T1959R/G651p
2943

Name: James W. Goodfellow Date of Degree: May 24, 1959

Institution: Oklahoma State University, Stillwater, Oklahoma

Title of Study: A PLAN FOR THE STUDY OF ATOMIC ENERGY IN THE JUNIOR AND SENIOR HIGH SCHOOL

Pages in Study: 30

Candidate for Degree of Master of Science

Major Field: Natural Science

Scope of Study: Changes in our way of living brought about by the advent of the Atomic Age have resulted in new problems for the schools. All students must acquire a basic understanding of the principles, the possibilities, and the hazards of atomic energy in the new era. Those students who plan to make science their life work must be given a basic training upon which to build. It is the purpose of the report to present a series of study units for junior and senior high schools which will meet the needs of both groups of students.

Findings and Conclusions: Correspondence with thirty-seven of the State Departments of Public Instruction indicates little organized effort to set up any state-wide atomic energy education programs. However, many schools are including some work of this nature interspersed in the science courses. The units presented in this report provide general information on the physical nature of matter for the seventh and eighth grades. In the general science class, since this is the only point of contact with all students, an attempt is made to provide understanding of the physical nature of atomic energy, its importance to mankind, and the social and economic implications. The units for the advanced science classes provide more detailed information and are designed to enrich science experiences through the use of radioisotopes.

ADVISER'S APPROVAL--------------

A PLAN FOR THE STUDY OF ATOMIC ENERGY IN THE JUNIOR AND SENIOR HIGH SCHOOL

By

JAMES WILLIAM GOODFELLOW

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1937

Submitted to the faculty of the Graduate
School of Oklahoma State University
in partial fulfillment of the
requirements for the degree
of
MASTER OF SCIENCE
May, 1959

A PLAN FOR THE STUDY OF ATOMIC ENERGY IN THE JUNIOR AND SENIOR HIGH SCHOOL

Report Approved:

Report Adviser

Dean of the Graduate School

TABLE OF CONTENTS

Chapter		Page
I.	THE PROBLEM	1
II.	NATURE OF MATTER UNITS IN 7th and/or 8th GRADES	4
III.	UNITS FOR THE GENERAL SCIENCE CLASS	7
IV.	UNITS FOR THE BIOLOGY CLASS	14
V.	RADIOISOTOPES IN THE CHEMISTRY CLASS	18
VI.	RADIOISOTOPES IN THE PHYSICS CLASS	19
VII.	TEACHING AIDS FOR JUNIOR AND SENIOR HIGH SCHOOLS.	22
	A Selected Bibliography	22
	Films	24
	Free Materials	25
	Charts and Tables	26

CHAPTER I

THE PROBLEM

The statement that we are in a New Era, the Atomic Age, has been made so often that it has become trite and meaningless. This seems to be true especially for many school administrators who, as a group, are intrusted with the task of keeping subject matter abreast with the needs of our future citizens.

Much is being added each year to the working knowledge we have of atomic energy. Research is adding new elements to the Periodic Table. There are over twelve hundred forms or isotopes of these elements known at this time and more are being added each year. Tools of research are being developed at an accelerated pace that make man's past efforts seem trivial indeed. Developments in medicine find man about to grasp victories over many of his age-old enemies.

Development of small and relatively inexpensive devices for converting atomic energy to electrical energy appear to be the next great step forward in the struggle to liberate man from hunger and poverty in the less favored areas of the world. Man is making progress in his effort to produce and control nuclear fusion power which will give him power comparable in scope and abundance to that of the sun.

With these developments comes a host of new responsibilities for the citizens of today and tomorrow. Waste products which are capable of emitting deadly radiation for centuries are being produced in ever-increasing amounts. Radioactive fall-out from nuclear bombs has been distributed over the entire earth. The increasing use of radioisotopes presents a potential radiation hazard to man.

Training requirements for the job opportunities ahead are changing drastically. It is no longer sufficient for the student to prepare himself for his father's profession. He must look ahead and anticipate the needs of the new age. Eugene B. Hotchkiss, vice-president of Vitro Corporation of America, stated on October 31, 1957, that "Two thousand nuclear engineers will be needed each year to man the nation's nuclear industry at its predicted rate of growth."

Statement of the Problem

The schools face a twofold problem. All students must acquire a basic understanding of the principles, the possibilities, and the hazards of atomic energy in this new era. Those students who plan to make science their field of endeavor must be given the basic training required so that they can pursue study in these fields successfully in college. It is the purpose of the writer to set up a plan for the study of atomic energy in the Junior and Senior High Schools that will meet these needs.

Methods of Investigation Used

All State Departments of Education were requested to furnish lesson plans and other materials used in their schools on the subject of atomic energy. Lectures by heads of the research teams of Los Alamos Laboratories were used. Training of the writer in the Radiation Biology Institute of the University of New Mexico and experience of the writer in using radioioisotopes in high school teaching were drawn upon.

Organization

The lesson plans are produced in outline form for the sake of brevity. The chapter on references provides a source of material that will aid the user in elaborating on the outlines to the extent desired. Material taken from lectures not available as source material is reproduced in greater detail.

CHAPTER II

NATURE OF MATTER UNITS

SEVENTH and/or EIGHTH GRADES

Materials

Wooden Blocks Labeled ${}_1p^1$ and ${}_0n^1$, Periodic Chart of the Elements, Chart of the Isotopes, Geiger Scaler-ratemeter, Cloud Chamber and Source of Light, Radiation Sources (Radium, $Cobalt_{60}$ Uranium Ore), Golf Ball, Pin with Colored Head.

Lesson Plan Outline

A. The Simplest Kind of Matter
   1. The simplest element (Latin - elementum) is hydrogen.
   2. The atom (Greek-a,not; tom,cut up) is one unit of an element.
   3. Dimensions of the atom: diameter of the entire atom 10^{-8} cm., diameter of the nucleus 10^{-12} cm. (If each person were the size of an atom, all the people in the world could be placed on the head of a pin.)
   4. Simple model of the atom
      a. The nucleus contains the proton which is positively charged, the electron in the orbit is negatively charged.
      b. Centripetal force balances the attraction of unlike charges and holds the electron in the orbit. (Illustrate with chalk on a string.)

B. Simple Diagramatic Concept of the Atom
   1. A student holds the golf ball which represents the nucleus.
   2. Another student holds the colored-headed pin which represents the electron.
   3. The student with the pin must be in his orbit about a mile from the nucleus and must run with speeds approaching the speed of light, (186,000 mi/sec.)

C. Space Concept of the Atom
   1. The greater part of the atom is space.
   2. A student holds his hand over the tube of the Geiger Counter which detects particles going through his hand from a radium source.

3. Description of Rutherford's alpha particle-gold foil experiment in which over 90% of the particles pass through the foil.

D. Building Blocks of the Atoms
1. The first building block of the nucleus is the proton, written ${}_{+1}p^1$. (Subscript refers to charge, superscript refers to mass in atomic mass units).
2. The electron is written ${}_{-1}e^0$ since it has a negative charge and a negligible mass.
3. ${}_{+1}p^1 + {}_{-1}e^0 \rightarrow {}_0n^1$, the neutron which has a mass of 1 amu (atomic mass unit) and no charge.

E. Hydrogen is written ${}_1H^1$ since it has one proton in the nucleus and a mass of one amu.
1. ${}_1H^1 + {}_0n^1 \rightarrow {}_1H^2$, a heavy isotope (Greek-isos, equal; topos, place) of hydrogen called deuterium.
2. ${}_1H^1 + 2{}_0n^1 \rightarrow {}_1H^3$, a heavy isotope of hydrogen called tritium.

F. Nature of Isotopes
1. Different forms of the same element having the same number of protons but different numbers of neutrons and therefore different masses.
2. The number of protons and the corresponding number of electrons in orbits determine the chemical characteristics of the element.
3. There are over 1200 isotopes of 104 elements and more being added each year. Of the 104 elements only 94 are found in nature.

G. More Complicated Atoms
1. ${}_1H^3 + {}_1p^1 \rightarrow {}_2He^4$, an atom of Helium.
2. ${}_2He^4 + {}_0n^1 \rightarrow {}_2He^5$, another isotope of Helium.
3. ${}_2He^5 + {}_1p^1 \rightarrow {}_3Li^6$, an atom of Lithium.

H. Energy Released by Fusion of Atoms
1. ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4$ (fusion of H atoms)
2. 2.014186 + 2.014186 = 4.003890 + 0.024482 amu's of mass lost.
3. 0.024482 x 931 = 22.8 Mev. (million electron volts)

I. Energy Released by Fission of Atoms
1. ${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{139} + {}_{36}Kr^{86} + 11{}_0n^1$
2. 235.12 + 1.009 = 138.92 + 85.94 + 11 x 1.009 + 0.17 amu's of mass lost.
3. 0.17 amu x 931 = 158.27 Mev. of energy.

J. Power from Fission
1. Experimental atomic reactor in Idaho produces power enough for a city of 40,000 people.
2. The complete reactor (shielding, instruments, fuel unit, etc.) is housed in a building the size of a large room and three stories high.

3. Fuel unit is the size of two suitcases and is charged with 13 pounds of Uranium.

K. Tracks of Nuclear Particles in Cloud Chamber
   1. Long straight tracks from cosmic rays or high energy beta particles.
   2. Short, heavy tracks from alpha particles.
   3. Faint, zig-zig tracks from low energy beta particles.

L. Detection of Radioactive Ore with Spinthariscope

M. Radioactive Isotopes
   1. Throw off particles at distinct, unique rate.
   2. Man cannot change the disintergration rate.
   3. Time required for a radioactive material to lose half its intensity called half-life.
   4. Isotope chart shows the stable and radioactive isotopes, the particles ejected, and the half-lives.

N. Uses of Radioisotopes
   1. I^{131} used in mapping thyroid.
   2. P^{32} used to map brain tumors.
   3. P^{32} used to show uptake of materials by the roots of plants.
   4. Fe^{59} used in determining blood volume.
   5. Co^{60} used in radiating cancer cells.
   6. C^{14} used to date wood. (Charred wood in an old campfire uncovered by the wind near Clovis, New Mexico was found to be 37,000 years old. This is the oldest trace of man found on this hemisphere.)

CHAPTER III

UNITS FOR THE GENERAL SCIENCE CLASS

Materials

Wooden Blocks Labeled $_1p^1$ and $_0n^1$, Periodic Chart of the Elements, Chart of the Isotopes, Geiger Scaler-Ratemeter, Cloud Chamber and Source of Light, Radiation Sources (Radium, Cobalt $_{60}$, Uranium ore), Radioisotopes (Phosphorus$_{32}$, Iodine$_{131}$), Golf Ball, and Pin with Colored Head.

Lesson Plan Outline

A. Physical Structure of Matter.

1. Concepts of the atom
   a. Democritus, the Greek philosopher, in 400 B.C. surmised that all objects are made of invisible, indivisible particles. Bunched together, they make one visible object; in another arrangement they make another visible object. These particles, atoms, are never destroyed, but are used over and over. They cannot be created. Aristotle disagreed and this concept of the atom faded for 1800 years.
   b. It was the quantitative measurements of the chemist, John Dalton, about 1800 that firmly established the atom concept as a fact. Chemical reactions showed each element had its own characteristic unit weight. The problem of transferring the atom from the realm of the philosopher to the quantitative world of the chemist can be somewhat appreciated by consideration of the smallness of that familiar group of two atoms of hydrogen bound to one atom of oxygen- the water molecule. A tablespoon of water would contain 6×10^{22} of these three-atom clusters. The wonder is that anything so small could be so concrete to the scientist.

2. The simple hydrogen atom. (Review from chapter II: A,B,C,D,E, and K.)
3. More complicated atoms
   a. $_1H^3 + {}_1p^1 \rightarrow {}_2He^4$, an atom of helium.
   b. $_2He^4 + {}_1P^1 \rightarrow {}_3Li^5$, an atom of lithium.
   c. $_3Li^5 + {}_0n^1 \rightarrow {}_3Li^6$, another isotope of lithium.
   d. $_3Li^6 + {}_1p^1 \rightarrow {}_4Be^7$, an atom of beryllium.

4. Theory of formation of elements
   a. In stars like our sun the proton-proton chain producing He is dominant.
   b. In red giants slow neutron capture results in formation of C^{12} from the He.
   c. In Supernova core the iron group elements are formed by the extreme densities and temperature.
   d. In the envelope of the supernova explosion rapid neutron capture results in formation of Cf^{254} with resulting decay forming the elements down to lead.
5. Electron shells and relationship to metallic and non-metallic characteristics.

B. Atomic Energy: Fusion and Fission
   1. Einstein's Mass-Energy Equation: $E=mc^2$
   2. Atomic mass units based on the wright of O^{16} = 16.00000 amu's.
   3. One amu of mass changed to energy = 931.2 Mev (Million electron volts).
   4. An electron volt is defined as the work done by an electron when it falls through a potential difference of one volt.[1]
   5. Fusion, the combining of two nuclei
      a. Review unit H chapter II.
      b. The more probable reaction is ${}_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + n$, substituting atomic weights for elements, $2.014714 + 3.016997 \neq 4.003879 + 1.008981$, reveals that 0.018872 amu's have changed to energy equal to 17.57 Mev.
      c. There is no radioactive waste from hydrogen fusion.
      d. Atomic bomb is used to produce sufficiently high temperatures to trigger the reaction.
      e. Radioactive fall-out results from the atomic explosion.
   6. Fission, the breaking up of a heavy nucleus into two parts
      a. Review units I and J of Chapter II.
      b. The energy released from fissioning one kilogram of U^{235} is about 8×10^{20} ergs, equivalent to the energy produced by burning about 3,500 tons of high grade coal.[2]

---

[1] Frank M. Durbin, Introduction to Physics, (Prentice-Hall, Englewood Cliffs, N.J., 1957) p. 556.

[2] Federal Civil Defense Administration, Technical Bulletin -11-22, (U.S. Government Printing Office, January 1957) p. 3.

e. Energy released by burning, a chemical process envolving only the orbital electrons, depends upon a rearrangement of the outermost orbital electrons. Fission and fusion involve the change of mass in the nucleus to energy by Einstein's formula $E = mc^2$.

C. Atomic Reactors (use as much material as desired from chapter VI-C).

D. Atomic Waste and Bomb Fall-out
   1. The fission products are radioactive.
      a. Explanation of radioactivity
      b. Explanation of half-life
      c. Examples of radioactive isotopes showing half-lives and types of radiation
   2. Uranium may fission into many different combinations or pairs of atoms.
   3. Waste from atomic reactors must be stored for long periods, as much as several centuries, until the intensity of radiation has decreased to a safe level.
   4. Disposal problems
      a. Some material highly radioactive with long half-lives.
      b. Some materials highly corrosive.
      c. Some placed in drums, surrounded with concrete and dumped in the ocean where the ocean floor has a deep cover of mud.
      d. Other methods explored include storage in salt domes, abandoned oil wells, and combining with clay in baked pellets for storage.
      e. Storage costs for radioactive wastes from reactors amounted to $10,000,000 dollars in 1957 according to Mr. C. W. Christensen, chief of the Waste Disposal Team of the Los Alamos Laboratories, in a lecture to the Radiation Biology Institute, University of New Mexico, July, 1957.

   5. In a bomb blast the fission products are thrown into the atmosphere and return to earth as fall-out which is radio-active material composed of dirt, stone, and other debris mixed with the fission products.
      a. Some of the fall-out from an atom bomb blast spreads over a relatively small area, possibly 200 miles long and several miles wide, depending on such factors as size of bomb, height above surface of earth detonation occurred, wind velocity, precipitation, etc. Some of the smaller particles may be carried around the earth.
      b. Fall-out from a hydrogen bomb may be thrown into the stratosphere and transported long distances. Doctor Ernest Anderson, chief of Biometrics, Los Alamos Laboratories, stated in July, 1957,

"

"It will take ten years for the radioactive material already placed in the atmosphere by our bomb tests to fall back to earth".

c. Strontium 90 is one of the most dangerous of the fall-out materials.
   1. Although produced only in the fissioning process and not found in nature, Sr^{90} has been found distributed over the entire earth by high altitude winds.
   2. Sr^{90} is taken into the body by food consumption.
   3. Sr^{90} behaves like calcium in the body and becomes a part of the bone cells.
   4. The half-life of Sr^{90} is 25 years.
   5. The beta particles emitted by Sr^{90} are weak and relatively harmless outside the body, but inside the bone cells can produce dangerous changes. Sr^{90} decays into Y^{90} which reaches a state of equilibrium with the Sr^{90}. In this state it is emitting as many betas as the Sr^{90} but they have an energy level of 2.24 Mev as compared to 0.54 Mev for the Sr betas. These Y^{90} betas are therefore dangerous and could cause severe skin damage.
   6. Analysis of bone samples from over the world show the Sr^{90} level well below the estimated danger point but continued bomb testing or nuclear war could bring fall-out levels above the MPL (maximum permissible level).

E. Uses of Radioisotopes
   1. Tracers in the field of biology.
      a. Tracing of foods we eat.
      b. Copper in blood formation.
      c. Diagnosis of brain tumors.
      d. Diagnosis of thyroid gland disturbances.
      e. Pumping action of the heart.
      f. Average life of red blood cells.
      g. Total volume of the blood.
   2. Tracers in the field of agriculture
      a. Photosynthesis studies.
      b. Fertilizer absorption by roots.
      c. Plant metabolism studies.
      d. Fertilizer absorption by leaves.
      e. Soil fertility studies.
      f. Action of insecticides.
      g. To study diet additives.
   3. Tracers in the field of industry
      a. Trace circulatory systems for leaks.
      b. To label oil shipments in pipe lines.
      c. To study effects and efficiencies of detergents.
      d. Wear determinations.

  e. Diffusion in solids - alloy studies.
  f. Lubrication studies.
  g. Floatation.
4. Non-tracer used in industry
  a. Radiographs of castings and welds.
  b. Thickness gauging of materials.
  c. Liquid level gauge.
  d. Density metering.
  e. Sterilization of foods.
  f. Creation of cross linkages in plastics.
  g. Checking fire brick loss in furnaces.
  h. C^{14} dating.
5. Therapeutic uses in medicine
  a. Hyperthroidism.
  b. Irradiation of cancer.
  c. Polythycemia and leukemia.
  d. Sterilization of bone grafts.

F. Defense against Radiation
1. Guarding against over-exposure by X-rays.
  a. Avoid unnecessary exposure.
  b. Insist on adequate shielding against scattered rays.
  c. Avoid exposure if at all possible during pregnancy and especially during the first five weeks of pregnancy.
2. Guarding against exposure to radiation from radioisotopes
  a. Handle isotope containers with tongs.
  b. Use rubber gloves to avoid exposure of skin to radioisotope solutions.
  c. Use lead shielding to absorb radiation.
  d. Avoid eating, drinking, or smoking in labs.
  e. Avoid spillage which will permit the material to dry and be carried by air currents.
  f. Monitor persons and labs for radiation hazards.
  g. Wear dosimeters or film badges if working with radioisotopes.
  h. Handle high intensity isotopes by remote control.
3. Defense against bomb blast radiation
  a. Initial radiation may be of limited importance since a person close enough to be damaged by initial radiation would probably be killed by other effects such as blast or heat.
  b. Initial radiation, that produced in the first minute after detonation, is made up primarily of neutrons and gamma rays.
  c. The initial radiation is very penetrating and may be dangerous to a distance of several miles from the blast.
  d. The most effective shielding is damp earth and concrete.
4. Defense against residual or fall-out readiation

a. Fall-out is classed as local, which may cover an area 200 by 40 miles, and world-wide, which would be of low intensity.
b. The best protection is distance and shielding.
c. Most of the fall-out particles decay rapidly losing as much as 98% of their intensity in the first 24 hours.
d. The gamma radiation is very penetrating and extensive shielding is required.
e. Alpha particles cannot penetrate the skin but become dangerous if allowed to enter the body. They may enter the body by being on food or water consumed, by being in air consumed during respiration, or by being deposited in breaks of the skin.
f. Beta radiation can be dangerous both internally and externally. It is most hazardous when the radioactive dust carrying the particles comes into direct contact with the skin or is taken internally.
g. Persons exposed to fall-out should be completely covered by clothing and breathe through a mask or handkerchief.
h. The dust should be washed off as quickly as possible.
i. Shielding is required as protection against gamma radiation. 36 inches of dirt, 24 inches of concrete, or 3 inches of lead are equivalent in absorption and will reduce exposure to 1/5000 of that in the open.
j. Radiation from fall-out builds up as the fall-out accumulates and then decreases through natural decay of radioactive elements.
k. Decontamination of materials exposed to fall-out must be carried out before they are used.

G. Social and Economic Implications

1. Dwindling energy supplies and growing demands for more energy require that we develop a new energy supply.
   a. In the past 100 years we have increased our per capita use of energy per year from about 10 million Btu's to about 75 million Btu's.[3]
   b. In the next 50 years we may increase this figure to 450 million Btu's per capita per year.[3]
   c. Fission and eventually fusion power is the most promising answer to this problem.
   d. For the first time in history the "have not"

---

[3]Lynn M. Bartlett, et al, <u>Nuclear Science in the Class room, A Handbook for Teachers</u>, (Michigan Department of Public Instruction, 1957), p. 117.

nations may have a source of power which will permit them to raise their living standards.

2. Control is necessary.
   a. Uncontrolled bomb testing by many nations would make fall-out levels dangerously high.
   b. Some testing is essential to develop new techniques of power and blasting uses.
   c. If adequate international control is not secured, the United States must continue testing in order to develop "clean" bombs which could be safely used as defensive measures against missiles.
   d. The increasing use of atomic power will make control of waste dumping a necessity.
   e. Atomic energy must be properly controlled if the world is to avoid catastrophe.
3. Social changes made possible by atomic energy
   a. New vocational opportunities will be almost unlimited in this new age.
   b. Improved living conditions will result in all parts of the world with the greatest changes occurring in those areas of current power shortage.
   c. The potentialities of atomic energy for peacetime uses are so great that its development promises a source of power sufficient for almost every need.
   d. Use of atomic power will revolutionize life in the world just as the use of fire revolutionized life in the dim past, steam power in the 19th century, and electric power revolutionized life in the early 20th century.
   e. Radioisotopes are revolutionizing medical and other research. The improvement of health and the extension of life will undoubtedly be very great.
   f. New metals and other materials are being produced which will open new horizons for man.
   g. Atomic energy, if successfully devoted to the welfare of mankind, may remove drudgery and economic insecurity to the extent that it will be possible for man to achieve a new degree of dignity and freedom.

CHAPTER IV

UNITS FOR THE BIOLOGY CLASS

Materials

Periodic Chart of the Elements, Chart of the Isotopes, Geiger Scaler-Ratemeter, Radiation Sourses (Radium, $Cobalt_{60}$, Uranium ore), Radioisotopes (See list in Appendix III), and X-Ray Film, Holders, and Developer.

Lesson Plan Outline

A. Radioisotopes (review Chapter II in as much detail as necessary to insure an understanding of the meaning of radioisotopes and radioactivity.

B. Cell Damage by Radiation
   1. Large protein molecules most susceptible to radiation damage.
   2. Cell enzymes are altered.
   3. Chromosomes may be broken up.
   4. Swelling of the nucleus.
   5. Increase in viscosity of the protoplasm.
   6. Permeability of cell wall increased.
   7. Cells may break and act as emboli in the blood thus blocking capillaries.

C. The Radiation Syndrome (somatic cell damage)
   1. Group I - Death certain; neuro death within two hours with exposure above 10,000 roentgens.
   2. Group II - Survival improbable
      a. Whole body radiation in excess of eight hundred roentgens.[4] (A roentgen is a unit of measurement of radiation amounting to the absorption of 93 ergs of energy by soft tissue.)
      b. Severe, and more or less continuous, vomiting occurring shortly after exposure, and followed by diarrhea, producing severe dehydration and apathy.
      c. Death due primarily to denuding of the villi of

---

[4]Samuel Glasstone, Sourcebook of Atomic Energy, (D. Van Nostrand Co., Inc., Princeton, N. J., 1950) p. 505.

the intestine with resulting hemorrhaging.
   d. Death usually occurs in three days although some victims may last two weeks.

3. Group III - Survival questionable
   a. Exposure amounting to 200 to 800 R with LD 50/30 dose (that amount which will kill 50% of those exposed in 30 days) believed to average 450 R.
   b. Vomiting will occur on the first day but will subside to be followed by a period of relative well-being from one to three weeks.
   c. Quiescent period followed by development of subcutaneous hemorrhages, sore mouth and throat, loss of hair, bloody diarrhea, loss of weight, and infection of thermal burns and other wounds that had been healing.
   d. Slow healing of wounds is the result of severe drop in white blood cell count.
4. Group IV - Survival probable
   a. Exposure up to 200 R.
   b. First day - transient nausea, some vomiting, and fatigue.
   c. Second to fourth week - slight feeling of ill health.
   d. Chief danger from infections resulting from low white blood cell count.
5. Survivors may suffer latent effects such as leukemia, cancer, cataract development, skin cancer, and general shortening of life.

D. Damage from Ingested Radioactive Materials[5]
1. In event of atomic accident or nuclear blast, there is danger of radioactive materials being breathed or swallowed.
2. Strontium$_{90}$ a dangerous fall-out material
   a. Sr^{90} is treated like calcium by the body and becomes a part of the bone cells.
   b. Source is wheat, milk, water, and vegetables.
   c. Half-life is 25 years.
   d. May cause leukemia and/or bone cancer.
   e. Has been scattered in minute quantities over the entire earth by high altitude winds.
   f. An intensity of 80 uuc (micro micro curies) is considered the MPL (maximum permissible level). The level at St. Louis, Missouri in December, 1958, was 15.6 uuc.
   g. A study of bone samples from all over the free world indicates that the highest concentrations of Sr^{90} are found in those individuals who have the greatest calcium requirements, ie. the young and the ill.

---

[5]Chapter VII, Chart 3, Radioisotopes in the Body.

3. A study of the chart referred to in footnote 5 will provide much useful information that can be studied in the same way that Sr^{90} has been treated.

E. Genetic Damage from Radiation

1. A most important study was made by the Genetic Committee of the National Academy of Science composed of 17 of the world's greatest geneticists and released in 1956.[6]
2. Major conclusions of the committee:
   a. There is no safe level of exposure.
   b. Genetic damage is cumulative.
   c. Radiation causes mutations which persist for generations.
   d. These mutations are nearly 100% harmful.
   e. A doubling of the radiation exposure to the gonads would result in 5 million children of presently living parents bearing and being affected by mutant genes in excess of normal mutations.
3. Recommendations of the committee
   a. Keep radiation exposure as small as possible.
   b. Keep a radiation exposure chart for every individual.
   c. Reduce medical X-rays to as low an amount as is consistent with medical safety.
   d. Shield gonads as completely as possible when X-rays are made of any part of the body.
   e. Previous recommendationsof MPL's should be reviewed often.
   f. No individual should receive more than 50 R exposure to age 30 nor more than 50 R additional to age 40.
   g. Every effort should be made to assign to exposure type jobs those individuals who are unlikely to have children.
4. The Genetic Committee estimated that on the average an individual receives to age 30 from background radiation 4.3 R to gonads, from medical X-rays 3.0 R to gonads, and from bomb fall-out, if continued at same rate as last 5 years, 0.2 R.

F. Health Physics

1. The best protection from fall-out is to remain in underground shelter until material decays to a safe intensity.
2. The air supply must be filtered.
3. Protective clothing should be worn if one has to

---

[6] Biological Effects of Atomic Radiation, (National Academy of Sciences, National Research Council, Washington, 1956) pp. 3-4, 14-20.

a. Glassware, tongs, etc. - sodium thiosulfate
b. Rubber gloves - soap and water
c. Lab clothing - washed by themselves in soap and water. If ineffective, use sodium or potassium citrate.
d. Skin - soap and water. If ineffective, use thick slurry of precipitated titanium oxide and wash for two minutes. Do not use brush which might break skin. Flush off with water.
e. Monitor materials and skin before and after decontamination.
f. Lesson plan Number 6 of the Federal Civil Defense Administration, National Headquarters, Battle Creek, Michigan contains four excellent decontamination exercises suitable for a biology class.

G. Uses of Radioisotopes (Review the uses of interest to a biology class previously covered in this report)

H. Uses of Radioisotopes in Teaching Biology. The most important use of radioisotopes in biology laboratories is as tracers in various experiments. The materials may be detected either by Geiger counter or by radioautograph. Either method is quite effective.

1. Translocation of radioactive phosphorus (P^{32}) in tomato plants via the roots.[7]
2. Translocation of radioactive phosphorus upward and downward in the tomato plant via the stem.[7]
3. Absorption of P^{32}, S^{35}, or Na^{22} through the leaves of tomato or pepper plants.
4. Removal by goldfish of radioactive phosphorus from water in a fish tank.[7]
5. Preparation of radioautographs.[7]
6. Detection of uptake of I^{131} by thyroid of laboratory animals.
7. Dilution technique of measurement of body fluid in laboratory animal with Na^{22}.
8. Measurement of blood volume of lab animal with Fe^{59}

[7]Samuel Schenberg, et al, Laboratory Experiments with Radioisotopes for High School Science Demonstrations, (United States Atomic Energy Commission, 1953) pp. 4-40.

CHAPTER V

RADIOISOTOPES IN THE CHEMISTRY CLASS

Materials

Periodic Chart of the Elements, Chart of the Isotopes, Geiger Scaler-Ratemeter, and Radioisotopes.

Lesson Plan Outline

A. Uses of Radiation Equipment in the Laboratory
   1. It is essential that safety precautions be carefully adhered to.
   2. No radioisotopes should be mixed together.
   3. Careful attention should be given to the geometry of the counting procedure when any comparative counts are to be made.

B. Uses of Radioisotopes in Chemistry Teaching
   1. Nuclear properties independent of chemical reaction.[8]
   2. Properties of isotopes of the same element.[8]
   3. Separation of uranium from its daughter products.[8]
   4. Diffusion using radioactive isotopes as tracers.[8]
   5. With the wide variety of radioisotopes available many dilution and tracer experiments may be set up to make the chemistry laboratory more interesting and meaningful.

---

[8]Ibid..

CHAPTER VI

RADIOISOTOPES IN THE PHYSICS CLASS

Materials

Periodic Chart of the Elements, Chart of the Isotopes, Geiger Scaler-Ratemeter, Civil Defense Portable Geiger Counter, and Radioisotopes.

Lesson Plan Outline

A. Nature of Matter and Structure of the Atom.
   1. Review from Chapter II of this report.

B. Nuclear Changes Resulting in Release of Energy by Fusion and Fission.
   1. Review and enlarge upon Chapter II of this report.

C. Atomic Reactors
   1. The atomic reactor depends upon a controlled chain fission reaction.
   2. If fewer than one neutron is released per fission, the reaction will die out.
   3. If greater than one neutron is released per fission, the reaction will build up exponentially and an explosion will occur.
   4. If exactly one neutron is available per fission, energy will be released at a constant rate.
   5. U^{238} averages less than one neutron per fission and so will not maintain a chain reaction.
   6. Th^{232}, U^{233}, U^{235}, and Pu^{239} are all capable of maintaining a chain reaction.
   7. Most reactors use enriched uranium as fuel, that is, a combination of U^{238} with one of the other fissionable materials listed in number 6 above. The one most commonly used is U^{235}.
   8. The first atomic reactor was set up in 1942 at the University of Chicago.
      a. The moderator was graphite blocks 4 1/8 x 4 1/8 x 16 1/2" with uranium cylinders 2 1/2 inches in diameter and weighing 6 pounds each placed between blocks in alternate rows.
      b. 41 tons of natural uranium was used.
      c. Cadmium strips as control rods were included as the pile was assembled.
      d. $B^{10}F_3$ ionization chambers were placed at various

points throughout the pile to measure the intensity of neutron flux.

e. Twelve inches of graphite covered the pile to serve as a neutron reflector.

f. When the 56th layer was added at 3:53 PM, December 2, 1942, flux was found to be 1.006 and the power began to rise exponentially. The cadmium control rods were reinserted when the power level reached 1/2 watt. Fermi wired Conant in Washington: "The Italian Navigator has landed on the foreign shore." Conant wired back: "Were the natives friendly?" Fermi replied, "Yes".

g. On December 12 the power was allowed to rise to 200 watts.

9. An experimental reactor in Idaho can produce enough power for the city of Enid, Oklahoma and has a fuel core the size of two ordinary suitcases charged with only thirteen pounds of enriched uranium.

10. All reactors produce heat as a result of the kinetic energy of the neutrons and fission products. The changing of this heat to usable energy is the engineering problem.

11. A small atomic device called a plasma thermocouple that produces electricity directly has been developed and is a big step toward more usable atomic power.

D. Atomic Waste and Waste Disposal

1. Review from Chapter II of this report as extensively as needed.
2. An additional proposal is that the more dangerous and long-lived isotopes such as Sr^{90} and Ce^{137} may be separated from the waste products so that the elaborate disposal precautions may be applied to the smaller amounts.

E. Nature of Background Radiation and Its Determination

1. Sources
   a. Cosmic ray bombardment of air molecules.
   b. Radioactive materials such as uranium, thorium, radium, etc., in the soil, bricks, concrete, etc. about us.
   c. Carbon $_{14}$ and potassium $_{42}$ taken into the body with food and water and air.
2. An interesting graph may be maintained daily of the background count taken inside the laboratory and outside the window of the laboratory.

F. Determination of the Starting Potential, Geiger Threshold, counting Plateau, and the Breakdown Voltage of the Geiger Scaler-Ratemeter.[9]

G. Determination of half-life.[9]

---

[9] Ibid.

H. Determination of Half-thickness of Common Building Material.[10]

I. Inverse Square Law.[10]

J. Absorption of Beta Radiation.[10]

K. Absorption of Gamma Radiation.[10]

L. Effect of a Magnetic Field upon Beta Particles and Gamma Rays.[10]

M. Thickness Measurement.[10]

N. Emergency Measurements of Radioactivity in Food and Water.[11]

---

[10] Ibid.

[11] Civil Defense Technical Bulletin-11-9, (Office of Civil and Defense Mobilization, 1952) pp. 1-2

CHAPTER VII

TEACHING AIDS FOR JUNIOR AND SENIOR HIGH SCHOOLS

A Selected Bibliography

Abrahams, Harold J. "Preparing High School Students for the Atomic Era." Science Education, XXXV (December, 1951), 266-68.

Anderson, Ernest C. "In Vivo Gamma Measurements at Very Low Levels with 4π Liquid Scintillation Detectors." IRE Transactions of the Professional Group on Nuclear Science, Vol. NS-3, No. 4, (Nov. 1956) pp. 96-102.

Anderson, Ernest C. et al. Science, Volume 125, Number 3261, June 28, 1957, 1273-1278.

Annotated Civil Defense- Bibliography for Teachers. Washington: US Govt. Printing Office, 1956.

Born, Max. The Restless Universe. New York: Dover Publications Inc., 1951.

Boswell, E. and J. Boswell. A Bibliography of Current Materials Dealing with Atomic Power and Related Atomic Energy Subjects for Non-Specialists. University of Michigan Fund for Peaceful Atomic Development, 1955.

Bradley, David. No Place to Hide. Boston: Little, Brown and Company, 1948.

Butts, Joseph S. Isotopes in Agriculture. Washington: Office of Technical Services, Dep't. of Commerce, 1956.

Citizenship for an Atomic Age. Special Issue. Washington: United States Government Printing Office, 1953, 15 pp.

Compton, Arthur Holley. Atomic Quest. New York: Oxford University Press, 1956.

Feinberg, J. G. The Atom Story. New York: Philosophical Library, 1953.

Gamow, George. The Birth and Death of the Sun. New York: The New American Library, 1952.

Glasstone, Samuel. Sourcebook on Atomic Energy. Princeton: D. Van Nostrand, 1950.

Haber, Heinz. Our Friend the Atom. New York: Dell Publishing Co., 1956.

Hevesy, George. Radioactive Indicators. New York: Dober Publications Inc., 1948.

Hood, Paul. Atoms without Anger. The Daily Oklahoman, April, 1956.

Libby, Willard. Radiocarbon Dating. Chicago: University of Chicago Press, 1955.

Major Activities in the Atomic Energy Program. Washington: US Govt. Printing Office. 1956, 256 pp.

Medical Aspects of Atomic Weapons. Washington: US Govt. Printing Office, 1950, 24 pp.

Nuclear Science in the Classroom. Lansing: Department of Public Instruction, 1957.

Oldenberg, Otto. Introduction to Atomic Physics. New York: McGraw-Hill Book Co., 1954.

Progress Report on Atomic Energy Research. Washington: US Govt. Printing Office. 1956.

Radiological Health Handbook. Washington: U.S. Department of Health, Education, and Welfare, 1957.

Schenberg, Samuel. Laboratory Experiments with Radioisotopes for High School Science Demonstrations. Washington: U. S. Govt. Printing Office, 1953, 53 pp.

Schubert, Jack and Ralph E. Lapp. Radiation: What It Is and How It Affects You. New York: Viking Press, 1957.

Stokley, James. The New World of the Atom. New York: Ives Washburn Inc., 1957.

The Atom and You. Des Moines: The Department of Public Instruction, 1950, 52 pp.

The Effects of Nuclear Weapons. Washington: U S Govt. Printing Office. 1957, 579 pp.

Titterton, E. W. Facing the Atomic Future. New York: St. Martins Press, 1956.

Films

Agriculture, Industry and Power, USIA's Atoms for Peace Series, 20 min., black & white, sound, free from USAEC.

A New Look at the "H" Bomb, 10 min., color, sound, free from Federal Civil Defense.

Atoms for Health, 12 1/2 min., black & white, sound, free from USAEC.

Borax: Construction and Operation of a Boiling Water Power Reactor, 14 min., black & white, sound, free from USAEC.

Facts about Fall-out, 12 min, black & white, sound, free from Federal Civil Defense.

Jobs in Atomic Energy, 12 1/2 min., black & white, sound, free from U.S. Atomic Energy Commission.

Let's Face It, 13 min., black & white, sound, free from Federal Civil Defense.

Medicine, U.S. Information Agency's Atoms for Peace Series, 20 min., black & white, sound, free from USAEC.

Operation Cue, 14 min., black & white, free from Federal Civil Defense.

Operation Ivy, 29 min., color, sound, free from Federal Civil Defense.

Radiation: Silent Servant of Mankind, 12 1/2 min., black & white, sound, free from USAEC.

The Atomic Detective, 12 1/2 min., black & white, sound, free from USAEC.

The House in the Middle, color, sound, free from Federal Civil Defense.

The Petrified River, 28 min., color, sound, free from USAEC.

Free Materials

Atomic Power and Safety, Consolidated Edison Co.
Developmental Fast Breeder Power Reaction, Power Reactor Development Co., Local Power Co.
Free and Inexpensive Literature Relating to Atomic Energy, American Museum of Atomic Energy.
Nuclides and Isotopes, General Electric Co.
Pathologic Effects of Atomic Radiation, National Academy of Sciences, National Research Council.
Radioisotopes in Agriculture, American Museum of Atomic Energy.
Reading List - Atomic Energy for All Ages, American Museum of Atomic Energy.
Selected Readings on Atomic Energy, Superintendent of Documents, Atomic Energy Commission.
Should You Be An Atomic Scientist, New York Life Insurance Co.
Slide Illustrations, American Museum of Atomic Energy.
The Atom in Our Hands, Union Carbide & Carbon Corp.
The Biological Effects of Atomic Radiation, (Summary Reports), National Academy of Sciences, National Research Council.
The Petrified River, Union Carbide and Carbon Corp.
The World Within the Atom, Westinghouse Electric Corp.
Using Atomic Energy in the Service of Mankind, Metropolitan Life Insurance Co.
You Can Understand the Atom, US Atomic Energy Commission.
101 Atomic Terms, Esso Research & Eng. Co.
From Division of Civilian Application, U.S. Atomic Energy Commission, Oak Ridge, Tennessee:

- Isotope Illustrations, Definitions of Radioisotopes
- Illustrations of Isotope Applications in Agriculture
- Illustrations of Isotope Applications
- Uses of Isotopes in Medical Research, Diagnosis and Therapy
- Illustrations of Isotope Applications in Biology and Medicine, Diagnosis
- Illustrations of Isotope Applications in Biology and Medicine, Research
- Illustrations of Isotope Applications in Biology and Medicine, Therapy
- Illustrations of Isotopes Characteristics
- Illustrations of Isotopes Production and Availability
- Uses of Isotopes in Industry and in Physical and Chemical Research
- Illustrations of Isotope Applications in Physical Sciences
- Illustrations of Isotope Applications in Industry

CHART 1. PROBABLE EARLY EFFECTS OF ACUTE RADIATION DOSES OVER WHOLE BODY TO MAN*

SUMMARY OF EFFECTS RESULTING FROM WHOLE BODY EXPOSURE TO RADIATION TO MAN

Mild Dose		Moderate Dose		Median Lethal Dose	Lethal Dose 6
0-25 r	50 r	100 r	200 r	400 r	600 r
No detectable clinical effects	Slight transient reductions in Lymphocytes and Neutrophils	Nausea and fatigue, with possible vomiting above 125 r	Nausea and vomiting within 24 hours	Nausea and vomiting in 1 to 2 hours	Nausea and vomiting in 1-2 hrs
			Latent period of about one week; perhaps longer.	Latent period, perhaps as long as one week.	Short latent period following initial nausea.
Probably no delayed effects	No other clinically detectable effects	Reduction in Lymphocytes and neutrophils with delayed recovery	Following latent period, epilation, loss of appetite, and general malaise.	Beginning epilation, loss of appetite, and general malaise accompanied by fever and severe inflamation of mouth and throat the third week	Diarrhoea, vomiting, inflamation of mouth and throat toward end of first week
	Delayed effects possible, but serious effect on average individual very improbable	Delayed effects may shorten life expectancy as much as one per cent.	Sore throat, pallor, petechiae, diarrhoea. Moderate emaciation. Possible death in 2 to 6 weeks in a small portion of individuals.	Pallor, petechiae, diarrhoea, nosebleeds, rapid emaciation about the fourth week. Some deaths in 2 to 6 weeks. Possible eventual death to 50% of the exposed individuals.	Fever, rapid emaciation and death as early as the second week with a possible eventual death to 100% of exposed individuals

*"The Effects of Atomic Weapons", U. S. Government Printing Office, 1950.

CHART 2. MEDICAL EFFECTS OF WHOLE-BODY RADIATION*

Time after exposure	Lethal Dose (600r)	Median Lethal Dose (400r)	Moderate Dose (300 to 100r)
First Week	Nausea and vomiting after 1-2 hours	Nausea and vomiting after 1-2 hours	
	No definite symptoms	"	
- - - - - - - - -	Diarrhea Vomiting Inflamation of mouth and throat	No definite symptoms	
Second Week	Fever Rapid emaciation Death (Mortality probably 100%)	Beginning epilation	No definite symptoms
- - - - - - - - -			
		Loss of apetite & general malaise Fever Severe inflamation of mouth & throat	Epilation Loss of apetite & general malaise
- - - - - - - - -			
Fourth Week		Pallor Petechise, diarrhea, and nose bleeds Rapid emaciation Death (Mortality probably 50%)	Sore throat Pallor Petechise Diarrhea Moderate emaciation (recovery likely unless complicated by poor previous health)

*Based on NAVMED P-1330, Army Pamphlet No. 8-11, and Air Force Manual AFM 160-11

CHART 3. RADIOISOTOPES IN THE BODY*

Nuclide	Physical (Half Life in Days)	Biological	Effective	Organ	% in Target Organ	% absorbed from G. I. Tract
Na^{24}	0.62	29	0.61	Whole body	100	95
K^{42}	0.52	33	0.51	Muscle mass	75	70
H^{3}	4.6×10^{3}	10	10	Whole body	100	100
I^{131}	8	180	7.7	Thyroid	20	100
P^{32}	14.3	1200	14	Bone, Lymphoid tissue	92	70
Fe^{59}	46.3	120	33	Red Blood corpuscle	65	80
C^{14}	2.1×10^{6}	Varies	Varies with compound			
S^{35}	87		Varies with compound			
Ce^{137}	1.1×10^{4}	140	124	Muscle mass	100	100
Po^{210}	138.3	57	40	Spleen and Lymphoid tissue	6	2
U^{238}	1.6×10^{12}	30	30	Kidney	6	0.05
$Ba\text{-}La^{140}$	12.8	200	12	Bone	65	10
Ca^{45}	152	13×10^{3}	151	Bone	99	90
$Sr.^{90}$	9.1×10^{3}	3.9×10^{3}	2.7×10^{3}	Bone	70	20-40
Ra^{226} Daughters	5.9×10^{5}	1.6×10^{4}	1.6×10^{4}	Bone	60	20
Pu^{239}	8.8×10^{6}	5×10^{4}	5×10^{4}	Bone	60	0.005
Am^{241}	1.8×10^{5}	890	890	Bone	60	0.05

*Doctor Harry Foreman, Head of Biometical Research, Los Alamos Laboratories.

TABLE 1. RADIOISOTOPES AVAILABLE TO HIGH SCHOOL TEACHERS

1. A general license has been issued allowing any individual, without special application, to purchase and/or possess the materials listed below in the quantities specified.
2. You may purchase, possess and/or use up to ten such quantities specified.

ISOTOPE	QUANTITY U CURIES	CHEMICAL	FORM	PHYSICAL HALF LIFE	ENERGY (Mev) BETA RANGES	GAMMA RAYS
Antimony-124	1	$SbCl_3$	2N HCl	60 days	0.50-2.29	.12-2.04
Carbon-14	##10	Na_2CO_3	H_2O	5568 years	0.155	none
Cerium-144	1	$CeCl_3$	1N HCl	282 days	1.17-2.97	0.6,2.6
Praseodymium-144						
Cesium-137	1	CsCl	1N HCl	30 years	0.51,1.17(Cs)	
Barium-137				2.6 min.		0.66 (Ba)
Cobalt-60	1	$CoCl_2$	1N HCl	5.3 years	0.31	1.17,1.33
#Hydrogen-3 (Tritium)	250	H_2O		12.5 years	0.02	none
Iodine-131	10	NaI	Na_2SO_3(Basic)	8.1 days	0.61 (87%)	0.364 (80%)
Iridium-192	10	Na_2IrCl_6	0.1N HCl	74.4 days	0.672	0.14-0.6
Iron-55	##5	$FeCl_3$	1N HCl	2.9 years	none	5.9 kev(X-Ray)
#Nickel-63	1	$NiCl_2$	1N HCl	85 years	0.067	none
Phosphorous-32	10	H_3PO_4	1N HCl	14.3 days	1.701	none
Promethium-147	10	$PmCl_3$	1N HCl	2.6 years	0.223	none
Ruthenium-106	1	$RuCl_3$	6N HCl	1 year	0.0392(Ru106)	0.5-2.41
Rhodium-106				30 secs.	2.0-3.5(Rh106)	
Scandium-46	1	$ScCl_3$	1N HCl	85 days	0.36	0.9,1.1
Sodium-22	##1	NaCl	1N HCl	2.6 years	0.54(Positron)	1.28
Strontium-90	0.1	$SrCl_2$	1N HCl	25 years	0.61 (Sr90)	none
Yttrium-90				2.5 days	2.18 (Y90)	
#Sulfur-35	50	H_2SO_4	0.1N HCl	87.1 days	0.167	none
Thallium-204	50	$TlNO_3$	3N HNO_3	4.0 years	0.765	none

#Isotopes so marked are capable of being detected only with sensitive laboratory instrumentation, e.g. geiger end window tube less than 2.5 mg/cm^2. All others can be detected with standard field-type survey instruments.
##These quantities are less than the maximum allowable under this program.

TABLE 2

REGULATIONS GOVERNING USE OF RADIOISOTOPES

The Atomic Energy Commission and allied industries encourage the use of radioactive materials for educational, research, and other interest stimulating purposes. In order to make these materials readily available and because the quantities involved require only minimal radiation safety measures, the A.E.C. authorizes purchase of microcurie amounts without special license as stated in Section 30.72 of the Federal Regulations.

These quantities are harmless when handled with proper care and require only minimal equipment and facilities and modest safety precautions although the following points must be observed.

A. Federal Regulation requires:

1. Exercising care to avoid contimination and ingestion or inhalation of the radioactive materials.
2. Minimizing excessive exposure of persons by use of shielding and/or distance from the radioactive material. If possible, use of tongs and tweezers in handling is recommended.
3. Storing and radioactive material in labeled containers under lock and key when not in use.

B. The Federal Regulation prohibits:

1. Possession or use at any one time of more than a total of ten such quantities, as listed in Section 30.72 of the regulation.
2. Effecting an increase in the radioactivity of any of these individual quantities by adding other radioactive material thereto, by combining radioisotopes from two or more quantities, or by altering them in any other manner so as to increase the radiation therefrom.
3. Administering externally or internally, or directing the administration of any part of these quantities to a human being for any purpose.
4. Adding or directing the addition of any part of these quantities to any food, beverage, cosmetic, drug, or other product designed for ingestion or inhalation by, or application to human beings.
5. Including any part of these quantities in any device, instrument, or apparatus intended for use in diagnosis, treatment, or prevention of disease in human beings, or animals, or otherwise intended to affect the structure of any function of the body of human beings or animals.

VITA

James William Goodfellow

Candidate for the Degree of

Master of Science

Report: A PLAN FOR THE STUDY OF ATOMIC ENERGY IN THE JUNIOR AND SENIOR HIGH SCHOOL

Major Field: Natural Science

Biographical:

Personal data: Born near Binger, Oklahoma, October 26, 1908, the son of Ira and Gertrude Goodfellow.

Education: Attended grade school in Gracemont, Oklahoma; graduated from Gracemont High School, Gracemont, Oklahoma, in 1924; received the Bachelor of Science Degree from the Oklahoma State University, Stillwater, Oklahoma, with a major in Mathematics in May, 1936, followed by a Bachelor of Science Degree from the same institution with a major in Vocational Agriculture in May, 1937; attended Radiation Biology Institute at University of New Mexico, Summer Session, 1957; attended advanced Chemistry-Physics Institute at University of Southern California, Summer Session, 1958; completed requirements for the Master of Science degree in May, 1959.

Professional experience: Taught science and mathematics in Oklahoma high schools from 1928 to 1935; Taught Vocational Agriculture at Tishomingo, Oklahoma from 1937 to 1942; spent nine years in the U. S. Air Force as navigator, navigation and meteorology instructor, Director of the Navigator Graduate Program Weather School, and in command of Over-water Navigation Research; prior to attending the Academic Year Institute at Oklahoma State University taught science two years at the Pond Creek, Oklahoma High School.