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CHEMISTRY IN THE ECONOMIC DEVELOPMENT OF NIGERIA.

by: O.L. OKE

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HISTORICAL BACKGROUND

In the beginning was the world, and the world was mysterious and the world was simple — trees were trees, mountains were mountains, water was water. Then came man and trees were no longer trees, mountains were no longer mountains and water was no more water. All these transformations took place through the ancient art known as alchemy. The name is derived from the Greek word "Kemeia" used at about the 4th century A.D. to designate the arts of metal working especially with reference to the supposed making of gold and silver from base metals. Under Arabian modification Kemeia became 'Alchemeia' and subsequently alchemy which includes all the chemical arts in general. These arts started in Egypt under the control of the priesthood and were carefully guarded and surrounded with secrecy and mystery.

Ancient Man concentrated his efforts on three aspects of life: food, medicine and ornament. He was able to collect wild plants for food and succeeded in domesticating some and so this aspect of science has received the least attention even up to the present day. I am sure that if my great, great, great grandfather should suddenly appear on earth today he would be completely lost about the incredible scientific development since his days (aeroplanes, cars, the telephone etc). The only time he would probably feel at home is when we are at table with the usual pounded yam which he was used to in his time!

Yet many changes have been brought about by Ancient Man's devoted attention to health and adornment. Thus in 1530 Henry Cornelius Agrippa in his work on 'The Vanity of the Arts and Science' quoted the proverb that 'every alchemist is a physician or a soapboiler'. The manuscripts which constituted the modern literature in chemistry originated from the so-called physicians, while the soapboilers were not interested in writing papers but only in the transmutation of base metals to precious metals for ornamental purposes, and how to perfect their chemical arts. In most cases their process involved using sound chemistry e.g. according to Theophrastus white lead was used as a pigment and externally in medicine. It was obtained from vinegar in closed vessels for 10 days after which the rust was scraped off and the process repeated. The product was powdered, boiled for a long time in water and allowed to settle. This is similar to the common so-called Dutch process for the manufacture of white lead! Theophrastus also discussed extensively the natural odours in general, the causes and sources, and described the making of perfumes and unguents and of various spices and odours and oils used as vehicles for retaining the perfumes. Although no distillation was used, the application of the water-bath principles was used i.e. using vessels standing in water but not in direct contact with fire so as to reduce considerable waste which would otherwise occur and to prevent the perfume from acquiring a burnt smell. The perfumes were mainly for Parthian Kings and were referred to as regal unguent.

Berthelot analysed a small votive figure from the excavations at Tello in ancient Chaldea, about 3000–4000 BC, and found it consisted of nearly pure copper. He also found that a small cylinder from Egypt, of about 4000 BC, was made of pure copper. This means that the mining and metallurgy of copper is at least 5000 years old. Similarly bronzes of copper and tin were found by Schliemann in the ruins of Troy, dating back to 2000 BC which, strange enough, consisted of constant composition of about 89% copper and 11% tin. The discovery of glass jars, glass figures and ornaments from Egyptian tombs indicates that glass-making is a very ancient art. The glasses were even coloured blue with cobalt, oxide and copper silicate; green with copper carbonate; red with lead and iron oxide; black with boneblack mixed with a little gum; yellow with iron salts; and pale rose with some organic dyes. More interestingly, Davy found that he could reproduce the blue glass by fusing together a definite amount (15 parts) of sodium carbonate, 20 parts of powdered flint and 3 parts of copper fillings.

Although, as I mentioned earlier, most of these processes involved a sound knowledge of chemistry, and no attempt was made to find out the theoretical aspects of the work.

However, philosophers like the great Aristotle made a considerable contribution towards the development of the theory of matter and its changes. Aristotle stated for example that sea water could be made fresh by percolation through clay; he believed that all substances might vary in properties according to the proportion of the four (Aristotelian) elements, of fire, air, earth and water, contained in them.

As time went on, the economic development in the Middle Ages reached a stage where gold became the main symbol of wealth and so all efforts were concentrated on making gold and the soapboilers started working in vain to achieve the aim which the physicians (philosophers) had led them to believe was possible such as the 'elixir of life' or the real transmutation of metals. Thus several methods were invented for making gold and according to Stilman, 'to augment gold, take Thracian cadmin (i.e. impure zinc oxide containing lead and copper oxide) and make the mixture with the cadmia in crust equal parts to that of gold. When the gold has been put into the furnace and has become of good colour throw in these two ingredients, and removing (the gold) let it cool and the gold will be doubled.'

Naturally with such economic boom there will be many crooks and alloys will be sold as gold. Methods were therefore devised for testing the purity of the gold by means of the colour, the weight (i.e. density) and the streak made by rubbing the metal upon touchstone (a black silicious stone). According to Pliny, experts could tell to a scruple how much silver, gold or copper was present, 'accuracy being so marvelous that they are never mistaken'.

Oyster pearls were also declared valuable. A curious method given for whitening pearls was that of causing it to be swallowed by a cock, afterwards killing the cock and recovering the pearl after which it would be found to be white. Artificial pearls were made as follows: 'mordant or roughen crystals in the urine of a young boy and powdered alum, then dip it in quicksilver and a woman's milk'.

This shows you how far and how deep people can think when there is an objective in view, even without theoretical knowledge.

Around the 13th century, due to the crusades, the Western scholars were brought into contact with Grecian classical literature as well as with Byzantine developments. Eminent scholars such as Roger Bacon and Marco Polo arose and universities commenced to be founded such as those at Naples, Mont Pelier, Paris, Padua, Oxford, Cambridge and Orleans. New ideas and interest started to spring up in chemistry, especially about the origin of metals from quicksilver (i.e. mercury) and sulphur. Unfortunately the progress was not as fast as it could have been because the alchemists became very important and swollen-headed and started to claim that they could definitely make gold and even prolong life indefinitely. Often their claims were associated with magical invocations and mystic charms, so much so that in 1317, Pope John XXII issued a decree to ban their activities and so did Charles V of France in 1380 forbade the possession of instruments and furnaces for alchemical operations. A similar decree was made in 1418 in England by Henry IV. This was a pity because it was at this stage that philosophers started thinking seriously about the theories of matter, occassionally backed by experiments, inspite of the fact that the logic was wrong Arnaldus for instance opined that ice or snow is converted by action of heat into water. Therefore it was first water, then snow or ice. But all metals can be converted into quicksliver, therefore they were first quicksilver ... therefore transmutation of metals is possible and easy. In the Same way it can be shown that the multiples of metals is possible: for everything that is born grows and multiplies as is clear with plants and trees. For from one seed a thousand seeds are procreated, from one tree proceed infinite shoots from which are produced a various and infinite number of trees and thus their number is increased and they multiply. But metals are born in the earth and grow, therefore augmentation and multiplication in these is possible, even to infinity ...' Later in the 16th century Paracelsus contributed a theoretical concept of the Trial Prima which had a pronounced influence over the subsequent centuries. The idea was that all matter from metals to man was made up of three principles; sulphur, mercury and salt. The combustible principle is the sulphur, the part that volatilises is mercury and the residue which turns to ashes is salt. It was Paracelsus who first pointed out to the physicians and soapboilers the importance of chemical experimentation and observation in the development of medicine. He encouraged the physicians and soapboilers to channel their efforts into more important fields than the search for gold-making. His estimate of the place of chemistry in medicine is illustrated in the following: 'Now further to the third foundation on which medicine stands, which is alchemy. When the physician is not skilled and experienced to the highest and greatest degree in this foundation, all his art is in vain. For nature is so subtle and so keen in her matters that she will not be used without great art. For she yields nothing that is perfected in its natural state, but man must perfect it. This perfecting is called alchemy. For the baker is an alchemist when he bakes bread, the wine grower when he makes wine, the weaver when he makes cloth. Therefore whatever grows in nature is useful to man, whoever brings it to the point to which it was intended by nature, he is an alchemist.' A prodigious collection of new production was obtained and introduced into medicine. The stock of chemical knowledge now began to accumulate with considerable rapidity.

By the 17th century there were sufficient experiments and observations indicating natural forces, rather than intervention of supernatural agencies, to warrant the search for these natural forces and to see whether the processes follow particular laws and processes. Then came one of the greatest chemists ever known, Robert Boyle. He is credited with being the first chemist to study chemistry for its own sake and not as accessory to medicine or any chemical art. After a series of experiments in sealed flasks, he proposed that the gain in weight of metal when heated was due to 'fixed fire substance'. He became a Fellow to the physics of air and experiments with various chemical reactions in air. Chemistry became more and more a subject to be reckoned with instead of being an appendix to medicine. In the 18th century came men like Stahl, Scheele, Black, Priestley, Cavendish and Lavoisier with the "Phlogiston" theory in an attempt to explain the theory of combustion, oxidation and reduction.

In the original theory Stahl claimed that metals are a combination of calx and phlogiston and on combustion they lose the phlogiston, leaving the calx. When however, the calx is heated with substances rich in phlogiston, such as oils, sulphur or charcoal, the calx recombine with the phlogiston to form the original metal. This was the first time that the theory of oxidation and reduction was elucidated.

As the knowledge increased people became more and more curious about some of the natural phenomena they observed and this led to the discovery and isolation of oxygen by Scheele who called it 'fixed air'. Cavendish proved that this fixed air ("dephlogisticated air) combines with "inflammable air" to form water. He considered the inflammable air as the phlogiston and hence we have Dephlogisticated air (Oxygen) = water deprived of phlogiston (i.e. hydrogen). This was the beginning of the overthrow of the phlogiston theory and it was from there that Lavoisier formulated the modern principles of oxidation and reduction, and then slowly the energetics of reactions. Then came Isaac Newton with his theory of chemical affinity – 'similia similibus' or like likes like and he started off the idea of chemical reactions in terms of mechanical forces i.e. as an attraction producing motion of some kind among the minuter particles or atoms of bodies. Thus chemistry was defined as 'the art of changing bodies by solution or coagulation – either the separating of parts before united, or uniting parts before separation, that is either the adding of bulk to bulk of separation of bulk from bulk – all operations therefore which chemistry performs on bodies are mere changes in respect of motion'. Then came Lomonossoff who approaching chemistry from the point of view of the physicist and mathematician, opined that changes of matter should be capable of explanation on the basis of mechanics, that they are due to the motions of the constituent particles. Dalton's concept that elements were composed of homogenous atoms of constant weight and that compounds are formed by combination of these atoms in definite simple proportion opened the way to our atomic and molecular theory, while the extension of electricity to chemical experimentation and theories by Davy, Faraday, Berzelius etc. led to a lot of curiosity and more research as well as a widening of the field of chemisty in the 19th century.

CHEMISTRY AS A PURE AND APPLIED DISCIPLINE

I have gone into all these details above in order to give a background to how chemistry first started as an ancient practical art (i.e. mission oriented,) and later grew when enough data were accumulated, stimulating sufficient interest for people to study the laws governing the observed phenomena (i.e. the theoretical aspect or curiosity oriented). Thus in this 20th century chemistry is practised either in terms of curiosity oriented research i.e. pure or basic research for which no application is apparent or else mission oriented research i.e. a field where application is evident. It is possible to ascertain how much curiosity oriented research has contributed to the economic development of an industrialised country by identifying key discoveries with profitable applications and estimating the economic benefit if it was discovered later. For example, let us consider the Chorleywood process of manufacturing bread where mechanical work with chemical improvers, is now substituted for yeast fermentation, resulting in a much faster reaction, saving a lot of time and money. Now, the effect of mechanical work was described by mission-oriented workers in the USA around 1926 but this could not have been taken advantage of in the UK at this time without the aid of chemical improvers such as ascorbic acid as was found by mission-oriented researchers. Ascorbic acid was accidentally discovered in 1920 by empirical researchers but its availability depended on the organic chemistry of the 1930s, and even if this was not available other compounds would have been used. Although if sufficient funds were available to the British Bakers Association the process could have been commercialised earlier but there is nothing to suggest that curiosity-oriented research could have had any accelerating effect. In a simialr way Gibbons *et al* (1970) considered several other key discoveries such as float glass, cryogenics, nuclear power, silicones etc. and concluded that it is very rare to pinpoint specific curiosity-oriented research from which wealth-producing applications are derived. This does not conclude that curiosity-oriented research is useless in economic terms, as occasionally ideas which arise unpredictably are sometimes applied later in industry. When in 1840, Faraday at one of his famous lectures was illustrating the peculiar behaviour of a magnet with respect to a spiral coil of wire connected to a galvanometer that would indicate the flow of current when the magnet was brought near and none when the magnet was withdrawn, a member of the audience, at the conclusion of the lecture asked him, 'Mr. Faraday, the behaviour of the magnet and the coil of wire was interesting, but of what possible use can it be?' Faraday answered politely 'Sir' of what use is a new born baby? Yet it was that same phenomenon Faraday employed to develop electrical generators which for the first time made it possible to produce electricity cheaply and in quantity and also to build electrified technology today. Isaac Asimov concluded 'we can only make the general rule that, through all of history, an increased understanding of the universe, however out-of-the-way a peculiar bit of new knowledge may seem however ethereal, however useless, has always ended in some practical application (even if sometimes only indirectly)'. The question is: are we in the developing countries prepared to wait?

My opinion is that time is against us, our efforts toward economic development cannot afford the luxury of curiosity-oriented research (at least to a large extent) and even the traditional pure chemistry teaching at the universities without modifications to include the applied aspects is not needed. What we really need is technological science (chemistry) in both our schools and universities in order to ensure relevance. I agree with Professor Awokoya that we cannot make our best scientific contribution to the economic development of our society solely by teaching the chemisty, physics, biology and mathematics the way it is being taught today in our universities and secondary schools. Rather, such instruction should complement strong agricultural, medical and technological core which responds directly to the essential needs of the country. We in the developing countries feel that science (especially chemistry) has contributed greatly to the economic development of the industrialised countries and so we assume that expansion of scientific research and teaching (as is done in these countries) will automatically lead to wealth. We have failed to realise that the majority of these basic sciences derive most of their impetus and motivation from these technologies, and also these industrialised countries with only 25% of the world's population have between 80–90% of the world's research power. If we therefore teach the basic sciences the way it is done in these countries without modification, and conduct similar research, it means our products will be more suitable for these countries than ours. I suppose this is one of the major causes of brain drain in developing countries.

Anyone intending to do research in the area of applied chemistry must have an objective in view whereas in an area of pure chemistry (if you really want to become a star) you usually have no choice but to jump on the band-wagon of the most topical subject in that area. The topic may be one initiated by an eminent scientist which would have been described by the experts as the hot spot for potential stars. The fact that all the big names in chemistry are in the area would be sufficient to attract young potential researchers who after obtaining their Ph.D. would be reluctant to change their field, and indeed, they, in turn will attract more people into the field. Unfortunately most if not all of these initiating ideas come from the Western Countries and none from the developing countries. Even if we try to initiate one here it will be difficult for it to filter through because we have not got the manpower, the team, the equipment and the necessary funding and influence to project such ideas. Ideas initiated by eminent scientists are more readily accepted and diffuse more rapidly down the line than those from elsewhere. In this case the aim of the chemist is not economic development of the country, but the development of chemistry. What tends to happen in developing countries therefore is a scientific capability which is not oriented to local needs but which instead 'is pursuing (and often failing to reach) the fashionable, fleeing coat-tails of the international scientific community'.

Let me make myself very clear. I am not saying we should stop or discourage research in basic or fundamental chemistry – the necessary foundations for the scientific capability and scientific standing of the country. What I would not like to see is a situation in which we build up a strong and successful indigenous scientific capability that results in 'internal brain drain'. This will happen unless policies for science in the national interest are equally strong.

Those of us in the research business in Nigeria know under what difficult situations we are working and in many cases the country does not appreciate or understand what we are doing. We are criticised and told that our work is not relevant and that we are living in an 'Ivory Tower'. Whenever there is an economic crisis the university is the first place to feel the pinch — drastic cuts in research and teaching equipment, no vote for chemicals, no travelling funds for conferences etc. Unlike the industrialists in industrialised countries, our industrialists do not see the value of our research and ignore the impact it could make in industry. Therefore they are unwilling to pump any money into research and development. This is not amazing, anyway, if one realises that most of the technologies and the raw materials are imported.

This discrepancy observation does not apply only to university education by the way, it is analogous to what obtains in our schools, especially in the rural areas where the gap between the culture in school and home is made so great and school work becomes so remote from the experience of the child that the value of an education resides in a piece of paper for obtaining a job. This leads to a type of inflation. Education becomes devalued and the more devalued it is, the greater the struggle to get it. The result is that holders of the West African School Certificates will start doing the work of skilled labourers and those with degrees, the job of school certificate holders.

MISSION OF THE CHEMISTRY DEPARTMENT

My own idea is that the mission should be threefold:

(1) To teach the science of chemistry by imparting knowledge of the occurence, properties, behaviour, reactions, applications and uses of substances found in nature or made by man, together with the underlying laws and principles

(2) To conduct, with advanced students, research aimed at discovering new knowledge when it appears that such knowledge may be useful and

(3) To make application of existing knowledge in the development of new products and processes, and in the solution of problems in production.

MY CONTRIBUTION

The question that has often bothered my mind is whether the undergraduate courses should be tailored to provide a purely vocational training, or instead be broadened so as to make them more relevant to the graduate who decides not to pursue chemisty professionally. In the former case one is not sure how far it could, or should be achieved in a rapidly changing employment situation. Broadening of the courses may lead to greater flexibility in students' career planning and to greater job motivation. My own feeling is more towards some rather radical innovations in undergraduate courses that could better serve the interests of our students in the context of modern industrial societies. Let me therefore discuss the proposal that I have engineered in my department.

The objective is that chemistry students should be trained within their 4-year degree programme in as practical manner as possible to tackle national problems and assist in the development of the economy. Colour and polymer chemistry is linked with industries traditional to Nigeria, and represents by far the largest avenue of employment in industrialised countries. Nutritional chemistry is extremely important in view of the colossal number of food industries springing up in the country. Analytical chemistry interacts closely with all branches of applied chemistry. Other areas such as pulp and paper chemistry etc. exist and are of interest. The idea is that at relatively early stages students should be given a broad survey of the field so that they can see their selected area of applied chemistry in perspective. In order that they can intelligently proceed to the applied aspects of the subject, students are first given a broad-based grounding for three years in pure chemsitry. In their second year the students are introduced to a course of the 'applied' type which is a wide-ranging survey of scientific and economic aspects of chemical industry which will be given by an industrialist. The long vacations of the second and third years will be spent in industry (a total of 6 months). The final year will then be devoted entirely to subject in the applied areas. Thus, though the coverage is broad, an overriding purpose is clear, and breadth is achieved without sacrificing intellectual coherence.

A graduate of the calibre we now propose to produce will be versed in chemistry with an applied orientation. Such graduates will be in demand both at national and international levels, and could help the country in many ways:

(i) They could help to reduce importation of food by applying their knowledge of food storage, preservation and processing, and producing substitutes from locally available resources. They could also assist the economy by converting waste products of agriculture and the food industries into animal feeds and human food.

(ii) Since these graduates would have done a three-year course in pure chemistry, they would, if the need arises, be suited to the teaching of chemistry (and probably also physics and mathematics) in secondary schools. Now that there is a rethinking of the content of science education in developing countries, the programme highlighted above will give us the singular advantage of producing professionals who will be able to promote the long-needed industrial chemistry and initiate nutrition programme in schools, colleges and Teacher Training Institutions. The proposed programme will therefore be a contribution to general education.

(iii) Such graduates should be in high demand in food industries, research establishments, hospitals, extension services, advisory services etc. and will be better prepared to contribute to the national economy.

Similarly, we have postgraduate courses (M.Sc. and Ph.D.) in Applied Chemistry. Students have been trained in my own area of research which is mainly nutritional chemistry relating to protein-energy malnutrition in Nigeria – a very complex problem which is probably the most serious one for children of today and could, in some developing countries, claim the lives of 50% before they are 5 years old. In my view one of the effective methods of solving the protein problem in Nigeria is through the introduction of unconventional types of food. The conventional type of agriculture has served the human race for centuries but there is reason to think that this system will not continue to be adequate indefinitely. Chemistry can make as great a contribution to civilisation in the next decade as agriculture has done for the past 9,000 years. This is because, through the knowledge of chemistry, man can now synthesize from non-living things most of the substances which are essential for human nutrition e.g. essential amino acids, vitamins etc. Other products like dye stuffs, resins, plastics, rubber, fibres etc. which were only available from plants are now synthesized in wide ranges and most of them have either displaced or are competing successfully with the natural products (McPherson 1965).

Every year about 250 new cases of protein-calorie malnutrition in children are seen at the University Teaching Hospital, Ibadan and about 300 at Ilesa. The disease is mainly due to low protein, high carbohydrate diets. Apart from growth, severe protein deficiency in children leads to *Kwashiorkor,* a disease which is prevalent throughout Africa.

One may argue that the obvious remedy for protein deficiency is to eat more of the conventional protein-rich foods such as meat, fish and dairy produce. However, consumption of these is restricted in Nigeria by a combination of inavailability, price and taboos. Since green leaves are abundant in Nigeria, it seems that the elimination of the fibre by extracting the protein from the leaf may offer the cheapest and most convenient method of supplementing protein needs. We have successfully produced leaf protein from a species of Nigerian vegetable called *Soko* and christened the product *Sokotein.*

From the amino acid analysis ***sokotein*** seems to be as good as animal protein like egg, cheese, milk and meat. Animal feeding trials were conducted to compare sokotein with milk anf fishmeal as protein supplement for rats, chicks and pigs. Results showed that *sokotein* is as good as milk and can replace the imported fishmeal as ration for rabbits, chicks and pigs.

The results obtained from animal experiments were sufficiently encouraging to justify some clinical trials. In cooperation with the Department of Chemical Pathology of the University College Ibadan *sokotein* was tried on 26 children with Kwashiorkor. The home diets to which the mothers were instructed to add sokotein consisted of eko (maize gruel), amala (yam flour pudding), eba (cassava pudding), rice, ewedu (vegetable soup) and okoro soup. The toal was approximately 3 tablespoonful a day. The results showed that within 10 days oedoma disappeared, the appetite improved and the children became more mentally alert. Diarrhoea spontaneously subsided. There was a good increase in weight. Some mothers even claimed their children were eating too much and getting too heavy!

Sokotein was incorporated into three Nigerian diets, maize gruel (eko) yam flour (amala) and vegetable soup for adults in acceptability trials. The sokotein contributed about 80–90% of the total protein in the gruel, and 40–60% in the yam flour and up to 80% in the vegetable. The foods were accepted and enjoyed by the different classes of the society.

Sokotein could cure Kwashiorkor in 5 weeks without the need for hospitalisation or change in diet or dietary habit. There is no taboo against it as it is extracted from local vegetables. It is also very cheap. A pilot plant has been built in Ibadan and is producing sokotein for more clinical trials.

We are also looking into the use of unconventional cereals like Amaranth seeds (tete), Celosia (soko), Corchorus (ewedu) etc. as sources of food and feed. Some of these pseudo-cereals like Amaranth have been referred to as the gentle giant of the past and the future. Amaranth, the super-plant, produces needs in yields surpassing soyabeans, and leaves outdoing spinach in food value. The high potential lies in the fact that it is a fast growing plant suitable for growing in areas with a short season and deficient soils where the conventional cereals cannot be grown with ease. The abundance of protein in the leaves and seeds as well as the high intake concentration in vacuolar sap indicates efficient nitrogen assimilation, a double advantage which no other plant possesses. The seeds could be cooked for gruel, popped and made into confections or powdered and made into a drink. The grains yield nutritious flour which can be made into bread, biscuits and in fact could be used essentially in the same way as wheat. We may therefore have a substitute for wheat and save a lot of foreign exchange used for importing wheat flour.

Another research project embarked on is the chemistry of cyanide toxicity. As we all know, cassava is our staple food and is not only one of the major causes of malnutrition but has also been implicated in the aetiology of tropical ataxic neuropathy and goiter. We are therefore looking into the problem of the cyanide in cassava and how to use the cassava as a cheap source of energy for livestock so as to release the more nutritious maize for human consumption and hence improve the nutritional status of the population. Leaf protein from cassava leaves could then be used as a substitute for the expensive imported fishmeal and thus we have a local basis for formulation of excellent livestock feed from locally availalbe materials.

We have also been able to show that the cyanide is no problem in the presence of balanced diets. The body contains the enzyme rhodanese which converts the toxic cyanide to thiocyanate which is consequently excreted in the urine. This enzyme uses methionine as the sulphur donor and hence the importance of a balanced diet especially with respect to protein. Under this condition the enzyme is so efficient that in rats it will even detoxify as much as 5000 ppm of added cyanide without any deleterious effect such as enlarged thyroids (goitre) or nerve degeneration. In fact our work in this field, coupled with available epidemiological data tends to indicate that cyanide in small and regular doses could be beneficial to one who consumes a balanced diet. Thus at one time thiocyanate was widely used in both Germany and the US as an effective agent for hypertension at serum levels of 4mg% and upward. This level happens to coincide with the level obtained in people who eat a lot of cassava regularly, sometimes three times a day. One can therefore infer that certain aspects of hypertension (at least those responsive to serum levels of thiocyanate of over 4mg% induced by administering thiocyanate medically) are partially related to a deficiency of thiocyanate (and hence cyanogenic glucoside) in the diet. In addition thiocyanate, in the presence of haemoglobin as peroxidase catalyst, is oxidised in the erythrocyte to cyanate (Wilson and Harris 1960). Cerami and Manning (1971) have shown that cyanate irreversibly inhibits the sickling of red blood cells *in vitro* and extends the life span of treated sickle cell to near normal range *in vivo*. Instead of treating sickle cell patients with a regular dose of cyanate or thiocyanate (both being equally effective), this could be obtained through the injection of cassava (cyanogenic glucosides). In this case the question of dose will be no problem, and this suggests that *a priori* such people consuming the cassava should derive some benefit from it which might even mask the haemoglobin ss identity and prevent painful crises in those who have sickle cell anaemia. In the US the anomalous gene is present in about 8% of the 22 million black people, causing disability in about 50,000. In contrast to this, there is a much higher trait in Africa (20–40% i.e. three times that of US Negroes), which suggests a higher incidence of sickle cell disease. But the disease seems to be relatively rare, e.g. up to 1950 only 106 cases were reported. Lehman and Raper (1956) studied 478 patients over 5 years from the Bamba tribe in western Uganda and found that 35% had the trait but there were no cases of sickle cell anaemia.

Neoplastic cells are devoid of the enzyme rhodanese but are surrounded instead by another enzyme, B-glucosidase, which releases bound cyanide (one of the most powerful cytotoxins) at the site of malignancy, so destroying the cancer cells. With somatic cells only a small part of the bound cyanide is released and this is immediately detoxified to thiocyanate by the rhodanese which is present in high amount. We therefore have a highly selective substance which is only toxic to the cancer cells and is completely non-toxic to normal cells (and in fact beneficial). The mechanism of action seems to be more certain in case of amygdalin. In the intestine the enzyme complex, emulsin, containing the enzymes B-glucosidase, benzocyanase and others degrades this cyanogenic glucoside into 4 components: hydrocyanic acid, benzaldehyde, prunasin and mandelonitrile, which are absorbed into the lymph and portal circulations. Prunasin

can circulate in the body and reach the malignant lesion, and as such hydrolyse to librate hydrocyanic acid, benzaldehyde and glucose. The mandelonitrite is absorbed from the intestine, going directly to the liver where it is converted by detoxificiation mechanism of joining it to glucuronic acid. It may then be excreted as the glucuronide or find its way to the site of a malignant lesion. Mandelonitrite of itself may undergo spontaneous hydrolysis to hydrocyanic acid and benzaldehyde or enzymic decomposition by benzocyanase present in the emulsin complex. Mandelonitrite glucuronide may be hydrolysed at the tumour site by B-glucuronidase to yield hydrocyanic acid, benzaldehyde and glucuronic acid. The benzaldehyde released through this process at the site of the malignant lesion may be reduced to benzyl alcohol, and combine with the thiocyanate to form benzo thiocyanate, which is further reduced to a thioalcohol, benzo mercaptan, and hydrocyanic acid. In this manner, hydrocyanic acid appears and may continue to do so in a cyclic manner until the cellular conditions that permit the reaction involved in the cycle are no longer operative. These phenomena would explain the synergistic effect of benzaldehyde and cyanide in depressing the metabolism of mouse tumour slices in the Warbury apparatus (Burket 1971). In the absence of rhodanese in the cancer cells, the cyanide exerts its lethal effects on cell respiration by interference with the cytochrome oxidase enzymes. Can this be one of the explanations for the low age-standardised incidence rate for cancer in men between 35 and 64 years old in Ibadan (5.9) and Kampala (3.5) where a lot of cyanophoric foods like cassava are eaten regularly, and the high rate in the Western countries like Connecticut (51.8), Scotland (51.5), England and Wales (37.3)?

Krebs (1970, 1972, 1978) has reported many cases in which cyanogenic glucoside has been used successfully in treating cancer. If the cyanogenic glucosides could inhibit tumours from growing then it must be capable of preventing it from getting a foothold.

Because of the above prophylasctic properties of cyanogenic glucosides, we have proposed the name vitamin B_{17} for this group of compounds.

The other aspect of research I am engaged in is in the search for sources of organic raw materials necessary to support our chemical industries. In spite of the fact that some of our chemicals can be obtained from renewable sources, it is amazing that most are still obtained from non-renewable sources like petroleum and coal. Even today many organic chemicals are more readily obtained from renewable resources e.g. carbohydrates. In fact many of the more expensive chemicals, currently obtained from coal or petroleum, may well be more readily obtained from carbohydrates and plants if this is adequately funded e.g. the production of biomase is about twice the production of coal or gas. Wood can be hydrolysed with sulphuric acid to yield 40-50% sugar which can then be converted to alcohol. The wash can be converted to fodder yeast and furfural. A good source of the carbohydrate is cornob which at the moment is wasted in Nigeria.

From our preliminary work we have found that corn cob contains about 0.21%N, 0.21%P, 0.93%Na. 0.01%Ca, 0.1%Mg and 0.01%Fe. The protein content is about 2%, fat 0.2%, crude fibre 37%, carbohydrate 60%, ash 1%. Previous work (Foley 1978) has shown that the carbohydrate is made up of xylose (23%), arabinose (3%), galactose (0.5%), glucose (3%). We have already produced furfural from the cobs and this can be used for the manufcture of plastics and resins, replacing formaldehyde which was previously used; it can also be used as a starting point for the manufacture of hexametheylene diamine and adipic acid which are intermediate in the manufacture of nylon products as fungicides, disinfectants and herbicides; it is a selective solvent for gums and other undesirable constituents from lubricating oil. Among its derivatives are furfural alcohol, tetrahydrofuran and furoic acid. We have also produced oxalic acid from corn cob by alkaline hydrolysis and this can be used for polyurethane, fibres, polythene etc.

We feel that there are four main approaches with corn cobs which are likely to be practicable on the large scale at a reasonable cost:

(a) Fermentation
(b) Oxidative degradation
(c) Alkaline degradation
(d) Saccarification i.e. conversion to carbohydrate.

It is possible to separate as much as 85% of the pentosans in corn cob as a solution of pentose in sulphuric acid. On neutralisation the pentoses, mainly xylose, crystallises out and can be fermented to yield butanol, acetone and alcohol. Enzymatic or chemical hydrolysis of the residual cellulose will yield dextrose which may be recovered or else fermented to yield alcohol. Part of petroleum can be substituted for alcohol as fuel and this will reduce the dependence on petroleum as source of energy. Corn cob can also be used as fuel – industrial fuel and fuel gas. A gas of the proper composition for making liquid fuels by Fischer-Tropsch process can also be obtained from corn cobs. Other possible products of hydrolysis are cellobiose, a disaccharide of potential interest in food industry. Xylose can be hydrogenated to give xylitol which is used extensively in sweetening diets as alternative to sucrose as it has been found to produce 90% fewer caries as well as diminished plaque formation. Other saccharides can be of use wither for animal feeding or as adhesives and humectants. The residual yeast can be used as feed. It is a good fibre source for animal and from observation it could be more functional than any other food fibre source for man and in some cases it has been incorporated into cookies which has acceptable taste and appearance. On the other hand the corn cob can be fermented directly by bacteria to yield industrially important chemicals like ethanol, butanol and acetone. Although the yield is low, cooperation with other departments can give rise to improved techniques and higher yields.

It is possible to obtain aromatic compounds from such materials as corn cobs by high temperature pyrolysis. Apart from this, the carbohydrate obtained from cornobs (e.g. sucrose, glucose, fructose, sorbitol etc) can be converted to other derivatives such as pentaerythritol sucrose, gluconic acid triacetals etc. Which can be utilised to provide a particular kind of polymer molecule. In short we are hoping to use corncobs for the production of gums, food, industrially important chemicals and fuel.

The whole idea of elaborating so much on my work is to try and show the ways and means I have been applying chemical research to the national needs viz food, health and chemical industries.

CRITICISM OF THE PRESENT SYSTEM

I will now try and express my feelings about the present system of teaching chemistry and comment on the type of research done in Nigeria.

Although chemistry is chemistry in developing and industrialised countries, I am of the opinion that the method of approach to the object should be different in each. The universities in the developing countries are still very rigid in their perspective on pure science such as chemistry. It has to be taught as a pure science and its application is left to the applied departments such as chemical engineering, biochemistry, agricultural chemistry, food science, pharmacy etc. Industry, therefore, tends to utilise these applied chemists and neglect the pure chemists. Ven den Berghe (1973) remarked of the University of Ibadan in Nigeria that:

> ... the university is in fact training a bureaucratic elite that resembles the mandarin class of Imperial china. It creates learned gentlemen versed in an esoteric and recondite intellectual tradition which is little more relevant to the realities of their society than the Confucian classics were to pre-revolutionary China. In a sense, the problem of relevance is further aggravated in Africa because that intellectual tradition is not only esoteric but entirely alien'.

A change in attitude is therefore needed by the universities in order to make them more relevant to the needs of their society.

This does not mean that universities should become technical institutes for training technicians, but it does mean that it is high time we reorganised our universities in such a way as to get the balance right between producing result-oriented industrially based scientists and the curiosity-oriented research scientists. One cannot be sacrificed for the other, but at the moment we seem to be neglecting the necessity for practical relevance in favour of 'pure' research.

Students who have no scientific background come into the university to read science for a variety of reasons. In their study of science, they proceed straight from the known to the unknown as little effort is made to relate the content of courses to their experience. There is a tendency to present a science, especially chemistry as a bag of not clearly related tricks. Now that will not do. For anything taught to qualify as education or culture it must be part of a coherent whole and also relate in some way to other things which the students learn. After 'suffering' for three years they obtain a degree. At this stage, all they want is a certificate which demonstrates the acquisition of specialised and esoteric knowledge contained in a 'language' in which they cannot think. Hence, many students see science as a conglomeration of facts with no relevance to their actual experience, or to their society. It is no more a basis for providing a general understanding of science than are the humanities. Granted, many students get over the initial difficulties and turn out to be competent chemists but most of these end up in the universities as lecturers, and there is a tendency for them, whether deliberately or not, to bring up students in their own image. They have, as it is said 'an imperfectly sublimated reproductive urge, and their metaphorical offspring may have to do some cutting of the metaphorical apron-strings'. The irony of the situation is that in the industrialised countries there is a strong tie between science and technology and also between technology and society (although there are problems in these societies as well in the relationship between industry and the universities). However, in developing countries which have imported this scientific and technological tradition, there does not appear to be this link. Not only does the link not exist but, worse still, the development of science and technology is completely controlled by that of the industrialised countries. We end up with the following relationship:

science	Technology	Society	(industrialised country)
science	Technology	Society	(developing country)

Students who get over the initial difficulties go abroad to read for a Ph.D in a narrow field of probably no relevance to their country and end up as experts in quantum chemistry, atomic physics etc. They prefer to remain within these fields because of the advantage and prestige confered on them by their specialisation and they aspire to train students along similar lines. In some cases the theoretical chemist advances to such a level of abstraction that he is frustrated due to the lack of expensive equipment in developing countries necessary to his specialisation and this leads to a brain drain.

It appears that we are making two basic mistakes:

1. We appear to be educating our students for expectations which are beyond the attainment of most of those reading science at university. We are, therefore, educating them for frustration and not fulfilment. Most students are destined to be teachers in secondary schools or, increasingly, industrial managers and their university education does not train them to apply their scientific knowledge to such situations but to undertake a kind of abstract research which they are unable to pursue and which their country does not need. This is why the teaching of science in universities must change – we seem to have started with the wrong assumptions with the result that university and industry are out of step.

2. Education is becoming far too specialised at far too early a stage. The result is that we are producing half-educated scientists who have little idea either about life or about how their specialist activities can play their part in modern society. This is primarily because we have not spent enough time discussing the need for science courses more appropriate to the needs of our society. We appear to lack any definition of the goals of our science education. If social goals are defined in general terms, i.e. to industrialise and to redistribute income; are we necessarily going to follow the example of the existing industrialised societies in our attempt to eliminate poverty and deprivation, and achieve economic growth? Is there an alternative approach of developing a technology appropriate to our needs and goals? I have been informed by Professor Jevons of Manchester University that successful cases of 'appropriate technology' in non-western countries are quite difficult to find and document. There was an example of dry cell manufacture in Southern India in which it was claimed that a non-capital intensive method is genuinely competitive against large scale 'western technology'. How many such cases can one cite in the developing countries? If there are some well documented examples, we might be able to make more specific statements about the kind of science we should teach in developing countries i.e. the example of appropriate technology would help us to make progress in defining appropriate science education and in fostering university-industry cooperation.

One way of achieving university-industry cooperation would be to try and relate the teaching of the pure sciences to the experience of the students. Science deals with measurement, established principles and theories which have to be understood and learned in the same way anywhere in the world. It is the application of such theory and principles which creates problems and the examples now used in teaching science in developing countries are totally inappropriate because the realisation of their achievement is beyond the means of local resources. Chemistry should be studied in order that we may better control our natural environment by applying the principles. Unless the application is understood and demonstrated, chemistry becomes purely theoretical and not easily comprehended.

This brings to mind the question of teaching a monkey to ride a bicycle (which I understand is not a difficult thing to do). This does not necessarily mean that the monkey concerned is on a higher plane than other monkeys, neither does the ability to make science incomprehensible.

Intend to agree with Arthur Lewis that we should divide university activities into two related areas; one section responsible for appropriate research and the other for teaching and curriculum development, with communication and movement between the two sectors. If this were done, we would have enough time to carry out important applied research in science which would then be used to provide relevant teaching materials. Those on the teaching side would have enough time to think of the best way to present material to students, look for local examples, gear the curriculum to the needs of their society and thus produce better educated science students. Researchers will also have more time to devote to relevant research, be more capable of producing highly skilled graduate students who will be able to read for higher degrees in their own country and so tackle problems of local importance. This will surely help to bridge the gap between industry and university. If undertaken by scientist of integrity, this should not mean betraying the intellectual ideals of the university for epheral social relevance but the attempt to apply those ideals within a social context.

In 1972 there was a two-day seminar involving the heads of the various unversity science departments and managers in industry in Nigeria. The idea was to discuss what each was doing and to see where we can cooperate. It became apparent from that meeting that:

(a) Industry is very particular about the type of engineers and economists they employ. They must have the appropriate specialist training. In the case of chemists it does not matter much, as long as they are self-disciplined and know some of the fundamental rules of their profession. They have to be retrained in any case and so all they require is the basic requirements of the discipline. Their job tend to be of the quality control type and once they master it they can pass the knowledge on to a less qualified assistant. Eventually, they become managers and administrators.

(b) Apart from engineers and economists, industrial firms, in fact, prefer to train their own men on the job. It has been clearly demonstrated that it is cheaper, there is much lower rate of turnover and the employees tend to have greater job satisfaction. Chemistry graduates on the other hand, tend to use particular industrial enterprises as jumping boards to other jobs. When they are first employed, they are happy because of the relatively high salaries. Later when the job becomes routine they get bored, start coming in late to work, looking for other jobs and finally they leave.

This provides a picture of the relationship between chemistry and industry in the developing countries. The applied chemists such as pharmacists, chemical engineers, biochemists and food chemists who have the ability to apply chemical concepts appear to do best in industry. There are also problems arising from the fact that industrial firms are often branches of large multi-national firms. One of the directors of a large industrial firm in Nigeria even went to the extent of stating that Nigerian taste is in fact decided at the head office in London when he was asked why the formulae for some of their locally produced tinned foods were not compounded in Nigeria.

My feeling is that there is too much dependence on the government. The government can not carry out all projects. Money should be redirected into industries and the Universities and government should allow a climate suitable for achieving the necessary goals especially as industries are more efficient than government. Politicians go and come (4-year term) but the big companies remain. Maximum advantage, however, could be achieved by the cooperation between government, industry and university. There is the case of the US Space Programme in a similar cooperation – A Professor of Psychiatry at the University of Michigan gave the clue to the method of selection of astronauts, the government produced the funds and industries carried out the necessary construction work. Similarly the production of synthetic rubber during the second world war was due to research by the universities through government support while industries constructed the building. On the other hand, industries too can not carry all the loads of research and development all the time and when it gets too expensive, government can help through tax reduction and other reliefs.

SUGGESTIONS

The science of chemistry is advancing so rapidly that chemists must "run to keep up". Continuing education in chemistry is therefore a "must". We must start thinking of dramatically expanding our emphasis on chemical education for both the scientist and non-scientist. Our Department needs to provide intensive short courses and other means of keeping abreast with progress. We should also start a consultancy service for the public and use the money accruing from it for research and development in the Department. The Department should maintain close relations with teaching and research in physics, biology, engineering, the social and political sciences and computer science, since some or all of the disciplines may be involved in practical problems. The Department should be concerned with the atrocious waste of natural gas at our oil wells, and at the same time we should start to visualise a petrochemical industry for Nigeria.

Let me make it clear that I am not trying to paly down the importance of basic or fundamental research. The government could subsidise basic research while the big companies put in funds on the best directions. A lot of fundamental work is needed to understand the chemistry of how the plant breaks the C – C and C – H bonds and form our raw materials so that we can do the conversions ourselves. The fields of electrochemistry, organometallics, catalysis and enzyme systems are important in this respect. However, I will suggest more emphasis on the applied research especially in the field of alternate sources of raw materials for chemicals, food and medicine, more so as we have a surplus of biomass which could be used as alternative. Different groups can be initiated around these topics and if sufficiently large, could result in an Institute within a university department. This system could form a transition between the University and industry. A more rapid progress can be made in this area of mission-oriented research than in the fundamental research. In addition, it is cheaper, more rewarding and of greater potential to the country. The government should formulate a clear-cut policy on this kind of research, choose such areas where there are already strong, able and matured scientists working so as to assist in building up a research group i.e. a selective research support. Since money is now short, only a few areas should be chosen but the policy should be designed to ensure rapid and successful development. If the work of a group is becoming too diverse from the exigencies of the

country then the NSTDA should take steps to re-orient or else cut down the research grant. There should be a periodic report (say annually) so as to discourage short term demonstration of relevance.

One area which I feel is neglected in research in developing countries in general is the application of our research data. I feel Nigeria can no more afford to waste too much money on useful research results that are published in some obscure journals or else put away in the files. Any useful result will have to be shown to be useful. Thus it will be necessary to communicate these results to NSTDA so as to sell them to local industries, agricultural set-ups, medical establishments and other concerns by demonstrating their effectiveness. This may have to call for an enterpreneurial trouble-shooting team of applied scientists to be attached to the NSTDA and probably the various Research Institutes. In order that they may be effective, such a team should have sufficient grant made to them so that they could promise full cash compensation, say, to a peasant farmer who may be worried that a new seed variety he is advised to try may prove to be a failure. After all, effective dissemination and diffusion of scientific knowledge is just as important as the actual research work at these Research Centres.

If we think of practical measures, one of the ways by which university-industry co-operation could be fostered is by organising compulsory lectures to be given by industrialists to students. This should be in the form of seminars and problem solving, preferably at times when the staff could also participate. The last day of every term, for example could be devoted to all-day seminars in which staff, graduate and undergraduate students will take part in conjunction with top officials from industry. Industrial problems would be discussed in groups, led by industrialists. Later, there should be a general discussion of the problems followed by lectures from guest speakers from industry. This would enable industrialists to present their problems to the unviersity and the discussion would be made into case studies for future reference. It is important that industry should be represented by their top executives which would inspire the students, as well as the staff. The problems should be real ones, they may even be problems which have already been solved by industry. It would give the universities the opportunity to see what industry's most pressing problems are, and industry the opportunity to see how the universities would tackle such problems. Teaching industrial methods will not alone be sufficient. Staff and students should organise regular visits to industrial plants in order to appreciate their complexity and to stimulate awareness of industrial problems. Students should be made to work in factories during the long vacation and this should be managed in such a way that students would be confronted with problems which they would write up and discuss in seminars, with comments from members of staff. This might even permit the beginning of the solution of a fundamental problem of developing societies: how to apply science.

Annual scientific meetings are usually organised by scientific societies on a large scale with little participation from industry except, occassionally, to finance them. This is not surprising because most of the scientific papers are both abstract and of no relevance to industry. Joint meetings should be organised at which industry's needs could be taken into consideration and its representatives could give papers on their own problems and how they might be solved. The crucial problem is that of 'publication'. The university don works hard on his pet problem, presents a paper on this and then expects it to be published so that it can be cited in his curriculum vitae. The more he publishes, the higher his prestige. Industrial problems, on the other, tend to be multidisciplinary in nature and may involve group work. The results are not necessarily written up in an academic fashion, and so the industrialist sees his chemistry education as a help in achieving his practical goals. After all, the industrial manager does not depend on publication in order to achieve promotion. This difference in criteria considered relevant for promotion in university and industry is probably the main cause of the lack of a bridge between the two institutions. Crossing over from one to the other is feasible in the applied sciences. An industrial employee could be employed in a university, provided he has obtained a Ph.D degree and has had the opportunity to undertake some research in his job (which would be rare in Nigeria). a university don who has made a name in his own field could cross over to industry and be accepted for the prestige he creates for the firm concerned rather than for what he could do. He will probably become a director of some kind, in a consultative capacity. This indicates that industry has not yet worked out the way in which expertise of the universities can be useful to them. However, it would be useful for the universities to offer consultancy services to industry. This would not only be useful to government and industry, it would also be a forum whereby theory and practice could be integrated by students and it would widen the outlook of both staff and students. Industry would take this seriously as a challenge and should be happy to bring other problems to be discussed and if possible, solved. The returns from these services could be ploughed back into further research or used to extend the consultancy service. These services could also serve as the basis for organising refresher courses for industry. Industries should be encouraged to have R & D sections and take up new projects that look promising. The R & D section could be set up in cooperation with the appropriate university department to encourage interaction and give focus to research. Such industries should benefit through tax relief, easy access to ordering equipment, chemicals etc.

RECOMMENDATIONS

I will like to make two special recommendations which I am sure will take care of the above suggestions:

> The creation of a Ministry for Science and Technology with a primary task of advising the government on the priorities that it should set for expenditures and use of manpower in the development and application of science and technology in the national interest. The Ministry should be organized into three operational branches: Government Branch, University Branch and Industry Branch.
>
> Responsibility for three distinct policy areas should rest with the Ministry as it is in Canada:

(i) *Policy for the support of science* which encompasses the acquisition of knowledge, the development of research capability, the provision of scientifically trained man-power and the dissemination of scientific information.

(ii) *Policy for the application of scientific and technological resources* which encompasses the wise, econoimic and coordinated use of scientific knowledge, manpower and facilities.

(iii) *Science in public policy* which encompasses the introduction of scientific knowledge, reasoning and methodology into the development of public policy at the strategic level. The Ministry should, naturally, have a liaison with NSTDA but under no circumstances should NSTDA come under the Ministry.

The second proposal is the establishment of Nutrition Foundation of Nigeria. I prefer the word "Nutrition" because this is a field that utilises an immense amount of the knowledge of chemistry especially, and other basic sciences as well as "soft" sciences, to carry out research and education in the field of health, maintenance and prevention of degenerative diseases. The Foundation will receive its support mainly from Food and food related companies in Nigeria and will be run by a Board of Trustees who would determine the functions and priorities of the Foundation. Some of the functions should include:

(a) Identifying, defining and selectively promoting the support of needed research in the field of nutrition and the nutritional value of food, as well as food safety and acceptability as influenced by current and developing technology;

(b) assisting in the development of personnel, libraries and media of scientific communication in order to advance research and the application of knowledge in nutrition;

(c) promoting the exchange, coordination and assessment of scientific information through continuous communication with other agencies and institutions by means of symposia and workshops that explore critical problems and existing knowledge in nutrition, nationally and internationally;

(d) providing a clear and unbiased scientific position on current developments in nutrition that the food industry can use for guidance in matters relating to food and nutrition, product safety, and consumer and government relations;

(e) serving in an advisory role through its capacity to draw on the most knowledgeable source of scientific information in academia, government and industry.

CONCLUSION

The Universities in Nigeria began as foreign institutions and are still not proving themselves relevant to local situations. We should redefine our goals in relation to our societies and train people to achieve them. One of these goals is industrialisation and so the university should try not only to develop manpower and skill but also to train an educated population which can adapt to an industrial civilisation. Industry and university should be regarded as complementary and one way of achieving this is by working out what we mean by an appropriate technology which will then help us to define what is appropriate science.

In my opinion the *Literature* is full of untapped information and is growing at such a rate that it is getting impossible to cope with. We in Nigeria can take advantage of the wealth of information available, and also of the abundance of natural resources and our knowledge of chemistry to achieve the goal of providing more abundant food and chemicals for our great Nation. I am sure with a judicious application of our knowledge of chemistry we can achieve this objective as well as preserve our environment so that once again mountains will become mountains, trees will become trees and water will become water.

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