6.2 Hydrocarbons: alkanes and alkenes

Answers to Exam practice questions

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1 a) i) 150 °C [1] at normal atmospheric pressure. [1]

ii) Saturated compounds have only single bonds between the atoms in their molecules. [1]

Unsaturated compounds have at least one double or triple bond between atoms in their molecules. [1]

Alkenes contain a C=C double bond. [1]

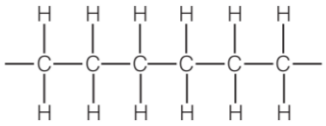
iii) Foods containing *cis* unsaturated fats are healthier than foods containing saturated fats [1] or *trans* unsaturated fats [1], which are major causes of arteriosclerosis (hardening of the arteries). [1]

b) i) Dilute sulfuric acid [1] and potassium manganate(VII) solution. [1]

ii) Ethane-1,2-diol [1]

iii) Antifreeze for windscreen washer fluid in winter. [1]

c) i) Relatively low temperature and pressure [1] and special catalysts [1]

ii)  [1]

d) Any four of: light, flexible, relatively strong, transparent, resistant to water, easily drawn into sheets, easily coloured. ([2] for four properties, [1] for two or three properties)

2 a) The crude oil is heated to about 400 °C [1] and then flows into the fractionating column. [1]

The column is hotter at the bottom and cooler at the top. [1]

Rising vapour condenses when it reaches a tray with liquid at a temperature just below its boiling temperature. [1]

A series of horizontal trays up the column [1] allows hydrocarbons with small molecules (low boiling temperatures) to rise higher up the column while larger molecules stay lower down. [1]

Fractions containing molecules of roughly the same mass are drawn off the column at various heights. [1]

(Any six points for [6])

b) i) Cracking is the conversion of heavier fractions from crude oil [1] containing long-chain alkanes [1] into smaller molecules in a mixture of alkanes and alkenes. [1]

ii) $C_{12}H_{26}(g) \rightarrow 2C_2H_4(g) + C_8H_{18}(g)$ [1]; octane [1]

iii) To speed up the cracking process [1]; to lower the temperature at which cracking occurs and save on energy costs. [1]

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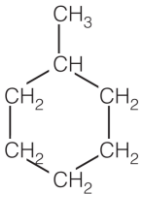
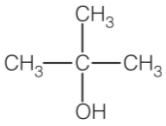
c) $CH_3(CH_2)_5CH_3(g) \rightarrow$  $+ H_2(g)$ [2]

d) i)  [1]

ii) Oxygen within their molecules facilitates the combustion [1] of the petrol to which they are added.

3 a) i) $C_5H_{12}(l) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(l)$ [1]

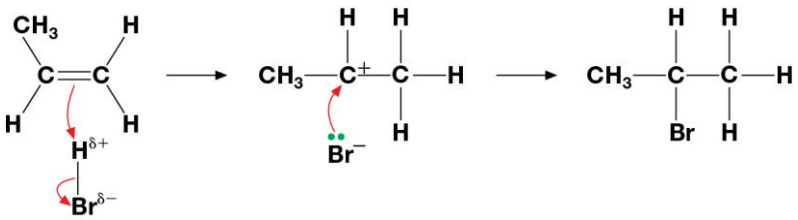
ii) $C_6H_{14}(l) + 6½O_2(g) \rightarrow 6CO(g) + 7H_2O(l)$ [1]

iii) $C_7H_{16}(l) + 4O_2(g) \rightarrow 7C(s) + 8H_2O(l)$ [1]

b) Pentene would burn with a more smoky flame [1] because it contains a higher percentage of carbon than pentane. [1]

4 a) i) Electrophilic addition is an addition reaction in which one molecule combines with another to form a single product [1] and in which one of the reacting molecules acts as an electrophile [1], attacking a negatively charged region [1] in the other reactant.

ii) 2-Bromopropane [1]

iii) 

Arrow from ethene to H [1]

Polarity of H–Br and arrow to Br [1]

Structure of carbocation [1]

Arrow from bromide to C+ [1]

iv) When H^+ adds to $CH_3CH{=}CH_2$, two carbocations are produced [1], $CH_3C^+HCH_3$ and $CH_3CH_2C^+H_2$ [1]. $CH_3C^+HCH_3$ is the more stable because of the inductive effect of two alkyl groups. [1] So it persists longer and reacts with more Br^- ions to form the major product.

b) 2-Chloro-1-iodopropane. [1] Iodine is $\delta+$ because chlorine is more electronegative [1], so iodine bonds first to the end carbon to form the more stable carbocation. [1]

c) $CH_3CH{=}CH_2 + Br_2 + H_2O \rightarrow CH_3CH(OH)CH_2Br + HBr$ [1]

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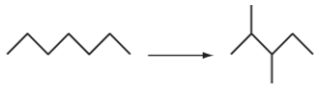
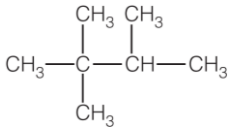
5 a) The change in structure of a molecule from one isomer to another. [1]

b) $CH_3(CH_2)_5CH_3 \rightarrow CH_3CH(CH_2)_3CH_3$ (with CH_3 branch) [1]

c)  [1]

d)  [1]

2,2,3-Trimethylbutane [1]

e) Heptane has larger molecules than hexane so more electrons. [1] So it has stronger London forces and its molecules require more energy before they have sufficient energy to escape from the attractions of their neighbours. [1]

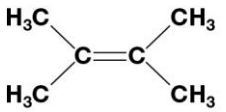
f) About 91 °C [1] (i.e. halfway between the boiling temperature of 2,3-dimethylpentane and heptane) because 2-methylhexane has about half the branching in its structure compared with 2,3-dimethylpentane but the same relative mass as both 2,3-dimethylpentane and heptane. [1]

6 a) Percentage of hydrogen = 14.3 [1]

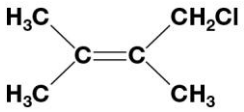
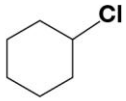
C: $\frac{85.7}{12.0} = 7.14$; H: $\frac{14.3}{1.0} = 14.3$ [1]

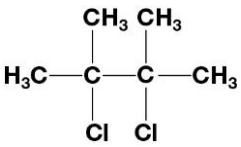
Simplest ratio 1 : 2 so empirical formula is CH_2. [1]

M_r = 84.0 so molecular formula is C_6H_{12}. [1]

b)  

X **Y**

c)  [1]

2,3-Dichloro-2,3-dimethylbutane [1]

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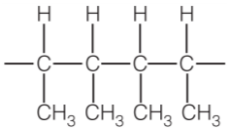
7 a) i) A compound produced by the addition reaction [1] of large numbers [1] of monomers/small molecules. [1]

ii) It consists of a mixture of polymer molecules with different chain lengths and different branched sections [1] which do not melt at the same temperature. [1]

iii)  [1]

iv) Any two of:

- sorting polymers prior to recycling using infrared and other techniques
- converting polymer waste into simpler compounds to use a feedstock for cracking
- incineration of polymer waste to release energy
- removal of toxic/harmful gases formed during incineration before release into the atmosphere. [2]

b) i) Removal/elimination of hydrogen from a compound. [1]

ii) $CH_2{=}CHCH{=}CH_2$ [1]

iii) $CH_3CH{=}CHCH_3 \rightarrow CH_2{=}CHCH{=}CH_2 + H_2$ [2]

(Allow [1] for $C_4H_8 \rightarrow C_4H_6 + H_2$)

8 a) The oil does not mix with water [1] so shaking is needed to transfer the bromine into the organic layer so it can react there with the oil. [1]

b) The lower aqueous layer would be very pale yellow/colourless. [1] The organic layer would be yellow/orange as it contains unreacted bromine molecules. [1]

c) The volumes of oil measured using a measuring cylinder will vary. [1] Either small amounts of oil could be weighed out or added from a burette [1] or alternatively a larger amount of oil could be added to a volumetric flask and a solution prepared which could be used for several experiments. [1]

d) Either the concentration of the bromine water could be reduced [1] or the concentration of the oil solution could be increased. [1]

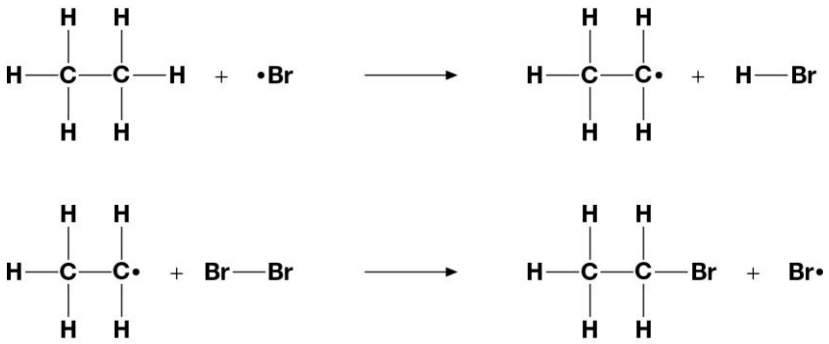
9 a) Bonds broken C–H (412) and Br–Br (193) [1] $412 + 193 = 605$ kJ mol^{-1} [1]

Bonds formed C–Br (276) and H–Br (366) [1] $276 + 366 = 642$ kJ mol^{-1} [1]

$\Delta H = +605 - 642 = -37$ kJ mol^{-1} [1]

(Extra $(5 \times 412) + 348 = 2408$ may be included on both sides.)

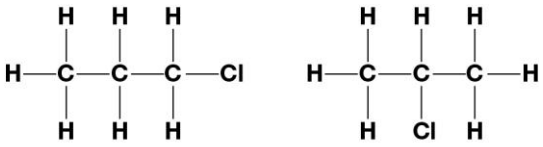
b)



[1] × 2 for equations

Propagation [1]

10 a)



1-chloropropane 2-chloropropane [2]

b) The excess of propane makes it more likely that chlorine radicals will collide with propane molecules[1] rather than with chloropropane molecules which would lead to further substitution. [1]

c) Radical on central C is more stable than radical on terminal C [1] (same as carbocations; similarly due to inductive effects). This would predict that there would be more 2-chloropropane than 1-chloropropane at lower temperatures. [1]

d) There are six H atoms on end C atoms and two H on the central C [1] so expected mole ratio statistically is 3 : 1 for 1-chloropropane to 2-chloropropane [1], assuming that substitution of any H is equally likely. [1]

e) At higher temperatures, sufficient activation energy is available; reactions are more rapid and stability of intermediates is less important. [1]

11 1000 dm^3 of petrol = 1000 × 1000 cm^3 = 1.00×10^6 cm^3 [1]

Mass of petrol = 0.8 g cm^{-3} × 1.00×10^6 cm^3 = 8.00×10^5 g [1]

Molar mass of octane = 114 g mol^{-1} [1]

Moles of octane = $\frac{8.00 \times 10^5 \text{ g}}{114 \text{ g mol}^{-1}}$ = 7.018×10^3 mol [1]

On combustion, 1 mole of octane produces 8 moles of CO_2 = 8 × 44.0 g CO_2 [1]

7.018×10^3 moles of octane produce 8 × 44.0 × 7.018×10^3 g CO_2 = 2.47×10^6 g CO_2 [1]