Surname	StemUp Model Solution	Centre Number	Candidate Number
Other Names			2

GCE AS – NEW AS

B410U10-1

S16-B410U10-1

CHEMISTRY – Component 1
The Language of Chemistry, Structure of Matter and Simple Reactions

A.M. FRIDAY, 27 May 2016

1 hours 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 8.**	**10**	
Section B	**9.**	**10**	
	10.	**12**	
	11.	**10**	
	12.	**12**	
	13.	**14**	
	14.	**12**	
	Total	**80**	

B410U101
01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:
- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions in the spaces provided.
Section B Answer **all** questions in the spaces provided.

Candidates are advised to allocate their time appropriately between **Section A (10 marks)** and **Section B (70 marks)**.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q.12***(a)*.

If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

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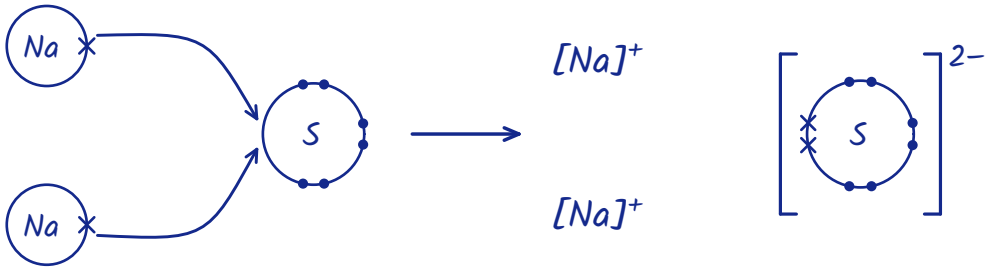
SECTION A

Answer **all** *questions in the spaces provided.*

1. Complete the electronic structure for a vanadium, V, atom. [1]

$1s^2 2s^2$ $2p^6 3s^2 3p^6 3d^3 4s^2$

2. Draw a dot and cross diagram to show the formation of sodium sulfide. Show the outer electrons only. [2]



3. Complete the equation below to show one form of radioactive decay. [1]

$^{23}_{12}Mg \longrightarrow {}^{23}_{11}Na + e^+$

4. Hydrogen sulfide reacts with sulfur dioxide.

$$2H_2S(g) + SO_2(g) \longrightarrow 2H_2O(l) + 3S(s)$$

Show, using oxidation states, that this is a redox reaction. [1]

S in H_2S is −2 and is oxidised to 0 in S; S in SO_2 is +4 and is reduced to 0 in S, so it is redox.

5. What is meant by the *Avogadro constant*? [1]

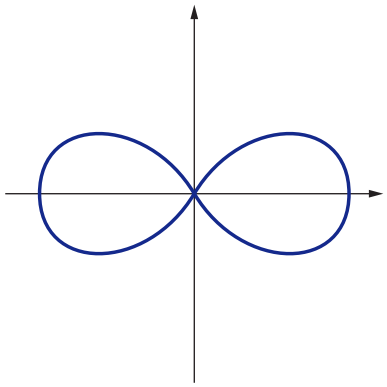
The number of particles (atoms, ions or molecules) in one mole of a substance; the number of atoms in exactly 12 g of ^{12}C (6.02×10^{23} mol^{-1}).

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6. Draw the shape of a 2p orbital on the axes below. [1]



7. Aspirin can be prepared by the reaction shown below.

$$C_6H_4(OH)COOH + (CH_3CO)_2O \longrightarrow \underset{\text{aspirin}}{C_6H_4(OCOCH_3)COOH} + CH_3COOH$$

Calculate the atom economy of this reaction. [2]

M_r $C_6H_4(OH)COOH$ = 138.06; M_r $(CH_3CO)_2O$ = 102.06

total M_r of reactants = 138.06 + 102.06 = 240.12

M_r aspirin $C_6H_4(OCOCH_3)COOH$ = 180.08

atom economy = (180.08 ÷ 240.12) × 100 = 75.0%

Atom economy = 75.0 %

8. Give a reason why some covalent bonds are polar. [1]

The two atoms have different electronegativities, so the bonding pair of electrons is pulled closer to the more electronegative atom.

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SECTION B

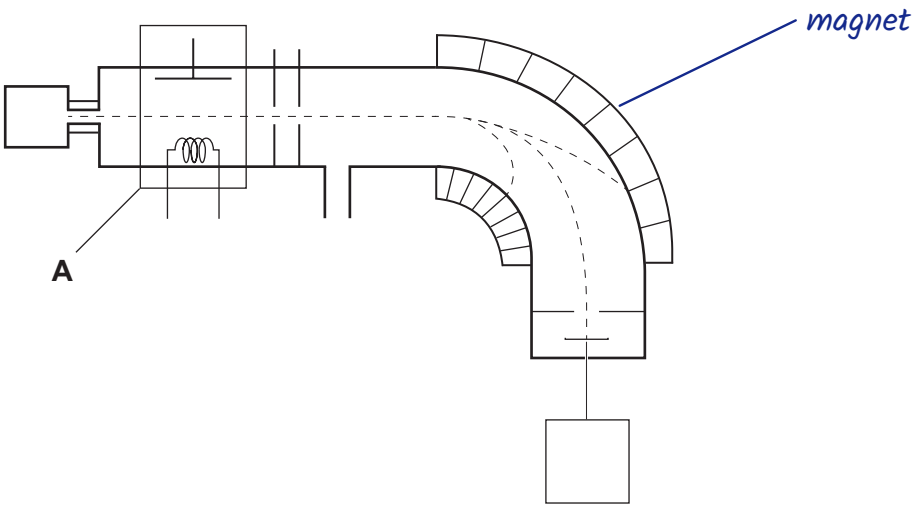
Answer **all** *questions in the spaces provided.*

9. A mass spectrometer can be used to find relative atomic mass, A_r, and relative molecular mass, M_r.

(a) Define *relative atomic mass*. [2]

The average (weighted mean) mass of one atom of the element, taking account of its isotopes, on a scale where one atom of ^{12}C has a mass of exactly 12.

(b) The diagram shows one type of mass spectrometer.



(i) On the diagram label the magnet. [1]

(ii) Explain what is happening in the mass spectrometer in the region labelled **A**. [2]

Ionisation: atoms are bombarded with high energy electrons from an electron gun. Electrons are knocked off, forming positive ions: $M(g) + e^- \rightarrow M^+(g) + 2e^-$

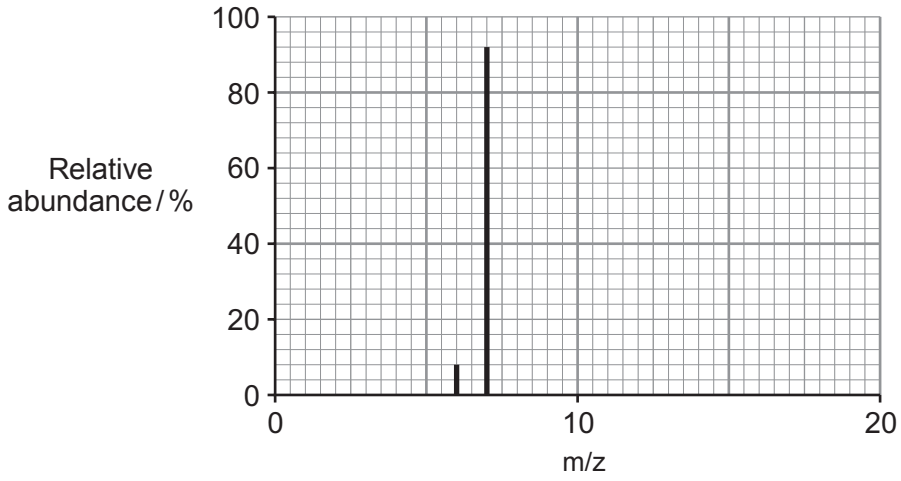
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(c) The mass spectrum below was obtained from a sample of lithium.

Use the spectrum to calculate the relative atomic mass for this sample of lithium. Give your answer to **three** significant figures. [2]



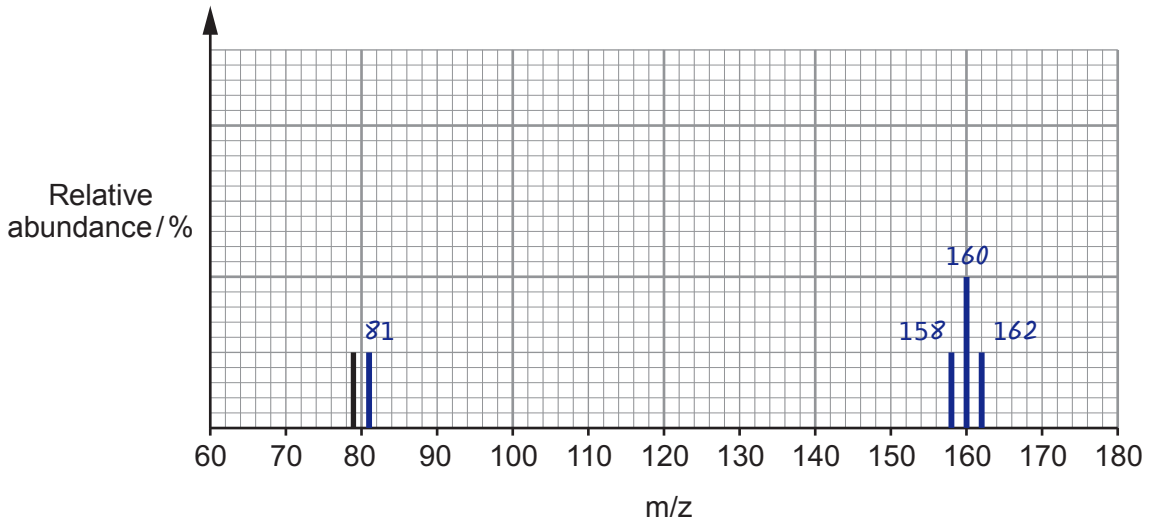
From the spectrum: ^{6}Li = 8% and ^{7}Li = 92%

A_r = [(6 × 8) + (7 × 92)] ÷ 100 = (48 + 644) ÷ 100

A_r = 6.92

Relative atomic mass = *6.92*

(d) Bromine exists as two isotopes with mass numbers 79 and 81. In a sample of bromine, Br_2, there are approximately the same amounts of each isotope. On the mass spectrum below, sketch lines to complete the mass spectrum that this sample of bromine would be expected to give. [3]



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10. Using ideas that you have studied in your Chemistry course comment on and explain the following observations.

(a) In sodium chloride and caesium chloride the arrangements of the particles in the solids are different. [4]

NaCl has a face-centred cubic (rock salt) lattice: each Na^+ is surrounded by 6 Cl^- ions and each Cl^- by 6 Na^+ ions, so 6:6 coordination.

CsCl has a body-centred cubic lattice: each Cs^+ is at the centre of a cube of 8 Cl^- ions (and vice versa), so 8:8 coordination.

This is because the Cs^+ ion is much bigger than the Na^+ ion, so more Cl^- ions can fit around it.

(b) Hydrogen sulfide, H_2S, is a gas at room temperature and pressure but water, H_2O, is a liquid under the same conditions. [4]

For a liquid to boil, the intermolecular forces between the molecules must be broken. O is very electronegative, so H_2O molecules are held together by hydrogen bonds.

S is less electronegative, so H_2S cannot form hydrogen bonds; its molecules are held by van der Waals forces only.

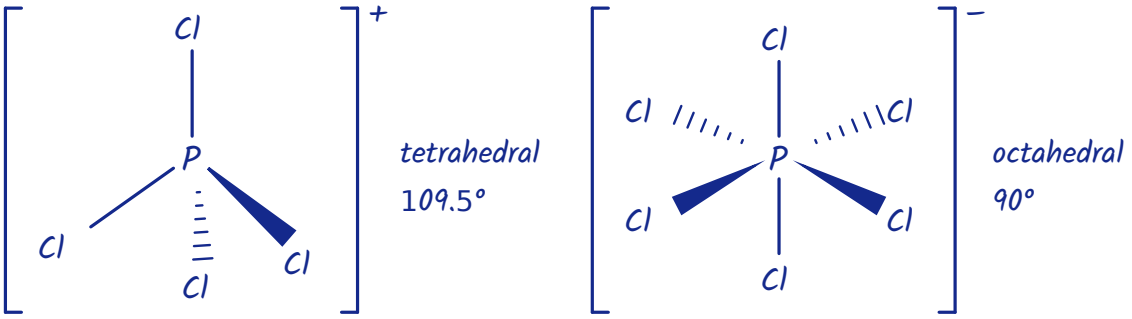
Van der Waals forces are weaker than hydrogen bonds, so less energy is needed to separate H_2S molecules and it is a gas.

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(c) The bond angles in the PCl_4^+ ion are greater than the bond angles in the PCl_6^- ion. [4]



PCl_4^+: P has 4 bonding pairs and no lone pairs, so the ion is tetrahedral with bond angles of 109.5°.

PCl_6^-: P has 6 bonding pairs and no lone pairs, so the ion is octahedral with bond angles of 90°.

Electron pairs repel and arrange themselves as far apart as possible (minimum repulsion), so with more pairs the angles are smaller.

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11. **X** and **Y** are metals that are in the **same group** of the Periodic Table. Aqueous solutions of a salt of each metal were added to three aqueous laboratory reagents. The observations made are shown in the table.

	$H_2SO_4(aq)$	NaOH(aq)	$Cl_2(aq)$
Salt of **X**	white precipitate	no visible reaction	orange/brown solution
Salt of **Y**	no visible reaction	white precipitate	orange/brown solution

(a) Suggest the identity of metal **X** and metal **Y**. Explain your reasoning. [3]

X is barium, Ba^{2+}

Y is magnesium, Mg^{2+}

Explanation

X forms an insoluble sulfate but Y forms an insoluble hydroxide. Down Group 2, sulfates become less soluble and hydroxides become more soluble.

(b) (i) Using the symbol **X** for the metal, write the **ionic** equation for the reaction of the salt of **X** with dilute sulfuric acid. Include state symbols. [1]

$X^{2+}(aq) + SO_4^{2-}(aq) \rightarrow XSO_4(s)$

(ii) Using the symbol **Y** for the metal, write the **ionic** equation for the reaction of the salt of **Y** with aqueous sodium hydroxide. Include state symbols. [1]

$Y^{2+}(aq) + 2OH^-(aq) \rightarrow Y(OH)_2(s)$

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(c) (i) Explain what happens when aqueous chlorine is added to solutions of the salts of **X** and **Y**. [3]

You should include:

- the identity of the orange/brown product
- the nature of the reaction occurring
- a suggested identity for the anion present in both salts

The orange/brown product is bromine, Br_2.

Chlorine is a stronger oxidising agent than bromine, so a redox (displacement) reaction occurs: $Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$

So the anion present in both salts is bromide, Br^-.

(ii) Describe a test that you could carry out on the salt solutions to confirm the identity of this anion. Include the observation expected in the test. [2]

Add dilute nitric acid and then aqueous silver nitrate, $AgNO_3(aq)$, to each salt solution.

A cream precipitate of AgBr forms, which is partially soluble in (dilute) ammonia solution, confirming Br^-.

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12. David said that sodium compounds give a yellow flame test because the heat makes the atoms move faster. He also said that the yellow flame was the sodium absorption spectrum consisting of one line because the atoms take in light of just one energy.

(a) Discuss how far you agree with David's statement and correct any errors which he has made. You should include the chemical principles involved. [6 QER]

David is partly wrong. The heat does not just make the atoms move faster: energy from the flame is absorbed by electrons in the sodium atoms, which are excited (promoted) from the ground state to higher energy levels.

The excited electrons are unstable and fall back to lower energy levels, emitting the energy difference as light of a definite frequency ($\Delta E = hf$). So the yellow flame is an emission spectrum, not an absorption spectrum. It is yellow because the energy emitted by the main transition in sodium is in the yellow part of the visible spectrum.

The spectrum does not have just one line: electrons can fall between many different energy levels, and each transition gives a line of a different energy. So the sodium spectrum is a series of lines that get closer together (converge) as the energy increases, because the energy levels get closer together. He is right only that each line has one fixed energy, as energy levels are quantised.

(b) A white solid is known to be either a magnesium or a potassium compound. Describe how you could carry out a flame test to identify the metal ion present. You should include the expected result for each compound. [2]

Dip a clean nichrome wire, moistened with conc. HCl, into the solid and hold it in a blue Bunsen flame.

Potassium gives a lilac flame; magnesium gives no colour (colourless).

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(c) (i) A line in a visible spectrum was observed at a wavelength of 500 nm. Calculate the energy involved in the formation of this line. Give your answer with its unit and in standard form. [3]

$E = hc/\lambda$

$E = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) \div (500 \times 10^{-9})$

$E = 3.98 \times 10^{-19}$ J

Energy = 3.98×10^{-19}

Unit = J

(ii) A line in another spectrum was found to have a higher energy associated with its formation so that it was no longer visible. In which part of the electromagnetic spectrum would it be found? [1]

Ultraviolet (UV) region

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13. *(a)* A student was told that a bottle of hydrochloric acid he was given was approximately of concentration 0.1 mol dm^{-3}. He was asked to determine the accurate concentration of the acid using a titration method. He had access to solid anhydrous sodium carbonate, Na_2CO_3, and the apparatus normally found in a school or college laboratory.

(i) Write the equation for the reaction between sodium carbonate and hydrochloric acid. [1]

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$

(ii) Describe how the student should carry out the determination of the concentration of the acid. You should include the apparatus required and the **masses** and **volumes** of any chemicals used.

I. Outline the preparation of a solution of sodium carbonate suitable for use in a titration against the hydrochloric acid. [3]

HCl reacts 2:1 with Na_2CO_3, so for 0.1 mol dm^{-3} HCl a solution of about 0.05 mol dm^{-3} Na_2CO_3 is needed.

M_r Na_2CO_3 = 106, so weigh accurately about 5.30 g per dm^3, i.e. 1.33 g for 250 cm^3.

Dissolve it in deionised water in a beaker, transfer the solution and all washings to a 250 cm^3 volumetric flask, make up to the mark and invert to mix.

II. Describe how the student should carry out the titration to determine the concentration of the acid. You do not need to describe how the apparatus is cleaned or set up. [3]

Pipette 25.0 cm^3 of the sodium carbonate solution into a conical flask and add a few drops of methyl orange indicator.

Add the hydrochloric acid from a burette, swirling, until the indicator just changes colour (yellow to orange): this is the end-point.

Repeat to get concordant titres (within 0.10 cm^3) and use the mean titre to calculate [HCl].

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(b) The student found in *(a)* that the hydrochloric acid had a concentration of 0.110 mol dm^{-3}. Calculate the pH of this solution. [2]

$pH = -\log[H^+]$

$pH = -\log(0.110)$

pH = 0.96

(c) Another student was given a sample of ore containing compounds of silver and was asked to find the percentage of silver in the ore.

He dissolved 2.48 g of the silver ore in nitric acid and added excess of the hydrochloric acid to precipitate the silver as silver chloride. He filtered off the precipitate of silver chloride and found its mass.

(i) State how the precipitate was treated in order to obtain the mass of the silver chloride. Explain why the precipitate was treated in this way. [2]

It was washed with distilled water and dried (heated to constant mass).

Washing removes soluble impurities (excess acid); heating to constant mass ensures all water is removed.

(ii) Write the **ionic** equation for the formation of this precipitate. Include state symbols. [1]

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

(iii) The mass of silver chloride obtained was 0.93 g. Calculate the percentage of silver in the ore. [2]

$M_r\ AgCl = 108 + 35.5 = 143.5$

mass of Ag = $(108 \div 143.5) \times 0.93 = 0.700$ g

% Ag = $(0.700 \div 2.48) \times 100 = 28.2\%$

Percentage = 28.2 %

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14. Emily was investigating the reversible reaction between methanol and ethanoic acid.

$$CH_3OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOCH_3(l) + H_2O(l) \quad \textbf{Reaction 1}$$

She followed these instructions.

- Heat 16.0 g of methanol with 36.0 g of ethanoic acid under reflux for one hour so that the reaction reaches equilibrium.
- Titrate the contents of the flask with aqueous sodium hydroxide. Complete this titration as quickly as possible.
- Note the volume of alkali used.

The equation for the reaction with sodium hydroxide is as follows.

$$CH_3COOH(l) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$$

(a) Write the expression for the equilibrium constant, K_c, for the reaction between methanol and ethanoic acid, **Reaction 1**. [1]

$$K_c = \frac{[CH_3COOCH_3]\,[H_2O]}{[CH_3COOH]\,[CH_3OH]}$$

(b) Emily calculated that she had used 0.220 mol of sodium hydroxide in her titration. How many moles of ethanoic acid were present in the flask at equilibrium? [1]

$CH_3COOH : NaOH = 1 : 1$

moles CH_3COOH = moles $NaOH$ = 0.220 mol

Number of moles of acid = 0.220

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(c) Emily also calculated that there were 0.12 mol of methanol in the flask at equilibrium. Her teacher told her that the equilibrium constant, K_c, for this reaction is 5.47.

Emily looks at the equation for the equilibrium and sees that the number of moles of ester, CH_3COOCH_3, and water at equilibrium would be the same.

Use these data, and the value found in *(b)*, to calculate the number of moles of ester present at equilibrium. In this reaction you should assume that the concentration, in mol dm^{-3}, is equal to the number of moles of each substance present. [3]

let x = moles of ester = moles of water at equilibrium

$K_c = x^2 \div (0.12 \times 0.220) = 5.47$

$x^2 = 5.47 \times 0.12 \times 0.220 = 0.144$

$x = \sqrt{0.144} = 0.38$ mol

Number of moles of ester = 0.38

(d) Another student carried out a similar experiment to that above to determine the value of the equilibrium constant, K_c. However he refluxed the mixture for only 30 minutes. When he calculated the value of K_c he found it to have a significantly lower value than that found in data books.

Give a possible explanation for the difference in the value of K_c. [1]

The reaction had not reached equilibrium after only 30 minutes, so less ester and water had formed.

(e) Explain why the heating should be carried out under reflux. [1]

To avoid loss of the volatile reagents (and products) by evaporation while the mixture is heated.

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(f) (i) Explain why the instructions said that the titration should be completed as quickly as possible. [2]

Water is added (in the aqueous NaOH) during the titration. If left too long, the ester would be hydrolysed (the reverse reaction would occur), forming more ethanoic acid to react with the NaOH.

(ii) What would be the effect on the value of K_c that Emily calculated if she took a long time carrying out the titration? Explain your answer. [1]

K_c would decrease, because there would be fewer moles of ester (and more moles of acid and alcohol) calculated.

(g) The value of K_c for this reaction decreases if the temperature at which it is carried out increases.

Deduce whether the forward reaction is exothermic or endothermic. Explain your reasoning. [2]

The forward reaction is exothermic. A decrease in K_c means the equilibrium moves to the left as temperature rises; higher temperature favours the endothermic (reverse) direction.

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END OF PAPER

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