Fuel Chemistry
FYUGP 3rd Sem
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# Unit 2: PETROLEUM

Petroleum (or crude oil), along with oil and coal, is classified as a fossil fuel. Fossil fuels are formed when sea plants and animals die, and the remains become buried under several thousand feet of silt, sand or mud. Fossil fuels take millions of years to form and therefore petroleum is also considered to be a non-renewable energy source. Petroleum is a complex, naturally occurring liquid mixture containing mostly hydrocarbons, but also containing some compounds of oxygen, nitrogen and sulfur. It is often referred to as the "black gold."

Originally the primary use of petroleum was as a lighting fuel once it had been distilled and turned into kerosene. When Edison opened the world's first electricity generating plant in 1882 the demand for kerosene began to drop. However, by this time Henry Ford had shown the world that the automobile would be the best form of transport for decades to come, and gasoline began to be a product in high demand. World War I was the real catalyst for petroleum production, with more petroleum being produced throughout the war than had ever been produced previously. In modern times petroleum is viewed as a valuable commodity, traded around the world in the same way as gold and diamonds.

Petrochemicals are produced mainly at a few manufacturing sites around the world. Petroleum is also the raw material for many industrial products, including pharmaceuticals, solvents, fertilizers, pesticides, synthetic fragrances, and plastics.



## Formation of Petroleum:

Petroleum, or crude oil, is formed through a multi-step geological process that takes millions of years. Here's an overview of how petroleum is formed:

1. Organic Matter Accumulation: Petroleum primarily originates from the remains of tiny marine organisms (plankton, algae, and microorganisms) that accumulated on the ocean floor. Over time, layers of sediment (sand, mud, and silt) build up over this organic material, creating an anaerobic (low oxygen) environment that prevents decay.

2. Diagenesis: As sediment layers increase, the heat and pressure cause chemical changes in the organic material. This process transforms it into kerogen, a solid, waxy substance.

3. Catagenesis: With increased temperature and pressure (typically between 60°C and 120°C), kerogen undergoes thermal cracking. This process breaks down kerogen into liquid and gaseous hydrocarbons, creating crude oil and natural gas.

4. Migration: The newly formed hydrocarbons begin to migrate from the source rock (where they formed) into porous rock formations (reservoir rocks) due to buoyancy. The hydrocarbons continue to move through the rock layers until they are trapped by impermeable layers (cap rocks).

5. Accumulation: Once hydrocarbons are trapped beneath cap rocks, they accumulate over time, forming reservoirs that can be tapped for extraction.

6. Preservation: The conditions of the surrounding environment, such as pressure, temperature, and geological activity, must remain stable for the petroleum to be preserved until it is discovered and extracted.

## PETROLEUM COMPOSITION

The composition of petroleum, or crude oil, is highly complex and varies significantly based on its source. It primarily consists of the following components:

1. Hydrocarbons
- Alkanes (Paraffins): Saturated hydrocarbons, including straight-chain (normal) and branched-chain forms. Common examples include methane, ethane, and octane.
- Cycloalkanes (Naphthenes): Saturated cyclic hydrocarbons, such as cyclohexane.
- Aromatics: Unsaturated hydrocarbons containing one or more benzene rings, like benzene, toluene, and naphthalene.

2. Non-Hydrocarbon Compounds
- Sulfur Compounds: Can include thiols, sulfides, and thiophenes, which affect refining and product quality.
- Nitrogen Compounds: Include various heterocyclic compounds, which can complicate refining processes.
- Oxygen Compounds: Found as carboxylic acids, phenols, and ketones; they can contribute to acidity in the crude.

3. Trace Metals
- Elements such as nickel, vanadium, iron, and others may be present in small amounts and can influence the refining process.

4. Water and Solids

- Crude oil often contains some water (emulsified or free) and solid particles, which need to be removed during processing.

## Types of Crude Oil

- **Light Crude Oil:** High in lighter hydrocarbons and low in sulfur; easier to refine.
- **Heavy Crude Oil:** Denser, richer in heavier hydrocarbons, and often higher in sulfur; more challenging to process.
- **Sweet Crude Oil:** Low sulfur content; more desirable for refining.
- **Sour Crude Oil:** Higher sulfur content; typically requires additional refining to reduce acidity.

## The Basic Composition of Petroleum

| | |
|---|---|
| Carbon | 84 to 87 % |
| Hydrogen | 11 to 14 % |
| Sulphur | 0.06 to 2 % |
| Nitrogen | 0.1 to 2 % |
| Oxygen | 0.1 to 0.2 % |
| Metals | 0 to 0.14 % |

# Uses of Petroleum:

Petroleum is a versatile resource with a wide range of uses across various sectors. Here are some of the primary applications:

*1. Fuels*

- Gasoline: Used in internal combustion engines for vehicles.
- Diesel: Powers trucks, buses, and heavy machinery.
- Jet Fuel: Fuels aircraft engines for commercial and military aviation.
- Heating Oil: Used for residential and commercial heating systems.

*2. Lubricants*

- Motor Oil: Reduces friction in engines and machinery.
- Industrial Lubricants: Used in manufacturing processes and equipment maintenance.

*3. Petrochemicals*

Petroleum serves as a feedstock to produce various chemicals, including:

- Plastics: Polyethylene, polypropylene, and PVC.
- Fertilizers: Nitrogen-based fertilizers.
- Synthetic Rubber: Used in tires and various industrial applications.
- Detergents and Surfactants: Used in cleaning products.

*4. Asphalt and Road Construction*

- Asphalt: Derived from petroleum, used for paving roads and roofing.

*5. Pharmaceuticals*

- Medicinal Compounds: Some pharmaceuticals and medicinal products are derived from petrochemicals.

*6. Cosmetics and Personal Care Products*

- Ingredients: Many cosmetics and personal care items contain petroleum-based ingredients.

*7. Energy Production*

- Electricity Generation: Petroleum can be burned in power plants to generate electricity.

*8. Miscellaneous Uses*

- Solvents: Used in paints, varnishes, and cleaning agents.
- Waxes: Found in candles, packaging, and coatings.
- Dyes and Pigments: Some colorants are derived from petroleum.

## Fractional Distillation of Petroleum:

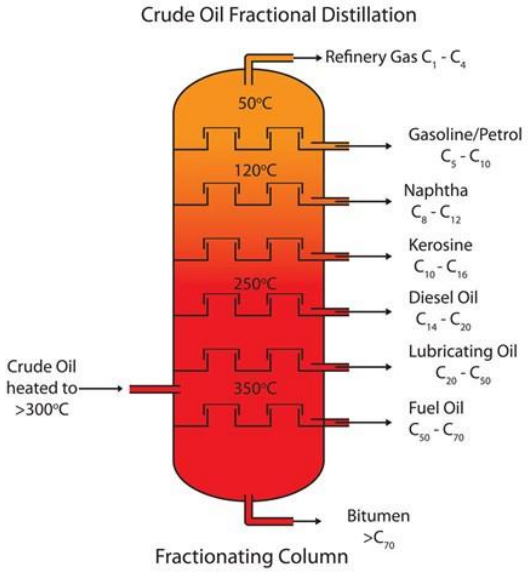
Petroleum can be separated into various types of fuel, by a process called refining, using fractional distillation. **Fractional distillation** is the process by which oil refineries separate crude oil into different, more useful hydrocarbon products based on their relative molecular weights in a distillation tower. This is the first step in the processing of crude oil, and it is the main separation process as it performs the initial rough separation of the different fuels.

Petrol, Diesel, and Kerosene are all products (or fractions) of the process of refining Petroleum.

On an industrial scale, the different fractions of Petroleum are separated out by fractional distillation. The Petroleum is heated up, and the gas produced enters the fractionating column. The column is very hot at the bottom and gets cooler as the gas travels up the column, this allows different fuels to drain out at different temperatures up the column, except for Bitumen, which is used to surface roads, this stays liquid and is drained off at the bottom of the column.

The fuels are drained off depending on the length of the hydrocarbon chain they are made up of.

The longer the hydrocarbon chain, the higher the boiling point and the earlier on the drain from the column.




There are several ways of classifying the useful fractions that are distilled from crude oil. One general way is by dividing into three categories: light, middle, and heavy fractions. Heavier components condense at higher temperatures and are removed at the bottom of the column. The

lighter fractions can rise higher in the column before they are cooled to their condensing temperature, allowing them to be removed at slightly higher levels. In addition to this, the fractions have the following properties:

- **Light distillate** is one of the more important fractions, and its products have boiling points around 70-200°C. Useful hydrocarbons in this range include gasoline, naphta (a chemical feedstock), kerosene, jet fuel, and paraffin. These products are highly volatile, have small molecules, have low boiling points, flow easily, and ignite easily.[4]
- **Medium distillate** are products that have boiling points of 200-350°C. Products in this range include diesel fuel and gas oil - used in the manufacturing of town gas and for commercial heating.
- **Heavy distillate** are the products with the lowest volatility and have boiling points above 350°C. These fractions can be solid or semi-solid and may need to be heated to flow. Fuel oil is produced in this fraction. These products have large molecules, a low volatility, flow poorly, and do not ignite easily.

However, there are two major components that are not accounted for in these three categories. At the very top of the tower are the gases that are too volatile to condense, such as propane and butane. At the bottom are the "residuals" that contain heavy tars too dense to rise the tower, including bitumen and other waxes. To further distill these, they undergo steam or vacuum distillation as they are very useful.