Catalysts in Petrochemical Industries

- Dr. Anil Lachke

Catalysis

Chemistry is the science of substances and their transformations. Chemistry makes many wonderful substances from animals and vegetables as well as from crude oil as a raw material. Some substances occur naturally, but many have to be chemically treated in some way to make them suitable for our specific needs. . Thousands of substances have been produced that are not easily found in nature but posses unique and useful properties. The list of chemistryôs good deeds is practically inexhaustible. Chemistry feeds us, clothes us, shoes us, and gives us the things without which modern civilized society cannot function. In order to get unique substances, two or more chemicals must come together and react! After all weôve all seen images of chemists cooking things up. May be weôve even turned up the flame a few times ourselves in the kitchen! And so we know that in order to speed up chemical reactions, high temperature certainly helps. If you wish to have an economical and ecofriendly approach towards your chemical transformations then you should use an appropriate catalyst. Catalysts change the reaction rate of chemical reactions favourably without undergoing any permanent change themselves.

Any chemical reaction that takes place with the aid of a catalyst is called a catalytic reaction. For example, heating a mixture of potassium chlorate and manganese dioxide produces oxygen quicker than heating potassium chlorate on its own. The manganese dioxide acts as a catalyst to speed up the reaction, and is left unchanged at the end. For this reason, the manganese dioxide does not appear in the chemical equation that shows the reaction.

A contact catalyst is one that has a large porous surface to which other substances adhere by a process called adsorption. Atoms or molecules of different substances collect on the surface of the catalyst. While on the surface they react together and are released in a different form. An example of such a reaction is the formation of ammonia from nitrogen and hydrogen. The catalyst used in this example is the iron ore magnetite.

Catalytic converters are used to clean-up exhaust gases in automobiles. It reduces the toxicity of emissions from the internal combustion engines. They are fitted in the motor vehicle exhaust system. A catalytic converter provides an environment for a chemical reaction where in toxic combustion by-products are converted to less toxic substances. The catalyst itself can be a precious metal, like platinum, palladium or rhodium. Platinum-rhodium catalysts are used as ñreduction catalystsò and platinum-palladium catalysts are used as ñoxidizing catalystsò. Zeolites are microporous aluminosilicate minerals, commonly used as commercial adsorbents. Synthetic zeolites are widely used as catalysts in the petrochemical industry.

Indian catalysis research

Indian catalysis research and development today is geared to serve the needs of the country on the one hand and the more challenging global requirements on the other. The research is focused, on innovative solutions to the problems of environmental pollution, safety in industrial practice and saving the energy requirement in chemical reactions. Catalysis R & D in Indian institutions now looks forward to the development of competitive catalysts and processes that are required to meet these challenges.

Indian per capita consumption of petroleum and petrochemical products was increased considerably during 1970s. Due to this rapid growth most of the laboratories initiated projects on the development of catalysis for petrochemicals and petroleum refinery processes with an emphasis on self-sufficiency and indigenization rather than on innovation. Catalysis research is expanded to cover topics such as synthesis and application of zeolites, molecular sieves, novel materials and photocatalysis. The globalization has resulted in many partnerships between Indian and foreign organizations. For example, a large amount of catalysis research carried out in CSIRôs (Council of Scientific & Industrial Research) laboratories. Mention must be made of NCL (National Chemical Laboratory, Pune), IIP (Indian Institute of Petroleum, Dehradun) and IICT (Indian institute of Chemical Technology, Hyderabad) in this regard. These laboratories have collaborations with multinational R & D Centres. Based on these activities, many catalysts/ processes developed in India are expected to go global in coming years. IPCL (Indian Petrochemical Ltd), PDIL (Projects & Development India Ltd.), IIT (Indian Institute of Technology, Mumbai/Kanpur), CFRI (Central Fuel Research Institute, Dhanbad) have also contributed substantially t the area of catalysts.

Mitti ka tel

Petroleum or crude oil is one of the worldôs most important sources of energy. This makes it very valuable to the countries where it is found. In the beginning, this oil was found to be useful for burning lamps for lighting the homes. In many Western countries, the oil was found to be useful for warming homes. Several business men sent a sample of the thick black oil to Yale University of USA. In 1860s, the sample was analyzed by Professor Benjamin Silliman. He reported that the ñsampleò is full of possibly useful chemicals. In other words, nothing will go as waste from this raw material. It is the chief source of hydrocarbons. Crude oil is generally a dark-coloured liquid with a peculiar smell; found underground either in certain shale rocks or held in huge natural reservoirs under pressure between non-porous layers of rock.

Hydrocarbons: This oil appears to be homogenous. In reality it is a made up of thousands of different combinations of the elements ï hydrogen and carbon. These combinations are called hydrocarbons. The hydrogen atoms are arranged in various patterns around the carbon atoms. The more carbon atoms a petroleum molecule contains, the thicker and heavier the hydrocarbon. Gasoline, for example, is made up of light hydrocarbons. Kerosene has slightly heavier hydrocarbons. Lubricating oil is heavier still, and asphalt for paving streets is made of very heavy hydrocarbons. The word petroleum comes from the Latin words *petra,* meaning rock; o*leum*, means oil. This oil was different than the animal or vegetable oil. People started calling this oil as ñ*rock-oil*ò or in India ñ*Mitti ka*

*tel*ò. People started using this oil for mainly for lighting their homes. Hundred years back, the oil was found to be an appropriate fuel for running the internal combustion engines. Cars started running on this liquid which was then an inexpensive fuel. Today, petroleum is much more than just a fuel for automobiles. It is used in the manufacture of thousands of productsé . From plastics to hand lotions, from asphalt to wax candles.

In search of oil (Background)

Oil began to form deep under the earth millions of years ago when plants and animals died and their skeletons settled at the bottom of seas and lakes. The remains were slowly buried under layers of sediment and in the course of time became crude oil. The oil usually lies trapped between domes of solid rock. Often there is a layer of salt water beneath it. In many cases the richest deposits of oil lie beneath a great amount of rock and can be reached only by expensive drilling operations. Geologists know which rock strata (layers) oil is most likely to be trapped in. They start with experimental data of areas likely to be oil-bearing. Then they begin to gather their evidence.

Fossils: Fossils help to date and identify rocks. Radioisotopes are used to obtain more accurate measurements of their age.

Magnetometer : A special instrument called a magnetometer trails behind an airplane as it flies at an even height a long a pattern of flight lines. As different types of rocks are magnetic to different degrees, the results from the magnetometer give a picture of the magnetic structure and thickness of the rocks deep underground.

Gravimeter: The earthôs gravity also changes from place to place. A gravimeter carried across land or mounted on a ship measures the different gravities of the rocks below dense rocks give a higher gravity reading.

Seismic tests: Then there are seismic tests. These are more exact. They measure the time it takes for shock waves from controlled explosions to reflect upward from rocks underground. The time it takes the shock waves to reach an underground layer and return to the surface shows how deep the layer is. It also gives clues about the type of rock from which the shock waves were reflected.

When all these tests are complete and if they show a good chance of oil being in a certain area, a test well is driven down into the rock. It is at this point that large amounts of money are needed to set up the drilling operation. It may cost billions of Rupees to develop a major oilfield before any oil is gotten out of it. Therefore, the exploration be as thorough as possible before any drilling starts. These days the computers are used to gather the information from all tests, but the sure presence of oil is still not known. If there is oil, it probably lies 3000 meters below the surface.

Early drilling

The Chinese began drilling for oil as long ago as 320 BC, but they did not really have the right equipment to drill deep enough. The first successful oil well was sunk by Edwin L. Drake, who drilled a well about 30 meters deep in USA (Pennsylvania) in 1859. This was the start of todayôs petroleum oil industry.

The story of oil exploration in India began in the dense jungles and swamps of Assam in the 19th century. In India, the first regular oil well was discovered in at Borbhil. The oil was also struck at Makum near Margherita at a depth of just 36 meters (118 feet). In 1890, noticing the oil seepages around Borbhil, one private company took a decision to drill an oil-well near the village. Mr. W. L. Lake was an oil enthusiastic technologist. He immediately started collecting drilling equipments, portable boilers and local labour. Elephants were used to drag the machinery on sleigh along animal tracks. Lot of digging was done. The legend has it that Mr. Lake used to urge his men ñDig boysé Digò; hence the name ñDigboiò! With such great efforts the oil-well ñDigboi Well No. 1ò started in the month of September, 1889. Digboi Well No. 2 started in February 1891. The oil production was going on well with 11 wells until 1894. By 1920 there were 80 wells with an average production of 350 bpd (Barrels per day). Thus, there was a modest progress of oil industry in India about 120 years back.

Production of petrochemicals with catalysts (Oil Refining)

The oil we used to make ñPetrolò (gasoline, or motor spirit) and other products, start out as raw black petroleum. It cannot be used as it is, straight from underground. It must be changed into the specific chemicals that people use. This process of changing petroleum into useful products is called refining. The modern oil refinery is a large and complicated factory. Automatic control of the various stages is efficient and safe. Teams of workers are needed to keep the refinery machinery ñrunningò smoothly.

The crude oil consists of many different chemicals with various chemical and physical properties. Distillation or fractionation is the first stage in petroleum refining. This separates out the various constituents) of the crude oil. Different hydrocarbons vaporize at different temperatures. Here, tall distillation columns are necessary. There are many separate trays that are fitted for collecting various chemicals. As the heating starts, partly vaporized oil is fed into the column part of the way up. The lightest fractions are gases. The gases gather at the top of the tower. Heavier fractions that are slower to evaporate gather at each lower stage. Usually, fractions from several stages are drawn off for further processing. The residue, which is left at the bottom of the tower, contains a wide range of petroleum parts. It can be used for fuel oil without any more processing. It can be further distilled to give bitumen or lubricating oils.

A process known as ***"cracking"*** breaks down large molecules into smaller ones. This is done either by thermal cracking, using high levels of heat and pressure, or by using less heat and pressure and a catalyst. Catalytic cracking is done by the fluid technique. In this, a catalyst in the form of a fine powder is poured like a liquid through the petroleum and out to a regenerator. In the regenerator, carbon that has become attached to the catalyst is removed. The catalyst is then returned to the refining cycle.

Catalytic cracking is normally used to make gasoline. The gasoline produced by this process has a higher octane number than gasoline produced by straight distillation. The octane number is a measure of the tendency of fuels to ñknockò (make a knocking noise) when used in automobile engines. The higher the number, the less is knock.

Another refining method is called hydrocracking. In this method, hydrogen and catalysts are used under high pressure. The process results in greater amounts of gasoline and less waste than catalytic cracking. During the cracking operation some gases are always formed. These gases are collected and then put under high temperatures and pressures in the presence of a catalyst. This process is called polymerization, joins molecules together to make larger molecules. These larger molecules (polymers) are used in the production of gasoline.

Some notes

1. The largest refinery in the world is **Jamnagar Refinery** in Gujarat. Refining capacity per day is 661000 barrels per day.
2. One Barrel is 42 gallons or approximately 160 litres
3. What one Barrel of crude oil makes?

Gasoline	74	lit
Distillate fuel oil	37	lit
Kerosene/Jet fuel	15	lit
Residual fuel oil	9	lit
Liquefied refinery gases	7	lit
Coke	7	lit
Asphalt &road oil	5	lit
Petrochemical Feed stock	5	lit

4. India has witnessed a spectacular growth in the refining sector. In 1947, there was only one refinery located in Digboi, with a capacity of only 0.25 million (250,000) tones/year. Today there are at least 20 refineries in India with an installed capacity of 60.4 millions/year. By the year 2012, Indiaôs oil refining capacity would be 65.3 million tones /year.

5. India has large reserve of trained and highly skilled manpower at a relatively much lower cost compared with advanced countries.
