FACTFILE:
GCE CHEMISTRY

2.3 ALKANES

Rewarding Learning

Alkanes

Students should be able to:

2.3.1 recall that alkanes are described as saturated hydrocarbons;

2.3.2 explain, in terms of van der Waals' forces, the variation in boiling points between alkanes with different numbers of carbon atoms;

2.3.3 explain, in terms of van der Waals' forces, the variation in boiling points between structural isomers of an alkane with the same molecular formula;

2.3.4 describe the complete and incomplete combustion of alkanes in air and link the appearance of the flame to the amount of carbon present;

2.3.5 recall that pollutants such as carbon monoxide, carbon, oxides of nitrogen and sulfur and unburned hydrocarbons are produced during the combustion of alkane fuels;

2.3.6 recall that the percentage of carbon dioxide in the atmosphere has risen from 0.03% to 0.04% because of combustion of organic compounds and is believed to have caused global warming;

2.3.7 explain how a catalytic converter reduces the environmental impact of burning alkane fuels;

2.3.8 describe the substitution reactions of alkanes by chlorine and by bromine;

2.3.9 define the terms radical, homolytic and heterolytic fission; and

2.3.10 outline the radical substitution mechanism involved in the photochemical halogenation of alkanes in terms of initiation, propagation and termination steps.

Alkanes

Alkanes are the simplest type of organic compound. They are ***saturated hydrocarbons*** and contain no c=c or c≡c bond. Organic compounds are named according to the IUPAC system of nomenclature. The name is composed of two parts; the first part (prefix) indicates the number of carbon atoms in the longest unbranched carbon chain. The last part (suffix) indicates which functional group is present. With the alkanes, the last part of the name ends in ***–ane***. The names of the first six unbranched alkanes are shown below:

Prefix	C atoms	Formula	Alkane
meth-	1	CH_4	methane
eth-	2	C_2H_6	ethane
prop-	3	C_3H_8	propane
but-	4	C_4H_{10}	butane
pent-	5	C_5H_{12}	pentane
hex-	6	C_6H_{14}	hexane

As C-H bonds are considered to be non-polar, the only forces acting between alkane molecules are van der Waals' forces. These forces increase in strength as the RMM of the molecule increases as there are more electrons present. Consequently, the boiling points of alkanes increase with increasing RMM. However, with increasing branching in isomeric alkanes, the boiling points decrease at the molecules cannot get as close and so the van der Waals' forces are not as strong. For example, the boiling point of 2-methylpropane (-11.7°C) is lower than butane (-1°C) despite both molecules having the same RMM.

Reactivity of Alkanes

1. Combustion

Alkanes are generally unreactive although they do undergo complete combustion, producing carbon dioxide and water. They are characterised by having large enthalpies of combustion and are used extensively as fuels.

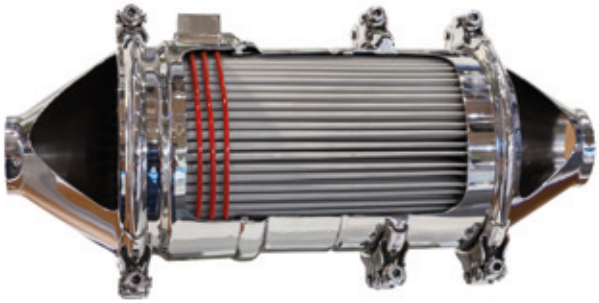
$$CH_{4(g)} + 2O_{2(g)} + CO_{2(g)} + 2H_2O_{(g)} \quad \Delta_cH = -890 \text{ kJ mol}^{-1}$$

The flame is orange and becomes a more sooty as the carbon content increases. Incomplete combustion leads to the formation of carbon monoxide, an odourless, colourless and highly poisonous gas. A sooty flame shows incomplete combustion.

When alkane fuels combust the following pollutant occur:

- Carbon dioxide
- Carbon monoxide
- Carbon
- Sulfur dioxide
- Oxides of nitrogen
- Unburned hydrocarbons

These pollutants are responsible for a number of environmental problems, including acid rain, global warming and smog. The percentage of CO_2 in the atmosphere has risen from 0.03% to 0.04% due to increased combustion of organic compounds and this is believed to have caused globel warming. Catalytic converters in an exhaust system reduce the environmental impact of these pollutants by converting them to less harmful products.



2. Substitution Reactions

A substitution reaction is one where one atom or group is replaced with a different atom or group. Alkanes can react with halogens, such as chlorine to produce halogenoalkanes,in a substitution reaction.

$$CH_4 + Cl_2 \rightarrow \underset{\text{chloromethane}}{CH_3Cl} + HCl$$

In the initiation step, UV light is required to produce radicals. Aradical is a particle with an unpaired electron. The radicals are formed via homolytic fission. Homolytic fission is bond breaking in which one of the shared electrons goes to each atom.

The highly reactive radicals react with the alkane molecules in a sequence of propagation steps, producing alkyl radicals and more halogen radicals. The reaction is completed when radicals react to form more stable species in a termination step..

intiation: $Cl_2 \xrightarrow{uv} 2Cl\bullet$

propagation: $CH_4 + Cl\bullet \longrightarrow CH_3\bullet + HCl$

$CH_3\bullet + Cl_2 \longrightarrow CH_3Cl + Cl\bullet$

termination: $Cl\bullet + Cl\bullet \longrightarrow Cl_2$

$CH_3\bullet + Cl\bullet \longrightarrow CH_3Cl$

$CH_3\bullet + CH_3\bullet \longrightarrow C_2H_6$

Credits

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Revision Questions

1 Which one of the following is a chain propagation step in the chlorination of methane?

A. $H\bullet + Cl_2 \rightarrow HCl + Cl\bullet$

B. $Cl\bullet + CH_4 \rightarrow CH_3Cl + H\bullet$

C. $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$

D. $CH_3\bullet + HCl \rightarrow CH_3Cl + H\bullet$

2 Three pentanes are possible theoretically and all occur in natural gas and petroleum gas. Their structures, "trivial" names and boiling points are shown below.

structure	trivial	boiling point/°c
$CH_3CH_2CH_2CH_2CH_3$	normal pentane	36
$H_3C-CH(CH_3)-CH_2CH_3$	isopentane	28
$H_3C-C(CH_3)_2-CH_3$	neopentane	9

(a) The three pentanes are regarded as **structural isomers**. Explain this term.

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..... [2]

(d) Deduce the IUPAC names for isopentane and neopentane.

isopentane ..... [1]

neopentane ..... [1]

(e) Explain why the pentanes have different boiling points.

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..... [2]

(f) All three pentanes burn in a limited and in a plentiful supply of air.

(i) Write the equation for the complete combustion of pentane.

..... [2]

(ii) Write an equation for the incomplete combustion of pentane to form carbon monoxide.

..... [2]

3 Which one of the following compounds will produce equal volumes of carbon dioxide and water vapour when burnt completely in oxygen?

A. C_2H_2

B. C_2H_4

C. C_2H_6

D. CH_4

[1]