OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.

Inaugural Lecture Series 98

REPLENISH THE EARTH AND SUBDUE IT

By J. B. Aladekomo

OBAFEMI AWOLOWO UNIVERSITY PRESS LIMITED

J. B. Aladekomo
Professor of Physics

REPLENISH THE EARTH AND SUBDUE IT

by

J. B. Aladekomo
Professor of Physics

An Inaugural Lecture delivered at the University of Ife, Ile - Ife (now Obafemi Awolowo University) on April 20, 1982.

Inaugural Lecture Series - 98 -

OBAFEMI AWOLOWO UNIVERSITY PRESS LTD, ILE-IFE, NIGERIA.

ISSN 0189–7845

Printed by
Obafemi Awolowo University Press Ltd, Ile-Ife, Nigeria.

Introduction

Mr. Vice-Chancellor, fellow scholars and students, visitors to the University, distinguished ladies and gentlemen. First, I wish to express my profound gratitude to the Almighty God that despite all odds and personal problems, He has granted me the high honour and privilege to stand among you today and deliver a lecture within a unique subject area that has revolutionized the world and has made a major impact on its political and economic developments.

It is a subject whose fundamental principles have led to the development of huge and powerful electric power stations which are very vital to the survival of the human race and its continual growth. It has furnished the electric motors and machines for motive power and Engineering applications.

It is a subject that has given birth to the transistor, integrated circuits and other components which constitute the cornerstone of instruments that are used in radio, television, communications, measurements and applications; pulse and digital circuitry for processing of millions of bits of information, information storage and computation generally.

It is a subject that has yielded the tools and equipment for diagnostic work in Medicine and the treatment of diseases. It is a subject that has furnished important information to Agriculturists on the climatic conditions and the soil, has provided the appropriate technology for mechanized farming and for improving the yield of Agricultural production.

It is a subject that has provided the equipment for the detailed study of Biological Systems including the physiology of plants and animals, and processes occuring at the molecular level within living cells. One major achievement worthy of special note in this field is the unravelling of the structure of Deoxyribose Nucleic Acid (DNA) which holds the key to inheritance and replication in plants and animals including man.

It is a subject where the discovery of fission (breaking up of heavy nuclei) has led to the development of nuclear power of enormous magnitude. As we shall see later, the nuclear energy is being harnessed for peaceful purposes. It is quite clear_that nuclear power has made a serious impact on world economy and civilization and its military application not only has a high political consequence but now poses a serious threat to the survival of the human race. The subject which has yielded the title of today's lecture as we know is Physics.

Some Consequences of Physics

The brief introductory account is by no means all the main achievements of Physics. We can go on and on giving a catalogue of discoveries that have been made in Physics, their consequences and applications in other areas of Science, Technology and science-related fields as well as their impact on human life in the twentieth century. Indeed such an account would run into books of several volumes. In fact, the findings of the last two or three decades alone are so immense that an expert who desires to cover all the fields adequately would need a few years of continuous reading to do so. Limited time at our disposal in today's lecture does not permit more than a brief review of a particular field within this expansive subject plus a discussion of some results relevant to the interest of the lecturer. That is what I will try to do during the course of the lecture.

It is a well known fact that Physics is the key to many other subjects providing the framework for the growth and development of other subjects as well as the precise investigative tools. A few common examples come readily to the mind.

The development of the microscope some centuries back during the time of Newton, Galileo, etc. started as attempts to find out what happened when single lenses are put together. We now know that microscopes have unravelled many inner secrets of the cells that make up plants and animals. The wealth of information uncovered by microscopes in Materials Science and Geology cannot be underestimated. Without the microscopes of different nature and forms, the development of our knowledge in these areas up to the present stage would have been impossible.

Another example is the development of Spectroscopic Instruments which could be rightly claimed to have started when Newton interposed a glass prism into the path of sunlight and found that the white light was composed of light of different colours the same as the colours of the rainbow. Spectroscopic instruments started initially as mere curiosities in Physical Science and quickly became valuable tools for investigating physical properties and effects and for evaluating the quantity of a given substance present in a mixture of other substances Nowadays, the methods and practice of Spectroscopy have been taken over in other areas of Science and Technology. They are indispensable to non-destructive testing in Engineering, prospecting work in Geology, research and investigative work in Biochemistry, Biology, Medicine and Agriculture. In short, the physical instruments of today which may look rather strange, seemingly irrelevant to the present needs and esoteric

in nature soon become, within a few years, the cornerstone of Biology, Engineering, Medicine and other Science based professions.

Physics is therefore a stimulating subject, a rapidly growing discipline whose influence has permeated all aspects of human living. As a result, some elementary knowledge of it by everyone becomes desirable if only to appreciate what is going on around us and derive more benefits from our environment.

However, it is sad to note that several people avoid the study of the subject even at the most elementary level because of the impression that it is a difficult or hard subject. They claim that Physicists are apt to clothe accounts and descriptions of their work in strange and extraordinary terminologies as well as complex Mathematical symbols and equations. I wish to assure listeners that for several years now Physicists have been making strenuous efforts to bridge this gap partly through Symposia and partly by the publication of scientific magazines and popular journals with articles written in "ordinary language". They have greatly enhanced the communication procedure with Physical information now reaching an ever-widening circle of the public.

The Physicists at Ife have played a very active role in the popularisation and the application of Physics in Nigeria today. As we shall see later in the lecture, by introducing programmes of interdisciplinary nature, they have increased the production of Physics Graduates sevenfold within a period of four years.

The Earth, Its Constituents and Resources

Let us focus our attention for a brief moment on the physical nature of the earth and its constituents. The earth we live in is one of a number of planets which move in elliptic paths or orbits round our sun, the whole Solar System being balanced by gravitational forces. The motion and behaviour of the planets conform to definite and well known physical laws. The earth itself is made up of a wide range of matter whose states of aggregation can be broadly classified as solids, liquids and gases. It is well known that a mantle of ionized gases and electrons exists in form of plasma round the earth. (Broadly speaking we can treat the plasma as the fourth state of matter). The layer round the earth called the *Ozonosphere* plays a very significant role in the control of the radiation arriving on the earth's surface while the *Ionosphere* is important in radio communication between different parts of the earth. As we shall see later in this lecture, plasmas are created artificially in the laboratory and they may well be destined to play a very important role in any energy revolution that could happen on earth in future.

Taking into account the latest discovery that occurred within the last few months, we now know that there are at least 107 elements[14] on earth. An element of course being the smallest chemically indivisible unit of a substance that is capable of free and independent existence. The lightest of the elements is hydrogen while the heaviest ones are the radioactive elements produced artificially within the laboratory. The basic building unit for all materials is the element. The elements of different types are combined in different proportions and amounts to produce all the matter that exist on earth. A few examples would be relevant at this point.

The metals which are characterized by their behaviour as good conductors of heat and electricity can combine to form hundreds of alloys of different compositions and having modified physical properties. Invariably these metals exist in nature as parts of ores which in turn are complex mixtures of various metals and other elements. Such ores have to be processed and extractive procedures adopted before the refined (or pure) metal emerges. From this practice has grown a branch of Engineering known as *Metallurgical Engineering* which is now indispensable to human civilization, technological progress and comfort.

The other common example concerns ceramics. Ceramics are non-metallic and inorganic materials which require high temperatures in their processing or use. They are characterized by their resistance to heat, corrosion, abrasion, wear, electrical and magnetic breakdown. Some typical examples are glass, bricks, tile, cement and dinnerware. Some other ceramics find widespread use as human bone and teeth replacement, high temperature linings and tools for machining and drilling.

Quite apart form all these inorganic materials, the earth is also richly blessed with (literally speaking) millions of fauna and flora which are broadly classified as organic matter. The building element here is carbon which is combined in various amounts with different elements such as hydrogen, oxygen, nitrogen, etc., to yield millions of other products classifiable as organic chemicals and drugs. The organic matter that have become fossilized over the years yield petroleum from which can be derived fuel, petroleum products, dyes, paints, synthetics, fibres, etc.

In short, we can see that the earth has an almost limitless store of materials of different nature and forms. In order to live, Man must interfere with his environment, he must change or transform materials present in nature to materials of other forms. We have seen that from the metal ores, Man can produce the refined metals which in turn can be processed to make agricultural tools and machinery; machines for

locomotion, haulage and large scale production of other materials. Metals are also used in making instruments for instant communication, world-wide dissemination of information and the tools and chemicals needed for the treatment and cure of diseases. The components of the different machines and instruments can be taken apart and re-cycled to make new components. In principle, this can be viewed as a sort of replenishment. Man also grows food and ingests it to nourish his body. This enables him to live, keep warm and carry out all his functions. The waste products that emanate from Man and the animals are fed back to the earth. The plants in turn absorb these as well as other elements present in the earth and through the action of sunlight, they produce further food for Man thus giving rise to a continuous cycle of changes. We can see from this brief account that both in nature and artificially, ceaseless and eternal cycles of changes exist on earth involving the processing of materials, their transfer and transformation to other forms of materials to yield products that provide Man with greater comfort and better quality of life. In short, we can summarize all the activities of Man on earth and his interaction and experience with nature as conforming to the well-known Biblical command that Man must "*replenish the earth and subdue it*" the title of today's lecture.[1]

Energy Considerations

A careful examination of all the processes earlier mentioned reveals that there is an underlying entity or agency required to effect these changes and transformations. That entity is called *energy*.

A short, concise and adequate definition of energy is difficult to achieve. Various people have defined it in different ways. Some have defined it as "*strength of expression*", others as "*internal power*" while others call it the "*agency needed to make things happen*"[5]. Another popular definition is "*energy is the capacity to do work*". We can look back through historical records and establish that the foundation for our present concept and understanding of energy was laid in the works of certain ancient masters who were philosophers and scientists.[5] Some outstanding examples were Aristotle the distinguished Greek philosopher and scientist whose treatise "*Physica*" is noteworthy. Ideas came from Leonardo da Vinci the eminent Italian artist, scientist and inventor and Galileo Galilei one of the most outstanding philosophers of the sixteenth century. Brilliant thoughts concerning energy also came from Sir Isaac Newton one of the greatest scientists and natural philosophers who ever lived. Limited time and space will not permit us to discuss the contributions of each of these past 'giants of knowledge' or even those of others who made significant contributions after them. However, we can state that a very big revolution occurred in the nineteenth century with the epoch making investigations of James Prescott Joule. He showed that heat energy was derivable form electricity and that mechanical work was convertible to heat. He made the first reliable measurement of the mechanical equivalent of heat. It is clear then that there are different forms of energy which can manifest itself in a variety of ways. The following forms are easily identifiable:

(a) *mechanical energy* - energy needed to accelerate a body from rest to a finite velocity.

(b) *heat energy* - kinetic energy of random thermal motion of matter on an atomic scale.

(c) *electrical energy* - energy due to charged bodies or due to the flow of electricity.

(d) *chemical energy* - energy of chemical bonds due to electrical forces in the atomic domain.

(e) *nuclear energy* - energy of nuclear binding due to nuclear forces.

(f) *gravitational energy* - energy due to mutual interaction of uncharged bodies.

(g) *light energy* - energy arising from electromagnetic radiation.

Role of Energy

Energy plays a crucial role in all of human activities. In fact, without making exaggerations, we can rightly claim that every single aspect of human experience whether it be something observed in the external world or what we do or what is done to us can be adequately described either as a transfer of energy from one place to another or the transformation of energy of one form to another. A few examples in our everyday life will illustrate this point.

In an electric power generating station, heat energy produced by burning oil or coal or any other fossil fuel is used to raise steam. This provides the power that drives the turbine which in turn drives the alternating current generator that provides electricity. When this is switched on in the home, the electrical current from the power station provides the energy that runs the bulb which gives out light or the electrical energy can in turn be transformed into heat for cooking.

Take another example in the running of a motor-car, the explosive mixture of gasoline vapour and air burns with the introduction of an electrical spark. This enables the chemical energy of the fuel to be transformed in part to the mechanical energy of the pistons. The motion energy of the pistons is transferred to the drive shaft and hence to the wheels for motion of the vehicle.

The winds of the gale and hurricane constitute another example of the transformation of heat energy communicated to the air into mechanical energy. We are all appreciative of the enormous amount of energy that are associated with winds and hurricanes and the destruction and carnage they can unleash in their paths.

The utilization of food in our bodies is another classic example of energy transformation. Following the swallowing of the food, the process of digestion in the body is rather complicated but it involves the breaking down of the food into simple units. The chemical energy locked away inside the simple units are then transformed into heat energy to keep the body warm or to mechanical energy in the muscles for motion of parts of the body or the body as a whole.

Laws of Energy Transformation

Having established that all human activities entail the transformation of energy, let us now devote a little time to examine the laws that govern the transformation. The first Law has its basis firmly rooted in Philosophy. All processes within human experience involve changes but in the midst of all these changes one entity stays constant, that entity is energy . This leads to a formulation of the law that whenever any change or process occurs the total energy is conserved that is the total energy before the process is the same as the energy after the process has occurred. There is "*constancy in the midst of change*"[5] - to quote a phrase. This can be re-stated as "*Energy can neither be created nor destroyed*". The law has been given different names such as law of conservation of energy, law of conservation of matter, First law of Thermodynamics, Fundamental law of Energy - to mention a few. Whatever name this law may be given, the effect is the same and human experience and all scientific investigations confirm its validity. Some everyday occurrences can be used to illustrate this principle.

A ball initially at rest on the roof of a building falls to the ground and collides with the floor generating heat and sound on impact. At the beginning, the energy of the ball is its potential energy by virtue of its position above the floor. On reaching the floor level (before impact), this energy is transformed into kinetic energy of motion. On impact with the floor the kinetic energy is transformed into heat energy and sound energy so at no time during the series of changes is energy destroyed or lost.

Take another example in the burning of wood. When this happens, this may create the impression that matter is lost or energy destroyed.

On the contrary, what happens is that the chemical energy released during the burning is transformed into heat energy and light energy while fumes of gases are produced as bye- products. If the gases are captured and retained, it can be established that the total energy released after the burning is the same as the initial energy before the wood burned.

These scientific changes that occur whether in matter in bulk or in the sub-atomic region which we shall see later led to the enuciation of the principle of equivalence of mass energy. This revolution in scientific thinking was generated by Albert Einstein the celebrated philosopher, scientist, and inventor - one of the most brilliant minds that ever lived. He put down in quantitative terms that matter can be transformed into energy and vice-versa - a further confirmation of the Energy Constancy Principle.

The Second Law to be considered places restrictions on possible energy transformations. One statement of it attributed to Kelvin and Planck[2] is that: *It is impossible to construct an engine that operating in a cycle will produce no effect other than the extraction of heat from a reservoir and the performance of an equivalent amount of work*". Another equivalent statement credited to Clausius[2] states that "*It is impossible to construct a device that operating in a cycle will produce no effect other than the transfer of heat form a cooler to a hotter body*". These two statements can be put simply by saying that when energy transformations occur, energy appears to pass from concentrated forms to diluted forms changing in such a way that the amount of work derivable from it decreases. The implication is that when we carry out energy transformations on the macro scale we can never attain 100% efficiency. If this second Law were not true, it would have been possible to operate a refrigerator passing heat from an ice-chest to the outside without the need of supplying external power (such as the electrical power needed to operate most refrigerators).

The deductions arising from these two laws are that whenever energy transformations occur whether in Physical or Chemical processes in the laboratory, or Engineering applications or Biological effects in nature, the transformations do conform to the two laws discussed above.

We now proceed to review the sources of energy available to Man and bring into focus the energy resources and reserves as well as the potentialities available to our great country. The sources can be classified into two major divisions namely Stored Energy Sources and Renewable or Continuous Energy Sources.

Sources of Stored Energy

There are two broad divisions to be considered. These are the fossil fuels and the nuclear fuels.

A Fossil Fuels

These are composed of organic matter mainly carbon and hydrogen with varying compositions of oxygen, nitrogen, sulphur etc. It is believed that thousands of years ago certain parts of the earth flourished with a lot of vegetation. Changes occurred that enveloped these in rocks and by process of compression over the years, coal, oil, natural gas etc. were produced.

Coal is the most abundant of the fossil fuel and the first of such to be utilized by man. It is used in open fires, electric power generating stations and as fuel in the steel industry and cement producing plant. It is estimated that the world reserves are in the region of 7.6×10^{12} tons[3] about 75% of which appear to be located in U.S.A., U.S.S.R. and China. Nigeria is blessed with coal with estimated reserves around 350 millions tons[4]. Unfortunately the use of coal has some disadvantages. Apart from the danger in mining, its combustion gives out products that not only create environmental problems but are hazardous to health.

At the present stage of world economy, oil appears to be the most significant fossil fuel because it is the most widely used. Refined products derived from crude oil find widespread use as fuel for locomotion in motor cars, railways, ocean going ships and aeroplanes and as fuel for running electric power generating stations. Other bye - products of oil include petrochemicals, paints and some synthetic products. Within the past two decades or so, Nigeria has risen to be one of the world's major oil producers and exporter with the result that an estimated 85%-90% of her foreign earnings now come from oil sales.

The geological history of formation of natural gas is very similar to that of oil, consequently, both are usually found in similar places. In comparison to coal, this is a clean and convenient fuel for heating and cooking as it is easily operated by turning a tap on or off. Apart from its domestic uses, it is a fuel for electric power stations and a valuable raw material for the large and growing petrochemicals industry. It has been established that Nigeria has a large reserve of natural gas which if properly harnessed would fulfil her needs for several decades to come.

Tar sands are sands which are impregnated with a heavy crude oil too viscous to allow recovery by flow into wells. One of the world's largest reserves exists in Alberta Canada. Recently, experts in our Department of Geology at the Obafemi Awolowo University, Ile-Ife established the existence of a large deposit of tar sands in the Ore area of Ondo State extending into Ogun State. Our attention is now being drawn to this precious resource not only as a source of energy but as a possible raw material for other industries.

Let us now examine briefly two other sources of stored energy namely Fission and Fusion.

B Nuclear Fission

A giant leap forward occurred in science during the third decade of this century with the discovery of nuclear fission by the eminent scientist Otto Hahn who was assisted at the time by Strassman. Lise Meitner and O. Frisch soon furnished the theoretical explanation. The discovery is that when a heavy nucleus such as that of uranium absorbs neutrons, it can fission into two intermediate nuclei yielding a large amount of energy. Some years later, a team of scientists at Chicago led by Enrico Fermi got the first nuclear reactor to operate successfully in a controlled manner thereby deriving useful energy from the process of fission. When uranium-235 absorbs neutrons it can undergo fission into two smaller nuclei releasing considerable energy and further neutrons. The neutrons so produced can be captured by further uranium nuclei which in turn produce further fission leading to a sustained chain reaction. If the chain reaction is divergent and left uncontrolled, it might lead to a violent explosion as in the nuclear bomb. However, if the chain reaction is controlled by careful use of moderators to slow down the neutrons and control rods to absorb them we have the nuclear reactors. The technology and use of a nuclear reactor are complex and demand a high level of scientific and engineering expertise. Such details are outside the scope of today's lecture. Suffice to say that the nuclear energy produced by reactors is used to generate electric power as in pressurized water reactors or boiling water reactors.

Another method of obtaining energy from nuclear fission is to utilize uranium-238 first bombarding it with neutrons to produce plutonium. The plutonium can then undergo nuclear fission as uranium-235 does to release a large amount of energy, fission fragments and more neutrons. The neutrons released can be used to make more plutonium-239 from natural uranium-238. Hence, we see that the reactor is made to produce fuel replacing the one it consumes - a process called *breeding*. All these have led to the building of the Breeder Reactor which requires more advanced technology than the ones mentioned earlier and is now being

developed not only as a source of nuclear energy but also as a means of generating further nuclear fuel from natural uranium- 238.

C Nuclear Fusion

The fusion of light elements offers another avenue for tapping the energy of the nucleus. Deuterons can fuse together under favourable conditions to produce Helium and yield enormous amount of energy. Three steps must be carried out to accomplish this task:

(a) The fuel must be heated to temperatures in the region of 100 million degrees.

(b) The fuel must be confined for a sufficient time to permit the release of more energy from fusion reactions than was required for the initial heating.

(c) The energy released from fusion has to be converted into a usable form.

At the present time, all three steps have been achieved in the hydrogen bomb. As for obtaining energy in a controlled manner from fusion, step (b) involving the confinement of the plasma presents the major problem. Attempts are being made to do this by the application of magnetic fields - magnetic confinement. Various massive experiments costing hundreds of millions of dollars are being undertaken on this aspect by the world's leaders in this area notably the U.S. and U.S.S.R. and names such as Tokomak T-3 toroidal confinement, Scylla IV open-ended *'theta pinch'* and 2X magnetic mirror experiments have now appeared in the scientific literature[6]. Recently, a new approach is being tried called *laser fusion.* Attempts are being made to cause fusion using intense bursts of laser light with the confinement time here being very short[12]. All the attempts made so far have not demonstrated that the derivation of useful energy from nuclear fusion is technologically and economically feasible.

Should a fusion reactor become a technological reality, it would offer fantastic advantages to mankind. A large quantity of energy similar to that of the sun would be available. The fuel source which would be the oceans is easily accessible and virtually inexhaustible. There should be little hazard from the generation of fusion power and there would be little or no damage to the environment. The efficiency of conversion is much higher than energy from any other source. The stakes are high and no wonder then that the world leaders in this area have invested heavily in the venture and are restricting the flow of information about their work.

Sources of Continuous Energy

The sources of continuous energy are by definition those that are renewed as fast as they are used. The energies derivable from them constitute vital links in the replenishment cycles of earth's resources. Three sources become clearly identifiable namely Tidal, Geothermal and Solar.

A. **Tidal Energy**

This originates from the gravitational, potential and kinetic energy of the earth - moon - sun system. It can be tapped from the coast line in regions where the sea is shallow particularly wherever high tides occur in coastal basins. By constructing a dam between the basin and the open sea, tidal energy can be harnessed and converted into electricity. Such plants are operating in France and U.S.A.

B **Geothermal Energy**

This is energy generated in the interior of the earth by various processes such as the decay of radioactive nuclei. Because the rate of heat flow from the interior to the surface is low compared say to the flow of solar energy arriving on earth, little attention had been paid to this energy source in the past. However, there are places in New Zealand and U.S.A. where electric power stations have been built harnessing energy from geothermal sources. Near to us here in Nigeria, Ikogosi warm spring comes readily to mind as a source of energy waiting to be tapped.

C **Solar Energy**

The sun can be regarded as a natural fusion reactor situated some 93 million miles away from the earth. Deep inside the interior of the sun where the temperatures are in millions of degrees, protons combine to produce helium giving off enormous quantities of energy. The energy released is converted into heat energy flowing towards its surface by convection and radiation. The surface of the sun is at a relatively lower temperature of about 5800°C. This energy is radiated to the earth in form of electromagnetic waves mainly as infra-red, visible and ultraviolet radiation. The amount of solar energy arriving on the earth is enormous and is estimated to be about 173 kilo billion watts ($173{,}000 \times 10^{12}$ watts). The solar energy is very vital to the survival of life on earth as we shall see shortly. The usage of solar energy on earth can be viewed in two broad aspects to which we can give the names Direct Utilization and Indirect Utilization.

(i) **Direct Utilization**

The embargo imposed on oil export by the Middle Eastern countries

in 1973-74 following the Yom Kipur War between Israel and the Arabs acted as a catalyst on the Western Industrialized countries in their search for alternative sources of energy. Energy from the sun is clearly one of the outstanding candidates for consideration because of some obvious advantages. First, the energy is there already being radiated to the earth copiously. Second, it is pollution free so its usage has minimal impact on the environment. This is unlike the burning of coal to tap its energy during which harmful gases are released and undesirable residues are left over. Third, solar energy is inexhaustible and is technologically feasible and practical for all climates. However, the major disadvantage is the discontinuity in its delivery because of the existence of nights and cloudy days. This implies that some means must be adopted for its storage to compensate for the "off" periods.

One of the major uses to which solar energy has been put is heating. By exposing plates of collectors of different shapes to the sun's radiation, energy is collected which can be used to heat water or even the homes in temperate countries. The energy can also be concentrated to produce fairly high temperatures in enclosures for drying agricultural crops etc. Solar energy has also been used with appropriate working fluids and heat pumps to cool homes. Solar energy is convertible to electric power by the use of photovoltaic cells which are semiconductor devices having the property of converting light energy to electrical energy without passing through a thermal stage. Each cell consists of a p-n junction which on exposure to sunlight generates electron - hole pairs that ultimately lead to the flow of electric current. Typical examples of solar cells in common use are made from cadmium sulphide, silicon etc.

(ii) **Indirect Utilization**

Indirect sources of solar energy on earth include winds, waves, water power and photosynthesis. Considering the first two, part of the energy from the sun falling on earth is converted into surface winds or ocean currents whose energies can be tapped with suitable mechanical devices. In some parts of the world, energy from the wind has been used for centuries either in wind mills or to operate pumps which deliver water for irrigation purposes. As for water power, the erection of a dam across a river has provided a means of obtaining hydroelectricity such as we have near us in Kainji.

1. **Photosynthesis** - One of the important biological processes is photosynthesis. It has taken place for millions of years and is the essential process for the replenishment of the earth by the provision of energy for plants so vital for the sustenance of life on

earth. It is the process whereby the solar energy of the physical world is transferred into storable biological energy which is then available for motive power of living things both plants and animals. Its special importance can be recognised from the fact that it spans the disciplines of Plant Physiology, Biochemistry, Photochemistry and Photophysics. A few words about the mechanism of photosynthesis is therefore relevant at this point. The overall process can be simply summarized by stating:

water + carbon dioxide + light = carbohydrate + oxygen.

From results of researches over the years and recent investigations still in progress elsewhere, it is generally agreed that the following three stages are identifiable as proceeding at the molecular level[7]

(a) Light is absorbed in form of photons by chlorophyll b and immediately transferred to chlorophyll a and then to certain 'light traps'.

(b) Part of the energy absorbed is used to oxidize water to oxygen Some of the energy is used in reducing nicotinamide adenine dinuclotide diphosphate (NADP) to (NADPH) while the rest is used in producing the energy rich compound adenosine triphosphate (ATP) from adenosine diphosphate (ADP).

(c) In the final phase, carbon dioxide is reduced to carbohydrate with NADPH supplying the 'reducing power' while ATP supplies the energy. This stage takes place in the body of the cell and proceeds in the presence of soluble enzymes. It is generally referred to as the *Calvin cycle.*

It is acknowledged that the mechanism of photosynthesis is more complex than here presented and not all the stages are clearly understood. One is also aware that various experiments are in progress some of which utilize laser light pulsed in the pico- second range to probe the details of the processes further and measure their rate constants.

However, we can make the valid conclusion that the effect of the overall process is that inorganic form of carbon is 'fixed' or converted into carbohydrate and for every carbon atom fixed eight photons of light are required.

We can now see that green plants obtain energy from the sun and carbon from the atmospheric carbon dioxide and by the process of photosynthesis produce storable chemical energy in form of food. Animals (herbivores) in turn obtain their own energy by eating plants. Some other animals (including man) obtain theirs either by eating the plants or the animals. Such a succession of eating and being eaten constitutes a food chain. The so-called wastes and products of respiration from these animals go back to the plants for replenishment in an endless cycle. There are several food chains the consideration of further details of which are outside the scope of today's lecture.

2. **Biomass** – Not all the products of photosynthesis are converted to food, some others are available as organic matter. Closely allied to the generation of organic matter is its utilization and utility as biomas. The structure of plants and animals is called *biomass.* It is an organic carbon based material which reacts with oxygen in combustion and natural metabolic process to produce heat. Biomass may be regarded as a source of renewable energy whose utilization poses little or no environmental hazards as its products do not pollute or damage the environment. Some of the methods by which biomass energy can be tapped are:

(a) Combustion which involves burning matter such as wood and peat.

(b) Pyrolysis which involves the heating or incomplete combustion of biomass in reduced amount of oxygen yielding such products as gases, liquids and solid residue.

(c) Fermentation - involving the fermentation of organic matter to produce ethyl alcohol which when mixed with petroleum becomes a fuel for internal combustion engines.

(d) Anaerobic digestion - involving the decomposition of organic matter in oxygen-free anaerobic surroundings to produce methane, carbon dioxide and nutrient-rich liquids. The advantage of this is that garbage accumulated as plant and animal waste enclosed in airtight container with the right kind of bacteria present becomes a source of biogas. This can be used as fuel for heating and cooking.

Energy Changes at the Atomic and Molecular Levels

Having discussed fairly extensively the material and energy resources available to mankind on the macro scale, let us now focus our attention on the consideration of energy changes and processes which occur within the atomic and molecular domain. The atoms and molecules that make up matter do continually undergo changes which are manifested in the re-arrangement, excitation or even ionization of the extra-nuclear electrons. We shall not bother about nuclear processes or changes for the present time. The interactions of the *'charge clouds'* or in chemical language *'orbitals'* of different atoms result in the formation of characteristic molecular bonds with the strength of each bond being a measure of its dissociation energy. The strongest bonds are the

Ionic and Covalent ones with bonding energies in the range 2 to 5 eV.

The excitation of atomic or molecular species can be achieved by the provision of energy in any of the following forms namely ionizing radiation, electromagnetic radiation, electric potential, magnetic field and heat energy. The absorbed energy when measured provides information about the absorption characteristics and the energy levels of the substance. In addition, the measurement of energy emitted following absorption, provides vital information about the structure, nature and constitution of the atomic or molecular species in question. The emission characterizes the atom in much the same way as the finger print characterizes the human being. In addition to electronic transitions which occur in atoms and molecules, they do perform vibrations and rotations whose energies are easily inferred from their emission spectra.

Earlier in this century, the work of Franck and Hertz firmly established that all atoms have discrete energy states and that during excitations atoms and molecules undergo transitions from lower to higher energy states while during the emission the transition is towards the ground state. The quantitative basis for these transitions lies in Quantum Mechanics a branch of Physics that started with the introduction of the Quantum concept by Max Planck. The underlying principle is that atoms and molecules absorb energy in discrete packets or quanta the size of a quantum being equal to the product of a universal constant *h* and the frequency of the radiation. The far-reaching consequences of the findings of Albert Einstein on photoelectric effect, Peter Debye on the specific heat of solids and A.H. Compton on photon scattering provided the validation of the Quantum concept. A new mechanics was thus created by incorporating the contributions of Erwin Schrodinger, Werner Heisenberg Max Born, Dirac, J.C. Slater etc. The Quantum Mechanics aided by its sister subjects Thermodynamics and Statistical Mechanics provides the quantitative tools which enable us to account for many atomic and molecular phenomena. As a result of its interdisciplinary nature, this field accommodates a wide spectrum of scientists ranging form Physical through Engineering to the Biological Sciences and names such as Quantum Physics, Quantum Electronics, Quantum Chemistry, Quantum Biochemistry and Quantum Biology have emerged.

Let us now consider those molecules which have been of special interest to me, the studies of which have taken a substantial proportion of my academic life. These are the polycyclic aromatic hydrocarbons.

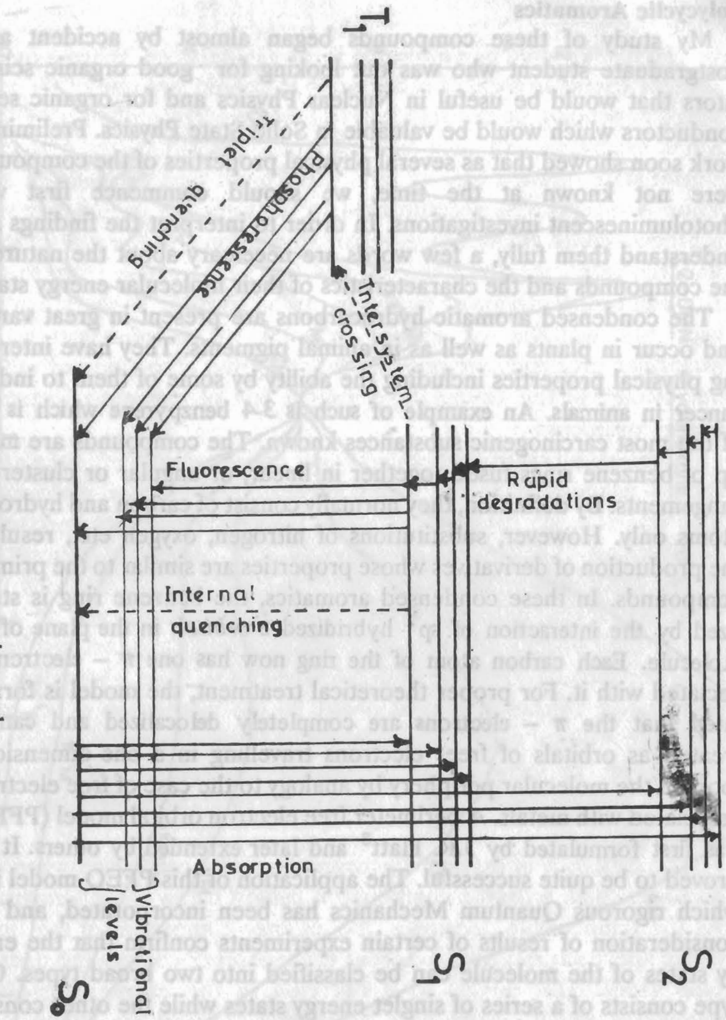


Fig. 1. Energy levels and the transitions giving rise to absorption and emission spectra.

Polycyclic Aromatics

My study of these compounds began almost by accident as a postgraduate student who was out looking for good organic scintillators that would be useful in Nuclear Physics and for organic semiconductors which would be valuable in Solid State Physics. Preliminary work soon showed that as several physical properties of the compounds were not known at the time, we should commence first with photoluminescent investigations. In order to interpret the findings and understand them fully, a few words are necessary about the nature of the compounds and the characteristics of their molecular energy states.

The condensed aromatic hydrocarbons are present in great variety and occur in plants as well as in animal pigments. They have interesting physical properties including the ability by some of them to induce cancer in animals. An example of such is 3-4 benzpyrene which is one of the most carcinogenic substances known. The compounds are made up of benzene rings fused together in linear, or angular or cluster arrangements. By definition, they normally consist of carbon and hydrogen atoms only. However, substitutions of nitrogen, oxygen etc., result in the production of derivatives whose properties are similar to the primary compounds. In these condensed aromatics, the benzene ring is stabilized by the interaction of sp^2 hybridized *σ orbitals* in the plane of the molecule. Each carbon atom of the ring now has one π – electron associated with it. For proper theoretical treatment, the model is formulated that the π – electrons are completely delocalized and can be treated as orbitals of free- electrons travelling in a one-dimensional loop on the molecular periphery by analogy to the case of free electrons associated with metals. A perimeter free electron orbital model (PFEO) was first formulated by J.R. Platt[8] and later extended by others. It has proved to be quite successful. The application of this PFEO model into which rigorous Quantum Mechanics has been incorporated, and the consideration of results of certain experiments confirm that the energy states of the molecule can be classified into two broad types. One type consists of a series of singlet energy states while the other consists of triplets with vibrational energy states superposed on the electronic levels. The photo- excitations that arise are due to the excitation of the π–electronic states (show slide). The singlet states are designated with the letter S with S_0,S_1 denoting the ground and first excited singlet states respectively. The letter T denotes the triplets in a similar way.

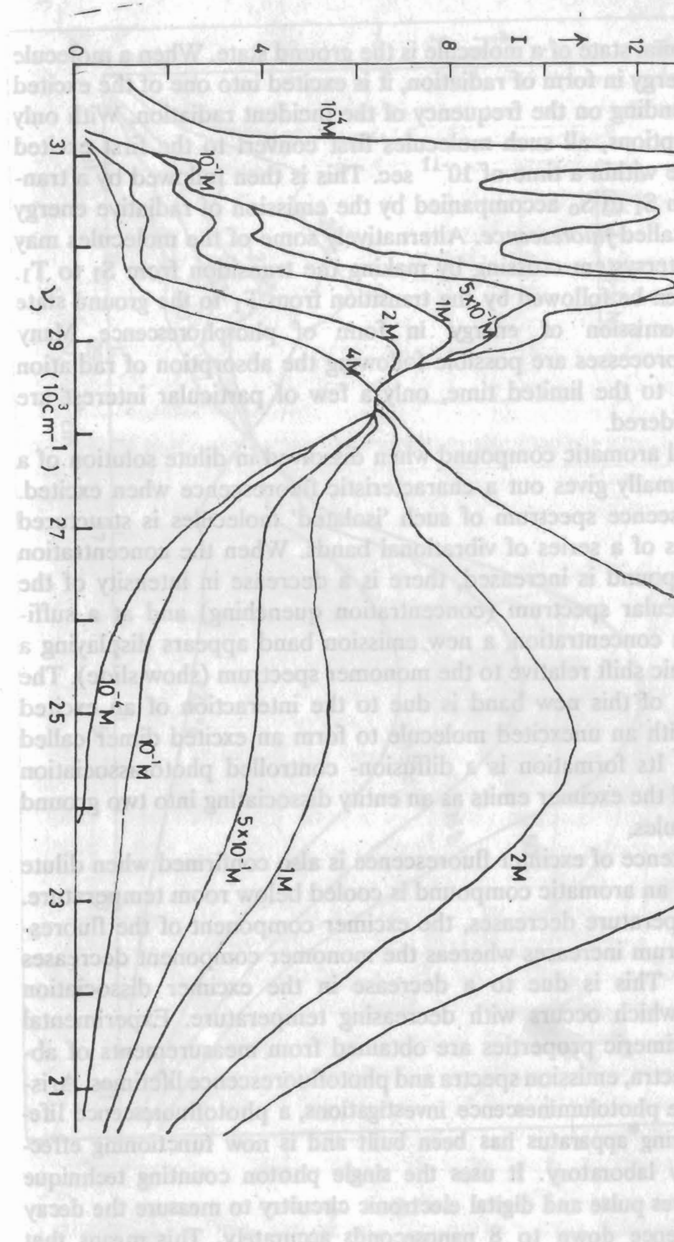
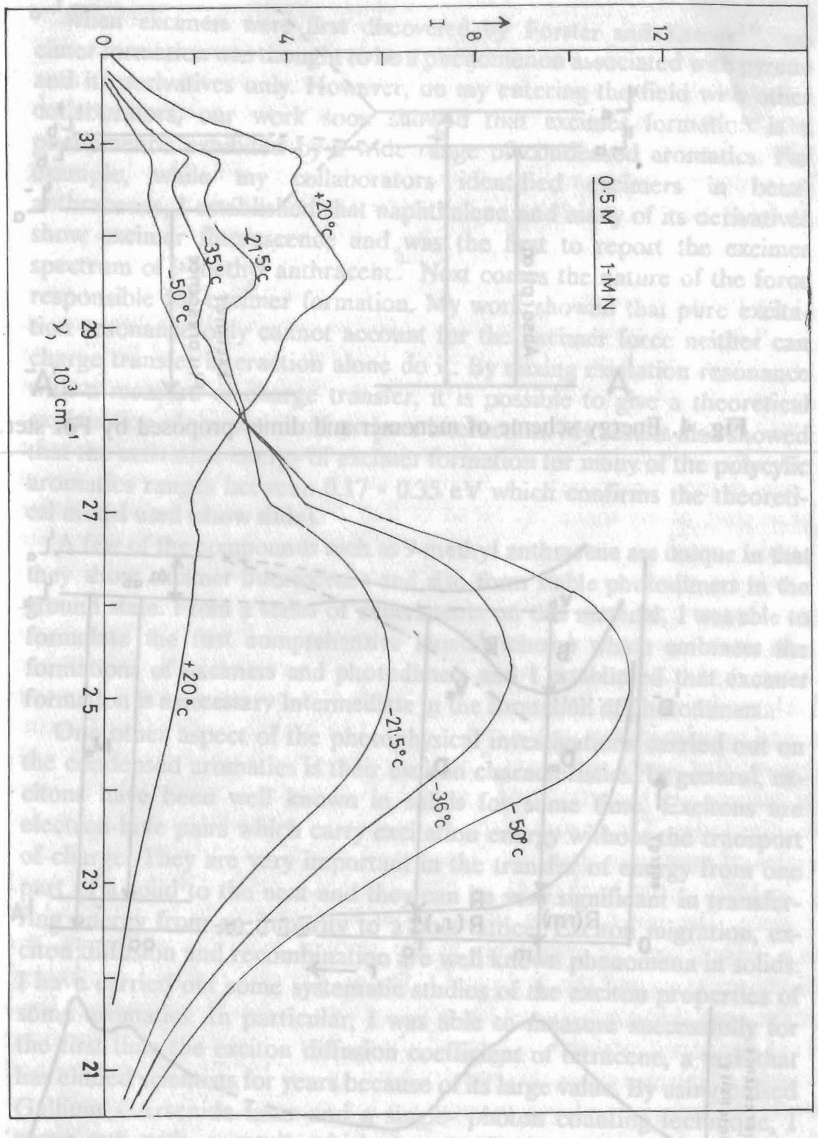


Fig. 2.

The normal state of a molecule is the ground state. When a molecule absorbs energy in form of radiation, it is excited into one of the excited states depending on the frequency of the incident radiation. With only a few exceptions, all such molecules first convert to the first excited singlet state within a time of 10^{-11} sec. This is then followed by a transition from S_1 to S_0 accompanied by the emission of radiative energy a process called *fluorescence*. Alternatively some of the molecules may undergo intersystem crossing by making the transition from S_1 to T_1. This can then be followed by the transition from T_1 to the ground state with the emission of energy in form of phosphorescence. Many molecular processes are possible following the absorption of radiation but owing to the limited time, only a few of particular interest are being considered.

A typical aromatic compound when dissolved in dilute solution of a solvent normally gives out a characteristic fluorescence when excited. The fluorescence spectrum of such 'isolated' molecules is structured and consists of a series of vibrational bands. When the concentration of the compound is increased, there is a decrease in intensity of the mono-molecular spectrum (concentration quenching) and at a sufficiently high concentration, a new emission band appears displaying a bathochromic shift relative to the monomer spectrum (show slide). The appearance of this new band is due to the interaction of an excited molecule with an unexcited molecule to form an excited dimer called an *excimer*. Its formation is a diffusion- controlled photo-association process and the excimer emits as an entity dissociating into two ground state molecules.

The existence of excimer fluorescence is also confirmed when dilute solutions of an aromatic compound is cooled below room temperature. As the temperature decreases, the excimer component of the fluorescence spectrum increases whereas the monomer component decreases (see slide). This is due to a decrease in the excimer dissociation parameter which occurs with decreasing temperature. Experimental data on excimeric properties are obtained from measurements of absorption spectra, emission spectra and photofluorescence lifetimes. Arising from the photoluminescence investigations, a photofluorescence lifetime measuring apparatus has been built and is now functioning effectively in my laboratory. It uses the single photon counting technique which involves pulse and digital electronic circuitry to measure the decay of luminescence down to 8 nanoseconds accurately. This means that molecular relaxation processes occurring within a few nanoseconds can be accurately monitored and measured and is the first of such equipment in this country.



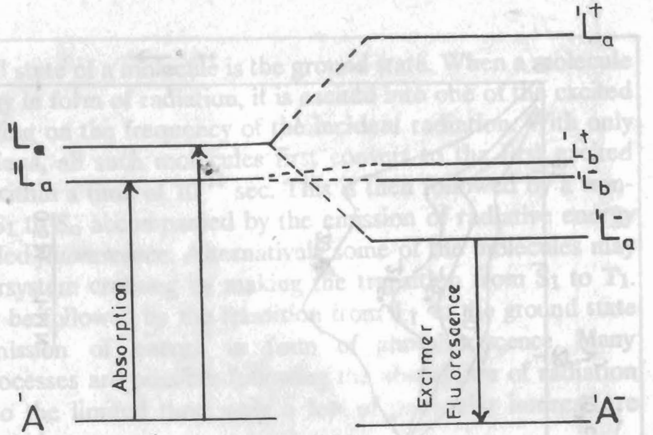


Fig. 4. Energy scheme of menomer and dimer proposed by För ster.

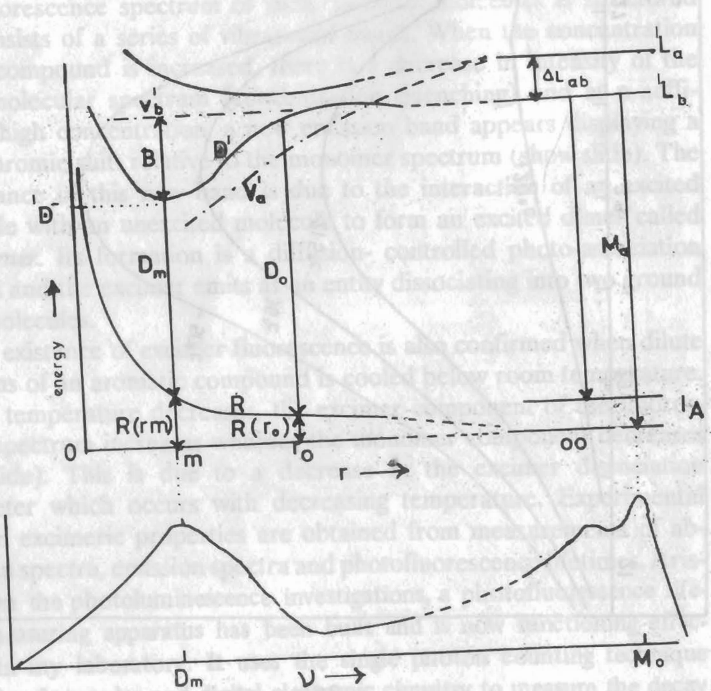


Fig. 5. Potential energy of ground and excited states as a function of intermolecular sepoaration r ($\propto = 0$).

When excimers were first discovered by Forster and Kasper[10], excimer formation was thought to be a phenomenon associated with pyrene and its derivatives only. However, on my entering the field with other collaborators, our work soon showed that excimer formation is a phenomenon exhibited by a wide range of condensed aromatics. For example, while my collaborators identified excimers in benzanthracenes, I established that naphthalene and many of its derivatives show excimer fluorescence and was the first to report the excimer spectrum of 9-methyl anthracene. Next comes the nature of the force responsible for excimer formation. My work showed that pure excitation resonance only cannot account for the excimer force neither can charge transfer interaction alone do it. By mixing excitation resonance with a measure of charge transfer, it is possible to give a theoretical explanation of the nature of excimer interaction. My results also showed that the activation energy of excimer formation for many of the polycylic aromatics ranges between 0.17 - 0.35 eV which confirms the theoretical model used (show slide).

A few of the compounds such as 9-methyl anthracene are unique in that they show excimer fluorescence and also form stable photodimers in the ground state. From a series of experiments on this material, I was able to formulate the first comprehensive kinetic scheme which embraces the formations of excimers and photodimers and I established that excimer formation is a necessary intermediate in the formation of photodimers.

One other aspect of the photophysical investigations carried out on the condensed aromatics is their exciton characteristics. In general, excitons have been well known in solids for some time. Excitons are electron-hole pairs which carry excitation energy without the transport of charge. They are very important in the transfer of energy from one part of a solid to the next and they can be very significant in transferring energy from an impurity to a host lattice. Exciton migration, exciton diffusion and recombination are well known phenomena in solids. I have carried out some systematic studies of the exciton properties of some aromatics. In particular, I was able to measure successfully for the first time the exciton diffusion coefficient of tetracene, a task that has eluded scientists for years because of its large value. By using pulsed Gallium - Arsenide laser and a single- photon counting technique, I came out with a result which is now being widely quoted in the field.[13]

If the question arises as to why a Physicist should bother to study the photophysical properties of these condensed aromatics, the answer is not far-fetched. Physics has the tools for making detailed studies of the nature of matter. The aromatics constitute a class among the simplest forms of organic matter found in living systems and hence are more amenable to detailed theoretical treatment. By understanding their physical properties fully, a big step forward would have been taken towards the understanding of the more complex molecules occurring in living systems and towards the understanding of life itself.

Concluding Remarks

It has long been realised that the key to our scientific advancement, economic development and overall progress as a nation lies in our ability to utilize optimally the various materials and energy resources with which the country is endowed. This is one of the major factors that motivated the Department of Physics in this University to start a new degree programme in Engineering Physics about six years ago at the start of my tenure as Head of that Department. The programme which provides options in Nuclear Engineering and Materials Science includes a core of courses in traditional Physics and selected options in Engineering type courses. The spectrum of coverage spans Energy, Nuclear Science and Engineering, Properties of Materials, Techniques and Applications in Science. Even though a relatively short time had elapsed since the Programme was started, it has made some concrete and positive impact on the community. This is a big credit to the Department that works as a team. The programme has been very popular with students and has attracted some of the best students entering the Universities today. The impact of the Programme is also reflected in the statistics of graduates from the Department which rose from the level of 7 in 1976 to the level of 41 in 1980 and has remained within that level since. The initial groups of graduates have proved to be attractive to a wide range of employers in the growing industries of Nigeria, the Polytechnics and the Technical Colleges. Reports received concerning the ones that went abroad for postgraduate studies show excellent level of academic performance in all cases. Departments of Physics from other Universities in the country have visited Ife for consultation and to obtain copies of our programme for guidance in their possible initiation of similar programmes. In all, we are convinced that while we might not have produced Engineers who would be immediately registrable professionally with the Council of Registered Engineers of Nigeria (C.O.R.E.N.), we have produced Applied Scientists who are able to fulfil vital roles in the country's economy.

The lecture today has shown that energy and materials constitute an inseparable entity. While we need materials to replenish our country, we need energy to subdue it and generate new materials. Results of various surveys and scientific investigations have confirmed that Nigeria is blessed with a rich store of materials and energy resources the types that if optimally used can transform it into one of the greatest countries on earth. Mention any element or energy resource and you would find that Nigeria has it. However, if the question is asked as to how these resources have been utilized so far, the answer is likely to be that we have not done what we should but we have wasted those resources we should not and there is no "economic health" in us. For the past decade or so, Nigeria has leaned heavily on a single resource - Petroleum which yields at least 80% of its foreign earnings. It is even doubtful if Nigeria derives full benefits from the oil as most of the sensitive technological aspects of the industry are effectively controlled by foreigners. Nigeria also burns off its rich store of natural gas. All these must stop if we are to survive the present and live to the future. We must develop other resources and re-cycle our materials for best results.

We are aware of the fact that Government is building 'Thermal Power Plants' which will utilize the natural gas for the production of electricity and we congratulate the Government for advancing us gradually into the steel age with the building of steel plants in various parts of the country. We welcome the fact the Federal Government has established a Ministry of Science and Technology and note that a new bill for the establishment of an Energy Commission is now before the National Assembly even though the contents of the bill are not yet published. All these are steps in the right direction but we must still do more. Realizing that time is against us with our rapidly increasing population, our rising level of demand for material comfort and our expensive taste we must now push vigorously the programme for optimal utilization of our materials and energy. The following suggestions would be useful:

(1) Government must now formulate a well articulated and comprehensive policy on Energy and materials resources. It should begin by providing a detailed catalogue of the various resources, their location and extent. It should state how the resources are to be tapped, as well as a programme of how each one can be optimally used. As no single person or group of people has all the knowledge, inputs should be invited from a wide range of people such as Physicists, Chemists, Engineers, Ecologists (for environmental implications), Social Scientists, etc.

(2) The teaching of Energy and Materials Science in the Universities should be encouraged with provisions of adequate funding and equipment. Experience here in Ife has demonstrated the value of such a programme. A lot of well-trained and qualified personnel would be needed in the country not only in the Industries but also to staff a National Research and Development Centre should the Government decide to create such an Institution. The Universities which are already experienced in personnel training generally, have a vital role to play in this regard.

(3) The impact of Energy and Materials is felt by all human beings, hence, an elementary knowledge about them by all and sundry then becomes highly desirable. This will furnish the correct orientation towards energy conservation and proper utilization of materials. As a step towards achieving this goal, I will recommend that every student who enters the University should receive a very elementary course in Materials Science and Energy. No eyebrows should be raised at this suggestion as one does not have to do any College Mathematics to understand the basic concepts and appreciate the fundamental ideas.

(4) A controversy was raging some months ago concerning whether or not Nigeria should develop her Nuclear Energy resources. In my view, the country has no other choice but to do so and Government should do all in its power to ensure its success. It is now clear that the country has a substantial reserve of uranium which should be mined and processed as our own nuclear fuel. We must avoid a situation which will fritter away this vital resource to foreigners and leave us with nothing to use in future when our level of technology becomes high. The point should also be noted that apart from vast quantities of energy available from nuclear sources the benefits and spin-offs from nuclear science and technology to other areas of human activities are immense.

(5) Government members particularly those who formulate and execute policies that relate to Energy and Materials, and legislators are welcomed to visit our Universities, see the scientists and science related professionals at work and interact closely with them. Such interaction has a mutually beneficial effect.

The implementation of these suggestions would go a long way towards our goal of continually replenishing Nigeria and making it a technologically strong and viable country.

Acknowledgments

I wish to thank all those who taught Physics at the University of Ibadan in the late fifties. My special thanks are due to all those who taught the subject in Manchester University in the early sixties. Among the latter group, I take this opportunity to pay a special tribute to the blessed memory of my teacher, colleague and friend Dr. J.B. Birks (deceased) who introduced me to Atomic and Molecular Physics and inspired me to pursue the interdisciplinary areas of science. A special dedication is made to the memory of my late father who has always supported me with his prayers while on earth and is still doing so now while he is in the community of God's servants in heaven.

Bibliography

1. The Christian Bible: Genesis Chp. 1 vs 28
2. Zemansky, M. W.: *Heat and Thermodynamics* McGraw Hill Pub. Co.
3. Thorndike, E. H.: *Energy and Environment: A Primer for Scientists and Engineers* Addision - Wesley Pub. Co.
4. Afonja, A.: Towards a Comprehensive Energy Policy for Nigeria Proceedings of the Energy Policy Conference in Jos, Aug. 1978 p.241
5. Lindsay R.B.: *Energy: Historical Development of the Concept* Dowden, Hutchison & Ross Inc. Publishers.
6. Post R.P.: Prospects for Fusion Power *Physics Today* April 1973, p.30
7. Levin, R.P.: *The Mechanism of Photosynthesis. Scientific American* Vol.221 No.6 p.58, Dec. 1969
8. Platt, J.R.: *Classification of Spectra of Cata- Condensed Hydrocarbons*. J. Chem. Phys. Vol.17 No.5 1949
9. Birks, J.B.: *Photophysics of Aromatic Molecules* Wiley Interscience Publishers.
10. Forster T. and Kasper, K.: Zeit fur Electrochem. Vol.59, p.977 1955.
11. Aladekomo J.B. & Birks, J.B.: Proc. Roy.Soc.A284, 551 (1965).
12. Nucholls, J. Emmett, J.and Wood, L. : Laser Induced Thermonuclear Fusion. *Physics Today* August. 1973 p.46.
13. Aladekomo, J.B., S. Arnold and M. Pope: Triplet Exciton Diffusion and Double Photon Absorption in Tetracene. Phys. Stat. Sol. (b) 80, p.333 (1977)
14. Butler, P.A.: New Transuranic element. *Physics Bulletin* Vol.32 No.9 p.283 (1981) (British Inst. of Physics Pub.)