

PROSPERITY ACADEMY

AS CHEMISTRY 9701

Crash Course

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ALKANES

COMPLETE NOTES



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Alkanes:- Alkanes are saturated hydrocarbons (they contain maximum number of hydrogens possible). Obtained from fractional distillation of crude oil.

General formula:- $C_n H_{2n+2}$

Intermolecular forces:- temporary dipoles \longrightarrow Low m.p and b.p

Polar or non polar:- Non polar \longrightarrow insoluble in water

e.g. methane: CH_4 , ethane: C_2H_6 , propane: C_3H_8 , butane: C_4H_{10} , pentane: C_5H_{12}
 $\xrightarrow{\text{m.p / b.p increases as no. of electrons increase hence temporary dipoles get stronger.}}$

Chemical properties:- Alkanes undergo 3 types of reactions:- (C-C, C-H bond energies are high + as bonds are non polar they don't attract nucleophiles or electrophiles)

1) Combustion:- Hydrocarbons burn in oxygen to produce CO_2 and H_2O

General equation:- $C_x H_y + \left(\frac{x+y}{4}\right) O_2 \longrightarrow x CO_2 + \frac{y}{2} H_2O$

e.g. $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

Environmental Consequences of combustion:-

- releases CO_2 gas which causes green house effect and contributes to global warming
 - CO can be released upon incomplete combustion which binds to haemoglobin making deoxyhaemoglobin which reduces oxygen carrying capability of blood.
 - At the high temperatures of combustion, NO & NO_2 are also made
 - Impurities in fuel can produce SO_2 as well
 - unburnt hydrocarbons can cause irritation and greenhouse effect
- $\xrightarrow{\text{Refer to Nitrogen \& Sulfur chapter to see problems caused by both and notes on catalytic converter.}}$

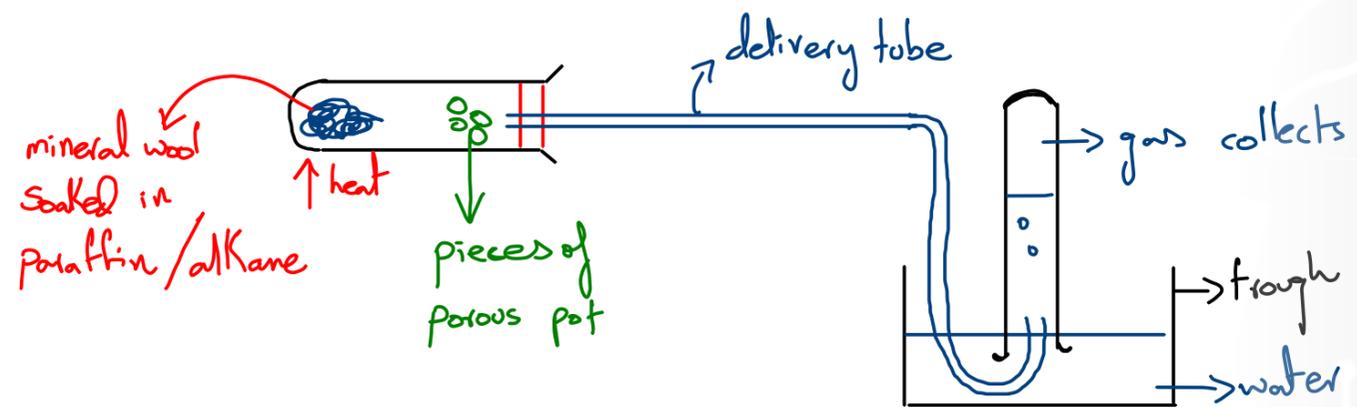
2) Cracking:- Process by which large alkane molecules are broken down into smaller alkanes and alkenes.

- To obtain motor fuel like octane
- To obtain alkenes such as ethene.

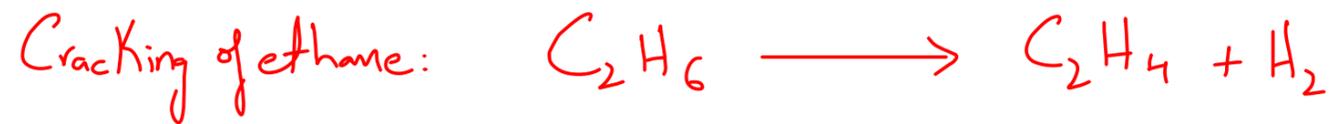
→ Thermal Cracking:- Uses high temperature ($450^{\circ}\text{C} - 700^{\circ}\text{C}$) and pressure of 70 atm
- Gives a high proportion of alkenes



→ Catalytic Cracking:- Uses Al_2O_3 & SiO_2 as catalyst with heating
- Gives high proportion of alkanes



(When dismantling the setup, remove the delivery tube first before stopping the heating, otherwise water will rush back from the delivery tube very fast and explode, this is known as 'suck back')



3) Free radical substitution of halogens:- Alkanes react with chlorine and bromine in presence of UV light.



Mechanism:- Free radical substitution

Free radical:- A species that contains an unpaired electron e.g. Cl^\cdot , Br^\cdot . They are very reactive

Homolytic fission:- The breaking of a covalent bond in such a way that each atom receives 1 electron. Shown by \curvearrowright (Half arrow head)

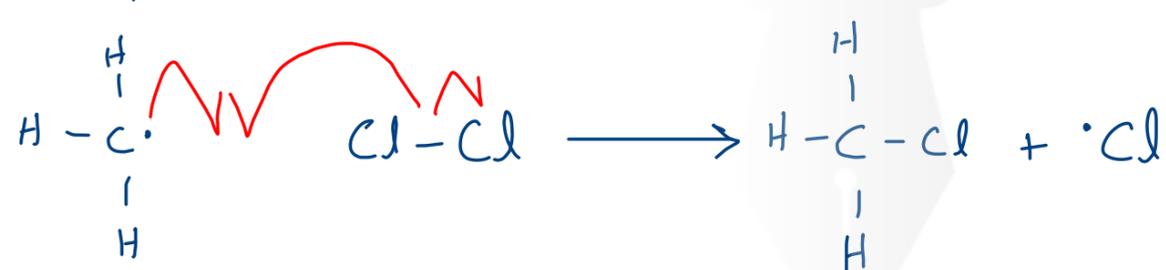
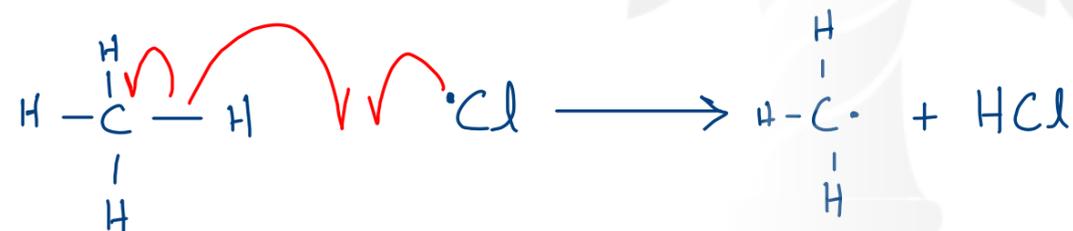
1) Initiation:-

2) Propagation:-

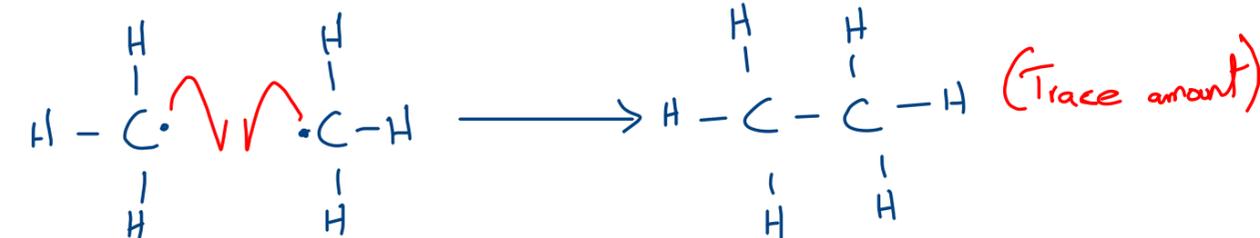
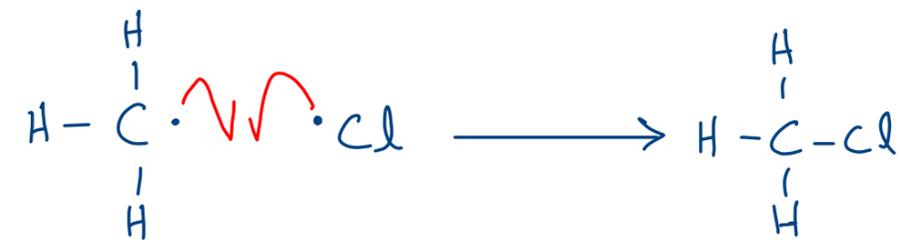
3) Termination:-



Free radicals produced from stable molecule



1 stable and 1 unstable molecule react to produce 1 stable and 1 unstable molecule

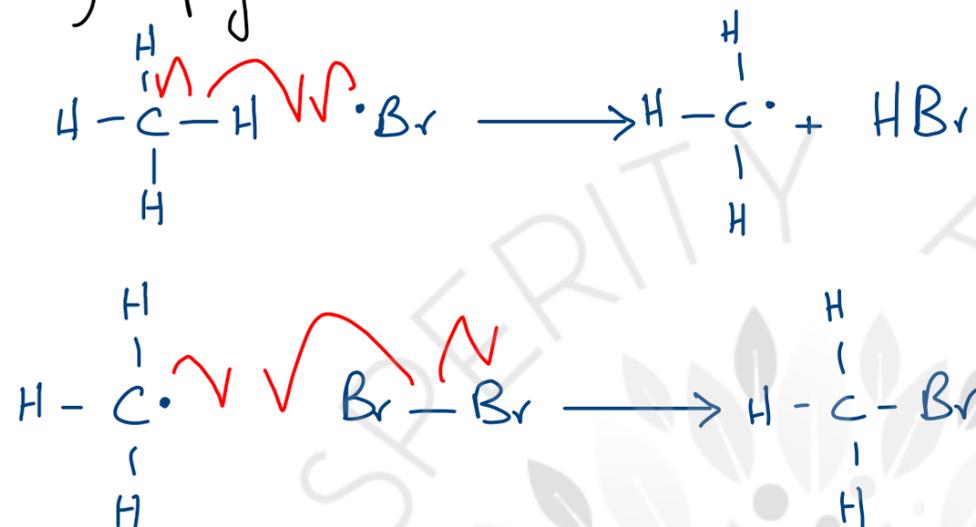


Any 2 unstable molecules react together to form a stable molecule.

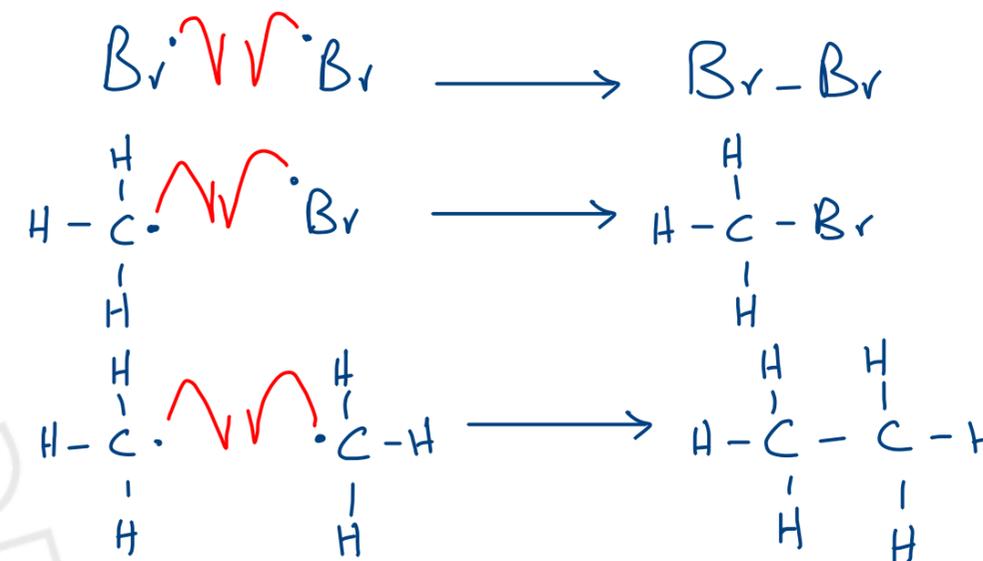
1) Initiation:-



2) Propagation



3) Termination:-



- 3 Chloroethane is used as a starting material for the production of 'time-release capsules' in pharmaceutical products. One way of preparing chloroethane is to react chlorine and ethane in the presence of ultraviolet light.

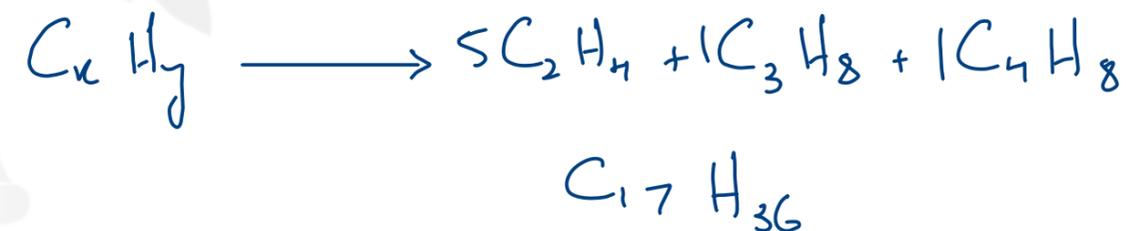
Which statement is correct about the **first** stage of the mechanism of this reaction?

- A The Cl - Cl bond is split homolytically.
 B The Cl - Cl bond is split heterolytically.
 C The C - H bond is split homolytically.
 D The C - H bond is split heterolytically.

- 9 On strong heating a hydrocarbon produces ethene, propane and but-1-ene in the mole ratio 5 : 1 : 1.

What is the molecular formula of the hydrocarbon?

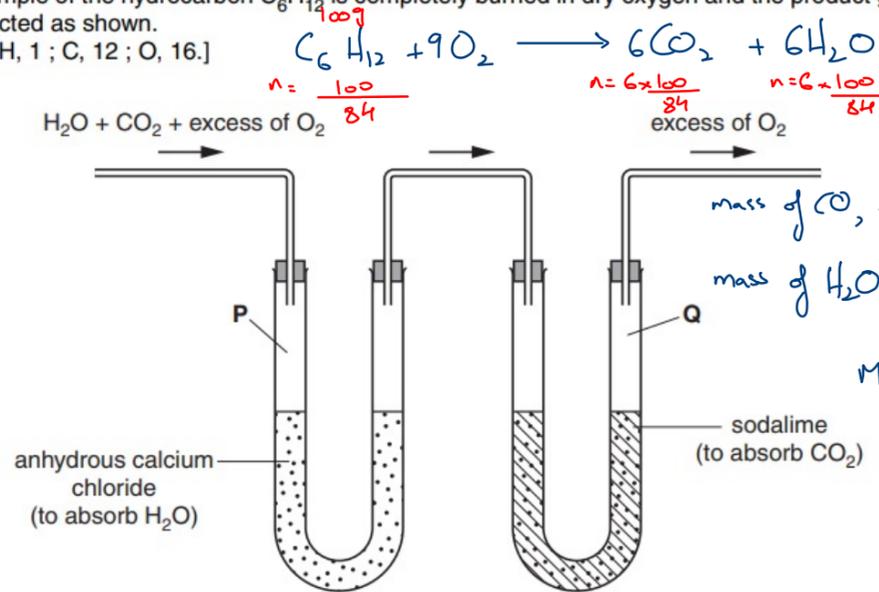
- A $\text{C}_{17}\text{H}_{34}$ B $\text{C}_{17}\text{H}_{36}$ C $\text{C}_{19}\text{H}_{38}$ D $\text{C}_{19}\text{H}_{40}$



- 5 Which pollutant is formed in the internal combustion engine and, if not removed by the catalytic converter, may become involved in the formation of acid rain?

- A C B C_8H_{18} C CO D NO

- 11 A sample of the hydrocarbon C_6H_{12} is completely burned in dry oxygen and the product gases are collected as shown.
[A_r: H, 1; C, 12; O, 16.]



$$\text{mass of } CO_2 = \left(\frac{6 \times 100}{84}\right) \times 44 = 314.28$$

$$\text{mass of } H_2O = \left(\frac{6 \times 100}{84}\right) \times 18 = 128.57$$

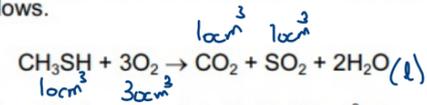
$$M_P / M_Q = 0.409$$

The increases in mass of the collecting vessels **P** and **Q** of the apparatus are M_P and M_Q , respectively.

What is the ratio M_P / M_Q ?

- A 0.41 B 0.82 C 1.2 D 2.4

- 14 The foul smell that skunks spray is due to a number of thiols, one of which is methanethiol, CH_3SH , which burns as follows.



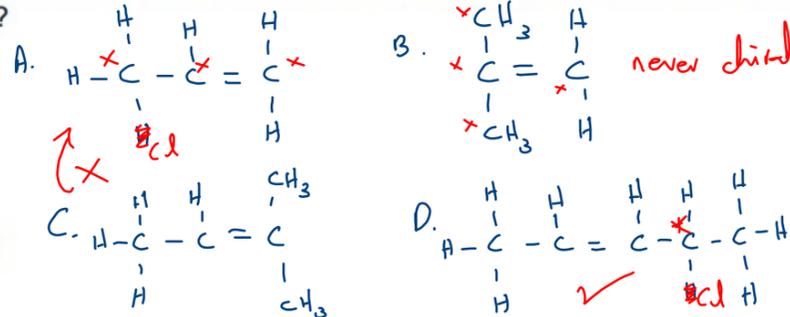
A sample of 10 cm^3 of methanethiol was exploded with 60 cm^3 of oxygen. $\rightarrow 30$ unused

What would be the final volume of the resultant mixture of gases when cooled to room temperature?

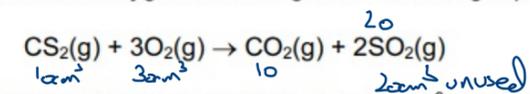
- A 20 cm^3 B 30 cm^3 C 50 cm^3 D 70 cm^3

- 23 Which hydrocarbon can form a monochloro-substitution derivative which shows **both** chirality and *cis-trans* isomerism?

- A $CH_3CH=CH_2$ B $(CH_3)_2C=CH_2$ C $CH_3CH=C(CH_3)_2$ D $CH_3CH=CHCH_2CH_3$



- 27 Carbon disulphide vapour burns in oxygen according to the following equation.



A sample of 10 cm^3 of carbon disulphide was burned in 50 cm^3 of oxygen. After measuring the volume of gas remaining, the product was treated with an excess of aqueous sodium hydroxide and the volume of gas measured again. All measurements were made at the same temperature and pressure, under such conditions that carbon disulphide was gaseous.

What were the measured volumes?

	volume of gas after burning / cm^3	volume of gas after adding NaOH(aq) / cm^3
<input type="radio"/> A	30	0
<input type="radio"/> B	30	20
<input checked="" type="radio"/> C	50	20
<input type="radio"/> D	50	40

$$\begin{matrix} 20 \\ 10 \\ -10 \\ \hline 20 \end{matrix} = \text{total}$$

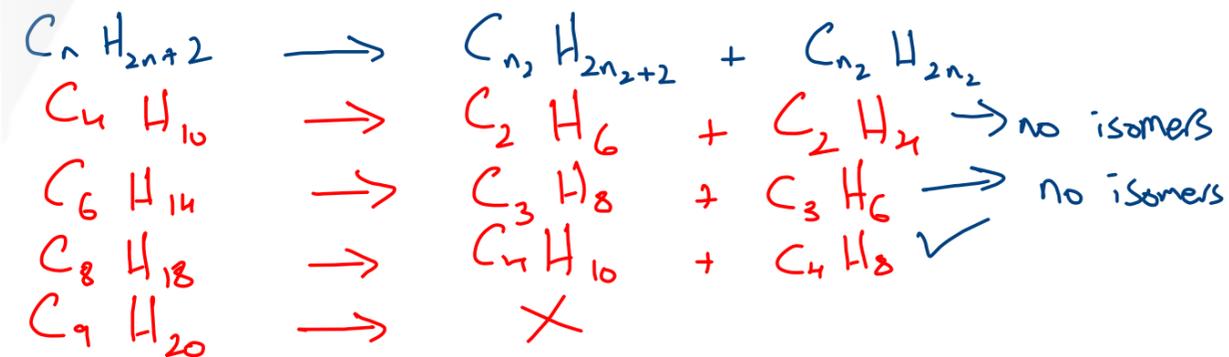
- 30 Which equation represents a valid propagation step in the free radical reaction between ethane and chlorine?

- A $C_2H_6 + Cl^\cdot \rightarrow C_2H_5Cl + H^\cdot$ B $C_2H_5Cl + Cl^\cdot \rightarrow C_2H_4Cl^\cdot + HCl$ C $C_2H_6 + H^\cdot \rightarrow C_2H_5^\cdot + HCl$ D $C_2H_5^\cdot + Cl^\cdot \rightarrow C_2H_5Cl$ termination

- 36 The cracking of a single hydrocarbon molecule, C_nH_{2n+2} , produces two hydrocarbon molecules only. Each hydrocarbon product contains the same number of carbon atoms in one molecule. Each hydrocarbon product has non-cyclic structural isomers.

What is the value of n ?

- A 4 B 6 C 8 D 9



40 Which volume of oxygen measured at room temperature and pressure is needed for complete combustion of 0.1 mol of propan-1-ol?

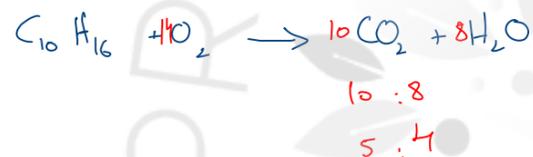
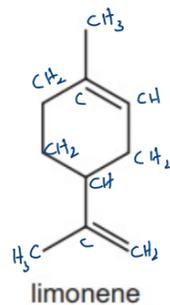
- A 10.8 dm³ B 12.0 dm³ C 21.6 dm³ D 24.0 dm³



$$0.1 \quad : \quad 0.45$$

$$0.45 \times 24 = 10.8 \text{ dm}^3$$

51 The citrus flavour of lemons is due to the compound limonene, present in both the peel and the juice.



What is the mole ratio of carbon dioxide to water produced when limonene is completely burnt in oxygen?

	number of moles carbon dioxide	number of moles water
A	4	3
<input checked="" type="radio"/> B	5	4
C	5	8
D	9	7

3

Crude oil is a naturally occurring flammable liquid which consists of a complex mixture of hydrocarbons. In order to separate the hydrocarbons the crude oil is subjected to fractional distillation.

(a) Explain what is meant by the following terms.

(i) hydrocarbon A compound containing only hydrogen and carbon

(ii) fractional distillation A technique by which compounds with different boiling and melting points are removed from a mixture [2]

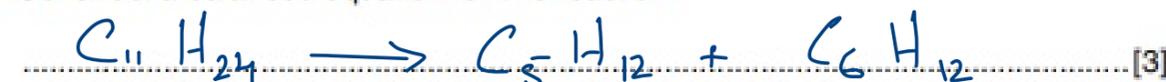
(b) Undecane, $C_{11}H_{24}$, is a long chain hydrocarbon which is present in crude oil. Such long chain hydrocarbons are 'cracked' to produce alkanes and alkenes which have smaller molecules.

(i) Give the conditions for two different processes by which long chain molecules may be cracked.

process 1 Thermal cracking using $450^{\circ}C - 700^{\circ}C$ of temperature at 70 atm of pressure

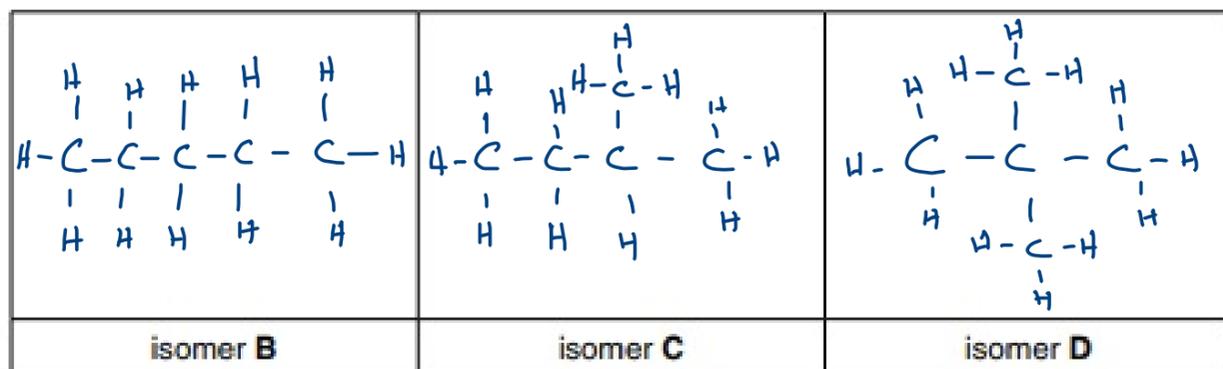
process 2 Using Al_2O_3 & SiO_2 as catalyst and heating

(ii) Undecane, $C_{11}H_{24}$, can be cracked to form pentane, C_5H_{12} , and an alkene. Construct a balanced equation for this reaction.



Pentane, C_5H_{12} , exhibits structural isomerism.

(c) (i) Draw the three structural isomers of pentane.



(ii) The three isomers of pentane have different boiling points.

Which of your isomers has the highest boiling point?

isomer B

Suggest an explanation for your answer.

It is a straight chained molecule and therefore has the greatest surface area over which temporary dipoles can act and it can also pack more closely. [6]

(e) The boiling points of methane, ethane, propane, and butane are given below.

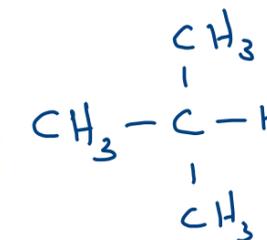
compound	CH_4	CH_3CH_3	$CH_3CH_2CH_3$	$CH_3(CH_2)_2CH_3$
boiling point/K	112	185	231	273

(i) Suggest an explanation for the increase in boiling points from methane to butane.

The carbon chain gets longer and so there is an increase in number of electrons which makes the temporary dipole forces stronger

(ii) The isomer of butane, 2-methylpropane, $(CH_3)_3CH$, has a boiling point of 261 K. Suggest an explanation for the difference between this value and that for butane in the table above.

Butane is straight chained while 2-methylpropane is branched so butane molecules can pack more closely and have greater area over which temporary dipoles can act [4]



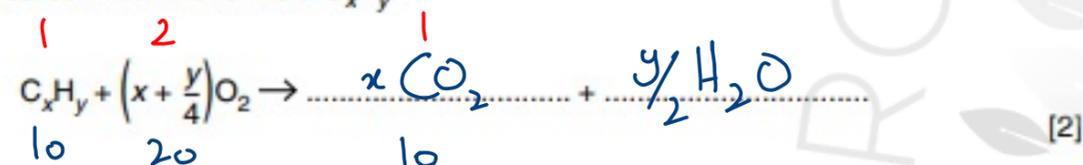
5 In 1814, Sir Humphrey Davy and Michael Faraday collected samples of a flammable gas, **A**, from the ground near Florence in Italy. They analysed **A** which they found to be a hydrocarbon. Further experiments were then carried out to determine the molecular formula of **A**.

(a) What is meant by the term *molecular formula*?

The molecular formula shows the number and different atoms of an element bonded together in 1 molecule of a compound [2]

Davy and Faraday deduced the formula of **A** by exploding it with an excess of oxygen and analysing the products of combustion.

(b) Complete and balance the following equation for the complete combustion of a hydrocarbon with the formula C_xH_y .



(c) When 10cm^3 of **A** was mixed at room temperature with 50cm^3 of oxygen (an excess) and exploded, 40cm^3 of gas remained after cooling the apparatus to room temperature and pressure.

When this 40cm^3 of gas was shaken with an excess of aqueous potassium hydroxide, KOH, 30cm^3 of gas still remained. \rightarrow oxygen

(i) What is the identity of the 30cm^3 of gas that remained at the end of the experiment?

O_2

(ii) The combustion of **A** produced a gas that reacted with the KOH(aq).

What is the identity of this gas?

CO_2

(iii) What volume of the gas you have identified in (ii) was produced by the combustion of **A**?

10cm^3

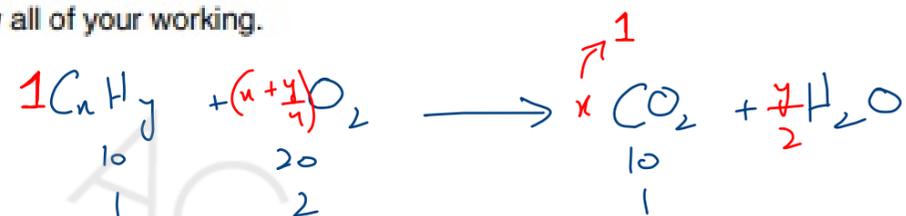
(iv) What volume of oxygen was used up in the combustion of **A**?

20cm^3

[4]

(d) Use your equation in (b) and your results from (c)(iii) and (c)(iv) to calculate the molecular formula of **A**.

Show all of your working.



1 mole of C_xH_y gives 1 mole of CO_2 so $x=1$

$$x + \frac{y}{4} = 2 \Rightarrow y = (2-1)4 = 4$$

Formula :- CH_4

[3]

11 Heptane, C_7H_{16} , is an undesirable component of petrol as it burns explosively causing 'knocking' in an engine.

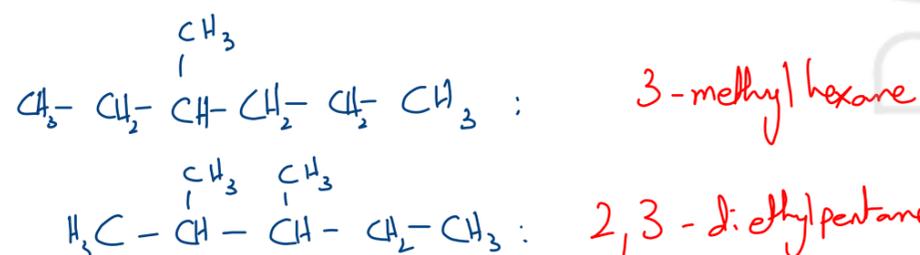
(a) There are nine structural isomers with the formula C_7H_{16} , only two of which contain chiral centres.

(i) Explain the meanings of the terms *structural isomers* and *chiral*.

structural isomers: Compounds having the same molecular formula but different structural formula

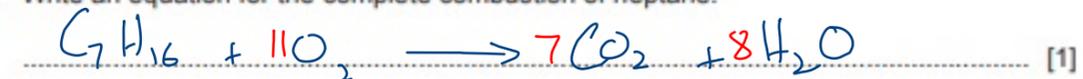
chiral: A carbon atom bonded to 4 other atoms or group of atoms.

(ii) Give the structures and names of the two structural isomers of C_7H_{16} which contain a chiral centre.



[4]

(b) (i) Write an equation for the complete combustion of heptane.



(ii) Write an equation for the incomplete combustion of heptane leading to the production of a solid pollutant.



(iii) Incomplete combustion can also lead to emission of unburnt hydrocarbons.

State one environmental consequence of this.

They cause greenhouse effect leading to global warming [1]

(c) The reaction of heptane with chlorine in the presence of UV light produces a wide variety of products.

Formation of the monochloroheptanes can be represented by the following equation.



(i) Name the mechanism of the reaction between heptane and chlorine in the presence of UV light.

Free radical substitution [1]

(ii) Describe this mechanism, using suitable equations and including the names of each stage in the process.

