

Chapter 11 — Hydrocarbons

2. Questions for Short Answers

1. Differentiate between an organic and an inorganic compound.

Ans: Organic compounds all contain carbon as an essential element, and apart from carbon most of them contain hydrogen and oxygen as well; organic chemistry is therefore defined as the chemistry of carbon compounds. They are covalent in nature, so their melting and boiling points are generally low and they are usually not soluble in water. Their molecules are usually large and complex and they exist in enormous numbers — several million are known. Inorganic compounds are obtained from minerals and are usually ionic, so they have high melting and boiling points and are generally soluble in water; their molecules are small and simple and their number is far smaller. Note that the ionic compounds of carbon itself — carbonates, cyanides, carbides and cyanates — and the oxides of carbon are classified as inorganic compounds.

2. Why are organic compounds found in large numbers?

Ans: The element carbon is present at the centre of the periodic table, so it is generally not possible for it to gain or lose electrons to form ionic bonds; instead it forms four covalent bonds. Because of its small size these covalent bonds are short and strong, and carbon forms strong and stable bonds not only with hydrogen, oxygen and nitrogen but also with itself. This self-linking property of carbon is called catenation. Due to catenation carbon forms long chains, which may be straight or branched, and it also forms rings of different sizes very easily. Since each different arrangement of the same atoms is a different compound, the number of compounds formed by carbon is far more than the total number of compounds formed by all the rest of the elements put together.

3. Name the products which are obtained when natural gas is oxidized under controlled conditions.

Ans: Natural gas is mainly methane, the simplest alkane. It is used mostly as a fuel, but when it is oxidized under controlled conditions instead of being allowed to burn completely, it gives a number of useful products. These are hydrogen gas, carbon black, carbon disulphide, chloroform and hydrocyanic acid. If methane is allowed to burn completely in excess oxygen, the products are simply carbon dioxide and water with the evolution of a large amount of heat: $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g}) + \text{heat}$.

4. How is the naphtha fraction decomposed to give lower hydrocarbons?

Ans: It is decomposed by the process called cracking. Cracking is the process in which hydrocarbons of higher molecular masses, which are lesser in demand, are broken up into smaller hydrocarbons which are more in demand; this is done by heating the hydrocarbons at high temperature in the presence of a catalyst. Fractional distillation of petroleum gives naphtha, which is a mixture of liquid hydrocarbons. This naphtha is then heated at around 500 °C in the presence of a catalyst called zeolite, and it gives alkanes and alkenes containing five to ten carbon atoms.

5. Write down the molecular formula, structural formula and the condensed structural formula for iso-butane.

Ans: Iso-butane is the branched isomer of butane, so its molecular formula is C_4H_{10} . Its condensed structural formula is $\text{CH}_3\text{—CH}(\text{CH}_3)\text{—CH}_3$, and its IUPAC name is 2-methylpropane. Its structural formula is drawn as a chain of three carbon atoms with a methyl branch on the middle carbon, every remaining valency of carbon being filled with hydrogen and every bond shown by a short line. (Note: in the chapter the compound $\text{CH}_3\text{—CH}(\text{CH}_3)\text{—CH}_2\text{—CH}_3$ is labelled '2-Methylbutane or iso-Butane'. That compound has five carbon atoms, C_5H_{12} , so it is really iso-pentane; iso-butane is the four-carbon compound given above.)

6. How are organic compounds useful for us?

Ans: Organic compounds are useful to us in almost every part of daily life. Most of the fuels which we use every day — natural gas, LPG, CNG, petrol, diesel and kerosene oil — are simple hydrocarbons. These hydrocarbons also serve as a feedstock to prepare more complex and useful compounds like plastics, medicines, synthetic fibres, paints and varnishes. Organic compounds also include the biomolecules on which life itself depends: proteins, enzymes, carbohydrates, lipids, vitamins and nucleic acids. Methane in particular is used to make hydrogen gas, carbon black, carbon disulphide, chloroform and hydrocyanic acid.

7. Write down the names of five such organic compounds which exist naturally.

Ans: Five organic compounds which exist naturally are: proteins, enzymes, carbohydrates, lipids and nucleic acids. Vitamins are another example. All of these are biomolecules, that is organic molecules which occur in living things; they are usually large in size and very complex in nature. Natural gas (methane) and petroleum are also naturally occurring organic substances.

8. Give the IUPAC name to the following compound: $\text{CH}_3 - \text{CH}(\text{CH}_3) - \text{CH}_2 - \text{CH}_3$

Ans: First the longest continuous chain is identified: it contains four carbon atoms, so the root is But-. The compound belongs to the alkanes, so the suffix -ane is added, giving butane. The only branch is a methyl group, which is added as the prefix methyl-. To specify where the branch occurs the longest chain is numbered starting from the end closest to the branch, which puts the methyl group on carbon number 2. The IUPAC name of the compound is therefore 2-methylbutane, which is also called iso-butane in the chapter. If butane has no branch at all it is called normal or n-butane.

9. How do the melting and boiling points of alkanes change when we move from lower members to higher members?

Ans: Both the melting points and the boiling points increase steadily as we move from the lower members to the higher members of the alkane series. Alkanes are non-polar covalent molecules and are held together only by weak intermolecular forces of attraction. As the number of carbon atoms increases, the molecule becomes bigger and heavier and the surface over which the molecules touch each other becomes larger, so these intermolecular forces become stronger. More energy is therefore needed to separate the molecules. This is why the first members — methane, ethane, propane and butane — are gases at room temperature, while the middle members are liquids and the higher members are waxy solids.

3. Constructed Response Questions

1. Why do alkanes show little reactivity towards the other reagents?

Ans: Alkanes are sometimes referred to as paraffins, which means 'little affinity', and this term describes their behaviour exactly. Their unreactivity is explained on the basis of the non-polarity of the bonds present in them. The electronegativity values of carbon (2.6) and hydrogen (2.1) do not differ appreciably, so the bonding electrons in the C—H bonds, and of course in the C—C bonds, are almost equally shared. This makes alkane molecules almost non-polar, and they carry no charged centre and no double bond. In view of this, reagents like acids, bases and oxidizing agents find no reaction site in an alkane molecule to which they could be attached, so alkanes remain chemically inert towards most laboratory reagents. They do, however, react with chlorine and with oxygen under suitable conditions.

2. Why does a mixture of natural gas and air explode?

Ans: Natural gas is mainly methane, and the combustion of methane is a strongly exothermic reaction: $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g}) + \text{heat}$. When natural gas leaks, it mixes thoroughly with the air of the room, so that the methane molecules and the oxygen molecules are already in intimate contact throughout the whole volume. Once this mixture is ignited by a spark or a flame, the reaction does not spread slowly from a surface as it does at a burner; it takes place almost instantly throughout the mixture. A very large amount of heat is released in a moment and the gases produced expand suddenly and enormously, and this sudden expansion is the explosion. This is the main cause of explosions in homes where gas leakage occurs.

3. How do you compare the melting and boiling points of inorganic and organic compounds?

Ans: Organic compounds are covalent in nature. They exist as separate molecules and the forces of attraction between one molecule and another are weak, so very little energy is needed to separate them; their melting points and boiling points are therefore generally low. Many of them are gases or low boiling liquids at room temperature — for example methane, ethane, propane and butane are all gases. Most inorganic compounds, on the other hand, are ionic. Their ions are held in a crystal lattice by strong electrostatic forces and a great deal of energy is needed to break this lattice, so their melting and boiling points are generally very high. Inorganic compounds with giant covalent structures, such as diamond and silica, also have very high melting points.

4. Reactions of alkanes with chlorine take place in the presence of sunlight. What is the role of sunlight in the reaction?

Ans: The reaction of an alkane with chlorine is a substitution reaction, in which a hydrogen atom of the alkane is replaced by a chlorine atom. Because these substitution reactions are carried out in the presence of UV light, they are called photochemical substitution reactions, and this is shown in the equation by writing $h\nu$ over the arrow: $\text{CH}_4 + \text{Cl}_2 \xrightarrow{h\nu} \text{CH}_3\text{Cl} + \text{HCl}$. The role of the sunlight is to supply the energy needed to start the reaction. The ultraviolet light is absorbed by the chlorine molecule and breaks the Cl—Cl bond, producing the reactive chlorine species which then attacks the alkane. Without this energy the alkane, being almost non-polar and unreactive, would not react with chlorine at all; in the dark the mixture can be kept without any reaction taking place.

5. How do you compare the boiling point of n-butane with that of iso-butane?

Ans: Both n-butane and iso-butane have the same molecular formula, so they have the same molecular mass, but n-butane has the higher boiling point. n-Butane, $\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_3$, is a straight unbranched chain, so its molecules are long and can come close to one another along their whole length; the surface of contact between neighbouring molecules is large and the intermolecular forces of attraction are therefore comparatively strong. Iso-butane is branched, which makes the molecule more compact and roughly spherical, so the molecules touch each other over a much smaller surface and the

intermolecular forces are weaker. Since less energy is needed to separate the molecules of the branched isomer, iso-butane boils at a lower temperature than n-butane.

6. Why are organic compounds not generally soluble in water?

Ans: Organic compounds are covalent in nature and most of them, especially the hydrocarbons, exist as non-polar molecules — in an alkane the electronegativity values of carbon and hydrogen differ so little that the bonding electrons are almost equally shared. Water, on the other hand, is a highly polar solvent. It dissolves a substance only when its molecules can develop strong attractions with the particles of that substance and pull them apart, as it does with the ions of an ionic compound. Water molecules cannot develop such strong attractions with non-polar organic molecules, so these molecules are not separated from one another and the compound remains undissolved. Organic compounds are, however, usually soluble in non-polar organic solvents such as ether, benzene and acetone.

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