THE IMPERATIVES FOR A VIRILE CHEMICAL INDUSTRY IN NIGERIA

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INTRODUCTION

I give thanks to the Almighty God for His grace to be alive today and to deliver the 13th Inaugural Lecture of this University, rated and acclaimed the best amongst all the Universities in Nigeria. I am glad to be identified with the University at this point in time and, in particular to deliver a Lecture which will mark the first of a series of Inaugural Lectures in the term of Prof. I. F. Adu, as Vice-Chancellor of the University. I hope the subject of my Lecture, namely "the Imperative for a Virile Chemical Industry in Nigeria" will be of sufficient appeal to the respectable audience gathered here today and that I would address the fundamental issues which it evokes. I have found the subject of particular interest not only because I am a chemist but also because of the profound role that the chemical industry well situated can play in the industrialization process of any country.

In the discussion of the subject I shall be drawn inexorably into the domain of the social scientists in which I claim no authority, but for which I crave indulgence. I shall examine the subject under the following perspective namely:

- An overview of the Nigerian Industrial Sector
- Conceptual framework of the Chemical Industry and its role in the Industrialization Process.
- Research and Development and its pivotal role in the chemical industry
- Chemical Education
- Towards an Enabling environment: the Political imperatives

THE NIGERIAN INDUSTRIAL SECTOR: AN OVERVIEW

Mr. Chairman, the Nigerian governments have, from independence set national objectives and targets through a number of Development Plans ostensibly to place the country on the path of development and to ensure the socio-economic well-being of her citizens. Thus, for four development plans and a rolling plan for the period 1962 – 92, the total budgeted capital expenditure was N309.1 billion, a huge investment at the time (See table 1). The first National Development plan (1962 – 68) had the primary objectives inter alia….

> "………….. to stimulate the establishment and growth of industries which contribute both directly and materially to economic growth (through import substitution) to enable Nigeria to participate to an increasing extent in the ownership, direction and Management of Nigerian industry and trade; to broaden the base of the economy and minimize the risk of over dependence on foreign trade, to secure full employment for the people and to make the fullest use of available resources" (Nduka, 1989).

The second National Development Plan emphasized large capital intensive projects in order to further enhance foreign exchange earnings. These include:

- Iron and Steel Complex
- Nitrogenous Fertilizer Plant
- Passenger Car Assembly Plant
- Petrochemical Complex
- Pulp and Paper Mills at Jebba and Iwopin
- Salt Refineries at Sapele and Otta.

These projects experienced delays in their implementation and consequently overlapped the third National Development Plan (1975 – 80). This plan period was characterized by an astronomical growth in the oil sector but led, paradoxically to a departure from the objectives and targets set for the preceding development plans.

The fourth National Development Plan (1981 – 85) was not implemented even though it sought to remediate the weaknesses in the previous plans.

Over the years, the government also put in place enabling instruments to facilitate industrialization process as envisaged in the plans. These include,
*The Nigerian Industrial Development Bank; Nigerian Bank for Commerce and Industry; National Economic Reconstruction fund established in 1964, 1973 and 1989 respectively. In addition, there was established amongst others, the Nigerian Agricultural and co-operative Bank in 1977 to provide Credit facilities to farmers and to ensure the success of government policy objectives in the agricultural sector. The pertinent question must now be; to what extent have the policy measures of government achieved the objectives envisaged, particularly in the <u>three</u> critical sectors namely, Agriculture, Iron and Steel and the Chemical Industry. These sector are critical because development in them can have multiple effects on the economy as has been demonstrated in several economies of the industrialized countries of Europe, North America and Japan and, in more recent times, in those of such developing countries as Brazil, south Korea, India, etc.

The need for a viable steel sub-sector as conceived by government was to broaden the productive base of the Nigeria economy by the provision from it of basic inputs to industry and to promote a market for minerals such as iron ore, bauxite, petroleum coke and pitch, soda ash and calcium fluoride (Obasanjo's Economic Direction, 2000). But the construction of Ajaokuta Steel plant proceeded for about two decades without completion and in spite of the completion of the Delta Steel and three Steel rolling mills in 1982/83, the general assessment of the Steel sub-sector is one of non-performance. The later is attributable to a number of factors, some of which have become very familiar national clichés, namely:

- Poor planning and implementation of project in the sub-sector
- Inadequate infrastructure
- Mismanagement
- Low staff morale

- Poor maintenance of equipment
- High debts, etc.

It is therefore not surprising that over the last decade, the per capital consumption of steel has remained low, i.e. about 28kg in contradistinction to values as high as 500kg (Japan) and 700kg (USA) (Tukur, 1991), a clear evidence of the rudimentary state of Nigeria's industrial base.

Developments in the agriculture and petroleum sectors in spite of the dependence of the economy on the latter have been less than impressive too. For agriculture, the output of traditional cash crops such as cocoa, cotton, rubber, groundnut and palm produce declined continuously over the last three decades (Obasanjo's Economic Direction, 2000) while they boost the economies of several countries in the world.

Endowed with crude oil and natural gas proven reserves of 27 billion barrels and 120 trillion standard cubit feet respectively, the oil sector is yet to provide the expected multiplier effects on the economy. Rather, it has occupied the focal point of the Nigerian Political drama.

Thus, the commanding heights of the Nigerian economy depend to a very large extent on import of raw materials and machineries, a dependence which has slowed the pace of industrial development in the face of an unmitigated decline in the value of the Naira against foreign currencies.

For the period, 1972 – 78, import of raw materials for the manufacturing industry was in the range, 21 – 30% of total expenditure on imports (Ikoku, 1981). For the adjustment period, 1985 – 94, import of raw materials was in the range 38.4 – 62.1% (Obadan & Ayodele, 1997). Over the period 1995 – 99, import of chemicals was in the ranged, 22.7 – 26.3% of total import (Table 2) (CBN, 2000).

Furthermore, a casual examination of some weekly imports as reported by the Central Bank of Nigeria for November, 2001 showed imports on chemicals alone at about 22.5% of total imports. Thus, the manufacturing sub-sector is hamstrung, characterized by capacity under-utilization averaging 30% over the last decade and is dependent on imports of raw materials which otherwise ought to be sources locally. Increasing the local content of industrial output, a key policy thrust of the Nigerian Industrial Policy (Industrial Policy, 1989) is one in which the chemical industry must of necessity feature. This was stressed in the 4th National Development Plan where the need to "encourage the establishment of those industries which produce raw materials for other industries" was recognized (Ikoku, 1981). In addition, the chemical industry fits into the larger objectives of technological development, the success of which according to Emovon (1989) can be "evaluated by the extent to which we are able to exploit and develop new usable products from our local raw materials".

From the foregoing, it is apparent that the tripod sectors, Agriculture, Iron and Steel and the Chemical Industry are not well developed to provide the necessary momentum for industrial development of the Nigeria economy. The quest for industrialization must ipso facto begin by the appropriate development of the steel sub-sector to stimulate the acquisition of the technical know-how for design, fabrication and manufacture of machines and machine tools. This must precede the development of a virile chemical industry in Nigeria.

The Chemical Industry

The Chemical Industry is ancient founded on a wide variety of sources of raw materials which include coal, molasses, fats and oil (of vegetable and animal origin), salt, metalliferous ores, water and the atmosphere. In all cases, the industry depends on the knowledge and application of chemistry and chemical technology. Because it is at the root of any industrialization process, the need for chemical industry in Nigeria for sustainable development cannot be over-emphasized. For example, the use of fertilizers and pesticides, both products of the Chemical Industry can be of tremendous boost to agriculture and promotes output. Similarly, the processing of solid minerals into products of high economic value through appropriate chemical technology is within the domain of the Chemical Industry.

The Chemical Industry is therefore recognized as:

> "a collection of industries engaged in making three categories of products; inorganic chemicals, organic chemicals and specialized products" (Ikoku, 1981).

In the category of inorganic chemicals are:

> Acids, alkalis, rare earths and their compounds, precious and rare metals and their compounds, non-metallic inorganic compounds of such elements as phosphorous, sulphur, nitrogen and halogens and industries gases.

Organic chemicals include high tonnage chemicals such as aliphatic and aromatic compounds derived largely from petroleum and/or coal, fine chemicals, fats and oils, waxes etc.

Specialized products cover a wide range of materials embracing, amongst others, adhesives, detergents, soaps, dyestuffs, essential oils and perfumes, explosives, fertilizers, food additives, fuel and oils, greases and lubricants, laboratory reagents, anti-corrosion agents, pesticides and herbicides, pharmaceuticals, pigments, plastics, rubber, water-treatment chemicals, electronic equipment components, etc.

It is evident from the foregoing that the chemical industry occupies a central position in relation to the other industrial sectors underscored by the fact that it is the producer of the primary raw materials which are feedstocks for the manufacture of a wide range of products. For example, sulphuric acid, an inorganic chemical is used on a wide scale as feedstock by many industries. Indeed, it is hard to find any important branch of the economy in which either sulphuric acid and or products derivable from it are not used. The largest consumption of sulphuric acid is in the manufacture of inorganic fertilizers such as superphosphate, ammonium sulphate, etc. It is also a feedstock for the manufacture of many other acids such as phosphoric, acetic, hydrochloric acid and their salts (figure 1). The acid is used in large quantities for the purification of petroleum products and for a number of processes in the manufacture of dyes, paints, pharmaceuticals, insecticides, detergent, artificial silk, lead batteries, explosives, etc.

Sulphuric acid is obtained from sulphur dioxide, a gas which can be derived in principle by burning sulphur containing substances. These include pyrites, sulphates such as gypsum, elemental sulphur, coal, oil and gas etc.

Another chemical, which is used on a large scale and for several industrial operations, is soda ash, sodium carbonate. It is widely used in the inorganic chemical industry for the production of soda products and inorganic salts; for operations in metallurgy, glass industry, petroleum product purification, pulp-and-paper, paint and vanish, textile, leather etc.

An important feature of the chemical industry is that often several intermediate products are obtained in the process of manufacture of a particular chemical substance. Such intermediates may lend themselves as feedstocks for other industries. For example, aspirin, an important analgesic is manufactured by the reaction of salicylic acid and acetic acid. These reactants are derived, through appropriate chemical technology from coal, limestone, sulphur, sodium chloride and petroleum, all naturally occurring materials.

As can be seen in Figure 2, the process of its manufacture can provide intermediate materials such as phenol, acetylene, calcium carbide, etc. Mr. Chairman, Nigeria is endowed with large reserves of solid minerals for sustainable development of the Chemical Industry.

Nigeria's reserve of solid minerals includes coal, columbite, lignite, barite, gypsum and iron ore.

The production profile of principal solid minerals for the period 1993 – 97 is represented in Table 3. But because the chemical products derivable from solid minerals are numerous, what is desirable is not the mere ability to export the raw materials but the conversion of such materials to other useful products.

Another source of chemicals is petroleum. Petroleum chemical manufacture represents that segment of the Chemical Industry which is concerned with production of chemicals from raw materials of petroleum origin. By its very nature, this segment represents the dominant source of supply of organic chemicals and to some extent certain specific inorganic chemicals. The manufacture of petrochemicals is a departure from the traditional function of petroleum industry which is concerned with separation of petroleum into its constituents through fractional distillation processes. It was the inadequacies of the products of these processes in quality and quantity that paved the way for chemical modifications of such products through thermal cracking and reforming processes. The resultant products were olefinic gases, which after considerable research became raw materials for a range of chemicals and chemical products, marking the beginning of the petrochemical industry in the early 1920s.

In order to broaden the base of the petroleum industry and to promote the growth and development of the numerous industries which depend on petrochemicals, the Nigerian government initiated the establishment of the petrochemical sectors of the Nigerian National Petroleum Corporation (NNPC) in Phases as follows:

Phase I: Construction of polypropylene plant at Ekpan near Warri to manufacture polypropylene a polymer from which are derived a range of polymer products. It was also to produce carbon black, a useful raw material for the print ink, tyre and rubber industries.

Construction of Linear Alkyl Benzene Plant at Kaduna to provide raw material for the manufacture of biodegradable synthetic detergents (Table 4). This was planned for execution for the period 1981 – 85.

Phase II. Construction of Olefin complex for the production of major plastic-based materials using natural gas as its main feedstock. The intention here was to satisfy demands from building, automative, agricultural, electrical, packaging, textile and other related industries (Table5). This was planned for completion in 1987

Phase III: Construction of aromatic complex, which would use aromatics from refined products of existing refineries and petrochemical plants. Completion date was 1990. Table 6 shows the actual product output of the phase 1 petrochemical plant. The products are useful industrial chemicals but the production levels were low at the time to make a significant difference in the demand profile, i.e. the demand for foreign exchange for importation of similar materials. Yet so much revenue can accrue from petrochemical products as has been demonstrated by the fact that Japan's earnings from petrochemicals alone amounted to US$20 billion in 1976 (Pierne & Brown, 1980) and perhaps much more in recent time.

It is against this background also that we must see as colossal waste of resources the flaring of natural gas which has been on for several years. Indeed, at inception, gas flaring amounted to over 80% of total output. For the year 2000, the output of natural gas was 44,233 million cubic metres (CBN, 2000) and the amount flared was 23,912 million cubic metres, accounting for 54.1% of total output. The downward trend is certainly a reflection of the present administration's desire to achieve zero flare in the very near future.

The liberalization of the downstream sector of the petroleum industry is a pragmatic move by government to ensure greater private sector initiatives in the sector.

Mr. Chairman, while this is a necessary step towards the reactivation of the sector, it is certainly not a sufficient condition to achieve the objective of promoting the growth of the chemical industry in Nigeria. The challenges before us in this regard are enormous; underscored by the notion that developing countries in general are incapable of sustaining such as enterprise. This is anchored on the premise that developing countries including those endowed with enormous oil reserves:

- Lack the expertise to build, operate and maintain chemical plants
- Lack the technique of distribution, technical services and industrial marketing
- Lack education and such services as effective communication network, water supplies, transportation, health care delivery system, etc.

These notions are not entirely misplaced judging from the Nigerian experience where for several years we have no demonstrable record of expertise in this regard. Even where we needed only to provide the finance for viable projects, we have over the years demonstrated a palpable lack of commitment for their completion and/or maintenance as in the case of the Ajaokuta Steel Project and of the dysfunctional refineries, turn-around only recently by the present Administration.

The issues of education and expertise are tied and certainly call for greater commitment to our educational system with a view to making it more functional and sound, and to support effective research and development (R & D) The cornerstone of any industrialization effort is research and development and is critical to the survival of the Chemical Industry. A typical Chemical Industry must have the expertise:

- to produce not just chemicals but even those that are rare and difficult to synthesize. Such chemicals include research products and intermediates obtained in laboratories round the world.
- to make products based on users' or customers' suggestions.
- for bulk-chemical manufacture as were for multi-step chemical syntheses.

These are typical features of the Chemical Industry which make it not only capital intensive and complex, but demanding of effective R & D capabilities.

RESEARCH AND DEVELOPMENT AND THE CHEMICAL INDUSTRY

Research and Development (R & D) is defined as:

> ***"….. any creative systematic activity undertaken in order to increase the stock of knowledge of man, culture and society and the use of this knowledge to devise new applications. It includes fundamental research (i.e. experimental or theoretical work undertaken with no immediate practical purpose in mind), applied research in such fields as agriculture, medicine, industrial chemistry, etc. (i.e. research directed primarily towards a special practical aim or objective) and experimental development work leading to new devices, products or processes)"(statistical year book, 1990)***

R & D is therefore the lynchpin of any industrial enterprise and from it can be derived comparative advantage by industry. For the chemical industry there is evidence that many were established as products of R & Ds. The rubber industry has its root in the classical R & D efforts of Charles Goodyear (1893) on the vulcanization of rubber. Goodyear had set out to *"cure"* rubber, i.e. introduce crosslinks into the polymer molecules to prevent degradation in a manner akin to curing of leather through tanning. He proceeded to mix rubber with sulphur and inadvertently left part of the sample in a metal pan on a hot stove while he went for lunch. On his return, he discovered the sample in the pan had melted and congealed into a mass that was stronger more elastic and less tacking than the original rubber. Vulcanization is now an industrial process in the rubber industry and its importance resides in the fact that no rubber is useful for the production of articles such as tyres, foam, hoses, etc. unless it is vulcanized.

Similarly, in medicine, it is believed that pain chemotherapy began with the isolation, in 1860, of salicyclic acid from the bark of willow. The isolation was a vital step towards the identification of it as the active principle in the extract which not only reduced fever but also relieved pain. But because salicyclic acid (1) has a sour taste and causes stomach irritation, further R & D efforts notable by Charles Frederick Gerhardt gave rise to the synthesis of the acety1 derivative, acetylsalicyclic acid (aspirin) (II)

Today, aspirin is an important product of the pharmaceutical industry underscored by the discovery also that it can reduce the risk of a first heart attack.

In the area of polymer chemistry Karl Ziegler (German) and Guilo Natta (Italian) won the 1963 Nobel Prize in Chemistry by the development of Polymerization catalysts with unique stereoregulating powers. Such catalysts were complexes formed from the interaction of alkyls of metals of groups I – III with halides and other derivatives of the transition metals of group IV – VIII of the periodic table. These catalysts enabled the production of linear, crystalline and high density polyethylene from ethylene in contrast to the highly branched and amorphous products of radical polymerization of the monomer. They enabled the production of polyisoprene of desired stereoregular specification yielding cis-1, 4; trans-1, 4, isotatic 1, 2 and syndiotactic 1, 2 polymer products depending on conditions and choice of catalysts. The stereo regularity of the polymer molecules conferred on them unique physico-chemical and mechanical properties which provided value-addition and widened the scope of industrial production and application.

Mr. Chairman, I will endeavour to locate some of my modest R & D efforts within the framework of the Chemical Industry.

Over the years, I have been involved in studies of ionic and free redical polymerization of reactive monomers; the chemical modification of natural polymers to enhance value addition and some aspects of raw materials research and development to enhance industrial application.

Polymerization of α - cyanoacrylates

Polymerization is a process by which small molecules join together in a repetitive manner to yield high molecular weight polymer or macromolecule having as many as up to 100,000 or more of the small molecules.

cyanoacrylate (III) is one of the chemical Products of Loctite Ltd. Dublin, an active principle of the widely known commercial product, “super-glue” adhesive. Very little was known of the kinetics and mechanism of polymerization of α-cyanoacrylate beyond the observation that it could undergo spontaneous reaction induced by adventitious substances in air to yield a high molecular weight polymer and to bind surfaces. Our studies on the monomer which was supported by Loctite have since established the following features of the polymerization:

- that α-cyanoacrylate can be initiated into polymerization by tertiary organic bases, phosphines and amines to give polymer molecules which are Zwitterionic having their counter cations, phosphonium or ammonium embodied in the polymer chain as the initial group (IV) (Cronin & Pepper , 1988).

- the growing end of the polymer chain is anionic.

- the initiation process is exothermic, and complex with negative temperature dependence.

- the polymerization has no intrinsic termination reaction and can sustain growth as long as there is monomer in the system.

Because α-cyanoacrylate is very reactive the commercial product is usually stabilized with chemical substances such as acids and hydroquinones. It also means that the stabilizer must be removed by a carefully designed process of fractional distillation at rotary pump reduced pressure and stored frozen at liquid nitrogen temperature. The sample can then be removed by thawing under dry nitrogen counterflow only immediately before experiment.

Polymerization of α-cyanoacrylate by quaternary ammonium salts, acetates and bromide shows the following features (Eromosele & Pepper, 1989):

- the growing polymers are not zwitterionic but macro-carbanions having their counter cations associated only by electrostatic interactions i.e. (v)

- the initiation process is composite involving a reversible precursor state and adduced to initiation chiefly by monomer-separated ion pairs of the ammonium salt.

- The polymerization proceeds to completion with half life of less than 5 seconds with propagation rate constants of close to $\mathbf{10^{6} lmol^{-1} s^{-1}}$ yielding molecular weight, on the average close to 10^{6}

α-cyanoacrylate is also amenable to initiation by cyclic carbonates to give zwitterionic polymer chains having oxonium/carbenium initial cation embodied in the polymer (Eromosele & Pepper, 1986). (vi)

Another interesting feature of α-cyanoacrylate polymerization is its apparent insensitivity to water even though it grows carbanionically in contradistinction to polystyryl carbanions which are vulnerable to termination by water.

We have established that the apparent insensitivity of α-cyanoacrylate carbanions to water arises from its extreme reactivity which results in propagation being more favoured over other reactions to which the carbanion may be susceptible (Eromosele *et al*, 1989).

Mr. Chairman, although this work may appear a research of a fundamental nature, the outcome in the knowledge of the kinetics and mechanism of polymerization of the α-cyanoacrylate was a justification, a posteriori for the material and financial support provided for it by Loctite Ltd, Dublin. Certainly, the understanding of the Kinetics and mechanisms of polymerization of the monomer was a critical requirement for the company in its R & D efforts to synthesize new products and to maintain comparative advantage in the market place.

Another reactive monomer on which we have carried out some studies is butylisocyanate (VII).

Butylisocyanate and its analogs polymerize only at very low temperatures often below – 20^oC and are therefore characterized by ceiling temperatures beyond which they cannot be converted to polymers. The polymerization of butylisocyanate showed interesting features namely:

- the polymer chain is stiff
- polymer formation is accompanied by a side product, isocyanurate, a cyclic trimer (VIII)

Isocyanurate is an important industrial material which is used in a number of polymer formulations. Of interest however was understanding the modus operandi of the cyclic trimer formation. In other words, whether it is a product of reversible propagation – depropagation equilibrium in which case the equilibrium conversion at any temperature is determined by the thermodynamics of the propagation step i.e. by its enthalpy and entropy changes, the latter being related to the equilibrium monomer concentration.

We have found the theory of propagation – depropagation earlier proposed by a number of workers inadequate to account for the observed results of the polymerization of butyisocyanate. Rather, we have established (Eromosele & Pepper, 1987) that the cyclic trimer was a product of a ‘back-biting” reaction of the growing polymer chain, kinetically an internal transfer reaction (IX). By this process, the last three chain units of the growing polymer chain undergo cyclization making it possible for the polymerization to proceed to completion by consumption of all monomer.

Consistent with government policy objectives to source raw materials locally, we have devoted some efforts at raw materials research and development. We have examined cellulosic fibres and have modified them to improve on their properties.

Cellulose, in particular cotton, is the most widely used textile fibre. This pre-eminence is due to a combination of properties, notably, abundance, low cost, fine cross-section, high strength and durability, high thermal stability, good mechanical properties, ability to absorb moisture, easy dyeability, wearing comfort, etc. (Hebeish and Guthrie, 1981). However, cellulosic fibres have some inherent drawbacks which include poor solubility in common solvents which makes improvements in fibre and yam through spinning processes almost impossible; poor crease resistance which makes garments made from it crumple easily during wears; lack of thermoplasticity which is required for heat-setting and shaping of garments; poor dimensional stability during laundering and ironing. These drawbacks and the fact that cellulose has encountered stiff competition from synthetic fibres make it necessary for property improvement by effecting appropriate changes in the physical and/or chemical structure of cellulose. On our part, we have made such changes by conversion of cellulosic fibres into graft copolymer derivatives, the other components of the grafts being synthetic polymers. In this way, desirable properties are conferred on the cellulose without altering its intrinsic properties. This modification is achieved through free radical polymerization reactions by the creation of free radical sites on the cellulose molecule each of which can then initiate the polymerization of monomers.

From our studies, we have established the following amongst others:

- For graph copolymerization of acrylic acid onto caeserweed fibres initiated by the ceric ion-toluene redox pair, the graft copolymer showed reduced solubility in 72% sulphuric acid. The same phenomenon was observed when polyacrylic acid was replaced with polymethacrylonitrile (Eromosele, 1994; Eromosele & Ahmed, 1996).

- Because polyacrylic acid is hygroscopic, its presence on the cellulose improved the water retention property of the fibre 5-fold at 53% graft yield (Table 7) (Eromosele, 1994). This was reversed by the introduction of hydrophobic polymethacrylonitrile on the cellulose fibre (Table 8).

- The Kinetics of some of the graft reactions were complex traceable to the mechanism of reaction of the redox initiators which included the reactions preceding those which created radical sites on the cellulose. For example, where p-xylene was a component of a redox pair, the graft reaction exhibited a minimum in the conversion profile and indication of the presence of two kinetically-controlled reaction processes associated with two initiating species, a p-xylyl radical (X) and an unstable and reactive di-radical derivative (XI) (Eromosele & Agbo, 1999).

Beyond modification, we have examined a number of cellulosic fibres from non-conventional sources (Eromosele *et al*., 1999; Eromosele & Egunsola, 2000) the overriding objective being to see if we could find ones with commensurate properties with those of the conventional types currently in demand in the world market. The tensile properties of such fibres are presented in Table 9. Although, the properties of the fibres were of much lower quality compared with those of Jute, flax, hemp, and remie, they nevertheless can be improved upon through appropriate chemical treatment to enhance their industrial application and economic value.

Mr. Chairman, the industrial applications of vegetable oils beyond their nutritional values make it necessary that we examine developments in this sector. Through R & Ds and chemical technology, a number of useful chemical materials are now derivable from vegetable oils as illustrated in Table 10 for castor oil and applicable to a number of other oils such as jojoba, crambe, palm oil, etc. For palm oil, Malaysia one of the 'Asian Tigers' has demonstrated how this commodity can be developed into a major economic plank of a country. Through R & Ds Malaysia has developed fuel from palm oil and has used it for electricity generating plants thereby ensuring value addition to the commodity and increased income for palm oil farmers.

Palm and palm kernel oils have also been fractionated to yield a number of chemicals such as methylesters, glycerol, fatty acids, fatty alcohol and fatty amines for various uses such as detergents and cosmetics. Arising from the economic value derivable from palm oil, Malaysia invested considerably in it by maintaining oil palm plantation of 3376 million hectares in year 2000 projected to increase to 3547 million hectares in the year 2001, constituting about 60% of total cultivated area of the country (Guardian, August, 31, 2001).

In the year 2001, there were 352 oil palm mills, 39 palm kernel crushers, 46 mejineries and 16 chemical plants in the country. In the same year, Malaysia maintained its lead as the top producer and exporter of palm oil in the world by producing 10.8 million tones and exporting 9.08 million tones of the commodity. Nigeria's output of major agricultural commodities for the period 1996 – 2000 are presented in Table 11 and it can be seen that for palm oil the output is low compared with Malaysia in addition to the fact that there is no demonstrable capability for full exploitation of the range of chemicals derivable from it. Other than Malaysia other countries at similar levels of development posses such capabilities. For example, the Indonesian palm oil producing industries produce chemicals based on palm oil at levels of several metric tones annually (Table 12).

Thus, Mr. Chairman our ability not only to produce this commodity but for their conversion to useful chemicals in order to stimulate the growth of industry should inform the policy objectives of government, and clearly stands in the domain of the chemical industry. In pursuance of this, we have examined a number of seed oils from plants the bulk of which grow in the wild in the savanna part of northern Nigeria (Eromosele & Eromosele, 1993; Eromosele et al, 1994; Eromosele, et al; 1998 Picture 1(Ximenia americana). A summary of characteristics of the oils is presented in Table 13. Again, the overriding interest in the study was to find seed oils with comparative if not superior properties to those of linseed oil, a raw material for the paint industry. So far the oils from Haematostaphis barteri (blood plum) and Ximenia, americana (wild ovive) seeds appear to satisfy the requirement having a total unsaturation of 79.01 and 92.42% respectively (table 14) (Eromosele & Eromosele, 2001). The total unsaturation and distribution of fatty acids in X. americana make it a very suitable base material for the synthesis of alkyd resin, a major recipe for oil paint production for which linseed oil and a few others have enjoyed enormous monopoly. I am glad to say, Mr. Chairman, that our R & D efforts on X. americana oil enjoys the recognition and financial support of the Raw Materials Research and Development Council, Abuja and that the oil is currently undergoing a pilot test as a material for paint based on our preliminary report on it.

Further value addition for the oil is envisaged from its possible application together with its heavy metal salt derivatives as stabilizers for polyvinylchloride (PVC) against thermal and thermo-oxidative degradation as has been demonstrated for a number of oils.

A project proposal in this regard has enjoyed the financial support of the Third World Academy of Sciences, at Trieste. The highlights on my R & D effort and many similar ones scattered in our Universities, Research Institutes, etc underscore the need for effective coordination and funding of such activities so that they are not dissipitated or end up as mere academic exercises but tied to national industrial policy objectives and targets. Secondly, they expose the intersectoral relationships between Agriculture, Iron and Steel and the Chemical Industry as development tripod. The need for funding of R & Ds for the Chemical Industry can be further appreciated against the backdrop of the experiences of other countries. For example, the U. K.'s in-house expenditure on R & Ds in the Chemical Industry in the 90s was as high as 24.2% of the total expenditure on R & D's across broad industrial sector (Webster, 1991). Indeed, U. K's export of chemicals and chemical products was up to 13.2% of total export in 1989.

It is instructive here to recognize the Nigerian Institutional framework for the promotion of R & Ds in the chemical and chemical product sector.

These include:

- the Federal Institute for Industrial Research, Oshodi.
- National Research Institute for Chemical Technology, Zaria.
- National Institute for Pharmaceutical Research and Development, Abuja

- Rubber Research Institute of Nigeria, Benin
- Raw Materials Research and Development Council, Abuja.

An overview of the activities of these institutions shows that they have tried to fulfil the objectives set for them within the limits and constraints of the Nigerian socio-political environment. In my humble opinion, these institutions could do much more than is presently possible if they are adequately funded and coordinated. For example, the National Research Institute for Chemical Technology (NARICT) which is charged amongst others, with conducting R & D for conversion of agricultural, solid minerals, and petrochemical products into industrial chemicals recently made pronouncement on the outcome of its R & D efforts.

NARICT has perfected the processes for the production of a number of industrial chemicals which includes:

- Dehydrated lime: an essential chemical for treatment of water.
- Essential Oil: derived from lemon grass and eucalyptus leaves; a valuable industrial material for the perfumery and cosmetics industry.
- Synthetic dyes: used extensively by the textile industry; plastics and petrochemicals.

In spite of these efforts and those of many others, and notwithstanding the fact that the government also established a National Office for Technology Acquisition and Promotion to assist in the commercialization of the products of Research Institutes, it is evident that the Chemical Industry in Nigeria is undeveloped, and science, engineering and technology appear to have made no impact on this sector. The government appears to recognize this situation attributing it to a number of reasons which include:

- Lack of the political will to mobilize science, engineering and technology manpower in the pursuit of national economic objectives (Obasanjo' Economic Direction, 2000)

The recognition by government of these limitations is noteworthy and shows there is still hope albeit raises some fundamental questions as to commitment to redress it particularly in the light of the recent budget proposal of ₦3.7 billion for Science and Technology which lags substantially behind Sports and Social Development at ₦25 billion.

CHEMICAL EDUCATION AND THE CHEMICAL INDUSTRY

There is no doubt that the Nigerian educational system is trying to recover from a dark phase which was characterized by:

- lack of basic infrastructure
- poor conditions of service
- lack of teachers accentuated by the brain drain phenomenon
- poor quality of teaching
- poor management
- corruption
- authoritarian leadership especially in the universities
- poor funding, etc.

The resultant effect of these factors has been poor quality products from our educational systems as affirmed by both local and international assessors. And because chemists in their studies must deal with chemicals and chemical reagents which are expendable laboratory wares, this branch of learning suffered considerably in the face of paucity of funds. More than any discipline teaching and research in chemistry are almost always the first to show sign of distress when funds are low, and expendable materials cannot be replenished. And because the discipline can be quite specific in materials needs, the situation could be such that <u>distilled</u> water would not substitute for <u>deionised</u> water for certain reactions. Thus, the training of chemist, biochemists, chemical Engineers, all of which depend on expendable laboratory wares to varying degrees remained inadequate over they years eliciting a regime of re-training programmes for their graduate products by industry and other sectors. Some industries even expressed grave concern on the fact that some graduate products were not amenable to such re-training programmes and thus had to embark on very stiff conditions for recruitment of manpower.

Mr. Chairman, we are now in the 21st century where the development of the human capital is an imperative in an increasingly globalising world in which the ability to compete and to maintain comparative advantage must derive from the knowledge factor. And because universities are expected to produce the high level manpower needs of society as well as advance knowledge through research, it calls for adequate funding to meet these challenges across the board and to meet the specific needs of its functional units. The emphasis of the latter is important because funds are usually low and a far cry from the budget such that the learning object of the university invariably loses its pre-eminent position, subsumed by the need to provide goods and services in the holistic approach to university management.

The government's provision for teaching and research equipment as a separate capital grant for universities is laudable but needs a complementary provision for expendable laboratory wares without which the equipment would serve no useful purpose as far as chemical education is concerned. This is particularly important in the light of the difficulty of running postgraduate programmes in the chemical sciences. A profile of the turn out of Masters and doctoral degrees from Nigeria universities for the period 1990 – 92 (Table 15) clearly shows that over the period we could hardly achieve an average of one Ph.D per Faculty per year. But the fact of the matter is that a good many universities could hardly produce Ph.Ds in the science related disciplines for years running. These reflect the low financial provision for postgraduate training and research, which ought to be the hobnob of university activity in the quest to advance knowledge and produce high level manpower.

Mr. Chairman, the Chemical Industry like all other industrial sector calls for manpower across the board but demands in particular well trained chemist, biochemists, chemical engineers and biotechnologists to fit not only into the process plant but to participate actively in R & D outfits. In other to achieve this objective, the following recommendations are important:

- The specialized Universities of Technology and Agriculture should put greater premium on industrial chemistry programmes both at the undergraduate and postgraduate levels not only because they are consistent with the objectives set for these types of university, but for the cost effective use of resources available for training.

- The teaching of chemistry at the secondary school level should locate chemistry in real life situations in order to stimulate greater interest in and better understanding of the subject.

- Government should provide adequate funds to maintain functional chemical laboratories at the secondary school level in order to prepare the students for the challenges of the subject at the tertiary level.

- Admissions into chemical science programmes should give cognizance to facilities on ground to ensure effective training on the programmes.

- Industrial training programme should be re-examined to ensure that is relevant to the needs of the trainee chemist.

- The Institute of Chartered Chemists of Nigeria (ICCON) should provide an enabling platform for professionalization of Chemistry by working closely with universities in their curriculum development on the subject.

TOWARDS A VIRILE CHEMICAL INDUSTRY AND INDUSTRIAL DEVELOPMENT IN NIGERIA.

Mr. Chairman, I have examined the Chemical Industry in Nigeria within the framework of National Development Plans, industrial policy objectives and the efforts which past governments have made to ensure that its unique role for the industrialization process is exercised. I am convinced that the policy objectives were well conceived in the national interest but unactualized due largely to vital national questions, which questions remain unanswered even now.

It is true that most of the ambitious projects intended to energize the industrialization processes were conceived over the period of military governance; but these were also periods of political instability characterized by corruption, insecurity and over-centralization of the instruments of governance. Thus, over the years, rather than industrialize, the country has de-industrialized as the private sector failed to respond positively to complement the efforts of government. The economy has thus remained a monoculture depending largely on oil the politics of which stand on the way to true national growth and development. From the proceeding discussion on this subject, it is obvious that the petrochemical sector is still dormant lending credence to the current efforts of government to liberalize the down stream sector of the petroleum industry.

The emphasis on sharing of revenue accruing from the sales of crude oil for development purposes is a symptom of a polity that is lethargic unable to ignite the creativity and ingenuity of her citizenry and put them on the path of wealth creation. What is desirable is a polity which puts greater premium on the knowledge factor through the development of expertise for the transformation of our vast resources into products of economic value. In this wise, it would not matter where the resource(s) are located and states could proceed to develop resources with which they are not naturally endowed.

Mr. Chairman, this will not be possible unless the Nigeria political environment is re-configured to provide an enabling platform for development. In the worlds of the scripture Matthew 6:33, it says,

"But seek ye first the kingdom of God and its righteousness; and all these things shall be added unto you".

The import of this scriptural text is that as a country we must avoid the pitfall of locating the cart before the horse; the horse being the politics which regulate the environment. The conflicts that have engulfed the country over the years reflect the contradictions in the body politics; contradictions which stand on the way to national consensus on matters of development and on the way forward; contradictions which vitiate the process of national integration and evolution of the Nigeria nation state and nationalism.

There seem now a burning desire by many Nigerians for a national re-birth but we must transcend the rhetorics of it. For, such re-birth must be one into which a national dialogue on structure and reform of the Nigerian polity dovetails, so that the latent energies of the Nigerian people can be channeled concertedly towards a common goal and destination.

Our recent experience at democratic governance holds a lot of promise for Nigeria in view of the resultant dividends which include:

- A liberal polity sustained on the rule of law.
- Privatisation of inefficient public-owned enterprises
- Private sector participation in tertiary education
- Liberalization of the communication and energy sectors
- Improved working conditions for workers, etc.

But there is still much more to be done to encourage long term investments by both local and foreign entrepreneur in order to stimulate the industrialization process. And because the Chemical Industry is by nature, capital intensive, it, of necessity, calls for long term investment assured of a favourable and stable political environment. This is a more critical imperative with regards to which all hands must be on deck to ensure a sustainable democratic governance in Nigeria anchored on the immutable principles of true Federalism, and nurtured by the people's constitution. The antecedental realities of development efforts of government do not point to lack of well-articulated policies and action plans, neither the financial wherewithal to achieve the set objectives. Rather, it is true to say that the failure to achieve development objectives often referred to as government's inability to implement policies reflect deep-seated contradictions in the body politic. Our collective efforts at reform of the Nigerian polity is therefore called for, and is germane against the overall need to create an enabling environment for industrial growth and development of the Nigerian state.

I thank you for your kind attention.

Table 1: Nigeria's Development Plans with their Capital Expenditure

Plant	**Duration**	**Capital Expenditure (N)**
First National Dev. Plan	1962 – 1968	2.2 billion
Second National Dev. Plan	1970 – 1974	3.2 billion
Third National Dev. Plan	1975 – 1980	53.6 billion
Fourth National Dev. Plan	1981 – 1985	82.0 billion
First National Rolling Plan	1990 – 1992	168.1 billion
Second National Rolling Plan	1993 – 1995	NA
Third National Rolling	1996 – 1998	NA

NA: Not available

Source: Federal Ministry of Budget and Planning Lagos.

Table 2: Import of Chemicals.

N'million

	1995	1996	1997	1998	1999
Animal and Vegetable oils and fat	8,306.4	7,314.1	11,840.0	10,886.4	12,073.8
% of Total import	(1.1%)	(1.3)	(1.4)	1.3	1.4
Chemical	198,598.6	133,905.1	191,977.7	192,606.3	196,630.6
% of Total import	(26.3)	(23.79)	(22.7)	(22.99)	(22.79)

Source: Central Bank of Nigeria Annual Report and Statement of Accounts, 2000.

Table 3: Production of Principal Solid Minerals (Metric Tons).

Year	Coal	Tin	Columbite	Marble	Limestone	Clay
1993	27,686	175.39	15.43	716	1411,045	625
1994	13,153	208.3	224.89	539.5	735,137	NA
1995	19,505	203.75	37.10	1329.0	3,656,598.1	NA
1966	15,310	139.35	56.56	477.0	3,290,938.3	NA
1997	20,766	42.45	29.57	20,346	3,301,041.4	NA

NA: Not Available
Source: Federal office of statistics (1998).

Table 4: Petrochemical Phase 1 Project.

Product	**Projected output mt/yr.**	**Main end use**
Polypropylene	5,000	Woven sacks, bottle crates, chairs, back covers, and lids, kitchen wares, drug packaging, upholstery, floor carpets and textile.
Carbon Black	25,000	Tyres, hoes, belts, foot wares, printer ink, carbon paper, pigments, electrodes.
Linear Alkylbenzene	30,000	Synthetic biodegradable detergents (powder), liquid detergent.
Heavy alkylate	2,700	Lube oil additives, thermal fluids, Transformer oil, Greases, etc.
Solvents	38,000	Degreases, metal cleaner, odourless paints, insecticides, printing ink, drying cleaning agents.
Benzene	15,000	Linear alkylbenzene manufacture, aromatic Solvents, Aviation gasoline.

Source: NNPC, Falomo, Lagos.

Table 5: Petrochemicals Phase II Project.

Products	Projected Output (Mt/yr)
Low density polyethylene	110,000
High Density polyethylene	70,000
Polypropylene	60,000
Vinyl Chloride monomer	145,000
Polyvinyl chloride	140,000
Ethylene oxide } Ethylene glycol	35,000
Plasticizer	30,000
Chlorine/caustic unit	90,000/102,000

Source: NNPC, Falomo, Lagos.

Table 6: Phase 1 Petrochemicals Products (Actual Output)

Products	Plant Site	Capacity (metric ton/year)
Carbon black	Ekpan	18,000
Polypropylene	- do -	13,000
Linear alkylbezene	Kaduna	30,000
Benzene	Kaduna	15,000
Kero solvents	Kaduna	30,000

Source: NNPC, Falomo, Lagos, 1990

Table 7: **Water Retention Capacity of polyacrylic acid – cellulose graft copolymer.**

Graft(%)	WRC (g/g)
23.3	4.29
31.0	5.28
53.0	5.39

Source: Eromosele, 1994.

Table 8: **Water Retention Capacity of Polymethacylonitrile – Cellulose graft copolymer**

Graft(%)	WRC (g/g)
52.7	11.87
93.1	4.45
113.3	2.23
116.5	2.19
144.2	1.78

Source: Eromosele and Ahmed, 1996.

Table 9: Tensile Properties of Fibres.

Fibres	Initial Modulus ($Ntex^{-1}$)	Specific Work of Rupture $mNtex^{-1}$)	Tenacity ($Ntex^{-1}$)	Breaking Extension (corrected for crimp) %	Crimp (%)	Crease Recovery (%)
Urtica dioica	3.73	3.38	0.13	3.9	2.0	27.8
Hibiscus sabdariffa	2.92	3.34	0.13	5.4	2.1	24.9
Hibiscus cannabinus	3.38	4.43	0.15	5.6	2.1	20.4
Urena lobata	5.25	2.88	0.19	3.7	0.9	29.9
Corchorus fascularis	4.25	2.39	0.13	3.9	2.4	18.4
Hibiscus esculentus	2.31	2.49	0.09	4.8	1.0	-
Adansonia digitata	1.40	1.29	0.05	4.8	1.0	20.7

Source; Eromosele *et al*., 1999

Table 10: Uses of Castor oil and its Derivatives.

Product from oil	Application
Polyamide 11 (nylon 11)	Engineering plastics (largest single use)
Hydrogenated castor oil	Principally as lubricating grease for auto, rail, tracks, aviation and marine applications.
Dehydrated oil and its acids	Coatings, inks, sealants and related products.
Sebacic acid	Component of nylon 6 – 10, lubricants, plasticizers for vinyl films including food wrap.
Ethoxylated oil	Industrial use in surfactants, emulsifiers, lubricants, agricultural applications, Coatings, cosmetics, and textiles processing.
Sulfanated (sulfated) oil	Lubricant surfactants as above
Polyurethane encapsulants	Electronics & telecommunication and coatings
Plasticizers	Esters of castor oil and its derivatives for coatings and plastic films.
Oxidized / Polymerized	Plasticizer for coatings, inks and sealant.

Source: INFORM 2(8) 692 (1991).

Table 11: Estimated Output of Major Agricultural Commodities, in Nigeria

'000 tons

	1996	1997	1998	1999	2000
Cotton seed	301	309	329	351	353
Palm kernel	548	550	572	600	629
Palm Oil	776	780	794	825	860
Groundnut oil	461	470	484	502	521
Rubber	245	250	255	265	275

Source: CBN Annual Report and statement of Accounts, 2000.

Table 12: Composition of palm oil processing Industries in Indonesia.

Type of Industry	**Annual production Capacity metric tons**
Cooking oil	1,496,372
Margarine and shortening	419,179
Cocoa butter substitutes	211,600
Battary soap	415,700
Oleochemicals:	
Fatty acid	57,200
Fatty alcohol	86,000
Stearic acid	117,900
Stabilizer	45,000
Glycerine	56,196

Source: INFORM 2 (12) 1082 (1991).

Table 13: Physico – Chemical Characteristics of Seed Oils

Seed	Oil %(w/w)	SV (mg KOH)	PV (mEq/kg)	IV (g/100g)	AV (mgKOH/g)	Refractive Index(20°c)	Status & Class of oil
natostaphis ari	54.5	213.0	27.5	125.7	0.11	-	Edible, SD
rium ocarpum	7.4	-	150	58.9	0.20	1.465	-,ND
nites tiaca	38.2	165.5	22.5	76.2	0.11	-	Edible, ND
enia ricana	49.9	182.3	29.4	149.8	0.14	-	Edible, SD
hira eolata	40.0	219.0	95a)	65.0	0.03	1.459	Not Edible, ND
hia sapida	26.0	261.0	135	87.6	0.34	1.449	-, ND
culia gera	33.0	212.8	35	67.3	0.50	1.465	Edible, ND
reocarya ea	42.0	199.3	25	69.0	0.25	1.462	Edible, ND
iya egalensis	52.5	186.0	26	68.0	-	-	-, ND
aruim weinfurthii	-	213.0	40	87.0	0.34	-	Edible, ND
delia uginea	54.7	32.3	<1	149.0	23.4	-	- , SD
sophilum dum	2.9	44.9	<1	157.5	26.9	-	- , SD
nodora ristica	52.0	74.3	6.5	177.5	16.3	-	Edible, D

SD, Semindrying; ND, Non-drying; D, Drying

Source: Eromosele, 1997

Table 14: Fatty acid Composition of Haematostaphis barteri and Ximenia americana seed oils.

Fatty acid	**H. barteri(%)**	**X. Americana (%)**
Caprylic	ND	0.55
Myristic	4.23	ND
Palmitic	1.35	3.31
Stearic	15.40	3.47
Oleic	69.35	72.09
Linoleic	ND	1.34
Linolenic	ND	10.31
Eicosadienoic	6.92	ND
Eicosatrienoic	ND	3.39
Arachidonic	ND	0.60
Erucic	2.74	3.46
Nervonic	ND	1.23
Total Unsaturation	79.01%	92.42%

ND: Not detected.

Source: Eromosele and Eromosele, 2001.

Table 15: Summary of Maters and PhD. Degrees 1990 – 1992.

Year	**Ph.D**		**Masters**	
	M	**F**	**M**	**F**
1990	287	72	3420	428
1991	332	55	4629	1032
1992	258	34	3918	824

Source: National Universities Commission.

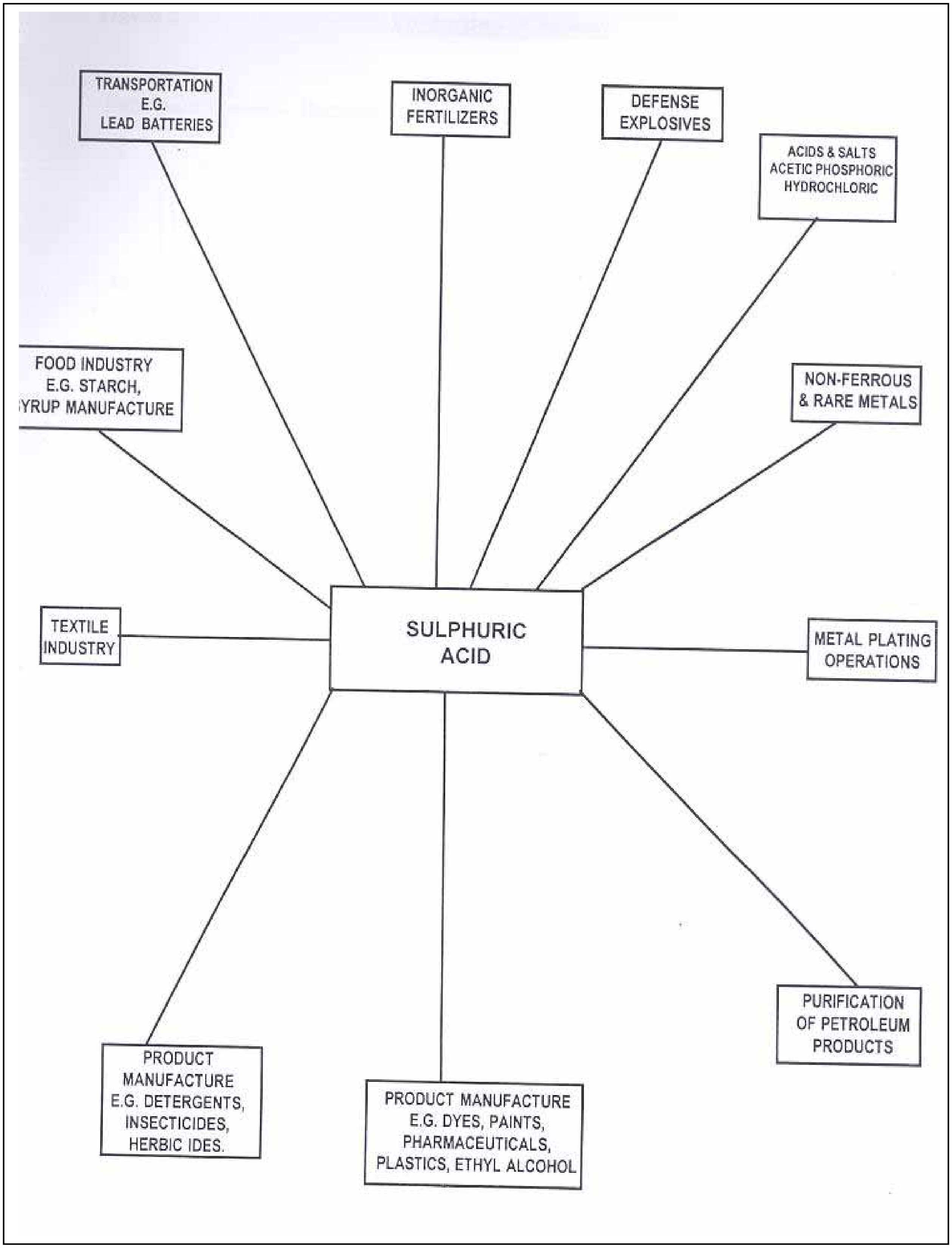
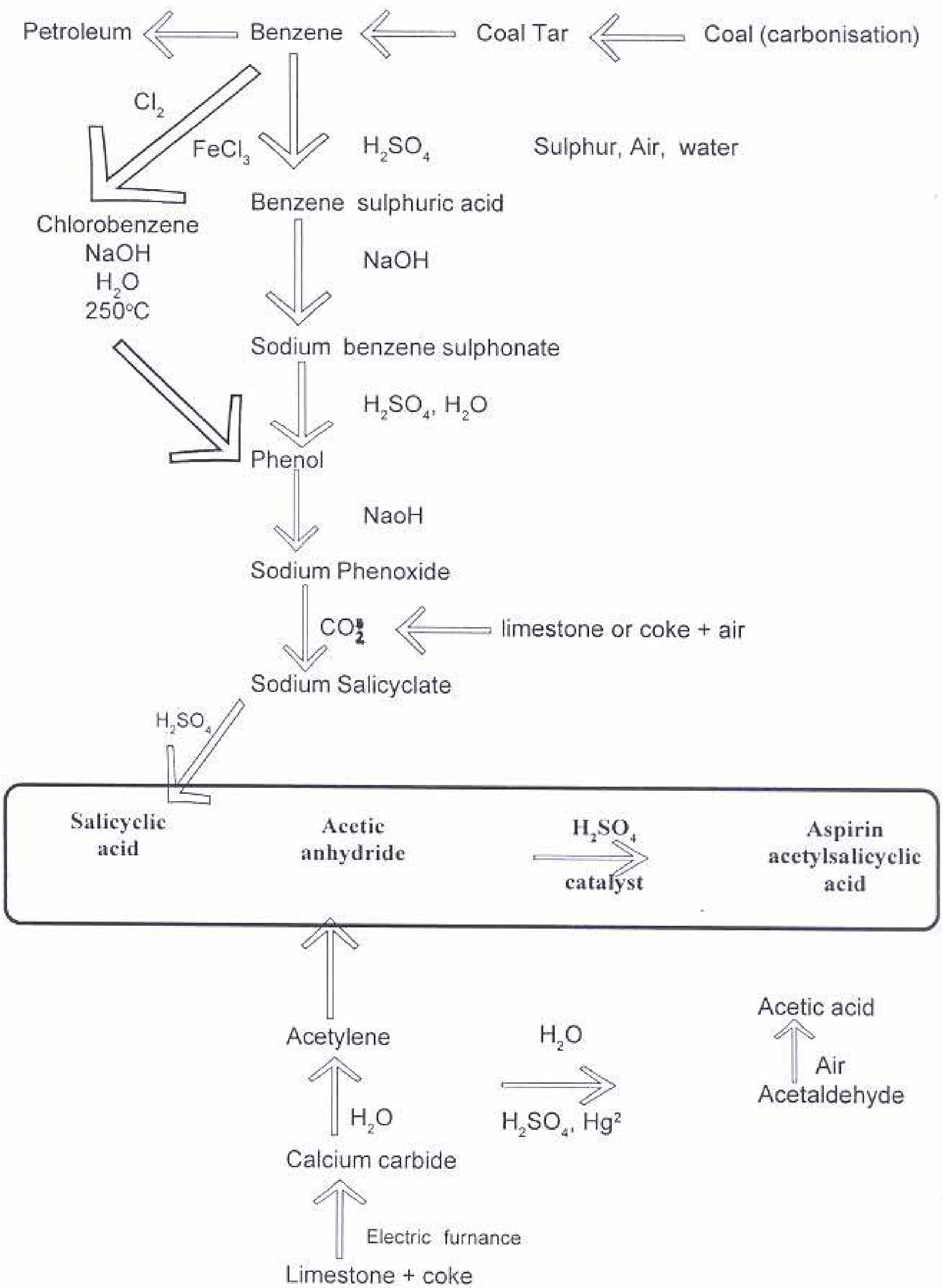
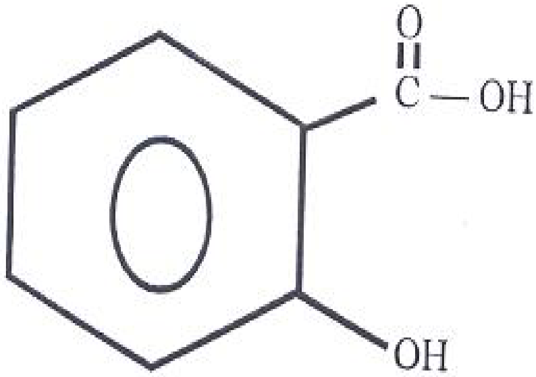

TRANSPORTATION
E.G.
LEAD BATTERIES
INORGANIC
FERTILIZERS
DEFENSE
EXPLOSIVES
ACIDS & SALTS
ACETIC PHOSPHORIC
HYDROCHLORIC
FOOD INDUSTRY
E.G. STARCH,
YRUP MANUFACTURE
NON-FERROUS
& RARE METALS
TEXTILE
INDUSTRY
SULPHURIC
ACID
METAL PLATING
OPERATIONS
PURIFICATION
OF PETROLEUM
PRODUCTS
PRODUCT
MANUFACTURE
E.G. DETERGENTS,
INSECTICIDES,
HERBIC IDES.
PRODUCT MANUFACTURE
E.G. DYES, PAINTS,
PHARMACEUTICALS,
PLASTICS, ETHYL ALCOHOL

Fig. 1.

Figure 2 **Production of Aspirin**

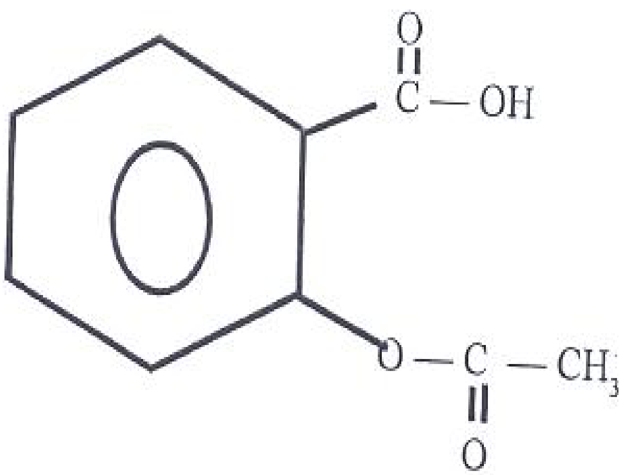


Source: Ikoku, 1981.



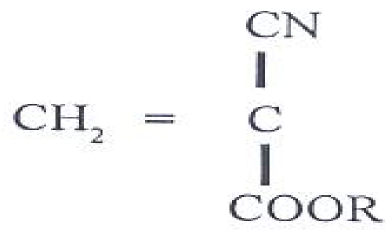
I

Salicyclic acid

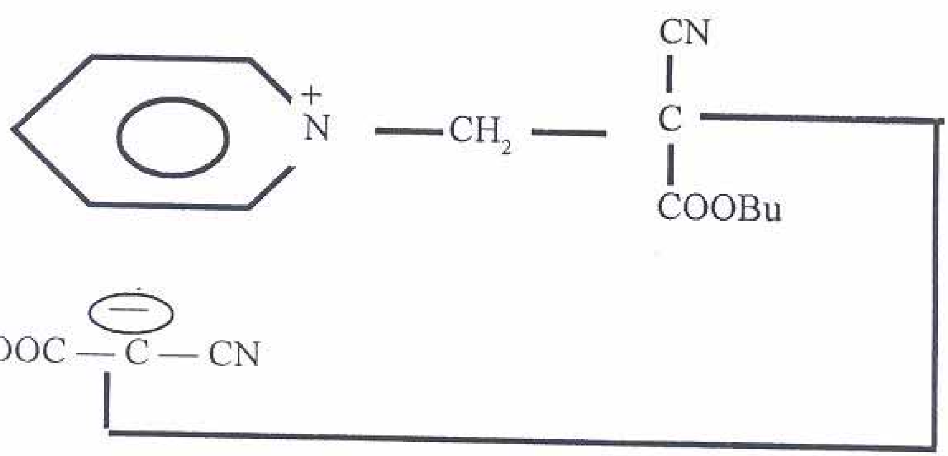


II

acetylisalicyclic acid

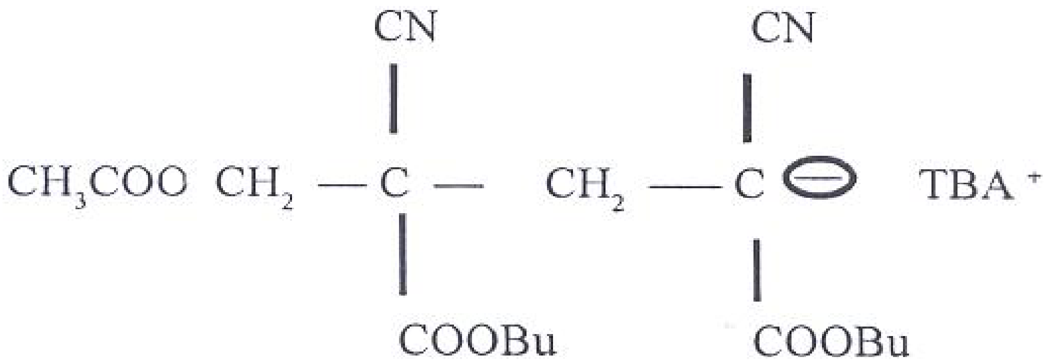


III

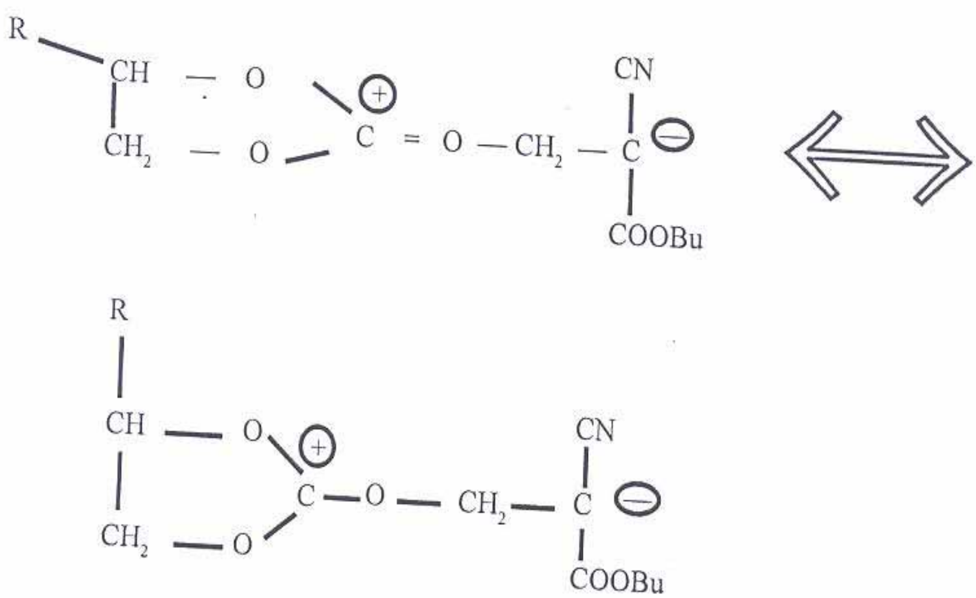


Zwitterionic Polymer Chain

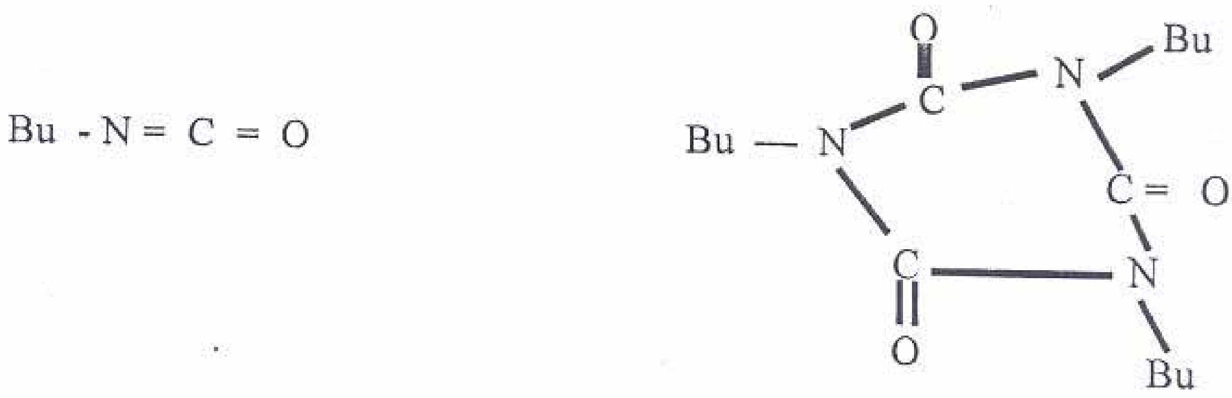
IV


CN
CN
CH3COO CH2 — C — CH2 — C
TBA+
COOBu
COOBu

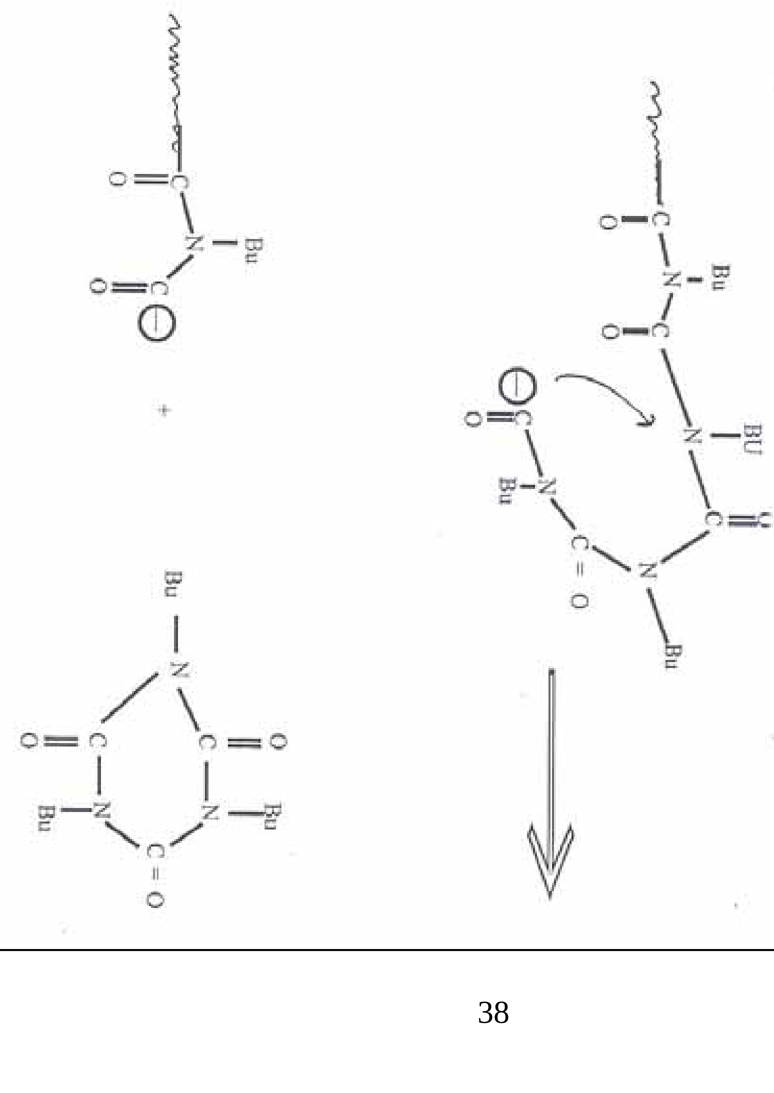
V

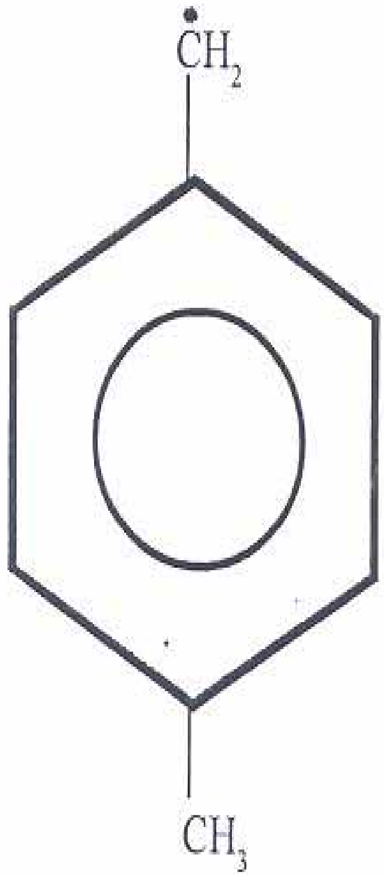

R
CH — O
CH2 — O
C = O — CH2 — C
CN
COOBu
R
CH — O
CH2 — O
C — O — CH2 — C
CN
COOBu

VI

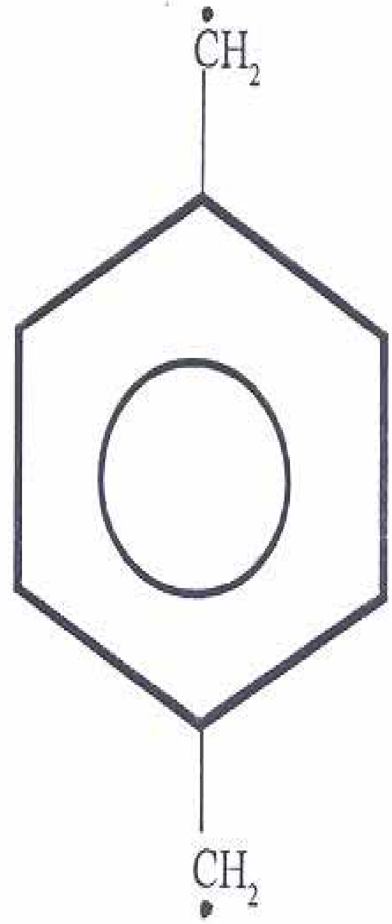


(VII) (VIII)





X



XI