

Making Stuffs, Hot Stuffs:
The Power of mind over Matter

COURTESIES

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Great Unilorites,
Ladies and Gentlemen.

INTRODUCTION

I feel highly honoured and privileged to present the 82nd Inaugural Lecture of the University of Ilorin. It is the 3rd Lecture from the Department of Chemistry, the 1st Lecture from our second arm of Chemistry, called Industrial Chemistry, and interestingly being delivered by my humble self – a Chemical Engineer by training and practice and an Industrial Chemistry Lecturer for the past 12 years.

I will start this lecture by quoting from the mother of all books, the Holy Quran. In the Holy Quran 96:1-5, Allah (SWT) says:

*“Read! (or Seek Knowledge!, or Learn!) in the name of thy Lord and Cherisher, who created .
Created man, out of a leech-like clot,
Read! (or Seek Knowledge!, or Learn!) and thy Lord is most bountiful,
He who taught the use of the pen,
Taught man that which he knew not”.*

In the Holy Quran 21:30, Allah (SWT) also says:

*“Do not the unbelievers see that the heavens and the earth were joined together before we clove them asunder?
We made from water, every living thing; will they not then believe?”*

There is no doubt we have a scientifically divine Creator, but so that mankind can better appreciate the divine creations, it is Allah (SWT) Himself who decreed that man should seek for knowledge. Just in the last few decades, modern Scientists are coming to the realization that the earth and indeed the other galaxies in the universe could only have been created from a single body split through what is known as Big Bang process. In the footnote on the last Quranic verse, the believers are informed that about 72% of the surface of our globe is covered

with water (H₂O), which, in a sense, to me, makes the water origin of living things more remarkable after I took an Advanced Quantum Chemistry class in 1986 where futilely we tried to prove that $H + H = He$. I will touch on this in some details later. I have quoted these two verses because I am delivering a lecture as an Industrial Chemist even though trained as a Chemical Engineer. The public perception of Chemistry is that it is a volatile subject, and the public image of Chemical Engineering is even more bewildering. I will attempt during the course of this inaugural lecture to remove the mysteries surrounding both disciplines, and in essence prove that they both merely require inner reflections to understand and apply. Both are disciplines essential to human, because as we can see, the Creator Himself has wrapped our earthly existence around Chemistry by saying we all are made from water. As we shall see later, no human mind is yet to decode how Allah used water to make flesh, cartilage, hair, bone, and the more complex human organs. Be that as it may, we must still learn Chemistry, because it is the science for minds **Curious about Nature**, and we must equally learn Chemical Engineering, because it is a discipline concerned with **Mastering Nature**. Civilization itself is defined as the level and measurement of man's ability not to merely understand and master nature, but in essence control it. In essence therefore, we are all practicing Chemists and Chemical Engineers by virtue of the fact that we cope with nature using both disciplines, despite our not all parading degrees in these two disciplines. Alchemy is the root of Chemistry as well as Chemical Engineering. At a recent conference between Scientists and Historians, Lawrence M. Principe of John Hopkins University, pointed out that in the 16th and 17th Centuries, Alchemy reached a peak in Europe in man's search for the hidden treasures and mysteries of nature. According to Principe (2006) the early Chemists are interested not so much in theory as in making substances with particular properties. For this reason, Chemistry as a science actually slumbered under Alchemy's influence through what Science Historians call its "postponed science revolution". For example in 1600, practicing Chemists (Alchemists) knew of just seven

metals – gold, silver, iron, copper, tin, lead and mercury. During that period, because grapes were turned to wine, wheat to bread, and sour green apple could grow into a sweet red one, it was assumed that it was the nature of things to change, even metals. The original seven known metals had common properties, they were shiny, and except for the liquid mercury, could be hammered, shaped and cast. The commonality of properties implied to the early Alchemists a commonality of composition and it was theorized, according to Principe, that all the metals were composed of the same essential ingredients in different proportions and degree of purity.

According to Science Historians, experimentalism was one of Alchemy's hallmarks, the idea of getting hands dirty and in a way forging early ideas about matter. Alchemists were known for bending over boiling crucibles in their shadowy laboratories, squeezing bellows before transformative flames and pouring over obscure formulas. By so doing some Alchemists stumbled on techniques and reactions of great values to later Chemists. It was experimentation by trial and error, Science Historians say, but it sometimes led to new chemicals and healing elixirs that laid the foundation of procedures such as; separating and refining, distilling and fermenting.

To underscore that alchemy was a very serious business during the Roman Empire era, according to these Science Historians, in 1601, Hans Heinrich Nueschler signed a contract with Duke Friedrich of Wuerttemberg in Stuttgart, to demonstrate his process for extracting a substantial amount of gold from a sample of silver. The Duke, keen on mining technology, promised a generous reward. Nueschler agreed to conduct the experiments at his own expense. After several months of failure and mounting debt, the desperate Alchemist resorted to fraud. He asked his brother to help by surreptitiously adding gold to the alchemical sample. His ploy was exposed. Nueschler was tried, convicted, and hanged.

According to Science Historians, "alchemy was a direct engagement with the political, economic, religious, and intellectual realities of the early modern world". The same is true today because the economy of the world today is driven by mass

production of mostly chemical products and this essentially is what Chemical Engineering is all about. As a matter of fact, the level of a nation's development today is a direct measure of that nation's utilization of Chemical Engineering principles.

At the turn of the 17th Century, King Henry IV of France was said to have surrounded himself with Alchemists who sought to resurrect plants from their ashes and experimented with ways to extend the Monarch's life. Amazingly, while this extraordinary idea may sound novel to mankind, Allah (SWT) had said several centuries earlier in the Holy Quran in Surah 6, verse 95 that:

"It is Allah, who causeth the seed-grain and the date stone to split and sprout.

He causeth the living to issue from the dead.

And He is the one to cause the dead to issue from the living.

That is Allah; then how are you deluded away from the truth?"

According to Science Historians, even geniuses of the highest order, like Isaac Newton, found Alchemy irresistible. He whose laws of gravity and optics ushered in modern Physics also delved into Alchemy with relentless energy. His notebooks, which the Smithsonian Institution called "an overlooked gem", contain thousand of pages on alchemic thoughts and experiments over thirty years. In one of his notebook entries, Newton cited the ideas of German Alchemists for initiating the processes by which metals were generated in nature, deep inside the earth. These involved the familiar alchemical theory of metallic generation through interaction of sulfur and mercury. Expanding on the theory, Newton wrote that: "these two spirits above all wander over the earth and bestow life on animals and vegetables, they make stones, salts and so forth". He further noted; "thus we have passed from a theory of mere metallic generation to one that is extended to explain the totality of life on earth, as well as the production of all mineral materials, not just metallic ones". Newton was said to have repeated experiments for the rest of his life aimed at fulfilling the words of the Emerald Tablet of Hermes, considered the founding text of Alchemy in ancient Egypt. Newton expected to achieve what the tablet said was the

una res, “the one thing” by which the world was created and with which one performs miracles. Hidden in the Holy Quran, however, is the divine verdict according to Surah 4 verse 57 that:

“Assuredly the creation of the heavens and the earth is a greater matter than the creation of men. Yet most men know not”.

Newton’s alchemical bent was not out of character according to the Science Historians, the British Chemist, Robert Boyle, a Newton contemporary, also had a foot on each side of the Alchemy – modern science divide. He dabbled for years in an alchemical obsession, the search for the philosopher’s *stone* – the long sought agent for transmuting lead to gold and unlocking other material and spiritual secrets. The *stone* was the unified theory of everything in that time. When it dawned on Boyle that he had set on an impossible mission, he wrote enviously in 1680 that “there exists, concealed in the world, a group of Chemists of a much higher order able to transmute impure metals into perfect ones”. At that time Boyle hurled harsh criticism at Alchemists, particularly the obscurity of their language and concepts. His purpose was to draw “the Chemists’ doctrine out of their dark and smoky laboratories into open light” and to engage in “better experiments and arguments”.

Even with Boyle’s criticism and even earlier attacks on alchemical practices, it was not until the 18th century before there was a clear separation between Alchemy and Chemistry.

Since the earliest development of modern atomic theory by John Dalton in 1807, there has been a devoted quest by their successors. Modern Chemists have shown great interest in studying the nature of atom and the way atoms join together to form molecule. The first serious attempt scientifically, using classical mechanics to explain the spectra of atoms was made by Kirchoff and Bunsen in 1861. Later, other scientists like Balmer in 1885, Lord Rayleigh and J.H. Jeans, Max Planck and even Albert Einstein in 1905 and Niels Bohr in 1913 made effort to understand and define atomic nature of matter. Their combined efforts were only able to explain hydrogen atom, and could not

explain the spectrum of any atom having more than one electron accurately and completely.

Later effort by Louis de Broglie in 1924 and shortly thereafter by Erwin Schrödinger and Werner Heisenberg led to the founding of quantum mechanics. Quantum mechanism introduced mathematical formalism to explain observed atomic quantities. The amazing conclusion of all the recent scientific efforts to understand atoms with all the hi-tech gadgetry at our disposal is that, apart from the acceptable definition of hydrogen atom, quantum mechanics still cannot completely define beyond hydrogen and hydrogen-like ions like He^+ , Li^{2+} , etc, without introducing perturbations or calculation errors into their representations (Hanna, 1969). The simplest of atoms after hydrogen atom is the helium atom having two protons and two electrons. Finding absolute mathematical solution for the allowed energy states and wave functions for the simple helium atom has proven impossible. Electron repulsion effect or electron correlation factor bottleneck is introduced into a problem that should be as easy as $1+1 = 2$, if mankind has correctly guessed Allah's (SWT) creative or divine Chemistry. As a matter of fact, the best three methods in quantum mechanics calculated $1+1$ to be 2.38, representing 38% error in making up helium atom from the combination of two hydrogen atoms; another method calculated $1+1$ to be between 2.05 and 2.17, and the third and the best method calculated $1+1$ to be between 2.02 and 2.06 for the helium atom. If two hydrogen atoms cannot be used to build helium atom by mankind without the introduction of perturbations or errors, you can imagine the problems faced by Chemists if they must quantum-mechanically or mathematically explain the formation of Be, B, C atomically and N_2 , O_2 , F_2 molecularly. Several other internationally foremost Chemists have since introduced approximations to reduce the perturbations introduced. I must submit here today therefore as a trained and practicing Chemist that theoretically, experimentally, and clinically it is clear now that Allah (SWT) has not created helium by adding two hydrogen atoms. It is also clear that the larger non-radioactive elements are not summations of a unit building atom, such as hydrogen, as men are now trying to guess and

prove. The obvious omission, therefore, whether intentionally or arrogantly, by the modern-day Scientists, Chemists in particular, after four centuries of futilely trying to build larger elements atomically from H-atom building block, is that there should have been and must be from now on a LAW OF ORIGINALITY OF ELEMENTS.

LAW OF ORIGINALITY OF ELEMENTS can simply be stated as:

- **Elements cannot be created; they can only be used in their natural forms or can be combined through chemical, nuclear or other reactions to form desired chemical products.**

I need to make a point here that according to many Chemistry textbooks and as an example from the table of atomic weights in a textbook by Daniel & Alberty (1975), Elements of terrestrial origin and artificial (**discovered?**) ones exist and are so listed. That notwithstanding, the so-called artificial elements of nuclear/radioactive chemistry origin, such as Berkelium, Californium, Francium, Plutonium, Americium, Fermium, and even the 118 Protons-containing element (yet to be named), considered the heaviest element produced jointly by the Russians and the American Chemists in October, 2006, are merely products of nuclear/radioactive reactions between two or more natural elements/particles, one of which must be a radioactive element. The basis of most of these artificial (nuclear/radioactive) elements is the realization by Scientists that there is transuranium element formation when Uranium undergoes radioactive reactions. As an example, "Plutonium is a transuranium element and according to Arthur and Elizabeth Rose (1956), "Plutonium occurs in nature in Uranium-containing ores in very small concentrations. Pitchblende contains one part Plutonium for every 10^{14} parts of Uranium. Naturally occurring Plutonium seems to consist of only the 239 isotope. For this reason, it is not thought to be primeval but to form by the action of stray neutrons on uranium. Plutonium is similar chemically to

Uranium”. Transuranium element formation as a matter of fact paved the way for most fusion/fission nuclear reactions and is the reason why most artificial elements involve the use of cyclotron to bombard already radioactive (or living) element with smaller elements or particles. Imprecision of bombardment in the cyclotron often leads to many isotopes of high instability and extremely short half-lives. On element 118, the “Baby Doe” of elements, from the internet, New York Times Science service quoted Dr. D. A. Shaughnessy, a Livermore Laboratory Scientist who worked on element 118 as saying, “the experiments were performed when Scientists at the Russian Laboratory used cyclotron to bash atoms of Calcium, with 20 protons, into a target of Californium with 98 protons, like little clumps of putty that they hoped would stick together”.

Incidentally, the element 118 discovery results were met with praise but also caution from other Scientists in the field. Dr. Witold Nazarewicz, a Nuclear Theorist at Oak Ridge National Laboratory was quoted to have said “One has to be extremely careful with those enthusiastic announcements on element 118 given the fraught history of the element. Nazarewicz was referring to earlier fraudulent claim by Dr. V. Ninov in 1999, who fabricated data to make his claims and was eventually fired by the Lawrence Berkeley National Laboratory.

So, whether the law I am postulating here eventually becomes a universally acclaimed chemical law or not, I must feel happy here as a muslim Scientist and Engineer, because ultimately Allah (SWT) has said that knowledge is His, He is the knowledgeable One, The Alim. Why do I say this?.

The French Monarch and all the “Alchemists” and Scientists concerned must have either read the Holy Quran and figured man’s ingenuity can decode Allah’s (SWT) code, or perhaps maybe the early Egyptians who introduced Alchemy to the world nursed the idea of decoding Allah’s (SWT) code of life and resurrection, then passed it on through their writings on [Emerald Tablet of Hermes](#).

As far as the Holy Quran is concerned, the issue of man creating his own elements is already concluded because Allah (SWT) says in the Holy Quran, Surah 4 verse 57 that:

“Assuredly the creation of the heavens and the earth is a greater matter than the creation of men. Yet most men know not”

Countlessly, the Holy Quran is always asking mankind to reflect. Reflect on what?; Reflect on creation; reflect on death; on divinity of creation; on non-living things; on earth endowment in the form of treasures; on the environment, and so on. Consequently, therefore, my dear Ladies and Gentlemen, two things in life have always fascinated me academically. The first is the search for the truth at all times and the second is the search for knowledge always.

With these two guide-lights you would perhaps understand why I choose to read Chemical Engineering (ChE) - a discipline that puts both principles to test always. Another name we coined for ChE in my undergraduate days is “the-show-me-it-can-be-done Engineering”.

I find myself in a unique position as a Chemical Engineering graduate professing Industrial Chemistry, because Chemical Engineering itself has traditionally been a union between Art and Science. When Science is adequate, it is used to solve ChE problems, otherwise Art, in the form of Engineering techniques, experience, and judgment can be employed to proffer complete solutions to technical problems.

As a discipline in Engineering, ChE has always been concerned about scaling up scientific (chemical and biological) experiments and discoveries to manufacture massive amount of products for the consumption of the yearning but highly qualitatively discerning masses.

After undergoing academic training, a good Chemical Engineer, and as a matter of fact a good Industrial Chemist, must be well rounded professionally to handle not only chemical plant problems but also identify and proffer remedies for consequential problems in the environment .

Chemical Engineering and indeed Industrial Chemistry too, train graduates to completely define and solve problems in solid - liquid - gas phases; material and energy balances and transfer; dimensionless number analysis for process scale up; energy

generation, conservation, and transformation; industrial and municipal water and waste treatment; paper making; paint making; fertilizer production; polymer synthesis and processing, and a host of other chemical processes.

In the early 1920's, Chemical Engineering was introduced as a separate discipline into the Universities of both America and England and has undergone considerable development since then. Prior to this period, the engineering of chemical plants was regarded as specific to an industry, and there was little common ground between one industry and another.

It is now realized however that all important unit operations have much in common, and if the underlying principles upon which the rational design and operation of basic types of engineering equipment depend are understood, their successful adaptation to manufacturing process becomes a matter of good management rather than of good fortune.

From the earlier treatise on the Alchemy, it becomes obvious that the practice of Chemical Engineering preceded any analysis or exposition of the principles upon which it is based as a practice. The unit operations of Chemical Engineering, the foundation on which the practice is based, can be so sophisticated sometimes that the operations are looked upon as specially adapted to these conditions alone, and consequently not frequently used by other industries that can benefit from their use.

The first textbook on Chemical Engineering was written by Walker, Lewis, McAdams, and Gilliland (1937) to provide university graduates with a sound understanding of the scientific and engineering principles upon which Chemical Engineering operations are based, and the development of the methods for applying these principles to the solution of such problems that present themselves in Chemical Engineering practice. In other words, to sensitize brooding Chemical Engineers to "design" apparatus adapted for any particular purpose, rather than just "build" it and then rely on large scale experimentation with expensive changes in construction to effect efficient operations. The book had a total of eighteen chapters on: Industrial Stoichiometry, Fluid flow, Heat flow, Fuels and Power,

Combustion, Furnaces and Kilns, Gas producers, Comminutions, Mechanical Separations, Filtration, Vapourization, Evaporation, Diffusion, Absorption and Extraction, Distillation, Humidity, Air Conditioning, and Drying. These eighteen chapters dealt with ChE unit operations mostly, and it is interesting to note that today there are more than a hundred ChE unit operations, some of them related and others entirely devoted to specific ChE processes.

According to Coulson and Richardson (1954), the four most important fundamental relationships underlying all phases of Chemical Engineering are material and energy balances, the laws of reaction equilibrium and of reaction rate. The four fundamentals are also true for Chemistry and indeed Industrial Chemistry, because an Industrial Chemist must be acquainted with these four fundamental ChE principles to professionally design the appliances suitable for large scale operations as distinct from laboratory practice. The proper choice of the specific appliances depends upon such acquaintance. In general, the choice of appliances used greatly dictates the success of a process upon which the product quality in turn depends.

One of my lecturers in the USA once opined that “anyone who trains successfully to be a Chemical Engineer can thereafter become whatever else he/she chooses to be professionally”. Not surprisingly therefore, a lot of my mates ended up in the medical school, in the law school, and even in business and management schools. This assertive statement has been imprinted on my mind since my sophomore year. It has guided me after ten years of Research and Development engagements on three continents to switch to self employment when I first returned to Nigeria after two decades in the USA, and finally to being a lecturer in Industrial Chemistry even though trained as a Chemical Engineer.

The point I am trying to make here is that all elements and possible products that can be obtained from them have been preordained by our Creator, Allah (SWT) the all-knowing. In essence that is why some reactions occur chemically and others

do not. We all know that from oxygen and hydrogen, Allah (SWT) made water. When water is suitable we use it in the liquid phase as water. When we prefer the water colder, we can bring the water temperature down as low as 0°C, at which point it turns solid but is still chemically water. At other times we may prefer it hot, when it gets as hot as 100°C, it turns to steam which is the gas phase existence of the same chemical composition, H₂O. For each transformation an element or matter undergoes, there must be a reason and need for it. To borrow the terrestrial existence of non-radioactive elements classification from Prof. Hanna (1969), it is up to the Chemist or Chemical Engineer to use an element as it exists terrestrially, or transform it through chemical, physical or sometimes mechanical means to the desired state. As simple as water appears to be, when it is combined with carbon dioxide in a biochemical reaction in plants, starch is formed by photosynthesis and through starch, chemical energy is produced. The presence or absence of water can dictate to large extent whether ionization reaction occurs in most inorganic salts or not.

It will not be an overstatement therefore to say that there is nothing new under the sun, but Chemists, Engineers, and Scientists amongst us must continually use natural and intuitive inspirations to make what is terrestrially or naturally available be transformable into what is needed. We are living in a material world and the Chemist, Industrial Chemists, and Chemical Engineers amongst us must continuously seek in their minds for transformative power over matter. Nature itself provides abundance correlative inspirations to draw from, it is up to every scientific mind to be alive and use mind ingenuity to master and control matter.

MY HUMBLE CONTRIBUTIONS TO KNOWLEDGE

My Bachelor's, Master's and Doctorate degrees are all in Chemical Engineering. My area of specialization is in reaction

engineering with emphasis on heterogeneous catalysis. My area of specialization availed me the opportunity of having indepth study of chemical kinetics, which is the study of the rate of chemical reactions and of the molecular processes by which reactions occur; and chemical thermodynamics, which is the study of energy and order-disorder, and their connections with chemical changes and chemical equilibrium. In addition, to train fully for heterogeneous catalysis specialization, I delved into crystallography and structural design and manipulations of matter.

A chemical kineticist in practice uses obtained laboratory data on a process to define not only the reaction rate but design the reactor of choice to use to optimize conversion upon scale up. In designing his reaction system industrially, he must come up with optimum integration of factors affecting reaction rate which include: Temperature, Pressure, Composition, Phase of reactant, Catalyst, Flow condition, Mixing efficiency, Heat transfer limitation, Mass transfer limitation and raw materials/products economics.

My first contribution to knowledge was in 1988, when I was completing my PhD programme. I made a novel contribution to the field of catalysis. The oil industry uses millions of tons of a catalyst known as CoMo for crude oil pretreatment. CoMo stands for a bimetallic oxide catalyst of Cobalt Oxide and Molybdenum Oxide and is perhaps the biggest, most utilized catalyst in the world. The catalyst is incorporated into gamma – alumina support typically. CoMo is capable of serving five catalytic roles in petroleum crude pre-treatment, namely, (i) hydrodesulfurization (HDS), (ii) hydrodenitrogenation (HDN), (iii) hydrocracking (HCK), (iv) hydrogenation (HYD), and (v) hydrodeoxygenation (HDO). Although much information has emerged from studies and industrial utilization of CoMo, more needs to be known about the uncoupled effects of the geometric and the electronic structures of the catalyst on HDS.

Because of the dwindling crude oil reserves globally, more dirty petroleum feedstock and liquefied coal are processed to meet the ever increasing global domestic and industrial demands.

Apart from the fact that sweet crude oil (less than 0.1 % sulfur compounds) earns more money, the equipment lifespan is increased when sulfur is removed from the sour crude oil (containing as much as 3% sulfur compounds) due to corrosion rate reduction. Sulfur removal before processing also reduces air pollution due to petroleum product utilization and promotes colour stability in petroleum products. The most difficult sulfur compounds in petroleum crude oils are the thiophenic compounds due to their low reactivity.

A series of laboratory self-synthesized ternary molybdenum chalcogenides (TMC) having easily manipulated electronic and geometric structures were used to desulfurize thiophenic compounds. The synthesized ternary molybdenum chalcogenides were patterned after the Chevrel Phase Compounds (CPC), a group of compounds earlier investigated for their superconductivity due to their easily manipulated structures (Chevrel and Sergent, 1982).

The general formula of the investigated TMC is $M_zMo_{3n}X_{3n+2}$, where "X" stands for chalcogenic elements such as sulfur, selenium and tellurium, "M" stands for one of about ten investigated out of about forty possible cation elements, and "n" is a number not less than 2. By varying "z", the stoichiometric coefficient of M between 1 and 4, the oxidation state of Mo in the TMC varied between +2 and +2.66. The unit building block in TMC structure is Mo_6X_8 , as shown below.

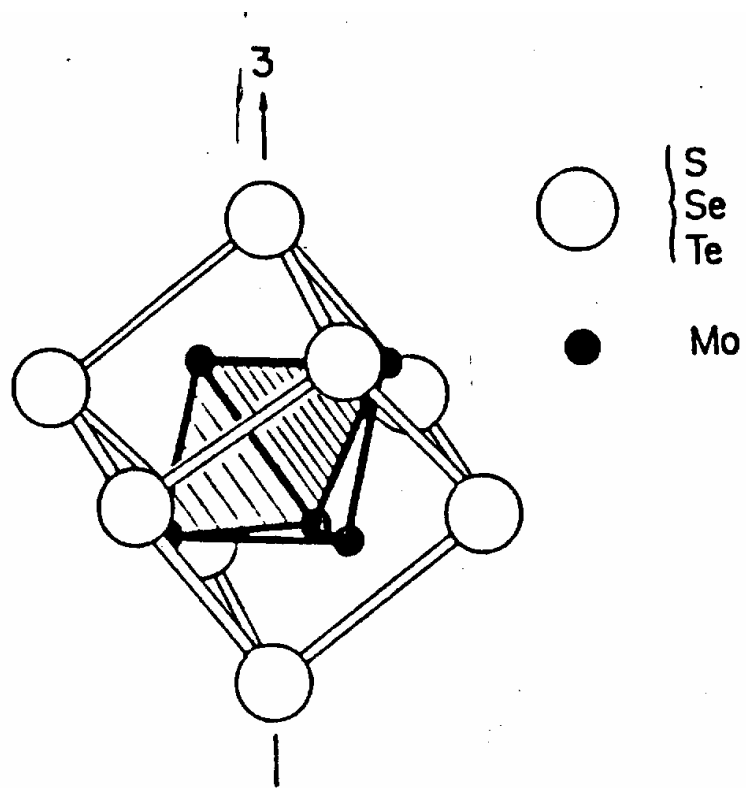


Figure 1a: TMC Unit Building Block: Mo_6X_8

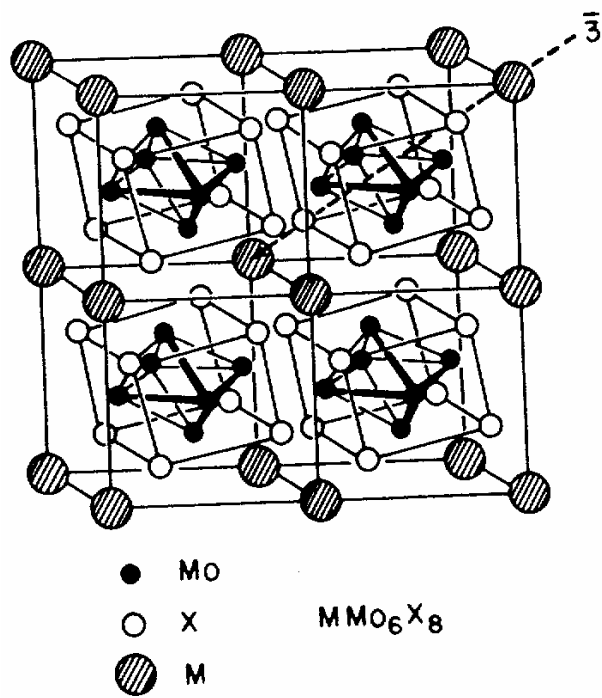


Figure 1b: The Structure of MMo_6X_8 .

The unit building blocks leave channels in the TMC structure where the cation element M is inserted. There are three groups of TMC structures, namely small, intermediate and big, based on the size of the inserted cation M in the structure. An example of small cation TMC is $\text{Cu}_z\text{Mo}_6\text{X}_8$, of an intermediate TMC is $\text{In}_z\text{Mo}_6\text{X}_8$, and of a big TMC is $\text{Ho}_z\text{Mo}_6\text{X}_8$. Due to substitutional limitation in TMC, there are fewer selenide TMC samples and even fewer telluride TMC samples compared to sulfide TMC. With all the complexities surrounding the use of CoMo as HDS catalyst, TMC gives a less complex option to supported CoMo problems because the oxidation state of Mo atom is easily manipulated in TMC, the promoter cation element, M is easily tailored and incorporated, and the structure of bulk TMC is not only well defined, it is also easily characterized by X-ray diffraction technique.

Reaction Mechanism

Although there are several proposals for the HDS reaction mechanism, such as the two-point adsorption of thiophene through one of its double bonds by Griffith *et al.* (1949) and four-point adsorption by Nicholson (1962) the study that the HDS studies was patterned after is the one-point adsorption proposed by Lipsch and Schuit (1969).

On the basis of a vacancy creation by the hydrogen reduction prior to HDS step, the following reaction mechanism was suggested for thiophene HDS reaction.

- (1) Thiophene is adsorbed on an ion vacancy formed by reduction of MoO_3 . The sulfur atom becomes bonded to the molybdenum atom.
- (2) One hydrogen atom is transferred from an adjacent OH group to the adsorbed molecule. One C – S bond is broken.
- (3) A second hydrogen atom is transferred, breaking the other C – S bond.

- (4) Molecule 1,3-butadiene desorbs. The butadiene molecule is then hydrogenated further on other sites or may be on the same site.
- (5) The original catalytic (vacant) site is restored by a reaction with two hydrogen molecules and desorption of an H_2S molecule.

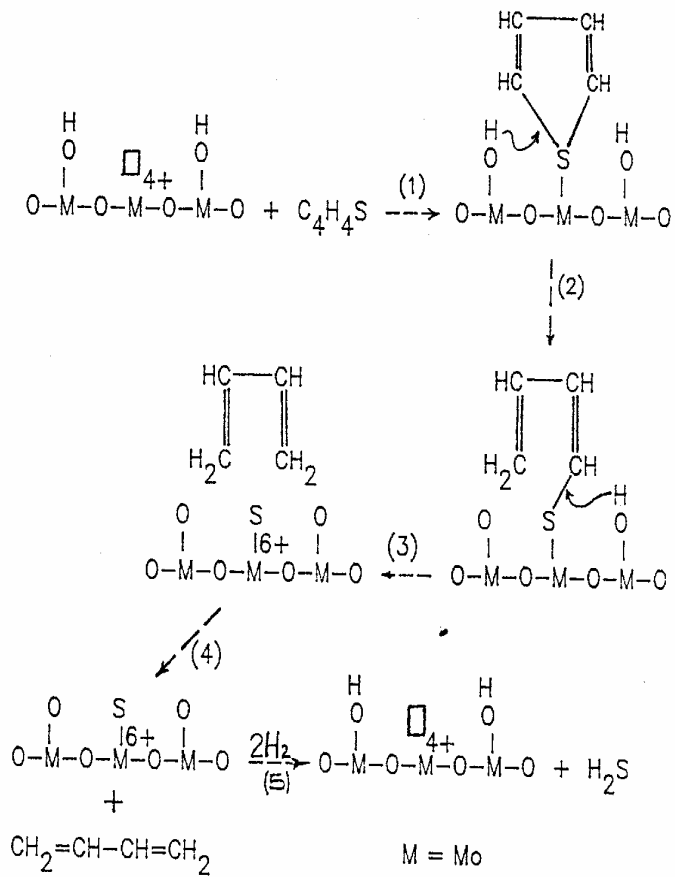


Figure 2: Proposed Reaction Mechanism for Thiophene HDS

H₂S gas that was evolved during the HDS reaction was trapped in ethanolamine liquid column that was changed periodically to prevent the desorbed H₂S from fouling up the laboratory.

The TMC samples were synthesized by precisely measuring the component elements into a quartz ampoule, thoroughly purging with helium gas, then evacuating gases from the ampoule completely before sealing the ampoule. Fusion treatment of the ampoule sample for homogenization at 1200°C was carried out in a muffle furnace. Grinding of ampoule content and high temperature fusion treatment was carried out at least twice for each sample to obtain acceptably homogeneous sample.

Powder X-ray diffraction analysis was used to show high degree of crystallinity in all the TMC samples. X-ray fluorescence (XRF) was used to carry out elemental microanalysis on the samples surface before and after HDS reactions. Scanning Electron Microscopy (SEM-EDAX) was used to map the surface composition and texture of the catalysts before and after the HDS reactions. Atomic Absorption Spectroscopy (AAS) was used to carry out elemental analysis on fresh and used catalyst samples. X-ray photoelectron spectroscopy (XPS) was used to determine the oxidation state of the Mo atoms on the catalyst surface. A self-constructed vacuum glassware setup was used to carry out (Brunauer, Emmett and Teller) BET method specific surface area determination and also used to determine vacant/active sites in the catalysts.

To determine the vacant sites in the samples prepared, O₂ chemisorption was carried out in a volumetric apparatus equipped with Barocell using a low-temperature static method as reported by Reddy *et al.* (1985) with some modifications.

All catalyst samples were first activated in a stream of H₂/H₂S at 400°C for at least 4 hours. HDS activity determination was carried out at 400°C and atmospheric pressure in a quartz glass and stainless steel apparatus to prevent chemical attack of equipment materials by the sulfur compounds and to prevent erroneous product analysis.

Plug flow reactor type was used by suspending/supporting catalyst samples by glass-wool in a quartz tube whose

temperature was monitored by digital thermometer connected to iron-constantan thermocouple.

The effluent gas stream from the HDS reaction was analyzed in a Hewlett Packard model 5710A flame ionization detector gas chromatograph coupled with a Hewlett Packard model 3392A integrator.

BULK TMC CATALYST HDS RESULTS:

Comparison of the hydrocarbon product distribution for the TMC catalysts when evaluated for HDS reactions indicated that as proposed:

*1, 3-butadiene was the initial product of thiophene desulfurization. Further hydrogenation resulted in the formation of the butanes as the major products.

*All the bulk TMC catalysts showed lower HDS activities compared to the typical gamma-alumina supported CoMo catalysts.

*The HDS activities observed can be categorized according to the size of the ternary element in the TMC structure. The big cation TMC exhibited the highest observed HDS activities. The medium cation TMC showed lower HDS activities compared to the big cation ones but higher activities than those of the small cation TMC.

*The activity observed in the big cation TMC was found to be most stable in the continuous HDS over a long period of time. In the small and medium cation TMC however, there was noticeable decrease in the observed HDS activities as the run progressed over a long period of time.

The observed variation in HDS activities with respect to cation size was shown by the X-ray fluorescence (XRF) – scanning electron microscopy (SEM) analysis to be attributed to structural instability at the catalyst surface during the HDS reaction. Migration of small cation from the surface of TMC catalyst, inwardly to the bulk, resulted in surface enrichment of Mo atom as verified by X-ray photoelectron spectroscopy (XPS). Another consequence of the cation movement from the surface inward was the variance of HDS product selectivity, such that the smaller the cation, the poorer the selectivity with respect to

desulfurization. In the same vein the smaller the cation, the higher the hydrogenation activity of the catalyst (Kareem, and Miranda,1989; Kareem *et al.*, 1989).

SUPPORTED OXIDE CATALYST HDS RESULTS:

With the initial success achieved on the bulk TMC catalyst samples based on CPC formulation, investigation was shifted to gamma-alumina supported CPC equivalence of the TMC catalysts.

To prepare single cation supported TMC samples, oxides of Cu, Pb, In, Mo, Sn, Co, and Ho were impregnated on gamma-alumina support in a single impregnation method typically used for CoMo catalyst preparation.

To prepare double cation supported TMC samples, taking Mo as the “targeted” or “main” catalyst element, the other six elements were used to co-promote Mo in a binary oxide, CPC equivalent modes. As shown in Figure 3, the 1:6 cation element to Mo ratio was not the only sample synthesized, co-promotion ratio was investigated to find the optimum co-promotion ratio or carry out what is known in the heterogeneous catalysis parlance as volcano effect test (Miranda and Kareem, 1988).

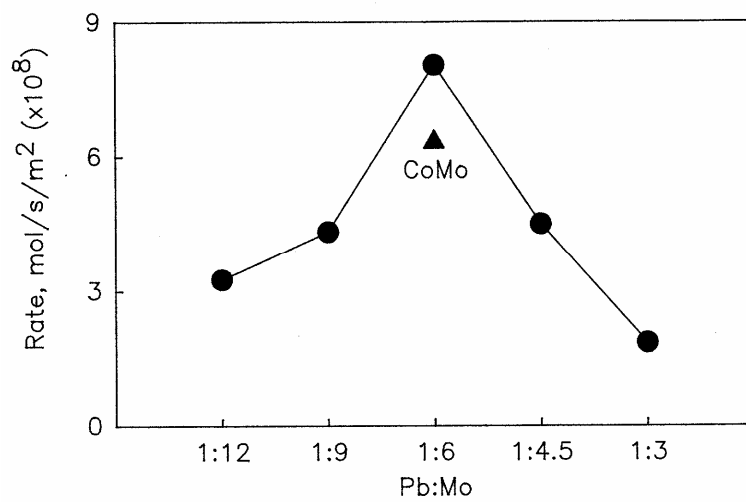


Figure 3: Volcano Effect: Co-Promotion Activity of Pb on Mo for HDS Reactions.

Overall, over twenty samples each of the bulk TMC extended building block TMC (Mo_9X_{11} and $\text{Mo}_{15}\text{X}_{19}$) and gamma – alumina supported binary oxides based on CPC ratio were synthesized, characterized and tested for their HDS activity on thiophene. In presenting these results, TMC and extended building block-TMC are grouped such that the effect of valence electron concentration (VEC), chalcogen type, and cluster size are considered separately. For the gamma – alumina supported catalysts, the promotion of Mo atom by the other cation element such as Pb, Sn, Cu, or Ho is contrasted with the promotion by Co.

For the bulk TMC catalysts, reported rates of reaction were obtained under differential reactor conditions. However, the reactor operated as an integral reactor for the supported catalysts and the rates reported are the average rates for the packed bed reactions. In the bulk TMC samples, there was no concern for intra-particle diffusional limitations since the particles were mostly crystalline. The average specific surface area was between 0.5 and 5.0 m^2/g . In the supported catalysts however the specific surface area was between 160 – 225 m^2/g , and consideration was given to intra-particle diffusional limitations in the HDS rate calculations. The operating conditions were similar for all tested samples (catalyst loading, temperature, pressure, weight hourly space velocity, mesh sizing) so that comparison of rates is possible. The average HDS rate for thiophene in the bed is given as:

$$r = \frac{f \cdot x}{w}$$

where “r” is the reaction rate in mol/s/g, “f” is the flow rate of thiophene in mol/s, “x” is the conversion of thiophene defined as the moles of the product on carbon-basis (excluding coke) as a ratio of the thiophene feed on carbon-basis , and ‘w’ is the mass of catalyst in gram.

The HDS activity is expressed as the generation rate of all hydrocarbons products except coke, the HYD activity as the rate of production of butane and butenes, and the hydrocracking (HCK) activity as the rate of production of $C_1 - C_3$ hydrocarbons.

EXTENDED CLUSTER BULK TMC CATALYSTS

- (1) TMC and extended cluster TMC with high oxidation number per Mo atom possess high HDS and HCK activity and low HYD activity.
- (2) Because of a high dispersion of its Mo atoms in the lattice structure, as determined from its lower X/Mo ratio, $M_zMo_9X_{11}$ with its intermediate building block size exhibits higher HDS activity compared to small building block, $M_zMo_6X_8$ and large building block, $M_zMo_{15}X_{19}$.
- (3) For the chalcogenic substitution in TMC, high electronegativity value is more important in promoting the HDS activity than the Mo dispersion. The sulfides are more active than selenides and tellurides.

SUPPORTED TMC OXIDE CATALYSTS

- (4) Pb, Ho, and Sn are good co-promoter elements for gamma-alumina supported MoO_3 as HDS catalyst. The order of promotion is $Pb > Co > Ho > Sn$.
- (5) Single cation oxides of Pb, Sn, Ho, Co, and Mo supported on gamma-alumina are good HDS catalysts. The order of their HDS activity is $Co \gg Mo \gg Pb \gg Sn \gg Ho$. The point to be made here is that when synergically co-promoting HDS catalysis, Co can better serve as the main catalytic element, instead of the widely held conception that Mo is the main catalytic element.

- (6) The gamma-alumina supported 1:6 Pb:Mo catalyst (templating CPC formula) provides such a synergic combination of Pb:Mo that makes the catalyst superior to the world-wide commercially accepted CoMo catalyst used for HDS reactions (Kareem, 2000).

CATALYST PRE-TREATMENT METHOD

- (7) Though typically the preferred technique globally, pre-sulfidation with H_2/H_2S before commencing HDS promotes cracking; it also reduces HDS activity in both bulk and supported catalysis.
- (8) H_2 reduction step prior to thiophene HDS creates more coordinative unsaturation in the Mo atom than the H_2/H_2S sulfidation / reduction step (Kareem, 1988).

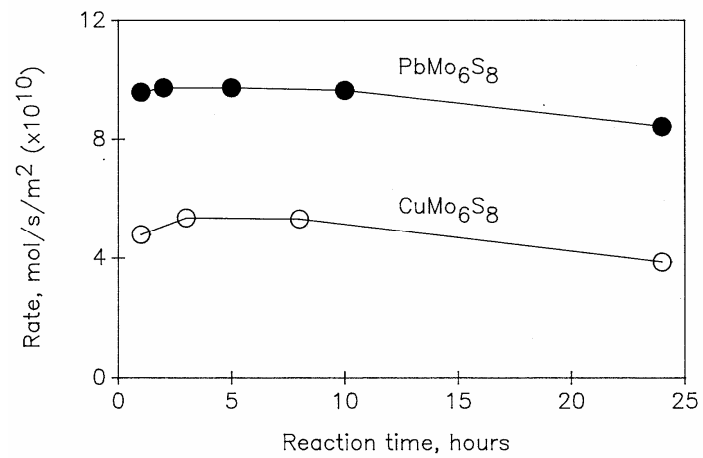


Figure 4: HDS Rate versus Time for PbMo_6S_8 and CuMo_6S_8 : Cation Size Variation.

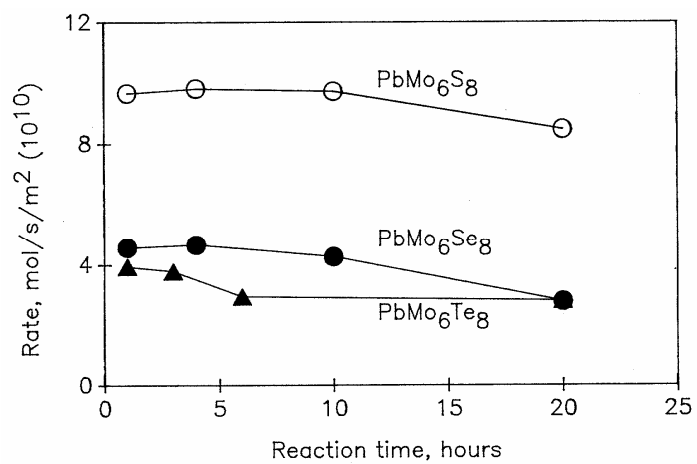


Figure 5: HDS Rate versus Time for PbMo₆S₈, PbMo₆Se₈ and PbMo₆Te₈ :Chalcogen Type Variation.

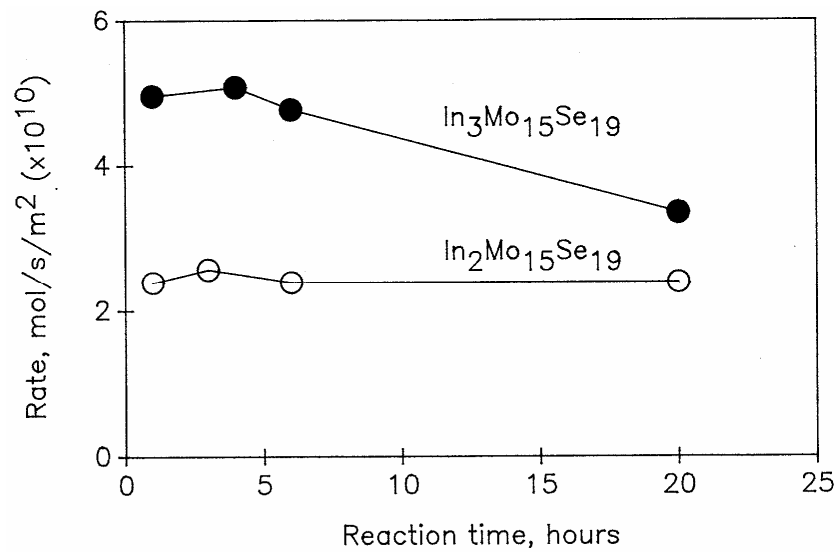


Figure 6: HDS Rate versus Time for In₃Mo₁₅S₁₉ and In₂Mo₁₅S₁₉ :Valence Electron Concentration Variation.

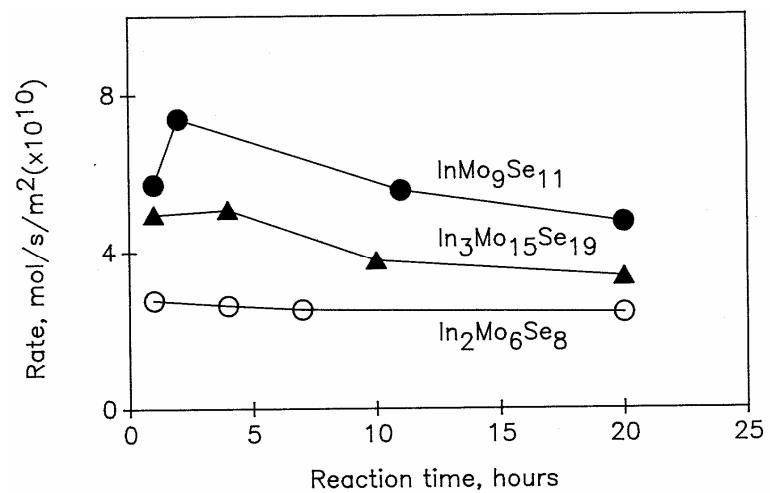


Figure 7: HDS Rate versus Time for $\text{In}_2\text{Mo}_6\text{Se}_8$, $\text{In}_3\text{Mo}_{15}\text{Se}_{19}$ and $\text{InMo}_9\text{Se}_{11}$:Building Block Variation.

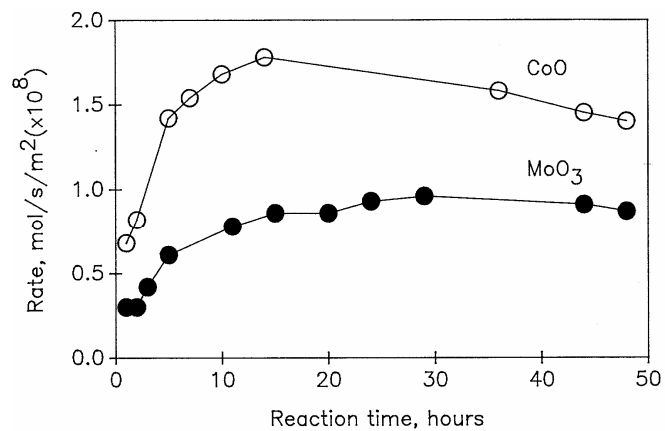


Figure 8: HDS Rate versus Time for Supported CoO and MoO₃ Catalysts: Promotion/Catalytic Activity.

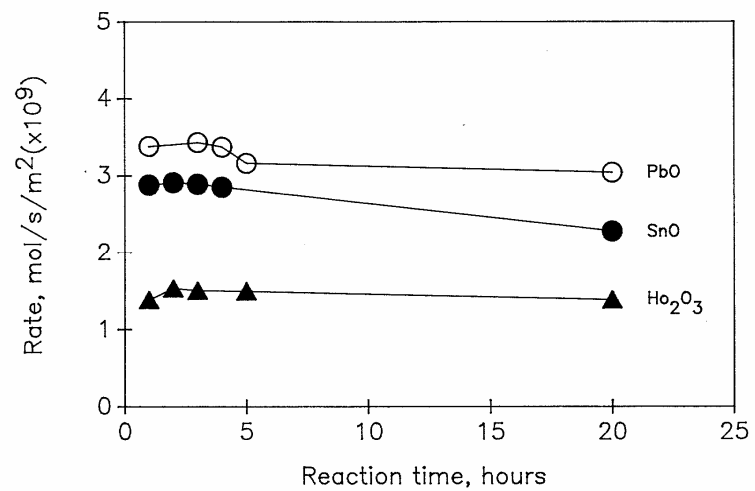


Figure 9: HDS Rate versus Time for Supported PbO, SnO and Ho_2O_3 Catalysts: Catalytic Activity.

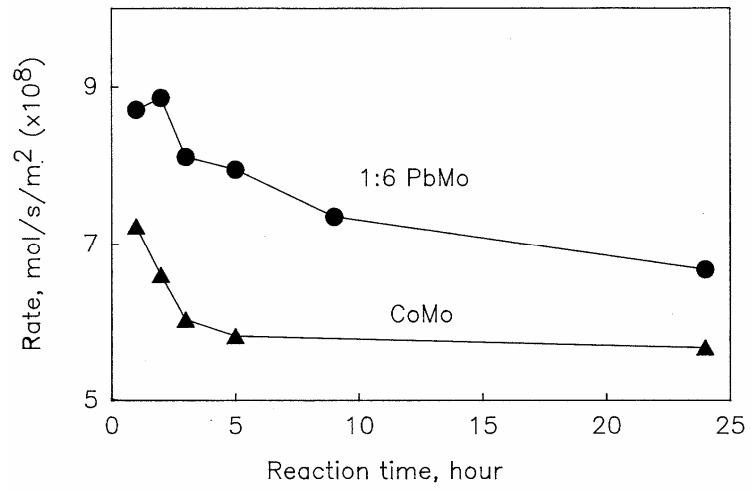


Figure 10: HDS Rate versus Time for Supported PbMo, CoMo Catalysts: Comparative Catalytic Study.

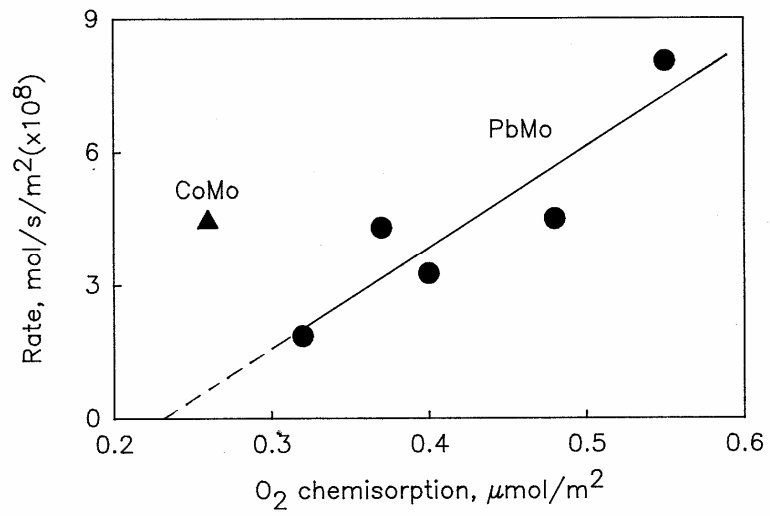


Figure 11: HDS Rate versus O₂- Chemisorption for Supported CoMo and PbMo Catalysts: Active Sites.

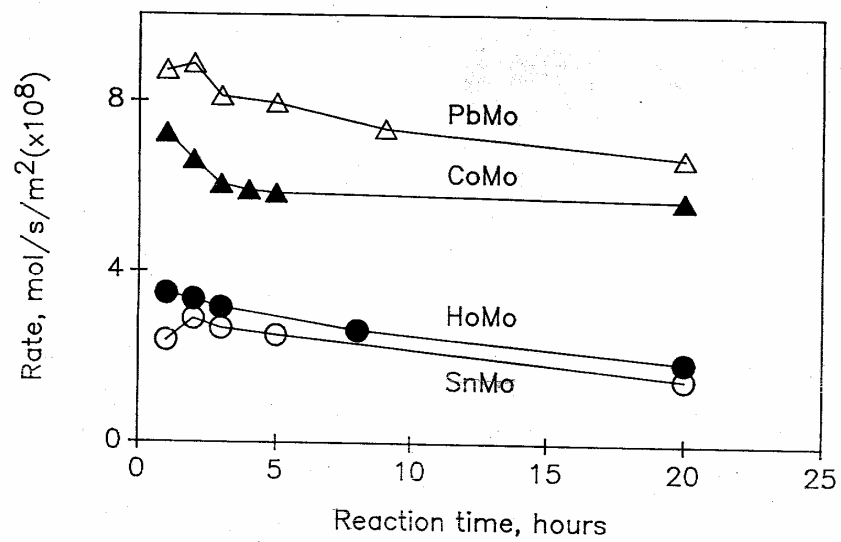


Figure 12: Comparative HDS Rate versus Time for Supported PbMo, CoMo, SnMo and HoMo Catalysts.

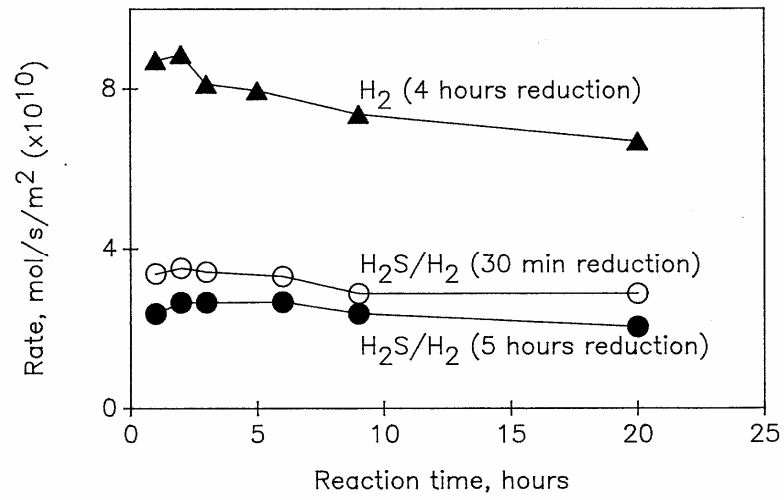


Figure 13: Comparative Pre-treatment: Catalyst Activation for Supported PbMo Catalyst.

This investigation took the whole three years I spent in completing my Ph.D. The results were patented by the University of Louisville, Kentucky, USA. The work also earned me induction into **Sigma Xi**, (ΣX) an International Honours Society for Scientists. The credit of this work must go to my late Mother, unschooled, but definitely my best teacher, who though only spent ten years with me, developed my inner vision by constantly drumming it into my ears that:

“It is impossible to know it all, but whatever genius you lack intellectually, you must always be ready to make it up with mind effort. Never forget that hardwork never kills a man, it is idleness that first kills the mind, then the man”.

Mr. Vice-Chancellor Sir, I will now report my second major contribution to knowledge. I have chosen to report this second technological contribution of mine because it revolutionized the nonwoven/diaper industry worldwide and because although many notable Engineers and Scientists had sought solution to the nagging quality problem of continuous containment of multiple urinations in baby diapers and permanent or durable hydrophilicity in other nonwoven fabric applications, proffered solutions were short of the target point.

Before I was given this assignment in 1989, earlier researchers reported marginal success in their work, the fabrics produced were not properly wettable and when coupled with durably wettable requirements, their early investigations failed to meet the company's and indeed the Nonwoven Industry's quest for a durably wettable fabrics made out of olefinic resins (Kareem, 1992).

The goal of the investigation was to develop a pilot scale method of imparting permanently hydrophilic property to polyolefin blown micro-fiber (BMF) webs. For economic reasons, the investigation was geared towards polyolefins, polypropylene (PP) web in particular, otherwise, at a higher material cost to the Nonwoven Industry, Allied Company's CFX Nylon (80%Nylon-

6/20% Polyethylene Oxide) would have met the goal of this investigation. The raw material cost ratio between using CFX Nylon and PP was about 4:1, which translates to millions of dollars savings, if polyolefins could be used instead of CFX Nylon. Beside raw materials cost, there were other processing factors that further made the processing of CFX Nylon unattractive to the Nonwoven Industry.

The problem with using polyolefin resins as raw material for BMF webs, however, was that the BMF webs as made are inherently hydrophobic and highly olephilic in nature, yet it had been the preferred fabric worldwide in the multi-billion dollars baby diaper business for ages. The common method of imparting hydrophilicity to the BMF webs industrially then was to topically apply surfactant solutions on the BMF webs in a post-production fashion. The hydrophilicity obtained was never permanent; loaded surfactants leached away readily, and a bigger problem with the known method of application then was also non-uniformity of surfactant application. Only when highly concentrated and potent surfactant solutions are used can remarkably uniform treatment be imparted to the BMF webs matrix.

The early methods indicated that although “ideally”, melt additive option was the ultimate, (but due to production scale practicability) topical methods of surfactant treatment in post-web fabrication mode could only be used due to the technical limitation of imparting hydrophilicity to the BMF webs in the melt. After intense investigation, four major successful methods of permanently imparting hydrophilic property to PP BMF webs that can be used for making baby diapers were discovered. The four methods are summarized below. A schematic diagram of the surfactant treatment points in the BMF web production process line is shown in Figure 14.

Injection Methods

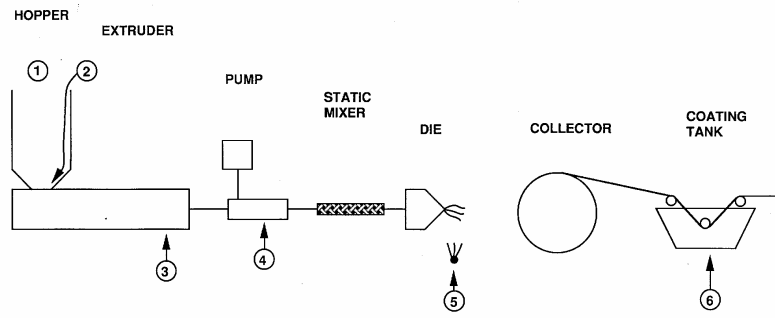


Figure 14: Incorporation of Surfactants into Polymer Melt

1. When dealing with high temperature/heat stable surfactant compounds, the hydrophilic agent (powder, pellet or liquid) can be blended at a desired level with the resin and together fed into the hopper. While this may give a good distribution of the additives in the resin, a problem associated with this method was the constant bridging in the hopper and screw slippage experienced at high blend level (>2%).

For some surfactant additives this method was practicable.

2. Another way of incorporating the additives into the resin is to pump the additives (liquids) into the bottom of the hopper, right on top of the extruder screw using a peristaltic pump. This method has an advantage over method 1 of preventing resin bridging in the hopper.

3. The additives can be pumped at high pressure into either the transition or the metering section of the extruder. While this method has the advantage of minimizing additive decomposition, additional mixing (static mixer) is often required to obtain homogeneous mixing of the additive in the molten resin.

4. The additive can be pumped at high pressure through an injection port after the neck tube. This method is very similar to method 3; it is just a bit more downstream in the extrusion process and requires a good static mixer for homogeneity also. For surfactants that are temperature or heat sensitive, this method is preferred to method 3.

The period between 1988 and 1992 marked my teething era professionally, because although I was accustomed to using reactors as a Chemical Engineer, the 3M job required that I used extruders to produce polymers in-situ through reactive reactions. Many notable investigations and results were recorded during this period (Kareem *et al.*, 1990; Kareem, 1990; Kareem *et al.*, 1991; Kareem, 1992; Kareem *et al.*, 1992}, the most outstanding being the permanent hydrophilicity investigation on polyolefin BMF webs. This hydrophilic investigation earned me recognition

in the Non-woven industry and this almost became a nightmare because I was hunted day and night by employment agencies, known otherwise as head hunters. After the work was patented by 3M in 1992, my mind was set and homebound.

Mr. Vice-Chancellor, Sir, my third contribution to academics was in 1992 when I was engaged by the Saudi Government as an Expatriate. With the hope of augmenting their available liquid petroleum stock, the Saudi Government in their Research Institute located at the King Fahd University of Petroleum and Minerals, in Dhahran, KSA initiated research effort to oligomerize and hence liquefy the typically flared natural gas. I was recruited when I was about leaving USA for Nigeria as the Lead-Engineer for the catalytic, natural gas oligomerization effort. During this engagement, I had the opportunity to work with some World-Class Engineers and Scientists, including Professor Olagoke Olabisi of the Polymer Blends fame and Professor W. Kiem, a Consultant to the German Government on Science, to name a few. The Unit had two strategies. The first was to use available, globally known capabilities to load nickel based catalyst onto a good support and evaluate it for α - olefin oligomerization. The second strategy, for which I was actually recruited through a global head-hunt, was to heterogenize Ziegler-Natta catalyst and evaluate it for α - olefin oligomerization. Both strategies worked out in the end. In the pilot unit, I was able to load nickel nitrate on silica-alumina support obtained from CSIR in South Africa using ion-exchange technique which subsequently upon evaluation gave a good yield of α - olefin liquid products using ethylene as the feed gas (Kareem, 2000).

Overall, five temperature conditions were used, namely: 100°C, 150°C, 200°C, 250°C and 300°C. The pressure in the fixed-bed reactor setup was maintained at 500psi. The weight hourly space velocity (WHSV) which is a measure of the ethylene gas flow through the fixed bed reactor was maintained at 2.25. At 100°C, 2.00ml of liquid product was collected in 14hours. At 200°C, 65.80ml of liquid product was collected in 20hours. At 300°C,

108 ml of liquid product was collected in 29hours. The carbon count distribution obtained through gas chromatograph analysis was mostly between C₄ and C₁₀ for the runs at 200°C and 300°C. For 100°C run, however, over 90% of the product distribution was between C₈ and C₁₂.

Table 1 shows the oligomerization products selectivity variation with the reaction temperature, while Table 2 shows the reactor effluent gas stream compositional variation with temperature.

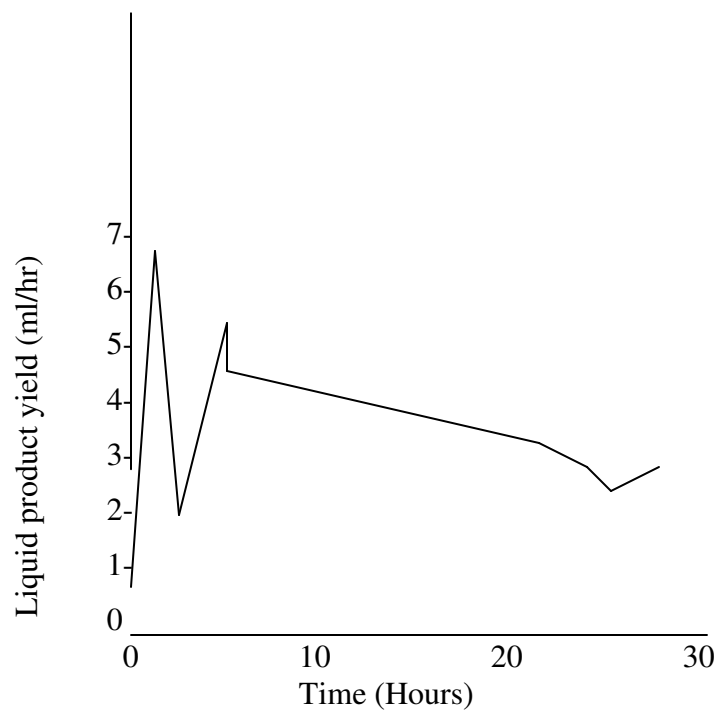


Figure 15: Hourly Liquid Product Yield for Oligomerization Reaction at 300°C, 500psi and WHSV = 2.25

Table 1: Oligomerization products selectivity variation (mole %) with reaction temperature

Olefin	Mole% at (run temperatures (°C))				
	(100)	(150)	(200)	(250)	(300)
C ₄	0.00	29.10	23.80	27.10	37.90
C ₆	4.80	46.00	37.60	28.80	37.20
C ₈	31.20	20.00	26.30	27.10	16.20
C ₁₀	35.50	4.70	8.60	11.70	6.20
C ₁₂	28.50	0.20	3.70	5.30	2.50

Evidently, selectivity is favoured at 100⁰C reaction temperature, at which point, the catalyst activity is very low. Temperatures above 150⁰C favour oligomerization yield at the expense of product selectivity. At 150⁰C, a lot of the feed gas passes through the reaction bed un-oligomerized as evident in the effluent gas stream analysis in Table 2.

Table 2: Reactor effluent gas stream compositional variation with temperature

Olefin	Mole % at Temperature (°C))		
	(150)	(250)	(300)
C ₂	97.10	46.50	45.20
n-C ₄	0.50	9.30	12.20
t-C ₄	1.50	26.90	25.40
c-C ₄	0.80	17.20	17.10

After this initial success, the second option of heterogenizing Ziegler–Natta homogeneous catalyst and using it for the liquefaction/oligomerization reaction was pursued. For almost a year it proved impossible, because of the unstable nature of the homogeneous Ziegler-Natta catalyst itself even when successfully made under inert conditions. Transfer of catalyst made under inert condition, heterogenized under inert condition, to the reactor at ambient/pressurized condition, made whatever success initially experienced non-fruitful.

A breakthrough finally came from an inspirational childhood experience with my late mother, who once answered my childish question during child-birth labour when my younger brother was being born, by telling me that Allah (S.W.T.) “puts babies inside mothers, a little bit at a time”. At 2:00am one night in 1994, I went to the laboratory to put together in a meticulous manner, bit by bit, in-situ, a heterogenized Ziegler–Natta catalyst system that was later scaled up and patented by my Saudi Government employer. My group leader, Professor Olagoke Olabisi, was to later baptize it publicly as my “ship in the bottle” technique.

With the oligomerization reaction heterogeneously catalyzed, an alternative to the highly energy-intensive method of mechanically compressing and cooling successively the flare gases (as done by the Nigerian government today) to obtain liquefied gas was found. Against all pleas, individually and managerially, I left Saudi in 1994 after my first contract of two years expired, determined to come home to once again feel the spirit of belonging, to once again tap into the root that made me.

Mr. Vice-Chancellor, Sir, to give my fourth but not the last contribution to the field of Chemical Engineering, I will quote my political and spiritual mentor, the late Malcolm X (El-Hajj Malik El-Shabazz), by saying “this cock has finally come home to roost”. I returned to Nigeria towards the end of 1994 with divided opinion on whether to pursue an OPEC offer in Geneva or be self employed. When it dawned on me that I might be dissatisfied with the former option, I settled for self-employment by deciding to manufacture toilet/bath soap. For about eight months, I manufactured on a rather large scale at my factory in

Fate, quality “soap only” product that was well accepted by the consumers. I had intimate but rather frustrating interaction with our money-worshipping, seriously shrewd retailers in Ilorin Metropolis such that by the time I ran into a merchant in Abuja ready to buy all I can produce and pay up instantly, the idea of other options beside soap had set in.

My next product (but actually the first choice of product to manufacture on a large scale even before soap) had always been portable water packaging. I took a membrane separation graduate course that made me fall in love with the idea of providing portable water from the most brackish of water supply. I had problems initially with packaging of purified water because most plastic bottles manufacturers/suppliers were asking for a price I considered ridiculous for empty plastic bottles. Fortunately one day, I observed an old man using a locally fabricated electrical machine to cut chin-chin plastic. Mr. Vice Chancellor, Sir, that marked the beginning of “pure water” business in Ilorin and most probably in Nigeria, I dare say. From the ideas I could borrow from the chin-chin nylon cutting machine, I was able to design the packaging, label my brand “Delight” and sell portable water (now baptized “pure water”) to informed “consumers” at Kwara Polytechnics, Unilorin Mini-Campus and few other places like Eiyenkorin and Yoruba Road stalls for a long period of time before everyone joined the trade to my delight. The socio-economic impact of “pure” water business success is no longer story to anyone in Nigeria today.

Distinguished Ladies and Gentlemen, that period when I returned to Nigeria after over two decades of sojourn outside also happened to be the peak of petrol scarcity nationwide. My community service role during that period was to finish making my productions, be it soap or water packaging and head for Adewole Petrol Station where I was publicly trusted with the role of petrol buying queue Commandant. With the support of the public, including the unruly cab-drivers, I was able to put all petrol buyers in check whether military or civilian, until one day when an Army recruit got out of control and wanted to shoot me. Thank God I was not even hurt, but that day, a petrol buyer got interested in knowing which type of Doctor I was, that had been

offering selfless service to the residents of Adewole Estate and the public in general. With the benefit of hindsight, I thank God that I played the role to a fault, because no matter how long I met the queue, I made sure and conspicuously too that I myself stayed in queue only to buy whenever it got to my turn. The God-sent customer was no other person than Professor Musbau Akanji, who got so interested when informed that I was trained as a Chemical Engineer, that he not only invited me to the University of Ilorin to apply for employment as an Industrial Chemistry lecturer, but also played the Big Brother role fully to assure my temporary engagement. He was indeed my mentor during my early turbulent days of trying to adjust to the “Nigerian” style of University life. My life has not been the same since I joined the University system, I have never been happier in my life, even during the earlier period when I was assigned as many as seven courses to lecture and ended up not being paid my first take-home salary for up to eight months, the romance is just impossible to describe. For the first time I ran into young and talented minds that I could identify with amongst the students which just challenged me to give to them more than I had been given myself academically.

Mr. Vice-Chancellor, Sir, I was not the only one in love; my students demanded and got more than my classroom engagement. They learnt on open-workshop basis how to make soap, after-shave, candles, dustless-chalk, etc. The romance with my academic engagement got so serious that many times I preferred to put it before my family commitment. Thank God, I have had so many adopted kids amongst my students; my blood kids also know that they have inherited countless siblings through my academic engagement.

Mr. Vice-Chancellor, Sir, what has been my major scholarly contribution?. I have through lectures, workshops, demonstrations, exhibitions, and project assignments turned out scores of undergraduate and graduate students able to actualize the use of Industrial Chemistry to transform shortfall into windfall by producing hot stuffs using the power of mind over matter.

To mention a few, I taught my students how to use Chemistry to design catalytic conversion system for automobile exhaust scrubbing, to decolourize red-oil, to make dustless chalk, to make activated carbon from animal and plant wastes, to hydrogenate cooking oil to make lard/butter, to produce polyurethane from castor-oil and a host of other locally relevant products {Kareem and Kadiri, 1998; Kareem, 2000; Kareem and Sheriff, 2002; Kareem and Adisa, 2002}.

Distinguished Ladies and Gentlemen, my utmost contribution came out of wanting to rescue a business that was blooming, but giving the whole Nation pollution concern from the indiscriminate disposal of packaging materials for the product. I am talking about the “pure water” business that I helped introduce and that countless Nigerians are making a living on with the least sweat today. About four years ago, when Nigerians had fully adopted the N5.00 a sachet – pure water habit, it dawned on the Law-Makers that unless something is done and quickly too, the reckless dumping of empty packaging pure water sachets on our street may end up defacing our society beyond recognition because of the non-decomposing nature of the polymer material used in producing them. Discussion was rife then at all levels of government on the need to ban the water sachet business and hence force millions of benefiting Nigerians out of business and back to the old days of buying only bottled water or soft drinks if they must quench their thirst. It dawned on me then that there must be a scientific way of bailing the Nation and the masses out of the jam.

Mr. Vice-Chancellor, Sir, on virtually every issue, Allah (SWT) has guidance for mankind, and in the Holy Quran, Surah 6 verse 141, the last sentence of the verse says:

But waste not (of Our Provisions) by excess, for Allah loveth not the wasters.

Mr. Vice-Chancellor, Sir, all environmentally problematic wastes are humanly generated, either directly or indirectly. I say this because nature has its own way of ecologically transforming

and therefore conserving natural, non-human made wastes. The public view of waste materials is that of something unwanted, economically worthless, aesthetically undesirable and environmentally problematic especially when time is taken into account. As a matter of fact, waste generation is inevitable whether domestically, industrially or otherwise, the way to properly manage the waste generated is what must be sought. Nature has endowed us with microbes that help decompose most of the organic and natural wastes generated. The introduction of polymeric materials and products by man on industrial and global level has however introduced into the ecosystem another class of solid wastes that cannot be decomposed by microbes easily or at all.

Man's daily thrashing of old, obsolete, damaged and useless objects coupled with the fast changing technological advancements and the rapidly increasing world population compound the problems faced by the municipal waste management outfits. Beyond management, Science and Engineering must continuously look for ways of utilizing the wastes generated either as substitute raw materials elsewhere or transformed engineering materials. If care is not taken, at the rate generated, land-filling will eventually become impracticable for burying some classes of solid wastes generated.

There are three known methods of solid waste management scientifically and technically throughout the world especially with respect to polymeric wastes. The non-feasible and worst of the three options is land-filling of such waste due to the inability of natural microbes to attack and breakdown polymer wastes. A pseudo-land-filling Nigerian option is to allow disposed materials to litter our surroundings, this is not a good option either because such waste ends up either clogging our sewage system or getting ingested and killing livestock as prevalent in the Northern States of Nigeria. The second option is feasible because the polyethylene material used in making sachet packaging films can be burned in an incinerator to generate heat with its associated smoke pollution. What renders this option impracticable is that the average mass of the empty sachet is between 0.3g and 0.4g. As disposed therefore, especially when

totally empty, wind factor ends up dumping the sachets in gutters or filthy corners where massive collection becomes a major problem. The amount of sachets to collect to make this a technically feasible option is so large that the end may just not justify the means. The opportunity cost therefore makes this second option awkwardly feasible.

The third and rather well accepted option is to recycle the disposed sachet films by cutting them into bits and blending them in small fractions with virgin polymer for further processing into another or same product through extrusion process. The point to note here however is that, polymer recycling, as popular and easily applied as it is, cannot be truly considered a technically feasible option because defects are inherently introduced into the formed product when a virgin polymer is blended with the recycled polymer in any proportion. Apart from the material heterogeneity, thermal history heterogeneity of the two polymers (virgin and recycled) in the blend, ends up introducing defect or fracture points into the polymer matrix sooner than later in the finished product.

Mr. Vice-Chancellor, Sir, an innovative answer to polymer waste recovery will therefore be products where inherent defects are not self-introduced by the producers. The novel (pure water sachet) PWS products that the Nation has come to acknowledge as inventions are products of many mind journeys, mind laboratory experiments and unrelenting improvisory actualization of ideas. My study therefore can be considered *ab initio* as the fourth, classical and innovative method of polymer waste management. What was sought was a way of totally transforming the polymer waste to other desirable products. It can best be described as direct conversion of polymer wastes to useful and valuable products. It is a novel method of polymer waste management totally different from land-filling, incinerating, and recycling.

- The first obvious direct conversion product targeted from disposed pure water sachet (PWS) was actually carbon black, a material used for ink, printer toner powder and other industrial applications. Experimentally, it proved difficult, because although

small amount was produced, the yield was so poor initially that it was considered uneconomical as a product. It was produced using destructive combustion method. Notably, the success realized was the experimental observations and deductions that eventually led to many other desirable products.

- In reality, the first successful direct conversion product of PWS turned out to be the **Candle**. It was made from the realization that polyolefin, the group to which polyethylene, the material used to make PWS belongs could replace the paraffinic materials typically used in fueling candle wick. Programmed scissioning or reverse oligomerization of the polyethylene chains in PWS was used to get rid of the contained oil such that the remaining molten material could be poured into a mould that cured into candle of any desired shape once a cotton wick is centered in the mould before pouring the melt.
- **Lubricating grease** was the next direct conversion product made out of the disposed PWS. In a reaction similar to candle making but involving systematic trapping of the released oil, optimized wax-oil ratio was achieved possessing excellent grease characteristics. By appropriately introducing industrially prescribed amount of Sodium-based surfactant, heavy duty lubricating oil able to withstand higher temperature application was made.
- **Shoe polish** was the next direct conversion product made out of the disposed PWS. As produced, the lubricating grease without the surfactant can serve excellently as neutral shoe polish. It has light greenish-brown, non-staining colour. For colours darker than light brown, pigments can be added as desired. Non-smearing black polish was actually made by blending finely powdered charcoal with the light brown lubricating grease.
- **Oleosorbent particle** was the next direct conversion product made out of the disposed PWS. Based on polymer phase change theory and using polymer-solvent

reaction systems, the thin film PWS material possessing oleophobic, hydrophobic, and liquid impermeable characteristics was turned into a highly porous, still hydrophobic, but highly oleophilic state. The transformed characteristics are, and have been demonstrated to be ideally suited for oil-spill management. This is a multi-billion Naira idea when fully developed.

- **All purpose filter particle** was the next direct conversion product made out of the disposed PWS. The oil sorbing particles, being dustless, can be crushed and then sieved to any desired particle size for excellent filtration applications involving oils and all organic fluids at atmospheric pressure. Under high vacuum or high pressure, the filter particles can be used in all-purpose fluid, including aqueous fluid applications.
- The first targeted product of direct conversion of PWS, **Carbon Black**, actually considered the simplest, but later turning out difficult to produce at reasonable yield, has now been produced at high yield. When scaled up, this new method of polymer waste management will save the Nations, millions of barrel of diesel/kerosene presently utilized for making carbon black product worldwide. This is also a golden idea, worth billions of Naira economically.

The solvent-based polymer waste recovery reaction used in converting the waste sachets to porous particles, allows variability in the density and porosity of the transformed particles. The particle size is operator-controlled, which renders the particles adaptable to many other applications. The particles can find applications in macro, micro, and even nanotechnology such as in Microbiology as microbial organisms “basket”, in Mechanical Engineering as porous bricks’ perforator, and oleo-septum filter aid. In Civil Engineering the particles are compounded with other materials to make light weight, water-proofed surface layering construction material. Eventually, it is hoped that with the right catalyst, and right reaction systems,

“pure water” sachet material will one day in the nearest future be depolymerized, and subsequently oligomerized to make liquid petroleum fractions. It will then simply and truly be a scientific realization of **the power of mind over matter**.

RECOMMENDATIONS

Mr. Vice Chancellor, Sir, I have attempted to present in this lecture, as simply as possible, the use of scientific and technological ideas to solve problems locally and globally.

Somewhere along the line, I hope I have also clearly indicated the need to make more products so that more people can be happier. The challenges facing a scientist are numerous. With total dedication, a scientist must carry about technical challenges, body and soul, until he/she can proffer solution from available means.

In concluding this lecture, I want to make a few recommendations.

1. To achieve a sustainable industrial / technological growth in Nigeria, our education system must be able to sensitize our kids right from the primary school to have interest in the sciences. Parents and teachers must provide enabling environment and must also tolerate even annoying mind probes by inquisitive kids by providing genuine answers to even the most awkward questions.

Major scientific breakthroughs require well nurtured, disciplined minds and all efforts must be expended to develop and sustain such minds from childhood. The typical method of making science students cram theories and equations is outdated and can never bear useful results. The right way of building scientific minds is to ensure absolute understanding of the basic principles by

the students that can be called upon for solutions on real life problems when needed.

2. I am sure the Nation is now aware that the technology transfer fervently sought in the past decades, can never solve our problems. To get on the technological train, the solution backed by proper funding by the Federal Government is to challenge Universities and Research Institutes to find solutions to all our local problems. With the advent of Information Technology, foreign ideas can be easily borrowed when necessary to compliment local solutions.
As long as technology is strangely transferred, the problems presently experienced in our refineries and other chemical industries are inevitable.
3. I know that fellow Nigerians are richly endowed with good technical ideas. Our Government must provide the means to galvanize these ideas so as to rapidly Launch Nigeria into the technological orbit. For a starter, I will strongly recommend that all Science and Technology Students be encouraged to take at least one course on “Inventions and Patent”. Such course should be focused on solving local problems principally but can also be used to broaden students’ knowledge base beyond the routine exercise of theorems and equations cramming.
4. The country seriously needs a National socio – technical consortium between the academia, organized industrial sector and Government with a view of identifying industrial problems that should be targeted for research project/studies by the academia. The academia should be funded properly; possibly jointly, by the industries and Government to look into short term and long term solutions for all locally relevant problems. The Annual Universities Research Exhibition is a good idea, the Government must however work extra hard to co-opt concerned personnel in the

Industries to participate more actively and ensure rapid scale – up / development of research discoveries.

5. Unlike our colleagues in other countries, I have come to the realization that Nigerian Researchers do not like engaging themselves in multidisciplinary studies and this could actually be the reason why outstanding results are few.

Cross – fertilization of ideas during research investigations between Scientists, Engineers and researchers in Arts and humanities can only produce robust solution with wide application to a larger spectrum of the public problems. I will pray that academics realize the gain in and engage more in multidisciplinary studies.

ACKNOWLEDGEMENT

My Story is that of a sanctified orphan who made it against all odds. For over four decades Allah (SWT), Himself has taught me the true meaning of Lordship. For being my Lord (Rabbi) and being there since all these decades I know I owe Him debt of indescribable magnitude, Al–hamdulillah Robbil a alameen.

For my late Parents, I thank them immensely for teaching me about piety, contentment, hardwork and loving fellow human beings. May their gentle souls rest in peace. (Amin).

Alhaji Obale, Alhaji Kuranga and Alhaji Sanusi were God sent people who came to my aid materialistically and spiritually when I hopelessly orphaned, May their gentle souls rest in peace (Amin).

I was fortunate to meet families like the Ijaiyas, the Kawus, the Olodans, the Akoshiles, the Agbabiakas, the Ariyos, the Olotas,

the Ikoros, and my in – laws, the Kadiris. These people in no small way contributed to make coming this far in life for me easy. May Allah (SWT) reward them all bountifully.

For being with me along, I thank my childhood and fraternal friends: Snr. Ibrahim Badmos, Commodore B. Afolayan, Justice S. Kawu, Dr. R. Balogun, Dr. S. Adedayo and his wife, Biola, Dr. A. Adekeye and a host of others.

To my super – teachers, starting with Alhaji Y.S. Ariyo, Dr. Mrs. Agboola, the late Mr. J.J. Salami, Prof. R. Miranda, Prof. J.C. Watters and a host of others, right from Primary through graduate school. I thank you all. May Allah (SWT) reward you all abundantly.

I am profoundly grateful to my brothers and sister, Hadji Shehu, Anti Adija, Hamza and Kamaldeen. You have all made life worth living for me.

I am grateful to my students in the Department of Chemistry, I also wish to thank the teaching and non – teaching staff of this great institution that have made my coping easy. Prof. M. Akanji and Late Prof. J. Owoyale stand out, May Allah (SWT) continue to love you both.

Nigeria is blessed with the likes of Chief Bashorun J.K. Randle, a truly exceptional philanthropist, who after spending a million Naira to promote my work told his National audience that the nation needs more Kareem, rather than agree with him, I pray that Allah (SWT) bless the nation with more of his like. May Allah (SWT) reward him beyond human imagination.

I have come this far through the sacrifice of my sister and wife, Hadja Falilat Iyabo Abdulkareem. I thank Allah (SWT) for His Blessings on you. I thank Allah (SWT) immensely for my bunch, namely: Aisha Adetoni, in the USA, Sulyman Olorundemilade, Zainab Olorunbukade, Maryam Toloruntomilade, Aminah Olorunfadekemi, and the baby, Biliqees Tolorunwumilade.

For providing the opportunity to deliver this lecture, I thank the Vice Chancellor, Prof. Shamsudeen O. O. Amali (OFR), the DVCs and other Principal Officers. Finally, for everyone else in the audience I thank you all for being here to witness the deliverance.

Summarily my distinguished Ladies and Gentlemen what is our take home message?. Our Nation needs more Scholars, more Industrial Chemists, more Chemical Engineers, to engage themselves in bringing material windfall into every demand area where there is material shortfall. **To be great, our Nation must make stuffs, hot stuffs, using the power of mind over matter.**

May Allah (SWT) Bless you all.

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