STUDY PACK : 4.C

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ORGANIC CHEMISTRY

ALKANES

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1. Why are Alkanes known as 'saturated hydrocarbons'?

Because they contain only C-C single bonds.

2. Write down the general formula of Alkanes and cycloalkanes & define what 'n' means?

3. Explain what a '**Homologous series**' is?

A homologous series is a series of organic compounds which contains the same general formula & the same functional group and each adjacent molecules in the series will differ each other with a $-CH_2$ group.

4. Comment on the chemical properties of a set of molecules, which show homology

They all exhibit similar chemical properties due to the presence of the same functional group.

5. Comment how physical properties of a homologous series differ as $-CH_2-$ groups increase.

As the no. of C atoms increases, the number of electrons in the molecule increase which accounts for increase in the strength of the intermolecular forces down the homologous series. Thus the melting & boiling point of alkanes increases as the number of carbon atoms increase.

6. Classify alkanes as liquids, solids & gases with respect to their number of carbon atoms

7. Explain why, as the number of carbon atoms increase, their physical state changes?

As the relative molecular mass increases with increased number of C atoms, the intermolecular forces become stronger as a result their physical state will change from gases, liquids to waxy solids.

8. Explain why, with branching of alkanes, the boiling & melting points decrease than in straight chain alkanes. Hence write the isomers of C_5H_{12} in increasing order of their boiling points.

Branched isomers contains/exhibit lower boiling points than straight chain isomers as the intermolecular forces weakening with branching due to less surface area.

9. State the other physical properties of alkanes

They are immiscible in water (they do not dissolve in water) because they are neither ionic nor can they form intermolecular attractions with water.

10. Comment on the Chemical properties of alkanes.

Alkanes are relatively inert (they do not react with acids or alkali)

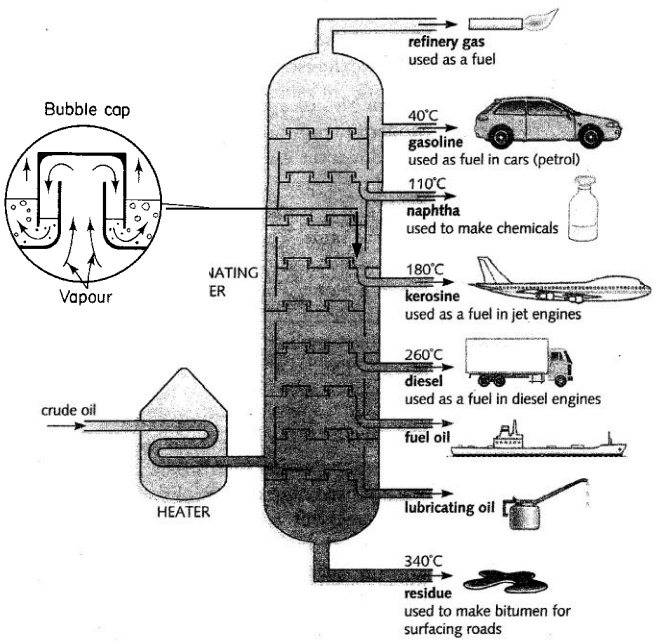
11. State the uses of alkanes in our lives & the sources from, which they are obtained

Alkanes are useful as hydrocarbon fuels; petrol, diesel, kerosene ect. They are obtained by the fractional distillation of crude oil and cracking of hydrocarbons.

12. Describe briefly how crude oil is separated in to useful fractions by **fractional distillation** & name the fractions in their order of respective boiling points

Crude oil is a complex mixture of hydrocarbons which itself is not very useful. In order to convert crude oil to in to useful products it has to be fractionally distilled. Fractional distillation is based on the boiling points of each fraction.

In the refinery process, crude oil is heated to a temperature of 350-400^{0}C & pumped in at the base of the fractional distillation tower (fractionating column). The fractional distillation column contains series of horizontal trays with bubble caps. As it boils the vapour passes up the tower through a series of bubble caps & condenses as it rises further up the column at different temperatures. The <u>smaller</u>, lighter hydrocarbon with lower boiling point distills off first at the top & the <u>long chain</u>, heavier hydrocarbons with higher boiling point distills off last.



Different terms are used in UK & US

UK	US
Crude oil	petroleum
Petrol	gasoline
Paraffin	kerosene

13. Explain the importance of cracking & describe how long-chain hydrocarbons are cracked to give more short-chain hydrocarbons.

Cracking is the braking of C-C bonds in long chain hydrocarbon to obtain more useful smaller hydrocarbons. Short chain hydrocarbons like petrol has a demand greater than the supply due to ever increasing numbers of motor vehicles. The demand exceeds that which can be obtained solely by fractional distillation. Also the distillation tower produces more long chain fraction & less short chain hydrocarbons therefore in cracking larger molecules more valuable smaller fractions can be obtained.

Cracking takes place in a huge reactor where particles of powdered silica & alumina are mixed with the larger hydrocarbon at the temperature around 600^0C-$700\ ^0C$ the cracked vapours containing smaller molecules are separated by distillation.

$$C_{10}H_{22} \xrightarrow[SiO_2/Al_2O_3]{} C_8H_{18} + C_2H_4$$

(alkane) (alkene)

All cracking reactions produce alkane with a shorter chain than the original & the alkene (ethene, propene/butene)

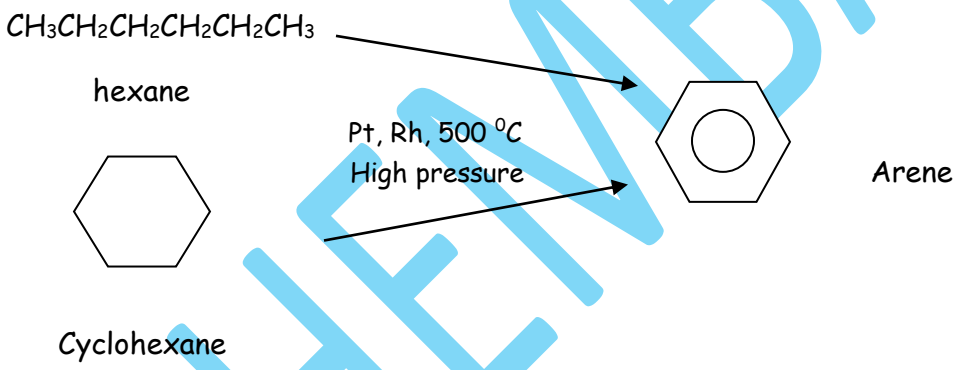
14. Describe the reformation of crude oil.

Reformation is the modification of the structure by converting a straight chain hydrocarbons (aliphatic hydrocarbons) & cyclic alkanes (alicyclic hydrocarbons) into branched chains or closed chain aromatic hydrocarbons / arenes (cyclic hydrocarbons with delocalized electrons) Hydrogen gas is produced as a bi product.

Reforming is generally done on the naptha fraction (fraction below gasoline) to produce more gasoline. This is a process designed to increase the volume of gasoline that can be produced from a barrel of crude oil. When the molecule is branched or cyclic there can be more molecules closely arranged in a given volume thus increasing the efficiency of the fuel by giving out more energy upon combustion.

Hydrocarbons in the naphtha stream have roughly the same number of carbon atoms as those in gasoline, but their structure is generally more complex. Reforming rearranges naphtha hydrocarbons into gasoline molecules.

Reformation is done by "Pt" and "Rh" supported on an inert material such as aluminium oxide at temperature of 500 ^0C.



15. Discuss the potential damage to the environment, which may cause by the burning of hydrocarbons into the atmosphere by combustion engines.

Most of air pollution is a result burning of hydrocarbons fuels. Below substances account for more than 90% of air pollution.

1. <u>Oxides of carbon:</u> (CO, CO_2)

CO is very poisonous as it reacts with haemoglobin to form the bright red compound carboxy haemoglobin. This presents haemoglobin from charring O_2 to the various organs. Which leads to dizziness & headaches prolonged exposure may result in death.

Higher levels of CO_2 cause increased greenhouse effect. This results in global warming. The effects of global warming are many, melting of polar ice caps due to increased temperature which will results in increase in sea levels, hence a threaten to low-lying lands. Global warming also results in climate change.

2. Oxide of nitrogen: (NO,NO_2)

Many health problems such as permanent lung damage, severe eye irritation & acid rain.

3. Oxide of sulfur (SO_2): acid rain, Many respiratory diseases.

4. 'Pb' Particles: cause brain damage.

5. Unburnt hydrocarbons : Carcinogenic (Cancer causive)

16. Discuss the possible reasons for developing alternative fuels & suggest some examples for such sources.

As the use of hydrocarbon fuels increases day by day, the level of pollutant released to be air also increase. Also the demand for petroleum fuels increases day by day as it is a finite, non-renewable source. As the sustainability of crude oil is limited & their effect of combustion is harmful it is important to develop alternate fuels.

Alternate energy source such as solar power can be used to power motor vehicles.

Hydrogen gas is used as a fuel in rockets. The reaction of hydrogen with oxygen gas is highly exothermic reaction resulting a much more energy release than hydrocarbon fuel. The only by product formed is water.

H_2 derived from H_2O also used as a fuel in fuel cells in cars. Here H_2 reacts with O_2 to generate electricity. Electricity from this cell then powers an electric motor.

17. Explain what is meant by 'carbon neutrality' and 'carbon footprint'.

- **Carbon-footprint:**

Carbon footprint measures the total amount of greenhouse gases produced by a process. Carbon footprint measures the total mass of CO_2 produced by a fuel from its production to its combustion.

A carbon footprint of a fossil fuel is the amount of 'C' released on combustion plus the CO_2 released due to its transportation, refining & distribution.

As for the carbon footprint of a bio fuel then it is the amount of CO_2 absorbed during the growth should be subtracted from the total mass of CO_2 produced on combustion. This means that although a biofuel releases CO_2 the carbon footprint is much less than that of a fossil fuel.

No fuel has a zero-carbon footprint. Even H_2 has a considerable footprint as it is made from methane.

- **Carbon neutrality:**

A process is said to be carbon neutral if the CO_2 or other greenhouse gases released by the substance is balanced by actions which remove the equivalent amount of CO_2 from the atmosphere by that substance.

No fuel is carbon neutral. The term carbon neutral is often misused to denote no net CO_2 produced at the point of use. Thus biofuels & H_2 are sometimes described as carbon neutral, By ignoring all the CO_2 released before they are used. Similarly energy produced by a wind turbine also not carbon neutral as the manufacture involves high energy process.

18. Describe & apply the concept of carbon neutrality to different fuels, such as petrol, bio-ethanol, bio-diesel & hydrogen.

Petrol as any other fossil fuel produce CO_2 upon combustion therefore it is not carbon neutral.
Biofuels are made from renewable organic materials such as bioethanol, biodiesel have a carbon footprint because fertilizers & fuel are used when the plants are grown.

Bio ethanol is manufactured by the fermentation of carbohydrates. In recent years there has been a rapid expansion in the production of bioethanol as a fuel, particularly in countries like Brazil & USA. The apparent advantage of bioethanol is that it is carbon neutral. Same quantity of CO_2 is given out as the amount of CO_2 absorbed during photosynthesis.

Biodiesel is made by mixing vegetable oil with methanol & an acid catalyst. This produces the methyl ester of the unsaturated acids. A typical methyl ester in biodiesel is $C_{17}H_{31}COOCH_3$. Biodiesel have a similar combustion properties to diesel produced from petroleum. As fuel is used during the growth of crops to obtain vegetable oil bio diesel still leaves a carbon footprint. Biodiesel made from soya beans reduce the emissions by 41% compared with diesel fuel.

Hydrogen gas when combined with oxygen in fuel cells produce electricity to power the motor vehicles. As H_2 is not found naturally it is currently manufactured by methane reacting with steam in a catalytic process & produce CO & H_2 gas. As hydrogen gas is produced by natural gas (methane) & it produces CO it has a significant carbon footprint. If renewable energy is used in the manufacture of H_2 then will be carbon neutral.

Reactions of Alkanes

1. What type of Organic Reaction Alkanes usually undergo?

Combustion and substitution.

Combustion

Like all Organic Compounds Alkanes burn in air or Oxygen when ignited. The products of combustion depend on the supply of Oxygen.

(a). Complete combustion : In **plentiful** supply of air or excess Oxygen, the combustion products are **H_2O** & **CO_2**

$$CH_{4(g)} + 2O_{2(g)} \xrightarrow{\triangle} CO_{2(g)} + 2H_2O_{(l)}$$

(b). Incomplete combustion : In a **limited** supply of Oxygen, carbon monoxide or carbon or even a mixture of both could be formed

$$CH_{4(g)} + O_{2(g)} \xrightarrow{\triangle} 2H_2O_{(l)} + C_{(s)}$$

$$CH_{4(g)} + 3/2O_{2(g)} \xrightarrow{\triangle} CO_{(g)} + 2H_2O_{(l)}$$

2. What can you say about the energy given out in the complete & incomplete combustion are they the same?

   Complete combustion gives out more energy than incomplete combustion.

3. What can you say about the energy given out as the alkane become higher in carbon atoms?

   Hydrocarbons with higher no.of 'C' gives out more energy than the smaller hydrocarbons.

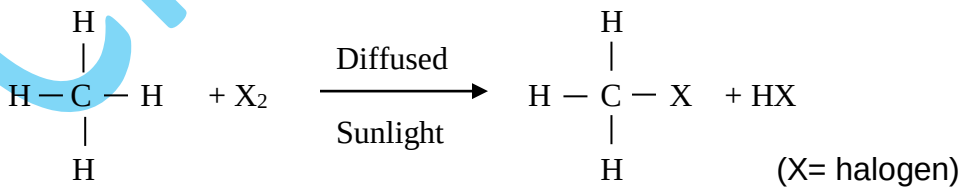
4. Write a balanced common general equation to represent the combustion of Alkanes

Halogenation of Alkanes.

Halogenation is the introduction of a halogen atom to an alkane molecule. This is a **substitution reaction**, which means that a halogen atom replaces one or more of hydrogen atoms in the alkane

'F_2', 'Cl_2', 'Br_2' react with alkanes in presence of **diffused** (not direct) **sunlight**, which acts as a photo catalyst & it, is the **ultra violet** (U.V) light.

As a result hydrogen halide is produced with the **halo alkane** as the major product. In order to initiate the reaction energy is needed to break the halogen bond (ie: Cl-Cl bond). This energy is obtained by the diffused sunlight



- Direct Sun light is explosive!

With excess halogen or if left exposed to the light, more than one hydrogen or sometimes all the 'H' could be substituted by halogens stepwise.

5. Show how tetra chloro methane is produced stepwise from methane

Reaction Mechanisms

1. What are the information we can gather from reaction mechanisms?

Reaction mechanisms provide information on:

i. The bonds which are broken during the reaction
ii. The bonds which are made during the reaction
iii. How the bonds are broken
iv. The order of breaking and making of bonds

2. Describe how the movement of electrons are shown in heterolytic & hemolytic reaction mechanisms

- Heterolytic reaction mechanism:-

A curved arrow is used to indicate the movement of a pair of electrons. If an electron pair is moved, then the arrow should start at the lone pair, or if a bond is broken, then the arrow should start at the middle of the bond.

Likewise, if a bond is formed, the point of the arrow should end between the bonded atoms. If the bond is broken, the arrow should end at the atom which the lone pair is donated.

- Homolytic reaction mechanism:-

  A half pointed, curved arrow (like a fish hook) is used to represent the movement of a single electron. The arrow should start at the middle of the bond and be pointed towards the atoms.

Homolytic free radical substitution of alkanes with chlorine

3. Describe the mechanism of the reaction of methane with chlorine gas in diffused sunlight.

The mechanism of homolytic free radical substitution of methane has three steps. (Free radicals are species with an unpaired electron, represented by a single dot)

I. Initiation step: Free radicals are generated by homolytic fission, the energy is given by the UV light.

II. Propagation step: The highly reactive radical produced in the initiation step abstracts an 'H' atom from methane, forming HCl and methyl radical. The reaction continues as the methyl radical reacts with 'Cl' to form Cl radical. This repeats over and over.

III. Termination step: The radicals combine to form a molecule, this brings the reaction to an end.

Initiation:

Propagation:

Possible termination steps:

4. Write the mechanism of the formation of tetrachloro methane stepwise from methane.