Importance of Alkanes

Alkanes are obtained from the distillation of crude oil. Crude oil is the byproduct of microbial degradation of living organic matter animal, (plankton), remains, brought about over many years by high pressures and temperatures, (generally plant remains produce gas).

Crude oil is a dark viscous liquid, it varies considerably in composition depending on its source. Crude oil is a mixture of about 150 compounds; contains both branched and unbranched alkanes, aromatic compounds, nitrogen and sulphur -containing compounds, (sulphur compounds produce acidic sulphur dioxide when burned). Crude oil is difficult to ignite.

Crude oil is of very little use as it is. To yield volatile substances which can be used as fuels, thus crude oil is first separated into **fractions** by fractional distillation, i.e. into groups of hydrocarbons of similar chain length and therefore similar properties.

Fractional distillation is carried out first by heating the crude oil in a furnace so that it vaporises, the vapours pass into a tower which is cooler at the top than at the bottom. The lowest temperatures are at the top of the column and the highest are at the bottom, closest to the heat source. The vapours pass up the tower via a series of trays containing bubble caps and eventually condense to a liquid when they arrive at a tray that is sufficiently cool. The liquid that condenses on each tray is piped off separately. Shorter chain hydrocarbons have lower boiling points, so that the higher the tray is up the tower, the shorter the chain length that collect there, i.e the most volatile component collects at the top, whilst the least volatile component collects at the bottom. Each fraction is a mixture of hydrocarbons which boils over a limited range of temperatures.

A very high boiling temperature fraction called the **residue** collects at the base of the column while gases are taken from the top of the column. The residue can be used for road tar , road surfacing, and roofing. Besides being used as fuels, all these fractions are important for the petrochemical industry.

The petroleum fractions with 1 to 12 carbon atoms in the molecule are in demand in larger quantities than the fractions with bigger molecules.

Cracking

This is used to obtain more of lower molecular mass alkanes which are more easily vaporised and are more useful fuels. Cracking has two useful results, firstly, shorter chains are produced, and secondly, some of the products are alkenes. Alkenes, (being more reactive than alkanes), are useful as **chemical feedstock** (chemicals that are used as the basis for producing other chemicals), for conversion to other compounds. Different cracking processes can be used. **Steam cracking** involves mixing naphtha or gas oil with steam and passing through a furnace at 1100 K. **Catalytic cracking** takes place at a lower temperature (800 K) using a surface catalyst consisting of silicon dioxide and aluminium oxide:

$$\underset{\text{large molecules}}{\text{Alkanes with}} \xrightarrow{Al_2O_3 / SiO_2} \underset{\text{smaller molecules}}{\text{alkane with}} + \text{Alkene} + \text{Hydrogen}$$

Example:

$$\underset{\text{Propane}}{2\,CH_3CH_2CH_{3(g)}} \longrightarrow \underset{\text{Methane}}{CH_{4(g)}} + \underset{\text{Propene}}{CH_3CH=CH_{2(g)}} + \underset{\text{Ethene}}{CH_2=CH_{2(g)}} + H_{2(g)}$$

Alkylation

Alkylation is used to make branched-chain alkanes, since these have higher **octane numbers** than straight-chain compounds.

Some hydrocarbons in an automobile engine, under high temperature and pressure, may ignite too quickly. This disrupts the normal cycle of compression and expansion in the engine cylinder, and causes the phenomenon of "knocking." This can be heard as a high pitched noise when the engine has to work hard, as in going up a hill slowly in high gear. This knocking property of a motor fuel is indicated by its octane number. Heptane, C_7H_{16}, knocks badly and arbitrarily is assigned an octane number of 0, however isooctane, correctly named: 2,2,4-trimethylpentane is assigned a value of 100. The octane number of a fuel measures its resistance to knocking. The octane number of a fuel is found by comparing its performance with a mixture of heptane and 2,2,4-trimethylpentane. Straight chain alkanes have lower octane numbers than do branched alkanes, and aromatics have even higher numbers.

The addition of tetraethyl lead, $Pb(C_2H_5)_4$, TEL, reduces knocking. However it also releases lead compounds into the air in the exhaust gases, and concern over the increasing levels of these toxic compounds has lead to a phasing out of TEL. Most vehicles now use unleaded petrol.

Now higher octane numbers are obtained by adding extra amounts of high octane hydrocarbons, especially branched-chain alkanes and arenes. In alkylation, straight- chain alkanes together with alkenes, in the presence of a catalyst are converted into branched-chain alkanes:

$$\text{tertiary alkane} + \text{alkene} \xrightarrow[H_2SO_4 \text{ as catalyst}]{20\ ^{O}C \text{ / conc.}} \text{Branched-chain alkane}$$

Reforming

Reforming converts straight-chain alkanes into aromatic compounds, e.g. benzene, since a large number of important chemicals are derived from benzene, and aromatic compounds are highly efficient fuels. Because the process reforms a new hydrocarbon from an old one .: it is referred to as reforming and the product is known as reformate. If a platinum catalyst is used, the process is called **platforming.**

$$C_6H_{14(l)} \xrightarrow[Al_2O_3 \text{ catalyst ((or Pt/10 atm)}]{\text{Vapour at } 500\ ^{O}C/\ 40 \text{ atm}} C_6H_{6(l)} + 4\ H_{2(g)}$$

Note: Aromatic hydrocarbons are carcinogenic and are thus not added to fuels.

Assignment

1.(a) The major processes used in the refining of crude petroleum are fractional distillation and cracking. Briefly state the principles of each process and explain why each process is necessary.

(b) Some of the compounds in crude oil contain sulphur. Give two reasons why sulphur compounds are removed from petrol during its manufacture.

2. Heptane and octane are liquids at room temperature with boiling points of 98 ^{O}C and 126 ^{O}C respectively.

a) (i) what type of intermolecular forces of attraction are present in such liquids?

ii) by what process would a mixture containing a mole fraction of 0.5 heptane be separated into pure heptane and pure octane?

b) Liquid alkanes such as heptane and octane occur in petrol used as fuel to drive cars.

i) Give two reasons why liquid fuels are generally preferred to gaseous ones.

ii) The combustion of octane in car engines is often incomplete. Write an equation for the combustion of octane to form carbon monoxide and water only.

iii) The combustion characteristics of fuels for internal combustion engines in cars can be considerably improved by adding branched chain alkanes, cycloalkanes, aromatic hydrocarbons, or tetraethyl lead. Two of these are now considered to be hazaradous to health. Select these two and identify the health hazard with which each is associated.

iii) Describe the function of a catalytic converter in a car.