PUBLIC LECTURE SERIES

CHEMICAL INDUSTRY: AN INDEX OF THE TECHNOLOGICAL DEVELOPMENT OF A NATION

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1. INTRODUCTION

Definition and Explanation of some Terms

What is a chemical industry?

It is difficult to define chemical industry exactly because of the absolute necessity for chemicals in almost every manufacturing industry. However, chemical industry can be defined as one that consists of all companies engaged in converting raw materials obtained from the environment (air, water, petroleum, minerals, agricultural products etc) into basic chemicals or chemical intermediates as well as the companies that convert these intermediates into consumer products.

It is central to modern world economy, converting raw materials into more than 70,000 different products. Polymers and plastics, especially polyethylene, propylene, polyvinyl chloride, polyethylene terephthalate, polystyrene and polycarbonate comprise about 80% of industry's output worldwide. Chemicals are used to make a wide variety of consumer goods, as well as thousands of products that are essential inputs to agriculture, manufacturing, construction and service industries. The chemical industry itself consumes about 26% of its own output. Major industrial customers include rubber and plastic companies, textiles, apparel, petroleum refining, pulp and paper and primary metals. Chemicals manufacture is nearly a $ 2 trillion global enterprise, and the EU and U.S. chemical companies are the world's largest producers.[1]

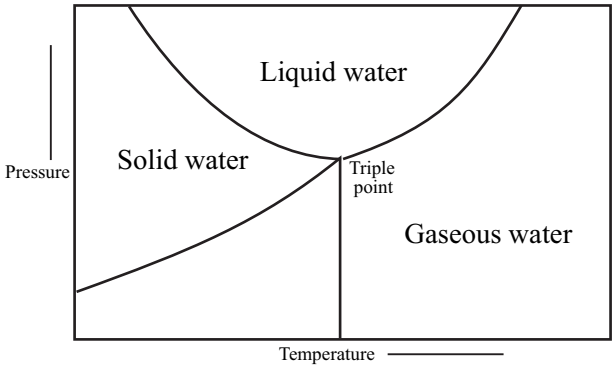
What is a Chemical?

A chemical on the other hand is a substance used in or produced by the process of chemistry. A chemical has a defined atomic or molecular structure that results from, or takes part in reactions involving changes in its structure, composition and properties. For instance, the common table salt which is chemically called sodium chloride, NaCl is produced by the reaction of sodium (Na) with chlorine (Cl) atoms:

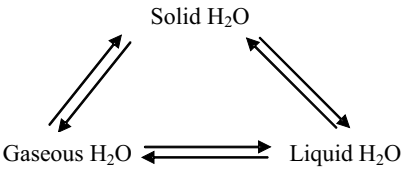
$$Na_{(s)} + \tfrac{1}{2}Cl_{2\,(g)} \;?\; NaCl_{(s)}$$

What is Chemistry?

Chemistry is the study of matter and its properties, the changes that matter undergoes and the energy associated with these changes. Matter on the other hand is anything that has mass and volume and commonly occurs in three physical forms called states namely: gas, liquid and solid depending on the temperature and pressure of the surrounding; to illustrate this, let us consider water:



At one atmosphere pressure, water exists in the liquid state from 0ºC to 100 ºC. At 0ºC, it freezes to become solid water (ice) and at 100ºC it boils to become gaseous water. At 0ºC and 1 atmosphere pressure the three forms of water are at equilibrium i.e.



Chemistry is the central science.[1] It rests on the foundation of mathematics and physics and in turn underlies the life sciences in biology and medicine. In order to understand the living system fully, one must first understand the chemical reactions and chemical influences that operate within them. It is a core subject in all science related programmes: Agriculture, engineering, medicine, biochemistry, microbiology, pharmacy etc. Since Chemistry is a broad, field it is subdivided into five branches namely: organic, inorganic, analytical, physical chemistry and biochemistry.

Organic Chemistry is the study of compounds of carbon and hydrogen.

Inorganic Chemistry is the study of substances that do not contain carbon bonded to hydrogen. The branch of chemistry that deals with the detection or identification of substances present in a sample or with the amount of each substance that is present is called ***analytical chemistry***.

Physical chemistry applies the mathematical theories and

methods of physics to the properties of matter and to the study of chemical processes and the accompanying energy changes.

Biochemistry is the study of the chemistry of processes in living organisms.

Chemistry is a challenging and exciting subject as an academic discipline. Its principles and ideas are to produce the chemicals from which all manner of materials and consumer products are manufactured.

Industry and Technology

Industry is organized economic activity connected with the production, manufacture or construction of a particular product or range of products.

Technology is the study of development and application of devices, machines (or tools), methods for manufacturing and productive processes. Development is the process of changing and becoming larger, stronger, more impressive, successful or advanced.

Who is a Chemist?

Often the word Chemist to a number of people means the person who dispenses drugs in a pharmacist's store. No! A chemist is a person who has undergone training in chemistry as a discipline and practices chemistry as a profession either as a teacher or a practitioner in any applied aspect of chemistry like chemical manufacturing or allied industries.

In general, chemists study the composition, structure and characteristics of matter in an attempt to improve existing

substances and products, discover new ones, improve and develop chemical processes in line with technological advancement.

Listen to what one author wrote about chemists:

"In the beginning God made heaven and earth. And God saw everything that He made, and behold it was very good…and on the seventh day, He rested. (Gen 1:1-2:2). After God rested there were other things that still needed to be made due to the insatiable demands of human beings, therefore God looked upon the face of the earth and found
His chosen friends (the Chemists) and He commissioned them to continue with the creation, transformation and refining other things which still needed to be created from those things that had been made. Chemists are therefore, the chosen friends of God.
What better profession should anyone wish to be called into other than chemistry?"

It was late Dr. A. K. Fasina, a renowned chemist and one time president of the Chemical Society of Nigeria who said, *"The greatest power in the world is the power of creating something from nothing; that power belongs to God. The next power is that of changing matter from one form to another; God gave that power to chemists."*

2. THE CHEMICAL INDUSTRY

The chemical industry includes those manufacturing processes whose products result from (a) chemical reactions between organic materials or inorganic materials, or both; (b) extraction , separation or purification of a natural product, with or without the aid of chemical reactions; the preparation of specially formulated mixtures of materials, either natural or synthetic. Examples of products from the chemical industry are plastics, resins, dyes,

pharmaceuticals, perfumes, inorganics and synthetic organic materials, textiles, soap, detergents, paints, cosmetics etc.

The global chemical industry is valued at one and half trillion US dollars today with more than 70,000 commercial products. The total world trade in chemicals is valued at US$ 400 billion which is about 10% of the value of the global trade.[2]

The three largest sectors within the world chemical industry are petrochemicals, (30%), pharmaceuticals (16.5%) and performance chemicals, (16%). The European Union (EU), the U.S.A and Germany are the three largest manufacturers of chemicals followed by Japan, France and United Kingdom, Italy and other Asian countries.

3. IMPACT OF CHEMICAL INDUSTRY ON SOCIETY

It is obvious from the brief discussion of the chemical industry in section two of this lecture that chemical industry as a whole makes a great contribution to society by improving the welfare of mankind and providing employment around the world.

All we have to do to appreciate the impact of chemical industry on modern society is to take a quick look around us even as we are seated now.

Robert A. Smiley and Harold L. Jackson, authors of the book, *Chemistry and Chemical Industry* have this to say on how chemical industry contributes to our daily lives:[3]

"For example, when you get up in the morning, you brush your

teeth using toothpaste, which is a mixture of chemicals squeezed from a plastic tube onto plastic bristles mounted in a plastic handle.

You may take a shower using soap and shampoo, each made by the chemical industry, and finally dry, brush, or comb you hair with other articles made of plastic. While doing this, you will likely be looking into a mirror over porcelain or cultured marble sink while standing on vinyl plastic floor covering, tile, or carpeting, all of which are products of the chemical industry. The varnish coating, the wooden floors of your house and the paint of wallpaper covering the walls are products of the chemical industry.

At breakfast, it is likely that the kitchen counters and table are topped with plastic, as are the chairs. The refrigerator would not work without chemicals either for the refrigerator unit or the insulation in its walls. The interior is plastic lined and the exterior has a durable coating made possible by the chemical industry. Your breakfast food is probably fresh because it was treated with chemical preservatives and/or shipped in a box with a plastic lining.

The car or bus that you go to work in is totally chemical dependent, from the anti-corrosion treatment of the metal, the protective paint and the plastic parts and tires to the chemical battery that starts the vehicle, the oil that lubricates it, and the gasoline that fuels it. And so it goes".

Indeed, life as we know it today could not exist without chemistry and the chemical industry.
No wonder the rhetorical maxim: "What on earth is not chemistry?" In other words,

Chemistry Rules the World!

4. A BRIEF HISTORY OF THE CHEMICAL INDUSTRY

The use of chemicals dated back to the ancient civilization i.e. the Middle Ages (about the 15th Century). The evolution of modern chemical industry may be considered to have begun during the industrial revolution (in the nineteenth century) and developed to provide chemicals for use by other industries. Examples are sodium hydroxide for soap making, bleaching powder for cotton, silica and sodium carbonate for glassmaking. All these are inorganic chemicals.

The discovery of the first synthetic dyestuff, *mauve,* in the 1860s by W.H Perkins was instrumental to the evolution of the organic chemical industry in the United Kingdom and Germany.[4]

The dawn of the twentieth century brought fundamental changes in the industry due to the emphasis on research on the applied aspects of chemistry. This resulted in the German chemical industry producing about 75% of the world market in chemicals due to the following factors: the discovery of new dyestuffs, development of both the contact process for the manufacture of sulphuric acid, H_2SO_4 and the Haber process for ammonia, NH_3, production.

The Haber process brought about a major breakthrough in technology that of being able to carry out chemical reactions under conditions of very high pressure.

This technological breakthrough helped Germany in the production of nitrogen based compounds (ammonium salts for fertilizers and nitric acid for the manufacture of explosives) with the outbreak of World War 1 in 1914.

The organic chemical industry has grown remarkably since 1940 as a result of the development and growth of the petroleum sector. The rapid growth in petrochemicals in the 1960s and 1970s was largely due to the enormous increase in the demand for synthetic polymers such as polyethylene, polypropylene, nylon, polyesters and epoxy resins.

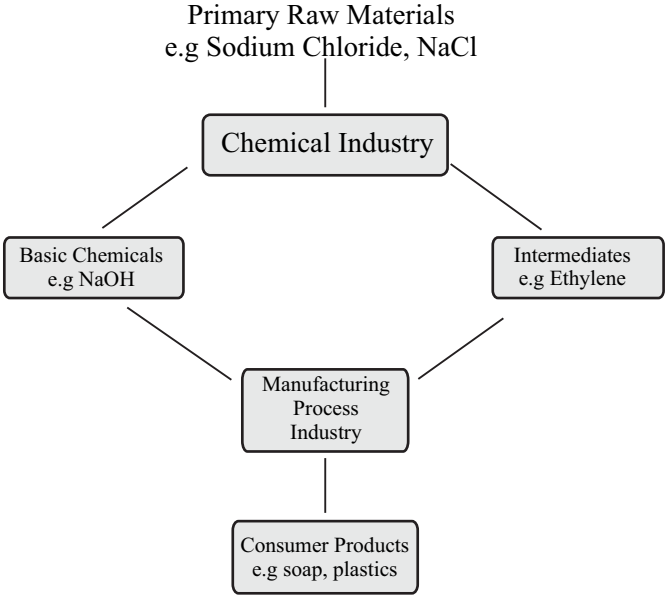
The chemical industry today is highly research and development (R&D) intensive and very technological based. It takes full advantage of the latest advances in electronics and engineering. Computers are very widely used for all sorts of applications, from automatic control of chemical plants, to molecular modelling of structure of new compounds, to the control of analytical instruments in the laboratory etc.

Many of the basic processes for producing key intermediate chemicals have lost their patent production over the years, enabling other countries of the world who wish to venture into this area, to buy their own manufacturing plants. As a result, petroleum producing countries such as Korea, Mexico, Saudi Arabia and other Middle Eastern countries have entered and rapidly expanded their production of the aromatic petrochemical intermediates for the manufacture of synthetic polymer products.

There is also a growing shift in the global chemical industry as a result of both the rapidly growing population and the industrial development of South Asian countries. It is envisaged that China with its large population will become both a major market and producer of chemicals during the twenty first century.

5. CLASSIFICATION OF CHEMICALS

Chemical products are made from raw materials which are obtained from air, water, petroleum and natural gas, coal, agricultural products and minerals. Some of them are in their final or finished states while majority are intermediates which in turn are used as raw materials in many manufacturing process industries to produce consumer goods as indicated in the flow chart below:



The number of chemicals in the world is enormous but they can be broadly classified into two categories namely;
a) Basic chemicals and
b) End or consumer products.

Basic chemicals are generally chemicals used by chemical manufacturing process industries which turn basic chemicals into useful end products that are part of our daily life. Examples of basic chemicals are sulphuric acid, H_2SO_4; sodium hydroxide, NaOH; phosphoric acid, H_3PO_4; nitric acid, HNO_3; ammonia, NH_3; chlorine, CI_2; oxygen, O_2; nitrogen, N_2; hydrogen, H_2; methane, CH_4; ethylene, C_2H_4; propylene, C_3H_6 etc.

While consumer products are materials (chemical products) arising from reaction of basic chemicals with either other raw materials or intermediate products to produce materials which are important for daily living e.g. pharmaceuticals, textile fibres, soaps, detergents, paints, cosmetics, dyes and pigments, fertilizers and other agricultural chemicals. The process involved is generally mixing of chemicals.

Chemicals can be further classified into inorganic and organic chemicals.

Inorganic Chemicals

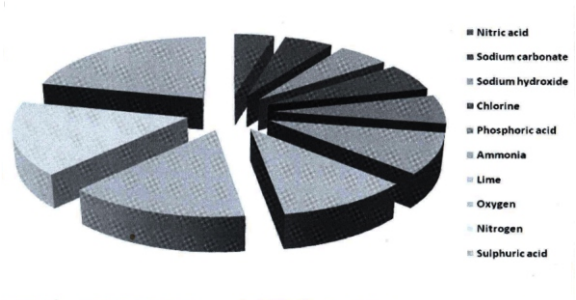
Inorganic chemicals are derived from minerals in the ground or from the air, but not from living matter. The table below shows the ten most important inorganic chemicals, their sources and uses.

Table 1: The ten most important inorganic chemicals

S/N	Chemicals	Sources or Manufacture	Major Uses
1	Sulphuric acid, H_2SO_4		For making fertilizers, petroleum refining, synthetic rubber and other plastics, manufacture of inorganic pigments, water treatment chemicals paints, car batteries.
2	Nitrogen, N_2	Liquefaction of filtered air followed by distillation.	Manufacture of ammonia, nitric acid, ammonium fertilizers (ammonium nitrate, urea, ammonium sulfate); provides inert atmosphere for chemical reactions, metal treating, food processing (freezing).
3	Oxygen, O_2	Distillation of liquid air	Metallurgy (making steel) metal fabrication, chemical manufacturing, Medical & life support applications, sewage treatment, rocket propellant, paper bleaching.
4	Lime, CaO	Calcination of limesone in a kiln	For making steel and chemicals, water treatment pollution control, pulp and paper construction
5	Ammonia, NH_3	$3H_2 + N_2 \xleftarrow{catalyst} \rightarrow 2NH_3$	Manufacture of nitric acid, urea, ammonium salts, all of which are used in fertilizers and explosives.
6	Phosphoric acid, H_3PO_4	Mineral reaction of phosphate rock with H_2SO_4 $Ca_3(PO_4) + 3H_2SO_4$? $2H_3PO_4 + 3\ CaSO_4$ (Phosphate rock) (gypsum)	Preparation of ammonium and calcium salts used in fertilizers, water softeners and detergents, animal feeds, baking powder, acidifying soft drinks e.g. Coca-Cola, organic phosphates as flame retardants
7	Chlorine, Cl_2	Co-produced with NaOH by the electrolysis of salt (brine).	Water purification, metal extraction, production of organic compounds used in plastics, pesticides herbicides, refrigeration, fluids, solvents.

8	**Sodium hydroxide, NaOH**	**Electrolysis of salt (brine)** $2\ NaCl + 2H_2O$ $2NaOH + H_2 + Cl_2$	**Chemicals manufacture, soaps and detergents, petroleum, food processing, pulp and paper industry, textile manufacture, water treatment.**
9	**Sodium carbonate,** Na_2CO_3	**In U.S.A 95% is obtained from the ore, "trona" mined primarily from Wyoming** **Elsewhere in the World by "Solvay" process using limestone and NaCl as raw materials**	**Over 50% for glass making, preparation of chemicals (e.g sodium silicate, sodium phosphate), soaps & detergents, pulp & paper industry, water treatment.**
10	**Nitric acid,** HNO_3		**Manufacture of fertilizer, a raw material for manufacture of nylon. Manufacture of virtually all gunpowder and explosives (nitroglycerin, nitrocellulose, TNT, ammonium nitrate etc.) Starting materials for polyurethane elastomers and paints.**

Important Inorganic Chemicals



1999 United State annual production in Billion pound per year

Organic Chemicals

All organic chemicals are by definition based on chemicals derived from living matter. Even petroleum and natural gas are believed to have been formed by the microbial decomposition of ancient marine plants and animals. The raw material sources for organic chemicals are:

I) Petroleum and natural gas which are non-renewable energy sources. This source constitutes about 90% of all organic chemicals produced.

ii) Coal: This was the principal organic chemical raw material prior to World War II. It is more difficult to process than petroleum. It is also a non-renewable energy source.

iii) Biomass (carbohydrates) includes chemicals obtained from wood, sugar, grain etc. It is a renewable source and will probably become more important in future.

iv) Animal and vegetable oils. The chemicals from this source are from animal and vegetable and are known as "fatty acid" products. This is also a renewable source.

Petrochemicals

Petrochemicals are chemicals made from petroleum (crude oil) and natural gas. Petroleum and natural gas are made of hydrocarbon molecules which are comprised of one or more carbon atoms, to which hydrogen atoms are attached. Currently, oil and gas are the main sources of the raw materials because they are the least expensive, most readily available, and can be processed

most easily into primary petrochemicals listed in table 2. Only about five percent of the oil and gas consumed each year is needed to make all the petrochemical products. Petrochemicals have had a dramatic impact on our food, clothing, shelter and leisure. Some synthetics, tailored for particular uses, actually perform better than products made from natural because of their unique properties.

Primary Petrochemicals

Primary Petrochemicals include: olefins (ethylene, propylene and butadiene) aromatics (benzene, toluene and xylenes); and methanol.

Intermediates and Derivatives

Petrochemical intermediates are generally produced by chemical conversion of primary petrochemicals to form more complicated products (see the right of table 2). Petrochemical derivatives can be made in a variety of ways: directly from primary petrochemicals; through intermediate products which still contain only carbon and hydrogen; and through intermediates which incorporate chlorine, nitrogen or oxygen in the finished derivative. In some cases, they are finished products; in others, more steps are needed to arrive at the desired composition. Of all the processes used, one of the most important is polymerisation. It is used in the production of plastics, fibres and synthetic rubber, the main finished petrochemical derivatives. Some typical petrochemical intermediates are:

- Vinyl acetate for paint, paper and textile coatings
- Vinyl chloride for polyvinyl chloride (PVC), resin manufacture
- Ethylene glycol for polyester textile fibres
- Styrene which is important in rubber and plastic manufacturing.

The major end products number in the thousands, some going in as inputs into the chemical industry for further processes. The more

common consumer products made from petrochemicals include adhesives, plastics, soaps, detergents, solvents, paints, drugs, fertilizers, pesticides, insecticides, and other agrochemicals, explosives, synthetic fibres, synthetic rubber, flooring and insulating materials.

Table 2: Examples of Primary Petrochemicals, Petrochemical Intermediates and Derivatives

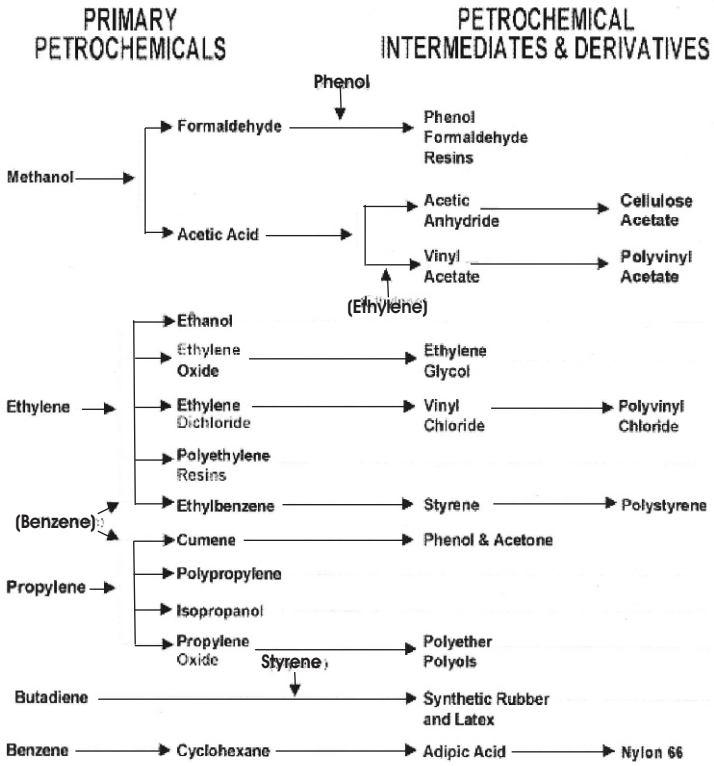
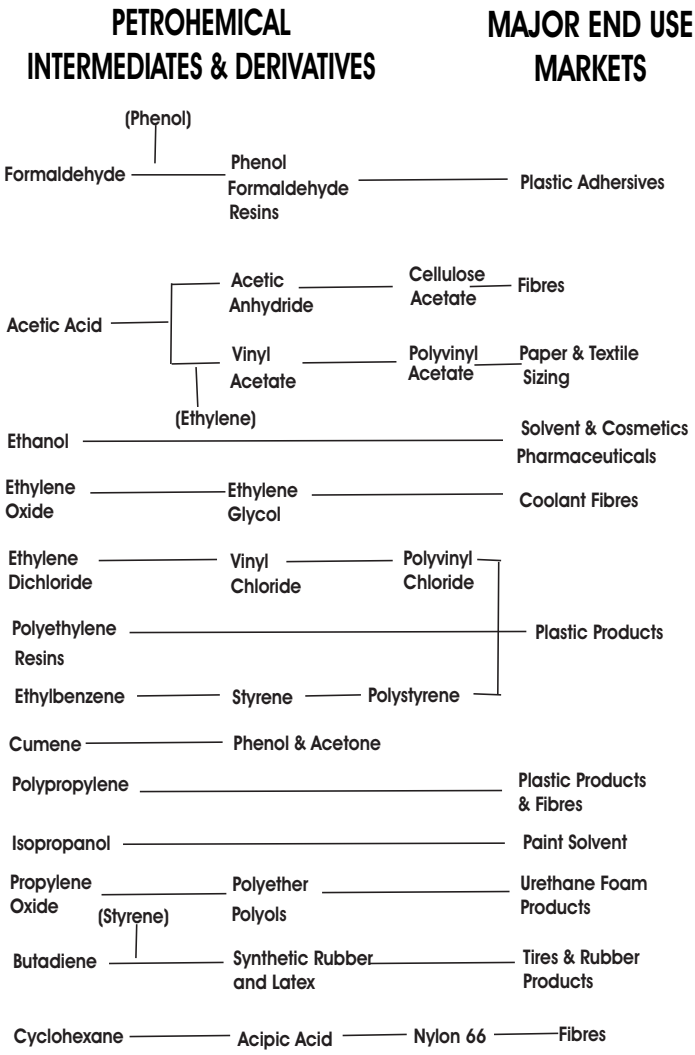
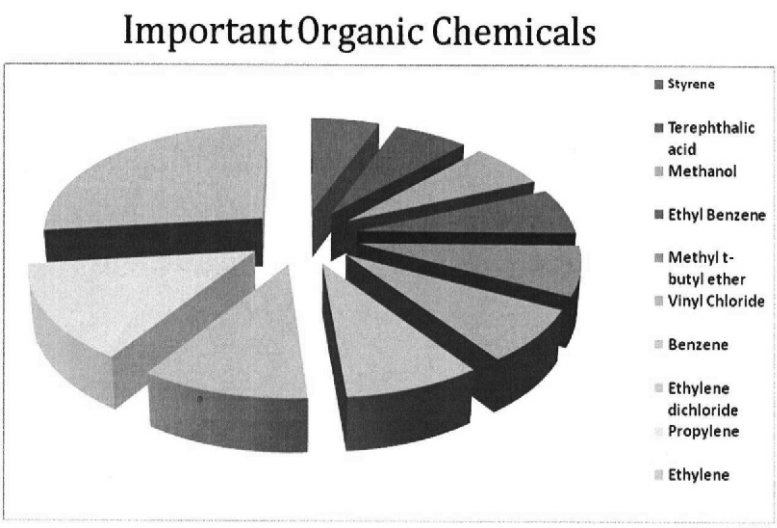


Table 3: Example of Petrochemical Intermediates & Derivatives and Major End Use Markets





1999 United State annual production in Billion pound per year

Top 20 Chemicals

This list includes the most recent figures for the United States chemical industry. These figures are obtained from government, trade associations reports, and industry estimates. The list includes chemically homogeneous finished products. It does not include minerals which do not require processing, such as salt and sulphur, and petrochemical feed stocks such as ethane and butane which are considered products of oil companies.

Table 4: Top 20 Chemicals[6]

Rank (by mass)	Chemical	2006 Production (in 10^9 kg)
1	Sulfuric acid	35.9
2	Ethylene	25.0
3	Polyethylene	17.3
4	Propylene	15.6
5	Phosphoric acid	10.7
6	Ammonia	10.4
7	Chlorine	10.2
8	Ethylene dichloride	9.7
9	Polypropylene	8.3
10	Sodium hydroxide	8.0
11	Benzene	7.6
12	Polyvinyl chloride	6.8
13	Nitric acid	6.6
14	Ammonium nitrate	6.3
15	Urea	5.4
16	Ethyl benzene	5.3
17	Styrene	4.8
18	Hydrogen chloride	4.1
19	Cumene	3.6
20	Ethylene oxide	3.4

World Ranking of Chemical Companies in the 21st Century

Historically and presently, the Chemical Industry has been concentrated in three areas of the world: Western Europe, North America and Japan[3].

In the year 2000, U.S.A. was the largest producer of chemicals in the world[2]. The total value of chemicals produced in U.S.A. during this period was $460 billion. There were over 12,000

chemical plants in U.S.A with 170 U.S. chemical companies operating an additional 3,000 chemical plants in foreign countries. The Chemical Industry employed over 1,000,000 workers.

The chemical industry includes large, medium and small companies that are located worldwide. Companies with sales of chemical products greater than $10 billion dollars in fiscal year 2005 are shown below. For some of these companies the chemical sales represented only a portion of their total sales; for example Exxon Mobil's chemical sales were only 8.7 percent of their total sales.

Table 5: World Ranking of Chemical Companies in the 21st Century[2]

COMPANY, HEADQUARTERS	2005 Chemical Sales, billions	Rank
BASF, AG, Ludwigshafen, Germany	$53.2	1
Dow Chemical, Midland, Michigan U.S.A.	$46.3	2
Shell Chemicals, Netherlands/UK	$35	3
Bayer, AG, Leverkusen, Germany	$34.1	4
INEOS, Lyndhurst, UK	$33A	5
ExxonMobil, Irving, Texas, U.S.A	$31.2	6
DuPont, Wilmington, Delaware, U.S.A	$28.5	7
Mitsubishi Chemical, Tokyo, Japan	$21.9	8
Lyondell Chemical, Houston, Texas, U.S.A.	$18.6	9
Saudi Basic Industries Corporation, Riyadh, Saudi Arabia	$18.4	10
Akzo Nobel, Arnhem, Netherlands	$16.2	11
Degussa, AG, Düsseldorf, Germany	$14.6	12

Sumitomo Chemical, Tokyo, Japan	$14.1	13
Asahi Kasei, Tokyo, Japan	$13.6	14
Mitsui Chemicals, Tokyo, Japan	$13.4	15
Air Liquide, Paris, France	$13.0	16
Toray Industries, Tokyo, Japan	$13.0	17
Huntsman Corp., Salt Lake City, Utah, U.S.A.	$13.0	18
Chevron Phillips, The Woodlands, Texas, U.S.A.	$10.7	19
Solvay SA, Brussels, Belgium	$10.7	20
Imperial Chemical Industries(ICI), London, UK	$10.6	21
Shin-Etsu Chemical Co., Ltd., Tokyo, Japan	$10.2	22
DSM NV, Heerlen, Netherlands	$10.2	23

There is not a single African country or any of the developing countries in the list. This reminds one of the World ranking of Universities where there is not a single Nigerian University in the first 200 universities. However, there is hope because the traditional dominance of chemical production by Western Europe, North America and Japan is being challenged by changes in

feedstock availability and price, labour and energy cost, differential rates of economic growth and environmental pressures. Instrumental in the changing structure of the global chemical industry has been the growth of China, India, Korea, the Middle East, South East Asia, Malaysia, Nigeria, Trinidad, Thailand, Brazil, Venezuela and Indonesia.

6 THE NIGERIAN CHEMICAL INDUSTRY

Although there are many chemical manufacturing process industries in Nigeria ranging from small, medium to large companies such as soap and detergent, fertilizers and agrochemicals, pharmaceuticals, cosmetics and toiletries, paints and allied products, polymers, synthetic rubber and textile fibres, there are only very few chemical industries that produce basic chemicals. The manufacturing process industries are not primary chemical industries because they do not manufacture most of the chemicals they use for their manufacturing processes. Almost all the basic chemicals used are imported. The secondary and tertiary institutions in Nigeria running chemical-based practical e.g. chemistry, biochemistry, chemical engineering etc are not left out. Most of the chemicals required for experimental work are imported. I know how much chemicals we consume in the Department of Chemistry per session. All are imported!

Table 6: Some Basic Chemicals Consumed by the Textile Industry[7]

Caustic Soda	**Hydrogen peroxide**
Soda ash	**Sodium chloride**
Sodium silicate	**Sodium sulphate**
Sodium sulphide	**Sodium meta-silicate**
Ammonium sulphate	**Hydrochloric acid**
Sulphuric acid	**Formic acid**
Acetic acid	**Urea**
Alum	**Dispersing agents**
Wetting agents	**Detergents**
Brightening agents	**Emulsifiers**

Until recently the textile industry is one of the most successful manufacturing sectors in Nigeria. In 1989 there were about 178 registered textile mills in Nigeria with 93 in Lagos, 25 in Kano and 15 in Kaduna, with the rest in other parts of the country. The textile industry is a large consumer of chemicals. The table shows that most of the chemicals are imported. The industrial gases (N_2, O_2, N_2O, Cl_2) produced in Nigeria by BOC Gases and Air Liquide America are not converted into any chemical products. Apart from the primary petrochemicals, the only basic chemical manufactured in Nigeria is sulphuric acid. The trona processing plant jointly owned by RMRDC and Borno State Government a few years ago never functioned at any time due to some technological fault. It was understood that it has been taken over by Borno State Government. Let us hope it will soon start functioning.

Challenges

The major challenges in the development of basic chemicals in Nigeria are:

i) The technologies involved in most cases are capital intensive.

Ii) Lack of regular supply of electricity. This has seriously hindered a lot of developments in virtually all sectors of the economy.

iii) Lack of political will for industrialization and the crave for getting rich quick. As a result, those who have the money are not willing to invest it in the development of the chemical industry or any project that will not yield quick profit. The mentality of buying and selling has eaten deep into our system. We have become a country where the industrialized countries dump their goods.

iv) The propensity for importation of materials that we can produce in the nation. Let me site the example of sugar. The Bacita Sugar Factory and the allied product, ethanol in Kwara State were doing well in the late 1960s to mid 1970s. The molasses from the sugar factory was to be feedstock for the production of ethanol. The sugar factory was 'killed' when a Nigeria business tycoon became the sole importer of virtually all the required sugar needed in the country. As a result of the 'demise' of the sugar factory, the ethanol factory also died when there were no molasses to feed it. **What a shame!**

There is no earthly reason why we should be importing sugar. The land is there, the existing factory could have been developed, expanded and would have been producing most of the ethanol required by the manufacturing companies in the country.

Brazil today is a major sugarcane-growing, sugar and ethanol producing country.

V) Lack of nationalism. Selfishness and greed have been the bane of our nation. Imagine in a poverty stricken state, the Governor of a State embezzled about 96 billion naira. This is the amount discovered; he could have stolen much more. Let me crave your indulgence by citing the reason why we are not able to grow wheat in Nigeria. Some of us will remember in the 1990s when the Federal Government wanted to ban the importation of wheat. She made efforts to support the growth of wheat in some parts of the Northern region where the climate is suitable for its growth. Shortly after, every state became suitable for wheat growing all because each state wanted her share of the national cake. That is why the programme died a natural death.

What about our railway system? Why is it not working? Those who were in the position to make it work were more interested in enriching themselves by buying fleets of trucks that are plying all over the country from Sokoto to Lagos, Lagos to Onitsha etc. Those trucks have constituted a big nuisance on some of our major roads in the country.

You probably are asking what these examples have to do with the chemical industry in Nigeria. The same malaise of selfishness, greed and propensity for importation has affected the development of chemical industries.

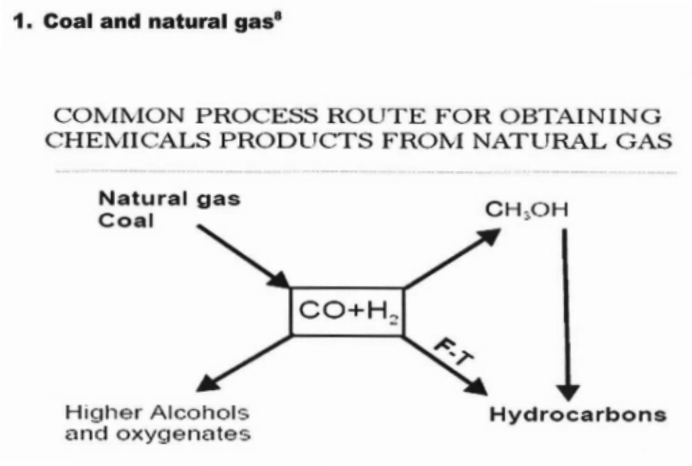
Prospects

Nigeria is well endowed with abundant natural resources: petroleum, natural gas, coal, agricultural products and minerals. These are essential raw materials required for establishing viable and strong chemical industries. Towards this end, the Federal Government of Nigeria established "The Raw Materials Research and Development Council (RMRDC) by Decree No 39 of 1987 with the mandate to promote the development and utilization of Nigeria's industrial raw materials.

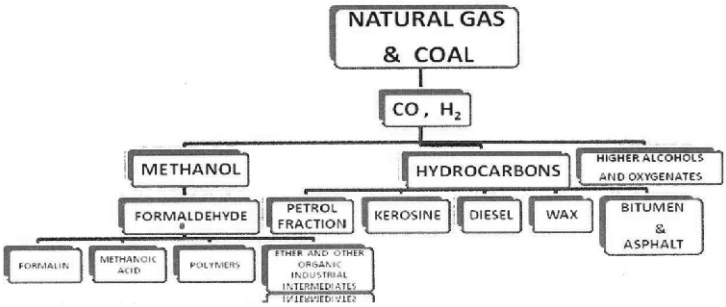
Its mission is to promote the growth of process technology and resource-based industries in Nigeria. Although much has been achieved by RMRDC since it was established, there is much more to be done particularly in the basic chemical industry sector.

Nigeria has a great potential for growth in the chemical industry. I will like to consider the chemicals that can be produced from the following raw materials:

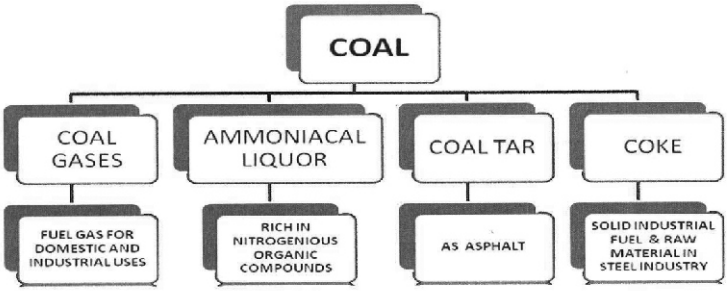
1. Coal and natural gas[8]



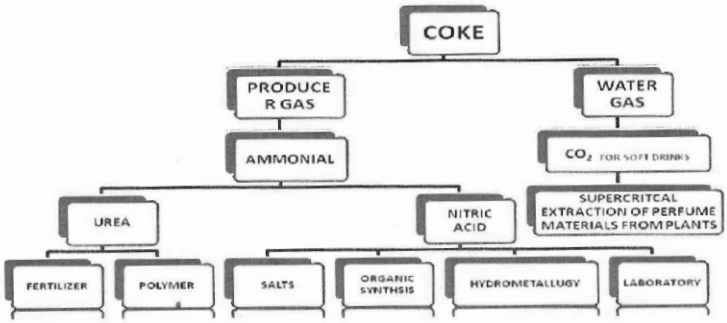
CHEMICAL PRODUCTS FROM COAL AND NATURAL GAS



CHEMICAL PRODUCTS FROM COAL



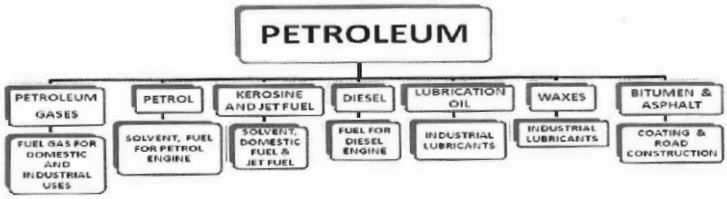
PRODUCTS FROM COKE



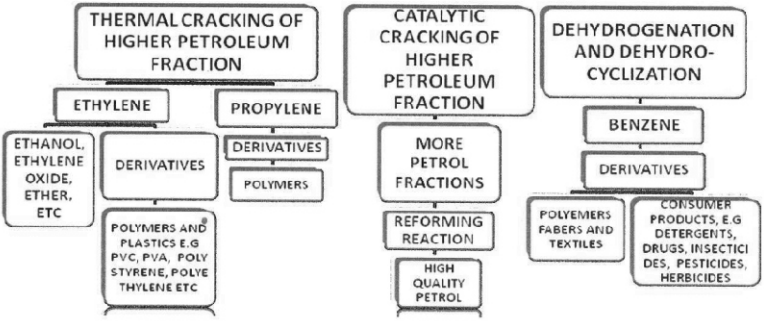
The coal in Nigeria has hardly been utilised for production of chemicals; rather it is being used for electricity generation, fuel and for solid fuel in metallurgical industries.

2. Petroleum [9]

PRODUCTS FROM PETROLEUM



CHEMICAL PRODUCTS AND INDUSTIAL INTERMEDIATES FROM PETROLEUM



Some Mineral Deposits in Nigeria used as Chemical Raw Materials

Nigeria is blessed with abundant mineral deposits many of which can be converted to chemicals that are essential raw materials for manufacturing process industries. Examples of such minerals are indicated in Table 7 below:

Table 7: Some Mineral Deposits in Nigeria used as Chemical Raw Materials[13, 14]

S/N	Mineral Deposit	Location/Possible Source	Potential for Commercialization
1	Limestone	Anambra, Kogi, Kwara, Oyo, Cross River, Benue, Gombe	Excellent
2	Salt/Brine NaCl	Plateau, Benue, Ebonyi	Very good
3	Phosphate	Bauchi, Sokoto,	Very good

3	Phosphate $Ca_3(PO4)_3$	Bauchi, Sokoto, Ogun	Very good
4	Trona $Na_2CO_3.NaHCO_3$	Shores of Lake Chad, Borno, Yobe, Nguru	Very good
5	Kaolin $Al_2SIO_5(OH)_4$	Ogun, Katsina, Onibode, Katrina	Very good
6	Talc $Mg_3Si_4O_{10}$ $(OH)_2$	Kogi, Niger, Osun	Good
7	Sulphur (S)	No local natural source. Synthetically from KRPC, Kaduna	Fair

While a number of these minerals have been processed to meet the needs of the local chemical manufacturing industries in the country, the only basic chemical manufactured in Nigeria is sulphuric acid as mentioned earlier but the quantity produced is far short of the demand. Consequently, there is need to increase the production of the existing industries and for more viable and bigger ones to be established.

Limestone is the primary source of calcium oxide also known as quick lime. This is obtained by calcinating limestone ($CaCO_3$) in a kiln:
Most manufacturing industries such as Cement and Sugar industries produce their lime on site. However, there are small scale factories that manufacture the product.
In view of the wide applications of lime and the great demand for it, bigger kilns should be built to increase production capacity.

Salt/brine (NaCl) is the raw material for the Chlor - alkali industry, one of the top ten most important chemical industries in the world.

The chemical process is based on the electrolysis of common as shown below:

$$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^- \text{ (Anodic reaction)}$$

$$2Na^+(aq) + 2H_2O(l) + 2e^- \rightarrow 2NaOH(aq) + H_2(g) \text{ (Cathodic reaction)}$$

$$2Na^+(aq) + 2Cl^-(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) + Cl_2(g) \text{ (Net '')}$$

Thus, the main products of the electrolysis are caustic soda, NaOH, and chlorine. Derivatives of chlorine include hydrochloric acid, sodium chlorate, polyvinyl chloride, PVC.

Basic Chemical Industries: A look at Sodium Carbonate (Na_2CO_3) Manufacture

Nigeria is abundant in limestone ($CaCO_3$) and salt/brine (NaCl) which are the main raw materials for the manufacture of sodium carbonate through the "Solvay" process.
Considering its wide industrial applications, it will be a profitable venture for Nigeria to go into the production of this chemical.

The Solvay process:

Produces soda ash (predominantly sodium carbonate, Na_2CO_3) from brine (as a source of sodium chloride, NaCl) and limestone (as a source of calcium carbonate, $CaCO_3$). The overall process is:

$$2NaCl(aq) + CaCO_3(s) \rightarrow Na_2CO_3(s) + CaCl_2(aq)$$

Actual implementation of this overall reaction is intricate. A

simplified description can be given using the four different, interacting chemical reactions illustrated in the figure below. In the first step in the process, CO_2 passes through a concentrated aqueous solution of NaCl and ammonia, NH_3:

$$NaCl(aq)+CO_2(g)+NH_3(g)+H_2O(l)\rightarrow NaHCO_3(s)+NH_4Cl(aq) \quad \text{(I)}$$

In industrial practice, the reaction is carried out by passing concentrated brine through two towers. In the first, NH_3 bubbles up through the brine and is absorbed by it. In the second, CO_2 bubbles up through the ammoniated brine and $NaHCO_3$ precipitates out of the solution, which occurs because $NaHCO_3$ is less soluble in a basic solution than is NaCl. The NH_3 buffers the solution at a basic pH; without it, a hydrochloric acid by - product would render the solution acidic and arrest the precipitation.

The necessary NH_3 catalyst for reaction (I) is reclaimed in a later step and as a result relatively little net NH_3 is consumed.

The CO_2 required for reaction (I) is produced by heating the limestone at 950-1100 °C. The $CaCO_3$ in the limestone is partially converted to quicklime (CaO) and CO_2.

$$CaCO_3(s)\xrightarrow{heat} CO_2(g)+CaO(s) \quad \text{(II)}$$

The $NaHCO_3$ that precipitates out in reaction (I) is filtered from the hot NH_4Cl solution, and the solution is then reacted with the quicklime (CaO) left over from heating the limestone in step (II), which re-generates NH_3 and produces $CaCl_2$ by-product:

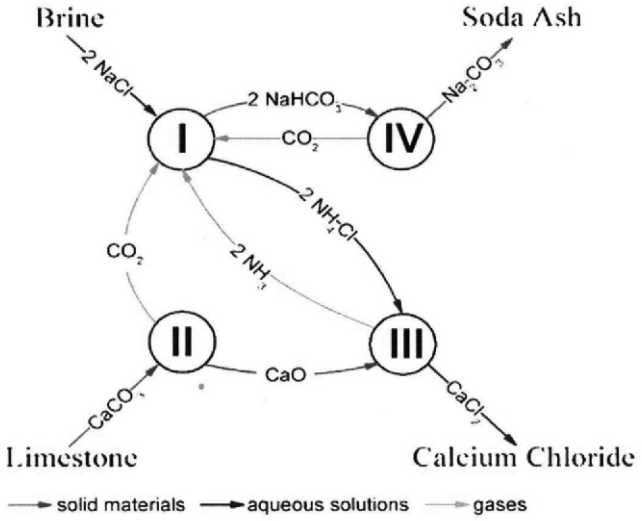
$$2NH_4Cl(aq)+CaO(s)\rightarrow NH_3(g)+CaCl_2(aq)+H_2O(l) \quad \text{(III)}$$

The NH_3 from reaction (III) is recycled back to the initial brine solution of reaction (I). The $NaHCO_3$ precipitated from reaction (I) is then converted to the final Na_2CO3 product by calcination at 160

230 ° C, producing H_2O and CO_2 as by products.

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g) \quad \text{(IV)}$$

The CO_2 from step (IV) is recovered for re-use in step (I). When properly designed and operated, a Solvay plant can reclaim almost all its NH_3 and consumes only small amounts of additional NH_3 to make up for losses. The only major inputs to the Solvay process are salt, limestone and thermal energy; and its only major by product is $CaCl_2$ which is sold as road salt.



Uses of Sodium Carbonate:

Na_2CO_3 is used in many large – scale industrial processes and its production is sometimes used as an indicator of economic health of a nation. Principal uses include:

- **Glass – making: more than half the worldwide production of Na_2CO_3 is used to make glass.**
- **Water – treatment: used to soften water and in washing powder both domestically and industrially**
- **Soap and detergent manufacture: often used as a cheaper alternative to lye (NaOH).**
- **Paper – making: used to make sodium bisulfite ($NaHSO_3$) for the separation of lignin from cellulose.**
- **Alkali: as a common base in many chemical factories because it is cheaper than NaOH and far safer to handle.**
- **Making sodium bicarbonate used in baking powder.**

Chemical Industry: The Good and the Bad

In this lecture, I have discussed how the Chemical Industry is absolutely essential to our daily living. While mentioning the good aspect of the chemical industry, it is important to discuss briefly its adverse effects on humans and the environment.

There are thousands of factories in the world including Nigeria that are polluting the atmosphere, water and land through the release of toxic chemicals, metals, gases, particulate matter and liquid.[9]

These chemicals are released from petroleum refining, chemicals, metal-processing, pharmaceuticals, paint, cement, glass, pesticides, fertilizers, explosives, plastic-producing plants etc.

The discharge of pollutants from industries has created problems for the people living in the cities and the suburbs of the plants. These discharges may cause nausea, allergies, irritation to the eyes and other diseases. These pollutants cause the depletion of the ozone layer and the increase in the level of carbon dioxide which has led to global warming.

In view of these damages done by industrial pollutants, the

Chemical Industry is highly regulated by such bodies as the Federal Ministry of Environment (FMENV) in Nigeria and the Environmental Protection Agency (EPA) in U.S.A.

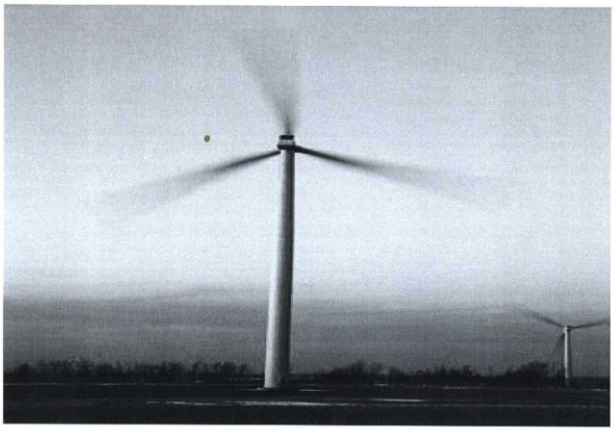
Industrial pollution can be greatly reduced by adopting effective preventive measures that will ameliorate the adverse environmental impacts of pollutants. Remember the old adage "prevention is better than cure".
The objective of the industrial pollution prevention is to reduce and manage waste products in a suitable way like recycling as well as using environment-friendly energy sources such as:

Geothermal

Hydroelectricity

Biofuel

Solar



Wind Energy

I

Green Chemistry, also known as Sustainable Chemistry, by definition refers to "environmentally friendly chemicals and processes that result in reduced waste, eliminating costly end-of-the pipe treatments; safer products; and reduced use of energy resources.[11]

7 CONCLUSION

* It is clear from this lecture that chemistry and the chemical industry affect virtually every aspect of our lives. Without the chemical industry, we will have no cars, airplanes, computers, televisions, electric lights, drugs, plastics and most of other chemical products we enjoy today.
* The place of basic chemicals in the manufacturing processes is very important.
* The need for chemical industries to pay greater attention to industrial pollution prevention has been highlighted. It is expected that Green Chemistry will play a major role in the future.
* For Nigeria to achieve her goal of being on the list of top 20 most industrialized nations of the world in 2020, she must develop some important basic chemical industries in order to meet the chemical requirements of the existing manufacturing process industries/companies and establish new ones.

RECOMMENDATIONS

I wish to recommend as follows:

* *The Federal Government of Nigeria should:*
* provide enabling environment that will ensure the regular supply of electricity, security, good road network, water supply, and tax incentives that will encourage both local and foreign investors.
* make and implement laws that will check indiscriminate importation of goods that can be produced locally; this will boost the growth of local industries.
* release funds and work out favourable loan schemes for entrepreneurs interested in establishing capital - intensive chemical industries.
* encourage development of technologies necessary for the production of the following basic chemicals: NaOH (via Chlor-alkali process), sodium carbonate (via solvay process), ammonia and methanol (from natural gas).
* ensure the early completion of the Eleme Petrochemical Company. While in support of the privatization policy, entrepreneurs with the necessary expertise should be given the chance to operate it.

We need urgently, selfless, patriotic, nationalistic and visionary leaders that will drive the development of our abundant natural and human resources to alleviate poverty in Nigeria and to transform her from a developing to a developed country. Thank God that Covenant University is poised for raising such a new generation of leaders.

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