State of Iowa
1952

SCIENTIFIC AND SOCIAL ASPECTS OF ATOMIC ENERGY

A SOURCE BOOK
FOR
GENERAL USE IN COLLEGES

VOLUME IV

THE IOWA PLAN FOR ATOMIC ENERGY EDUCATION

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(A Source Book for General Use in Colleges)

Volume IV
The Iowa Plan for Atomic Energy Education

Issued by the
Department of
Public Instruction
Jessie M. Parker
Superintendent
Des Moines, Iowa

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"The release of atomic energy on a large scale is practical. It is reasonable to anticipate that this new source of energy will cause profound changes in our present way of life." — Quoted from the Atomic Energy Act of 1946.

"Unless the people have the essential facts about atomic energy, they cannot act wisely nor can they act democratically." — David Lilienthal, formerly chairman of the Atomic Energy Commission.

IOWA PLAN FOR ATOMIC ENERGY EDUCATION

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FOREWORD

About five years ago the Iowa State Department of Public Instruction became impressed with the need for promoting Atomic Energy Education throughout the state. Following a series of conferences, in which responsible educators and laymen shared their views on this problem, plans were made to develop material for use at the elementary, high school, college, and adult education levels. This volume is a resource book for use with and by college students.

Actually, many of the materials in this volume have their origin in the Atomic Energy Day programs which were sponsored by Cornell College and Luther College two or three years ago. Lectures given on these occasions seemed to contain such valuable content that they were rewritten and brought up-to-date for inclusion in this present publication. Additional chapters were added as seemed needed to give a well-rounded coverage of the subject. A thorough examination of the newer literature and audio-visual materials was made so that all such references would be especially significant and up-to-date.

As suggested in the Introduction this publication is largely a resource manual containing much of the basic information about atomic energy and its social implications which informed college students ought to know. It is expected that colleges will adapt these materials to their local curriculum patterns; consequently there is little in this volume suggesting specific ways for teaching about atomic energy.

Despite the increase in college enrollment during recent years the college student remains an educationally-privileged citizen. It is reasonable to expect that he will become aware of the tremendous importance of nuclear energy in our present-day world. As a college educated person he should feel an equal measure of responsibility for at least a modest knowledge of the science of the atom and its social implications. It is his duty to play the part of an intelligent citizen in the great task of making atomic energy work for a world at peace.

JESSIE M. PARKER, Superintendent
Iowa State Department of Public Instruction

December, 1952

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INTRODUCTION

THE NATURE OF THIS BOOKLET

Unlike the other volumes in the Iowa Plan for Atomic Energy Education, the present volume is not a program of recommended activities but a resource manual designed to contain many of the basic facts to which informed citizens may wish to refer and which a person with a college education may be reasonably expected to know.

The harnessing of Atomic Energy is not only a notable scientific achievement; it is also the fundamental social fact of today. It has changed the strategy of war and added urgency to the search for a basis of permanent peace. It has modified the structure of Government and given rise to revolutionary international plans involving national sovereignty. It has increased human well-being through new processes in medical, agricultural and industrial research. In the forseeable future it will modify industrial economy and can change the economic geography of whole continents.[1] In short, the release of Atomic Energy has made more urgent the search for solutions to the existing social problems that confront human society in a scientific age and has created several new problems equally difficult to solve.

It should be obvious to anyone who lives in the almost constant revolutions of the 20th Century that the forces released by scientific discovery and harnessed through technology impose a major strain on a democratic society. Unless citizens understand the nature of these forces the survival of grass roots democracy is indeed debatable —the old classical education is not of itself adequate for citizen control of the modern state.[2]

In accordance with this view, which is the expressed philosophy of the Iowa Committee, the present volume is first concerned with the nature of atomic energy. It is not, however, a scientific text book. It confines itself to the basic unchanging facts of what atomic energy is, how it was discovered, and how it is put to work. These are set forth logically, simply, and with the minimum use of technical language consistent with absolute accuracy. They are designed as the proper foundation on which to consider the social and governmental issues that conclude the booklet.

THE USES OF THIS BOOKLET

This volume is presented as a series of authoritative and up-to-date lectures. In rejecting the idea of writing a college program, the Production Committee had in mind both the peculiar problems of college organization and the function of this booklet in relation to the others that comprise the Iowa Plan. Because of the professional and pre-professional nature of much college work, including the training of students for the profession of scholarship itself, departmentalization of teaching is inevitably more rigid at the college level than at others. While colleges are increasingly interested in general education, their programs and procedures in this area differ greatly. It is not possible to design one specific atomic energy program suitable for all colleges. Moreover, the continual addition of new courses serves to complicate administration, raises difficulties of accreditation, and sometimes confuses rather than enlightens students. The present booklet was therefore designed to be of maximum use in existing courses at the college level and at the same time to be a general resource book for workshops and special intensive short courses devoted to the subject.

For the same reason, it was decided that the printed lecture was the best form of presentation. For the student who is asked to read, the published lecture is as valuable a form of information as any other printed document. For the lecturer in the social sciences who may wish his students to be acquainted with some of the basic facts of atomic energy before discussing its problems, the existence of authoritative ready-made lectures should be of value. The same is true for the science lecturer who wishes his students to consider occasionally the social implications of scientific endeavor without committing them to extra courses in the social studies.

Science students and those in allied fields become acquainted with the scientific facts of atomic energy in the course of their normal studies. Some effort should be made to orient these students to the social implications of atomic energy in their future work. It is particularly important that students in the technical fields become conscious of the impact of technology on society at an early age. The Atomic Age being itself young, well-prepared young people may help avert some of the crises it can generate. This booklet can be used to accomplish that end in the minimum of time. It can be done by assigned student reading and discussion or by lectures based on those herein printed but given by the lecturers with whom the students are already at work.[3] In the social studies, particularly sociology, economics and government courses, this booklet can again be used as assigned student reading or by the instructor in preparing lectures to explain the nature of atomic energy before considering the social problems involved. Its use in general courses in science or social science or in interdepartmental core courses is obvious.

Intensive workshops and short courses are increasingly characteristic of higher education. According to nation wide studies made by the Committee, the current tendency is to study atomic energy through such workshops. This is particularly true of teacher training institutions, which have done more about atomic energy education than any other college group. The present volume provides adequate content for workshops and short courses where facts must be quickly acquired before their significance can be discussed.

Some colleges have experimented with an intensive day devoted entirely to the subject of atomic energy. In Iowa, two such days have been held, at Cornell College, Mount Vernon and Luther College, Decorah.[4] Other colleges, notably the State University of Iowa, have experimented with extensive non-credit lecture series for stu-

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[1] Australia affords a good example. The interior of the southern continent is rich in iron but devoid of coal. A semi-desert, there is no possibility of producing hydroelectric power. Australia's heavy industries are therefore in coastal cities close to coal or hydro-electric power and vulnerable to the enemy in the event of war. Uranium ore has now been discovered and is being mined in the desert area. While commercial manufacture will remain close to its markets and continue to use coal and hydro-electric power, it now appears economically possible to establish strategic industries in the more secure interior by substituting uranium fuel for manufacturing power.

[2] The influence of technology on governmental and social change is discussed in Chapters VI and VII.

[3] See Appendix

[4] See Appendix

dents, the lecturers being drawn from the many departments concerned.[5] This volume is a suitable resource book for programs of either type.

On all campuses, a great deal of informal educational activity is continually going on. In including atomic energy education in such activities, the fifth volume of the series, which is devoted to Adult Education programs of many types, should be used as a companion volume. It is particularly applicable to the great number of student discussion societies that exist on any campus, including the churches that students regularly attend. The moral problems of the Atomic Age have proved of absorbing interest to these students.

As has been stated, the five volumes of the Iowa series are functionally related. Volumes II, III and V, concerned respectively with elementary, secondary, and adult education, are fundamentally program designs, the "what to do" and the "how to do it". In addition to its specific use as a resource manual for existing college courses, the present volume may be considered as a factual resource supplement to the others.

Iowa is unusually well endowed with institutions of higher learning. If each of these institutions, including the junior colleges, endeavors in its own way to reach its entire student body, a nucleus of informed citizens will rapidly become available to every community in the state.

For The Production Committee

Guy Wagner, Editor

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[5] See Appendix. Also Chapters VI and VII of Volume V, "Iowa Citizens Investigate the Atom," published by the Iowa State Department of Public Instruction, Des Moines. 1952.

CHAPTER I

THE STRUCTURE OF MATTER*

MOLECULES

The name "Atomic Energy" has come to mean energy produced by changes in the nuclei of atoms, though ordinary burning of fuels also involves changes in atoms. To understand either process one must know something of the nature and structure of matter.

There are many kinds of matter. Suppose we consider a few drops of water in a large sealed glass tube at room temperature (see Figure 1a). The liquid occupies a definite volume in the lowest part of the tube. When the tube is heated the water seems to be destroyed. At least it becomes invisible as in Figure 1b. But when the tube is cooled, the water reappears and fills the same volume as it filled before it was evaporated. Successive evaporations to invisible gas or successive freezing to solid ice do not change the amount of the water, or its nature, permanently. If the tube is kept sealed and the temperature is brought back to room temperature the water is visible again.

Where was the water when the tube looked as if it were empty? When water is heated, it separates into many very small particles. Each particle is far too small to be seen with the highest power of a microscope, but the return of the liquid water on cooling indicates that the water did not escape from the tube. There are many other simple evidences that the water remains in the tube. First, the tube and its contents weigh the same while the water is invisible as they weigh when the water is visible. Second, the pressure in the heated tube becomes greater than the pressure in a similar heated tube which contains no water. Indeed, the pressure due to the particles of water in a heated sealed glass tube containing too much water would become great enough to shatter the tube and cause an explosion.

All of the power of a steam locomotive hauling a long train of freight cars up a grade is due to invisible particles of water vapor exerting pressure against the pistons causing them to move in the cylinders. These small particles are all alike and each one of them is called a MOLECULE. When a lump of sugar dissolves in water and disappears, it might seem that the sugar had been destroyed. But the water may be evaporated carefully and the sugar left behind will weigh exactly as much as the sugar which was dissolved in the water. While the sugar was in the water and invisible one could detect its presence by its taste and by many other observations such as the rotation of polarized light, the rise of the boiling point, and the lowering of the freezing point. The same amount of sugar produces the same effects on all such measurable changes in properties, so it is reasonable to assume that the small particles of sugar are like each other in all particulars. Again, these similar smallest particles of sugar are called MOLECULES.

Many such experiments have been performed using many substances. The results of these experiments show that each of some hundreds of thousands of substances can be separated in particles too small to be seen by a microscope but yet capable of becoming the original substance

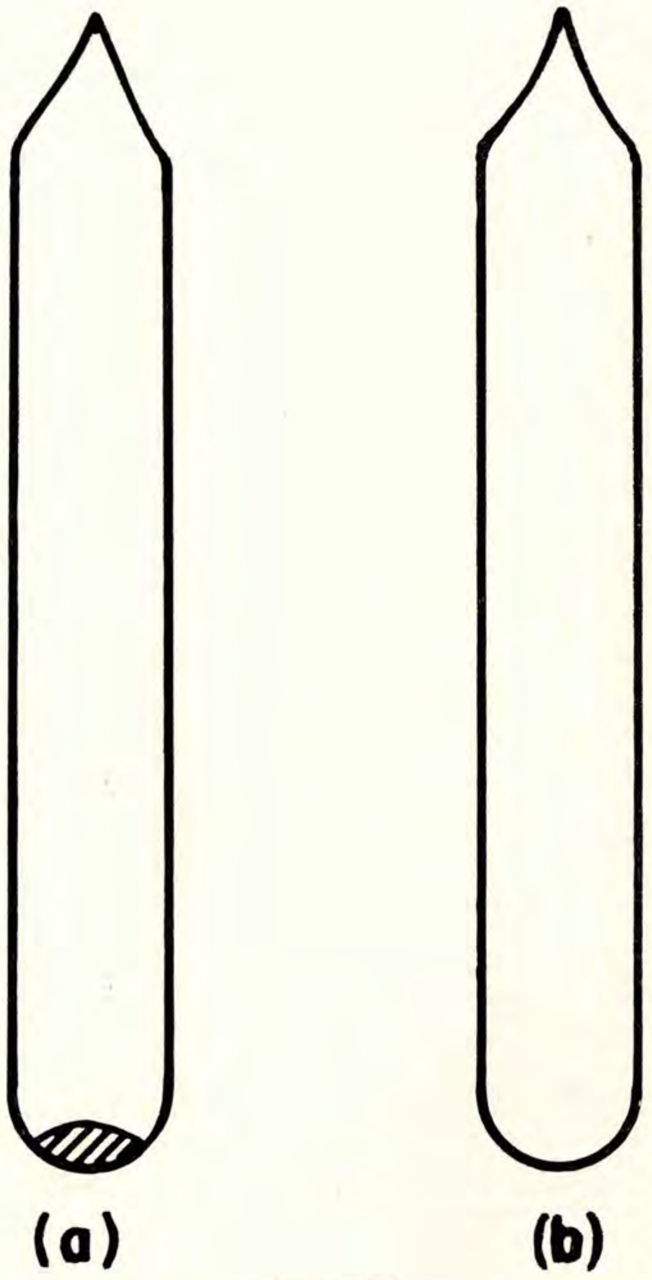

Figure 1

The volume of water which can be evaporated in a closed space, safely, is relatively small. The vapor of water produces a pressure of about one atmosphere (15 lbs. per square inch) if confined in a volume 1600 times as large as the volume of liquid water. A quart of water contains about 24,000 drops. Then 15 drops (24,000 ÷ 1600) of water in a quart container would produce a pressure of about one atmosphere, or the pressure in a quart container would be about one pound per square inch for each drop of water evaporated.

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*Prepared by F. E. Brown, Iowa State College, and George Glockler, State University of Iowa.

when they are again collected into particles large enough to be visible. Each of the known substances is composed of very small similar particles called MOLECULES of that substance.

ATOMS

These molecules are not the smallest particles. If water is subjected to the action of a direct electrical current (Figure 2), an invisible colorless gas appears at each of the two electrodes. The gas freed at the positively charged electrode occupies about 800 times the volume of the water which disappeared and it weighs eight-ninths as much. The gas freed at the negatively charged electrode fills 1600 times the volume of the liquid water but weighs only one-ninth as much. When the two gases are mixed together, the water does not reappear. If the two gases are ignited after being mixed, an explosion occurs, or they may be brought together (as air and fuel gas are brought together) and burned in a burner. If all of the resulting vapors of the explosion or of the burning should be saved carefully, water would be the only resulting substance. The amount of water formed would be the same as the amount of water decomposed in the electrolysis. The gas found in the larger volume at the negative electrode could be identified as hydrogen and the other gas as oxygen. When any sample of hydrogen unites with oxygen, water forms. The chemist says, "Water is a compound composed of hydrogen and oxygen."

Further investigation shows that treatment of water with a metal like sodium (Figure 3) can remove half of the hydrogen from water and form a compound of hydrogen, oxygen, and sodium. Further treatment with a metal like zinc removes the remainder of the hydrogen. The compound remaining is composed of sodium, oxygen, and zinc. Whenever oxygen is removed from water, all of the oxygen is removed from any molecule whenever any oxygen is removed. This would seem to prove that each molecule of water contains one indivisible particle of oxygen and two indivisible particles of hydrogen. In chemical shorthand we express this by the formula H_2O. This means that there are two individual particles of hydrogen (H for hydrogen and the small figure $_2$ tells how many) and no number with the oxygen indicates one indivisible particle of oxygen.

It will be noted that these small particles of hydrogen and oxygen used in building molecules of water were not called molecules of oxygen or molecules of hydrogen, but indivisible particles. A shorter name derived from Greek which means indivisible particle was bestowed on very small particles by Leucippus and Democritus about 500 B.C. and that name ATOM was used by Dalton, the founder of the modern atomic theory, 2300 years later. A molecule of water is composed of two atoms of hydrogen and one atom of oxygen. A molecule of hydrogen is composed of two atoms of hydrogen and a molecule of oxygen is composed of two atoms of oxygen. If one wrote a shorthand expression of what happens when hydrogen burns or explodes by union with oxygen, it might be $H_2 + O_2 + H_2$ becomes HOH + HOH or $2H_2 + O_2 = 2H_2O$. It is even known that the two hydrogen atoms and the oxygen atom are not in a straight line in the water molecule but would appear as shown in Figure 4, if we could see a molecule of water.

A study of all of the substances known in 1930 indicated that they could be separated into, or made up from, about 90 kinds of ATOMS though more than 300,000 substances had been investigated. This may seem incredible. But if one remembers that 600,000 entries appear in a Webster Unabridged Dictionary and that all of these are spelled out by different arrangements of 26 English letters, by analogy he can understand how 90 kinds of atoms could be arranged in thousands of patterns. Each pattern would vary in number and/or kind of atoms, would have different properties, and would be a molecule of a different substance. The substances formed from only one kind of atoms are called elements. In 1950, 98 elements had been discovered or prepared.

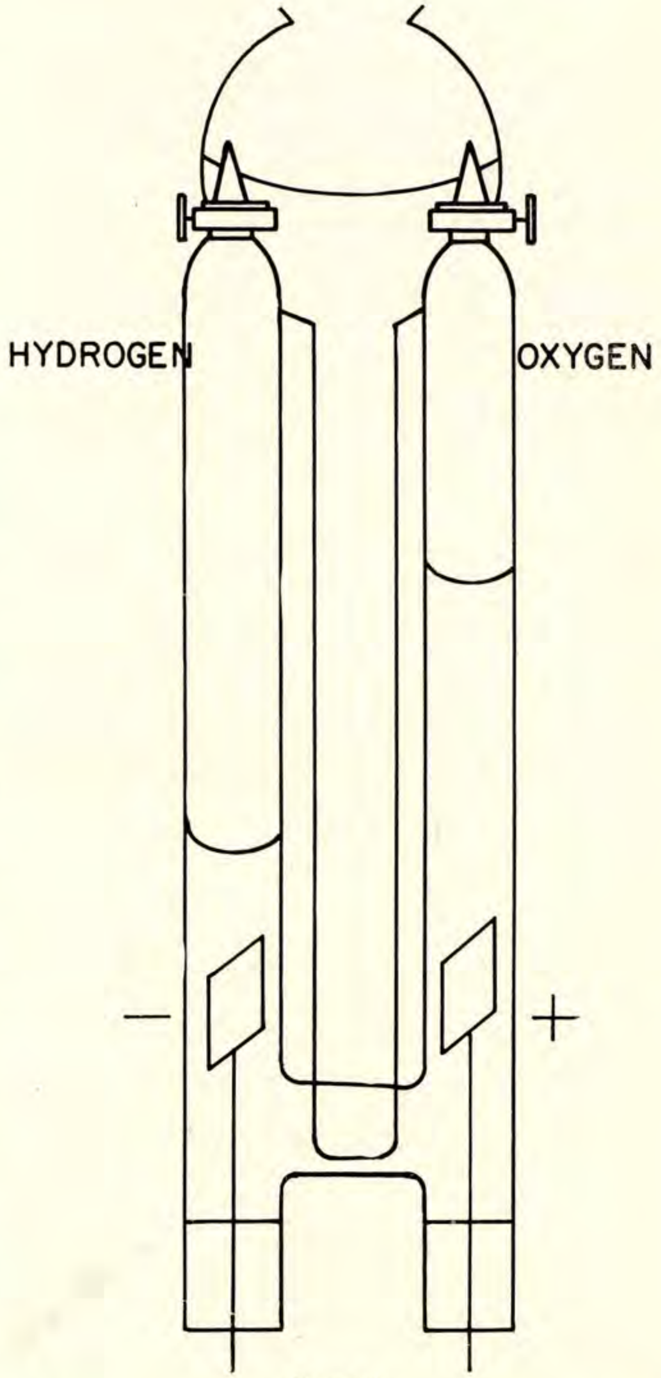

Figure 2

When water is decomposed by passing a direct current of electricity through it, one cubic inch of liquid water produces almost a cubic foot of hydrogen and one-half of a cubic foot of oxygen. Two molecules of water ($2\ H_2O$) become two molecules of hydrogen ($2\ H_2$) and one molecule of oxygen (O_2).

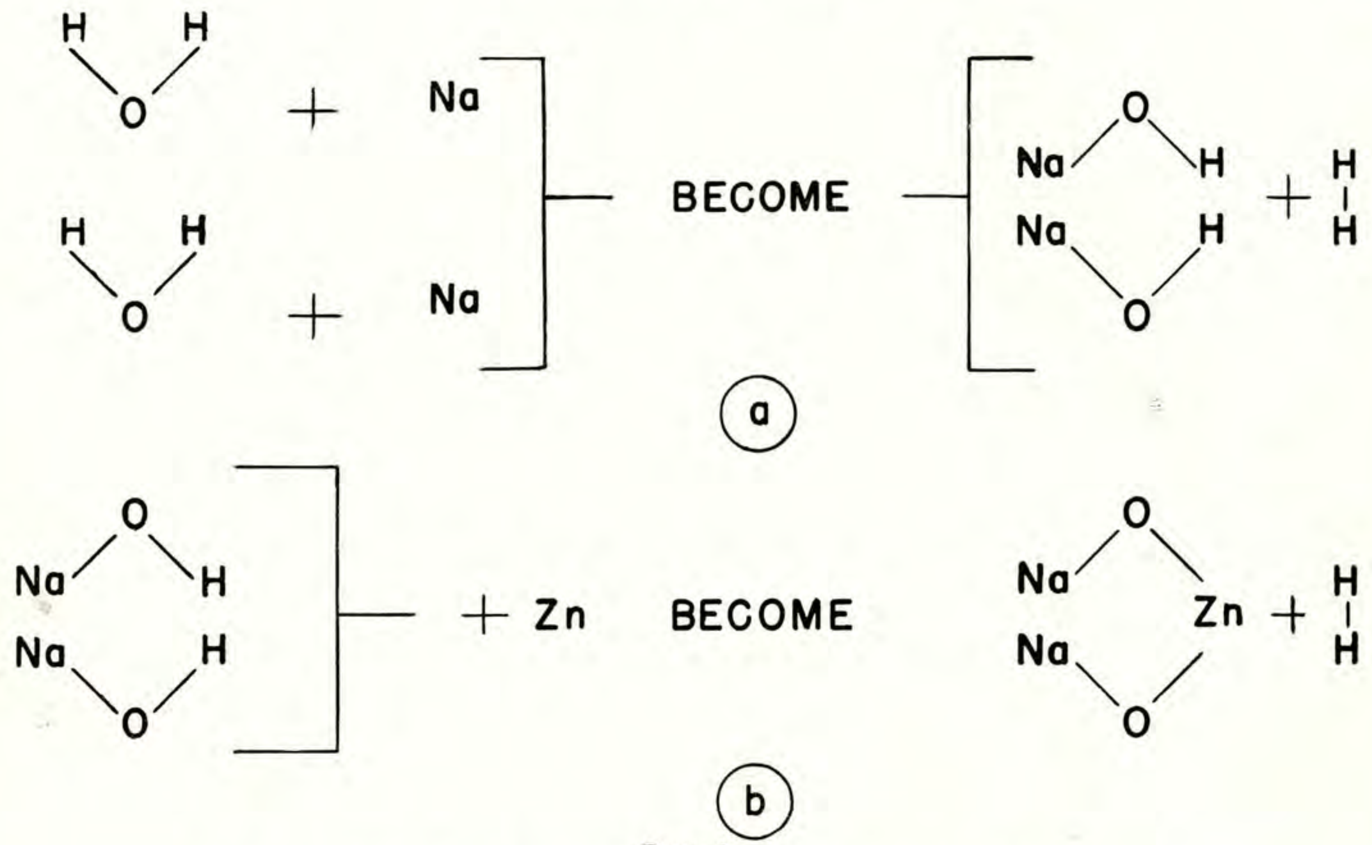

Figure 3

The very active metal sodium (Na) displaces one-half of the hydrogen from each molecule of water with which it reacts. The substances formed are free hydrogen (H_2), and sodium hydroxide or lye. Zinc (Zn) reacts with the sodium hydroxide and displaces the other half of the hydrogen.

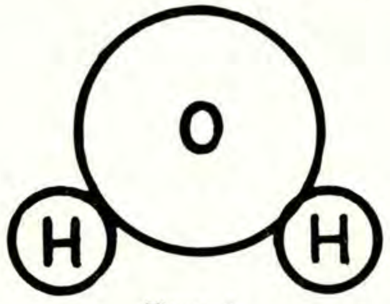

Figure 4

STRUCTURE OF ATOMS

The preparation of indivisible particles seems to be a contradiction and it is. Atoms are not indivisible. They can be separated into pieces. Pieces can be added to atoms in such a way that a new kind of atom is formed. But these are recent discoveries. Until about 1900 atoms were believed to be indivisible. In 1896 the phenomenon called radioactivity was discovered. Natural radioactivity is an activity of some particular natural elements. Their activity produces light, heat, conductivity of the air surrounding them, and death to living cells. These effects are due to radiation of waves, like light but of shorter wave lengths, and of particles. One particle becomes an atom of helium and another was soon recognized as a small particle of negative electricity. Very soon it was shown that all atoms contained these particles of negative electricity and the particles were named ELECTRONS. Further study revealed the fact that the atoms of all elements are composed of two parts: first, a small nucleus which contains almost all of the mass, and second, the ELECTRONS which are around it somewhat as planets are distributed around the sun in the solar system.

Atoms are held together in molecules by forces arising from loss, or gain, or sharing of electrons. The electrons farthest from the nucleus are especially active in forming bonds between atoms. The energy accompanying chemical changes is due to the rearrangement of these bonding electrons. Then, the energy of burning fuel is also "atomic energy" as is all energy arising from any chemical reaction. The electrons arrange themselves in shells, the capacity of which increases with distance from the nucleus. Each element has atoms with a different number of electrons, and consequently a different arrangement of electrons, and different possibilities of gaining, losing, and sharing electrons. This is what makes each element different from other elements. The elements are formed so that all numbers of electrons from one to 98 are found in regular succession in the shells of electrons which surround nuclei of atoms now known. A great deal of force is necessary to hold 98 independent negative charges of electricity in any systematic arrangement. Moreover all unmodified atoms are neutral, and complete molecules of all substances are neutral. Neutrality of atoms and molecules requires a supply of positive electricity from which positive particles can be taken. These particles must exactly neutralize any number of electrons from 1 to 98.

A particle which weighs 1838 times as much as an electron, and has a positive charge exactly as great as the negative charge on the electron, has been found. This particle is called a PROTON.

A third particle with almost the same weight as the proton but bearing no electrical charge has also been found. This last particle is called a NEUTRON. From these three particles, neutral atoms of all known weights and properties can be formed. It seems that a neutron (or neutrons) is required in any nucleus containing more than one proton. This is to be expected, for two charges of positive electricity should repel each other.

The small heavy nucleus of an atom is composed of protons and neutrons. All numbers of protons from 1 to 98 appear in different nuclei. A number called the atomic number is given to each element. This number is the number of protons in its nucleus. The hydrogen nucleus may be one proton. Around this proton as a nucleus revolves one electron. This is a neutral hydrogen atom. Relatively few hydrogen nuclei (one in 6000) contain one proton and one neutron. Such nuclei still require only one electron for neutrality. Their chemical behavior is very nearly like that of an atom whose nucleus is merely a proton though they are twice as heavy. Such atoms are called deuterium or heavy hydrogen. Ordinary hydrogen and heavy hydrogen are two different nuclear forms or "isotopes" of the same element. The combination of deuterium with oxygen forms heavy water. Figure 5 shows models of some atoms as chemists and physicists portray them. Uranium, the heaviest natural atom found in fairly large quantities, has an atomic number 92 and an atomic weight of 238. The nucleus of each of its atoms contains 92 protons, and 146 neutrons. Ninety-two electrons are arranged in shells around each nucleus to form a neutral atom of uranium.

Loss, or gain, or sharing of the external electrons leads to changes in the numbers, or kinds, or arrangements of unchanged nuclei of atoms in molecules. These changes are called chemical changes. Changes in which whole molecules are separated from each other are called physical changes. Some examples of physical changes are: making sawdust, grinding corn meal, atomizing perfumery, dissolving sugar in water or evaporating gasoline. Physical changes produce no new kinds of molecules and, therefore, no new substances. Chemical changes are more profound than physical changes. Chemical changes produce new kinds of molecules but do not produce any new kinds of atoms. There are changes more fundamental than chemical change. They are called nuclear changes and are of two types: radioactivity and nuclear reactions. In these changes new kinds of atoms are produced.

NUCLEAR CHANGES — RADIOACTIVITY

The amount of energy associated with a change is some indication of the profundity of the change. A gram of most substances may be powdered by an amount of energy corresponding to only a few calories. When a gram of a combustible substance burns (a chemical reaction) much more heat is involved. If a gram of carbon is burned, about 8000 calories of heat are evolved. When radioactive or nuclear changes occur, the energy produced is greater than the energy associated with a chemical change by a hundred thousand fold. A gram of radium changing into radon by one radioactive transformation initially produces 25 calories per hour. The rate of heat evolution decreases regularly until 1600 years later when it is 12.5 calories per hour and one-half of the radium will have been converted to radon. The average rate of evolution will be $[(25+12.5) \div 2] = 18.75$ calories per hour for 1600 years. This will be $(18.75 \times 24 \times 365.25 \times 1600) = 263{,}000{,}000$ calories when the radium is only half gone.

Natural radioactivity consists in the change of atoms like those of naturally found radium into other atoms like radon, also found wherever radium is found. These changes take place spontaneously at rates which are not affected by heat, pressure, or any other conditions available in 1900. The change occurs in the nucleus, the very dense and very small central part of the atom. As a result of what happens in the nucleus, three kinds of radiations appear. One radiation, the alpha particle, is the nucleus of a helium atom which is ejected with a velocity as great as 18,000 miles per second, about one-tenth the speed of light. The alpha particle carries a positive charge of two. As soon as its velocity is decreased by collisions sufficiently to permit electrons to adhere to it, two electrons are picked up and the alpha particle has become a helium atom. A second radiation, called a beta particle, is an electron. The electron has a mass 1/7532 that of an alpha particle and carries one charge of negative electricity. The third radiation, the gamma ray, is a wave similar to light waves but the wave length of a gamma ray is about 1/100,000 that of a wave of visible light. The energy with which these radiations leave the nuclei of radioactive atoms indicates some unstable condition or some source of power within the nuclei of such atoms.

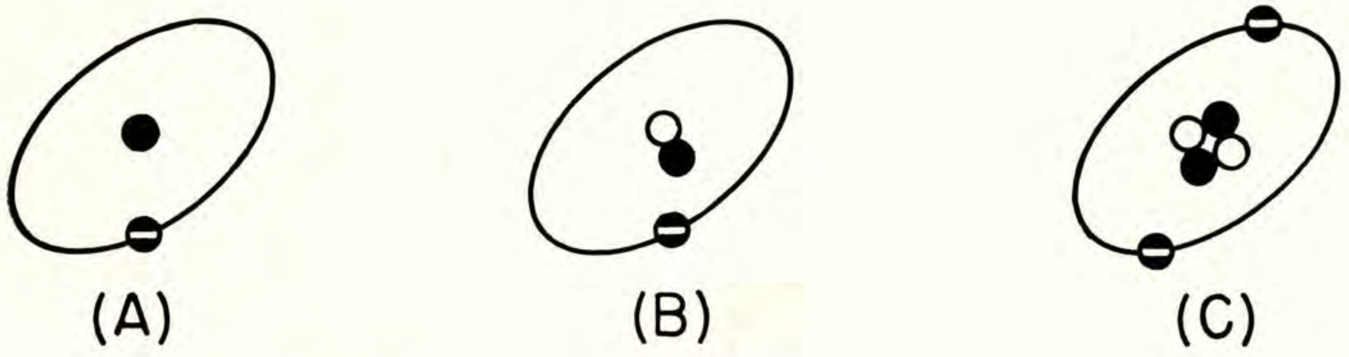

Figure 5

(A) Hydrogen. One proton and one electron.

(B) Deuterium or heavy hydrogen. One proton and one neutron in the nucleus and one electron in the shell.

(A) and (B) are isotopes.

(C) Helium. Two protons and two neutrons in the nucleus and two electrons in the shell.

The stability of a nucleus is found to depend on the number of protons and the ratio of neutrons to protons in the nucleus. The lightest nucleus, that of ordinary hydrogen, is just one proton. Its isotope, heavy hydrogen or deuterium, has one neutron and one proton in its nucleus. With other light nuclei, those containing up to 20 protons, that is, through the element calcium, the stable varieties or isotopes have almost the same number of neutrons as protons. As we go to heavier nuclei more neutrons than protons are required for stability until we reach bismuth with 83 protons and 126 neutrons. There are no stable nuclei with more than 83 protons.

Considering the elements up to bismuth, each element may have one or more stable combinations of neutrons and protons. There are two, however, those with 43 and 61 protons, for which no number of neutrons gives a stable form. For many elements, 26 to be exact, only one particular number of neutrons is right and they have only one stable isotope. On the other hand, one element, tin, has 10 stable isotopes and the other 54 range from two to nine. Beside these stable nuclei each element has others, and in most cases many others, that are not stable because they contain an unsuitable ratio of neutrons to protons.

If there are too many neutrons the unstable or radioactive isotope transforms itself into a stable one by the emission of a beta particle. We can think of this process as the conversion of a neutron into a proton plus an electron inside the nucleus and the sudden ejection of that electron as a beta particle. The nucleus which remains after the process has one more proton and one less neutron than the original nucleus and is usually stable. In some cases, however, a number of such processes are necessary before a stable nucleus is reached.

The reverse process, conversion of a proton into a neutrons, also occurs inside nuclei when there are too few neutrons for the number of protons. This gives rise to one or the other of two different types of radioactivity. Either the proton may yield a neutron and a positive electron, or positron, which is ejected from the nucleus; or the nucleus may pull in an electron from the outer part of the atom which then combines with a proton to form a neutron inside the nucleus. Both of these types of radioactive processes are common.

As was stated previously, none of the nuclei containing more than 83 protons are stable. Elements having 84 to 98 protons are known only in radioactive forms. Of these, uranium with 92 protons (the heaviest naturally occurring element), thorium with 90 protons, and plutonium with 94 protons are of great interest in the development of atomic energy, as we shall see. It is in these heavy nuclei that the process of alpha particle emission occurs and it is almost completely restricted to this region. Beta particle emission and the other processes mentioned above also occur in these elements.

The source of power or energy for the radiations is conversion of mass to energy. Einstein inferred from theoretical considerations that the energy equivalent of mass is expressed by the equation $E = mc^2$, in which the energy, E, is expressed in ergs, the mass, m is expressed in grams (454 grams = 1 pound), and c is the velocity of light in centimeters per second, which is 3×10^{10} or 30,000,000,000. That is, when one gram of matter is converted into energy, the energy produced is 3×10^{10} squared $(3 \times 10^{10})^2$ or 9×10^{20} ergs. A kilowatt hour is 3.6×10^{13} ergs, so one gram (one 454th of a pound) of matter will produce $(9 \times 10^{20}) \div (3.6 \times 10^{13})$ or 2.5×10^7, or 25,000,000 kilowatt hours of energy, if it disappears as matter and is converted into energy. At one cent per kilowatt hour, this energy would cost $250,000.

NUCLEAR CHANGES — NUCLEAR REACTIONS

When protons and neutrons are packed together in nuclei, a small fraction of their mass disappears and energy corresponding to the loss of mass appears. For instance the mass of a proton is 1.00758 avograms (units used in weighing atoms) and the mass of a neutron is 1.00894 avograms. The alpha particle is composed of two protons and two neutrons and should weigh $(2 \times 1.00758) + (2 \times 1.00894) = 4.03304$ avograms. When the mass of an alpha particle is determined, it is found to be 4.00280 avograms. Then 4.03304 — 4.00280 or 0.03024 avograms disappear whenever 4.00280 avograms of helium nuclei are formed from protons and neutrons. If 4.00280 grams of helium were formed from protons and neutrons, 0.03024 grams of matter would be converted into $0.03024 \times 25{,}000{,}000$ or 756,000 kilowatt hours of electrical energy. At one cent per kilowatt hour, this would cost $7560.

Nuclei which contain about 25 protons and 26 or 27 neutrons in each nucleus have lost the most mass per proton and neutron combined. These nuclei released more energy per unit mass when formed, have less energy per unit mass left in them and are more stable than most other nuclei. In theory, heavier nuclei could separate into lighter pieces, evolve energy and become more stable by approaching a weight of about 50 avograms. Also in theory, light nuclei could combine into heavier nuclei, evolve energy and become more stable by approaching this same weight in each nucleus.

About the time this was appreciated, scientists were seeking methods for changing the ratio of neutrons and protons in the nuclei.

It was found that positive particles such as the proton, the deuteron (the nucleus of a heavy hydrogen atom) and the nucleus of the helium atom could be accelerated to velocities above one-tenth the velocity of light by linear accelerators, or by Van de Graaff machines, or by cyclotrons. Particles with velocities and energies as great as these could overcome the repulsion of the positive charge and enter the nucleus. If the nucleus was stable before the positive particle entered, it was likely to be unstable afterward. If unstable, it might break into pieces immediately or it might decompose over a period of time as naturally radioactive atoms decompose. Artificial decomposition of atoms can also be brought about by electrons accelerated in betatrons and synchrotrons and by very energetic, or "hard" X-rays. Using these radiations many of the stable nuclei were converted into new unstable nuclei.

The decomposition of the new nuclei produced two new particles. First, the positron, a particle weighing the same as an electron and carrying an equal charge of electricity but with a positive instead of negative electrical charge. Second, the neutron which has been mentioned as a constituent of the nucleus. It weighs very nearly the same as a proton or a hydrogen atom but has no electrical charge. The neutron can both pass through the cloud of electrons which surrounds a nucleus and also enter a nucleus without encountering the deflection or repulsion due to electrical charges of the same kind. Nuclei are just as unstable when the proportions of the neutrons are too large as when the proportions are too small. It was soon discovered that the production and introduction of neutrons into nuclei was a very fruitful method for producing new isotopes. In a few years, at least 500 such isotopes have been produced by introducing neutrons or accelerated protons, deuterons, helium nuclei, or electrons into nuclei. These new kinds of atoms include nuclei containing 43, 61 and 85 protons (which are not found in nature) and all numbers of protons from 93 to 98 inclusive. This adds nine elements, not previously known, to the chemist's list.

FISSION

Building new kinds of chemical elements is not the most interesting new development arising from the study of these new elements and their behaviors. Not only do neutrons enter nuclei, produce instability, and cause disruption of these nuclei, but some disruptions produce neutrons when they occur. For instance, when a neutron enters the nucleus of the isotope of uranium which weighs 235 avograms, the nucleus decomposes into two nuclei of medium weight and several neutrons and gamma rays are radiated. In most fissions there is a lighter nucleus weighing 85 to 105 avograms and a heavier one weighing 130 to 150. Fission into two nuclei of equal or almost equal weight, about 117 avograms, occurs less frequently but does occur, as does splitting into nuclei as far apart as 72 and 162. These new nuclei fly apart with tremendous energies, far higher even than are found in other nuclear reactions we have mentioned. However, they are soon slowed down, they pick up electrons to become neutral atoms, and the net result is that the material through which they have passed has been heated to high temperatures.

However, they are not yet normal atoms. These new nuclei have too many neutrons and too few protons. This situation is remedied by the conversion of neutrons to protons in the process of beta particle emission, as mentioned earlier. These beta particles are often accompanied by gamma rays, and these processes give atomic energy some of its tremendous radiation hazard. Immediately after the fission of some uranium-235 the radiation begins, but it rapidly diminishes. Some of it lasts hours, less for days, and still less for years.

It is the extra neutrons produced in fission which make possible the utilization of the fission reaction and its extraordinarily large energy as a source of power. These neutrons enable us to set up chains of fission processes, each fission step producing neutrons which in turn produce fission. Later chapters will discuss the different types of chain reactions in their applications as explosives and as controlled sources of power and of neutrons.

NOTES

CHAPTER II

ENERGY — ITS NATURE AND SOURCES*

A GENERAL CONCEPT OF ENERGY

This section is designed to impart to non-science students some fundamental ideas which will enable them to appreciate the meaning of the general concept of energy and to compare the various kinds of energy as to their form and magnitude.

One part of the task of chemists and physicists is to investigate and try to understand the realm of nature and inanimate matter. The work of chemists has been pretty largely concerned with matter itself, its forms and structure, how and why elements combine, what reactions are possible, and so on. However, in doing these things the chemist must also be concerned with energy.

Most of the questions which the physicist asks about nature can be classified broadly under the heading of energy but he of necessity must also be concerned with matter.

What is the meaning of this widely used concept of energy? It is both comprehensive and fundamental which may be why it seems a little difficult to define adequately.

Let us start by linking energy with the ability to do work; for example, to overcome resisting forces throughout some distance, or to raise or lower weights from some point to some other point, or to change the motion of objects. Changing the state of matter from solid to liquid or from liquid to gaseous states, illuminating objects and thence exciting the optic nerves, vibrating elastic bodies and thence exciting the auditory nerves, and a whole host of other common occurrences are manifestations of energy.

Heat and electrical energy are forms of energy because they can do work. Coal, oil, and gasoline contain energy because, when made to react chemically with oxygen under proper conditions, they produce the heat energy that will do the work. It is energy that moves otherwise inanimate matter. Energy makes all the ceaseless activity of this old world possible. Modern civilization depends for its continued existence upon the availability and use of tremendous amounts of energy in forms that will suit the special needs of the user. For that reason, the peoples of the world are becoming more and more energy conscious.

PHYSICAL ENERGY

The kinds of energy with which we are concerned may be classified as physical, chemical, and atomic — more properly nuclear energies. Physical energy should not be confused with muscular or mental energy. It refers to energies which have their origin and existence in some physical characteristic, rather than by virtue of some chemical change involving the combination or dissociation of atoms or molecules or by any change in the nucleus of the atom. For example, mechanical energy is energy possessed by matter, either matter in large chunks, or smaller particles of matter, by virtue of their motion or because of their position. The heat energy of a body is simply the combined energy of the molecules of that body by reason of their random, non-directed motion. Electrical energy, for the most part, is the energy of charged particles in motion. Work has been done by some agency in separating positive and negative charges against forces which tend to hold them together, in consequence of which energy has been acquired by the separated charges. When an electrical circuit is completed, this energy exhibits itself in the form of an electrical current. Light, X-rays, radio waves, and even sound waves, though different from the others, are physical energies transferred from one place to another by means of the motion of a special configuration known as a wave form, but whatever the particular kind of energy they all have the capacity for doing work. Now let us hasten on to a brief discussion of chemical energy.

CHEMICAL ENERGY

In some such process as starting a fire by rubbing together two pieces of dry wood, primitive man learned how to liberate and to use for his own purposes, the energy from chemical transformations. Centuries later man discovered certain chemical combinations whose transformation resulted in a more **rapid** evolution of energy in the form of heat. Then he learned how to harness this energy to serve his purposes, some useful, some destructive. He also discovered that certain chemical transformations occurred so rapidly that the transformation was almost instantaneous and resulted in such enormous local pressures that the walls of the enclosure were ripped to pieces. These high explosives have found their application both in peaceful pursuits, such as mining and roadbuilding, and in the prosecution of wartime objectives. Much of the history of human civilization is intimately related to and, in large measure based upon, man's utilization of the energy liberated from chemical transformations.

Every chemical change is accompanied by an energy change. A molecule of a given substance at a given temperature possesses a definite amount of chemical energy by virtue of its structure. Whenever a chemical reaction takes place, the new molecules of the products which are formed also possess an amount of chemical energy which may be greater or may be less than that of the atoms or molecules from which they are formed. If the energy of the products is greater than that of reactants, energy must be absorbed from some external source when the reaction takes place. On the other hand, if the products possess less energy than the reactants, the excess energy is liberated by the reaction. It is only with the latter kind of chemical change that we are concerned here.

For the benefit of those who are unfamiliar with the chemical processes, let us recall some common, well-known examples. When heated to a sufficiently high temperature, the surface atoms of carbon in a piece of coal begin to unite with oxygen atoms from the surrounding air. As a result of the reaction, energy in the form of heat is liberated—more energy than was expended in promoting the reaction, so that there is a net gain in available energy. However, since the reactions take place only at the surface, the process is comparatively slow. We have essentially the same process in the cylinder of an internal combustion engine except that

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*Prepared by R. A. Rogers, Iowa State Teachers College.

it is a much speedier one since the finely vaporized material has a much larger surface contact with the air with which it is mixed. The rapid union of oxygen atoms with carbon atoms and with hydrogen atoms to form carbon dioxide (CO_2) and water vapor (H_2O), respectively, liberates in a very short time the large amount of energy involved in these chemical transformations.

Some chemical transformations, once started, proceed with such rapidity that the reaction is classified as an explosion rather than burning. This is due to the fact that the various kinds of atoms necessary for these reactions are already present within the same molecule and all that is needed is a sufficient mechanical or thermal or other disturbance to bring certain atoms in the molecule into close proximity to other atoms in the molecule with which they have a very strong tendency to unite. Owing to the strong attraction between these atomic pairs, a readjustment takes place immediately and the complex molecule breaks up into many parts with the liberation of a large excess of energy. Thus, nitroglycerine and TNT do not go off under ordinary conditions but will explode when one produces a sufficiently strong disturbance of their molecular structures either by heating or by subjection to a powerful mechanical impact. The important thing to remember about an explosive is the rapidity with which the reaction takes place as compared with the ordinary burning process.

As has been indicated before, in most instances chemical energy is liberated only after one has first supplied some energy to start the transformation taking place. When a system possesses a stockpile of energy which can be set free only by the expenditure of a certain small amount of energy, it is generally spoken of as being in a **metastable** state. Such a situation is analogous to a rock which reposes in the saddle back of two mountain peaks which rise majestically on the two sides of a narrow island in the ocean. Some energy must be expended in doing the work of lifting the stone up and over one of the peaks after which it makes available a great deal of energy as it plummets down the mountain side and goes to the bottom of the sea. Most chemical compounds are analogous to the stone on the bottom of the ocean bed, i.e., they are already near the state of stable equilibrium and there is little opportunity for obtaining energy from them because they have already given up nearly all of the energy which it is possible for them to develop. So, in looking about for chemicals from which to secure chemical energy, only a small fraction of the matter at hand is found suitable. Our fuels such as oil and coal and gas are good possibilities. Most other materials occurring naturally are already near their stable states and are comparatively useless as potential sources of energy. Even coal and oil can hardly be considered as common, natural minerals because of the peculiar conditions under which they were formed in past geologic ages. At the rapidly increasing rate at which the limited supply of these substances is being used up we are faced with the problem of finding a substitute for these sources of energy when the deposits of coal and oil are exhausted. Within the past decade, approximately, researches have revealed to mankind a new and unmeasured source of energy. This source lies deep in the interior of the atom in that tiniest of tiny specks—the atomic nucleus.

NUCLEAR ENERGY

The energies so far considered have involved either no change at all in individual atoms or at most a relatively small change in the energy possessed by the electrons in the outer structure of the atom. So now let us turn our attention to that tiny little core or heart of the atom which we call the nucleus. Energy from the nucleus may come in several ways:

(A) One way is known as the radioactive process. Spontaneous disintegration of the nucleus occurs with the expulsion of high speed alpha particles, helium nuclei, or very high speed electrons, called beta particles, often accompanied by pulses or photons of radiant energy called gamma rays.

(B) A second way is in the fission process. The bombardment of and penetration into a nucleus by some particle, such as a neutron, result in the splitting of the nucleus into two fragments of approximately equal masses. Initially, the two fragments are highly unstable and further disintegrate with the ejection of a number of high speed neutrons and electrons. Most important of all—when the masses of all the fragments are added up and compared with the mass of the original nucleus and bombarding particle, it is found that some mass has disappeared. What has become of it? Careful measurement of experimental results reveal unmistakable evidence that this lost mass was converted into energy according to the now famous Einstein equation, $E = mc^2$. In this equation E is the energy in ergs, m is the mass in grams, and c is the velocity of light in centimeters per sec. (3×10^{10}). Theory, confirmed by experiment, indicates that the heavier elements, in general, are the most susceptible to this kind of process.

(C) A third way is the fusion process, in which a number of nuclei of small mass are brought together, under suitable conditions, to form a heavier nucleus. Again there is a loss of mass which is converted into an equivalent amount of energy. Strangely enough, the greatest production of energy takes place through the fusion of the nuclei of the lightest of all elements—hydrogen—into a heavier nucleus such as helium. Hence, fission of the heaviest nuclei into lighter ones and the fusion of the lightest nuclei into heavier ones are both productive of great amounts of energy.

SOME COMPARISONS OF MAGNITUDE

Now, briefly, let us try to make some comparisons between the energies involved for a few sample cases—physical, chemical, and nuclear. Most of you are acquainted with the kilowatt-hour as a unit of electrical energy. You know that an ordinary home with the usual number of home appliances, such as toasters, irons, refrigerators, radios, washers, mixers, electric clocks, electric ranges, etc., may require 250-300 kilowatt hours per month. Whether you know the exact meaning of the kilowatt hour isn't important. The comparison of the number of such units of energy is important. In each instance one pound of substance is used to make the comparison easy.

1 pound of any body with 100 feet to fall has . .	.000037	KW-HR
1 pound traveling 100 feet/sec. has	.0000588	KW-HR
1 pound of water when formed from H_2 and O_2 releases	2.00	KW-HR
1 pound of coal (heat of combustion 12,000 BTU/lb.) has	3.52	KW-HR
1 pound of gasoline (heat of combustion 20,000 BTU/lb) has	5.52	KW-HR
1 pound of TNT (1/8 heat of comb. of coal)[1] has only	.44	KW-HR
1 pound of U-235 or Pu-239 in fission process yields (.1% efficiency)[2]	11,400,000.00	KW-HR
1 pound of hydrogen converted to helium yields[3]	85,352,000.00	KW-HR

SUMMARY AND CONCLUSIONS

From nature man must extract the energy necessary to perform the ever-expanding tasks of a mechanized and industrialized world economy. As civilization has evolved, he has developed new methods of utilizing already known stockpiles of energy and has sought new sources, as yet unknown and untapped. To those ends he has harnessed the physical and chemical properties of matter so as to provide his requirements for energy up to the present time. However, the threat of depletion of many sources of energy, coupled with an increased demand for both civil and military purposes, has stimulated research to the end that a new source of energy has been discovered which dwarfs into insignificance all previously known sources. As shown by the foregoing table, the energy available in the nuclei of atoms is millions of times greater than can be obtained by older means from equal masses of matter. If, as appears probable, the efficiency of extraction of energy through nuclear fission and/or fusion can be sufficiently increased, man will have at his disposal an almost unlimited supply of energy. We may well believe with Norman Cousins that "The human community today is at one of those rare pivotal points in history. A wrong turning now could mean that nothing on the earth will become cheaper than human life, for nothing will be more easily expended or dispensed with. But a proper turning now could mark the beginning of a vast upward surge in human history, infusing life with enriched purpose and meaning."

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1. But the explosion takes place in a very short time so the power produced by the TNT is enormously greater.

2. Atom for atom nearly 50,000,000 times that for coal. Enough energy from 1 pound to run a 100 watt bulb continuously for 13,000 years.

3. The yield per atom isn't as great as for U-235 but it takes so many more hydrogen atoms to make a pound. Enough energy to run a 1 h.p. motor continuously for about 13,000 years.

CHAPTER III

ATOMIC FUELS*

In general there are two classes of fuels for atomic energy. One type is made up of heavy atoms like those of uranium 235. Energy is released when these atoms are split into two smaller atoms roughly equal in size. The other type consists of light weight atoms, such as hydrogen and lithium, which through some mechanism may be made to combine with one another to form new atoms. In both cases a loss in mass is experienced and consequently energy is produced. The fuels considered here are the heavy atom fuels that were used in atomic bombs during the last few days of World War II. Discussion of the light atom fuels is not a part of this chapter.

Uranium 235, plutonium 239 and uranium 233 are the potential atomic fuels for use in atomic bombs, atomic power plants and atomic fuel generators. These fuels are not found in nature in a form readily adaptable for use in atomic bombs. The source material for uranium 235 and for plutonium is normal uranium which contains only about seven tenths of one per cent of uranium 235 diluted with about 99.3 per cent of uranium 238. The uranium 238 cannot be used directly as an atomic fuel, but under proper conditions in an atomic furnace or generator uranium 238 can be converted to plutonium 239 which is a very potent atomic fuel. The first half dozen or so atomic bombs have been fired with either uranium 235 or plutonium as the fuel. The uranium 233 atomic fuel is made from thorium by a reaction that can take place in an atomic furnace. The thorium is, in a way then, like uranium 238; neither is an atomic fuel but both can be converted in an atomic furnace to other elements which are atomic fuels.

So it may be seen that two elements, uranium and thorium, whose ores occur in widely scattered areas contain all the necessary materials for making fuels for atomic bombs. Control of these two elements throughout the world seems to be essential to the safety of civilization. It will be seen later that the atomic fuels offer many valuable assets such as useful power, tools for tracer studies in science, and the treatment and diagnosis of disease. But some sure way of obtaining international control of atomic fuels must be enforced before the full and rapid development of all phases of atomic energy for the benefit of all mankind can be realized.

Figure 6

Atomic Energy Plant At Oak Ridge, Tennessee

(Courtesy Atomic Energy Commission)

Suppose we start with normal uranium and look at some of the phenomena and processes associated with obtaining and using U-235 as a fuel for atomic bombs. Although it and the other fuels have important uses other than in bombs, the nuclear reactions are all essentially the same and the method of obtaining a concentrated fuel is the same regardless of the intended use of that fuel. The U-235 can be separated from U-238 only by physical methods that depend on the slight difference in the weights of their atoms. The large ratio of approximately 140 atoms of U-238 to each atom of U-235 in the natural uranium ore also complicates the process for producing high purity U-235.

The most successful method for large scale concentration of the U-235 to date employs the gaseous diffusion process. The normal uranium is used in the form of a volatile compound. The molecules of the gaseous compound differ in weight depending on whether the uranium atom that is a part of the molecule is U-235 or the heavier U-238. On the average lighter weight gas molecules move faster than heavier gas molecules at the same temperature. Essentially, then, the separation depends on the molecules containing U-235 outrunning the heavier molecules through a long series of barriers. The result is a concentration of the desired product at the head of the gas stream. Figure 6 shows a photograph of the plant at Oak Ridge, Tennessee, where this is done. The building is equivalent to 3 or 4 stories in height and has a roof area of 60 acres. It is in this building that the U-235's are outrunning the U-238's. The U-235 is then collected and converted to a form for use as a concentrated atomic fuel. Consideration of the processes for obtaining Pu-239 and U-233 will be deferred until later in this section. Let us consider the U-235 we have just concentrated in the discussion of atomic fission, chain reactions, and other topics. Pu-239 and U-233 could equally well be used in place of the U-235 in this discussion.

ATOMIC FISSION

The fundamental process on which the "A" bomb operates is fission of the atoms of the fuel. The black and white spheres in the large clusters in Figure 7 represent neutrons and protons that make up the nucleus of a U-235 atom. The 92 electrons that normally circulate around the nucleus of the atom are not represented in this diagram. The figure shows a free neutron approaching the U-235 nucleus, and subsequent steps in the fission process. This neutron passes into the nucleus which then splits or fissions into two new but smaller nuclei and a number of free neutrons. When a large number of U-235 atoms undergo fission, the products will include a large variety of atoms, since the nuclei of U-235 atoms can split in a number of ways and give different sized fragments. Most of these fission products are unstable (radioactive) atoms. In addition to the fission product atoms, note that three neutrons are shown set free here. The number of neutrons set free when an atom fissions varies from fission to fission, but for the sake of simplification of the discussion, we will consider three free neutrons for each fission.

If we could collect and accurately weigh all the particles resulting from the fission and compare this weight with that of the one neutron plus the U-235 atom that re-

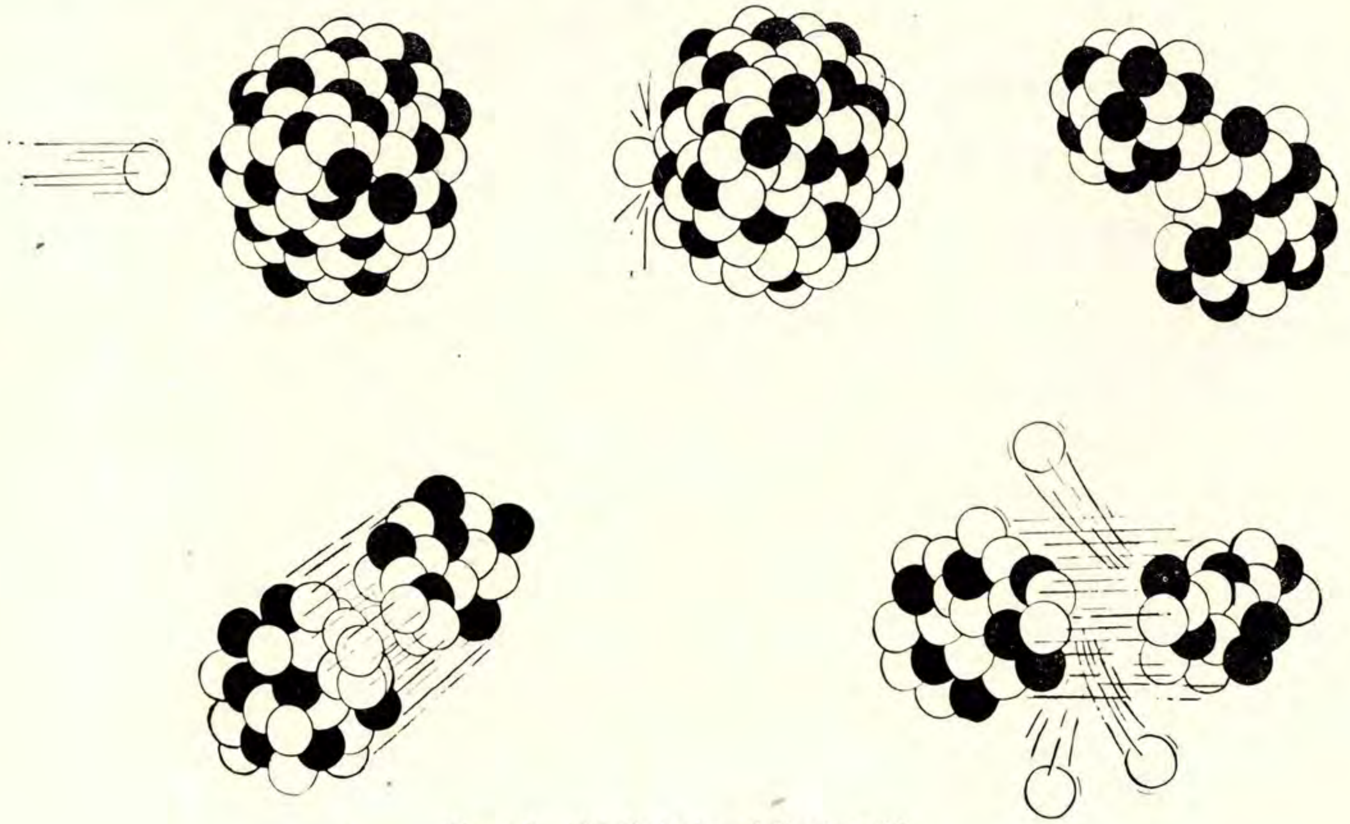

Figure 7 — The Fissioning of Uranium 235

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*Prepared by Harley A. Wilhelm, Iowa State College.

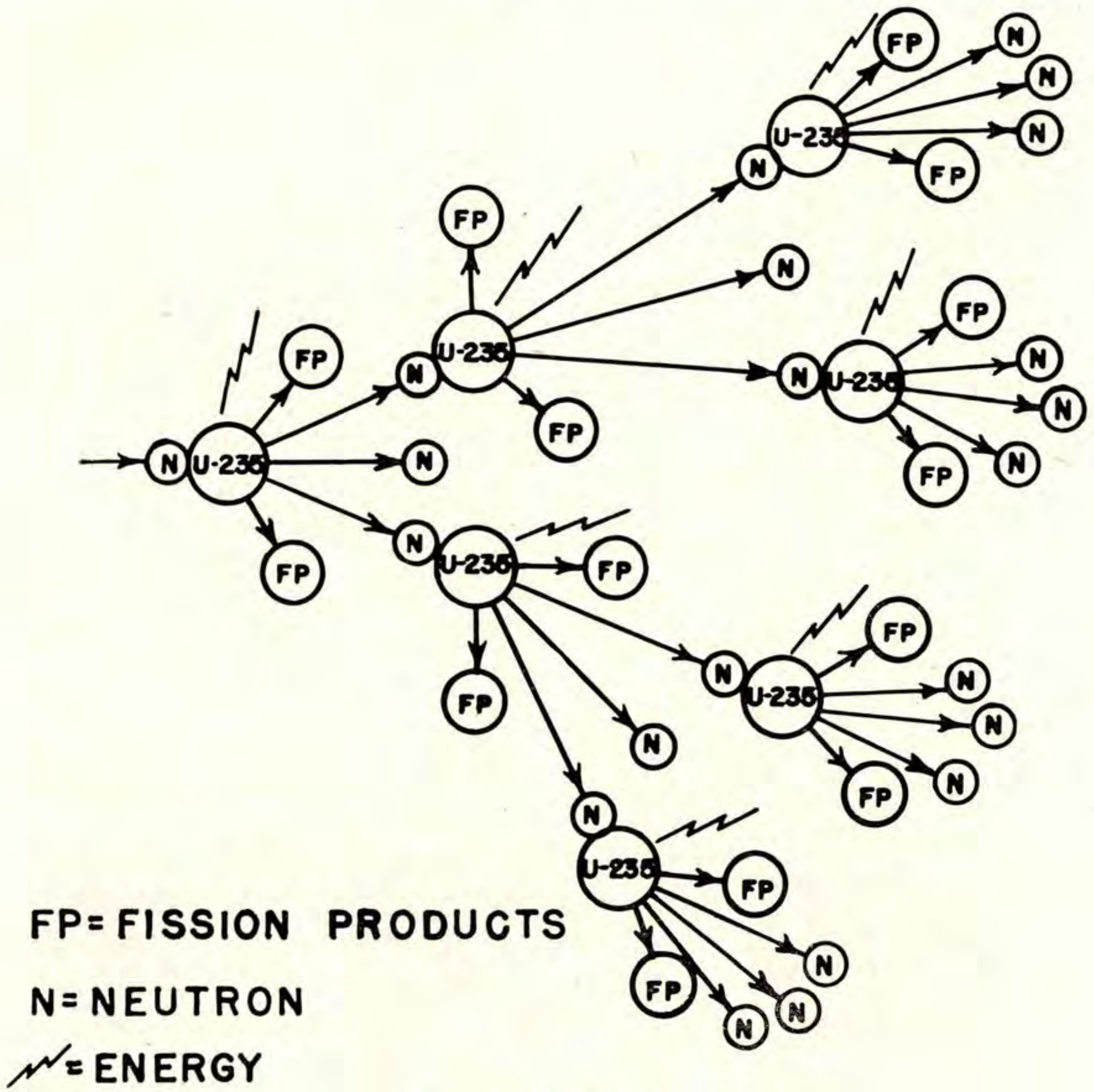

Figure 8 — Chain Reaction

acted in the first place, we would find that 0.1% of the mass (weight) has disappeared. It is this loss in mass that gives rise to the large amount of energy associated with the atomic bomb where billions of trillions of atoms may fission in a very very small fraction of a second. Einstein's equation, $E = mc^2$, gives a quantitative relationship between a **loss in mass** (m) and the energy (E) realized, where (c) represents the velocity of light, which is 3×10^{10} centimeters (or about a billion feet) per second. Since c is squared in this equation, one can readily see that the **loss in mass** does not have to be very large in order to give considerable energy. This energy is realized largely in the form of rapid motion or high temperature of the products of the fission. Radiations such as heat, light and gamma rays carry some of this energy and the radioactive decay of the fission products after the process also carries a part.

CHAIN REACTIONS

If the neutrons produced by this fission process are used to fission new U-235 atoms and this continues on and on we have a chain reaction shown diagramatically in Figure 8. It is seen here that starting with one free neutron at the left we have an increasing number of free neutrons as the expanding chain reaction continues to the right. In the diagram two neutrons are shown being utilized in the reaction. The other free neutron produced by fission as shown in Figure 7 is assumed here to be lost from the piece of uranium or tied up by some side reaction.

The expanding chain reaction is the main process which causes the explosion of an atom bomb. Associated with this explosion are other effects which can be pointed out in connection with Figure 8. The fission processes and the chain reaction throughout the fuel of an atomic bomb are practically instantaneous. So, in an unbelievably short time, the fuel has reacted and we have a large variety of fission product atoms that are intensely radioactive. We have a large number of free neutrons because the expanding chain ran out of fuel. These neutrons are very penetrating and they radiate or travel from the center of the explosion with very high velocities. Plants, animals, and many inert materials exposed to intense neutron radiation are affected. During the progress of the chain reaction, radiant energy in the form of gamma rays, light, and heat are released from each of the billions of trillions of atoms that undergo fission. The cumulative heat radiated is sufficient to start fires and cause severe burns at some distance from the exploding bomb before the full effect of the damaging explosion wave gets there. The gamma rays travel with the speed of light, are very penetrating and can severely damage living organisms.

CRITICAL MASS

Figure 8 was oversimplified in order to present the main ideas connected with the chain reaction. Let us get closer to a true picture of what we have and what may go on inside a solid piece of U-235 metal. There are certain conditions of size and shape necessary in order to get a chain reaction to propagate throughout the atomic fuel.

First of all let us take a closer look at the atom of uranium. Atoms are so small that it would take about ten billion billion uranium atoms to make a solid piece of uranium metal the size of the head of a common pin. In spite of the small size of atoms the scientist knows much more about their inside structure than is known about the inside of the earth. Let us suppose that a piece of uranium could be expanded up to such a size that the outer electron orbits of its atoms would be a half mile in diameter and the nuclei, where the fission process must take place, are correspondingly expanded. One single atom would then have a cross section of about 120 acres and its nucleus, where the mass is concentrated, would be about the size of a baseball at the center of this half mile diameter sphere. Suppose we imagine our position to be at one of these nuclei where we see the start of a chain reaction. The baseball is split and two or three neutrons, about the size of a marble on this expanded scale, are shot out in random directions. The next closest nucleus would have to be a half mile away in the center of the next atom. The chances of a marble hitting a baseball at a distance of ½ mile would be practically nil, especially when there is no tendency for the marble to be aimed in any specific direction. The neutrons produced by fission are not then going to hit the nuclei of the neighboring atoms as sketched in Figure 8. A neutron will have to travel through many, many atoms before it collides with a nucleus and we get a repetition of the fission process.

If the piece of atomic fuel is relatively small there is a good probability that the neutron will pass out of the fuel entirely and be lost from the chain reaction. If the amount or shape of the atomic fuel is such that the neutrons get out of the fuel too easily and do not cause sufficient new fissions then the chain reaction will die. Such a fuel assembly is said to be "sub-critical." In order to get the neutrons produced by fission to cause other atoms to fission and obtain an expanding chain reaction, the size and shape of the atomic fuel must be such that we will get on the average more than one additional atom to split for each atom that has split. This fuel assembly is said to be "super-critical." An assembly in which fission by continuous chain reaction is proceeding at a constant rate is said to be at "critical." Figure 9 represents a method by which a system of atomic fuel can be kept sub-critical and therefore stable and then readily converted to a super-critical condition with a resulting atomic explosion. In the figure (A) and (B) represent two separate hemispheres of atomic fuel such as U-235. These pieces are each sub-critical because there is so much surface through which neutrons can escape (indicated by arrows) from each piece that should a chain reaction start it would soon die due to loss of too many neutrons without causing fissions. If these two sub-critical pieces are suddenly brought together (C), then part of the loss is checked because neutrons now flow between the two pieces and although there is still some loss of neutrons at the surface of the sphere the combination makes it possible to increase the amount of fission in each generation, giving a super-critical assembly and an explosion.

THE FIRST ATOM BOMB

In July of 1945 an assembly of atomic fuel was mounted on a high steel tower out in the desert area of Alamogordo, New Mexico. When all observers and their instruments were ready, the fuel was made super-critical and the explosion followed.

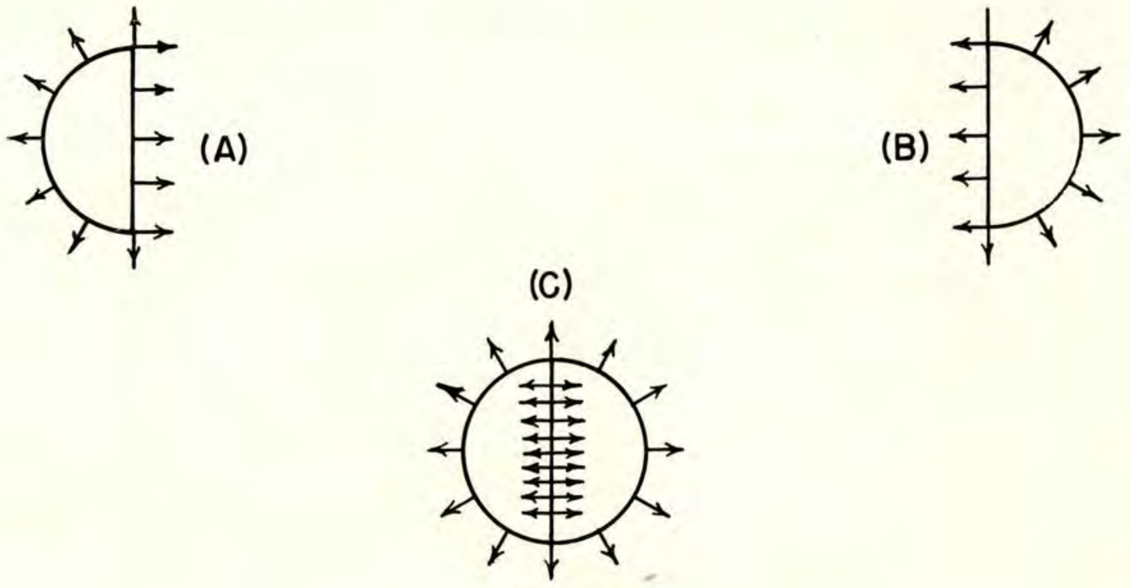

Figure 9

Figure 10

Figure 10 shows a photograph made just one fortieth of a second after the explosion was set off. At this time the fission process was completed. Intense gamma rays, heat rays, neutrons, and an intense light flash had been sent out. The radioactive fission products which may be considered as the ashes from the burnt atom fuel were in the vapor state and were still within the explosion envelope. The steel tower was also almost completely vaporized at this time. Force of the explosion which followed was quite effective for a number of miles around.

Figure 11 is a photograph of the same test explosion 15 seconds after the bomb was fired. Here the mushroom of hot gases, including the highly radioactive fission products, is well formed. In this case most of the fission products were taken high in the atmosphere and were well scattered as they passed over the midwest. Only in special cases were these radioactive materials detected later.

Figure 11

The underwater bomb test at Bikini after the close of the war introduced a few new points of interest in connection with atomic explosions. First the radioactive ashes from the explosion were mixed with steam and water and consequently a good share came back down over the ships and surface of the lagoon. Another important factor here is the radioactivity generated in the salt of the sea water. Residual free neutrons from the explosion caused sodium atoms of the salt to change to a radioactive isotope of sodium. Consequently much radioactivity was left on the ships and within the immediate area of the explosion.

THE ATOMIC "PILE"

While the amount of concentrated atomic fuel necessary for an atomic bomb can be measured in pounds it is possible to get a continuous chain reaction to take place in the U-235 of normal uranium if we properly assemble tons of this dilute material. The first such assembly was set up under the West Stands of Stagg Field at the University of Chicago and operated on December 2, 1942. This chain reacting assembly was called a "pile" and with the many variations possible such terms as a nuclear reactor, atomic furnace, atomic generator, breeder pile, power pile, etc., are used to denote assemblies that are the same or have essentially the same features. The principal use of the atomic pile has been the generation of Pu-239 from U-238. The reaction by which this change takes place is shown schematically in Figure 12. Across the top of this figure the U-235 chain reaction is represented, but instead of the expanding chain of Figure 8 only one neutron is utilized per fission to produce a new fission; therefore, the fission process takes place at a constant level of activity. The extra neutron in each case is picked up by one of the many U-238 atoms associated with the U-235 atoms in the tons of normal uranium assembled in the pile. Addition of one neutron to a U-238 atom changes it to U-239 which is unstable (radioactive) and Np-239 is formed from the U-239. The Np-239 is likewise unstable and it decays to Pu-239 which is fairly stable to radioactive decay. Briefly then, as indicated in the figure, Pu-239 is formed from U-238 some time after the U-238 picks up a neutron in such an atomic pile. The plutonium being a different chemical element can then be separated chemically from the unchanged uranium and the fission products. The Pu-239 can then be concentrated and made to serve as an atomic fuel in the same manner as U-235.

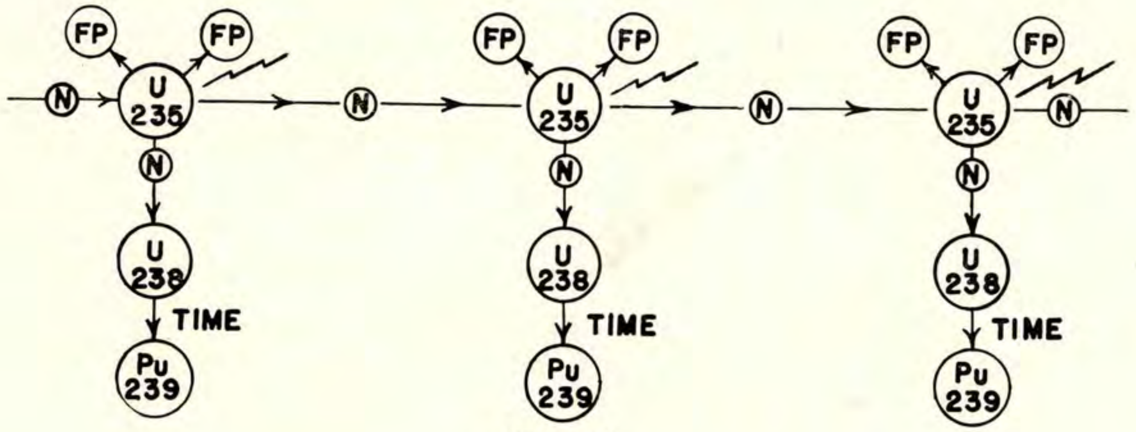

Figure 12

A reactor or pile in which plutonium is produced is represented in Figure 13. There are essentially five main components in the pile. First, it must have an atomic fuel. In this case the fuel is U-235 which is introduced as a small part of the tons of normal uranium in the pile.

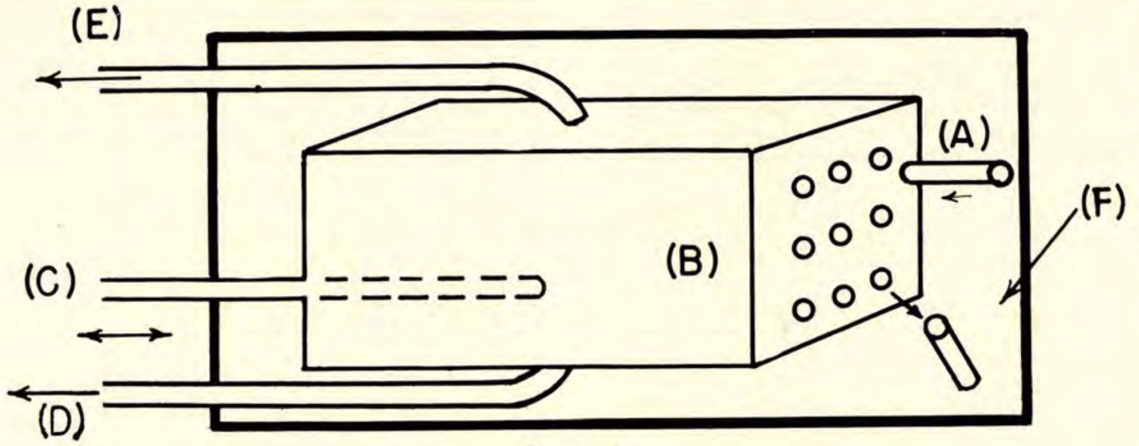

Figure 13

The uranium is usually in the form of metal rods which must be sealed in thin walled aluminum cans to protect them from oxidation as they heat up when the pile is in operation. At (A) such a canned uranium rod is represented as being introduced into the pile.

Second, a moderator must be used to slow down the neutrons given off by U-235 fission so that the chain reaction can continue efficiently. Slow neutrons are much more effective in causing U-235 nuclei to fission than are fast ones in the presence of the large amount of U-238. The moderator is usually a material having light weight atoms which the neutrons can hit and thereby lose part of their motion. A number of collisions must occur between a neutron and other atoms before the neutron is slowed down sufficiently. Carbon in the form of graphite is a fairly good moderator material and in the figure it is indicated by the large block (B) having regularly spaced holes for the fuel rods.

The third point to be considered in connection with Figure 13 is the means for controlling the reaction, because if the chain reaction were allowed to continue to expand the pile would burn itself up or possibly explode in a reaction similar to, but much less violent than, an atomic bomb. It so happens that atoms of some materials have a very strong ability to capture free neutrons and hold them. If such a material in the form of rods is placed in a pile it can completely stop the chain reaction by capturing the neutrons and thus making them unavailable to the fuel in sufficient amounts to propagate the chain. Boron and cadmium are effective materials for capture of the neutrons in a pile, and rods containing either of these can be moved in and out of the pile and positioned in the pile to allow the chain reaction to operate at the desired level of reaction. If a pile is operating at a constant level it can be speeded up to a higher level by merely backing the control rods (C) of Figure 13 farther out of the pile. After the latter has reached the higher level, the rod is replaced at its original position to hold that level of operation. The operating level can be decreased to a new lower level or the pile completely shut down by merely pushing the control rods farther in the pile. In order to start a pile that has been completely shut down, it is only necessary to adjust the position of the control rods; there are always a few free neutrons available to start the chain reaction again.

In operating a pile to produce Pu-239 it is very desirable to have it operate at as high a power level as possible in order to speed up the rate of production. However, the higher rates of operation mean higher rates of fission of U-235 which mean greater amounts of heat generated. Cooling the pile is, then, the fourth matter for consideration in connection with pile operation. The pile may be air cooled if the level of operation is only moderate, but for the rate of plutonium production desired in the Hanford Plants it is necessary to use water as a coolant. The pipes (D) and (E) in the figure represent the carriers of the cooling water or air which keep the temperature of the pile at a sufficiently low value to eliminate heat damage to the elements of the pile.

When a pile is in operation many neutrons and gamma rays are emitted and pass out through its surfaces. Due to the damaging effects of these radiations to living tissues it is essential that the pile be properly shielded to protect the operators. The shield, the fifth essential part of the pile, may be made of concrete about five feet in thickness. This shield (F) completely encloses the pile when it is in operation. Zigzag ports or removable panels in the shield afford access to the pile through this shield.

After a charge of uranium has been in the pile long enough to convert the proper amount of U-238 to Pu-239, then the canned rods are discharged from the pile and chemical treatments remove the unchanged uranium and fission products and concentrate the atomic fuel, Pu-239. The fission products, or ashes from the atomic fuel, are extremely radioactive and complicate these chemical treatments by making it necessary to carry out the processing by remote control behind heavy shields.

By introducing thorium which is 100% Th-232 into a pile, U-233, the other of the three atomic fuels, can be produced. A neutron is captured by Th-232, forming Th-233 which is very unstable (radioactive) and decays to Pa-233, which still undergoes further radioactive decay to give U-233. The mechanism of this conversion parallels that for converting U-238 to Pu-239 as in Figure 12. Following sufficient exposure in the pile the thorium is removed and given a chemical treatment to separate and concentrate the U-233.

If we refer back to Figure 7 we note that three neutrons were liberated when only one was used in causing the fission. However, in the discussions connected with Figure 12 we utilize only two of these neutrons and according to this figure we would get only one Pu-239 atom for each atom of U-235 burned up. If we consider that the third neutron of Figure 7 is made available for the process of Figure 12, then we should get two Pu-239 atoms for each U-235 burned or we would be producing twice as much atomic fuel as we burn. Possibly this 100% gain in fuel cannot be realized in practice but a pile so constructed as to produce more fuel than it burns is called a breeder pile. Earlier in the discussion of Figure 7 it was pointed out that the number of neutrons set free per fission is a variable but an average number of anything greater than two would make a breeder gain theoretically possible. It is interesting to speculate that the energy from such a breeder pile be employed to generate power for use as electricity. In such a case we might burn atomic fuel to get electric power and end up with more new atomic fuel than we burned. Atomic bombs can also be made with either Pu-239 or U-233, the products of breeder piles; therefore, an atomic power plant could possibly produce atomic fuel and be a potential munitions plant. It seems quite necessary then that all atomic installations throughout the world be under strict inspection and control of a responsible organization with powers international in scope to enforce adequate measures for the best interests of all mankind.

So far in the discussion we have considered U-235 as the driving fuel, but now that we have Pu-239 and U-233 these can conceivably be utilized in place of U-235 to set up the controlled chain reaction for producing the extra free neutrons to convert all the uranium and all the thorium into atomic fuels. Nature supplied us with only a small amount of atomic fuel, .7% U-235 in normal uranium, with which to start this fuel generating program. We are either fortunate or unfortunate that this small amount of U-235 was included in the make up of uranium. Only the future can determine whether man will eventually use the resulting atomic energy for his benefit or his destruction.

NOTES

CHAPTER IV

ATOMIC ENERGY FOR POWER*

THE RELEASE OF ATOMIC POWER

A simple explanation of what atomic energy is and how it is obtained may help in the understanding of its relationship to the electric power which we now use in our homes and factories. The energy which is commonly referred to as "atomic energy" is in fact more correctly referred to as **nuclear energy** since it comes from the nucleus of the atom rather than from the various possible associations of atoms which are involved in chemical energy and from which we now get the power which lightens our daily tasks at home, on the farm, and in the factory.

The aspect of nuclear or atomic energy which makes it interesting and exciting is the enormous amount of energy that can be obtained from a small quantity of matter. An easy way to understand this is to compare a well-known chemical energy-producing reaction with a nuclear energy-producing reaction. These reactions can be compared best by comparing the energy involved in a single nuclear or atomic process and then by inferring from this energy the energy involved in the reactions of appreciable quantities of matter. A molecule of TNT furnishes a good example of chemical energy for comparison with the nucleus of U-235. The TNT molecule has a molecular weight of 227 mass units which is approximately the same as the 235 mass units in the uranium nucleus. Also, the reaction involving either of these particles requires the addition of no mass such as that of the oxygen necessary for the burning of coal. When a TNT molecule explodes, giving off its energy, it splits into various pieces just as the U-235 splits or fissions. This similarity makes the comparison appropriate.

On the molecular scale it is useful and customary for physicists to measure energy in electron volts. This unit of energy is the amount of energy which an electron receives when accelerated through the potential of one volt. In terms of the energy units more commonly used in physics, an electron volt is equal to 1.6×10^{-12} ergs. An exploding TNT molecule releases in the form of kinetic energy of its fragments approximately 4 electron volts of energy. This amount of energy is roughly of the order of magnitude of the amount of energy per molecule released in many familiar chemical reactions. On the other hand, fission of a U-235 nucleus gives to its fragments an energy approaching 200 million electron volts. Thus, the ratio of energy released per unit mass between U-235 and TNT is approximately 50 million to one. Then, 50 million pounds of TNT, or 25 thousand tons of TNT, are equivalent to one pound of U-235 in available energy content. It is this tremendous ratio which makes atomic energy so attractive.

We have known now for some years that the energy of plutonium and of U-235 and other uranium isotopes can be released gradually at controlled rates in an atomic pile as well as instantaneously in an atomic bomb. This energy, of course, takes the form of heat, particularly after it has been degraded by contact with a sufficient quantity of inert matter. The atomic energy so released can be utilized at almost any temperature which the structural materials required to hold it together can withstand. The temperature of the initial fission particles is, of course, enormous. A gas, each of whose particles on the average has one electron volt of energy, is at a temperature of approximately 10,000 degrees Kelvin, or absolute temperature. Since the energy is distributed approximately equally to fragments, the initial particles in a fission reaction form a gas having a temperature of approximately 10^{12} degrees Kelvin. This temperature is, of course, quickly degraded by radiation and conduction so that the amount of heat it represents is spread out through the inert material surrounding the reaction. The whole equipment is raised to a temperature which depends on the ratio of the mass of the fission fragments to the total mass of the reactor. In addition to the regular fission fragments, a controlled nuclear reactor gives off a copious supply of escaping neutrons. Enormous quantities of gamma rays are also produced, both from the fission and from the decay of radioactive fission fragments.

PROBLEMS OF ATOMIC POWER

The foregoing discussion of the fission process indicates that severe engineering difficulties must be solved before nuclear energy can be used for the generation of electrical power. From the standpoint of the power engineer, nuclear energy is merely a source of heat although it is a possible source of extremely high temperature. Although high temperature makes possible a high theoretical thermodynamic efficiency, the temperature which can be used in a practical machine is actually limited by the strength of its structural materials at high temperatures. A consideration of known structural materials leads to the conclusion that the usable temperatures in connection with nuclear power will probably be no greater than those now used with chemical fuels. The fission reaction will, therefore, have to be diluted with sufficient inert material to bring the reaction temperature within this range.

When this problem is solved, we are faced with an even more serious one, namely, that of disposing of the stray radiations (neutrons and gamma rays) which are destructive to all living matter and from which the operating personnel and the surrounding countryside must be shielded. Both the neutrons and gamma rays from nuclear fission are extremely penetrating. So far the only effective shield known is the mere mass of intervening material. An adequate shield for a small nuclear engine must weigh many tons indeed. For this and other reasons the use of nuclear power for the propulsion of commercial aircraft, automobiles or locomotives does not appear feasible with our present knowledge. For stationary power plants and for ships and submarines the mass of shielding required will not be so great a problem. However, there is an additional problem that is serious in all these cases. That is the problem which corresponds to getting rid of the ashes and smoke in an ordinary power plant using chemical fuels. Unfortunately the ashes and smoke from a nuclear engine will contain fission products which are radioactive substances. Anyone who is familiar with the history of radioactivity will know how serious radium poisoning is and thereby have a clue to the undesirability of permitting radioactive materials to escape into the air or into soil and water.

These are only a few of the more obvious problems in connection with utilization of nuclear energy for power

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*Prepared by Winfield W. Salisbury, formerly of Collins Radio Co., Cedar Rapids production. They indicate the great engineering difficulties involved and that such peaceful uses of nuclear energy may be a long way off. The viewpoint here presented seems a pessimistic one. However, the possibilities of nuclear energy are enormous and are probably worth the effort required to bring them under control. One must be cautious and not expect too much too soon. A proper perspective will permit us to keep up the long continued effort necessary to produce in our society the nuclear revolution which should logically follow the discovery of atomic fission and add to the benefits of the industrial revolution.

NOTES

CHAPTER V

RADIOACTIVE ISOTOPES IN SERVICE*

The benefits of atomic energy through its production of useful power are still a long way off, but there is one type of benefit which is being realized at the present time. This is the research tool, radioactive tracers, a by-product of the operation of neutron reactors or piles.

Such a machine must be designed so that there is some flexibility in its operation—some excess of neutrons which can be produced in addition to those which are needed for stable operation—in order to start the reactor. These excess neutrons are usually absorbed by a control rod which can in part be replaced by elements which one desires to make radioactive.

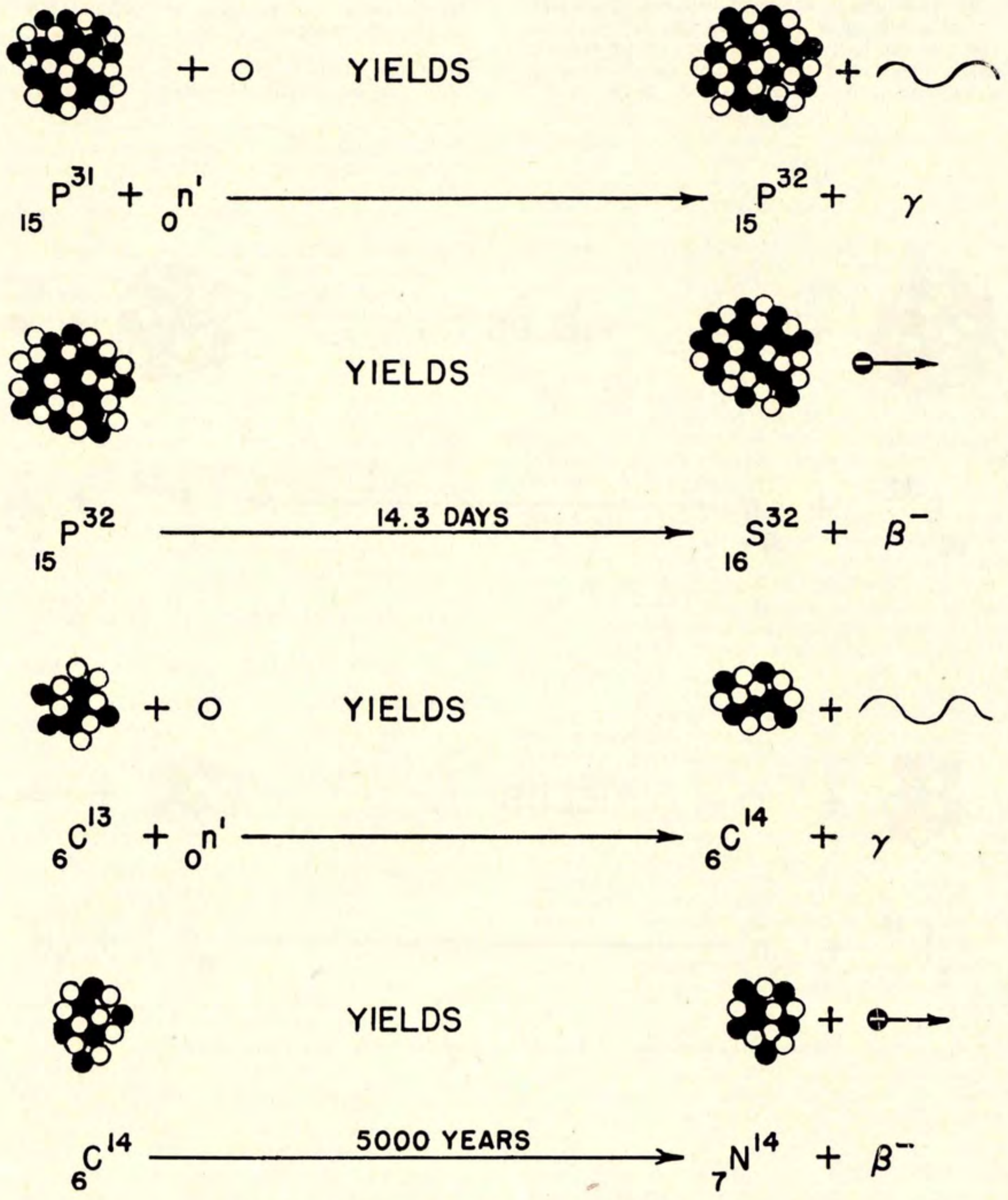

Figure 14. Formation and decay of P^{32} and C^{14}

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*Prepared by A. F. Voigt, Iowa State College

THE PRODUCTION OF TRACERS

Most of the radioactive isotopes sold by the Atomic Energy Commission are made in this way. The most common nuclear reaction used is one in which a neutron is absorbed by a stable atom making it radioactive as well as heavier by one atomic weight unit. High energy gamma radiation is given off at the instant of formation of the new nucleus, but what remains may sit around for years before it undergoes its radioactive decay. Each radioactive substance has its own characteristic period for decay which cannot be changed by any chemical process. This period is usually measured by its "half-life", the time required for one half of the amount you have to decay. This value does not depend at all on how much you have. The half-lives of different isotopes range from less than a millionth of a second to ten billion years, but only those whose half-lives are from about an hour to a thousand years are of much use in tracer research. As typical examples, the formation and decay of P^{32} are illustrated in (1) and (2) of Figure 14 and the formation and decay of C^{14} are shown in (3) and (4) of this same figure.

The disadvantage of this method is that the new atoms are mixed with a vastly larger number of the "parent" ones. The two kinds are chemically identical and cannot be separated without going to prohibitive expense. For some uses these concentrations are adequate but for others they are not. It would be very desirable to have a method for producing radioisotopes in which the new atoms would be chemically different from their parents. Such methods, using the nuclear reactors, exist for a very few of the important materials. Thus the P^{32} and C^{14} mentioned above can also be made by reactions in which sulfur and nitrogen are irradiated with neutrons, as illustrated in Figure 15.

Now the atom is phosphorus and its parent is sulfur. This pair can readily be separated so that the radioactive atoms can be prepared at a concentration as high as could be desired. In addition to P^{32} and C^{14}, tritium or H^3, S^{35}, and Ca^{45} are prepared by such methods. You will remember, from the foregoing discussion, that when uranium splits in the fission process, the atoms it forms are not stable but are highly radioactive. Why, you may ask, are these not used for tracer experiments? The answer is that not many of the elements represented in the fission products are of much interest to biologists, since they occur seldom if ever in plants and animals. There is one exception; one of the best-sellers in the isotope line is I^{131} which has an eight day half-life. This is separated by a chemical method from the other fission products and uranium and can be prepared in highly concentrated form.

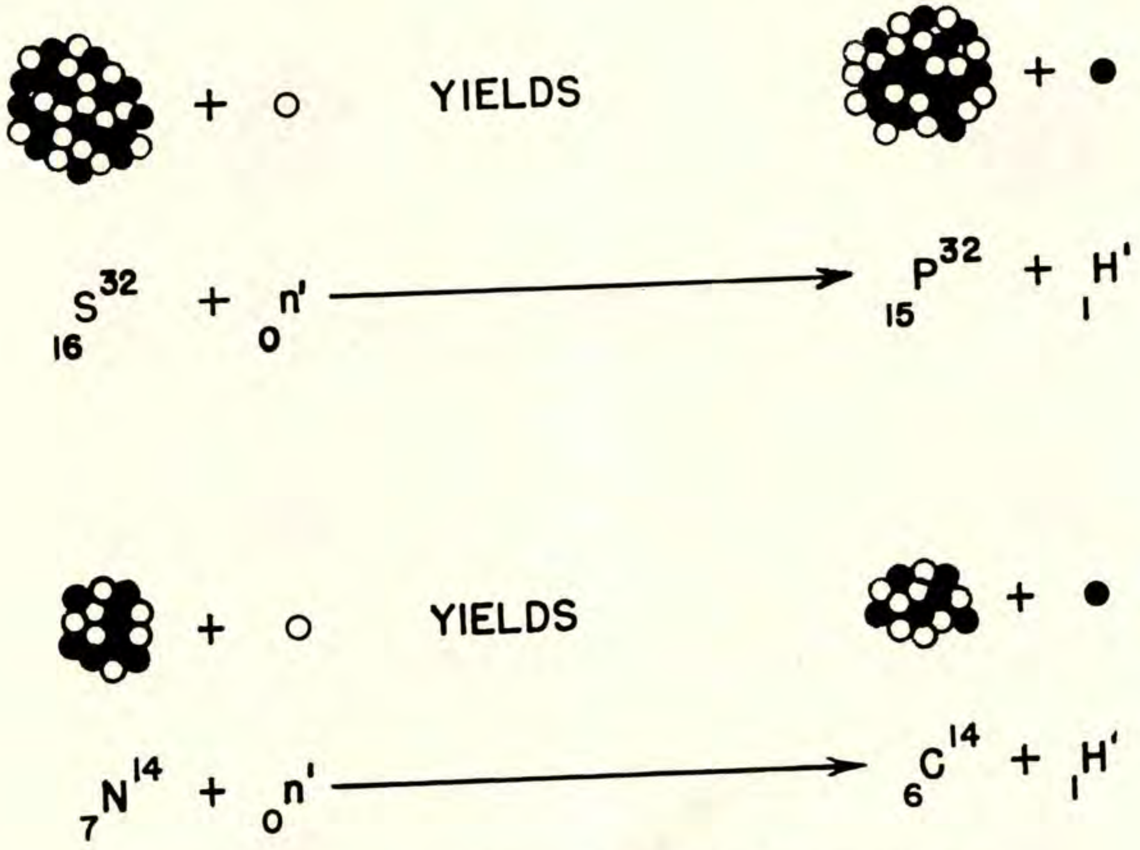


Figure 15. Formation of P^{32} from Sulphur, and C^{14} from nitrogen

Now we have our isotopes made but we do not have them at the laboratory in a form in which they can be used. Many of the materials are shipped to research laboratories without chemical separation but others are taken through separations before being sent. In any case they have to be handled for shipment. Handling is done with long tongs and by remote control; chemical operations are done on the other side of concrete walls by observing the process with mirrors and periscopes.

Radioactive materials can, if properly packed, be shipped by railway or air express. They are usually put into a lead container weighing 20 to 300 pounds for such shipment. If the half-life is short, air express is used and the isotope can be delivered in less than 24 hours after it is removed from the pile.

After reaching its destination special tools and equipment often have to be used when working with a radioactive substance, at least until a small part of it can be taken out for use and the rest put into storage. Good ventilation is especially important. Inhaling the dust or fumes might introduce some of the highly toxic material into the body where in some cases it may remain for years giving off its toxic radiation. If the active material is on the laboratory bench it can be left there at night, but if it has gotten into your body it will be irradiating you 24 hours a day until it is excreted or has decayed.

ISOTOPES AS SOURCES OF RADIATION

The uses of radioactive materials can be divided into two quite distinct categories. In one the biological effect of the radiations is studied or used, and in the other the system is studied as it would be in the absence of any radiation. It is apparent that studies of the first type use much larger amounts of radioactive materials than do those of the second type.

For many years radiation from X-ray machines and from radium has been used to treat patients with cancer, a type of treatment that is somewhat hazardous and is only justified because the cancer if unchecked would be fatal. The basis of the treatment is that the cancer cells are more easily damaged or destroyed by radiation than are normal ones and by carefully controlling the amount of radiation the cancer can be removed without injuring the body too much. One disadvantage is that this proper level of radiation is hard to find; another that over-dosages of radiation, while they might not produce an immediate effect, may in themselves induce additional cancerous growths. Radioactive isotopes fit into this picture in several ways. Some common and inexpensive material such as cobalt metal may be put into a pile and irradiated for some time. When removed the cobalt gives off gamma rays and may be used as a substitute for radium at a cost which is a small per cent of the cost of radium.

The primary advantage of artificial radioactive materials over radium, however, is that many common elements may be made radioactive. These may, in the form of a simple compound or in a complex molecule, be taken up to a greater extent by tumorous tissue than they are by normal tissue. As one example of this, we all know that the thyroid gland collects iodine from the blood stream and uses it to make thyroxine, a very important body regulating hormone. If the thyroid is too active or not active enough the body's rate of metabolism is not properly adjusted and serious conditions may result. While physicians are usually able to diagnose these conditions in conventional ways, there do exist other conditions which are similar enough so that mistakes can be made. If sodium iodide containing radioactive iodine is fed to or injected into such a patient, the rate and extent of uptake of the iodide by the thyroid can be determined by a Geiger counter outside the throat. It can readily and accurately be told whether the uptake is too little, normal, or too much, and correct treatment can be given. This can be done with an amount of radioactivity which is too little to affect the thyroid gland by its radiations.

It is also possible to treat overactive thyroids using this same principle by feeding a large enough amount of radioactivity to produce a definite destructive effect on the thyroid. Since the iodine is so much more concentrated in the thyroid than anywhere else in the body, no such destructive effect is noticed outside the thyroid. Though it is not given for ordinary overactive thyroids there are growths or tumors of the thyroid which are sufficiently serious to justify the use of this radical treatment, in which the dose of radiation given in the so called "atomic cocktail" may be enough to completely destroy the thyroid gland.

There are similar diagnostic and therapeutic uses of these by-products of atomic energy in which other elements are used and in some cases made a part of a complex compound which is selectively absorbed by undesirable tissue. Of course this is a worthwhile goal of research—to find such a compound which is 100% taken up by cancerous tumors in which all the radiation from the compound is absorbed. The side effects caused by the action of the radiation on well tissue would then be unimportant and larger doses could be given which would ensure sufficient irradiation of the cancerous tissue to destroy it. At present this is still a goal but it does not appear to be an unattainable one.

Another type of research in which the effect of radiation on living matter is being studied was brought about as a result of rumors that plants in Hiroshima were growing much more luxuriantly than in the surrounding countryside after August 6, 1945. It appeared to some people that the radiation might be having beneficial effect on plant growth. It is well known that at high levels of radiation, plant growth can be retarded, stopped or the plant can be killed as the dose is increased. On the other hand at low levels there is no effect. Whether or not there is a region between those extremes in which beneficial effect is observed is the question these investigations wish to answer. To date no positive results have been observed. Any claims by charlatans that they have on the market a "radioactive fertilizer" which will increase your corn yield are pure bunk.

It was found some years ago that the number of genetic changes occurring in each generation of living organisms can be increased markedly by irradiating the organism

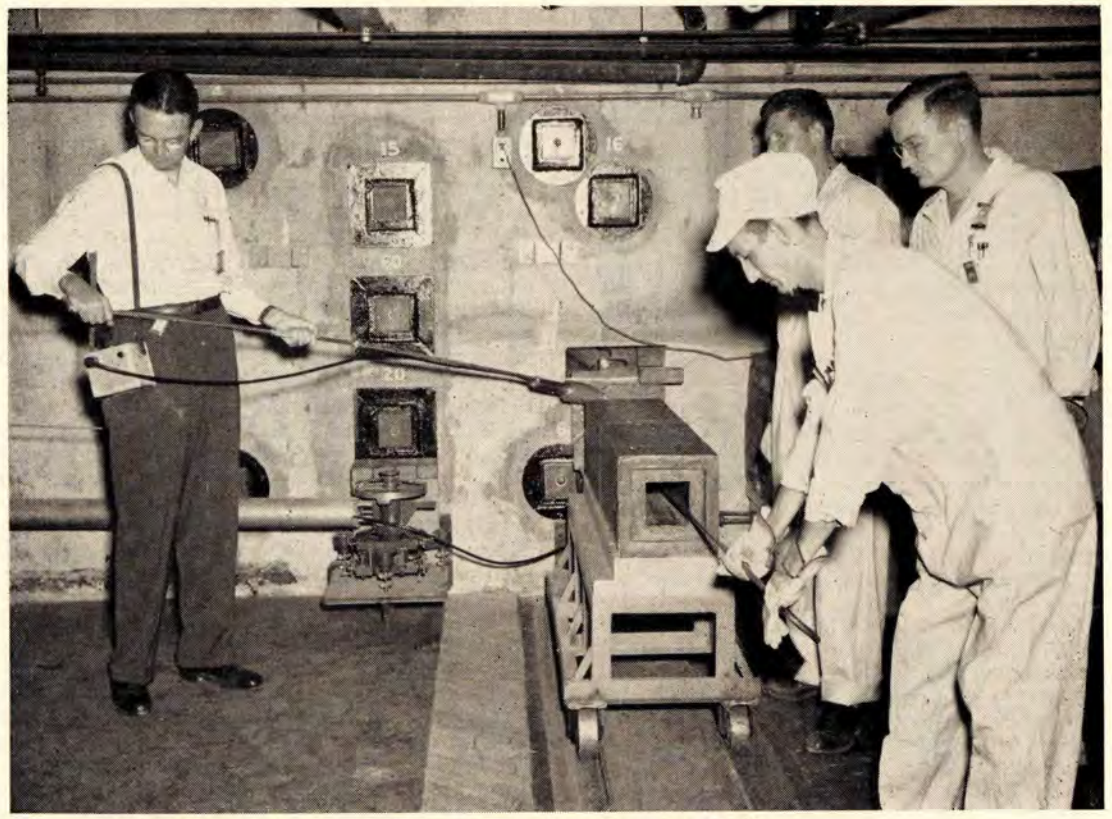
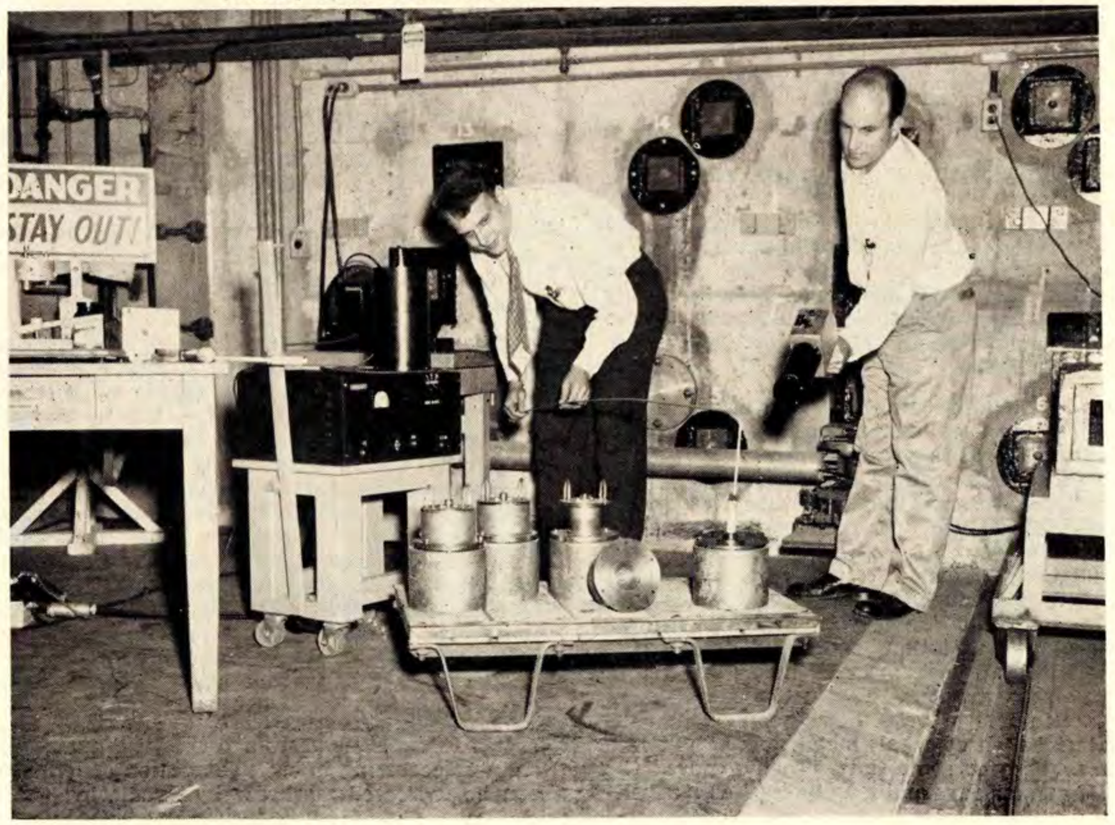


Figure 16. ABOVE: Pulling an isotope stringer from the atomic pile

Figure 17. BELOW: Putting a can of radioisotopes in a lead shipping container
(Courtesy United States Army)



with X-rays or gamma rays from radium. Since the radiations from these by-product materials have similar effect, it is logical that study of this phenomenon should be emphasized now that the radioactive materials are readily available and their use is widespread. Also, a part of the overall defense program in an atomic age is to know all that can be known about the effects of penetrating radiation on living matter in order to reduce as much as possible any harmful effects. Since the life cycle of smaller organisms and plants is so much shorter than that of large animals and man, most of these studies are done on plants (corn is a frequent choice) or insects. **Drosophila melanogaster,** the tiny fruit fly, is famous in the scientific world for its use in increasing knowledge of the laws of genetics and the frequency of genetic change which has resulted from its use in experiments of this kind.

Most of the genetic changes or mutations which are induced by radiation are not beneficial to the organism, so there is small hope that improved strains of corn or hogs will be produced directly as a result of the use of radiation. However, an increase in our knowledge of the rate of change and the character of mutations will in the long run lead to advancement in our techniques of production of hybrid plants and livestock that could make our present methods look primitive.

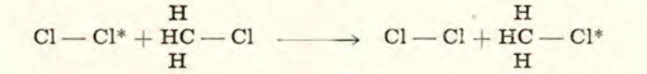
ISOTOPES AS TRACERS IN CHEMISTRY

Of greater interest in the fields of chemistry, metallurgy and the various branches of biology, are the studies in which the amount of radioactive material is too small to affect the system and its normal behavior can be studied using tracers.

In chemistry, tracers have been used to determine the course of reactions and their mechanisms. A particular type of process which cannot be studied without tracers is the exchange of the same kind of atoms between various forms. Examples of this exchange process are such reactions as

$$\mathrm{Cl - Cl^* + Cl^- \longrightarrow Cl - Cl + Cl^{*-}}$$

in which the * designates the radioactive chlorine atoms. $\mathrm{Cl - Cl}$ is chlorine (as chlorine gas) and the $\mathrm{Cl^-}$ is the chloride ion, the form of chloride found in ordinary salt, sodium chloride. The above process takes place very rapidly in water solution. The process below does not take place at an appreciable rate.



$$\mathrm{Cl - Cl^* + H\overset{H}{\underset{H}{C}} - Cl \longrightarrow Cl - Cl + H\overset{H}{\underset{H}{C}} - Cl^*}$$

In this case the chlorine in the compound is bound tightly to a carbon atom. If such exchange takes place, it indicates that the chlorine is held by a bond from which it can break loose, while a lack of exchange shows that it cannot and is thus held by a more permanent bond. Information about the type of bond can thus be obtained by these tracer experiments. Other chemical applications exist in the use of tracers to determine the presence of extremely small amounts of elements in solutions of very slightly soluble substances. Many materials which are ordinarily considered insoluble are actually soluble but the amount dissolved cannot be detected by ordinary means. Tracers in some cases provide a method for determining these small amounts that is more sensitive than any other. The behavior at the surfaces of solids in liquids or gases, the distribution of substances between insoluble liquids like oil and water, are topics in which our knowledge is being increased by the application of tracers.

In the field of metallurgy we are interested in the nature of materials and their behavior at high temperatures. Under such conditions materials behave somewhat differently than they do at ordinary temperatures. For example, if a metal which melts at a high temperature is heated not quite hot enough to melt it, we find that the atoms do not stay in one place but migrate slowly through the other atoms or "diffuse." With radioactive tracers we are now able to determine the rate of this diffusion of a metal in itself and since the method is so sensitive, the process can be observed even if it is very slow. The chemical reactions which produce our steel, aluminum and other metals are also being studied using tracers to follow the course of some material through the various steps.

ISOTOPES AS TRACERS IN BIOLOGY

It is in the field of biology that most of the research using tracers is being done. This is so because the biological problems are so complex that a new tool like tracers fills a definite need here more than in any other field.

One of the simplest kinds of experiments, in principle at least, is determining the location of a particular element or compound in a plant or animal. In many cases this can be done with a highly pictorial technique known as radioautography. Using this technique a plant, for example, takes its own picture with the radiations that it emits because it has taken up radioactive material. Thus a tomato plant fed phosphorus-32 as a part of phosphate fertilizer grew the leaf which when laid on a photographic film for 12 hours exposed the picture shown in Figure 18. In this picture the outline of the leaf and the location of the phosphorus within it can easily be seen. This same technique can be carried into microscopic studies and radioactive material can be located even within a single cell as shown in Figure 19. Here we see both the cellular structure of the thyroid gland of an animal and small black dots due to radiation from iodine-131 which was taken up by the gland while it was in the animal.

One of the most important of the problems in which research is being pushed is the general subject of enzyme controlled processes. This covers a tremendous area extending into zoology, physiology, bacteriology, botany and other fields. One of the most important of these processes is photosynthesis, the sunlight-induced reaction which is the primary producer of all our food. This is a very complicated process whereby energy from the sun is stored as chemical energy in carbohydrates. It takes place by means of a series of chemical reactions in which the simple compounds, carbon dioxide and water, are converted into the complex carbohydrates plus oxygen. The nature of the steps in this process has been a deep dark mystery though it has been studied by many brilliant scientists. With the advent of the tracer technique considerable progress has been made toward an understanding of these steps and the behavior of the carbon, particularly, through photosynthesis.

Other enzymic reactions are those in which the carbohydrates are in turn converted into fats and proteins in the plant and animal body. Then other enzymes control the storage of the food substances in the body and their break down or metabolism by reactions in which the reverse of photosynthesis takes place—they are caused to react with oxygen yielding carbon dioxide and water. Diseases, for instance diabetes, may result when these reactions do not occur properly and it is the hope

Figure 18. Radioautograph of Tomato Leaf Containing Radioactive Phosphorus.

of being able to alleviate such diseases that is one of the stimuli of the physiological chemist.

Another example could be drawn from the nutritional behavior of proteins. These complex and extremely large molecules are made up of small units, known as amino acids. The animal body is able to manufacture or synthesize some of these amino acids from other food stuffs, but others must be present in its food. The behavior in the body of those amino acids which are essential to the diet is again a problem of considerable biochemical interest.

One of the great drawbacks to research with complicated substances is that the radioactive material (most frequently carbon-14) must be put into the complex molecule before the behavior of the latter can be studied. This is in many cases a major research problem in itself and it has been a deterrent to work of this sort. Progress is being made, however, and many biologically important tagged compounds can be bought, at a price which seems rather high except that the alternative, synthesizing them yourself, could be even more expensive. Another procedure which is being used is to grow plants or organisms in an atmosphere of radioactive CO_2. The various substances in the plant will then contain radioactive carbon. Isolation of these substances can be done using standard methods. If a plant which is the source of a medicinal drug is so grown, the drug which can be separated will be tagged and its behavior in an animal can be studied. Biological methods of tagging have been used for more complex systems as well. Red blood corpuscles have been tagged with radioactive iron or phosphorus and their subsequent behavior in the body has been studied. Even mosquitoes have been tagged in order to follow the distance of their migration from an original starting point.

ISOTOPES AS TRACERS IN AGRICULTURE

The examples above are a part of more or less pure or fundamental science, but there are also applications to the part of science that deals with direct improvement of our daily living, in other words with applied science. As an example of this applications to agriculture might be cited. One of the largest scale programs is one which has been and is being sponsored by the United States Department of Agriculture in collaboration with many of the state experiment stations, including the Agricultural Experiment Station at Ames. In this program the uptake of phosphate fertilizer by various crops under a variety of conditions is being investigated. A large part of the phosphate fertilizer added yearly to the soil by the farmers of America is essentially lost, since it does not appear in the crop. Consequently, it is of great importance to know in what form such fertilizer should be applied and how and when it should be added to the soil for each crop and in each of the multitudinous varieties of soil which occur in this country. This research program has set out to obtain this information. Phosphate from the fertilizer is made distinguishable from phosphate from the soil by making the former radioactive. It is then a simple matter to determine under a given set of conditions what fraction of the phosphate in the grown plant came from the fertilizer and what from the soil. Hence the conditions giving the best return can be chosen and used by the farmers.

Other soil research using phosphate and other fertilizer components is also being done with the intent of determining what chemical reactions fix fertilizer in soil and in some cases render it unavailable to the plant. Such topics as the exchange of potassium and calcium between the soil particles and solution might be mentioned.

This discussion should not be concluded without saying something about obtaining radioisotopes. The Atomic Energy Commission through its Isotopes Division makes these available at almost nominal cost to qualified research agencies. In fact, for research on the problem of cancer, the only charge is that for handling and shipping.

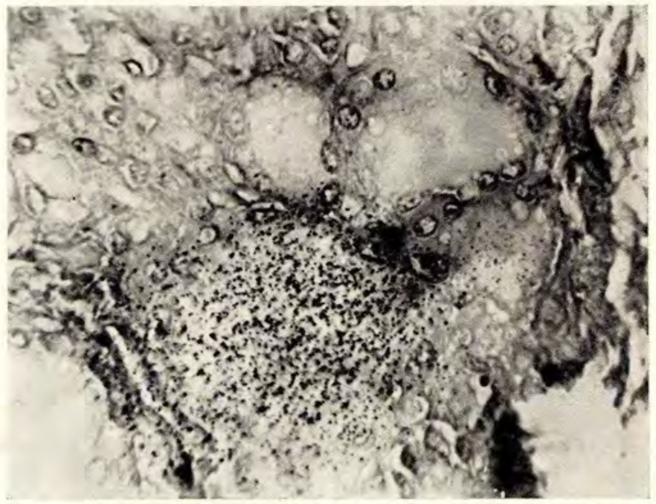


Figure 19. Photomicrograph of a Tissue Section—Radioautograph Preparation: Thyroid tissue containing radioactive iodine was mounted on a photographic plate. After exposure, the photographic image was developed and the tissue was stained. This combination was enlarged by photomicrography for this picture. (x350).

However, before he can obtain radioactive material from the AEC, either directly or through any firm or institution which itself obtained the isotopes from the AEC, the applicant must show training and capability in handling the material. He must have adequate instruments for making the measurements and for monitoring the radiation levels as he is working. He must also legally accept the responsibility for the material and its handling and guarantee that it will be used with complete safety to himself, his co-workers and his community. It is obvious that to do this a person must be connected with an institution which has a reasonable budget for research.

NOTES

CHAPTER VI

SOCIAL TRENDS AND ATOMIC ENERGY*

TECHNOLOGY AND SOCIAL CHANGE

It is obvious that society as a complex of social relationships never stands still; it is in a perennial state of flux. The alterations in the nature, content, and structure of social groups and institutions, and in the relationships among men, groups, and institutions, during a sequence of time is called social change.

Social change must be thought of as a continuous process. This does not mean that the rate of social change is always the same. There were periods in which social change appears to have been quite slow. In contrast to geological or biological change, however, social transformations often occur with amazing celerity.

There are many theories which attempt to explain the causes of social change. Since the 17th century, however, no factor has loomed as potent in creating social change as the advancement in science and technology. Technological innovations have invoked revolutionary changes in man's mode of life.

One of the most significant technological inventions of recent times—an invention without the accompanying development of social controls— is, of course, the discovery of atomic energy. Let us think of the social implications of atomic energy in two frameworks; that is, in terms of war or the threat of war, and secondly in terms of peace.

It is quite obvious even to those who have not given too much thought to the problem that the atomic bomb has increased the destructive power of man tremendously. But the atomic bomb should not be thought of as the basic cause, but only as a symptom of the crises which confront civilization today. The crux of the world crises lies in the accelerated growth of destructive weapons without the simultaneous growth of social institutions capable of controlling the use of this destructive power. This acceleration in the power to kill and devastate is part of the general rapid growth of technological and material culture. Now let us turn to the social implications of technological advancement which include the advancement of atomic energy within the framework of the threat of war.

SOCIAL IMPLICATIONS OF ATOMIC ENERGY IN A WORLD AT WAR

The first implication will be the continuation of a trend that is already going on—that is, a greater and greater restriction on the diffusion of scientific knowledge between countries and even within countries, in the fear that vital secrets of war may be revealed. If it is true, and we have tremendous evidence that it is, that the life blood of culture growth among any people depends on the free passage, communication and exchange of ideas and things among these people, then it follows that at least one source of this growth will disappear. One need but ponder the diversity of the cultural origin that made even the atomic bomb possible—Einstein, Fermi, Curie, Urey, Chadwick, Niels Bohr, Oppenheimer and many others—to understand the significance of this point.

Secondly, there is always a tendency in a country preparing for war or to meet war, to concentrate on those applied aspects of science conducive to the efficient participation in war. This is frequently accompanied by a neglect of those fertile and at the moment unusable fields of investigation that might be classed as science for science's sake which calls for absolutely free inquiry; that constitutes that kind of intellectual activity which may not have any forseeable application but without which, paradoxically enough, applied technology is well nigh impossible. Note the improbability of an atomic bomb without an Einstein theory; aviation without a theory of gravity; and so on. Many people believe that it would only have been a matter of years for Germany under Hitler to dry up at the scientific source because her entire concentration was on applied science which it would tend to be in a warring military culture. As the poet puts it: "It is much less what we do than what we think, which fits us for the future." Or as some of you have frequently heard:

> "Back of the beating hammer
> By which the steel is wrought,
> Back of the workshop's clamor
> The seeker may find the thought."

The increase in centralization of national governmental power in a world preparing for war and with the threat of atomic bomb attacks is very likely. This is a trend that has been going on for some time but it received tremendous impetus during the last war and has grown bigger and more embracing than ever. Witness for example the number of controls set up in the last months by the federal government with comparatively little objection from any source. Two decades ago it would undoubtedly have aroused much greater public opposition.

These may be necessary steps to meet the social, economic, and defense problems of a technological civilization. It may be rather difficult to reverse this trend of administrative centralization of federal power until the use of the atomic bomb in warfare is outlawed. It is now quite evident that preparation for war is quite like war itself in the expansion of the functions of government and the encroachment on individual liberties which seems to be a necessity in a nation engaged in warfare.

One further trend that some writers, like W. F. Ogburn, forsee in the threat of war in an atomic age is the necessity for the decentralization of our large cities. This is a tremendous task. It has been estimated that the monetary cost would be close to 300 billion dollars if all cities were reduced to a population of 50,000. There are 200 cities with a population greater than 50,000 in the United States. The problem of who was to move and to where would be difficult. It is probable if this ever became necessary that factories with their workers and workers' families would be moved out first and those engaged in servicing the workers would follow afterwards.

There would be a tremendous change in the military manpower needs with a consequent effect on many social institutions. Marriages might be delayed or hastened; education on the college level would be much affected and vocational choices of young men and women might be directed into those areas where manpower was needed to further defense effort.

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*Prepared by Joseph B. Gittler, Iowa State College

SOCIAL IMPLICATIONS OF ATOMIC ENERGY IN A WORLD AT PEACE

Now, let us suppose that the threat of war was removed. What changes or trends may we then expect in our society as a result of the discovery of atomic energy? Once again we would find that the specific social trends already existent would be given further impetus since many of these trends are a result of technological and scientific knowledge.

If atomic science contributes to medicine and to the cures of various diseases—and it appears that it will—interesting effects on population trends may be expected.

The United States which contains between 6 and 7 per cent of the world's population shows some interesting growth trends. While our population has shown a numerical growth from decade to decade, since 1860, every decade has shown a smaller increase than the preceding one. The cessation of European immigration to the U. S. after World War I helped contribute to a sharp decline in the **rate** of growth. In addition to immigration, population grows by the factor of natural increase. This consists of excess births over deaths during a given period American birth rates still exceed death rates so that the American population will continue to grow. If medicine through atomic science will lower the death rate still further and if the birth rate does not decline correspondingly, we can expect a continuation of the trend of growing population.

In addition to the trend of population growth, the bulk of Americans are, on the average, getting to be an older people. The proportion of older persons in our population is much greater than it was years ago. In 1850, 5 per cent of the population in the U. S. was over 60 years of age; in 1940 the figure reached 10 per cent. One estimate places the proportion over 60 by 1980 at 20 per cent, or 4 times the 1850 figure.

This change may be said to be due largely to two factors. First, the curtailment of immigrants to the U. S. caused fewer persons in the younger age category since the bulk of the immigrants were in this age category. Secondly, the average expectancy of life has increased. Whereas the expectancy of life at birth for males was only 35 years at the close of the Revolutionary War, it was 55 years in 1920, 59 years in 1930, 63 years in 1940, and about 67 years today. The expectancy of life of females follows the same course, except that females live 2 or 3 years longer. If atomic science aids in the prolongation of life we can surely expect an ever larger proportion of our population to be of older age.

The implications of an aging population are numerous. It certainly affects our economic institutions. On the whole businesses that serve older people will be increased. A great proportion of our population will be in need of financial help. Recreation and leisure time activities will probably adjust to the older age pattern. Adult education will be given much impetus. To the degree that there is a correlation between age and conservatism, the U. S. will tend to be more conservative.

Technology and cheap power have greatly increased mobility and communication between peoples. The availability and use of cheap atomic power would greatly reenforce this trend. An interesting point might be called to your attention in this connection. Many people have long held that with this greater contact and communication there would inevitably come greater understanding which would usher in a peaceful and prosperous world based on shared values and goals. It has been argued that people would grow more like each other when their cultures were diffused through the medium of new technological developments. Unfortunately, this point of view can no longer be held with sanguinity. There is much evidence to show that these new inventions have not led to greater homogeneity among the peoples of the world (except perhaps in a few instances of material culture) nor have they led to any noticeable abatement of misunderstandings, hatreds, and antagonisms. Then, too, we frequently find that greater contact among peoples may widen the area of possible conflicts which did not arise when the contact was negligible. Without modern military weapons, and modern transportation, it would be questionable whether we in the United States would be so perturbed about the problems of Asia and Eastern Europe. Frequency and intimacy of contacts can become the basis of conflict as well as harmony. It becomes a crucial problem for social science to determine the precise circumstances that lead to the one or the other.

If atomic science should lead to mobile power machinery, interesting trends may develop in the furthering of the urban trend. It is trite to refer to the trend of urbanization and suburbanization in the U. S. The urban trend is real and unceasing. Urbanization, however, cannot be limited to actual residence in cities. If habits, dress, political thinking and commercialized recreation are significant, urbanization is spreading to resident rural people at a very rapid pace. Styles in **Vogue** do not differ too greatly from those in the Montgomery Ward catalogue. The general urban trend has led to interesting theories about the responsibility in the formation of a unique type of person resulting from the more rapid tempo, the greater density of population, the anonymity of its social relations, the greater mobility of its people, its specialization, and its commercialized living.

American farming has always been, on the whole, highly mechanized. This mechanization has gone forward steadily. Atomic energy should reenforce this trend. The increase in the use of the machine on the farm, as well as the advent, in general, of new technologies such as radio, television, and the motion picture has truly broken down the barrier of isolation in rural life. Consolidated schools have replaced the one-room school house; the town church has grown at the expense of the open-country church; farmers' organizations have made inroads into the heretofore almost complete individualism of the farmer. It is likely that we shall see more of these trends in the rural areas.

These are some of the major social trends that are obviously connected with technology and so with atomic technology. I have tried to give you some picture of the nature of social change; what makes for social change; the role of technology in social change; the role of atomic technology in a society preparing for war, and some of the implications of atomic technology for a society at peace.

THE LAG BETWEEN TECHNOLOGY AND SOCIAL SCIENCE

I have suggested also that one of the most crucial problems of the atomic age consists of the lag in our culture between the velocity of inventions of destruction and the slowness of social inventions for the control of these instruments of destruction. As a result, a multitude of nostrums and schools of thought are seeking to solve this dilemma. Sometimes this problem has led to an extreme skepticism, fatalism, and hopelessness about man's ability to cope with the atomic crises. In other quarters it has led to an attack on what is frequently called **scientism.** This argument is based on a hatred for science; it sees it as a diabolical evil of mysterious origin that has befallen mankind. It is, I think, needless to point out that the greatness and the limitations of science are inseparable. It is the greatness of modern science that it recognizes its own limitations. We cannot ask of science that which it is incapable of giving.

That modern science, like all things, contains its own share of corruption; that men of science only too often fail to live up to their own standards; that science can be used for violent and criminal ends; that man will plunder, abuse and kill—all this is no argument against science. Science does not give us the aims and value systems of human relations. We must look elsewhere for these.

Our hope must lie in the social sciences which only too slowly are trying to throw light upon man's crucial problems in dealing with man. Philosophy and religion, making use of the knowledge of the sciences, both natural and social, may provide some more forceful dynamic in helping man to bridge the gap between the great potential usefulness of atomic power and the abyss of destruction that lies within it. Certain it is that what men have been able to create, men ought to be able to control.

NOTES

CHAPTER VII

GOVERNMENT IN THE ATOMIC AGE*

It has been said that government is merely the legalizing, codifying and regulating of customs already established; the law always follows the social fact. If this were true of modern society, as it possibly is of primitive societies, there need be no fear for the continued stability of democratic institutions in the atomic age. The peoples would accommodate their way of life to the new force, as they have to telephones and railroads, and the laws would ultimately reflect the state of accommodation. The wishes and the established procedures of the peoples would have dictated the nature of the laws.

It has also been said, notably by Dr. Samuel Johnson, that all peoples ultimately have the sort of government they want; if a significant number of people really desire change, then change will inevitably occur. It has been argued, with plausible historical support, that the fascist government of Italy, the Nazi government of Germany, the communist governments of Russia and China attained power with the sanction of their peoples, not because they were elected in the American manner but because inadequate popular support was given to opposing forces. At the level of common conversation this was the remark, less frequent today, that the Russian government suited the Russians, the Nazi government the Germans, and that neither was of any concern of, or constituted any threat to, the institutions of free peoples.

The contemporary status of television offers a good example of both theories of government. The movement of popular demand from radio and movies to television is faster than the provision of channels by the Federal Communications Commission. But this does not constitute a dictation by government to the people; it is a problem of electronics and of economic justice. The channels will be provided as quickly as possible and the governmental regulations will follow the social fact of public demand. This was the first principle explained above. In the United States, nation-wide access to television will be achieved by assigning channels to privately-owned stations and corporations which will produce their own programs. In England it will be achieved through the British Broadcasting Commission, a public agency which will both control the channels and produce the programs. In neither country will there be any significant demand for a change in the system of control. This was the second principle.

POPULAR FALLACIES

How applicable are these comfortable and widely held theories of government in the atomic age? Is there a danger in accepting them today without most careful examination?

The disparity between the speed of technological inventiveness and that of social inventiveness (which should devise adequate controls for the forces released by technology) has been presented in the previous chapter. It is now said that atomic energy, precisely because it is so disproportionately more powerful than all preceding forces used by man, will increase this disparity so rapidly as to be beyond the control of the slow machinery of democracy. It is as though mankind moved from the horse and buggy to the one hundred eighty horsepower automobile in, say, one day. Such a revolution in transportation would create a traffic problem so great that immediate, centralized and absolute control of all highways would seem to be an inescapable necessity. The philosopher Thomas Hobbes, whose 17th century English homeland was in a state of civil war, argued that free people would ultimately contract with each other to create a dictatorial government merely because such would insure that man could live safely along side man. Were he alive today, Hobbes might seriously advance the apparently fantastic suggestion that for the sake of physical safety free Americans must contract to abolish Congress and vest all governmental authority in the Chairman of the Atomic Energy Commission!

But there is another side to this coin! Against this extreme or alarmist view, it may be argued that in America our increasing awareness of the problem and the growing volume of research in the social sciences is an adequate safeguard. It can certainly be pointed out that the American system of government was sufficiently flexible to design legislation for the control of the new forces within two years of their first public appearance in the shape of an atom bomb. So long as a freely elected government is able to design legislation suitable to the technological facts of our age, it may be believed that democratic institutions are operating to express the will of the people and that individual freedom is in no danger from government.

Between elections, however, it sometimes becomes necessary to make laws for the control of some technological factor which may not have been in existence at the time of the election, and which has not yet found its place in the habitual life of the people. Thus a government, which is theoretically elected to carry out the public will, may be obligated to educate its constituents to the support of legislation resulting from technological necessities. In a technological age, government of the people, for the people, and by the people's representatives may sometimes prove remote from the grass roots democracy which is our tradition.

It should be carefully noted that such actions are usually taken of necessity. When modern science makes it possible to rain high explosives from the air on American soil, it may be necessary to declare war on the enemy without waiting to consult the people. But a series of such crises may result in a series of such actions and possibly in the complete stagnation of effective democratic government. The latter was the case in Italy and Germany. Both nations were unable to maintain, through constitutional procedures, a satisfactory control over technologies hopelessly strained by modern mechanized war. When the King of Italy telephoned for Mussolini, when President Hindenburg sent for Hitler, their actions were constitutional and were taken at the advice of a great

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*Prepared by Hew Roberts, State University of Iowa

Editor's Note: A number of the issues presented in this chapter are controversial. Though the examples are often hypothetical the problems are real. It is not the intent of the Production Committee to promote any particular side of these issues. The object of this chapter is to involve students, with the guidance of their instructors, in discussions typical of those that have already reached the public since the passing of the Atomic Energy Act. It is not expected or desired that students give blanket acceptance to any given point of view.

many earnest and honest citizens who believed that the only solution of the continuing crisis lay in the concentrating of power in the hands of one person who appeared to have answers and the capacity to achieve them.

Thus it would appear that the popular statements with which this chapter opens and which appear to hold true for technological advances such as television, are of very doubtful validity in the Atomic Age. Free elections do not guarantee that government by the people will be a reality and governmental action is certainly no longer merely the legalizing and the codifying of public actions already sanctioned by custom. Nor is there any guarantee that peoples will always have the governments they want or deserve.

It seems important, therefore, to consider the governmental machinery we have as the result of the discovery of atomic energy and whether that machinery can work toward the preservation of democracy in this new technological era. In the field of atomic endeavor, there are already certain limitations upon freedom of choice of employment and of the conditions of employment. With respect to atomic operations there are restrictions upon the investment of free capital and the function of private enterprise. Limitations on freedom of speech and publication, and therefore even of thought, are not inconceivable.

Yet in theory the entire atomic energy enterprise is public. Speaking at Bowdoin College in 1949, Mr. Sumner T. Pike of the Atomic Energy Commission referred to the Atomic Energy Act in these words: "This act indeed is an experiment in government. It puts the citizens of the United States, through their government, in complete charge and ownership of one of the most complex, diverse, exciting and difficult enterprises which the world has ever seen."

In what ways does the citizen direct this experiment in government? In effect, the Atomic Energy Act which was signed by President Truman on August 1, 1946, nationalized the control of atomic energy. The vexing questions which have since caused some dissatisfaction are concerned with the relative efficiency of government and private enterprise; with whether nationalization actually does result in popular control; and with the possibility that those factors which insure at least some public control may prove actually damaging to the operation of the enterprise.

THE ATOMIC ENERGY ACT

A great deal of study, thinking and debate went into the Atomic Energy Act. In October, 1945, a special committee of 11 senators commenced "to make a full, complete and continuing study and investigation with respect to problems relating to the development, use and control of atomic energy." The principles resulting from their deliberations seem at times contradictory.

The recommendation that the enterprise should be a national one was based first on the need for an effective security program. Apart from the military significance of atomic weapons and the need for secrecy in their development, it was felt that the dangerous materials used in atomic energy and the facilities for their manufacture must be under strict governmental control. Second, the initial expenditures, without hope of immediate profit, were seen to be so great that only the government could afford the capital outlay. Third, it was recommended that scientific research be stimulated and encouraged but above all that it remain essentially free. Fourth, with the full potential of the new power only partially explored, it seemed proper that this power should be held in trust for the whole people. Thus the government was enjoined to nationalize atomic operations (because security is absolutely necessary) and, at the same time, to preserve and stimulate free research. In a nation whose citizens had benefited from the exploitation of steam, oil and electricity by private enterprise, atomic energy was to be exploited by government as a trust for the people. In a nation skeptical about governmental enterprise and critical of nationalization in foreign powers, an enormous industrial undertaking was set up as a nationalized monopoly.

When we turn to the provisions of the Act, we find a good example of the political genius of the American people in compromising between apparent contradictions. It is a typical system of checks and balances. It creates a five man Atomic Energy Commission appointed by the President but subject to the approval of the Senate. The members are all civilians and devote their entire time to problems of the development of atomic energy. Public ownership is guaranteed by a governmental monopoly of atomic inventions, patents, facilities and raw materials used to produce atomic energy. In addition to the commissioners, the General Manager, who is the chief executive officer, is also appointed by the President subject to approval of the Senate. Thus, through appointments made by their elected president and confirmed by their elected representatives, the public has theoretical control over the policies and management of its enterprise.

Not only has the public a theoretical control over the personnel which head its enterprise, but also provision is made for a Congressional watchdog on the activities of these people, a shareholders' committee, as it were, to watch the board of management. This is the Joint Congressional Committee on Atomic Energy, composed of nine members of the Senate and nine of the House of Representatives. It is also stipulated that not more than five members from either house shall be of any one party. The Atomic Energy Commission is obliged by the Act to keep the Joint Congressional Committee fully and currently informed of its activities. The Committee has its own staff which has complete access to the Commission's offices and to the operating plants throughout the nation. The Committee is enjoined to make continuing studies of the activities of the Commission and to report from time to time to the Senate and the House by bill or otherwise its recommendations with respect to matters within its jurisdiction. Let us mark well that last phrase: **within its jurisdiction.**

The next problem was to insure that this public corporation had access to the best brains of the nation just as any private corporation seeks to obtain the services of the most skilled or learned people, not necessarily by employing them full time. The act therefore created a General Advisory Committee consisting of nine members appointed by the President for six year terms. The personnel of the Committee is distinguished and varied. It is drawn from academic institutions such as Harvard University, from specialized institutes such as that for advanced study at Princeton, and from private enterprise in fields of engineering and electronics such as the United Fruit Company and the Bell Telephone Laboratories. This Committee meets as a whole, bi-monthly, but individual members and sub-committees are in constant contact with both administrative and field problems faced by the Commission.

With the public assured of control over its enterprise and access to the most skilled advice, there remained the problem of national defense. In a disunited world

wherein other nations have developed atomic weapons, it is obvious that military applications of atomic energy are of vital importance. To the student who reflects for a moment on the complexity of modern war, it will also be obvious that military applications of atomic energy cannot be studied in isolation from high strategy, tactics, logistics and other matters that are the proper concern of the Department of Defense and the fighting forces. To insure such continuous cooperation, the Military Liaison Committee was established. This very important committee has, in the American tradition, a civilian chairman appointed by the President with the advice and consent of the Senate. It is otherwise composed of representatives of the Departments of Army, Navy and Air Force designated by the respective secretaries of those Departments. It has its offices in the headquarters of the Atomic Energy Commission and is in constant contact with the Commission staff on "all atomic energy matters which the Committee deems to relate to military applications, including the development, manufacture, use and storage of bombs, the allocation of fissionable material for military research, and the control of information relating to the manufacture or utilization of atomic weapons."* As the relations between Commission and Committee involve in some measure the defense of the United States, a provision was made for the settlement of a major dispute, should such occur. The Committee was empowered to refer the matter to the Secretary of Defense, who might in turn seek the final decision of the President. This provision also we should mark well. As will be seen in a hypothetical case to be considered later in this chapter, its use could result in an anomalous and probably unforeseen governmental impasse.

With legislation on the statute book so carefully designed to safeguard the public interest, it may be thought that the common man can safely forget all about his vast public enterprise and leave its entire operation to those immediately responsible under the Act. At least some members of the public, however, are directly involved in the enterprise, for practically all of atomic production and research is actually carried out by private or semi-private firms and organizations under contract with the Commission. Where and on what democratic principles is the line to be drawn between what is necessarily governmental and what is legitimately private enterprise? More than ninety per cent of those employed in atomic energy projects are not employees of the Commission or of any government agency. Shall the same security provisions and loyalty checks apply to the scientist employee in General Electric Corporation's contractual work in atomic energy as apply to the stenographer in the AEC Offices at Oak Ridge? Here are further deep problems of principle, administration and common living which must give us pause.

THE ATOMIC ENERGY ACT AT WORK

The college student may realize the complexity of these problems by considering only the one which is nearest to him, the question of free research. One of the four statutory divisions of the Atomic Energy Commission is responsible for physical research and one for biological and medical research. A great deal of this research is carried on by colleges. In accordance with the recommendations of the 11 senators who first designed the framework within which the Atomic Energy Act was conceived, this research is carried on with an amazing amount of freedom.

Many college personnel do research which is of potential interest to the Atomic Energy Commission. The research projects may be roughly classified into three groups. First would be what we may call "free" research in which the scientist simply pursues his own interest in his own way under no obligation to anyone save the college which employs him and to the high ethical standards of scientists. Second is contractual research in which a department or college may receive financial assistance from the Atomic Energy Commission to carry on, in the college laboratories, research of interest to both the college and the Commission. A local example of the latter may be found in the Medical Laboratories of the State University of Iowa. The third type is also contractual but is usually referred to as programmatic*. In this case a college which already carries on the other two types of research may contract with the Atomic Energy Commission to do certain specific research which the Commission wants done and which may extend beyond the usual college program. If large sums of money are involved in this type of research, some of it may be expended to acquire facilities without which it would be impossible to carry out the programmatic research. A local example of the latter is the Ames Laboratory of the Atomic Energy Commission at Iowa State College.

Some scientists work exclusively in programmatic research. Many more work in two or three of the types simultaneously. A few, who at one time worked exclusively on government projects, have returned to the so-called free research because they are more interested in projects that lie outside the scope of the government's program and that may require a far freer time schedule; or because they have a college man's desire to teach and to help train the scientists of the future. And there are some scientists who have ethical or moral reasons for not wishing to be connected with research basic to a military program.

It will be seen that this program of research is consistent with the views of the eleven senators who laid down the principles under which the Atomic Energy Act was designed. These principles insure that research in military problems can be conducted with efficiency and security under a system that at the same time encourages the maximum of free research. Whichever type of research a college engages in, it is necessarily subject to certain restrictions, real and imaginary. The men doing the research must be competent. College men, of course, are not employed by the commission but by their respective colleges. The equipment provided must meet the Commission's requirements for the safety of those working with radioactive materials. This equipment is again the property of the college and is installed by it. Thus the college is "free" in its choice of personnel, equipment, and research projects but must meet certain requirements of competence and safety which are just as necessary and advisable as traffic lights at an intersection. But because many of the materials which are used in atomic research are under the control of the Commission it may be seen as having an indirect jurisdiction over the personnel, equipment and research programs of the free institutions of learning. **The writer knows of no case where this indirect control has been exercised by the Commission.** This theoretical jurisdiction

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*__Major Activities in the Atomic Energy Program,__ January-June, 1952, United States Atomic Energy Commission, Washington, D. C., pp. 53-54.

*Programmatic research is research directed toward the solution of a specific problem, such as the development of an alloy which would be used as a structural part in a submarine reactor.

constitutes an imaginary restriction and the student may wonder why it is raised in this chapter. It is of the nature of democratic freedom that imaginary restrictions sometimes become real issues of government. The running controversy over federal aid to education is a very pertinent example. Even the opinions of people not engaged in research or professionally connected with education may become forces in the shaping of governmental policy when such issues are considered.

Let us take a hypothetical example. Suppose that the present successful policy of the Atomic Energy Commission should be considered hazardous to national welfare because one or two of the thousands of scientists involved in atomic research were found to hold subversive political opinions. Assume that this fear, aired in press, radio and the usual letters to congressmen, should result in a recommendation to Congress by the Joint Congressional Committee that all scientific research be done only in laboratories directly controlled by the Commission. Several things of vital concern to college students and faculty could result. The program of college research could be closed out completely. This would commit the nation to vast capital expenditure to duplicate all the laboratories and equipment that at present exist on college campuses. It would also slow down the rate of productive research because it would exclude many brilliant scientists who do not happen to be connected with programmatic research and who would automatically lose access to the financial support and materials they need. Some of these men might have to be drafted in some way or another, as they usually are in dictatorships. Alternatively only those colleges engaged in programmatic research would be allowed to work in the field of atomic energy. Apart from research, this would be detrimental to the teaching program of the far greater number of colleges which have no programmatic research. Interference with the teaching program might eventually result in an insufficient number of trained scientists to carry on the required research.

Still another possibility is the extension of governmental security regulations, oaths or supervision to apply to scientists and students engaged of their own choice in nuclear research in independent laboratories and colleges. If such occurred, it might create an invidious distinction between scientists engaged in nuclear research and scientists engaged on other projects, both groups being members of the same department or college. It would certainly seem to create a distinction between the scientist and the non-scientist for whom no such special regulations would exist. Even where no person suffers any actual disability, such distinctions may create tensions. They involve rights and traditions such as the undefined but strong tradition called academic freedom. They involve individual interpretation of these rights and traditions. They may generate emotional reactions militating against dispassionate consideration of the relationship of individual to government in work of national importance—another illustration of the imaginary restriction becoming a real problem in a democratic nation which respects the individual personality.

INTERNAL FRICTIONS

Before any of these results were felt at the college level there could have occurred at the governmental level a situation sufficiently obscure as to be unnoticed by the public, yet so involved as to expose a possible complete malfunction of our existing democratic machinery. Research policy being a matter for the Atomic Energy Commission, there would naturally be a dispute between it and the Joint Congressional Committee over any legislation the latter proposed in contradiction of the Commission's plans. The matter would probably be referred to the General Advisory Committee. If this Committee could not convince the Joint Congressional Committee of the danger that limiting research might limit progress and therefore our lead in an atomic weapons race, it could choose to take the issues out into public discussion, for its members are not government servants and can act as any other citizens may act when their conscience moves them to seek access to the public. At this stage, the Military Liaison Committee might feel that issues of security were involved, and refer the matter to the President through the Secretary of Defense. Despite all the checks and balances of our democratic machinery for controlling atomic energy, the "final" decision would thus be arbitrarily made. But in fact it may not be the final decision. Though the President would have ruled on what policy should operate **at the time of appeal to him**, he cannot limit the legislative sovereignty of Congress, any member of which could still initiate legislation which might ultimately be passed even over a Presidential veto. If the legislation were indeed unwise, the product of fear or misunderstanding, the proper democratic procedure of congressional legislative sovereignty would, ironically, have results detrimental to the national welfare. This is a hypothetical case but a real possibility. Something like it has occurred.

In a free democracy, the final arbiter of policy should be the people. Here the general thesis of the previous chapter can be concentrated in a concrete example which demonstrates clearly the potential weakness of popular government faced with problems of atomic technology. Radioactive isotopes for research purposes are exported to foreign nations by the Atomic Energy Commission as well as being made available to research agencies in America. In 1948 it was discovered that one of the nations receiving radioactive isotopes from Oak Ridge was Norway, which has a short common frontier with Russia. A voice of alarm was raised in Congress and for some time there was the threat of legislation to prevent the export of radioactive isotopes. A debate in Congress inevitably reaches the public through press and radio. The most common expression of public opinion, through the channel of letters to the press, appeared to favor the discontinuation of all exports from the atomic project. As the student who has read the scientific chapters in this volume knows, the debate was irrelevant and the alarm unnecessary, for the United States has no monopoly on the manufacture of radioactive isotopes, even on this continent, nor is an atomic pile necessary to their production. The electorate was apparently unaware of the scientific ingredients of the problem and therefore incapable of instructing its representatives. Were the latter capable of informing the electorate? Obviously, our representatives can hardly be expected to have quick and sure knowledge of all of the diversified problems with which they are constantly being faced. A member of the Commission thought **at the time** that there were perhaps few representatives whose educational experiences had prepared them to resolve this problem in which science and technics were a vital ingredient.

Thus a brief glance at that apparently most dispassionate of activities, pure scientific research, automatically involves the thoughtful student in major governmental and political problems. How much more aggravated might this become in connection with private enterprise other than college endeavour! Not only research but much

production is carried out by private concerns under contract with the Atomic Energy Commission; indeed, the Commission works entirely through contractors. As the major contracting party and in particular as the sole source of fissionable material, the Commission has even more potential control over private enterprise than it has over college research. This is because the interest of private enterprise in atomic energy is in industrial power which must use considerable quantities of fissionable materials while college research seldom involves any.*

Does this control by the Atomic Energy Commission over research with and production of fissionable materials slow down the efficiency of the total national effort? The former chairman of the Atomic Energy Commission, David Lilienthal, has stated that it does. Does it interfere with the traditional rights of private enterprise in America? Obviously it does. Can Congress or the public settle these issues? A distinguished educator thinks not. Observing this possibility of uninformed legislation, a member of the General Advisory Committee discussed in public the advisability of establishing a committee of scientists, engineers and informed laymen to which all proposed legislation concerning atomic energy should be automatically referred. Committees with advisory powers only are common in democratic government. The suggested committee, however, was to have something close to veto power!

This appears to be an example of how freedom might be lost in trying to save it. The proposal, rising exclusively out of the unequal development of physical and social science, bears an accidental resemblance to the actual practice of government in Soviet Russia. Russia has an elected Congress which is authorized to initiate legislation. It also has a central committee, the former Politburo, whose members are not publicly elected. This committee represents the present leaders of communist doctrine. All legislation proposed by the presidium of the elected Congress must be referred to the committee of thirteen which will judge of its appropriateness in terms of communist doctrine. It would be much the same if we were to oblige Congress to refer all legislation touching upon religion to the College of Cardinals or some other body of church governors. To Americans the suggestion is absurd. To Americans, however, the wisdom of all legislation pertaining to atomic energy is vital. Shall we have a committee of thirteen for atomic energy laws? The educator's suggestion was not acted upon and should perhaps not be taken seriously, though it was seriously offered. Meanwhile the problem remains. How shall it be resolved without limiting the sovereignty or restricting the debates of the sovereign legislative organ of United States government?

We are back in the original apparent conflict of principles laid down by the eleven senators who provided the framework within which the Atomic Energy Act was designed, the conflict between governmental control for security and the maximum of free research and effort necessary for progress. The relationship of this problem to the thesis of the previous chapter and the above illustrations can be best understood if we step outside ourselves and our national boundaries.

INTERNATIONAL FRICTIONS

Within America, the raw materials of atomic energy are legally owned by the Atomic Energy Commission. Originally, however, many of these materials do not belong to the Commission or to any other American agency but to the foreign nations from which we buy them. Our chief sources of uranium are Belgium (the Belgian Congo), Canada and Australia. All of these are small sovereign nations. Czechoslovakia, in whose boundaries lie the richest uranium mines of Europe, is also a small nation but is no longer sovereign. Independent states may sell uranium ore to whom they choose, but the Soviet satellite states may supply the Soviets alone. The uranium mines of Czechoslovakia were in large part the reason behind the allegedly altruistic desire of the Russians to "liberate" Czechoslovakia. This type of liberation is of course merely another name for imperialist conquest and monopoly of sources of raw materials.

To insure America's supply of uranium ores, the sovereign rights of the small nations that are rich in these ores must either be guaranteed by us or some other form of international control must be established. The League of Nations and the United Nations are both founded on the pre-atomic age conception of the free association of sovereign states. It will be seen that atomic technology has already created serious doubts about the success of international organizations founded on this philosophy.

Once again American political genius produced a plan for government at the international level which it was thought would really meet the scientific and technical facts of atomic energy. The proposal, commonly known as the Acheson-Lilienthal Report or simply as the Baruch Plan, was ultimately presented to the United Nations by Bernard Baruch in 1946. It is unnecessary for the student to know all its provisions but three of them illustrate the importance of taking the facts of technology into account when thinking about practical designs for effective government. The report proposed:

1. That there should be developed an international authority to serve as a world-wide inspection system, to operate the atomic energy plants of the world, and engage in world wide research.
2. That this authority should be given title to all uranium and thorium mines and should carry on all dangerous operations under an international monopoly, much as the Atomic Energy Commission of the United States has title to the nation's supply of fissionable materials and operates of its own authority the major plants for its primary products.
3. That fissionable materials which are properly "denatured", so that they would be useless for weapons but usable for power, should be leased by this international authority for the use of national authorities in any country, just as radioactive isotopes are now released by the Atomic Energy Commission to any competent research workers in hospitals.

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*The problem of college research in relation to governmental operations such as the atomic energy project has been discussed in this chapter because it is close to the environment the student knows best. Though a small problem in the national scene, it does contain the elements of larger problems that have been and may again be publicly discussed. Typical questions are: Should the atomic project be under military or civilian control? What moral issues are involved in the use of atomic weapons and what is the place of moral issues in national policy and strategy? Is international control possible or desirable; if so, what should be its nature and how can it be achieved? What problems are involved in the control and restriction of scientific information? Is it possible to delimit satisfactorily the functions of colleges, private industry and government in research and production? When atomic power is produced for commercial use, who shall own or control the means of production and distribution? Should democratic western nations cooperate in atomic energy research or preserve complete secrecy one from another? Discussion of such questions may help students appreciate more clearly the responsibilities of democratic citizenship in a technological age. Both science and social science instructors should assist students in preliminary reading and planning, for the purpose of the discussion is not to air opinions but to understand issues and the knowledge required for intelligent solution of them.

It will be seen that this proposal is truly revolutionary for it offers to transfer voluntarily an element of American sovereignty to an international body not exclusively controlled by American citizens. It is also truly in the American tradition by which the individual states resigned some of their sovereignty to the federal authority in return for the security thus guaranteed. Finally, it is truly in accordance with the actualities of the atomic age. If the sources of uranium were the sole property of a world organization, any nation seeking to "liberate" another for the sake of its uranium ore would be automatically engaging the world.

A counter proposal was offered by the Russians later in the same year. As eventually modified, the Russian plan accepted the idea of a world authority but did not give it title to uranium ore or to the ownership of atomic plants throughout the world and conceded it the right of inspection only once per month. We are not here concerned with the sincerity of the Russian proposal but only with its suitability as a form of government in the Atomic Age. The student who understands atomic science can see the weakness of the Russian plan at once. As the actual quantity of fissionable material required to make a bomb is physically small, nations whose plants were inspected only once a month could easily conceal quantities of fissionable products secretly used in preparations for war. This would be as true for the United States as for Russia; in fact, the Russian plan would leave the world pretty much as it is today. For neither Britain, Russia nor the United States, the three nations which have atomic weapons, knows the exact nature of the weapons of the other, or their quantity of stored material.

Russia's many distinguished scientists would understand the inadequacies of the Russian Plan, but they have no direct or indirect voice in government and certainly no appeal to public opinion. We might conclude that the Russian political leaders, if sincere, did not understand the physical forces about which they offered plans. The nature of a foreign government in the Atomic Age has therefore become a concern not only of its citizens but of ourselves. Nations may ultimately get the government they want or deserve, but do they get the government **we** want or deserve? One wonders what the learned and oracular Dr. Johnson would say today.*

EDUCATION AND GOVERNMENT

As we have seen, it is possible for our democratic political system to produce unsuitable legislation if the political leaders do not understand contemporary technology and if the electorate is incapable of intelligently advising with them on these matters. How are they to be informed and when? Michael Amrine, an eminent atomic energy educator, stated in a series of newspaper articles that President Truman was not briefed on the atomic bomb until three weeks after he took office. This is surprising if true, but consider the situation in any political campaign. The candidates have probably been briefed but little, if at all, on the latest atomic development, yet they may offer for public choice a wide range of policies concerning its control.

As the person constitutionally responsible for our foreign policy, the atomic age will confront each successive president with problems of international government or of bilateral national agreements whose clauses will involve an understanding of the nature of American security in the Atomic Age. Let us again take a concrete example. The press speculations concerning the British atomic weapon which was tested in great secrecy in the Indian Ocean were couched in the usual alarming language. The British weapon was "better"; it was "more powerful"; it was "the H-Bomb". These statements mean little except that there appeared to be differences between the British weapon and ours. If so, it would be expedient to know of the differences in order to judge of the effectiveness of either weapon. With this in mind, no less a person than General Omar Bradley has suggested that absolute secrecy even in the production of weapons may be detrimental to security in the long run.

As we have seen in a glance at the complicated nature of the relationship of college research to the Atomic Energy Commission, the problem of secrecy is not a simple one. It involves on the one hand adequate access to information for the development of atomic energy enterprises, both civil and military, and on the other an assurance that information of potential use to an enemy or possible enemy is subject to proper security measures.

This places an enormous responsibility on government. In any country, the first function of government is the protection of the nation. Protection involves the continual improvement of the means of defense and the preservation of secrecy concerning them. When the improvement of the means of defense is inseparable from the advancement of scientific knowledge, the ultimate security of the nation depends upon a balance between secrecy and scientific achievement. Decisions of this nature cannot be divorced from opinions, often formed with little knowledge of relevant facts. Should absolute secrecy be observed, even at the risk of slowing progress? Should we have absolute faith in the capacity of America to retain scientific and technical leadership, and therefore pay little attention to secrecy? From the range of opinions that lie between these extremes, enormous pressures are brought to bear upon the personnel in positions of governmental responsibility whose ultimate decisions must be the right ones for America, irrespective of this or that pressure.

It would appear that not only the President, but those who support or oppose his policies in Congress, must understand the technical realities of the world in which we live. The adult citizenry of America, whether governing or governed, had little knowledge of or interest in atomic technology and its implications in 1944. In 1946, when the Atomic Energy Act was passed, there had been a sharp realization of its implications in war and international diplomacy, but little dissemination of the sort of knowledge needed to make judgments concerning its proper control. What appears to be the situation today?

Two quotations from a former member of the Atomic Energy Commission, Mr. W. W. Waymack, serve to indicate the improvement taking place and to remind the reader that the relationship between education and democracy in America is real, practical and of continuing importance. An Iowan, a former editor with a keen perception of the importance of atomic energy education at all levels and through all media, Mr. Waymack did much to encourage and assist the committee which developed the Iowa Plan for Atomic Energy Education. Early in 1950 he bluntly called the writer's attention to the sort of difficulty that occurred on occasions in the first years of the new experiment in government: ". . . The most dangerous fact in the atomic energy field since 1946 has been the . . . inclination of nearly all our political leaders . . . to look upon national security as a simplicity, not as a tough and delicate complexity that it is. Hence the tendency to identify Security completely with Secrecy." Less than three years later he was able to write: "No perfection now, to be sure, but a much, much better understanding. Events have helped toward this. But the real force, to which events have contributed, has been the dissipation of that . . . smog of ignorance."

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*No better example of the impact of technology on social organization exists than the problem of the relation of domestic events in one nation to domestic events in another. In an age of jet planes and atomic weapons a revolution in a foreign country may have a different significance for Americans than it did in the days of clipper ships and cannon balls. An advanced discussion about the international control of atomic energy can be built upon this problem.

It is important to maintain the improvement, for it represents the adjustment of government to reality which is vital if free institutions are to survive. If there were no improvement, if the social lag discussed in the previous chapter were to increase instead of decrease, it is logical to suppose that representative government in an age of advanced technology may ultimately result in governmental action inimical to national security. This is a sobering thought. If it were ever to occur in our country, Congressional authority might be abrogated or at least temporarily suspended. History affords ample evidence that the most freedom loving peoples will willingly concentrate extraordinary powers in the hands of executive government for the duration of any major crisis. If the crisis were to continue indefinitely, so would executive government. The student need only explore the contemporary history of Europe to find evidence of this phenomenon.

SUMMARY AND IMPLICATIONS

Each of the existing and projected problems of government briefly reviewed in this chapter is worthy of more detailed exploration and discussion. For convenience, they are here grouped and summarized:

1. Problems within government, such as the proper operation of the agencies created by the Atomic Energy Act, questions of jurisdiction and decentralization of authority, and continuing evaluation.
2. Problems between government and non-government agencies, such as the proper limits of government action and private enterprise, the amount of regulation of the latter, the distribution of materials and the right use of contractual power.
3. Problems between government and persons, such as trade unionists in governmental agencies, security provisions for persons not in government employ, availability to the nation of its best brains and the political and emotional reactions of people in relation to government.
4. Problems of security, which include elements of the above problems and also larger issues such as access to scientific data both from within and without the national boundaries, the delimitation of military secrecy between ourselves and our allies, the continued sovereign independence of small states rich in uranium, and collective security.
5. General problems of political theory such as the qualifications of political leaders, the relation of foreign governments to the common man in America, the possible voluntary surrender of elements of national sovereignty, the limitation of the internal sovereignty of legislative bodies by special committees or agencies of atomic technology, the growth of indirect government and the ultimate potential breakdown of representative government owing to the technological ignorance of the constituents.
6. Problems of personal adjustment to technological reality such as the continued co-existence of both government and private enterprise, the wise or unwise adherence to tradition, the understanding of scientific development as a conditioning element in social and political life, and the individual responsibility (especially of leaders) for continued educational endeavor outside the accepted vocational work.

Possibly all these problems are summed up in the last group. Let us conclude by asking what are the implications for college students as members of the educationally privileged.

The most obvious, yet often the most neglected, is the importance of acquiring adequate pertinent knowledge, properly integrated and thought through. This may require a definite act of will; it is not easy for a student to devote time to the acquisition of knowledge which does not further his immediate professional training or appeal to his natural interests. Democracy in the Atomic Age will need not only trained leaders but a nucleus of informed voters in every community. College graduates could well be the sort of citizens who, in addition to exercising their professional functions, become known in their communities as having the special knowledge which citizens of less education may wish to have readily available as the occasion arises.

A student who makes this definite act of will automatically views college education as a dichotomy; exposure to education (1) for personal success and (2) for constructive free citizenship. The latter phrase is not a cliché when examined in the light of the former. Education for personal success involves more than class attendance; it involves learning how to continue to acquire knowledge, and select from it factors relevant to situations that will occur in post-graduate business or professional life. The intellectual content of citizenship requires the same sort of growth in educational skill. The student today is finishing his formal education in the dawn of the Atomic Age. To remain an intelligent as well as a good citizen in the future, he must achieve self-direction in the continuing acquisition and selection of knowledge relevant to his life as citizen **governing**, as distinct from his life as citizen **earning**. The thinking student will see that this dichotomy of intellectual activity is not a matter of choice but of necessity. The Jeffersonian concept of free society does not divorce the responsibilities of getting a living from those of maintaining the freedom to get a living as one wishes.

The student who thus conducts his college life will be adjusting himself emotionally as well as intellectually to life in the Atomic Age. He will be aware of the necessity of social changes to meet technological changes. He will be prepared to experiment, and competent to evaluate or at least to support evaluation. What sort of research into government will the Atomic Age, itself a product of scientific research, make it necessary for him to support? Here is the answer as given by W. W. Waymack, the distinguished Iowan who, when a member of the Atomic Energy Commission, did so much to encourage his fellow Iowans to undertake the work which has become the Iowa Plan for Atomic Energy Education.

After his retirement from the Commission, Mr. Waymack continued his reflections on the educational implications of the atomic energy project. Optimistic about the continued improvement of the governmental operation, the correction of mistakes "in our clumsy and chaotic and sometimes brutal American way," he felt that the national experience, full of lessons, successes and failures, is already large enough to merit a study of the total performance as well as the functions of the individual components. If there have been weaknesses and failures, what have they been? Why did they happen? How can they be permanently corrected? In a free nation with a system of changing government, how can they be avoided in the future?

He was quick to perceive that the greatest mistake that a nation or its government may make is essentially a moral one, "the fundamental mistake of failing to perceive responsibility, failing to measure it adequately, failing to try to rise to it." College students may well consider this statement from such an experienced civic leader. Moral attitudes often govern the extent and diligence with which men pursue understanding beyond the immediate requirements of getting a living. Moral attitudes distinguish the conscientious citizen's examination of governmental problems and his contribution to policy from the irresponsible citizen's idle criticism of government.

Is it right to examine and discuss the problems, the achievements, the failures and the issues involved in free government in the Atomic Age? Is inquiry into government a function of education? Mr. Waymack would probably say **yes.** For those who believe that the inseparability of freedom and education is a reality and not a rhetorical phrase, the concluding words of one of his letters have a certain timelessness: "It seems to me that this kind of inquiry simply has to be made. It seems to me that it is the imperative of practical education."

NOTES

BIBLIOGRAPHY

SELECTED READINGS ON ATOMIC ENERGY*

Below is a list of selected readings on all aspects of atomic energy. These books are recommended as being suitable for the general college student. This list should be supplemented by reference to the various current magazines, most of which carry articles from time to time on recent developments in the atomic energy field. Consult the **Education Index** or the **Reader's Guide to Periodical Literature** for titles.

The U. S. Government Printing Office has for sale, at a low price, many good publications on atomic energy, including various pamphlets and booklets on civil defense. These are available from the Superintendent of Documents. Ask for their free price list of publications relating to atomic energy and civil defense.

Comprehensive bibliographies on atomic energy are available free from the U. S. Office of Education and from the U. S. Atomic Energy Commission. The latter will also send reprints, copies of speeches, and other useful material on atomic energy upon request. Write to the Educational Services Division, U. S. Atomic Energy Commission, Washington, D. C.

1. **A General Account of the Development of Methods of Using Atomic Energy for Military Purposes Under the Auspices of the United States Government, 1940-45.** By H. D. Smyth. Washington, D. C., U. S. Government Printing Office, 1945. 182 p.

   This is the famous Smyth Report—the authoritative and official account of the development of atomic energy by the U. S. Government during World War II.

2. **Atomics for the Millions.** By Maxwell Leigh Eidinoff and Hyman Ruchlis. New York, McGraw-Hill, 1947. 281 p.

   A simplified presentation tracing the development of the atom from early Greek theory to present application. Many excellent diagrams help make the text clear.

3. **Explaining the Atom.** By Selig Hecht. New York, Viking, 1947. 205 p.

   A classic volume explaining atomic energy in simple language—what an atom is, how man learned to split it, and why it produces energy when split. The book does not contain many diagrams, but the explanations are unusually clear and almost storylike.

4. **The Atom at Work.** By Jacob Sacks. New York, Ronald Press, 1951. 327 p.

   A non-technical book on the scientific aspects of the atom, isotopes and radioactivity, with special emphasis on the constructive side of atomic energy. Extensive discussion of the applications of atomic energy in the fields of biology, medicine, agriculture, and industry.

5. **Sourcebook on Atomic Energy.** By Samuel Glasstone. New York, Van Nostrand, 1950. 546 p.

   This book contains extensive descriptive material on all phases of atomic energy, especially the Government's program in this field. Prepared by the U. S. Atomic Energy Commission.

6. **Applied Nuclear Physics.** By E. C. Pollard and W. L. Davidson. New York, Wiley, 1951. 352 p.

   A text for the serious student who wishes to go more deeply into the scientific aspects of the atom.

7. **Atomic Energy and the Hydrogen Bomb.** By Gerald Wendt. New York, McBride, 1950. 192 p.

   An account of the principles of atomic energy, including hydrogen bombs.

8. **Atomic Energy in War and Peace.** By Burr W. Leyson. New York, Dutton, 1951. 217 p.

   A book describing the operation and effects of the atomic bomb, with a chapter on defense measures; the hydrogen bomb; the production of fissionable materials; and atomic energy research.

9. **It's Your Atomic Age.** By Lester del Rey. New York, Abelard Press, 1951. 226 p.

   An explanation in simple, everyday terms of the meaning of atomic energy to the average person: the nature, development, and uses of atomic energy; the physiological effects of radiation; the atomic and hydrogen bombs and their military and political significance.

10. **Dawn Over Zero.** By William L. Laurence. New York, Knopf, 1946. 274 p.

    The dramatic story of the development of the atomic bomb by the science reporter of **The New York Times,** who was the only newspaperman to witness the first atomic test explosion and the bombing of Nagasaki.

11. **Early Tales of the Atomic Age.** By Daniel Lang. New York, Doubleday, 1948. 223 p.

    Thirteen stories about the people and places of a strange new era, explaining not the bomb, but the men who made it.

12. **Hiroshima.** By John Hersey. New York, Knopf, 1946. 117 p. (Published also in paper-bound edition by Bantam Books, New York.)

    An account of what happened to six survivors of the blast of the first atom bomb to be dropped on a city. Excellent literature as well as a gripping story.

13. **The Effects of Atomic Weapons.** Prepared under the direction of the Los Alamos Scientific Laboratory for and in cooperation with the U. S. Department of Defense and the U. S. Atomic Energy Commission. Washington, D. C., U. S. Government Printing Office, 1950. 456 p.

    This is the most complete and authoritative account of what happens in an atomic explosion and what the effects are. Somewhat technical in parts but most of the book can be understood by the general reader.

14. **Must We Hide?** By R. E. Lapp. Cambridge, Mass., Addison-Wesley Press, 1949. 182 p.

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*Prepared by Emil Miller, Luther College.

Considers the results of the Japanese bombing and translates these effects to American cities. It points out which of our cities are most vulnerable and what defenses may be prepared against possible future attacks.

15. **How to Survive an Atomic Bomb.** By Richard Gerstell. Washington, Combat Forces Press, 1950. 150 p. (Published also in paper-bound edition by Bantam Books, New York.)

    What happens when a bomb strikes, and what the individual can do for his own protection. Written in question and answer form.

16. **Atomic Energy, Double-Edged Sword of Science.** By R. Will Burnett. Columbus, Ohio, Chas. Merrill Co., 1950. 32 p.

    A science-social science study unit. Prepared for the North Central Association of Colleges and Secondary Schools.

17. **The Atomic Era—Can It Bring Peace and Abundance?** Ed. by Freda Kirchwey. New York, McBride, 1950. 176 p.

    An account of the complex problems confronting the world as a result of the development of atomic energy. The papers included in this collection were presented at The Nation Associates' conference, and have been amplified and organized to present a many-sided discussion.

18. **Readings for the Atomic Age.** Ed. by M. D. Hoffman. New York, Globe Book Co., 1950. 406 p.

    Includes selections from **Modern Arms and Free Men,** by V. Bush; **Set Your Clock at U235,** by N. Corwin; **Modern Man Is Obsolete,** by N. Cousins; **The Real Problem Is in the Hearts of Men,** by A. Einstein; **The Bomb That Fell on America,** by H. Hagedorn; **Dawn Over Zero,** by W. L. Laurence; **Science and Man's Fate** and the **UN Universal Declaration of Human Rights,** by David E. Lilienthal.

19. **The H-Bomb.** Introduction by Albert Einstein, commentary by George Fielding Eliot. New York, Didier, 1950. 175 p.

    A collection of papers on the theory of the H-bomb, its military value and political aspects, and scientists and the H-bomb. Contributors are: Stewart Alsop, Atomic Energy Commission, Robert F. Bacher, Hanson W. Baldwin, Hans Bethe, David E. Lilienthal, Walter Lippman, Brien McMahon, Hans Morgenthau, Leo Szilard, Editors of **Time**, Harold Urey, Richard K. Winslow, University of Chicago Round Table.

20. **The Control of Atomic Energy; a Study of Its Social, Economic, and Political Implications.** By J. R. Newman and B. S. Miller. New York, McGraw-Hill, 1948. 434 p.

    A clear analysis of the import and wide power and scope of the Atomic Energy Commission. Some of the subjects discussed are: organization and structure of the Commission, production and ownership of fissionable material, radio-active by-products, patents and inventions, research, military application, industrial and commercial uses, and control of information.

21. **Minutes to Midnight; the International Control of Atomic Energy.** Ed. by Eugene Rabinowitch. Chicago, Bulletin of the Atomic Scientists, 1950. 128 p.

    A collection of original memoranda, State papers, reports, speeches, and articles, giving the story of international control up to the time when the American monopoly of atomic weapons was known to have ended, and work on the development of the hydrogen bomb was announced. Editorial commentary serves to connect the various threads of the story.

22. **Modern Arms and Free Men.** By Vannevar Bush. New York, Simon and Schuster, 1949. 273 p.

    An examination of how modern science and the democratic process are affecting the nature of war. Technical and military estimates and assessments of the two World Wars and the period between them, in terms of the role that applied science played in fighting the wars and in affecting military thinking.

23. **Economic Aspects of Atomic Power.** Ed. by Sam H. Schurr and Jacob Marschak. Princeton, N. J., Princeton University Press, 1950. 285 p.

    A comprehensive exploratory study of the economic feasibility of atomic power, undertaken by the Cowles Commission for Research in Economics.

24. **Atomic Power, An Economic and Social Analysis.** By Walter Isard and Vincent Whitney. New York, Blakiston, 1952. 235 p.

    Provides and interprets some of the data needed for intelligent consideration of the problem of international control, and evaluates the possibility of the use of atomic power in industry.

25. **Federal Information Controls in Peacetime.** Comp. by R. E. Summers. New York, H. W. Wilson Co., 1949. 301 p. (The Reference Shelf, Vol. 20, No. 6.)

    Basic issues and implications involved in the policy of secrecy concerning atomic energy and related matters.

26. **This I Do Believe.** By David E. Lilienthal. New York, Harper, 1949. 208 p.

    The author's concept of the essentials of democracy and the reasons for his faith in those precepts based on 20 years' experience as an American public servant. Three chapters are devoted to the atomic energy enterprise and how this "new force" can be used to strengthen democracy.

27. **Opportunities in Atomic Energy.** By K. D. Hartzell. New York, Grosset and Dunlap, 1951. 143 p.

    A vocational guidance manual outlining what atomic energy is, the American program for atomic energy development and the principal types of personnel engaged in and required for its development.

28. **Semiannual Reports of the U. S. Atomic Energy Commission to the Congress of the United States.** Washington, D. C., U. S. Government Printing Office, beginning 1947.

    These official reports describe the Commission's progress and purposes. Beginning with the Fourth, each report is devoted primarily to some phase of the Commission's extensive program of developing atomic energy in all its aspects.

29. **Bulletin of the Atomic Scientists.** Educational Foundation for Nuclear Science, Inc., 956 East 58th St., Chicago 37, Ill.

    A magazine for science and public affairs. Published monthly by a group of atomic scientists. Contains authoritative articles on all phases of atomic energy, with special emphasis on its social implications.

AUDIO-VISUAL MATERIALS[*]

The field of atomic energy and its implications is well illustrated with audio-visual aids. Their coverage includes historical backgrounds, the Manhattan Project, effects of bombing, peace-time uses, moral and political issues and an increasing number of good technical films especially designed for college teaching. A choice of aids is naturally governed by their function in course work or general studies. Certain technical films, for example, should be shown only to science students. Their chief value is to give the student a vicarious experience of the work going forward in specialized national laboratories and research projects that he is not able to visit. Other technical films should be specifically reserved for students in the social studies and humanities. They are expressly designed to give non-scientists an essential understanding of the physical forces whose control remains one of the major unsolved social problems of today.

Non-technical films may have a wider audience. The scientist and the social scientist have equally a vested interest in the satisfactory solution of social problems. Moral questions rising from atomic energy are at least as pertinent to the physics student as to the young theologian, and possibly far more personal. But the use of these films will again be governed by the teaching situation. A lecturer in the social studies or humanities may prefer to raise problems by lectures and assigned reading while a science teacher may choose films to bring his science students as quickly as possible to the point of intelligent social discussion.

Certain films, such as documentaries of the effects of atom bombing, have no specific teaching value. Their use is as a challenge, especially to those students, now the preponderant group on all campuses, for whom World War II was not a personal experience. Such films should be used sparingly and always in conjunction with other aids, lectures or readings designed to give him factual knowledge for his thinking and discussion. The student who is emotionally stirred and then denied access to materials for thought and expression will rapidly withdraw himself permanently from the very issues in which a college seeks to stimulate his interest.

The annotated list which follows is a MINIMUM list of suggested audio-visual aids for varied college use. In Iowa, no college need provide itself with a costly permanent library of audio-visual aids. Two such film libraries specifically designated to serve the state are the Bureeu of Audio-Visual Aids at the State University of Iowa, Iowa City, and the Audio-Visual Aids Service at Iowa State College, Ames. Because the other volumes of the Iowa Plan are extensively used in the public schools, colleges can work cooperatively with the local school board and the local library to help provide, without duplication, a good selection of audio-visual aids usable at all levels of educational activity.

Films of Introductory Challenge.

TALE OF TWO CITIES: Presents the destructive results of the bombings of Hiroshima and Nagasaki. Many close-up shots that show the effect of the blast and radiation on buildings and materials are included. The opening and closing scenes are of the Alamogordo ezplosion and are likewise impressive. Black and white film. (20 min. Army Signal Corps, Central Film Library, Ft. Sheridan, Illinois)

OPERATION CROSSROADS: An official Navy film (in full color) of the two Bikini test explosions and the preliminary preparations. The photography is excellent, the scenes of the explosions awe-inspiring. (27 minutes. Department of the Navy, Washington, D. C.)

ONE WORLD OR NONE: Produced under the auspices of the National Committee on Atomic Information to appeal to the widest possible audience and to impress the individual with the crucial nature of the problem. Using special animation techniques as well as action shots, it impressively conveys the basic facts that there can be no real secrets; that the atomic bomb is a unique weapon that can not be compared to any previous weapon; that there can be no adequate defense; and that a system of international control must be achieved. Narration by Raymond Swing. (9 minutes. Film Publishers, Inc. 25 Broad St., New York 4, N. Y.)

Films of Historical Background.

ATOMIC POWER: A popular treatment of the fundamentals of nuclear physics and the events leading to the wartime American production program. Included are re-enactments by the scientists themselves of important meetings and experiments. Excellent background material. Black and white film. (10 minutes. March of Time, New York)

THE BEGINNING OR THE END: The professionally produced story, at times very moving, of how America became aware that her enemies were working on atomic weapons and the dramatic events which followed. The best film on the Manhattan Project yet produced. (28 minutes. Teaching Films Custodians, 25 W. 43rd, New York, N. Y.)

INSIDE THE ATOM: A documentary showing the various phases of research work at the Chalk River Atomic Energy Plant in Ontario, Canada. The handling and uses of radioactive isotopes are portrayed. The audience is taken right inside one of the biggest atomic energy plants on this continent. (12 minutes. National Film Board, Ottawa, Canada.)

Science Films for Social Studies Courses.

ATOMIC ENERGY: A pure science film, with no political references, designed solely as an introduction to atomic principles, including fission and chain reactions. (10 minutes. Encyclopoedia Britannica, Wilmette, Illinois)

THE SCIENTIFIC METHOD: Explains the principles of thought employed by all scientists and illustrates their utilization in everyday living. Not strictly an atomic energy film, it is of importance because the major social problems of the Atomic Age rise from the harnessing of natural forces through scientific method. (12 minutes. Encyclopoedia Britannica, Wilmette, Illinois)

REPORT ON THE ATOM: The future applications of atomic energy in a world at peace. The major

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[*] Prepared by Hew Roberts, University of Iowa.

emphasis is on the present program for harnessing the atom for research in industry, agriculture and medicine. Interior scenes in the various Atomic Energy Commission laboratories are depicted, affording the student some impressions of the size and complexity of the Commission's research program. There is a speech by Mr. Lilienthal on the dangers of excess secrecy. (19 minutes. March of Time, New York.)

ATOMIC RADIATION: Explains the fundamentals of atomic radiation. Describes how man has been able to reproduce in the laboratory some of the natural forms of radiation. Explains the use of alpha, beta, gamma rays and neutron particles in radioisotope research. (12 minutes. Encyclopoedia Britannica, Wilmette, Illinois)

MATTER AND ENERGY: Explains the forms of matter, physical and chemical change and nuclear fission. (11 minutes. Coronet Film Productions, Chicago, Illinois.)

Science Films for Science and Technical Courses.

ATOM SMASHERS: Describes how physical scientists are developing machines and techniques for the production and use of nuclear radiation in many beneficial fields. Calls attention to the importance of accelerators—particularly the cyclotron—and their contribution as tools of nuclear research. Illustrates how the products of "atom smashing" are identified, and demonstrates protective measures taken against the dangers inherent in this research. (12 minutes. Encyclopoedia Britannica, Wilmette, Illinois)

THE ATOM AND BIOLOGICAL SCIENCE: Deals principally with the biological effects of high energy radiations. Explains how we are learning to utilize the good effects of these radiations on organisms as well as to guard against their harmful effects. Points out the different types of high energy radiation and explains their varied effects on organisms, making clear that the effects are essentially the same, regardless of the type involved. (12 minutes. Encyclopoedia Britannica, Wilmette, Illinois.)

CARBON FOURTEEN: Explains the use of radioactive carbon (carbon 14) as a means of dating historic and prehistoric objects. Tells the story of half-life in clear, understandable terms. Illustrates the role of carbon 14 in tracing the vital processes of growth and decay in living things. Shows how carbon 14 is permitting an approach to a solution of the riddle of photosynthesis and how it has an important bearing on observational methods in life sciences. (12 minutes. Encyclopoedia Britannica, Wilmette, Illinois)

Applications of Atomic Energy for All Students.

THE ATOM AND INDUSTRY: Reveals how radioactive isotopes are providing new techniques of measurement and quality control in a wide variety of industries. Indicates how the radiation symbol is becoming a common sight in factories and laboratories and how workers are learning to handle radioactive materials safely. (12 minutes. Encyclopoedia Britannica, Wilmette, Illinois.)

THE ATOM AND MEDICINE: Describes the increasingly important role of radioactive isotopes in hospitals, clinics, and doctors' offices. Clarifies misconceptions about the handling, cost, dosage, and alleged dangers of radioactive isotope diagnosis and therapy. (12 minutes. Encyclopoedia Britannica, Wilmette, Illinois.)

THE ATOM AND AGRICULTURE: Tells the important story of the use of radioactive tracers with phosphate fertilizers; the effect of the fertilizers on a variety of crops grown under a variety of conditions. Depicts other experiments with plants, soils, and animals. (12 minutes. Encyclopoedia Britannica, Wilmette, Illinois.)

Social Problems and Implications for All Students.

THE HIROSHIMA MEDICAL CASES: An unemotional Japanese film which is an excellent opening for both moral and political discussion. (From the Army, Fort Riley, Kansas.)

ONE WORLD OR NONE: Described above. Introduces the problem of international control as a **physical** necessity.

THE ATOM BOMB — RIGHT OR WRONG? Designed for church or college chapel use by a college pastor and with his commentary, but professionally produced. Introduces the problems of national and international control as a **moral** necessity. (19 minutes. Federal Council of Churches of Christ in America and RKO Pathé)

THE BEGINNING OR THE END: Described above. Raises the social problems of government activity, finance, security, civilian-military cooperation, and joint international activity.

INFLATION: Without specific reference to atomic energy, shows the effects of war or defense crises on the national economy. (17 minutes. Encyclopoedia Britannica Films, Wilmette, Illinois.)

CENTRALIZATION AND DECENTRALIZATION: There is no better example of these problems than the machinery for both centralizing control and decentralizing research and production of atomic energy. (20 minutes. Encyclopoedia Britannica, Wilmette, Illinois.)

WORLD BALANCE OF POWER: Not specifically concerned with atomic energy, but raising a problem that is more vital in the Atomic Age than ever before. (20 minutes. Encyclopoedia Britannica, Wilmette, Illinois.)

DUCK AND COVER: The strange public apathy toward civil defense is a major social problem. Iowa's State University was the first college in America to accept the challenge of apathy and offer work in civil defense for atomic war. All colleges should accept some leadership. This is one of many films obtainable from the Iowa Office of Civil Defense, Des Moines.

Film Strips and Recordings.

For college classes devoted to discussion, a film strip or a recording is sometimes more useful than a film as it can be interrupted at the leader's convenience. Film strips that can safely be recommended as not too elementary for college students are: ATOMIC ENERGY (New York Times School Service, Times Square, New York), THE ATOM AT WORK (Society of Visual Education, Chicago, Illinois) and WORLD CONTROL OF ATOMIC ENERGY (Film Publishers, 25 Broad Street, New York). Recordings of value are THE ATOM BOMB and PEACETIME USES OF ATOMIC ENERGY (Lewellen's Club Productions, 8 S. Michigan Ave., Chicago 3, Illinois)

Plays.

It should not be forgotten that the college drama group can present a "living" audio-visual aid. "$E = mc^2$," a play written by a former Iowan, Shallie Flanagan, is obtainable from Samuel French, Inc. 25 W. 45th, New York. College drama students may be encouraged to write their own playlets, as has been done in Wisconsin's Idea Theatre.

NOTES

APPENDIX

EXPERIMENTS IN PRACTICAL APPLICATION*

As was the case with each section of the Iowa Plan, the College Production Committee conducted a series of practical tests of its material during the course of its deliberations. These included incorporating the material into an existing college course, presenting a general course open to all students, conducting an intensive one-day workshop involving the Committee members as faculty, and observing a second one-day workshop patterned on the Iowa model but without the direct participation of the Committee. Brief notes on these experiments follow.

INCORPORATION IN A COLLEGE COURSE

A group of civil engineering students in the State University of Iowa was used. Four two-hour sessions of a regular weekly seminar were set aside and the content of each session planned by students and faculty on the basis of manuscript material supplied by the Production Committee. The basic scientific facts were already known to the students so the four sessions dealt with problems of research and security, war and peace, economic and social change and democratic philosophy in the Atomic Age. Each session began with a brief lecture adapted from the manuscript supplied by the Production Committee and followed by open discussion. The students appeared to find the social impact of atomic technology a new and exciting field of thought. In every case the seminar lasted longer than the prescribed time. Finally, the students involved requested that "at least two more sessions" be devoted to the further consideration of social implications. The Production Committee concluded that it is quite possible to orient science and technical students toward the social problems of the Atomic Age through existing courses and seminars in the departments concerned and with a minimum of added work for faculty members.

A LECTURE COURSE IN THE GENERAL EDUCATION PROGRAM

Two experimental campus courses open to all students were conducted for the Production Committee by the State University of Iowa and planned in consultation with its Student Council. They consisted of twenty-two lecture-discussions presented in the evening by a faculty drawn from Physics, Chemistry, Bio-Chemistry, Medicine, Engineering, Sociology, Economics, Political Science, Education and Journalism. Two major difficulties appeared. The first was a lack of coherence in the lecture program. It proved impossible with so large an interdepartmental faculty to plan the course as an effective unit and to ensure that the unity was preserved throughout the presentation, which would have meant continual faculty meetings. Without relief from regular departmental duties, faculty could not or would not find adequate planning time. The second problem was accreditation. To design assigned reading and an examination for the course was not practicable and therefore it was offered on a non-credit basis. The average student carries the maximum permitted credit schedule and finds it undesirable to devote his entire spare time to a single non-credit activity. Accordingly, the size of the student audience tended to decline. The Production Committee believes that these problems are probably common to all colleges and that the material is therefore better incorporated in existing general or special courses, or presented as a workshop.

ONE-DAY WORKSHOPS

By invitation of President Russell D. Cole of Cornell College, Mount Vernon, Iowa, the Production Committee was able to experiment with the presentation and evaluation of an intensive one-day study for all students in a liberal arts college. Atomic Energy Day was planned by a joint committee drawn from the Production Committee and the faculty of Cornell College. This committee also discharged the preliminary work of collecting and arranging exhibits, planning and rehearsing student panels and conducting preliminary tests. All class activities of the college were suspended on the day of presentation and the entire student body attended the program, which was presented exactly on the following schedule:

MORNING

Dr. F. E. Brown, Iowa State College, Chairman

8:45- 8:55	Atomic Energy—Russel D. Cole, President Cornell College
8:55- 9:25	The Atom and Radioactivity—George Glockler, State University of Iowa
9:25- 9:40	Energy—Physical, Chemical and Nuclear—Robert A. Rogers, Iowa State Teachers College
9:40-10:10	Atomic Fuels, Chain Reactions and the Atom Bomb—Harley A. Wilhelm, Ames Laboratory, United States Atomic Energy Commission and Institute for Atomic Research, Iowa State College
10:10-11:00	Discussion groups and exhibits (see list below.)
11:10-11:30	Power from Atomic Energy—Winfield W. Salisbury, Collins Radio Co.
11:30-12:00	Radioactive Isotopes in Service—Adolph F. Voigt, Ames Laboratory, United States Atomic Energy Commission and Institute for Atomic Research, Iowa State College
12:15- 1:30	Exhibits will be shown and explained by assistants

LUNCHEON

(At luncheon faculty were scattered among student tables)

AFTERNOON

Prof. Hew Roberts, The State University of Iowa, Chairman

1:30- 2:10	Atomic Energy and Social Trends—Joseph B. Gittler, Iowa State College
2:10- 2:25	Summary, Hew Roberts, Chairman
2:35- 3:25	Discussion groups, carried on simultaneously: 1. The Moral Aspects of the Atomic Problem—Miron A. Morrill, Cornell College, and panel of Cornell students. 2. The Impact of Secrecy on the Development of Science—Arthur Roberts, State University of Iowa, and panel of Cornell students. 3. Controls: Domestic and International—Emil C. Miller, Luther College, and panel of Cornell Students.
3:35- 4:20	Concluding Summarization, Prof. Hew Roberts and George Glasheen, Washington, D.C., Assistant Director of Educational Services of the U. S. Atomic Energy Commission.

THE EXHIBITS

Exhibit materials to be explained in informal discussion by our guests, Cornell college faculty members and Cornell students. Exhibits and discussion leaders are as follows:

F. E. Brown, Iowa State College
The Hydrogen Bomb

J. B. Culbertson, Cornell College
Isotopes, Isobars, Chain Reactions

George Glockler, State University of Iowa
The Atom and Radioactivity

Robert A. Rogers, Iowa State Teachers College
Energy (Physical, Chemical and Nuclear)

Winfield W. Salisbury, Collins Radio Company
Cyclotron Type Accelerators (A model cyclotron will be present and used).

C. D. Starr, Cornell College
Methods for Obtaining Pure Fissionable Materials

Adolf F. Voigt, Institute for Atomic Research, Iowa State College
The Energy of Mass and The Energy of the Sun; Interconversion of Energy

Harley A. Wilhelm, Institute for Atomic Research, Iowa State College
Metallurgy

Collins Radio Company
Radiation and Counters and Detectors
Radioactive Sand from Alamogordo
One Milligram of Radium

Iowa State College and Ames Laboratory, United States Atomic Energy Commission
Large Rods of Uranium and Thorium
Samples of Rare Metals
A Portable Radiation Counter
Ores of Uranium and Thorium
Compounds of Uranium, Thorium and Rare Elements
Use of Tracers in Agricultural Research
Radiation Counters and Detectors

State University of Iowa
A Model of a Van de Graaff Machine
Uranium Compounds
Radiation Counters and Detectors

Cornell College
Mousetrap Bomb—A Model Chain Reaction

A unique feature of Atomic Energy Day at Cornell College was a subjective and objective evaluation, carried out by a committee and an independent examining agency.[1] The objective evaluation consisted of a double test administered to all Cornell College students one week before the program was presented. The test dealt first with exact knowledge of the sort of facts that would eventually be presented in the program, and second with attitudes to atomic energy and its problems. One month after the program, both tests were administered a second time to all students during their regular class hours. The subjective evaluation was conducted by Cornell College faculty in a series of discussions with the students who had attended the program. The material thus collected was discussed and digested by a representative of the Production Committee, Dr. Donald F. Howard of Iowa State Teachers College; a representative of the host institution, Dr. James Ennis; and a representative of a college which might be interested in the Cornell day as a model, Dr. Emil C. Miller of Luther College, Decorah. Their deliberations resulted in a subsequent Atomic Energy Day at Luther College, Decorah, Iowa. This final try-out is most important for it was the independent test of the Production Committee's model program.

Using almost exclusively its own faculty and resources, Luther College produced a program which differed in minor but important respects from the Cornell program. Because the differences represent the necessary adjustments when a college operates without the direct assistance of the Iowa Committee, the program is here printed:

Tuesday evening, February 20

8:00 o'clock,	Introductory Remarks, Prof. Hew Roberts, Professor of Education, University of Iowa; and Prof. Emil Miller, Head of Department of Physics, Luther College. Visual Aids, including the official Navy film of the Bikini Bomb Tests in color.

Wednesday, February 21

10:00-11:30,	Basic Information Lectures: "What Is the Atom?"—Prof. Arnold Matthees "How the Atom Bomb Works"—Prof. Emil Miller "Non-military Uses of Atomic Energy" —Prof. George Knudson
11:30- 1:20,	Films and Exhibits. Continuous showing of ten excellent films on all phases of Atomic Energy. Exhibits include the famed Life Magazine Exhibit.
1:30- 2:20,	Address: "The Social Significance of Atomic Energy", Prof. Hew Roberts
2:30- 3:30,	Discussion Groups: 1. "The Atom Bomb—Right or Wrong?" Prof. Gerhard Belgum, Moderator, and Student Panel. 2. "Atomic Energy Development—Public or Private?" Prof. David T. Nelson, Moderator, and Student Panel. 3. "Atomic Politics: Is International Control of Atomic Energy Possible?" Prof. Frank Barth, Moderator, and Student Panel. 4. "The Security Problem: Secrecy vs. Scientific Freedom in a Democracy". Prof. Sherman Hoslett, Moderator, and Student Panel.

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*Prepared by Hew Roberts, University of Iowa.

[1] Examinations Services, State University of Iowa

3:40- 4:00, Summary Reports from Discussion Groups.

4:00- 4:30, Concluding Address, "Education in the Atomic Age", Prof. Hew Roberts.

4:30- 7:00, Films and Exhibits.

The reader may note that:

(a) The introductory session was held the evening before the program, giving students a less concentrated experience and permitting the visiting lecturer to familiarize himself with faculty, students and program, and adjust his work to theirs.

(b) Longer but fewer lectures made adequate use of the smaller faculty.

(c) Greater use was made of audio-visual aids.

(d) The discussion and report sessions were extended.

(e) Continuity was emphasized by using a single speaker for opening, transition, and conclusion.

Observers felt that, because of its homogeneity, the Luther Day was in some ways more acceptable to students than the Cornell Day. The Production Committee concluded that any Iowa college is able to arrange a workshop program on the basis of the material now available in this volume.

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