation |
| 1.1.7 | TNAT-7 | Cyclotron |
| 1.1.8 | TNAT-9 | Measurement of Radioactive Radiation |
| 1.1.9 | TNAT-10 | Stable, Natural and Artificial Radioactive Isotopes |
| 1.1.10 | TNAT-11 | Electron Shell System of Elements |
| 1.1.11 | TNAT-12 | Periodic System of Elements |

### Health Physics Charts

| | | |
|---|---|---|
| 1.1.12 | TPH-1 | Mutual Interaction of Charged Particles and Neutrons with Matter |
| 1.1.13 | TPH-2 | Mutual Interaction of X and $\gamma$ Rays with Matter |
| 1.1.14 | TPH-3 | Somatic Ray Injuries |
| 1.1.15 | TPH-4 | Genetic Ray Injuries |
| 1.1.16 | TPH-5 | Man's Exposure to X-Rays |
| 1.1.17 | TPH-6 | Three Basic Protective Measures |
| 1.1.18 | TPH-7 | Measuring Man's Exposure to Rays |

2. Overhead Projector Transparencies

2.1. Western Publishing Co., Racine, Wisconsin

| | | |
|---|---|---|
| 2.1.1 | #J9-049 | Atoms |
| 2.1.2 | #J9-050 | Molecules |
| 2.1.3 | #J9-051 | Nuclear Fission |
| 2.1.4 | #J9-052 | Nuclear Reactor |
| 2.1.5 | #J8-070 | Isotopes of Uranium |
| 2.1.6 | #J8-071 | Radiation |
| 2.1.7 | #J8-072 | Radioactive Decomposition |
| 2.1.8 | #J8-073 | Disintegration Series |
| 2.1.9 | #J8-074 | Atomic Fission |
| 2.1.10 | #J8-075 | Chain Reaction |
| 2.1.11 | #J8-076 | $E=mc^2$ |
| 2.1.12 | #J8-077 | Atomic Reactor |
| 2.1.13 | #J8-078 | Artificial Elements |
| 2.1.14 | #J8-079 | Atomic Fusion |
| 2.1.15 | #J8-057 | Isotopes of Hydrogen |
| 2.1.16 | #J8-060 | Periodic Table of Elements |
| 2.1.17 | #J8-062 | Electron Shells |

2.2. United Transparencies, Inc., Binghampton, N.Y.

| | | |
|---|---|---|
| 2.2.1 | Ph-7.102 | Molecular Models |
| 2.2.2 | Ph-7.103 | Hydrogen Atom |
| 2.2.3 | Ph-7.104 | Carbon Atom |
| 2.2.4 | Ch-2.420 | Radioactive Sources |
| 2.2.5 | Ch-2.421 | Nuclear Disintegration |
| 2.2.6 | Ch-2.422 | Reactor |
| 2.2.7 | Ch-2.423 | Cyclotron |
| 2.2.8 | Ch-2.440 | Transmutation |
| 2.2.9 | Ch-2.450 | Fusion |
| 2.2.10 | Sc-8197 | Uranium Decay Dating |
| 2.2.11 | Sc-8198 | Carbon-14 Dating |
| 2.2.12 | Sc-8212 | Radiation |
| 2.2.13 | Sc-8213 | Radium Decay Curve |
| 2.2.14 | Sc-8214 | Isotopes |
| 2.2.15 | Sc-8215 | Nuclear Fission |
| 2.2.16 | Sc-8216 | Nuclear Fusion |

2.2 United Transparencies, Inc., Binghampton, N.Y. (Cont'd)

| | | |
|---|---|---|
| 2.2.17 | Sc-8322 | Decay Schemes for Neutrons |
| 2.2.18 | Sc-8323 | Carbon-14 Decay |
| 2.2.19 | Sc-8324 | Basic Geiger Counter |
| 2.2.20 | Sc-8325 | Chain Reaction-Fission |
| 2.2.21 | Sc-8326 | Fusion |
| 2.2.22 | Sc-8327 | Fusion-2 Helium Nuclei |
| 2.2.23 | Sc-8328 | Radioactive Fallout |
| 2.2.24 | Ch-6616 | Periodic Table of Ionization Energies |
| 2.2.25 | Ch-6617 | Ionization Energy vs. Atomic Number |
| 2.2.26 | Ch-6695 | Effect of Magnet on Different Types of Radiation |
| 2.2.27 | Ch-6696 | Uranium Decay Series |
| 2.2.28 | Ch-6697 | Alpha and Beta Emissions in U-238 Decay |
| 2.2.29 | Ch-6698 | Historic Nuclear Disintegration performed by Rutherford |
| 2.2.30 | Ch-6699 | Fission makes a chain reaction possible |

2.3 Educational Audio-Visual, Pleasantville, New York

| | | |
|---|---|---|
| 2.3.1 | 3PP321 | Nuclear Chemistry<br>Radioactive Series for Uranium-238<br>The 4 Naturally Radioactive Disintegration Series<br>Graph of Stable Nuclides<br>Binding Energy |
| 2.3.2 | 3P914 | Radioactive Sources |
| 2.3.3 | 3P915 | Nuclear Disintegration |
| 2.3.4 | 3P916 | Reactor |
| 2.3.5 | 3P917 | Cyclotron |
| 2.3.6 | 3P918 | Transmutation |
| 2.3.7 | 3P919 | Fusion |

2.4 School Products Co., Inc., New York, N. Y.

| | | |
|---|---|---|
| 2.4.1 | Ch-6606 | Isotopes of $H_2$ |
| 2.4.2 | Ch-6607 | $He_4$ Atom |
| 2.4.3 | Ch-6608 | $Li_7$ Atom |
| 2.4.4 | Ch-6609 | Electronic Energy |
| 2.4.5 | Ch-6611 | Spatial Orientation of S Orbitals |
| 2.4.6 | Ch-6612 | Spatial Orientation of p Orbitals |
| 2.4.7 | Ch-6696 | Uranium Decay |
| 2.4.8 | Ch-6697 | Alpha and Beta Particle Emissions |
| 2.4.9 | Ch-6698 | Nuclear Disintegration |
| 2.4.10 | Ch-6699 | Chain Reaction |
| 2.4.11 | Sc-8212 | Radiation |
| 2.4.12 | Sc-8213 | Radiation Decay |
| 2.4.13 | Sc-8214 | Isotopes |
| 2.4.14 | Sc-8215 | Nuclear Fission |
| 2.4.15 | Sc-8216 | Nuclear Fusion |
| 2.4.16 | Sc-8324 | Basic Geiger Counter |
| 2.4.17 | Sc-8328 | Radioactive Fallout |
| 2.4.18 | C-33 | Ionizing Radiation |
| 2.4.19 | C-36 | Types of Radiation |
| 2.4.20 | C-37 | Radioactive Decay |

3. Film Strips

3.1 The Jam Handy Organization, Detroit, Michigan

3.1.1 Series #1390 The Atom and its Nucleus

3.1.1.1 Exploring the Atom
3.1.1.2 Discovering Isotopes
3.1.1.3 What is Radioactivity?
3.1.1.4 Radioactive Transmutation and Half-Life
3.1.1.5 Bombarding the Nucleus
3.1.1.6 The Secret of Nuclear Energy
3.1.1.7 Using Nuclear Energy

3.2 Society for Visual Education, Chicago, Illinois

3.2.1 #R413-1 Nuclear Radiation Detectors
3.2.1.1 #R413-1RR Record for 3.2.1
3.2.2 #R413-2 Uses of Nuclear Radiation in Medicine
3.2.2.1 #R413-2RR Record for 3.2.2
3.2.3 #R413-3 Nuclear Radiation in Earth Studies
3.2.3.1 #R413-2RR Record for 3.2.3
3.2.4 #R413-4 Nuclear Radiation in Outer Space
3.2.4.1 #R413-3RR Record for 3.2.4
3.2.5 #R413-5 Uses of Nuclear Radiation in Industry
3.2.5.1 #R413-3RR Record for 3.2.5
3.2.6 #R413-6 Nuclear Radiation Fallout
3.2.6.1 #R413-4RR Record for 3.2.6

3.3 Encyclopedia Brittanica Educational Corp., Chicago, Ill.

3.3.1 #10690 Series - The Atom

3.3.1.1 Introducing Atomic Energy
3.3.1.2 Harnessing the Atom
3.3.1.3 Radioisotopes: Natural and Man-made
3.3.1.4 Radiation and its Practical Uses
3.3.1.5 Measuring with Radiation
3.3.1.6 The Atomic Detective

3.3.2 #9190 Series - Atomic and Molecular Models

3.3.2.1 Relative Sizes of Atoms
3.3.2.2 Relative Sizes of Ions
3.3.2.3 Sizes and Shapes of Molecules
3.3.2.4 Shapes and Properties of Molecules
3.3.2.5 Construction of Molecular Models

3.4 Stanley Bowman Co., Valhalla, New York

3.4.1

| | | |
|---|---|---|
| 3.4.1.1 | 1051M | Nuclear Radiation; Detectors |
| 3.4.1.2 | 1052M | Nuclear Radiation used in Medicine |
| 3.4.1.3 | 1053M | Nuclear Radiation used in Earth Science |
| 3.4.1.4 | 1054M | Nuclear Radiation used in Outer Space |
| 3.4.1.5 | 1055M | Nuclear Radiation used in Industry |
| 3.4.1.6 | 1056M | Nuclear Radiation - Fallout |
| 3.4.1.7 | 8468 | History of Atomic Concepts (Early Ideas) |
| 3.4.1.8 | 8469 | History of Atomic Concepts (Modern Views) |
| 3.4.1.9 | 8470 | The Nucleus (52) |
| 3.4.1.10 | 8443 | Story of the Atomic Bomb (73) |
| 3.4.1.11 | 8448 | Safety in Atomic Attack (90) |

3.5 Popular Science Publishing Co. - Audio-Visual Div., New York

3.5.1

| | | |
|---|---|---|
| 3.5.1.1 | 1510 | Living Things and Radiation |
| 3.5.1.2 | 1501 | Radioisotopes - A Biological Tool |
| 3.5.1.3 | 595 | Atomic Detectives |
| 3.5.1.4 | 645 | Evolution of the Elements |
| 3.5.1.5 | 582 | What's in the Atom |
| 3.5.1.6 | 593 | What is a Neutron |
| 3.5.1.7 | 651 | Radioactivity |
| 3.5.1.8 | 641 | Radiation Detection |
| 3.5.1.9 | 631 | Particle Accelerators |
| 3.5.1.10 | 568 | Using Atomic Energy for Electric Power |

3.6 Film Strip-of-the Month Club, New York, N.Y.

3.6.1

| | | |
|---|---|---|
| 3.6.1.1 | 568 | Using Atomic Energy for Power |
| 3.6.1.2 | 582 | What's in the Atom |
| 3.6.1.3 | 593 | What is a Neutron |
| 3.6.1.4 | 595 | Atomic Detectives |
| 3.6.1.5 | 612 | Electromagnetic Radiations |

3.7 Educational Audio-Visual, Pleasantville, New York

3.7.1

| | |
|---|---|
| FH3531 | Atoms and their Energy |
| 3.7.1.1 | (a) Atoms, Atoms Everywhere |
| 3.7.1.2 | (b) Elements: What are they |
| 3.7.1.3 | (c) Radioactive Isotopes |
| 3.7.1.4 | (d) Putting Atoms to Work |

3.7.2

| | |
|---|---|
| | Atomic Physics |
| 3.7.2.1 | (a) The Electron |
| 3.7.2.2 | (b) The Positive Particle |
| 3.7.2.3 | (c) The Nucleus |
| 3.7.2.4 | (d) Atom Smashers |
| 3.7.2.5 | (e) Uranium Fission |

4. Film Cartridge or Single-Concept Films (Loops)

4.1 Communication Films Monterey Park, California

| | |
|---|---|
| 4.1.1 #59600-1 | Nuclear Radiation Detectors, Part 1 |
| 4.1.2 #59600-2 | Nuclear Radiation Detectors, Part 2 |
| 4.1.3 #59600-3 | Nuclear Radiation Detectors, Part 3 |
| 4.1.4 #59600-4 | Biological Effects of Nuclear Radiation |
| 4.1.5 #59600-5 | Atmospheric Distribution of Nuclear Fallout |

4.2 Encyclopedia Brittanica Educational Corp., Chicago, Ill.

| | |
|---|---|
| 4.2.1 #R80206 | Chain Reaction |
| 4.2.2 #R80207 | Critical Size |
| 4.2.3 #R80208 | Rutherford Royd's Ident. Alpha particles in Helium |

4.3 Ealing Film Loops, Popular Science Pub. Co., A-V Div., New York

| | |
|---|---|
| 4.3.1 80-200 | Radioactive Decay |

4.4 Life Filmstrips, New York, N.Y.

| | |
|---|---|
| 4.4.1 | The Atom |

# 5. Films

## 5.1 Encyclopedia Brittanica Education Corp., Chicago, Ill.

5.1.1 #2103 The Van Allen Radiation Belts - Exploring in Space
5.1.2 #1673 Explaining Matter: Atoms and Molecules
5.1.3 #1890 Atomic Energy - Inside the Atom
5.1.4 #1888 Electrons at Work

## 5.2 Indiana University A-V Center, Bloomington, Indiana

5.2.1 How Big is an Atom?
5.2.2 What Makes Atoms Stick Together?
5.2.3 Invisible Bullets
5.2.4 Working with Radiation
5.2.5 Searching for the Ultimate (Atom Smashers)
5.2.6 Atomic Furnaces
5.2.7 Tracing Airborne Radioactivity
5.2.8 Tracing Living Cells (Isotope Tracers)

## 5.3 Coronet Films, Chicago, Illinois

5.3.1 Introducing Atoms and Nuclear Energy
5.3.2 Matter and Energy
5.3.3 Atomic Research-Areas and Development
5.3.4 Exploring the Atomic Nucleus
5.3.5 Radiation in Biology: An Introduction

## 5.4 International Film Bureau, Chicago, Ill.

5.4.1 Conquest of the Atom (21FB250)
5.4.2 Discovery of Radioactivity (21FB395)
5.4.3 A New Reality (3/21FB)

## 5.5 Eye Gate House, Jamaica, New York

5.5.1 Atoms and Atomic Energy (177F)

5.6 University of Southern California, Los Angeles, Calif.

5.6.1 Atom Smashers
5.6.2 Atomic Alchemist
5.6.3 Atomic Energy - An Introduction
5.6.4 Atomic Energy - Inside the Atom
5.6.5 Atomic Radiation
5.6.6 Atomic Furnaces
5.6.7 Beyond Uranium
5.6.8 Carbon Fourteen
5.6.9 How Big is an Atom
5.6.10 Isotopes
5.6.11 Jobs in Atomic Energy
5.6.12 Making Elements
5.6.13 Master-Slave
5.6.14 Principles of X-Rays
5.6.15 Radiation - Silent Servant of Mankind

5.7 United World Films, New York, N.Y.

5.7.1 Atom Smashing
5.7.2 Atomic Theory
5.7.3 Controlling Atomic Energy
5.7.4 Nuclear Structure
5.7.5 Particles of Matter
5.7.6 Rays from Atoms
5.7.7 Uranium Fission

5.8 United States Atomic Energy Commission

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NOTE: Parenthetical information following each title indicates- B-Black and White, C-Color, Number-Running time in minutes, I-Recommended for Elementary School, II-Recommended for Junior and Senior High School, III-Recommended for College and University.

5.8.1 A IS FOR ATOM (C-15) I,II
5.8.2 AGRICULTURE, INDUSTRY, AND POWER (B-20) II
5.8.3 ALCHEMIST'S DREAM, THE (B-29) II, III
5.8.4 ALPHA, BETA, AND GAMMA (B-44) II, III
5.8.5 ARMY PACKAGE POWER REACTOR (C-25) II, III
5.8.6 ART OF SEPARATION, THE (B-29) II, III
5.8.7 ATOM AND AGRICULTURE, THE (B-10), II, III
5.8.8 ATOM AND BIOLOGICAL SCIENCE, THE (B-12) II, III
5.8.9 ATOM AND INDUSTRY, THE (B-10) II
5.8.10 ATOM AND THE DOCTOR, THE (B-12) II
5.8.11 ATOM AND YOU, THE (B-16) II
5.8.12 ATOM AND THE WEATHER, THE (B-12) II
5.8.13 ATOM COMES TO TOWN, THE (C-29) II
5.8.14 ATOM IN INDUSTRY, THE (B-12) II, III
5.8.15 ATOM IN PHYSICAL SCIENCE, THE (B-26) II, III
5.8.16 ATOM IN THE HOSPITAL, THE (C-12) II
5.8.17 ATOM SMASHERS (B-12) II
5.8.18 ATOMIC AGE FARMER (B-12) II
5.8.19 ATOMIC ALCHEMIST, THE (B-12) II
5.8.20 ATOMIC BIOLOGY FOR MEDICINE (B-12) II
5.8.21 ATOMIC CITIES (B-12) II
5.8.22 ATOMIC DETECTIVE (B-12) II
5.8.23 ATOMIC ENERGY (B-10) I, II
5.8.24 ATOMIC ENERGY AS A FORCE FOR GOOD (B-25) II
5.8.25 ATOMIC ENERGY CAN BE A BLESSING (B-25) II
5.8.26 ATOMIC FINGERPRINT, THE (B & C-12) II
5.8.27 ATOMIC FURNACES (B-29) II, III
5.8.28 ATOMIC FURNACES (B-12) II
5.8.29 ATOMIC GOLD RUSH (B-12) II
5.8.30 ATOMIC GREENHOUSE, THE (B-12) II
5.8.31 ATOMIC METALLURGY (B-12) II
5.8.32 ATOMIC PHARMACY, THE (B-12) II

5.8.33 ATOMIC PHYSICS (B-90) II, III
5.8.34 ATOMIC POWER AND THE UNITED STATES (B-25) II
5.8.35 ATOMIC POWER PRODUCTION (C-14) II
5.8.36 ATOMIC RESEARCH: AREAS AND DEVELOPMENT (B-12) I, II
5.8.37 ATOMIC TESTS IN NEVADA (C-25) II
5.8.38 ATOMIC VENTURE (C-23) II, III
5.8.39 ATOMIC WEATHERMAN: STRONTIUM-90 ISOTOPIC APPLICATIONS (C-18) II, III
5.8.40 ATOMIC ZOO, THE (B-12) II
5.8.41 ATOMS AT WORK: THE LATIN AMERICAN EXHIBIT (C-14) II
5.8.42 ATOMS FOR HEALTH (B-12) II
5.8.43 ATOMS FOR PEACE (B-17) II
5.8.44 ATOMS FOR PEACE: GENEVA 1958 (B-15) II, III
5.8.45 ATOMS FOR SPACE (C-28) II
5.8.46 ATOMS FOR THE AMERICAS (C-28) III
5.8.47 ATOMS ON THE FARM (C-12) II
5.8.48 BASIC PRINCIPLES OF POWER REACTORS (C-8) II
5.8.49 BETA RAY SPECTROMETER (C-7) III
5.8.50 BIKINI RADIOBIOLOGICAL LABORATORY (C-22) II, III
5.8.51 BORAX: CONSTRUCTION AND OPERATION OF A BOILING WATER REACTOR (B-14) II
5.8.52 BREEDER IN THE DESERT, A (B-29) II, III
5.8.53 BUILDING BLOCKS OF LIFE (B-29) II, III
5.8.54 BUILDING FOR ATOMIC ENERGY (C-21) II, III
5.8.55
5.8.56 CHEMICAL SOMERSAULT, A (B-29) II, III
5.8.57 CLEAN AIR IS A BREEZE (C-16) III
5.8.58 CONTROLLING ATOMIC ENERGY (C-13) I
5.8.59 DAWN'S EARLY LIGHT, A (C-40) II
5.8.60 DOWN ON THE FARM (B-29) II, III
5.8.61 ENGINEERING FOR RADIOISOTOPES (B-21) II
5.8.62 ENVIRONMENTAL TESTING AT SANDIA (C-28) II, III
5.8.63 ETERNAL CYCLE, THE (B-12) II
5.8.64 EXPERIMENTS IN CONTROLLING BRUSH FIRES WITH DETERGENT FOAM (C-6) II, III
5.8.65 FIRE FIGHTING IN THE NUCLEAR AGE (C-14) II, III
5.8.66 FOUNDATIONS FOR THE FUTURE (B-29) II, III
5.8.67 FUEL OF THE FUTURE, THE (B-29) II, III
5.8.68 FULL SPEED AHEAD (C-15) II
5.8.69 GASEOUS DIFFUSION (B-3) II
5.8.70 GAUGING THICKNESS WITH RADIOISOTOPES (B-4) II, III
5.8.71 GIANT OF THE EARTH (B-26) II
5.8.72 GROUP SHELTER (C-10) II, III
5.8.73 HALLAM NUCLEAR POWER FACILITY (C-20) II, III

5.8.74 HANDLE WITH CARE: THE SAFE HANDLING OF RADIOISOTOPES (B-21) II
5.8.75 HARNESSING THE RAINBOW (B-29) II, III
5.8.76 HARVEST OF AN ATOMIC AGE (C-20) II
5.8.77 HIGH ENERGY PEOPLE, THE (C-5) II, III
5.8.78 HIGH ENERGY RADIATIONS FOR MANKIND (C-16) II, III
5.8.79 IMMUNE RESPONSE, THE (B-29) II, III
5.8.80 INDUSTRIAL APPLICATIONS OF NUCLEAR EXPLOSIVES (C-11) II, III
5.8.81 INDUSTRIAL APPLICATIONS OF RADIOISOTOPES (C-57) II, III
5.8.82 INDUSTRIAL ATOM, THE (B-12) II
5.8.83 INTERNATIONAL ATOM, THE (C-27) II
5.8.84 INTRODUCING ATOMS AND NUCLEAR ENERGY (C-11) I, II
5.8.85 INVISIBLE BULLETS (B-29) II, III
5.8.86 ISOTOPES (C-20) II, III
5.8.87 JOBS IN ATOMIC ENERGY (B-12) II
5.8.88 LIVING SOLID, THE (B-29) II, III
5.8.89 LIVING WITH A GLOVED BOX (C-15) III
5.8.90 LIVING WITH RADIATION (C-28) II, III
5.8.91 LIVING WITH THE ATOM (C-18) II
5.8.92 ML-1 MOBILE NUCLEAR POWER PLANT (C-26) II, III
5.8.93 MACHINES THAT THINK (B-29) II, III
5.8.94
5.8.95 MAGNETIC BOTTLE, THE (C-10) II, III
5.8.96 MAN AND RADIATION (C-28) II
5.8.97 MAN AND THE ATOM (C-59) II
5.8.98 MANY FACES OF ARGONNE, THE (C-60) II, III
5.8.99 MASTER SLAVE, THE (B-12) II
5.8.100 MEDICINE (C-20) II
5.8.101 METALS FRONTIER (C-22) II, III
5.8.102 MICROSCOPE FOR THE UNKNOWN (B-29) II, III
5.8.103 NEW POWER, THE (C-45) II, III
5.8.104 NUCLEAR ENERGY GOES RURAL (C-14) II, III
5.8.105 NUCLEAR POWER FOR SPACE - SNAP 9A (C-12) II, III
5.8.106 NUCLEAR REACTIONS (B-29) II, III
5.8.107 NUCLEAR REACTORS FOR RESEARCH (C-15) II, III
5.8.108 NUCLEAR REACTORS FOR SPACE (C-17) II, III
5.8.109 NUCLEAR SHIP SAVANNAH, THE (C-28) II
5.8.110 OF MAN AND MATTER (C-29) II, III
5.8.111 OFFSITE MONITORING OF FALLOUT FROM NUCLEAR TESTS (C-29) II, III
5.8.112 OPERATION CROSSROADS (C-27) II
5.8.113 OPERATION GREENHOUSE (C-25) II

5.8.114 OPERATION IVY (C-28) II
5.8.115 OPERATION SANDSTONE (C-18) II
5.8.116 OPPORTUNITY UNLIMITED: FRIENDLY ATOMS IN INDUSTRY (C-28) II
5.8.117 OUR NEAREST STAR (C-12) II, III
5.8.118 PAX ATOMIS: SNAP-7 TERRESTRIAL ISOTOPIC POWER SYSTEMS (C-25) II, III
5.8.119 PETRIFIED RIVER, THE (C-28) II
5.8.120 PIQUA NUCLEAR POWER FACILITY, THE (C-23) II, III
5.8.121 PM-1 NUCLEAR POWER PLANT (C-20) II, III
5.8.122 PM-3A NUCLEAR POWER PLANT - ANTARCTICA (C-20) II, III
5.8.123 PORTSMOUTH STORY, THE (B-23) II, III
5.8.124 POWER AND PROMISE (C-29) II, III
5.8.125 POWER FOR PROPULSION (C-15) II
5.8.126 POWER UNLIMITED (B-12) II
5.8.127 PRIMER ON MONITORING (C-30) III
5.8.128 PRINCIPLES OF THERMAL, FAST AND BREEDER REACTORS (C-9) II, III
5.8.129 PRODUCTION OF URANIUM FEED MATERIALS (C-28) II, III
5.8.130 PROJECT DUGOUT (C-8) II, III
5.8.131 PROJECT GNOME (C-29) II, III
5.8.132 PROJECT ROVER (C-21) II, III
5.8.133 PROJECT SEDAN (C-8) II, III
5.8.134 PROJECT SHOAL (C-17) II, III
5.8.135 PROPERTIES OF RADIATION (B-30) II, III
5.8.136 PROTECTING THE ATOMIC WORKER (B-12) II
5.8.137 RADIATION AND MATTER (B-44) II, III
5.8.138 RADIATION AND THE POPULATION (B-29) II, III
5.8.139 RADIATION DETECTION BY IONIZATION (B-30) II, III
5.8.140 RADIATION DETECTION BY SCINTILLATION (B-30) II, III
5.8.141 RADIATION IN BIOLOGY: AN INTRODUCTION (C-13) II
5.8.142 RADIATION IN PERSPECTIVE (C-43) II, III
5.8.143 RADIATION PROTECTION IN NUCLEAR MEDICINE (C-45) III
5.8.144 RADIATION SAFETY IN NUCLEAR ENERGY EXPLORATIONS (C-24) II, III
5.8.145 RADIATION: SILENT SERVANT OF MANKIND (B-12) II
5.8.146 RADIOISOTOPE APPLICATIONS IN INDUSTRY (B-26) II, III
5.8.147 RADIOISOTOPE APPLICATIONS IN MEDICINE (B-26) II, III
5.8.148 RADIOISOTOPES IN BIOLOGY AND AGRICULTURE (B-26) II, III
5.8.149 RADIOISOTOPES: SAFE SERVANTS OF INDUSTRY (C-28) II, III
5.8.150 RADIOLOGICAL SAFETY (B-30) II, III
5.8.151 REGULATION OF ATOMIC RADIATION, THE (C-28) II
5.8.152 RIDDLE OF PHOTOSYNTHESIS (B-12) II
5.8.153 ROUNDUP (C-18) II, III
5.8.154 SCIENTIFIC ADVANCEMENT (C-20) II

5.8.155 SEARCH - URANIUM PROSPECTING AND MINING, THE (B-23) II, III
5.8.156 SEARCHING FOR THE ULTIMATE (B-29) II, III
5.8.157 SNAP-III OPERATIONAL TESTS (C-18) II, III
5.8.158 SNAPSHOT (C-29) II, III
5.8.159 STORY OF CAMP CENTURY: CITY UNDER THE ICE, THE (C-32) II
5.8.160 TAGGING THE ATOM (B-12) II
5.8.161 TALE OF TWO CITIES (B-14) II
5.8.162 TARGET NEVADA (C-16) II
5.8.163 TECHNICAL INFORMATION SERVICES OF THE AEC (C-20) II, III
5.8.164 TESTING FOR TOMORROW (B-29) II, III
5.8.165 TIME - THE SUREST POISON (B-29) II, III
5.8.166 TOMORROW'S POWER - TODAY (C-5) I, II
5.8.157 TRACING AIRBORNE RADIOACTIVITY (B-29) II, III
5.8.168 TRACING LIVING CELLS (B-29) II, III
5.8.169 TRAINING MEN FOR THE ATOMIC AGE (B-20) II, III
5.8.170 UNDER WAY (C-20) II
5.8.171
5.8.172 UNLOCKING THE ATOM (B-20) II
5.8.173 WORKING TOGETHER (B-20) II
5.8.174 WORKING WITH RADIATION (B-29) II, III
5.8.175 WORLDS WITHIN, THE (C-29) II, III
5.8.176 ATOMIC ENERGY FOR SPACE (C-17) II
5.8.177 ATOMS ON THE MOVE: TRANSPORTATION OF RADIOACTIVE MATERIALS (C-24) II, III
5.8.178 ATOMIC POWER TODAY: SERVICE WITH SAFETY (C-28) II, III
5.8.179 FARM FRESH TO YOU (C-13) II, III
5.8.180 FIRST REACTOR IN SPACE: SNAP-10A (C-14) I, II, III
5.8.181 FRESHER THE BETTER, THE (C-13) II, III
5.8.182 NUCLEAR WITNESS, THE: ACTIVATION ANALYSIS IN CRIME INVESTIGATION (C-28) III
5.8.183 PLOWSHARE (C-28) II, III
5.8.184 RADIOISOTOPE SCANNING IN MEDICINE (C-16) III
5.8.185 R-A-P: RADIOLOGICAL ASSISTANCE PROGRAM (C-26) III
5.8.186 RETURN TO BIKINI (C-23) II, III
5.8.187 SAFETY IN THE PLOWSHARE PROGRAM (C-22) III
5.8.188 SNAP-8: SYSTEM FOR NUCLEAR AUXILIARY POWER (C-10) II, III
5.8.189 TOMORROWS SCIENTISTS AT ARGONNE (C-13) II, III

## 6.0 RADIOISOTOPES - DISCUSSION

1. The word "isotope" derives from two Greek words meaning "the same place" and refer to atoms of an element which have the same place in the Periodic Table as other atoms of that element but which have a different atomic weight. The existence of these was discovered by Frederick Soddy in England, Theodore Richards in the United States and Kasimir Fajans in Germany, all working independently of each other. The name "isotope" was coined by Soddy and has, of course, been in common use ever since.

   It is not intended that the purview of the discussion here should cover exhaustively the entire field of isotopes. Suffice it to say that there are two broad classifications, (a) natural isotopes and, (b) artificial isotopes. The first occur in nature to varying extents. That is, some elements have only one natural form while others have a number of isotopes all occurring naturally.

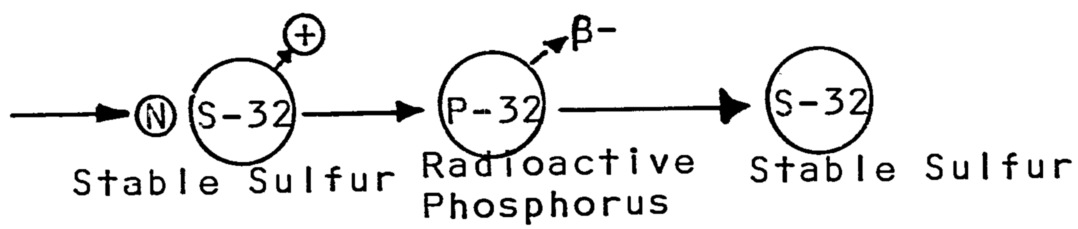
   Artificial isotopes are those which are man-made and radioactive. It is these with which we are to be concerned here. Even here we must limit our considerations as a matter of practicality. Although over one-thousand radioisotopes have been made artificially, only about 150 are sold commercially and of these, approximately 20 (or less) will find their way into the high school laboratory.

2. The power of a nuclear reactor like that of a nuclear bomb comes from the energy released when atoms fission in a chain reaction. The factor differentiating the reactor from the bomb is that its chain reaction is controlled. Its utility as regards the production of radioisotopes however, stems from the fact that the reactor makes available predictable quantities of neutrons.

   Generally speaking, any stable substance exposed to neutron bombardment becomes radioactive hence, the subjecting of various elements to such bombardment produces radioisotopes. Again, as a generalization, a material to be irradiated is placed in an aluminum capsule which is in turn inserted into the body of a reactor and allowed to remain there for a predetermined length of time. At the end of that time the capsule is removed. Through a series of chemical and physical separations the radioisotope is isolated and packaged for shipment and subsequent use as a tracer element, as a therapeutic or diagnostic medium, incorporated into a compound for research purposes, etc. This is an oversimplification of course. Perhaps a concrete example of specific radioisotope production will serve well to illustrate the processes involved.

The importance of phosphorus in biological systems is well recognized. Aside from its role in biological structural materials such as bone, phosphorus plays an important role in the storage and transfer of energy in biological reactions and synthetic pathways. While the simple element phosphorus has one stable isotope with a mass number of 31, five radioactive isotopes of phosphorus are known. Only P-32 and P-33 are sufficiently long-lived to be effectively used as tracers and only P-32 has been used to any extent.

Phosphorus-32 is produced in a reactor by bombarding sulfur with neutrons. The reaction proceeds by the capture of a neutron by the nucleus of the sulfur atoms, followed by the release of a proton. In the preparation of Phosphorus-32, highly purified sulfur is irradiated. After irradiation the sulfur is fused and mixed with acetic acid to produce phosphoric acid in the resultant melt. The phosphoric acid is then recovered by distillation and purified. Carrier-free phosphoric acid is usually prepared through the use of an ion-exchange resin to remove cations. Pictorially, the production and subsequent decay is as follows:




In the study of biological systems, radioactive carbon-14 has proven to be the most important single tracer isotope. This utility is obvious in view of the universality of carbon as a central element in biological systems.

The most commonly used production method for this radioisotope is the bombardment of a suitable nitrogen ($N^{14}$) target with slow neutrons. In this reaction a target material such as boron nitride or beryllium nitride is bombarded with neutrons in a reactor. The unstable neucleus thus formed will then expel a proton. The reaction may be written as follows:

$$_{7}N^{14} + {_o}n^{1} \dashrightarrow {_6}C^{14} + H^{1}$$

Currently, production procedures are based on the use of solid beryllium nitride as a target material. Following irradiation, extraction and conversion, the isotope is supplied generally in the form of barium carbonate and may contain 10 to 20 per cent as C-14.

It should be mentioned here that radioisotopes can also be made by particle accelerators which are used to bombard the target material with protons of deuterons. In general, this is a very expensive method for such production. Firstly, because the operation of the equipment necessary for this procedure is costly and secondly, because the yield of radioisotopic material is small. Nevertheless, this may still be the most expedious method for the production of some isotopes e.g., Sodium-22, Sodium-24, Cobalt-57, etc.

3. On August 2, 1946 the National Laboratories at Oak Ridge, Tennessee shipped a small amount of C-14. Since that time many thousands of shipments of radioisotopes have been made to hospitals, educational institutions, and private industry. For many years following that 1946 shipment, Oak Ridge remained as the major producer and supplier of radioisotopic material. As a matter of government policy, the U. S. Atomic Energy Commission, which governed the operation of the Oak Ridge laboratory and other similar installations, continued to supply radioactive material until such time as private industry was both willing and able to assume this function. In recent years the production of many radioisotopes has been discontinued as a function of the national laboratories and are now available through commercial suppliers. Some radioisotopes which industry could not distribute economically are still supplied by government laboratories as well as very large activities of some others.

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 6.1 | Atomic Corporation of America<br>7901 San Fernando Road<br>Sun Valley, California | Radioisotopes | |
| 6.1.1 | | Iodine-131, 10 microcuries | 110 |
| 6.1.2 | | Phosphorus-32, 10uc | 205 |
| 6.1.3.1 | | Calcium-45, 1uc | 310 |
| 6.1.3.2 | | Calcium-45, 10uc | |
| 6.1.4.1 | | Carbon-14, 1uc | 330 |
| 6.1.4.2 | | 10uc | |
| 6.1.4.3 | | 50uc | |
| 6.1.5 | | Cesium-137, 1uc | 350 |
| 6.1.6 | | Chlorine-36, 1uc | 370 |
| 6.1.7.1 | | Chromium-51, 1uc | 390 |
| 6.1.7.2 | | 10uc | |
| 6.1.7.3 | | 50uc | |
| 6.1.8 | | Cobalt-60, 1uc | 400 |
| 6.1.9 | | Iron-59, 1uc | 430 |
| 6.1.10 | | Nickel-63, 1uc | 450 |
| 6.1.11.1 | | Sodium-22, 1uc | 510 |
| 6.1.11.2 | | 10uc | |
| 6.1.12 | | Strontium-90, .1uc | 535 |
| 6.1.13.1 | | Sulfur-35, 1uc | 550 |
| 6.1.13.2 | | 10uc | |
| 6.1.13.3 | | 50uc | |
| 6.1.14.1 | | Thallium-204, 1uc | 570 |
| 6.1.14.2 | | 10uc | |
| 6.1.14.3 | | 50uc | |
| 6.1.15 | | Cerium-144, 1uc | |
| 6.1.16.1 | | Zinc-65, 1uc | 610 |
| 6.1.16.2 | | 10uc | |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 6.1.1 | Activity contained in 5ml. aqueous solution. | 5.00 | A | Stock | |
| 6.1.2 | " | 5.00 | A | Stock | |
| 6.1.3.1 | " | 5.00 | A | Stock | |
| 6.1.3.2 | " | 6.00 | A | Stock | |
| 6.1.4.1 | " | | A | Stock | |
| 6.1.4.2 | " | 5.00 | A | Stock | |
| 6.1.4.3 | " | 6.00 | A | Stock | |
| 6.1.5 | " | 5.00 | A | Stock | |
| 6.1.6 | " | 8.00 | A | Stock | |
| 6.1.7.1 | " | | A | Stock | |
| 6.1.7.2 | " | 5.00 | A | Stock | |
| 6.1.7.3 | " | 6.00 | A | Stock | |
| 6.1.8 | " | 5.00 | A | Stock | |
| 6.1.9 | " | 5.00 | A | Stock | |
| 6.1.10 | " | 5.00 | A | Stock | |
| 6.1.11.1 | " | 6.00 | A | Stock | |
| 6.1.11.2 | " | 20.00 | A | Stock | |
| 6.1.12 | " | 5.00 | A | Stock | |
| 6.1.13.1 | | | A | Stock | |
| 6.1.13.2 | " | 5.00 | A | Stock | |
| 6.1.13.3 | " | 6.00 | A | Stock | |
| 6.1.14.1 | | | A | Stock | |
| 6.1.14.2 | " | 5.00 | A | Stock | |
| 6.1.14.3 | " | 6.00 | A | Stock | |
| 6.1.15 | " | 6.00 | A | Stock | |
| 6.1.16.1 | " | 5.00 | A | Stock | |
| 6.1.16.2 | " | 6.00 | A | Stock | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 6.2 | Macalaster Scientific Corp.<br>Watertown, Massachusetts | Radioisotopes | |
| 6.2.1 | | Iodine-131, 10uc | 17231 |
| 6.2.2 | | Phosphorus-32, 10uc | 17232 |
| 6.2.3 | | Calcium-45, 10uc | 17235 |
| 6.2.4 | | Carbon-14, 50uc | 17207 |
| 6.2.5 | | Cesium-137, 1uc | 17210 |
| 6.2.6 | | Chlorine-36, 1uc | 17223 |
| 6.2.7 | | Cobalt-60, 1uc | 17209 |
| 6.2.8 | | Iron-59, 1uc | 17240 |
| 6.2.9 | | Nickel-63, 1uc | 17214 |
| 6.2.10 | | Sodium-22, 10uc | 17213 |
| 6.2.11 | | Strontium-90, 0.1uc | 17218 |
| 6.2.12 | | Sulfur-35, 50uc | 17217 |
| 6.2.13 | | Thallium-204, 50uc | 17219 |
| 6.2.14 | | Zinc-65, 10uc | 17246 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 6.2.1 | | 7.00 | A | | |
| 6.2.2 | | 7.00 | A | | |
| 6.2.3 | | 7.00 | A | | |
| 6.2.4 | Barium Carbonate | 7.00 | A | | |
| 6.2.5 | | 7.00 | A | | |
| 6.2.6 | | 7.00 | A | | |
| 6.2.7 | | 7.00 | A | | |
| 6.2.8 | | 7.00 | A | | |
| 6.2.9 | | 7.00 | A | | |
| 6.2.10 | | 7.00 | A | | |
| 6.2.11 | | 7.00 | A | | |
| 6.2.12 | | 7.00 | A | | |
| 6.2.13 | Not Listed | | | | |
| 6.2.14 | | 7.00 | A | | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 6.3 | General Radioisotope Processing Co.<br>Richmond, Calif. | | |
| 6.3.1 | | Iodine-131, 10uc | 223 |
| 6.3.2 | | Phosphorus-32, 10uc | 227 |
| 6.3.3 | | Calcium-45, 10uc | 113 |
| 6.3.4 | | Carbon-14, 50uc | 117 |
| 6.3.5 | | Cesium-137, 1uc | 125 |
| 6.3.6 | | Chlorine-36, 0.5uc | 126 |
| 6.3.7 | | Chromium-51, 50uc | 126-2 |
| 6.3.8 | | Cobalt-60, 1uc | 129 |
| 6.3.9 | | Nickel-63, 1uc | 142 |
| 6.3.10 | | Sodium-22, 10uc | 157 |
| 6.3.11 | | Strontium-90, 0.1uc | 161 |
| 6.3.12 | | Sulfur-35, 50uc | 165 |
| 6.3.13 | | Thallium-204, 50uc | 169 |
| 6.3.14 | | Cerium-144, 1uc | 121 |
| 6.3.15 | | Zinc-65, 10uc | 177 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 6.3.1 | | 8.00 | A | Stock | |
| 6.3.2 | | 8.00 | A | Stock | |
| 6.3.3 | | 6.00 | A | Stock | |
| 6.3.4 | | 6.00 | A | Stock | |
| 6.3.5 | | 6.00 | A | Stock | |
| 6.3.6 | | 3.00 | A | Stock | |
| 6.3.7 | Not Listed | | | | |
| 6.3.8 | | 6.00 | A | Stock | |
| 6.3.9 | | 6.00 | A | Stock | |
| 6.3.10 | | 20.00 | A | Stock | |
| 6.3.11 | | 6.00 | A | Stock | |
| 6.3.12 | | 6.00 | A | Stock | |
| 6.3.13 | | 6.00 | A | Stock | |
| 6.3.14 | | 6.00 | A | Stock | |
| 6.3.15 | | 6.00 | A | Stock | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 6.4 | Iso-Serv Div. Cambridge Nuclear Cambridge, Massachusetts. | | |
| 6.4.1 | | Iodine-131, 10uc | CN-5315-S |
| 6.4.2 | | Phosphorus-32, 10uc | CN-1525-S |
| 6.4.3 | | Calcium-45, 10uc | CN-2055-S |
| 6.4.4 | | Carbon-14, 50uc | CN-0645-S |
| 6.4.5 | | Cesium-137, 1uc | CN-5575-S |
| 6.4.6 | | Chlorine-36, 1uc | CN-1765-S |
| 6.4.7 | | Chromium-51, 50uc | CN-2415-S |
| 6.4.8 | | Cobalt-60, 1uc | CN-2705-S |
| 6.4.9 | | Iron-59, 1uc | CN-2645-S |
| 6.4.10 | | Nickel-63, 1uc | CN-2835-S |
| 6.4.11 | | Sodium-22, 10uc | CN-1125-S |
| 6.4.12 | | Strontium-90, 0.1uc | CN-3805-S |
| 6.4.13 | | Thallium-204, 50uc | CN-8145-S |
| 6.4.14 | | Cerium-144, 1uc | CN-5845-S |
| 6.4.15 | | Zinc-65, 10uc | CN-3055-S |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 6.4.1 | | 6.00 | A | | |
| 6.4.2 | | 6.00 | A | | |
| 6.4.3 | | 6.00 | A | | |
| 6.4.4 | | 6.00 | A | | |
| 6.4.5 | | 6.00 | A | | |
| 6.4.6 | | 15.00 | A | | |
| 6.4.7 | | 6.00 | A | | |
| 6.4.8 | | 6.00 | A | | |
| 6.4.9 | | 6.00 | A | | |
| 6.4.10 | | 6.00 | A | | |
| 6.4.11 | | 6.00 | A | | |
| 6.4.12 | | 6.00 | A | | |
| 6.4.13 | | 6.00 | A | | |
| 6.4.14 | | 6.00 | A | | |
| 6.4.15 | | 6.00 | A | | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 6.5 | Atomic Accessories Div.<br>Baird Atomic, Cambridge, Mass. | | |
| 6.5.1 | | Carbon-14, 50uc | EL 1 |
| 6.5.2 | | Sodium-22, 1uc | EL 2 |
| 6.5.3 | | Chlorine-36, 1uc | EL 3 |
| 6.5.4 | | Manganese-54, 1uc | EL 4 |
| 6.5.5 | | Iron-55, 10uc | EL 5 |
| 6.5.6 | | Cobalt-57, 1uc | EL 6 |
| 6.5.7 | | Cobalt-60, 1uc | EL 7 |
| 6.5.8 | | Zinc-65, 10uc | EL 8 |
| 6.5.9 | | Nickel-63, 1uc | EL 9 |
| 6.5.10 | | Strontium-90, 0.1uc | EL 10 |
| 6.5.11 | | Cesium-137, 1uc | EL 11 |
| 6.5.12 | | Barium-133, 1uc | EL 12 |
| 6.5.13 | | Promethium-147, 10uc | EL 13 |
| 6.5.14 | | Thallium-204, 50uc | EL 14 |
| 6.5.15 | | Lead-210, 10uc | EL 15 |
| 6.5.16 | | Uranyl Nitrate, 5 gms. | EL 16 |
| 6.5.17 | | Iodine-131, 10uc | EL 17 |
| 6.5.18 | | Phosphorus-32, 10uc | EL 18 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 6.5.1 | Cost: 50.00 for choice of any 6 sources.<br>100.00 for choice of any 15 sources. | | A | | |
| 6.5.2 | | | | | |
| 6.5.3 | | | | | |
| 6.5.4 | | | | | |
| 6.5.5 | | | | | |
| 6.5.6 | | | | | |
| 6.5.7 | | | | | |
| 6.5.8 | | | | | |
| 6.5.9 | | | | | |
| 6.5.10 | | | | | |
| 6.5.11 | | | | | |
| 6.5.12 | | | | | |
| 6.5.13 | | | | | |
| 6.5.14 | | | | | |
| 6.5.15 | | | | | |
| 6.5.16 | | | | | |
| 6.5.17 | | | | | |
| 6.5.18 | | | | | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 7.1.1 | Atomic Corporation of America | Autoradiography Kit | AR-1 |
| 7.1.2 | | Fallout Detection Kit | AK-5 |
| 7.2.1 | Baird Atomic | Autoradiography Kit | 916-357 |
| 7.3.1 | Nuclear-Chicago | Autoradiography Kit | 180150 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 7.1.1 | Film (8 pieces), developer, fixer, trays, sandwich boards, rubber bands, film hangers, instructions. | 5.00 | A | Stock | Requires no darkroom facilities |
| 7.1.2 | Film, fallout tray, developer, fixer, reference source, instructions. | 3.00 | A | Stock | |
| 7.2.1 | Kit with film, source, developer, fixer, holders, darkroom lamp and signs. | 55.00 | A | | Requires darkroom facilities |
| 7.3.1 | Film (6 pieces), print roller, print coater, bean seeds, source, instructions. | 18.00 | A | | Requires darkroom facilities |

## 8.0 DISCUSSION - INSTRUMENTATION

Some comments about Instrumentation might be useful to the reader of a report such as this as regards the manner in which available instrumentation functions in the detection of nuclear events. The importance of such a function lies in the fact that atomic and nuclear radiations cannot be detected by human senses directly therefore, some mechanism must be interposed between the nuclear event and the senses in order to produce an awareness in an observer that such an event has occurred. Most mechanisms which are in current use are designed to detect radiations through their interactions with matter. The principal effect of these interactions is the formation of ions and it is the detection of ions that forms the basis for radiation detectors.

An ion is a charged particle which has been produced by its interaction with another charged particle thus leaving it with an unbalanced charge (positive or negative). For example, a charged particle passing close to an atom, may push or pull an electron from an outer orbit about that atom. The atom now missing an electron has a positive charge and the ejected free electron is a negative ion. Considered together they are an "ion pair".

The most common radiation detectors in current use fall generally into five types:

1. Photographic emulsion. Historically, this was the method first used by Henri Bacquerel in 1895 to detect radiation. An ionized particle passing through a photographic emulsion sets up a photochemical reaction similar to that of light thus causing a blackening of the film. Although it is possible to detect a single nuclear event through the medium of auto-radiography the process is usually applied to the visualization of a relatively large number of these events. For example, in tracing the path of radioactive material through a biological system, the specimen containing the radioactive material is applied to the film for a time after which the film is developed and fixed in the normal manner.

2. Cloud Chamber - a cylinder capped at the bottom end and covered with a transparent "view plate" containing a supersaturated atmosphere of alcohol or other vapor. As the charged particles enter the chamber they create ions which serve as nuclei on which the vapor condenses to form a visible trail similar to those left by airplanes flying at high altitudes.

The various radiations give vapor trails differing in appearance because of the variation in the number of ion pairs produced per unit length of the path. Alpha particles yield short, thick paths, while high-energy beta particles produce long, thin trails.

3. Electroscope (quartz-fiber type) - These are 'instruments' which do not require a continuous external voltage for their operation. An extremely thin quartz fiber is mounted inside a metal ionization chamber and charged from a battery or other source of direct voltage. Mutual repulsion causes the fiber to deflect away from the mounting. Ions formed inside the chamber will neutralize the charge and the fiber will return to its uncharged position. Thus, introducing a radioactive source into an electroscope chamber containing a charged fiber will neutralize that charge at a rate commensurate with the amount of activity contained in that source.

4. Geiger Counters - the common Geiger tube is a gas-filled tube having a central wire as an anode and an outer cylinder as a cathode. A charged particle entering the Geiger tube ionizes the gas. These ions are then attracted to the electrode oppositely charged. As the ions speed toward the electrodes they in turn cause a cascade of further or secondary ionization in the gas within the tube. At the high voltage maintained in the circuit, one ion pair is enough to produce an avalanche of ions which results in a surge of current in the circuit. Each pulse of current received is registered on a suitable meter and represents the detection of a single charged particle entering the Geiger tube.

Although the above discussion is admittedly an oversimplification, it does nevertheless describe in general terms, the basis for the majority of nuclear detection instruments now in common use.

5. Scientillation counters. Scintillations are light flashes given off when certain radiations strike a material known as a phosphor. As the radiation strikes a phosphor, part of the energy which causes excitation and ionization is emitted as visible light. Each individual light flash or scintillation indicates the collision of a particle with the phosphor. In the counter arrangement the individual scintillations are detected and amplified by a photomultiplier tube. The resultant output is fed into a suitable counter instrument for readout.

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
| --- | --- | --- | --- |
| 8.1.1 | Atomic Corporation of America<br>Sun Valley, Calif. | Cloud Chamber | Atomajor |
| 8.1.2 | | Cloud Chamber | Atominor |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.1.1 | Glass chamber, with clearing field connections and sources | 35.00 | B | Stock | |
| 8.1.2 | Plastic chamber, with alpha and beta sources | 2.50 | A | Stock | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.2.1 | Atomic Laboratories Div. Central Scientific Co., Chicago, Ill. | Geiger Counter -- Ratemeter | 71236 |
| 8.2.2 | | Scaler | 71208 |
| 8.2.3 | | Scaler | 71211 |
| 8.2.4 | | Ratemeter | 71201 |
| 8.2.5 | | Ratemeter | 71202 |
| 8.2.6 | | G-M Tube | 71227 |
| 8.2.7 | | G-M Tube | 71218 |
| 8.2.8 | | G-M Probe | 71203 |
| 8.2.9 | | G-M Probe | 71204 |
| 8.2.10 | | Sample Holder | 71207 |
| 8.2.11 | | Timer | 73425-1 |
| 8.2.12 | | Diffusion Cloud Chamber | 71856 |
| 8.2.13 | | Scaler | 71295 |
| 8.2.14 | | Radioisotope Milker | 71224-4 |
| 8.2.15 | | Radioisotope Milker | 71224-5 |
| 8.2.16 | | Radioisotope Milker | 71224-6 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.2.1 | Comb. Alpha, Geiger ratemeter and Neutron detector. | 450.00 | C | -- | Portable |
| 8.2.2 | Transistorized scaler less G-M Tube & Probe | 295.00 | B | Stock | AC Power |
| 8.2.3 | Transistorized scaler less G-M Tube & Probe | 305.00 | B | Stock | Battery Oper. |
| 8.2.4 | Transistorized ratemeter less tube & probe | 179.50 | B | Stock | AC Power |
| 8.2.5 | Transistorized ratemeter less tube & probe | 192.50 | B | Stock | Battery Oper. |
| 8.2.6 | Side Window | 14.50 | B | Stock | |
| 8.2.7 | End Window | 61.00 | B | Stock | |
| 8.2.8 | Standard Side-Window Probe | 12.50 | B | Stock | |
| 8.2.9 | End-Window Probe | 18.00 | B | Stock | |
| 8.2.10 | Aluminum holder with 9 planchet positions | 22.50 | B | Stock | |
| 8.2.11 | Electric interval type -- Sweep hand | 25.00 | B | Stock | |
| 8.2.12 | Glass chamber | 32.50 | B | Stock | Clearing field connections. |
| 8.2.13 | Transistorized, with all accessories | 795.00 | B | Stock | Incl. liq. & sealed sources Scaler without access. $495.00 |
| 8.2.14 | Barium-137--Cesium-137 | 40.00 | B | Stock | Inc. Generator resin & manual |
| 8.2.15 | Yttrium-90--Strontium-90 | 40.00 | B | Stock | |
| 8.2.16 | Praseodymium-144--Cerium-144 | 40.00 | B | Stock | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.3.1 | Baird Atomic (Atomic Accessories, Inc.) Cambridge, Massachusetts | Scaler System | 916-344 |
| 8.3.2 | | Scaler System | 916-345 |
| 8.3.3 | | Scaler System | 916-346 |
| 8.3.4 | | Scaler System | 916-345 |
| 8.3.5 | | Backscatter Kit | 916-02 |
| 8.3.6 | | Electroscope-Radioassay | 916-10 |
| 8.3.7 | | Diffusion Cloud Chamber | 916-27 |
| 8.3.8 | | Ratemeter | 916-43 |
| 8.3.9 | | Ratemeter | 912-434 |
| 8.3.10 | | Projection Meter | 916-365 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.3.1 | "Scalette" system for physics | 405.00 | B | Unknown | Incl. all acces. and instruct. manual. |
| 8.3.2 | "Scalette" system for biology | 415.00 | B | Unknown | Incl. all acces. and instruct. manual. |
| 8.3.3 | "Scalette" system for chemistry | 435.00 | B | Unknown | Incl. all acces. and instruct. manual |
| 8.3.4 | Application kit for wear testing, thickness gauging, etc. | 415.00 | B | Unknown | Incl. access. sources and instruct. man. |
| 8.3.5 | For use with "Scalette" systems | 45.00 | B | Unknown | |
| 8.3.6 | | 150.00 | B | Unknown | Sources and exper. book. |
| 8.3.7 | Glass chamber | 39.50 | B | Unknown | |
| 8.3.8 | Kit for physics | 230.00 | B | Unknown | Sources and exper. book. |
| 8.3.9 | Kit for biology | 235.00 | B | Unknown | |
| 8.3.10 | Adaptor for overhead projection of ratemeter readings. (Model 912-434) | 35.00 | B | Unknown | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.3.11 | Baird Atomic (Cont'd) | G-M Counting Kit | EK-I |
| 8.3.12 | | G-M Counting Kit | EK-II |
| 8.3.13 | | Radiochromatography Kit | -- |
| 8.3.14 | | G-M System | EK-III |
| 8.3.15 | | Gas Flow System | EK-V |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.3.11 | General purpose scaler and accessories | 615.00 | B | Unknown | Timer, stand cable, detector, sources & signs. |
| 8.3.12 | General purpose scaler and accessories | 740.00 | B | Unknown | Incl. more source planchets, pipett absorber set. |
| 8.3.13 | Ratemeter with motor-driven chart recorder | 600.00 | C | Unknown | |
| 8.3.14 | Scaler with all accessories including autoradiography kit packed in heavy-duty suitcase. | 690.00 | C | Unknown | Incl. gas flow |
| 8.3.15 | Scaler with all accessories for gas-flow counting, includes autoradiography | 890.00 | C | Unknown | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.4.1 | Educational Materials and Equipment | Cloud Chamber | EME |
| 8.4.2 | | Scaler | EME |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.4.1 | Glass chamber with AC light source Clearing Field | 36.45 | B | Unknown | |
| 8.4.2 | Solid-state decade scaler with accessories | 390.00 | B | | No tube stand |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.5.1 | Macalaster Scientific Corp., Watertown, Mass. | Binary Scaler and G-M Tube | 55030 |
| 8.5.2 | | Electric Stopwatch | 2482 |
| 8.5.3 | | Diffusion Cloud Chamber | 17100 |
| 8.5.4 | | G-M Tube, Miniature, Halogen Type | 55020 |
| 8.5.5 | | Electroscope, Radioassay | 17182 |
| 8.5.6 | | Electroscope Equipment (assortment) | 17185 |



2

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.5.1 | Four-stage, solid-state, electronic binary counter | 145.00 | B | In Stock | |
| 8.5.2 | Five digit odometer | 49.50 | B | In Stock | Adaptable to scaler |
| 8.5.3 | Plastic chamber | 3.00 | B | In Stock | |
| 8.5.4 | Thin end-window | 30.00 | B | In Stock | |
| 8.5.5 | | 100.00 | B | In Stock | |
| 8.5.6 | Electroscope plus accessories | 130.00 | B | In Stock | Sealed sources, planchets and absorbers. |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.6.1 | Nuclear Corp. of America, Denville, N.J. | Scaler | BC-594A |
| 8.6.2 | The Nucleus, Oak Ridge, Tenn. | Ratemeter | LL |
| 8.6.3 | | Scaler | KK |
| 8.6.4 | | Timer | ET-100 |
| 8.6.5 | | Cloud Chamber | C-200 |
| 8.6.6 | | Electroscope Kit | ES-1 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.6.1 | Solid-state binary scaler, built-in timer | | B | Unknown | |
| 8.6.2 | Ratemeter with accessories and source | 220.00 | B | Stock | |
| 8.6.3 | Solid-state scaler with accessories | 370.00 | B | Stock | |
| 8.6.4 | Timer for Model KK scaler | 45.00 | B | Stock | |
| 8.6.5 | Glass chamber | 34.00 | B | Stock | |
| 8.6.6 | Quartz-fiber type with accessories | 125.00 | B | Stock | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.7.1 | Picker Nuclear, Los Angeles, Calif. | Scaler | 620-009 |
| 8.7.2 | | Scaler | 620-008 |
| 8.7.3 | | Scaler | 620-007 |
| 8.7.4 | | Scaler-Ratemeter | 620-006 |
| 8.7.5 | | Scaler | 600-010 |
| 8.7.6 | | Ratemeter | 600-012 |
| 8.7.7 | | Sample Spinner | 25-0410 |
| 8.7.8 | | G-M Survey Meter | 600-180 |
| 8.7.9 | | Labmonitor (Survey Meter) | 600-081 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
| --- | --- | --- | --- | --- | --- |
| 8.7.1 | Scaler training kit with accessories and manual. | | B | | |
| 8.7.2 | Flow-counter training system with access. and manual. | | C | | |
| 8.7.3 | Well-type scintillation training system with accessories and manual. | | C | | |
| 8.7.4 | Scaler with separate connected ratemeter with accessories and manual. | | C | | |
| 8.7.5 | Solid-state scaler used in above systems. | | C | | |
| 8.7.6 | Solid-state ratemeter, 5 ranges, designed for operation with Model 600-010 scaler. | | C | | |
| 8.7.7 | | | C | | |
| 8.7.8 | Solid-state with detachable probe. | | C | | |
| 8.7.9 | Survey meter for lab. use - End window. | | C | | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.8.1 | Rayscope Company | Geiger Counter | DG-7 |
| 8.8.2 | | Geiger Counter | DG-2 |
| 8.8.3 | | Scintillation Counter | DS-235 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.8.1 | G-M counter, detachable probe | 150.00 | B | | |
| 8.8.2 | G-M counter with built-in detector | 115.00 | B | | |
| 8.8.3 | Gun-type | 515.00 | B | | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.9.1 | Tracerlab, Richmond, Calif. | Scaler | GCS-1 |
| 8.9.2 | | Scaler | GFS-2 |
| 8.9.3 | | Scaler | SDS-3S |
| 8.9.4 | | Scaler | SDS-3W |
| 8.9.5 | | Scaler | UCS-4S |
| 8.9.6 | | Scaler | UCS-4W |
| 8.9.7 | | Scaler | 131NA |
| 8.9.8 | | Dual Timer | T1 |
| 8.9.9 | | Interval Timer | T3 |
| 8.9.10 | | Detector Stand | TS-1 |
| 8.9.11 | | Lead Shield | LS-1 |
| 8.9.12 | | Absorber Kit | AB-1 |
| 8.9.13 | | Absorber Kit | AB-2 |
| 8.9.14 | | Ratemeter | 231A |
| 8.9.15 | | Scaler | 132M |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.9.1 | Scaler with accessories and source | 645.00 | B | | |
| 8.9.2 | Gas-Flow counting system | 810.00 | C | | |
| 8.9.3 | Solid Scintillation counting system | 870.00 | C | | |
| 8.9.4 | Well scintillation counting system | 870.00 | C | | |
| 8.9.5 | G-M and scintillation counting system | 1270.00 | C | | |
| 8.9.6 | Well scintillation and G-M counting system | 1270.00 | B | | |
| 8.9.7 | Solid-state scaler | 450.00 | B | | |
| 8.9.8 | Timer, 1sec. -60min. with automatic scaler shutoff. | 95.00 | B | | |
| 8.9.9 | Synchronous timer, scaler-controlled | 50.00 | B | | |
| 8.9.10 | Universal detector stand, 7 shelf positions | 40.00 | B | | |
| 8.9.11 | Shield for TS-1 Stand | 45.00 | B | | |
| 8.9.12 | 10 Aluminum absorbers in case. | 40.00 | B | | |
| 8.9.13 | 31 Absorbers (24-Al, 6-Pb, 1-blank) | 85.00 | B | | |
| 8.9.14 | | 475.00 | C | | |
| 8.9.15 | Solid-state | 1395.00 | C | | |

| CODE NO. | SUPPLIER | ITEM | CAT. NO. |
|---|---|---|---|
| 8.10.1 | Welch Scientific Co., Skokie, Ill. | Scaler Kit | 2190 |
| 8.10.2 | | G-M Tube | 2190F |
| 8.10.3 | | Scaler | 2190B |
| 8.10.4 | | Tube mount and reference source | 2190G |
| 8.10.5 | | Ratemeter | 2192 |
| 8.10.6 | | Ratemeter | 2192B |
| 8.10.7 | | G-M Tube | 2192C |
| 6.10.1<br>9.10.1 | | Accessory Kit | 2190H |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.10.1 | Scaler, GM End-window tube, 6 sources Tube holder, etc. | 495.00 | B | | |
| 8.10.2 | End-window, halogen-quenched, 1.4mg. window | 62.50 | B | | |
| 8.10.3 | Model 2190 Scaler minus accessories | 345.00 | B | | |
| 8.10.4 | Aluminum tube mount plus $Ra^{226}$ source | 49.50 | B | | |
| 8.10.5 | Ratemeter with side-window GM tube and probe, 2 Radium sources, Absorber kit, etc. | 194.00 | B | | |
| 8.10.6 | Ratemeter minus accessories | 169.50 | B | | |
| 8.10.7 | Side-window tube (beta-gamma) | 24.50 | B | | |
| 6.10.1<br>9.10.1 | 6 Isotopes ($C^{14}$, $Zn^{65}$, $Pb^{210}$, $Ca^{45}$, $Co^{60}$, $Ce^{144}$), planchets, micropipettes, etc. | 59.50 | B | | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.11.1 | Nuclear Equipment and Chemical Corp. | Scaler System | 2201-4 |
| 8.11.2 | | Scaler System | 2201-5 |
| 8.11.3 | | G-M Thin-window Probe | 2210 |
| 8.11.4 | | Scintillation Probe | 2211 |
| 8.11.5 | | Sample Stand for Scintillation Probe | 2212 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.11.1 | Scaler, absorber set, timer, sources and manual. Less GM tube. (Built-in sample holder.) | 475.00 | B | Stock | 4-decade |
| 8.11.2 | Scaler and accessories as above. | 525.00 | B | Stock | 5-decade |
| 8.11.3 | | 75.00 | B | Stock | |
| 8.11.4 | 1"x1" NaI Crystal | 195.00 | C | Stock | |
| 8.11.5 | | 35.00 | C | Stock | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 8.12.1 | Quantum Electronics, Richmond, Cal. | Scaler Q-5 | 8238-1 |
| 8.12.2 | | Scaler Q-6 | 8238-2 |
| 8.12.3 | | Scaler Q-5A | 8238-3 |
| 8.12.4 | | Scaler Q-6A | 8238-4 |
| 8.12.5 | | Ratemeter Q-1 | 9437-1 |
| 8.12.6 | | Geiger tube and probe | 8122-5 |
| 8.12.7 | | Geiger tube and probe | 8120 |
| 8.12.8 | | Alpha Detector | 8130 |
| 8.12.9 | | Preamplifier | 8129-9 |
| 8.12.10 | | Scintillation Probe | 8124 |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 8.12.1 | Solid-state, 5-digit readout | 495.00 | B | Stock | |
| 8.12.2 | Same as 8238-1 except 6-digit readout | 575.00 | B | Stock | |
| 8.12.3 | Same as 8238-1 plus meter for high-voltage readout and 6 preset count levels | 605.00 | B | Stock | |
| 8.12.4 | Same as 8238-2 plus meter for high-voltage readout and 8 preset count levels | 695.00 | B | Stock | |
| 8.12.5 | Solid-state. Loudspeaker, 5 counting ranges | 295.00 | B | Stock | |
| 8.12.6 | Side-window | 20.00 | B | Stock | |
| 8.12.7 | End-window | 75.00 | B | Stock | |
| 8.12.8 | | 120.00 | C | | |
| 8.12.9 | For Alpha detector operation | 165.00 | C | | |
| 8.12.10 | 1" dia. NaI Crystal and Phototube | 225.00 | C | | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 9.1 | Atomic Corporation of America<br>Sun Valley, Calif. | | |
| 9.1.1 | | Safety Tray | |
| 9.1.2 | | Warning Label | |
| 9.1.3 | | Warning Label | |
| 9.1.4 | | Warning Label | |
| 9.1.5 | | Plastic Gloves | |
| 9.1.6 | | U-V Light | |
| 9.2 | Baird Atomic | | |
| 9.2.1 | | Safety Tray | |
| 9.2.2 | | Warning Label | |
| 9.2.3 | | Warning Label | |
| 9.2.4 | | Warning Label | |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 9.1.1 | Plastic Tray 12 x 18 | 3.00 | A | Stock | |
| 9.1.2 | "Caution Radioactive Materials" 1"x2", 18 foot roll self-stick | 1.00 | A | Stock | |
| 9.1.3 | "Caution Radioactive Materials" 5"x6" self-stick | 2.60/12 | A | Stock | |
| 9.1.4 | "Caution Radiation Area" 8"x10" placard | 3.00/12 | A | Stock | |
| 9.1.5 | Disposable gloves | 5.00/100 | A | Stock | |
| 9.1.6 | Short wave | 15.00 | A | Stock | |
| 9.2.1 | White enamel | 4.50 | A | | |
| 9.2.2 | "Caution Radiation Materials" 1"x2", 180 foot roll | 7.75 | A | | |
| 9.2.3 | "Caution Radiation Materials" 5"x6" self-stick | 4.00/20 | A | | |
| 9.2.4 | "Caution Radiation Area" | 3.50/20 | A | | |

| CODE NO. | SUPPLIER | ITEM | SUPPLIER'S CAT. NO. |
|---|---|---|---|
| 9.3 | Central Scientific Co. Chicago, Illinois | | |
| 9.3.1 | | Atomic Model | 71302 |
| 9.3.2 | | U-V Light | 71404-1 |
| 9.4 | Fisher Scientific Co. | | |
| 9.4.1 | | U-V Light | |
| 9.5 | Macalaster Scientific Corp. | | |
| 9.5.1 | | U-V Light | |
| 9.6 | Wards Natural Science Establishment | | |
| 9.6.1 | | U-V Light | |
| 9.7 | Welch Scientific Co. | | |
| 9.7.1 | | U-V Light | |

| CODE NO. | ITEM DESCRIPTION | COST | SOPHIST. | AVAILABILITY | COMMENTS |
|---|---|---|---|---|---|
| 9.3.1 | Metal disc with circles representing nucleus and three outer rings. Electrons represented by white spheres held in place by magnets. | 29.50 | A | Stock | |
| 9.3.2 | Short wave | 14.75 | A | | |
| 9.4.1 | Short wave | 14.75 | A | | |
| 9.5.1 | Short wave | 13.50 | A | | |
| 9.6.1 | Short wave | 14.75 | A | | |
| 9.7.1 | Short wave | 14.75 | A | | |

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10.27.3 Our Atomic World.
10.27.4 Atoms At The Science Fair.
10.27.5 Careers In Atomic Energy.
10.27.6 Atoms In Agriculture.
10.27.7 Food Preservation by Irradiation
10.27.8 Atomic Power Safety.
10.27.9 Radioisotopes in Industry.
10.27.10 Power Reactors In Small Packages.
10.27.11 Nuclear Power and Merchant Shipping.
10.27.12 Nondestructive Testing.
10.27.13 Controlled Nuclear Fusion.
10.27.14 Synthetic Transuranium Elements.
10.27.15 Plutonium.
10.27.16 Rare Earths - The Fraternal Fifteen
10.27.17 Plowshare.
10.27.18 Direct Conversion of Energy.
10.27.19 Accelerators.
10.27.20 Power From Radioisotopes.
10.27.21 Neutron Activation Analysis.
10.27.22 Radioactive Wastes.
10.27.23 Atomic Fuel.
10.27.24 Whole Body Counters.
10.27.25 Microstructure of Matter.
10.27.26 Nuclear Reactors.
10.27.27 Research Reactors.

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APPLICATION CLASSIFICATION OF BIBLIOGRAPHIC REFERENCES

| | STUDENT REFERENCES | TEACHER REFERENCES | LIBRARY SPECIAL TOPIC REFERENCES |
|---|---|---|---|
| LABORATORY EXERCISES | 10.1, 10.6, 10.11, 10.7 | 10.1, 10.2, 10.6, 10.12, 10.19, 10.21 | 10.9, 10.12, 10.6, 10.19, 10.21, 10.23 |
| NUCLEAR THEORY | 10.5, 10.10, 10.14, 10.20 | 10.10, 10.14 | 10.10, 10.20, 10.29, 10.30, 10.31 |
| GENERAL COVERAGE | 10.7, 10.10, 10.20, 10.23 | 10.2, 10.9, 10.10, 10.12, 10.19, 10.20 | 10.2, 10.4, 10.10, 10.16, 10.17, 10.19, 10.25, 10.26, 10.27.1, 10.27.2, 10.27.3, 10.27.4, 10.27.6, 10.27.7, 10.27.8, 10.27.9, 10.27.10, 10.27.11, 10.27.12, 10.27.13-10.27.16, 10.27.17, 10.27.18, 10.27.19-10.27.27 10.30, 10.31 |
| SOCIAL ASPECTS | 10.15, 10.17, 10.22, 10.24 | 10.13, 10.15, 10.16, 10.17, 10.18, 10.28 | 10.3, 10.8, 10.18, 10.22, 10.24, 10.27.5, 10.27.6, 10.27.8, 10.27.9, 10.27.11, 10.27.17, 10.27.18, 10.28 |

CORRELATION OF INSTRUCTIONAL AIDS WITH SECONDARY SCIENCE CURRICULA

NOTE:

1. "Curriculum Item" as used below identifies curriculum subject and sub-subject items as given in the document entitled, "Curriculum Analysis - Culver City Unified School District", submitted by the Xerox Education Division to Dr. James Camaren, Project Director, Nuclear Science Curriculum Project.

2. Text reading, lecture discussions, etc., are assumed to be part of the normal classroom activity and no special mention of these will be made under "Method".

BEVERLY HILLS HIGH SCHOOL - BIOLOGY (B.S.C.S.- Blue)

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Adaptation relates to natural selection<br>I.I.D.1<br>I.I.D.2 | 105 | 9.1.6, 9.3.2, 9.4.1, 9.5.1, 9.6.1, 9.7.1, 3.5.1.1, 4.1.4, 10.7, 10.35, 10.36, 10.51, 3.5.1.2 | Lab. Investigation - Bacterial adaptation to U-V light; Photoreactivation study in bacteria and yeast.<br>10.1 - Investigation 19 |
| Chemical Energy For Life - ATP<br>II.I.B.3 | 108 | 6.1.20, 10.7, 10.58, 10.89, 7.1.1, 7.2.1, 7.3.1<br>3.5.1.2 | Lab. Investigation - Bacterial Utilization of Glucose-C-14<br>10.1 - Investigation 16 |
| Chemical Energy For Life - ADP<br>II.I.B.4 | 108 | | Nuclear techniques possible for secondary level but no current references of procedures available. |
| Chemical Energy For Life - Fermentation.<br>II.I.B.5 | 108 | See II.I.B.4, Above. | |
| Cell Membrane<br>II.I.C.2 | 108 | 6.1.1, 10.7, 10.34<br>7.1.1, 7.2.1, 7.3.1<br>3.5.1.2 | Lab. Investigation - Permeability of a Membrane.<br>10.1 - Investigation 5 |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
| --- | --- | --- | --- |
| Diffusion<br><br>II.I.C.3 | 108 | See II.I.C.2,<br>(Page 108) | |
| Process of Active Transport<br><br>II.I.C.4 | 108 | 6.1.2, 10.7, 10.22, 10.44<br>8.1.1, 7.2.1, 7.3.1<br>3.5.1.2 | a. Lab Investigation - Bone uptake of phosphorus - 32<br><br>10.1 Investigation 12, 13<br>10.11 Experiment 46 |
| The Nucleic Acids<br><br>II.II.A | 108 | 6.1.2, 6.1.13<br>7.1.1, 7.2.1, 7.3.1<br>10.7<br>3.5.1.2<br>5.8.148 | a. Lab investigation - Bacterial Synthesis of DNA, RNA<br>(No formal procedure available) |
| Nature of Light<br><br>III.I.A.3 | 110 | 6.1.4<br>8.2.2, 8.3.2, 8.3.14, 8.5.1,<br>8.7.1, 8.7.4, 8.6.1, 8.4.2,<br>8.12.1, 8.12.2, 8.12.3,<br>8.12.4, 8.9.1, 8.10.1,<br>8.11.1<br>10.7<br>5.6.8, 5.8.113, 5.8.152,<br>7.1.1, 7.2.1, 7.3.1 | a. Lab investigation - colors of light vs. photosynthetic efficiency<br>10.1 - Investigation 10 |
| The Nature of Photosynthesis<br><br>III.I.B | 110 | 6.1.4, 10.7, 10.22, 10.44<br>7.1.1, 7.1.2, 7.1.3<br>6.1.2, 10.7<br><br>See also III, I.A.3<br>(Page 110) | a. Lab investigation - uptake of $CO_2$ in photosynthesis<br>10.1 - Investigation 9<br>10.11 - Experiment No. 51<br>b. Lab investigation - effect of presence and absence of light in photosynthesis<br>10.1 - Investigation 8 |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Mitochondria<br><br>III.I.E.3 | 110 | See II.I.B.3<br>(Page 108) | |
| Plant Development<br><br>V.II.G | 116 | 6.1.2, 7.1.1, 7.2.1,<br>7.3.1<br>10.7, 10.44 | a. Lab. investigation - Growth & Chemical activity in roots. 10.1 - Investigation 15<br>b. Lab. investigation - Effect of radiation on germination of seeds 10.11 - Experiment 43 |
| Regeneration in Plants<br><br>V.II.K.I | 116 | 6.1.2, 7.1.1, 7.2.1,<br>7.3.1<br>10.113 | a. Lab investigation P-32 uptake of regenerating sundew "leaves". Reference available Procedures not developed. |
| Variations in Development<br><br>V.II.K.3 | 116 | See V.II.G, Part b.<br>Page 116<br>(Note also, Beagle study U.C.-Davis) | |
| Uncontrolled Growth<br><br>V.II.K.4 | 116 | Ref. Amer. Cancer Society Films | |
| Mutations<br><br>VI.III.A.1 | 118 | 9.1.6, 9.3.2, 9.4.1,<br>9.5.1, 9.6.1,<br>10.7, 10.44, 10.112,<br>10.87<br>5.8.138 | a. Lab investigation - effect of U.V. on bacteria 10.1 - Investigation 18<br>b. Lab. investigation - effect of radiation on seed germination 10.11 - Experiment 43 |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Measuring Age of Human Fossils<br><br>VI.IV.A.3 | 119 | 2.2.11, 5.6.8 | Discussion, A-V presentation |
| Sampling of Population<br><br>VI.IV.C.2 | 119 | 6.1.2, 7.1.1, 7.2.1, 7.3.1<br>10.7 | a. Lab investigation - Determining population size by sampling techniques.<br>10.1- Investigation 4 |
| $CO_2$ in<br>Photosynthesis<br><br>VII.I.B.1 | 120 | 6.1.4, 7.1.1, 7.2.1, 7.3.1<br>10.7, 10.44, 10.87 | a. Lab. investigation - uptake of $CO_2$ by green plant.<br>10.1 - Investigation 9<br>10.11 - Experiment 51 |
| VII.I.B.2 | 120 | See VII.I.B.1 10.7<br>(Page 120) | |
| Chlorophyll<br>VII.I.B.5 | 120 | 6.1.4, 7.1.1, 7.2.1, 7.3.1<br>10.7, 10.44, 10.78, 10.106<br>8.2.2, 8.3.2, 8.3.14, 8.5.1,<br>8.7.1, 8.7.4, 8.6.1, 8.4.2,<br>8.12.1, 8.12.2, 8.12.3,<br>8.12.4, 8.9.1, 8.10.1, 8.11.1<br>5.6.8, 5.8.152 | a. Lab. investigation - Chromatographic separation of C-14 labeled chlorophyl and other compounds<br>10.1 - Investigation 9 |
| Transport of Materials In Multicellular - Plants<br><br>VII.I.B.6 | 120 | 6.1.2, 6.1.3, 6.1.4, 6.1.5,<br>6.1.6, 6.1.9, 6.1.11, 6.1.12,<br>6.1.13, 6.1.19<br>7.1.1, 7.2.1, 7.3.1<br>8.2.2, 8.3.2, 8.3.14, et.al.<br>See VII.I.B.5<br>10.7, 10.22, 10.44, 10.87,<br>10.10, 10.78, 10.106 | a. Lab Investigation - Uptake, transport of various isotopes in green plant<br>10.1 - Investigation 6 |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Photosynthesis and Growth Rate<br>VII.I.C.I | 120 | | Nuclear techniques possible for secondary level but no current references or procedures available. |
| Light Intensity<br>VII.I.C.2 | 120 | See VII.I.C.I Page 120 | |
| Mineral Nutrition and its Effect on Photosynthesis<br>VII.I.C.4 | 120 | See VII.I.C.I Page 120 | |
| Xylem<br>VII.II.A.2 | 120 | 6.1.2, 7.1.1, 7.2.1, 7.3.1<br>10.7 | a. Lab. investigation - Transport of phosphate thru xylem and phloem.<br>10.1 - Investigation 6 |
| Phloem<br>VII.II.A.3 | 120 | See VII.II.A.2 Page 120 | |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Water Transport<br><br>VII.II.A.4 | 120 | | Nuclear techniques possible for secondary level but no current references or procedures available. |
| Phloem<br><br>VII.II.A.6 | 120 | See VII.II.A.2 Page 120 | |
| Open Transport System<br><br>VII.II.B.1a | 121 | | Nuclear techniques possible for secondary level but no current references or procedures available. |
| Closed Transport System<br><br>VII.II.B.1b | 121 | 6.1.7, 6.1.9<br>8.2.2, 8.3.2, et.al.<br>See VII.I.B.5<br>Page 120 | a. Lab. investigation - Determination of blood volume.<br>10.11 - Experiment 50 |
| Urea Formation<br><br>VII.V.C.4 | 122 | 6.1.4<br>8.2.2, 8.3.2, et.al.<br>See VII.I.B.5<br>Page 120<br>7.1.1, 7.2.1, 7.3.1<br>10.7 | a. Lab investigation - Formation of Urea in a mammal.<br>10.1 - Investigation 17 |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Thyroid<br><br>VIII.I.C.3 | 123 | 6.1.1<br>10.44, 10.113<br>8.2.2, 8.3.2, et.al.<br>See VII.I.B.5 Page 120 | a. Lab. investigation - Uptake of I-131 by Thyroid gland.<br>10.11 - Experiment 49 |
| Bone<br><br>VIII.III.A.1 | 124 | 6.1.2, 6.1.3, 6.1.12<br>10.7, 10.44, 10.22, 10.87<br>7.1.1, 7.2.1, 7.3.1<br>8.2.2, 8.3.2, et. al.<br>See VII.I.B.5 Page 120<br>5.8.88 | a. Lab investigation - Incorporation of various isotopes in bone.<br>10.1 - Investigations 11. 12, 13<br>10.11 - Experiment 48 |
| Population Problems<br><br>IX.I.B. | 126 | See VI.IV.C.2 Page 119 | |
| Food Chains and Food Webs<br><br>IX.III.B.1 | 127 | 9.1.10.1<br><br>3.2.6, 4.1.5, 3.5.1.10<br>5.8.166, 5.8.167 | b. Lab. investigation - Radioactive fallout.<br><br>Discussion - Films |
| The Ecologist<br><br>IX.III.C.1 | 127 | 5.8.50, 5.8.186 | Films |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Malaria - A Biological Problem<br>I.III.A | 131 | 6.1.2<br>7.1.1, 7.2.1, 7.3.1<br>8.2.2, 8.3.2, et. al.<br>See VII.I.B.5 Page 120 | a. Lab. Investigation - Physiological Transfer of isotope from mammal to mosquito.<br>Nuclear technique possible for secondary level but no current references or procedures available. |
| Understanding The Structure of Matter<br>II.III.A | 136 | 1.1.1, 1.1.11<br>2.1.1 - 2.1.17<br>3.7.1.1<br>5.3.1, 5.3.2 | Discussion |
| Matter to Energy and Energy to Matter<br>II.III.C.2 | 136 | 2.1.11, 2.3.3, 2.2.5,<br>2.1.8<br>3.1.1.6<br>4.3.1<br>5.7.1, 5.7.6 | Discussion |
| Atomic Energy, A Special Type<br>II.III.D.2 | 137 | 3.7.1.1, 3.3.1.1, 3.1.1.6,<br>3.1.1.7<br>5.6.3, 5.6.4, 5.5.1<br>5.8.23, 5.8.24, 5.8.25<br>8.1.1, 8.1.2, 8.2.12,<br>8.3.7, 8.4.1, 8.5.3,<br>8.6.5 | Discussion |
| Atomic Structure<br>II.III.E.1a-c | 137 | 1.1.1 - 1.1.11<br>3.1.1.1, 3.3.2.1, 3.4.1.7,<br>3.4.1.8, 3.5.1.5<br>5.7.4, 5.2.1, 5.8.1<br>8.1.1, 8.1.2, 8.2.12, 8.3.7,<br>8.4.1, 8.5.3, 8.6.5<br>10.37, 10.57 | Discussion<br>Lab. - Cloud Chamber Demonstrations |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Isotope<br>II.III.E.1d | 137 | 2.2.14, 2.1.15, 2.1.5,<br>2.4.13, 3.1.1.2, 3.7.1.2<br>3.3.1.3, 3.5.1.2, 5.6.10,<br>5.6.8<br>5.8.86, 5.8.149, 5.8.148 | Discussion |
| Diffusion<br>II.III.E.7 | 139 | See II.I.C.3 Page 108 | |
| The Community<br>III.III | 140 | 5.8.50, 5.8.186 | Films |
| Incorporating Energy Within Living Cells<br>III.III.A.2 | 140 | See III.I.B Page 110 | |
| Phosphorus Cycle<br>III.III.A.4b | 140 | 6.1.2, 7.1.1, 7.2.1, 7.3.1<br>8.2.2, 8.3.2, et.al.<br>See VII.I.B.5<br>10.10 | Lab Investigation - Food Chain (Formal procedure not available) |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Nucleic Acids<br>III.IV.E | 141 | See II.II.A Page 108 | |
| Mutation<br>IV.II.G.2a | 146 | See VI.III.A.1<br>Page 118 | |
| Control of Spoilage of Food<br>IV.II.H.5 | 147 | 10.104.7<br>5.8.47 | Discussion |
| The Food Chain<br>VI.I.A.4b | 151 | See III.III.A.4b<br>Page 140 | |
| Photosynthesis Within the Biome<br>VI.I.A.4c | 151 | | Nuclear techniques possible for secondary level but no current references or procedures available. |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Fossil Evidence - Plants<br>VI.I.B.5 | 152 | See VI.IV.A.3 Page 119 | |
| Leaf Structure<br>VII.I.B.1 | 154 | See VII.I.B.6 Page 120 | |
| Absorption Spectrum of Chlorophyll<br>VII.I.C.3 | 154 | See III.I.A.3 Page 110 | |
| Absorption in Roots<br>VIII.I.A.3 | 155 | See VII.I.B.6 Page 120 | |
| Conduction in Roots<br>VIII.I.A.4 | 155 | See VII.I.B.6 Page 120 | |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Roots and Stems<br>VIII.I.D.3,4,5 | 156 | See V.II.G. Page 116 | |
| Conduction in Stems<br>VIII.II.A.4 | 156 | See VII.I.B.6 Page 120 | |
| Phloem and Xylem<br>VIII.II.C.3c.e | 157 | See VII.II.A.2 Page 120 | |
| Phloem and Xylem<br>VIII.II.E.1,2 | 157 | See VII.II.A.2 Page 120 | |
| Food Chain<br>X.I.A.2d | 162 | See III.III.A.4b Page 140 | |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Organs in Multicellular Animals<br>XI.I.A.2 | 165 | 6.1.2, 7.1.1, 7.2.1, 7.3.1<br>8.2.2, 8.3.2, et.al.<br>See VII.I.B.5 Page 120<br>10.7, 10.22, 10.44, 10.112<br>5.8.147, 5.8.63 | a. Lab investigation: Uptake of isotope in organs of warm and cold blooded animals<br>10.1 - Investigation 12<br>10.11 - Experiment 46 |
| Simple Diffusion<br>XI.I.C.1 | 165 | See II.I.C.2 Page 108 | |
| Closed Circulatory System<br>XI.I.C.3 | 165 | See VII.II.B.1b Page 121 | |
| Hepatic-Renal Function<br>XI.I.D.2 | 165 | See VII.V.C.4 Page 122 | |
| Oxidation of Glucose<br>XI.I.F.1 | 166 | See II.I.B.3 Page 108 | |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Skeletal System - Support<br>XI.I.G.4a | 166 | See II.I.C.4 Page 108<br>VIII.III.A.1 Page 124 | |
| Mutation<br>XII.IV.A | 170 | See VI.III.A.1 Page 118 | |
| | | | |
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| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| The Electron<br>V-II | 182 | 3.7.2.1<br>5.1.4 | |
| The Nucleus<br>V-III | 182 | 3.4.1.9, 3.7.2.3 | |
| Rutherford's Experiment<br>V-III-A-1 | 182 | 2.2.29, 4.2.3 | |
| Nuclear Charge<br>V-III-B | 182 | 2.2.26 | |
| Protons<br>V-III-C | 182 | 3.7.2.2 | |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Neutrons<br>V-III-D | 182 | 3.5.1.6 | |
| Isotopes<br>V-IV | 182 | 1.1.9, 2.1.5. 2.1.15,<br>2.2.14, 2.4.1, 2.4.13,<br>3.1.1.2, 3.3.1.3,<br>3.7.1.3<br>5.6.10, 5.8.149 | |
| C-12 Basis for Atomic Weights<br>V-IV-B | 182 | 2.2.3 | |
| Nature of Radioactivity<br>XI-I | 198 | 3.5.1.7, 5.4.2 | |
| Atomic Structure<br>XI-I-A | 198 | 1.1.1, 1.1.10, 1.1.11,<br>2.1.16, 2.1.17, 2.2.2,<br>2.4.2, 2.4.3,<br>3.4.1.7, 3.4.1.8, 3.5.1.5,<br>5.1.2, 5.3.1 | |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Rutherford's Experiment<br>XI-I-B | 198 | 2.2.29, 4.2.3 | |
| Nuclear Instability<br>XI-I-C | 198 | 1.1.2, 2.1.7, 2.1.8, 2.1.9, 2.1.10, 2.2.5, 2.2.8, 2.2.15, 2.2.16, 2.2.27, 2.3.3, 2.3.6 | |
| Neutron-Proton Ratio<br>XI-I-C-1 | 198 | 3.1.1.4 | |
| Disintegration Series<br>XI-I-D | 198 | 2.1.8, 2.2.10, 2.2.13, 2.2.27, 2.3.6, 3.1.1.4 | |
| Mother-Daughter Products<br>XI-I-D-1 | 198 | 8.2.14, 8.2.15, 8.2.16 | Laboratory Investigation - Radioisotope Milkers |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Einstein's Theory<br>XI-I-E | 198 | 2.1.11 | |
| Bonding Energy<br>XI-I-F | 198 | 2.3.1 | |
| Geiger Counter Survey Meter<br>XI-II-A-B | 198 | 2.2.19, 2.4.16, 3.2.1, 3.2.1.1, 3.4.1.1, 3.5.1.8, 4.1.1, 5.8.139, 8.8.1, 8.8.2 | Laboratory Investigation - The Geiger Counter<br>10.1 - Investigation 3<br>10.11 - Experiments 6 & 7 |
| Cloud Chamber<br>XI-II-C | 198 | 3.2.1, 3.2.1.1, 3.4.1.1, 3.5.1.8, 4.1.1, 8.1.1, 8.1.2, 8.2.12, 8.4.1, 8.5.3, 8.6.5 | Laboratory Investigation - Principles of the Cloud Chamber<br>10.11 - Experiment 2 |
| Bubble Chamber<br>XI-II-D | 198 | 3.2.1, 3.2.1.1, 4.1.1, 4.1.2, 4.1.3 | |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Scintillation Counter<br>VI-II-E | 198 | 3.2.1, 3.2.1.1, 4.1.1, 4.1.2, 4.1.3, 5.8.140, 8.8.3, 8.9.3, 8.9.4 | Laboratory Investigation - Scintillation Counting<br>10.11 - Experiment 11 |
| Film<br>XI-II-F | 198 | 3.2.1, 4.1.1, 6.1.2, 7.1.1, 7.2.1, 7.3.1 | Laboratory Investigation - Detection of Ionizing Radiation by Film.<br>10.1 - Investigation 1 |
| Artificial Radioactivity<br>XI-III | 198 | 2.2.11, 3.2.3, 3.2.3.1, 3.3.1.4, 3.3.1.5, 3.4.1.3, 3.5.1.2, 5.6.8 | |
| Cyclotron<br>XI-IV-B-1 | 198 | 1.1.7, 2.2.7, 2.3.5, 3.5.1.9, 3.7.2.4, 5.6.1, 5.7.1, 5.8.17 | Field Trip (Cyclotron) |
| Fission<br>XI-IV-C | 199 | 1.1.4, 2.1.3, 2.1.9, 2.2.15, 2.2.20, 2.2.30, 2.4.14, 3.7.2.5, 5.7.7 | |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Chain Reaction<br>XI-IV-C-1 | 199 | 2.1.10, 2.2.20, 2.2.30,<br>2.4.10,<br>4.2.1, 4.2.2 | |
| Reactor Theory<br>XI-IV-C-2 | 199 | 1.1.5, 2.1.4, 2.1.12,<br>2.2.6, 2.3.4, 3.5.1.10,<br>4.2.2, 5.2.6, 5.6.6,<br>5.8.5, 5.8.17, 5.8.28,<br>5.8.35, 5.8.128 | Field Trip - (Reactor) |
| Fusion<br>XI-IV-D | 199 | 2.1.14, 2.2.9, 2.2.16,<br>2.2.21, 2.2.22, 2.3.7,<br>2.4.15 | |
| Radioisotopes<br>XI-IV-E | 199 | 1.1.9, 2.1.5, 2.1.15,<br>2.2.14, 2.2.18, 2.4.1,<br>2.4.13, 3.1.1.2, 3.3.1.3 | |
| Fallout<br>XI-IV-E-1 | 199 | 2.2.23, 2.4.17, 3.2.6,<br>3.2.6.1, 3.4.1.6, 4.1.5,<br>5.2.7, 7.1.2 | Laboratory Investigation of fallout. |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Health Hazards<br>XI-!V-E-1-A | 199 | 1.1.14, 1.1.15, 3.4.1.11, 3.5.1.1, 4.1.4, 5.3.5 | |
| Medecine<br>XI-IV-E-2-a | 199 | 3.2.2, 3.2.2.1, 3.4.1.2, 3.5.1.2, 5.1.8, 5.8.10, 5.8.16, 5.8.20, 5.8.100, 5.8.147, 5.8.184 | |
| Research<br>XI-IV-E-2-b | 199 | 5.8.15, 5.8.36, 5.8.61 | |
| Others<br>XI-IV-E-2-C | 199 | 3.2.5, 3.2.5.1, 3.3.1.4, 3.3.1.5, 3.4.1.3, 3.4.1.4, 3.4.1.5, 5.8.7, 5.8.8, 5.8.9, 5.8.11, 5.8.14, 5.8.70, 5.8.81, 5.8.146, 5.8.148, 5.8.149 | |
| | | | |

| CURRICULUM ITEM | PAGE NO. | MEDIA | METHOD |
|---|---|---|---|
| Rutherford's Model of the Atom<br>X-I | 223 | 2.2.29, 4.2.3 | |
| Deflection of Alpha Particles<br>X-I-A | 223 | 2.2.26 | |
| Trajectories of Alpha Particles<br>X-I-B | 223 | 3.1.1.5 | |
| Structure of Atoms<br>X-III | 223 | 2.4.5, 2.4.6, 3.4.1.8 | |
| | | | |

# DISCUSSION OF EDUCATIONAL PLANT FACILITIES REQUIREMENTS FOR CLASSROOM LABORATORY USE OF RADIOACTIVE MATERIALS

# EDUCATIONAL PLANT FACILITIES

Except for demonstrations and laboratory exercises specifically directed to instruction in nuclear science topics, it would seem that no unusual facilities would be required. In the cases where the normal lecture-discussion activities take place all of the necessary facilities for the instructional process should already be at hand. Such things, for example, as audio-visual material and projection equipment will in all probability be available so that in an instance such as this, only the addition of the proper films, records, etc., need be acquired for the library in order to adequately cover the inclusion of a nuclear supplement to the curriculum. In addition, it would of course be advisable to procure an adequate supply of published reference material and a meaningful choice could be made from the classification of references in Section 2, Subsection 10.

Alterations to existing plant facilities will be indicated only in the case where a student-participation laboratory program is projected and even in that instance, the changes need be minimal. Based on such activities currently taking place in some school districts the following considerations seem to be most meaningful:

1. Instrumentation - Any special facilities which might be required in regard to say, counting equipment will depend firstly, the amount and type of instrumentation to be acquired and employed and secondly, on the intended distribution of such equipment. That is, will the equipment be purchased on the basis of a specified number of units which will be assigned to a single class or school or, can the curriculum in a school complex be so arranged as to permit the circulation of a group of instruments among a number of schools? In any event, the acquisition, maintenance and use of such equipment should pose no problems which would be different than those encountered with any other piece of laboratory equipment. As regards maintenance, nuclear instrumentation should be easily handled by those people who are charged with the responsibility for maintaining other types of instrumentation used by the school.

2. Darkroom facilities - Although there is film available for autoradiographic purposes which required no darkroom for the developing and fixing process (see section on instructional aids), it might be desirable to have a photographic darkroom available for special projects. If necessary, any totally dark area or a room which can be "blacked-out" will suffice. As far as the utility of such a facility by an entire class is concerned, that is for the most part out of the question because too many complications can ensue in connection with organizing the class for such unsupervisable activity. In general, it can be said that though a darkroom may be desirable on occasion, it will not have sufficient utility to warrant construction for a single purpose such as autoradiograph processing.

3. Radioisotope storage facilities - As long as radioisotopic material is received and handled in "license-exempt" activities, no special facilities are required beyond a lockable cabinet or drawer for storage purposes. Most student experimentation will concern itself with the use of relatively short-lived material so that the storage-time period need only be a few days at the outside. Standard test tube racks which will fit in a lockable drawer in the demonstration desk, teacher's desk, classroom storage cabinet, or file drawer are sufficient for storage of radioisotope vials.

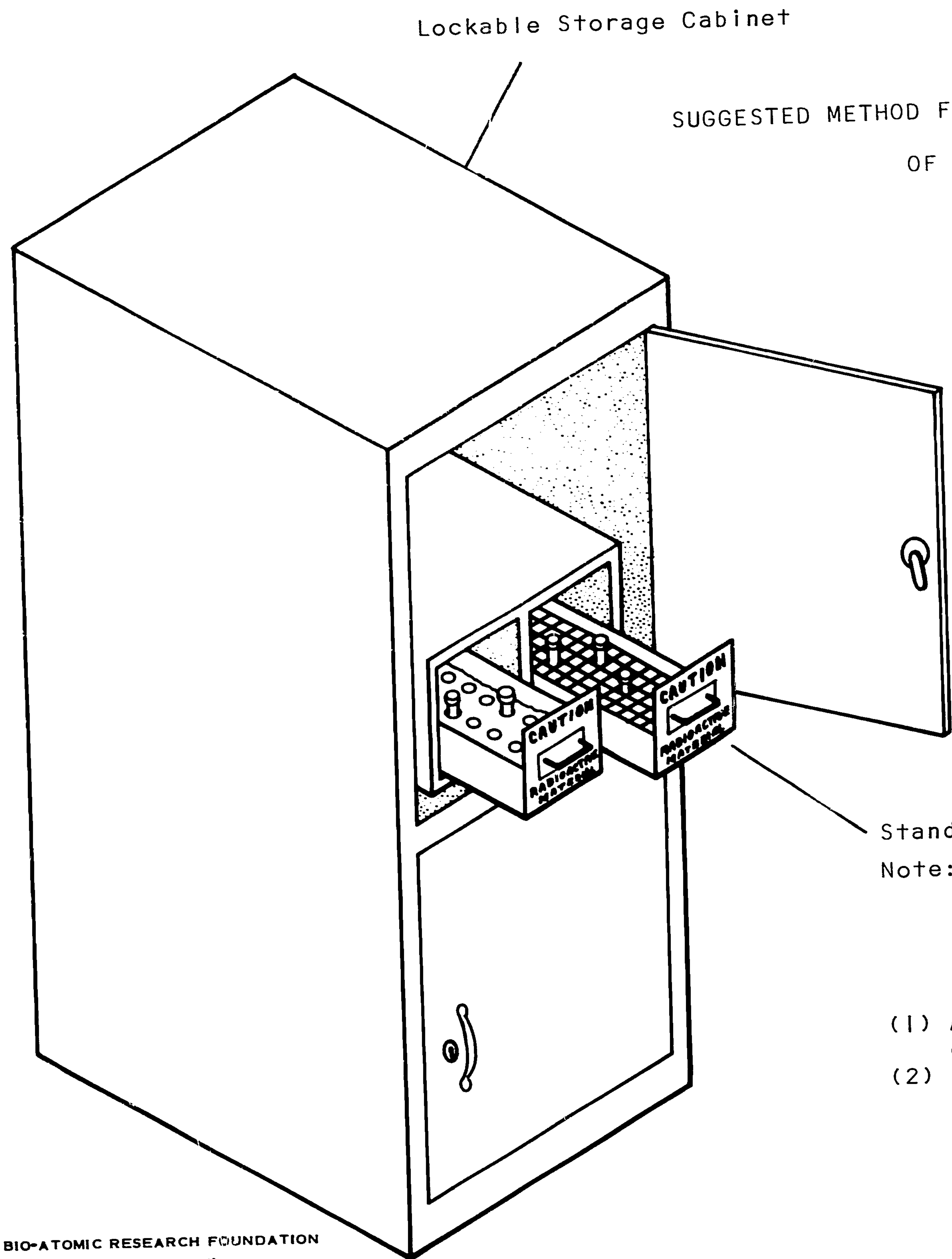
4. Disposal of radioactive waste - Again, with the use of "license-exempt" activities, no special facilities are required. Liquid wastes can be emptied into the normal sewage system with the addition of sufficient water to keep the concentration to the legal level. Solid radioactive waste can be stored in containers with lids. These should be of plastic or crockery construction (for easy decontamination) with a radioactivity warning sign affixed to each container. Solid radioactive waste can be disposed of at a convenient time by incineration (or by burial in the case of non-combustible material).

Reference:

(a) California Radiation Control Regulations - Title 17, paragraph 30355

(b) U. S. Atomic Energy Regulations - Title 10, Part 20, Paragraph 20.303 and Appendix B.

## SUGGESTED METHOD FOR INDIVIDUAL CLASSROOM STORAGE OF RADIOISOTOPE VIALS




Note: A single drawer will hold more than enough for one-classroom requirements. Two drawers are shown here to illustrate suggested methods for vial support.

(1) A standard test-tube vial rack of a size to fit in the drawer.

(2) A block of styrofoam with a series of holes of proper size to receive and hold the vials.

# RADIOISOTOPES

## LEGAL CONSIDERATIONS REGARDING THE USE OF RADIOACTIVE MATERIAL

The Atomic Energy Act of 1954 created, among other things, a set of rules and regulations governing the licensing of users of radioactive byproduct material. Public Law 86-373 effective September 23, 1959 added section 274 to the Act authorizing the transfer of certain licensing and regulatory authority to individual states. In March 1962 the first transfer of such authority was made to the State of Kentucky. Since then thirteen additional states have negotiated "agreements" with the U. S. Atomic Energy Commission and established their own regulatory agencies. California became an "agreement" state on September 1, 1962 and has been performing the licensing and regulation function since that time through a subdivision of the State Department of Health under the directorship of Dr. John Heslep.

Under the original Federal regulations, two classes of licenses were established, Specific and General. Specific licenses were granted to qualified users of radioactive byproduct material for stated purposes and under certain conditions, e.g., medical, industrial, etc. A General license implied the issuance of permission to possess and use radioactive material by any person without the necessity for an authorizing document.

Title 10, Chapter, 1, Part 30 of the Federal Regulations describes a General license as "effective without the filing of applications -- or the issuance of licensing documents to particular persons." This, in effect, granted to any person the right "to transfer, receive, use and import quantities of (radioactive) byproduct materials" as specified in a list of radioisotopes which limited the quantity to be contained in a single unit or package (Title 10, Part 30, Paragraph 30.72). Furthermore, the licensee was permitted the possession of up to ten of such "scheduled" quantities.

All of the various states which have assumed the regulatory authority in regard to the use of nuclear material have included the General license provision of the original Federal code. Thus, in effect, that provision remains as a governing factor whether it be in those areas still under the U. S. Atomic Energy Commission jurisdiction or in those areas where an individual states' regulations are in effect.

The importance of Title 10, Part 30 of the Federal regulations and its state counterparts lies in the fact that it is these regulations which control the storage and use of radioisotopes as a teaching tool at the high school level.

It is possible for a school to obtain a specific license for radioisotope storage and use however, it would be most impractical and uneconomical for the school to do so in most cases. A specific license implies the possession of relatively large quantities of radioactive material. Under existing regulations reception and storage facilities must be constructed and properly maintained together with the means and procedures for maintenance of acceptable records.

Dispensing of radioactive materials again necessitates the existence of proper facilities, personnel, monitoring and assay equipment and, of course, the inevitable record-keeping. Additionally, (under California regulations Par. 30194 and Par. 30195 (c), for example) in order to obtain approval for a specific license an application must generally have at his disposal:

(a) Persons qualified by reason of training and experience to use radioactive material of the kinds and quantities and for the purposes requested, in such manner as to provide reasonable and adequate assurance of protection to health, life and property.

(b) Equipment, facilities, proposed uses and procedures, etc., etc.

Furthermore, the department (of Public Health) must determine that:

(c) the issuance of the license will not be inimical to the health and safety of the public; and

(d) the applicant satisfies all applicable requirements of the Act and regulations thereunder.

Paragraph 30195(c) continues: For use of multiple quantities or types of radioactive material for research and development or for processing for distribution:

(1) The applicant has a radiation safety committee of at least three members which must evaluate all proposals for, and maintain surveillance over, all uses of radioactive material.
(2) The applicant has a radiation safety officer, who is a member of the radiation safety committee, and who is supported by a staff of a size and degree of competence appropriate to deal with radiation safety problems that might be encountered.
(3) The applicant furnished a detailed statement of the qualifications, duties, authority and responsibilities of the radiation safety committee and of the staff radiation safety group.

It can be readily seen then, that the establishment of a radioisotope laboratory for a school or district will require the creation of a rather large and burdensome organization together with the necessary physical facilities. Except for extremely rare instances such procedures will impose unnecessarily severe burdens on school personnel and certainly on the school budget.

It can be stated that high school utilization of radioisotopes as a teaching and learning tool can easily be effected by simple adherence to the rules as laid down by school district authorities for the storage, distribution and use of generally-licensed activities. (For example, see Regulations for Los Angeles City Schools, below.) This is entirely possible because the total requirement for radioactive material by an individual class can be kept below the maximum permissible activity especially if well-designed experimental procedures are employed. In fact, for most procedures, much below the maximum permissible activity will be adequate. This, coupled with a practical handling scheme should be all that might be necessary for the implementation of an effective classroom program.

## REGULATIONS

Following are references to the pertinent regulations which will govern the use of radioactive material in the classroom (unless further restrictions are imposed by the school administration - see "Los Angeles City School District Regulations", above).

a. California Radiation Control Regulations.
(Title 17 of the California Administrative Code)

1. Licensing - Article 4

Section 30191 - General Licenses, Source Material
Section 30192 - General Licenses, Other Radioactive Material
Section 30236 - Schedule B

2. Waste Disposal - Article 5

Section 30287 - Disposal by Release Into Sanitary Sewerage Systems
Section 30288 - Disposal by Burial in Soil
Section 30355 - Appendix A

Copies of the Regulations may be obtained from the State of California, Department of Public Health, Berkeley, California.

b. U. S. Atomic Energy Commission Regulations.

1. Licensing - Title 10 CFR, Part 30

Paragraph 30.21 - General Licenses
Paragraph 30.72 - Schedule B

2. Waste Disposal - Title 10 CFR, Part 20

Paragraph 20.303 - Disposal by Release into Sanitary Sewerage Systems
Paragraph 20.304 - Disposal by Burial in Soil
Paragraph 20.303 Appendix B, Table I, Column 2

Copies of the Regulations may be obtained from the U. S. Atomic Energy Commission, Division of Licensing and Regulation, Washington, D. C.

## OPERATIONAL CONSIDERATIONS REGARDING THE USE OF RADIOACTIVE MATERIAL

Perhaps the description of a current program will best serve to illustrate an effective method of receiving and handling radioisotopes in the classroom.

The use of radioisotopes for class work in the Los Angeles City Schools was sporadic and very infrequent. This, in spite of the fact that within the teacher corps there were quite a few graduates of the AEC-NSF Radiation Biology Institutes. Also, the Los Angeles district had created a Science Materials Center which acted as a center for the distribution of various materials to the science classes of the schools within the district. Radioisotopes were not handled primarily because of the licensing problems as described above.

In 1964, Mr. David McLaren, director of the Center at that time met with representatives of the Atomic Corporation of America in an attempt to solve the problem of distributing radioisotopes effectively so as to stimulate classroom experimentation with this material.

Many discussions and contacts followed the initial meeting and some months later a plan evolved which has been operating successfully for approximately three years. The distribution system is as follows:

1. A specific sum of money is deposited with the vendor (the Atomic Corporation of America in this case). A supply of blank, four-part voucher forms are sent to the Science Center and the delivery of these is considered tantamount to the delivery of material for accounting purposes. This arrangement has at least two great advantages. First, the acquisition of short-lived material is expedited through bypassing the normal purchasing process and second, acquisition of radioisotopes can be made without regard to fiscal problems. This last can be especially bothersome for summer classes supplies for which sometimes cannot be funded from the previous year's budget and the subsequent year's funds are perhaps not yet available.
2. The teacher, finding a need for a radioisotope or group of isotopes, contacts the Science Center in advance of the day on which such material will be required. The contact is usually by telephone although it can also be by intradistrict mail if the need is established sufficiently in advance of the need date.
3. The Center personnel then prepares one of the standard four-part voucher forms. One copy is retained at the Center and the remaining copies are sent to the Atomic Corporation of America laboratories where the order is filled and mailed prior to the need date.

4. Accompanying the radioisotope is a copy of the voucher. On receipt of the package, the teacher extracts the voucher copy and sends it to the Center by intradistrict mail. This copy is matched with the retained copy and both are filed. This provides the district with the following information:
   a. The radioisotope which was ordered had, in fact, arrived.
   b. The teacher who ordered and received the radioisotope and the school to which it was sent.
   c. The activity which was received and the time of arrival.
   d. The sum by which the account was debited.

The system as described above eliminates the great bulk of fiscal activity which would be unduly burdensome for a multipicity of small, irregularly-spaced purchases. More importantly however, it eliminates the need for any specific licensing while at the same time allowing district authority to maintain complete control over the distribution of radioactive material. Concentration of activity is avoided before it can occur and accurate records are automatically provided.

Although any school activity involving the use of radioisotopes can be carried on under regulations as laid down by the regulatory authority, it would seem to be a more effective procedure for the school or district to set down its own rules. These must be based on State or AEC rules of course, but can also incorporate directives which will spell out in greater detail, those items which are considered good laboratory practice.

Perhaps a concrete example will serve better to illustrate the point. In June 1964 the Curriculum Branch of the Los Angeles City School District published a set of "Regulations for Using Radioactive Materials". These have since been incorporated into the new District operations manual.

Following are the regulations:

Storage of Radioactive Isotopes

1. Storage facilities. Approved quantities of radioactive materials should be in locked storage when not in use.
2. Quantities in Storage. Each school will not exceed 10 scheduled quantities (see schedule B) in a given classroom or stockroom taking half-life into account.

Use of Radioactive Isotopes

1. The use of a dosimeter or film badge is not required for generally licensed quantities. However, proper precautions should be taken to make certain that no radioactive material has come in contact with the skin or has entered the body through the mouth or by breathing.
2. After handling radioactive materials, particularly liquids, the student or teacher must check his hands and body with a geiger counter for traces of radioactivity.
3. A thin rubber glove is sufficient shielding for alpha emitters. Beta emitters may be shielded by glass or aluminum. 12" tongs may be used to reduce the dose rate. No beta source should be handled with the fingers. The gamma source authorized for use in secondary schools should be handled in the same way as beta emitters.
4. Experiments should be performed in a manner to avoid contamination and reduce the dose rate. Experiments should not be performed where gaseous radioactive products are formed.
5. Precautions in Using Radioactive Materials.

   Maintain "good housekeeping" at all times.

   Wear plastic rubber gloves during each experiment and wash hands thoroughly after each experiment.

   Make all possible setups on easily cleaned trays. These should be covered with disposable absorbent paper.

   Keep all active solutions covered.

   Clamp all containers holding radioactive substances.

   Never pipette by mouth.

   Use tongs or tweezers in handling containers and specimens.

   Have available a paper lined garbage can for immediate disposal of all contaminated waste.

   Try out all new procedures with "dummy runs" not involving radioactive material.

   Never eat or drink in a room in which radioactive materials are used or stored.

Give immediate attention to cleaning up any contamination.

6. General Decontamination Procedures:

Hand and skin - Wash for a long time with mild soap and water.

Clothing - Ordinary laundry procedures are usually sufficient.

Glassware, rubber, linoleum, ceramic tile, painted surfaces, metal - Wash with detergent and hot water.

Laboratory traps and drains - Flush with continuously running water for 5 minutes.

Surface of work area - Do not use radioisotopes near unprotected wood, concrete or brick surfaces.

Emergency procedures - In the event of an emergency involving contamination contact by telephone the State Department of Public Health, 2151 Berkeley Way, Berkeley, California, and then notify the Safety Section. In addition, regular procedures specified in AR2325 are to be followed:

7. Disposal Procedures (approved, generally licensed quantities only):

Liquid radioactive waste: Water solutions may be diluted and flushed down the drain with large amounts of water.

Solid radioactive waste: Solid wastes of low activity may be wrapped or placed in covered containers, labeled, and placed in regular trash collection, after 7-10 half-lives have passed since the date of the initial measurement. Isotopes or other sources with long half-lives for which there is no longer any need shall be disposed of by arrangement through the Science Center.

In addition to the above it might be interesting to note the following: (These are attached to the Regulations).

## STUDENT'S STATEMENT

THIS IS TO CERTIFY that I have read the Science Laboratory Regulations for using radioactive materials as prescribed by the Los Angeles City Board of Education, and hereby agree to abide by them in the performance of all experiments.

Name of Student________________________________________ Date____________________

Address__________________________________________________________________

## PARENT'S OR GUARDIAN'S STATEMENT

I have read the foregoing and hereby pledge my cooperation in urging that_______

________________________________________ observes the safety instructions, out
(Name of student)

set forth for his protection.

____________________________________________________ Date____________________
(Signature of Parent or Guardian)

## INSURANCE REQUIREMENTS

Although insurance restrictions would not normally be considered as a "legal" constraint, it is nevertheless a practical restriction to the use of radioactive material in the high school laboratory where such use is specifically excluded by the contract. Discussions with insurance carriers and underwriters have disclosed that such exclusions usually result from a lack of information on the part of the underwriter. That is, he is not aware that radioisotopes can be purchased in "license-exempt" activities and that these have been adjudged by responsible authorities to be innocuous for its intended use. The inclusion of a restrictive clause in the insurance contract probably results from the unwillingness of the underwriter to investigate properly and the matter is made quite simple for him by his totally restricting any use of radioactive material.

As far as is presently known these exclusion clauses are not general among insurance contracts covering school activities and it would be impossible to document here the prevalance of such restrictive clauses among the policies currently in force. The Foundation has in the past, had occasion to discuss the matter with one underwriter and as a result, the clause restricting the use of radioactive material was deleted from the policy issued to a school district. This might indicate that if an exclusion clause did exist in a particular policy, proper discussions with the underwriter would probably serve to induce him to delete it.

DISCUSSION - TEACHER TRAINING REGARDING USE OF

RADIOACTIVE MATERIAL AS A TEACHING TOOL

## TEACHER TRAINING

It is not possible, nor even necessary to consider within the scope of this report, to delineate any requirements regarding the teacher's preparation for his classroom activity as regards the overall curriculum which is to be taught. Therefore, only that aspect which deals with the actual use of radioactive material in the classroom laboratory will be considered.

Past experience has shown that in the area of laboratory activities where radioisotopes are to be used as a tool in the teaching process, it is necessary only to provide such instruction as will enable a teacher to properly receive, store and utilize in the classroom on a student participating basis legal activities of radioisotopic material and to subsequently dispose of any resulting radioactively - contaminated waste in an approved manner. This indoctrination process has been accomplished in the past in as little as two short seminar sessions. As an adjunct to these however, it has been found useful to have available either on the institution campus or through telephone communication, some thoroughly trained resource person to whom a teacher can turn in the event some problem arises for which he cannot readily find an easy solution.

There are currently extant in the United States something over 5000 Summer Radiation Institute (AEC-NSF) graduates. In addition there are many other who have attended university-sponsored academic year institutes or sequential institutes which have nuclear subjects as the principal topic or as inclusions in the curriculum.

Reference to school district personnel records should readily reveal the presence of such trained people. There are also various agencies to which one can turn for information or assistance;

1. Local university or college.
2. State Atomic Energy agencies.
3. Local or regional Civil Defense Agencies.
4. Local chapters of professional societies.
5. Local industry.

Thus it can be readily seen that the use of nuclear material as an instructional tool can be easily implemented following a relatively short period of instruction in the mechanics of handling such material. Additionally, it should be evident that it would be a rare instance indeed where a teacher could not contact a proper resource person for information or assistance.

# CORRELATION OF INSTRUCTIONAL AIDS

WITH

NUCLEAR SCIENCE CURRICULUM MODULE OF INSTRUCTION

## NUCLEAR SCIENCE CURRICULUM - MODULE OF INSTRUCTION

Although the correlation of the herein designated media with the material developed by the Nuclear Science Curriculum Project is not within the scope of the present effort it was nevertheless felt that a correlation with one of the instructional modules would demonstrate the application of Method/Media decisions to identified behavioral objectives.

In 1965, a Faculty Orientation Program for the Oakland Community College was under development by the Instructional Materials Division of Litton Industries under the direction of Dr. R. E. Corrigan. As a part of that effort, Dr. Corrigan delineated a strategy (guidelines) for selecting instructional aids (media) and their use as instructional tools (method). He then described a "METHOD/MEDIA TRADEOFF -- the process of determining the best strategy for communicating and thus producing the desired, pre-defined learning product."

The intention then, was to utilize the available instructional materials in as efficient a manner as possible in order to achieve interim and terminal objectives previously defined. This intention prompted the development of a decision-making model for use as a criterion against which selections of media items were to be compared in order to determine their adequacy and/or suitability.

The model dictated the consideration of six variables as follows:

1. TASKS - A list of tasks which has been derived from a task analysis in connection with some predetermined objective and learning path.

2. RESPONSES - Student response expected in connection with the performance of a specific task.

3. CRITICALITY OF SIMULATION (Stimulus requirements) - Determination of the significance of a task as indicated by the task analysis.

4. LEARNING DIFFICULTY - Determination of the degree of "decision-making", problem-solving or skill involved in the performance of the task.

5. LEARNING METHOD - As defined in this plan, this is broken down into, a. Conventional lecture (a low feedback situation) and, b. Programmed instruction.

6. INSTRUCTIONAL SETTING - The consideration of where and how the student is to learn the material, i.e., whether the knowledge or skill is to be learned through self-instruction or in some group situation.

Actually, there is another criterion to be applied in making a media decision. That is one of cost effectiveness. In other words, is the use of the media which seem to be appropriate for the purpose justifiable on a basis of cost in relation to the product achieved? This might be especially pertinent in the nuclear area since instrumentation, for example, is relatively expensive and the requirements on a medium or large group basis could entail a sizable expenditure of funds. In this case then, the Method/Media Tradeoff would perhaps assume some priority in the assessment of the learning possible against the dollar cost of the equipment.

## Method/Media Selection Criteria

### Analysis Steps

| 1<br>Learner Tasks | 2<br>Learner Response Specifications | 3<br>Stimulus Requirements | 4<br>Simulation Requirements | 5<br>Media Selection Choices | 6<br>Criticality to Task Completion | 7<br>Learning Difficulty Involved |
|---|---|---|---|---|---|---|
| Classifications | | Visual | | | | |
| Sensing<br>determine presence or absence of stimuli | To sense: indicate presence of | Pictorial<br>A. still<br>B. motion | A. no real requirement | Still: books<br>papers<br>slides<br>filmstrip<br>transparencies | A. partial requirement for understanding for progression steps (flexible requirement for total success) | 1. simple: no difficult decision skills required<br>2. must apply self initiated strategy for correct performance (decision making skills) |
| Identifying<br>distinguishing among selective stimuli | to identify: determine and select based on specific characteristics | Symbolic<br>A. letters<br>B. arrows, etc.<br>C. words<br>D. diagrams | B. should be close to actual "real world" requirements | Motion: film<br>kinescope<br>Models: still (mock-up)<br>motion (analog) | (Teaching Step) | |
| | to recall: select and/or reconstruct from memory | Models<br>A. displays | | Audio: Tape<br>discs | | |
| Interpreting<br>identifying meaning of stimuli in terms of response | to compare: relate characteristics of one or more objects, symbols i.e.<br>A. like classes<br>B. different classes | Auditory<br>A. tones<br>B. frequency<br>C. loudness<br>D. sequence<br>E. pattern<br>F. discourse | | Feedback devices:<br>A. Programs<br>teaching machines<br>tape (language)<br>B. Vis. and Audio<br>programs<br>teaching machines | | |
| Decision Making<br>deriving conclusions from meaningful date | to choose: select between objects, symbols, rules, models | | C. demands actual simulation for achieving required performance | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| | to derive: deduce relationships from general to specifics, induce from a set of specifics a general application | | | | B. cannot complete tasks to follow without <u>total comprehension</u> (central focus)<br><br>IPS or TPS | 3. highest order of decision making and synthesis skills<br><br>(total initiation of method by learner) |
| 5. <u>Synthesizing</u> pulling together or integrating with strategy | <u>to apply</u>: perform action applying derived principles, rules, etc.<br><br><u>to solve for</u>: select appropriate strategy<br><br><u>to synthesize</u>: pull together for specific relationships | | | | | |

Referring to Dr. Corrigan's Method/Media Selection Criteria and bearing in mind the requirements for this "Module", we can then proceed to select the supportive media on the stated bases. The student in this case is primarily concerned with a process of identification and so supportive media is required to assist him in the recall and identification of information.

Again referring to the Selection Criteria under the heading, "Identifying", the stimulus requirements are Symbolic and/or Models. The former is served by films (both still and motion) and the latter by possibly, three-dimensional representations. Selection was made then, from the listed media. Where a specific film, for example, was indicated and none was listed by suppliers as available, a notation to that effect appears. Cost considerations were not deemed to be significant in the choice of media for this "Module".

Reference to the sections of the "Module" headed "References and Resources" will show the use of the code numbers herein included to indicate suggestions as to the material to be used in support of the attainment of the "Unit Objective".

## NUCLEAR SCIENCE CURRICULUM MODULE OF INSTRUCTION

UNIT: Basic Atomic Structure

COURSE INDEX: This unit should be introduced in an eighth grade general science course of study.

THRESHOLD KNOWLEDGE: There is no prerequisite for this unit. It is the first of the series and provides the foundation knowledge for succeeding units.

### UNIT OBJECTIVE

Using a periodic table, the learner will be able to identify and state the atomic number of a given element; the number of protons in the nucleus of a given element, an estimate of the number of neutrons in a given element; and the number of orbital electrons in a given element.

## RATIONAL FOR MODULE

This unit provides the basis for all future lessons of the Nuclear Science Curriculum. It provides the technical knowledge required to understand the effects of radiation on matter and thus the ramifications of these effects for use of irradiated products, using radiation methods for medical diagnosis and treatment, and working with radioactive materials.

## SEQUENCED HIERARCHIAL LEARNING PATH

**Present Concepts of Atomic Structure**

a. Nucleus composed of:

| | Symbol | Charge |
|---|---|---|
| neutrons | n | 0 |
| protons | p | + |

b. Orbital

Energy levels, binding energy, ionization potential

c. Terms and Symbols

| | Symbol |
|---|---|
| (1) Mass number | A (superscript) |
| (2) Atomic number | Z (subscript) |

(3) Definitions of nucleon, nuclide, isotope, ion, ionization

d. Periodicity of the elements

1. State the symbol and charge for neutron, electron and proton.

2. State mass relationships between neutrons, protons and electrons.

3. Identify the definition of a nucleon.

4. Identify the definition of a nuclide.

5. Identify the definition of atomic weight.

6. Distinguish between atomic weight and atomic mass.

7. Given an element with its mass number as a superscript and its atomic number as a subscript, distinguish one from the other.

8. Given the components of a carbon atom, construct a diagram according to Bohr's postulate of an atom.

Shown a Periodic Table, state: the atomic number of a given element; the atomic weight of a given element; the number of protons in the nucleus of a given element; and the number of orbital electrons in a given element.

# PROFICIENCY TEST FOR MODULE

| STIMULUS | RESPONSE |
|---|---|
| The Periodic Table of Elements from the Periodic Table | |
| 1. The atomic number of tin is_____ | 1. (50) |
| 2. The atomic weight of tin is_____ | 2. (118.69) |
| 3. How many protons are in the nucleus of "C" | 3. (6) |
| 4. How many neutrons would you estimate to be in the nucleus of C? | 4. (6) |
| 5. How many electrons would you estimate A1 to have? | 5. (13) |

This test may be used as a pre-test and post-test to measure learner's performance. Any one of the elements on the periodic table may be substituted in the above test to eliminate pre-post-test carry over.

## CRITERION TEST MEASURES FOR EACH INSTRUCTIONAL OBJECTIVE

| STIMULUS | RESPONSE | RECOMMENDED ACHIEVEMENT |
|---|---|---|
| 1. Complete the following chart by indicating the symbol and electrical charge for each of the particles. | | 90/100 |
| Particle — Symbol — Charge | | |
| Neutron | (n) (0) | |
| Electron | (e) (-) | |
| Proton | (p) (+) | |
| 2. Of the atomic particles discussed protons and ____________ have approximately the same mass while ____________ are about (2000/200) times lighter. | (neutrons) (electrons) (2000) | 95/100 |
| 3. Protons and neutrons are both called: | | 90/100 |
| ____ A. Particles | | |
| ____ B. Nucleons | | |
| (X) Both | | |
| ____ Neither | | |

RECOMMENDED ACHIEVEMENT

4. The term "Nuclide" is used to describe — $\frac{90}{100}$

_____ A. both protons and neutrons

(X) B. an atomic species characterized by the number of protons and neutrons it contains

_____ Both

_____ Neither

5.&6. The atomic weight of an element: — $\frac{90}{100}$

_____ A. is the weighted mean of the masses of the neutral atoms

_____ B. can differ from the atomic mass number because of the presence of isotopes

(X) Both

_____ Neither

7. In the expression: $U^{235}_{92}$ — $\frac{90}{100}$

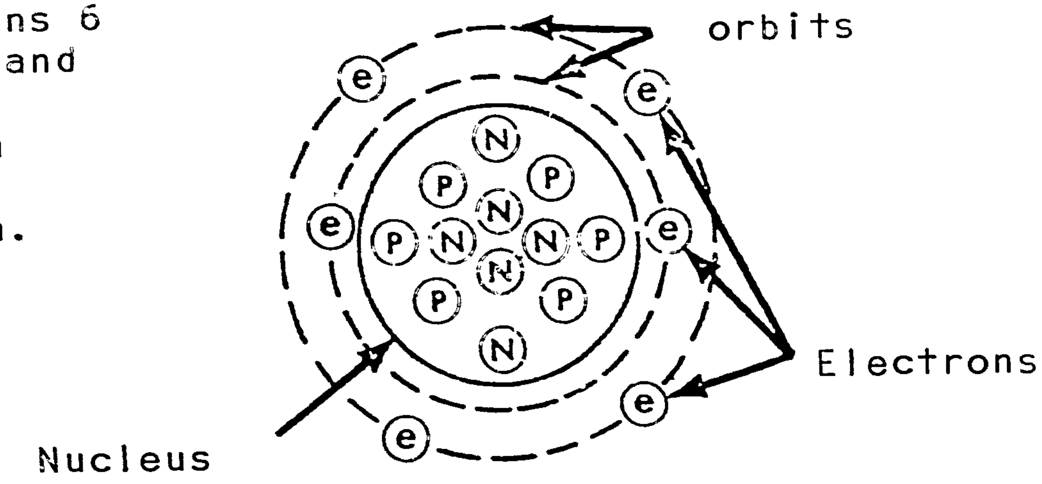
_____ A. the superscript (235) is the atomic number

_____ B. the subscript (92) is the atomic mass

_____ Both

(X) Neither

CRITERION TEST MEASURES
FOR EACH INSTRUCTIONAL OBJECTIVE

| STIMULUS | RESPONSE | RECOMMENDED ACHIEVEMENT |
|---|---|---|
| 8. A carbon atom contains 6 protons, 6 neutrons and 6 electrons. Draw a diagram of this atom according to Bohr's postulate of an atom. |  | 90/100 |

| INSTRUCTIONAL OBJECTIVE | LEARNING STEPS/ACTIVITIES |
|---|---|
| 1. State the symbol and charge for neutron, electron and proton. | Introduction to Unit. |
| 2. State mass relationships between neutrons, protons and electrons. | Develop the basic vocabulary and concepts of atomic structure through an historical approach. |
| 3. Identify the definition of a nucleon. | Discussion should bring out the following points: |
| | Definition of an atom.<br>Size concepts of an atom.<br>(Use comparisons with familiar objects and numbers). |
| | The discovery of the atomic nucleus. |
| | The discovery of the electron |
| | Space concepts in an atom.<br>(Make a comparison with the macroscopic world.) |
| | How electrons are attracted and "held" by the nucleus. |
| | The discovery of protons. Relative mass and charge of proton and neutron. |
| | The necessity of neutrons to account for the mass of the atom. No charge; mass=proton. |
| | Discuss and define a nucleon. |

| INSTRUCTIONAL OBJECTIVE | LEARNING STEPS/ACTIVITIES |
| --- | --- |
| 4. Identify the definition of a nuclide. | Explain to the learners that the difference between atoms of different elements is in the number of the particles of which they are composed.<br><br>Specifically, the atoms of each element have different numbers of protons and, therefore, also electrons.<br><br>Show some models of simple atom structure and have the learners diagram these models on the board identifying the structural parts of hydrogen and helium.<br><br>Discuss the value of a 3-dimensional model as opposed to drawing.<br><br>When the learner is doing helium, show how the number of neutrons can vary within the atoms of a given element. Then define isotope and nuclide. |

| INSTRUCTIONAL OBJECTIVE | LEARNING STEPS/ACTIVITIES |
|---|---|
| 5. Identify the definition of atomic weight. | In a discussion define atomic number and atomic weight. Using the periodic chart, show how to distinguish one from the other. |
| 6. Distinguish between atomic weight and atomic mass. | Account for the fact that individual isotopes of an element have an atomic mass that is a whole number, while the atomic weight of an element is usually shown as a decimal. |

| INSTRUCTIONAL OBJECTIVE | LEARNING STEPS/ACTIVITIES |
| --- | --- |
| 7. Given an element with its mass number as a superscript and its atomic number as a subscript, distinguish one from the other. | Demonstrate on the board how a specific nuclide is designated with the atomic mass number as a superscript and the atomic number as a subscript. Explain how to determine the number of neutrons in a nuclide by subtracting the atomic number from the atomic mass. |
| 8. Given the components of a carbon atom, construct a diagram according to Bohr's postulate of an atom. | Continue with the diagrams of successively heavier elements by indicating a specific isotope of the element and eliciting from the class the number and location of particles composing each.<br><br>Concept of energy levels could be introduced here as background for other, later objectives, e.g. ionization and chemical bonding. Should expect learners to be able to diagram electron configuration for elements 1-20.<br><br>Select specific nucleons from elements 1-20 and ask learners to draw diagrams, showing number of protons and neutrons in the nucleus and the number of electrons in the various energy levels. |

<u>Terminal Performance Objective</u>

Shown a Periodic Table, state: the atomic number of a given element; the atomic weight of a given element; the number of protons in the nucleus of a given element, an estimate of the number neutrons in a given element; and the number of orbital electrons in a given element.

REFERENCES AND RESOURCES

TEACHERS CRITIQUE

*8th Grade Text
The Atom and the Earth
Chap. 4, Sec. 11B

Transp.- Relative size of atom to learner's environment
Not currently available (to be develcped)

Film - How Big is an atom? 5.6.9
5.2.1

Single Concept 8 mm loops
1 (Size relationships of Atoms)
2 (Space relationships within an atom)
Not currently available (to be developed)

Selected Readings of the contribution of specific scientists to our knowledge of atomic structure and their experimental approach.

Rutherford
Planck
Bohr
Dalton
Thomson

REFERENCES AND RESOURCES

TEACHERS CRITIQUE

8th Grade Test
<u>The Molecule and the Biosphere</u>
Chap. 10, Sec. IIIA

Transp. <u>Atomic Structure</u> 2.1.1, 2.1.17, 2.2.2, 2.2.3,
(Series of overlays) 2.4.1, 2.4.2, 2.4.3

Film - A is for Atom 5.8.1

Film Strip - <u>Exploring the Atom</u> 3.1.1.1

Models - Models of simple atoms that can be taken apart. 9.3.1

REFERENCES AND RESOURCES

TEACHERS CRITIQUE

| | |
|---|---|
| Chart | Periodic Chart |
| Transparency 2.1.16 | Periodic Table of Elements |
| Film Strip 3.1.1.2, 3.4.1.7, 3.4.1.8 | Atomic and Molecular Weights |

8th Grade Text
The Atom and the Earth
Chap. 4, Sec. IV

| REFERENCES AND RESOURCES | TEACHERS CRITIQUE |
|---|---|

8th Grade Text
The Atom and The Earth
Chap. 4, Sec. IV, A, 2

Transparencies of atomic structure previously used.

Model of atoms used prior activity

8th Grade Text
The Molecule and the Biosphere
Chap. 10, Sec. III A.

8th Grade Text
The Atom and The Earth
Chap. 5, Sec. II