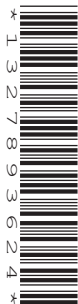


**Time allowed: 1 hour 30 minutes**

- a scientific or graphical calculator
- an HB pencil



## StemUp Model Solution

- Read each question carefully before you start your answer.

**2**  
**SECTION A**

You should spend a **maximum of 25 minutes** on this section.

Write your answer to each question in the box provided.

- 1** Which diagram shows a p-orbital?

|          |                                                                                   |
|----------|-----------------------------------------------------------------------------------|
| <b>A</b> |  |
| <b>B</b> |  |
| <b>C</b> |  |
| <b>D</b> |  |

Your answer

**C**

[1]

- 2** Which row shows the atomic structure of  $^{25}\text{Mg}^{2+}$ ?

|          | <b>Protons</b> | <b>Neutrons</b> | <b>Electrons</b> |
|----------|----------------|-----------------|------------------|
| <b>A</b> | 10             | 12              | 13               |
| <b>B</b> | 10             | 15              | 12               |
| <b>C</b> | 12             | 13              | 10               |
| <b>D</b> | 12             | 13              | 14               |

Your answer

**C**

[1]

- 3 A nitrogen oxide contains 36.84% of nitrogen by mass.

What is the empirical formula of the nitrogen oxide?

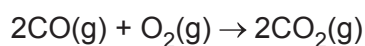
- A NO  
B NO<sub>2</sub>  
C N<sub>2</sub>O  
D N<sub>2</sub>O<sub>3</sub>

Your answer

D

[1]

- 4 Carbon monoxide reacts with oxygen to form carbon dioxide:



Which volumes of CO(g) and O<sub>2</sub>(g) produce the largest volume of CO<sub>2</sub>(g)?

All gas volumes are measured at RTP.

- A 1.00 dm<sup>3</sup> CO and 4.00 dm<sup>3</sup> O<sub>2</sub>  
B 2.00 dm<sup>3</sup> CO and 3.00 dm<sup>3</sup> O<sub>2</sub>  
C 3.00 dm<sup>3</sup> CO and 2.00 dm<sup>3</sup> O<sub>2</sub>  
D 4.00 dm<sup>3</sup> CO and 1.00 dm<sup>3</sup> O<sub>2</sub>

Your answer

C

[1]

- 5 Which reaction produces a product with linear molecules?

- A  $2\text{B} + 3\text{F}_2 \rightarrow$   
B  $\text{C} + \text{O}_2 \rightarrow$   
C  $2\text{H}_2 + \text{O}_2 \rightarrow$   
D  $\text{N}_2 + 3\text{H}_2 \rightarrow$

Your answer

B

[1]

- 6 Which statement about the periodic table is **not** correct?
- A Elements in the same group have similar **chemical** properties.
  - B The elements are ordered by increasing atomic mass.
  - C The elements are ordered by increasing atomic number.
  - D There is a repeating trend of **physical** and **chemical** properties across the periods.

Your answer

B

[1]

- 7 Group 2 compounds can be used in agriculture to neutralise acid soils and in medicine to treat indigestion.

Which Group 2 compound is **not** suitable for either use?

- A  $\text{Mg}(\text{OH})_2$
- B  $\text{MgSO}_4$
- C  $\text{CaCO}_3$
- D  $\text{CaO}$

Your answer

B

[1]

- 8 In the UK, water companies typically treat drinking water with chlorine gas at a concentration of  $0.500 \text{ mg dm}^{-3}$  or less.

Which statement about UK drinking water is correct?

- A Chlorine in drinking water can catalyse the breakdown of ozone.
- B Chlorine may form toxic chlorinated hydrocarbons.
- C Drinking water with a chlorine gas concentration of  $0.500 \text{ mg dm}^{-3}$  contains  $2.12 \times 10^{18}$  chlorine molecules in each  $\text{dm}^3$ .
- D In hot weather, chlorine can vaporise from drinking water to cause global warming.

Your answer

B

[1]

9 Which reaction does **not** show disproportionation of chlorine?

- A  $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$
- B  $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{HClO}$
- C  $2\text{ClO}_2 + 2\text{NaOH} \rightarrow \text{NaClO}_2 + \text{NaClO}_3 + \text{H}_2\text{O}$
- D  $2\text{NaOH} + \text{Cl}_2 \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$

Your answer

A

[1]

10 An unknown compound is tested to identify whether it contains sulfate, carbonate or halide ions.

What is the correct sequence of tests required?

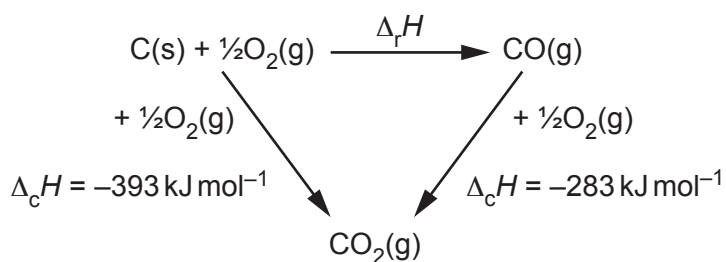
- A carbonate, halide, sulfate
- B carbonate, sulfate, halide
- C halide, carbonate, sulfate
- D sulfate, carbonate, halide

Your answer

B

[1]

11 An enthalpy cycle is shown below.



What is  $\Delta_r H$ , in  $\text{kJ mol}^{-1}$ , shown in the enthalpy cycle?

- A +676
- B +110
- C -110
- D -676

Your answer

C

[1]

- 12 A mixture of gases is heated in a closed container. The reaction rate increases.

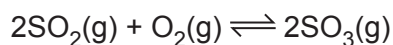
Which statement explains why the rate increases?

- A More molecules have an energy greater than the activation energy.
- B The activation energy decreases.
- C The activation energy increases.
- D The concentration of the gases increases.

Your answer A

[1]

- 13 The reversible reaction below is at equilibrium.



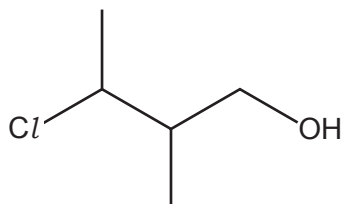
What is the expression for  $K_c$ ?

- A  $\frac{[\text{SO}_2(\text{g})]^2 [\text{O}_2(\text{g})]}{[\text{SO}_3(\text{g})]^2}$
- B  $\frac{[\text{SO}_3(\text{g})]^2}{[\text{SO}_2(\text{g})]^2 [\text{O}_2(\text{g})]}$
- C  $\frac{2[\text{SO}_2(\text{g})] + [\text{O}_2(\text{g})]}{2[\text{SO}_3(\text{g})]}$
- D  $\frac{2[\text{SO}_3(\text{g})]}{2[\text{SO}_2(\text{g})] + [\text{O}_2(\text{g})]}$

Your answer B

[1]

- 14 What is the name of the compound below?

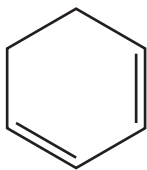


- A 1-chloro-1,2-dimethylpropan-3-ol
- B 2-chloro-3-methylbutan-4-ol
- C 3-chloro-2-methylbutan-1-ol
- D 3-chloro-2,3-dimethylpropan-1-ol

Your answer C

[1]

15 The structure of a hydrocarbon is shown below.



Which terms describe this hydrocarbon?

- A Alicyclic and saturated
- B Aliphatic and alicyclic
- C Aliphatic and aromatic
- D Aromatic and unsaturated

Your answer

B

[1]

16 Which property explains the low reactivity of alkanes?

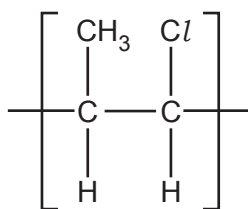
- A Low C–C bond enthalpy.
- B Low bond enthalpy of  $\pi$ -bonds.
- C Low polarity of  $\sigma$ -bonds.
- D Low reactivity of carbon and hydrogen.

Your answer

C

[1]

17 The repeat unit of an addition polymer is shown below.



Which statement about this addition polymer is correct?

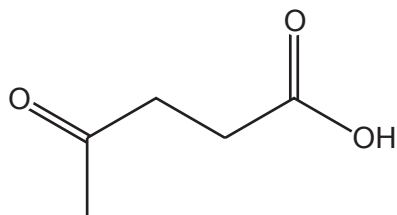
- A Combustion produces toxic alkaline fumes.
- B The addition polymer is biodegradable.
- C The monomer is  $\text{H}_3\text{CCH}=\text{CHCl}$ .
- D The repeat unit above is shown as a displayed formula.

Your answer

C

[1]

18 Which functional groups are present in the compound below?



- A Alcohol and aldehyde.
- B Alcohol and ketone.
- C Carboxylic acid and aldehyde.
- D Carboxylic acid and ketone.

Your answer

D

[1]

19 Which statement about infrared radiation (IR) is **not** correct?

- A Absorption of IR by molecules such as  $\text{CO}_2$ ,  $\text{H}_2\text{O}$  and  $\text{CH}_4$  has been linked to global warming.
- B IR causes CFC molecules to produce chlorine radicals that initiate ozone breakdown in the upper atmosphere.
- C IR causes some covalent bonds to vibrate more and absorb energy.
- D IR is used in modern breathalysers to detect ethanol.

Your answer

B

[1]

20 An alcohol  $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{OH}$  produces a mass spectrum.

The mass spectrum contains a large fragment ion at  $m/z = 45$ .

What is the possible identity of this fragment ion?

- A  $\text{CH}_2\text{CHOH}^+$
- B  $\text{CH}_2\text{CH}_2\text{OH}^+$
- C  $\text{CH}_3\text{CHOH}^+$
- D  $\text{CH}_3\text{CH}_2\text{CH}^+$

Your answer

C

[1]

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**Turn over for Section B**

**10**  
**SECTION B**

**21** This question is about iron.

**(a)** A sample of iron is isolated from a meteorite and analysed by mass spectrometry.

The mass spectrum shows peaks with the relative abundances below.

| Isotope            | $^{54}\text{Fe}$ | $^{56}\text{Fe}$ | $^{57}\text{Fe}$ | $^{58}\text{Fe}$ |
|--------------------|------------------|------------------|------------------|------------------|
| Relative abundance | 78.54%           | 8.88%            | 5.10%            | 7.48%            |

Calculate the relative atomic mass of the iron in the sample.

Give your answer to **2** decimal places.

$$\begin{aligned} A_r &= [(54 \times 78.54) + (56 \times 8.88) + (57 \times 5.10) + (58 \times 7.48)] \div 100 \\ &= 5462.98 \div 100 = 54.6298 \end{aligned}$$

relative atomic mass = .....54.63..... [2]

(b) Iron can be extracted from iron ores containing the oxide  $\text{Fe}_2\text{O}_3$ .

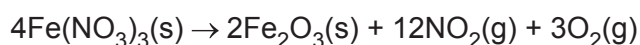
(i) What is the systematic name for  $\text{Fe}_2\text{O}_3$ ?

*iron(III) oxide* ..... [1]

(ii) Balance the equation for the reduction of  $\text{Fe}_2\text{O}_3$  with carbon monoxide.

...1...  $\text{Fe}_2\text{O}_3$  + ...3...  $\text{CO} \rightarrow$  ...2...  $\text{Fe}$  + ...3...  $\text{CO}_2$  [1]

(c) The iron compound,  $\text{Fe}(\text{NO}_3)_3$ , decomposes when heated.  
The equation for the decomposition of  $\text{Fe}(\text{NO}_3)_3$  is shown below.



Molar mass of  $\text{Fe}(\text{NO}_3)_3 = 241.8 \text{ g mol}^{-1}$

4.836 g of  $\text{Fe}(\text{NO}_3)_3$  is heated until it has completely decomposed.

Calculate the **total** volume of gas, in  $\text{dm}^3$ , produced at RTP.

$$n(\text{Fe}(\text{NO}_3)_3) = 4.836 \div 241.8 = 0.0200 \text{ mol}$$

$$n(\text{gas}) = n(\text{NO}_2) + n(\text{O}_2) = (12 + 3) \div 4 \times 0.0200$$

$$= 0.0600 + 0.0150 = 0.0750 \text{ mol}$$

$$\text{total volume} = 0.0750 \times 24.0 = 1.80 \text{ dm}^3$$

total volume of gas = .....1.80.....  $\text{dm}^3$  [3]

22 This question is about the reactions of acids.

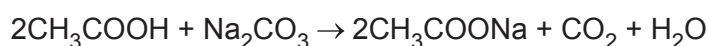
(a) What is the difference between a **strong** acid and a **weak** acid?

*A strong acid fully dissociates (ionises) in solution, but a weak acid only partially dissociates (ionises).* [1]

(b) Ethanoic acid,  $\text{CH}_3\text{COOH}$ , is found in some descalers to soften hard water.

A student carries out a titration with a standard solution of sodium carbonate,  $\text{Na}_2\text{CO}_3$ , to determine the percentage composition by mass of  $\text{CH}_3\text{COOH}$  in a descaler.

The equation is shown below.



(i) The method is outlined below:

- Dissolve 6.50 g of the descaler in distilled water.
- Transfer the solution into a  $250.0\text{ cm}^3$  volumetric flask.
- Make up to the mark with distilled water and invert several times.
- Pipette  $25.0\text{ cm}^3$  of this solution into a conical flask and add a few drops of indicator.
- Titrate this solution with  $0.200\text{ mol dm}^{-3}$   $\text{Na}_2\text{CO}_3(\text{aq})$ , in the burette.

The student carries out a trial titration, followed by further titrations.

The results are shown in the table below.

The trial titration has been omitted.

| Titration                       | 1     | 2     | 3     |
|---------------------------------|-------|-------|-------|
| Final reading / $\text{cm}^3$   | 48.95 | 24.15 | 48.35 |
| Initial reading / $\text{cm}^3$ | 24.55 | 0.00  | 24.10 |
| Titre / $\text{cm}^3$           | 24.40 | 24.15 | 24.25 |

Complete the table by adding the titres.

[1]

- (ii) Calculate the mean titre, to the nearest  $0.05 \text{ cm}^3$ , that the student should use for analysing these results.

*concordant titres (within  $0.10 \text{ cm}^3$ ): 24.15 and 24.25*

$$\text{mean} = (24.15 + 24.25) \div 2 = 24.20 \text{ cm}^3$$

mean titre = .....24.20.....  $\text{cm}^3$  [1]

- (iii) Calculate the percentage composition by mass of  $\text{CH}_3\text{COOH}$  in the descaler.

Assume that  $\text{CH}_3\text{COOH}$  is the only acid in the descaler.

Give your answer to **3** significant figures.

$$n(\text{Na}_2\text{CO}_3) = 0.200 \times 24.20 \div 1000 = 4.84 \times 10^{-3} \text{ mol}$$

$$n(\text{CH}_3\text{COOH}) \text{ in } 25.0 \text{ cm}^3 = 2 \times 4.84 \times 10^{-3} = 9.68 \times 10^{-3} \text{ mol}$$

$$n(\text{CH}_3\text{COOH}) \text{ in } 250.0 \text{ cm}^3 = 10 \times 9.68 \times 10^{-3} = 9.68 \times 10^{-2} \text{ mol}$$

$$M(\text{CH}_3\text{COOH}) = 60.0 \text{ g mol}^{-1}$$

$$\text{mass of } \text{CH}_3\text{COOH} = 60.0 \times 9.68 \times 10^{-2} = 5.808 \text{ g}$$

$$\% \text{ by mass} = (5.808 \div 6.50) \times 100 = 89.35\ldots$$

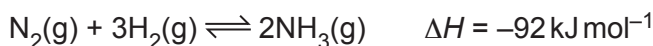
$$= 89.4\% \text{ (3 s.f.)}$$

percentage composition by mass = .....89.4..... % [5]

23 This question is about covalent compounds of nitrogen.

(a) Ammonia,  $\text{NH}_3$ , is manufactured by reacting nitrogen and hydrogen gases.

This is a reversible reaction and the equilibrium is shown below.



(i) This is an example of a dynamic equilibrium.

State 2 features of a dynamic equilibrium.

1 *The rate of the forward reaction equals the rate of the reverse reaction.*

2 *The concentrations of reactants and products remain constant (in a closed system).*

[2]

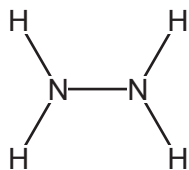
(ii) State and explain the conditions of temperature and pressure that would produce a large equilibrium yield of  $\text{NH}_3$ .

*Temperature: the forward reaction is exothermic ( $\Delta H$  is negative), so a low temperature shifts the position of equilibrium to the right, towards  $\text{NH}_3$ , to oppose the decrease in temperature.*

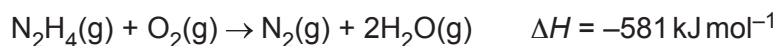
*Pressure: there are fewer gaseous moles on the right-hand side (4 mol of gas form 2 mol of gas), so a high pressure shifts the position of equilibrium to the right, towards  $\text{NH}_3$ , to reduce the pressure.*

[3]

(b) Hydrazine,  $\text{N}_2\text{H}_4$ , shown below, can be used as a rocket fuel.



As a fuel,  $\text{N}_2\text{H}_4$  reacts with oxygen as shown below.



Average bond enthalpies are shown in the table.

| Bond                                        | N–N  | O=O  | N≡N  | O–H  |
|---------------------------------------------|------|------|------|------|
| Average bond enthalpy/ $\text{kJ mol}^{-1}$ | +158 | +498 | +945 | +464 |

Calculate the average bond enthalpy of the N–H bond.

$$\text{bonds broken: } \text{N–N} + 4(\text{N–H}) + \text{O=O} = 158 + 4(\text{N–H}) + 498$$

$$\text{bonds made: } \text{N}\equiv\text{N} + 4(\text{O–H}) = 945 + (4 \times 464) = 2801$$

$$\Delta H = \Sigma(\text{bonds broken}) - \Sigma(\text{bonds made})$$

$$-581 = 158 + 4(\text{N–H}) + 498 - 2801$$

$$4(\text{N–H}) = 2801 - 581 - 158 - 498 = 1564$$

$$\text{N–H} = 1564 \div 4 = +391 \text{ kJ mol}^{-1}$$

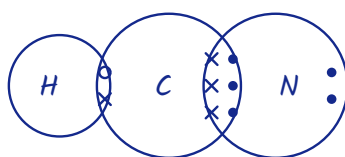
average bond enthalpy of N–H = .....+391.....  $\text{kJ mol}^{-1}$  [3]

(c) Hydrogen cyanide, HCN, is bonded by a single bond between the H and C atoms and a triple bond between the C and N atoms.

Draw a 'dot-and-cross' diagram for a molecule of HCN.

Use different symbols for electrons from H, C and N.

Show outer electrons only.



*o* = H electron

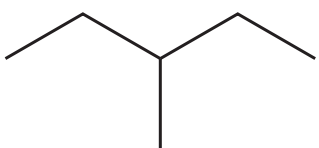
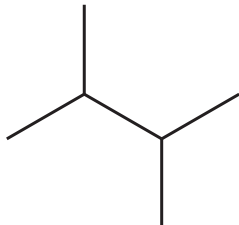
*x* = C electron

*•* = N electron

[2]

24 This question is about hydrocarbons.

(a) The skeletal formulae and boiling points of three isomers of  $C_6H_{14}$  are shown in the table below.

| Isomer   | Molecular formula | Skeletal formula                                                                   | Boiling point/<br>°C |
|----------|-------------------|------------------------------------------------------------------------------------|----------------------|
| <b>A</b> | $C_6H_{14}$       |   | 69                   |
| <b>B</b> | $C_6H_{14}$       |   | 63                   |
| <b>C</b> | $C_6H_{14}$       |  | 58                   |

State and explain the trend in the boiling points shown in the table.

Refer to the isomers **A**, **B** and **C** in your answer.

The boiling point decreases from A (69 °C) to B (63 °C) to C (58 °C) as branching increases: A is unbranched, B has one branch and C has two branches. More branching means fewer points of (surface) contact between the molecules. So there are weaker London forces (induced dipole-dipole interactions) between the molecules of C than B than A. Less energy is needed to overcome the weaker intermolecular forces, so the more branched isomer has the lower boiling point.

[4]

- (b) The hydrocarbon  $C_2H_6$  reacts with bromine,  $Br_2$ , to form  $C_2H_5Br$  under suitable conditions.

Complete the table below to show the mechanism for the three stages of the reaction of  $C_2H_6$  with  $Br_2$  to form  $C_2H_5Br$ .

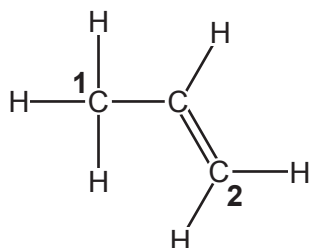
The equation for one of the possible reactions for termination has been completed.

In your equations, use molecular formulae and 'dots' ( $\bullet$ ) with any radicals.

|                    |                                                                                                                                                                                                                                                                                                         |
|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Initiation</b>  | Conditions ... <i>ultraviolet (UV) light</i> .....<br>Equation ..... <i><math>Br_2</math></i> ..... $\rightarrow$ ..... <i><math>2Br\bullet</math></i> .....                                                                                                                                            |
| <b>Propagation</b> | 1 ..... <i><math>C_2H_6 + Br\bullet</math></i> ..... $\rightarrow$ ..... <i><math>C_2H_5\bullet + HBr</math></i> .....<br>2 ..... <i><math>C_2H_5\bullet + Br_2</math></i> ..... $\rightarrow$ ..... <i><math>C_2H_5Br + Br\bullet</math></i> .....                                                     |
| <b>Termination</b> | 1 ..... $Br\bullet + Br\bullet \rightarrow Br_2$ .....<br>2 ..... <i><math>C_2H_5\bullet + Br\bullet</math></i> ..... $\rightarrow$ ..... <i><math>C_2H_5Br</math></i> .....<br>3 ..... <i><math>C_2H_5\bullet + C_2H_5\bullet</math></i> ..... $\rightarrow$ ..... <i><math>C_4H_{10}</math></i> ..... |

[5]

- (c) Propene,  $C_3H_6$ , has different bond angles and shapes around the carbon atoms. The displayed formula of a propene molecule is shown below.



Predict the bond angles and the names of the shapes around the C atoms **1** and **2** above, and explain why the bond angles and shapes are different.

| Carbon atom | Bond angle    | Name of shape          |
|-------------|---------------|------------------------|
| <b>1</b>    | $109.5^\circ$ | <i>tetrahedral</i>     |
| <b>2</b>    | $120^\circ$   | <i>trigonal planar</i> |

Explanation: *Around C1 there are 4 bonded pairs of electrons (4 single bonds), so the shape is tetrahedral and the bond angle is  $109.5^\circ$ .*  
*Around C2 there are 3 bonded regions of electrons (2 single bonds and 1 double bond), so the shape is trigonal planar and the bond angle is  $120^\circ$ .*  
*The electron pairs (bonded pairs) repel each other and arrange themselves as far apart as possible to minimise repulsion.*

[5]

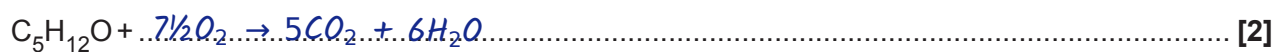
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**Turn over for the next question**

25 Three alcohols, **A**, **B** and **C**, are structural isomers with the molecular formula  $C_5H_{12}O$ .

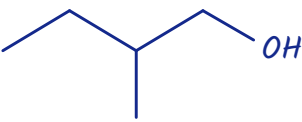
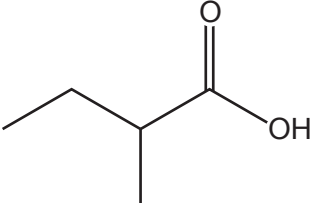
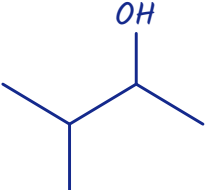
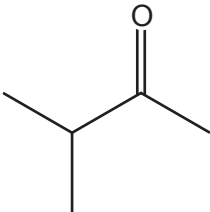
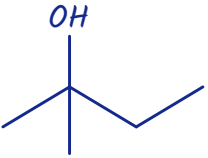
(a) **A**, **B** and **C** take part in combustion reactions.

Complete the equation for the complete combustion of  $C_5H_{12}O$ .



(b) Alcohols **A**, **B** and **C** are each refluxed with acidified dichromate(VI),  $H^+/Cr_2O_7^{2-}$ .  
The organic products are shown in the table below.

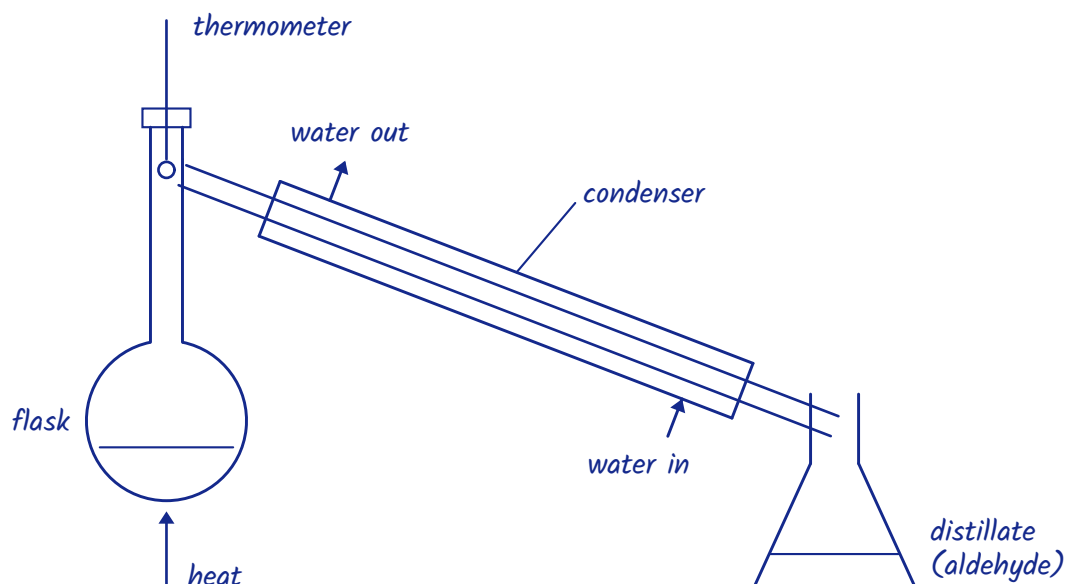
Complete the table to show the structures of alcohols **A**, **B** and **C**.

| Alcohol  | Structure of alcohol                                                                | Organic product after refluxing with $H^+/Cr_2O_7^{2-}$                              |
|----------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <b>A</b> |    |   |
| <b>B</b> |   |  |
| <b>C</b> |  | No reaction                                                                          |

[3]

- (c) Primary alcohols can be oxidised under distillation to make aldehydes.

Draw a labelled diagram to show how you would set up apparatus for distillation.



[2]

- (d) Alcohols can be prepared by the hydrolysis of haloalkanes with aqueous alkali.

- (i) Write an equation for the hydrolysis of 2-bromo-2-methylpropane.

Show organic compounds as structures.



[2]

- (ii) A student hydrolyses a chloroalkane,  $\text{RCl}$ , a bromoalkane,  $\text{RBr}$ , and an iodoalkane,  $\text{RI}$ .

For a fair comparison, the student has chosen the same R group for each haloalkane.

Predict, with a reason, the relative rates of hydrolysis of these three haloalkanes.

*Rate of hydrolysis: RI fastest > RBr > RCl slowest.*

*Bond enthalpy  $\text{C-Cl} > \text{C-Br} > \text{C-I}$ ; the  $\text{C-I}$  bond is the weakest, so it is broken most easily. (and  $\text{C-Cl}$  is the strongest, so it breaks most slowly).*

[2]

**END OF QUESTION PAPER**

[illegible]



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