

CHEMISTRY CONTEXTS 2.

MODULE 1:

CHAPTERS 1-3 ANSWERS

CHAPTER 1: ETHYLENE**Review exercise 1.1**

- 1 The word 'petrochemical' means any chemical that has been derived from petroleum, a liquid fossil fuel.
- 2 Fossil fuels are non-renewable resources with a huge demand. They are wanted both as a source of energy and as a source of petrochemical substances.

Review exercise 1.2

- 1 Ethylene (ethene) is the most widely used feedstock material derived from petroleum.
- 2
 - a Catalytic cracking produces shorter chain-length, lower-mass hydrocarbons from high mass petroleum fractions. Thermal steam cracking converts ethane and propane to ethylene.
 - b The proportions of products obtained from fractional distillation do not match the demands for the different products. Catalytic cracking allows for specific control of the types and amounts of products and hence more efficient use of the petroleum feedstock and its products.
 - c $\text{C}_9\text{H}_{20}(\text{g}) \rightarrow \text{C}_7\text{H}_{16}(\text{g}) + \text{C}_2\text{H}_4(\text{g})$
- 3 The catalysts used in cracking are zeolites. These solid crystalline substances adsorb the gaseous reactants, weakening their bonds and hence lowering the activation energies.

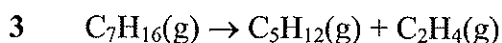
Review exercise 1.3

- 1 Alkenes are more reactive than alkanes because of the presence of the double bond, a centre of high electron density, in alkenes.
- 2 Place hexane and 1-hexene into separate test tubes. Add bromine water to a depth of about 1 cm, shake and allow to settle. If the bromine water is decolourised then the test tube contained 1-hexene and the product of this addition reaction is 1,2-dibromoethane. However, there may also be some 2-bromo-1-ethanol and hydrogen bromide as a result of the water present. If there is no change to the colour of the bromine water then the test tube contained hexane.
- 3
 - a $\text{C}_3\text{H}_6 + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_6\text{Cl}_2$ 1,2-dichloropropane
 - b $\text{C}_7\text{H}_{14} + \text{HBr} \rightarrow \text{C}_7\text{H}_{15}\text{Br}$ 2-bromoheptane, 1-bromoheptane. In practice only 2-bromoheptane forms (Markovnikov's rule).
 - c $\text{C}_6\text{H}_{12} + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{13}\text{OH}$ 3-hexanol
- 4
 - a Addition of hydrogen chloride to 1-butene

- b** Chlorination of 2-butene
- c** Addition using chlorine water to 2-butene
- d** Hydration of 1-butene
- e** Oxidation of 2-pentene by reacting with cold dilute potassium permanganate

Chapter 1 — Application and investigation**1 Investigation**

- 2 a** Cracking is used to produce hydrocarbons with lower molecular mass which have greater market demand, e.g. petrol, branch-chained alkanes to improve the performance of petrol; and to produce ethene which can be used as a starting material for many organic compounds.
- b** In catalytic cracking the material to be cracked is passed over a zeolite catalyst at a temperature of around 500°C. The reactants adsorb to the surface of the catalyst, which weakens their bonds, lowering the activation energy.
- c** Catalytic cracking uses zeolite crystals as catalysts to lower the activation energy in the cracking of high molecular mass hydrocarbons. Thermal cracking uses very high temperatures (around 800–900°C) to crack hydrocarbons such as ethane and propane, to produce needed alkenes.

**4 Investigation**

- 5** Alkenes contain a reactive double bond, which readily undergoes addition reactions in order to gain a more stable single bond.

6 a 1,2-dichloropropane

- b** 1-chlorobutane; 2-chlorobutane. In practice only 2-chlorobutane forms (Markovnikov's rule).

c ethanol

7 Investigation and class experimental work:

- a** 2-pentene with HCl

- b** 2-pentene with Cl_2

- c** propene with H_2O in the presence of a catalyst

- 8** Add bromine water to samples of each of cyclohexene and cyclohexane, shake and allow to settle. Cyclohexene undergoes an addition reaction with Br_2 across the double bond and thus the bromine water is decolourised. There is no rapid visible reaction with cyclohexane.

9 Investigation

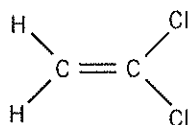
CHAPTER 2: POLYMERS

Review exercise 2.1

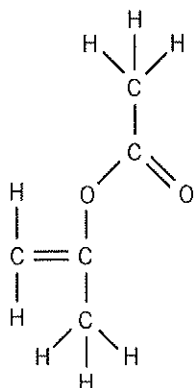
- 1 Polymerisation is the chemical reaction whereby monomers link together to form polymers.
- 2 Addition polymerisation: all atoms in the monomer are present in the polymer chain. Unsaturated monomers join together via breaking of a $C = C$ double bond.
- Condensation polymerisation: a reaction between two monomers, which can be different, during which a small molecule, such as water, is eliminated.

- 3 a Monomers have $C = C$ double bond.
- b Monomers each contain a functional group which may be different. Common groups are $-COOH$ (carboxylic acid), $-OH$ (alcohol) and $-NH_2$ (amine) group.

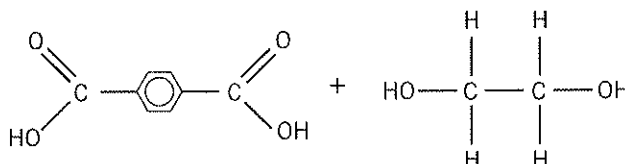
- 4 a i



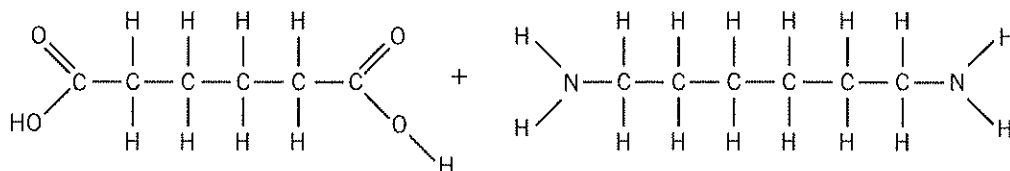
- ii



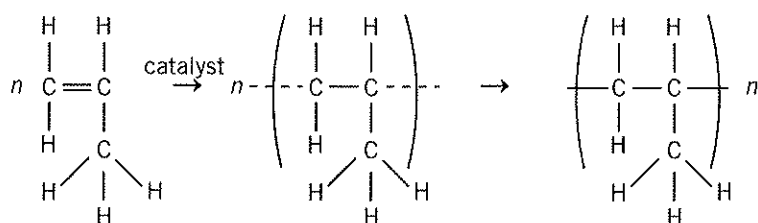
- b i



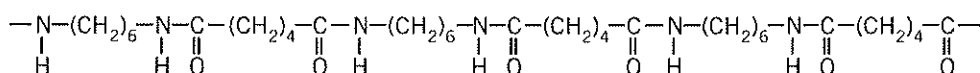
ii



5



6

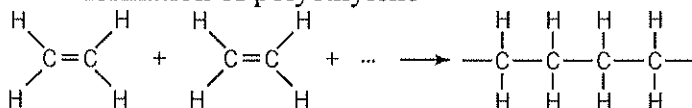


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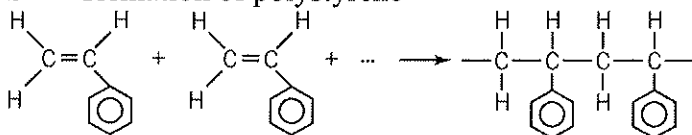
- Increased branching decreases hardness by making the polymer less compact and rigid.
- Cross-linking between polymer chains increases hardness because cross-linking is produced by covalent bonds linking chains together.
- Decreasing the length of polymer chains decreases hardness because there are less dispersion forces between the chains.
- Increasing the orderly arrangement of polymer chains increases hardness by making the polymer more dense and less flexible.
- Adding a plasticiser to a polymer decreases hardness because plasticisers are generally chosen to soften a polymer.

Review exercise 2.2

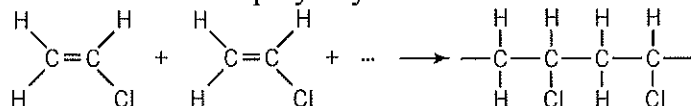
1 a formation of polyethylene



b formation of polystyrene



c formation of polyvinylchloride

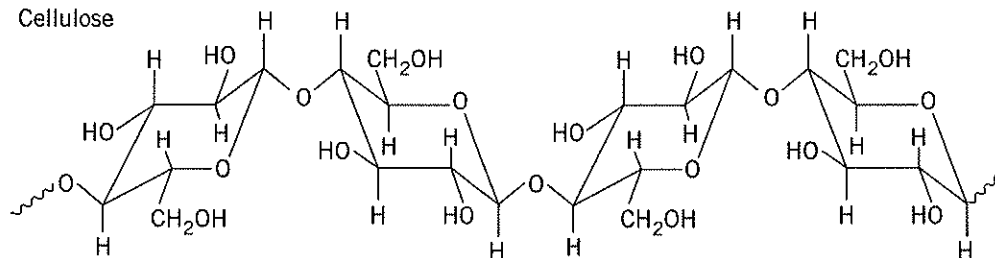


- 2 a chloroethylene
b phenylethylene or ethenylbenzene
- 3 LDPE is softer and more flexible due to greater branching of chains causing reduced dispersion forces.
HDPE has fewer branched chains, causing greater dispersion forces and hence greater hardness and strength.
- 4 1 monomer unit has molar mass of 62.5 g, so 15 000 monomer units have molar mass of 937 500 g.
- 5 a polystyrene because it is a cheap, lightweight insulating polymer
b low-density polyethene (LDPE) because it is mouldable, impermeable and flexible
c polypropene/nylon because it is lightweight and strong and easily formed into fibres
d LDPE because it is lightweight, cheap and flexible
e HDPE because it is tough and durable
f HDPE because it is rigid, tough and durable
g Teflon because it is tough, frictionless and resistant to heat and chemicals
h polyethene terephthalate (PET) because it is lightweight, tough and easily blown into a shapeable film

Review exercise 2.3

- 1 Most of the synthetic polymers made today are derived from the petrochemical industry, which relies on the non-renewable fossil fuel petroleum. However, these supplies will be rapidly used up, especially if we continue to demand their use as both a fuel and a feedstock. An alternative, renewable source of raw materials is needed.
- 2 Biomass is organic material derived from living organisms: plant material such as sugar and cellulose; animal material such as dung; and domestic and industrial organic waste.
- 3 Cellulose is a long-chain polymer of β -glucose units, $\text{C}_6\text{H}_{12}\text{O}_6$, where every second glucose unit is inverted to produce straightened chains.
- 4 A glucose unit loses an H from an $-\text{OH}$ group and joins to a carbon on a second glucose unit which has lost its $-\text{OH}$ group; this links the glucose units with the loss of H_2O and so the formation of cellulose is an example of condensation polymerisation.

Cellulose



- 5 Cellulose is made from repeating units of β -glucose with inversion of every second unit. This produces long, straight chains of cellulose which are linked to each other by hydrogen bonding. In plants, cellulose acts as a structural material. Starch (both amylose and amylopectin) is made from long-chain repeating units of α -glucose, which are also highly branched. This results in tightly coiled, compact, insoluble starch molecules, which are used as energy stores in plants.
- 6 Existing plant cellulose can be modified to produce biopolymers, such as celluloid and rayon, or it can be broken down into smaller units that can be used to build new polymers such as corn-starch polymers.

Review exercise 2.4

- 1 Silk is a biopolymer used in its natural form; rayon uses cellulose in a chemically modified form; lactic acid can be produced from the breakdown of starch and then used to make polylactic acid (PLA).
- 2 Advantages are that biopolymers come from plant material, which is a renewable resource, and that plastics made from biopolymers are easily broken down by bacteria and fungi.
- Disadvantages include the cost of production and that they are easily biodegradable, which is not useful in some applications.
- 3
- Plastic-producing bacteria are grown in fermentation vats and fed on molasses or methanol. Extraction of plastic from the bacterium involves breaking down the bacterium's cell walls and separating this from the cell debris.
 - The bacterium used is *Alcaligenes eutrophus*.
 - The plastic produced is of a type known as PHAs—polyhydroxyalkanoates—which have similar properties to polypropene.

Chapter 2 — Application and investigation

- 1 Monomer: small repeating units that join by covalent bonds to form a polymer, e.g. ethylene.

Polymer: large-chain molecule consisting of small repeating units called monomers, e.g. polyethylene.

Polymerisation: the chemical reaction by which monomers link together to form polymers, e.g. formation of polyethylene by addition reaction.

2 Investigation

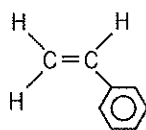
3 Polyethylene can have many different molecular chain lengths. Those with around 40 000 atoms per molecule are used for food wrap films; 60 000 atoms per molecule make milk containers; 80 000 atoms per molecule make bleach containers and 800 000 atoms per molecule can be used in artificial ice rinks. As chain length increases, density, hardness and melting point increase. Branching is possible in polyethylene, and as branching increases, density, hardness and melting point decrease, increasing the uses that can be made of polyethylene.

4 Molecular mass of 1 monomer = 28, so $84\,500 \div 28 = 3018$ monomer units

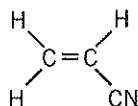
5 First-hand investigation

6 Investigation based on answer to Q5

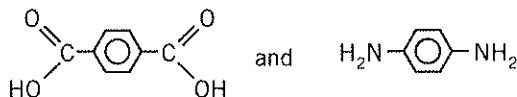
7 a



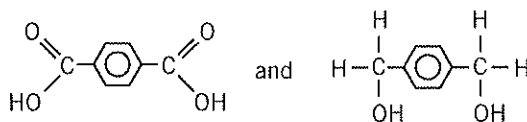
b



c



d



8 Investigation

9 Investigation

10 Investigation

CHAPTER 3: ETHANOL

Review exercise 3.1

1 a 1-propanol

b 4-chloro-2-pentanol

Solutions Manual: Module 1

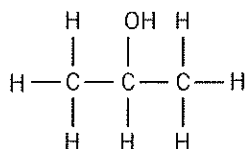
Production of materials

Chemistry
Contexts 2
SECOND EDITION

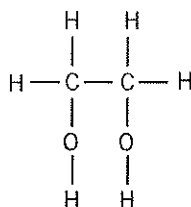
c 1,4-butanediol

d 2-methyl-2-propanol

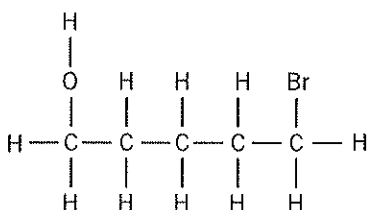
2 a



b

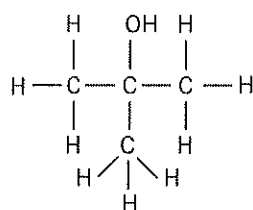


c



3

2-methyl-2-propanol



83°C

Solutions Manual: Module 1	Chemistry Contexts 2 SECOND EDITION
Production of materials	

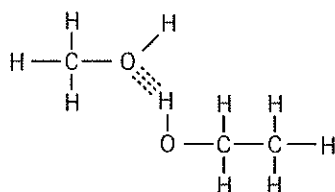
2-butanol <pre> H H OH H H — C — C — C — C — H H H H H </pre>	100°C
2-methyl-1-propanol <pre> H H H H — C — C — C — OH H C H H </pre>	108°C
1-butanol <pre> H H H H H — C — C — C — C — OH H H H H </pre>	118°C

- 4 Heat ethanol with an excess of concentrated sulfuric acid, or heat ethanol vapour over a catalyst at 350°C.
- 5 $\text{C}_2\text{H}_5\text{OH}(\text{l}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$

Review exercise 3.2

- Methylated spirits are 95% ethanol, 5% methanol and small quantities of foul-tasting chemicals. The additives are used to discourage people from drinking it.
- Ethanol has a short non-polar chain, which allows it to dissolve some non-polar substances. The –OH functional group makes ethanol polar, which allows it to act a solvent for polar substances.
- The ethanol molecule contains the polar –OH end and the non-polar hydrocarbon chain. Hence it is able to be used as a solvent for non-polar substances such as perfumes and aftershaves. The low boiling point ethanol evaporates easily with body heat, leaving the heavier fragrance components on the skin.

4



- 5 Ethanol is described as renewable because it can be derived from the starch and sugars present in various crops such as sugar cane and corn.
- 6 Cars using ethanol produce fewer pollutants. Ethanol is a renewable resource. However, no commercially viable method of obtaining ethanol is available and cars will need to be significantly modified to run on pure ethanol.

7	Mass of methanol burned	=	1.10 g
	Mass of water	=	100 g
	Mass of copper	=	200.0 g
	Temperature change	=	5°C
	Specific heat capacity water	=	4.18 J K ⁻¹ g ⁻¹
	Specific heat capacity copper	=	0.387 J K ⁻¹ g ⁻¹
	Heat released per 1.10 g methanol	=	-(mCΔT(copper) + mCΔT(water))
		=	-(200 × 0.387 × 5 + 100 × 4.18 × 5)
		=	-2477 J released by 1.10 g methanol
	Heat released per mole of methanol	=	-2477 × $\frac{32}{1.10}$
		=	-72 058 J mol ⁻¹
	∴ Molar heat of combustion	=	72 kJ mol ⁻¹

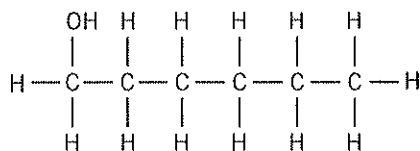
Review exercise 3.3

- 1 The acid catalyst is needed to cause the water molecule to attack the double bond in ethylene.
- 2
- $$\text{CH}_2=\text{CH}-\text{CH}_3(\text{g}) + \text{H}_2\text{O}(\text{g}) \xrightarrow{\text{H}^+} \text{CH}_3-\text{CHOH}-\text{CH}_3(\text{g}) \text{ (Markovnikov's rule)}$$
- 3 a carbohydrates, e.g. glucose, sucrose, starch, plus water and yeast

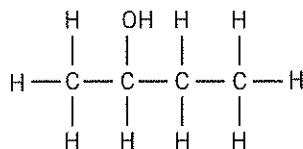
- b The yeasts produce enzymes which act as catalysts in the conversion of glucose to ethanol and carbon dioxide.
- c ethanol and carbon dioxide
- d exothermic
- e Once the ethanol concentration reaches 15% in the fermentation container, the yeast is killed and the reaction ceases. Therefore naturally fermented wines have ethanol concentrations of 12–15%.
- 4 Fermentation of glucose occurs best in the absence of oxygen (anaerobic conditions) and at a temperature of 35–40°C.
- 5 From the equation, and using $n = \text{mass (g)} \div \text{molar mass (g)}$
- $$\begin{aligned} \text{mass (ethanol)} &= 2 \times \text{mass(glucose)} \div \text{molar mass(glucose)} \times \text{molar mass(ethanol)} \\ &= 2 \times 500 \div 180.156 \times 46.068 \\ &= 255.7 \text{ g} \end{aligned}$$
- 6 From the equation, and using $n = \text{mass (g)} \div \text{molar mass (g)}$
- $$\begin{aligned} \text{mass (ethanol)} &= \text{mass (carbon dioxide lost)} \div \text{molar mass (carbon dioxide)} \times \text{molar mass (ethanol)} \\ &= 50.0 \div 44.01 \times 46.068 \\ &= 52.3 \text{ g} \end{aligned}$$

Chapter 3 — Application and investigation

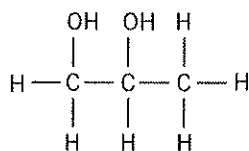
1 a



b



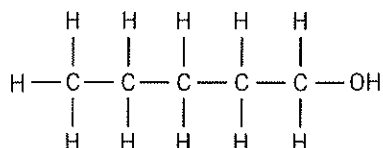
c



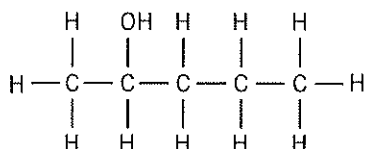
2 a 1-propanol

b 1,4-butanediol

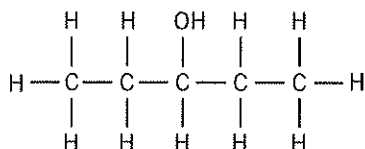
3



1-pentanol



2-pentanol



3-pentanol

4 Water, being polar, would not readily dissolve many esters with a non-polar component. Hexane, being non-polar, would not readily dissolve the polar esters. Ethanol, with its ability to dissolve both polar and non-polar components, is suitable for dissolving esters.

5 Investigation

6 Investigation

7 Investigation

8 Depends on responses to Questions 5, 6 and 7.

9 a Assume heat absorbed by copper is negligible.

Mass of fuel = 2.00 g

Mass of water = 500 g

Change in temp = 18.4°C

Specific heat water = 4.18 J K⁻¹ g⁻¹**Methanol**Heat released by 2 g = $-mC\Delta T$

$$= -(500 \times 4.18 \times 18.4)$$

$$= -38\,456\text{ J}$$

i Heat of combustion/g $= 38\,456 \div 2$

$$= 19\,228\text{ J g}^{-1} = 19.2\text{ kJ g}^{-1}$$

ii Heat of combustion/mole $= 38\,456 \times \frac{32}{2}$

$$= 61\,5296\text{ J mol}^{-1}$$

1-propanol

$$= 615\text{ kJ mol}^{-1}$$

Heat released by 2 g

$$= -mC\Delta T$$

$$= -(500 \times 4.18 \times 28.5)$$

$$= -59\,565\text{ J}$$

i Heat of combustion/g $= 59\,565 \div 2$

$$= 29\,782.5\text{ J g}^{-1} = 29.8\text{ kJ g}^{-1}$$

ii Heat of combustion/mole $= 59\,565 \times \frac{60.1}{2}$

$$= 1\,789\,928\text{ J mol}^{-1}$$

$$= 1790\text{ kJ mol}^{-1}$$

1-butanol

Heat released by 2 g

$$= -mC\Delta T$$

$$= -(500 \times 4.18 \times 31.5)$$

$$= -65\,835\text{ J}$$

i Heat of combustion/g $= 65\,835 \div 2$

$$= 32\,917.5\text{ J}$$

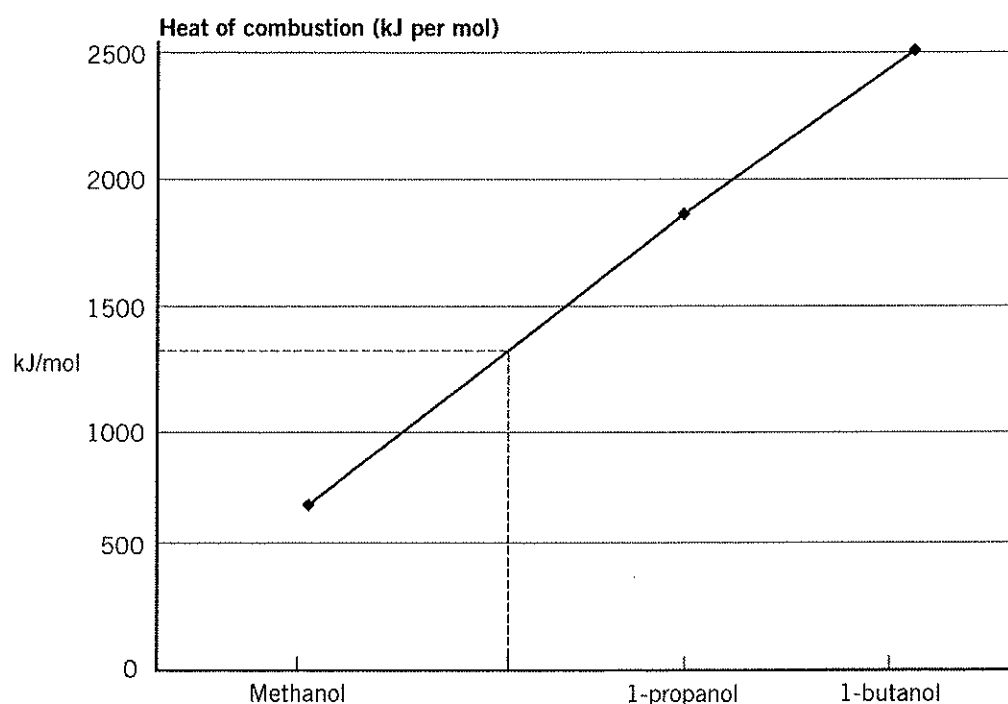
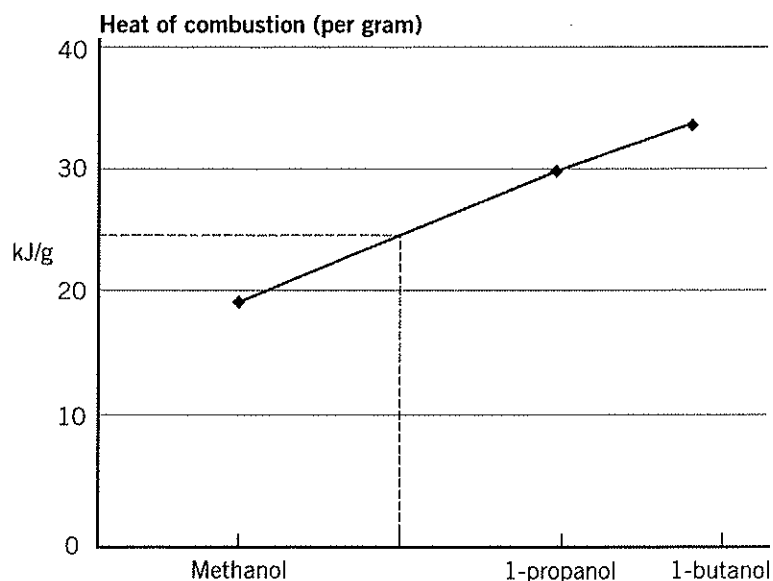
$$= 32.92\text{ kJ g}^{-1}$$

ii Heat of combustion/mole $= 65\,835 \times \frac{74.12}{2}$

$$= 2\,439\,845.1\text{ J}$$

$$= 2440\text{ kJ mol}^{-1}$$

b



- 10 The dehydration of ethanol to ethylene and water is carried out by heating ethanol with concentrated sulfuric acid as a catalyst, or by heating ethanol vapour over an alumina catalyst at 350°C . The hydration of ethylene to produce ethanol requires the addition of water in the presence of a sulfuric or phosphoric acid catalyst.

