Write your name here

Surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number | Candidate Number

Chemistry

Advanced

Paper 3: General and Practical Principles in Chemistry

Wednesday 20 June 2018 – Morning

Time: 2 hours 30 minutes

Paper Reference **9CH0/03**

Candidates must have: **Data Booklet**
Scientific calculator
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

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P 5 2 3 0 4 A 0 1 3 2

Pearson

Answer ALL questions.

Write your answers in the spaces provided.

1 This question is about some halogens and their compounds.

(a) The intermolecular attractions between halogen molecules are London forces.

(i) Describe how London forces form between halogen molecules.

(3)

(ii) The boiling temperatures of chlorine and bromine are shown in the table.

Halogen	Boiling temperature / °C
chlorine	−34
bromine	59

Explain why bromine has a higher boiling temperature than chlorine.

(2)

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(b) A student carries out experiments to determine the order of reactivity of three halogens: bromine, chlorine and iodine.
The student is provided with aqueous solutions of the following five substances:

- bromine
- iodine
- potassium chloride
- potassium bromide
- potassium iodide.

The student has **no** access to chlorine gas or chlorine water.
The student uses cyclohexane, an organic solvent, to identify the halogen present at the end of each experiment.

The student carries out the **smallest** number of experiments required to determine the order of reactivity of the halogens.

Describe the experiments and the expected observations.

Include in your answer **ionic** equations for any reactions that occur.

State symbols are **not** required.

(5)

(Total for Question 1 = 10 marks)

2 This question is about lactic acid (2-hydroxypropanoic acid), $CH_3CH(OH)COOH$.
Lactic acid is used to make biodegradable polymers.

(a) Lactic acid can be made in a two-step synthesis starting from ethanal, CH_3CHO.

Devise a reaction scheme for a two-step synthesis.

Include in your answer all reagents and conditions, the type of reaction occurring at each step, and a balanced equation for each reaction.
State symbols are **not** required.

(7)

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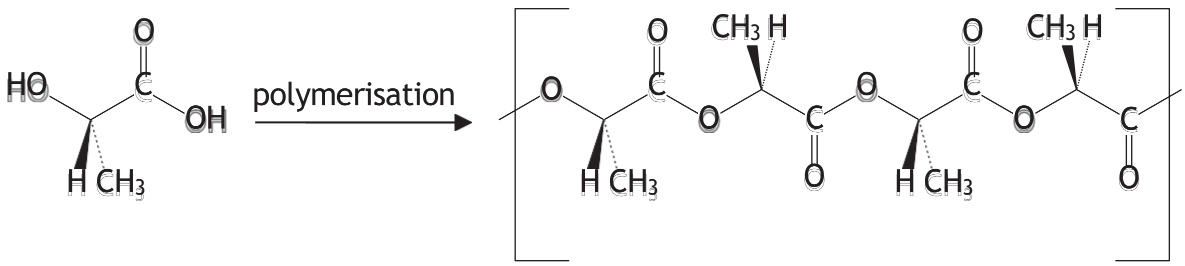
(b) Polymerisation of lactic acid forms poly(lactic acid) as shown in the diagram.



(i) State the type of polymerisation occurring in this reaction.

(1)

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(ii) **On the diagram**, draw a circle around the repeat unit of the polymer.

(1)

(Total for Question 2 = 9 marks)

3 This question is about the identification of a Group 2 carbonate.

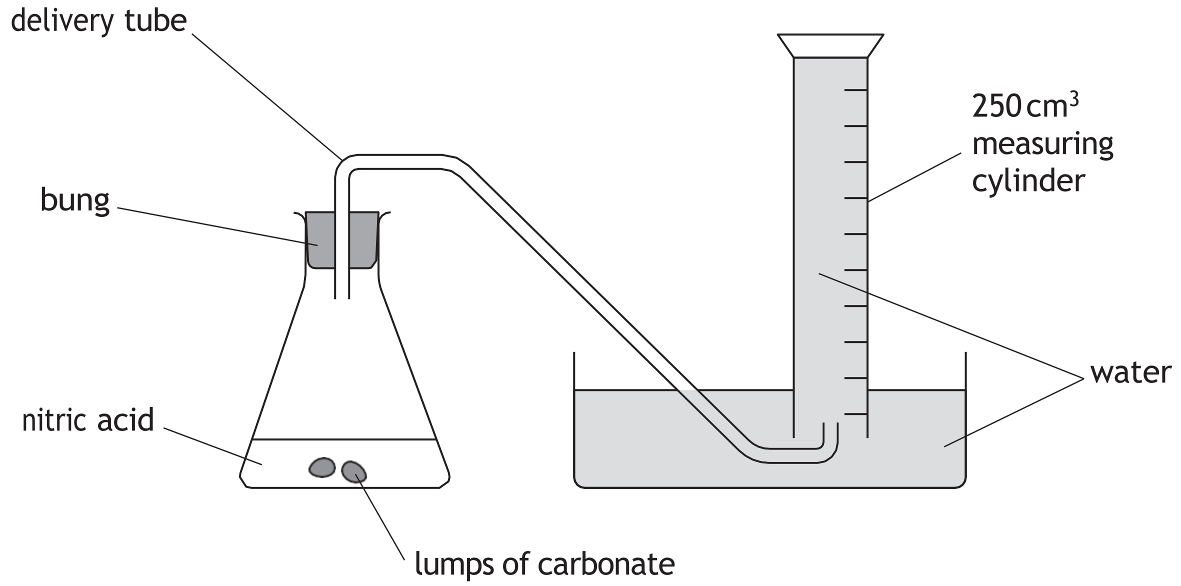
A chemistry teacher found a bottle containing lumps of a white solid. The original label was missing from the bottle. However, someone had written 'Group 2 carbonate' on the bottle. The lumps of the anhydrous white solid were pure and dry.

The chemistry teacher tried to identify the carbonate with the help of three students. The three students worked under identical conditions and shared the same weighing balance.

Student **1** recognised that if an acid is added to a carbonate, carbon dioxide is evolved. The student decided to measure the volume of carbon dioxide evolved when the Group 2 carbonate reacts with excess nitric acid.

The student knew that 1 mol of a Group 2 carbonate produces 1 mol of carbon dioxide.

Student **1** set up the apparatus shown below.



- Student **1** weighed out some of the Group 2 carbonate and added it to a 250 cm^3 conical flask.
- Student **1** then added 100 cm^3 of 0.200 mol dm^{-3} nitric acid to the conical flask and replaced the bung.
- Student **1** measured the volume of gas collected in the inverted measuring cylinder at room temperature and pressure (r.t.p.) when all the Group 2 carbonate had reacted.
- Student **1** obtained the results shown in Table 1.

Measurement		Value
Mass of weighing bottle and carbonate	/ g	13.247
Mass of empty weighing bottle	/ g	12.431
Mass of carbonate used	/ g	....
Volume of acid used	/ cm^3	100
Volume of gas collected	/ cm^3	225

Table 1

(a) Complete Table 1 to show the mass of the carbonate used.

(1)

(b) Calculate the amount, in moles, of carbon dioxide collected in the measuring cylinder at r.t.p.

(1)

(c) Calculate the molar mass of the Group 2 carbonate to an appropriate number of significant figures and hence deduce the identity of the Group 2 metal.

(4)

(d) Student **2** carried out the same experiment as Student **1**, using the same mass of the Group 2 carbonate.
Student **2** made no errors in their measurements or calculations but obtained a value for the molar mass which was 10 g mol^{-1} greater than the value obtained by Student **1**.

(i) Explain **one** procedural error which could have resulted in Student **2** obtaining a molar mass greater than that of Student **1**.

(2)

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(ii) It was later discovered that Student **2** had used 110 cm^3 of 0.200 mol dm^{-3} dilute nitric acid, instead of 100 cm^3 of 0.200 mol dm^{-3} dilute nitric acid.

Give a reason why this mistake would **not** have affected Student **2**'s result.

No calculation is required.

(1)

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(iii) The teacher noticed that Student **2** had used the Group 2 carbonate in powdered form rather than in lumps.
Explain how, if at all, this would affect the rate of reaction and the final volume of gas produced in the reaction.

(2)

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(e) Student **3** suggested a different experiment.

Student **3** realised that, by heating the carbonate, carbon dioxide would be lost and an oxide would remain.

Student **3** decided to measure the change in mass of the carbonate and to use this information to calculate its molar mass.

- Student **3** weighed an empty test tube.
- Using a spatula, Student **3** added some of the carbonate to the test tube.
- The test tube containing the carbonate was then weighed.
- The test tube and its contents were heated to constant mass.
- The results obtained by Student **3** are shown in Table 2.

Measurement		Value
Mass of carbonate + test tube	/ g	20.447
Mass of oxide + test tube	/ g	20.205
Mass of empty test tube	/ g	19.996

Table 2

(i) Write an equation, including state symbols, for the thermal decomposition of a Group 2 carbonate, MCO_3, where M represents the metal.

(1)

(ii) Using Student **3**'s results, calculate the molar mass of the Group 2 carbonate.

(3)

(f) Student **3** used the same balance as Student **1**.

Give a reason why the mass of the carbonate measured by Student **3** has a greater percentage uncertainty than that measured by Student **1**.

(1)

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(g) Student **3** noticed that on heating the test tube some solid was lost. Explain how this would affect the calculated value for the molar mass of the Group 2 carbonate.

(2)

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(Total for Question 3 = 18 marks)

4 This question is about the use of NMR spectroscopy to distinguish between isomers of $C_6H_{12}O_2$.

(a) Tetramethylsilane (TMS) is a compound used as a standard when recording both ^{1}H and ^{13}C NMR spectra.

(i) Give the structural formula of TMS.

(1)

(ii) TMS is an inert and non-toxic compound. State **two** other reasons why TMS is suitable for use as a standard when recording NMR spectra.

(2)

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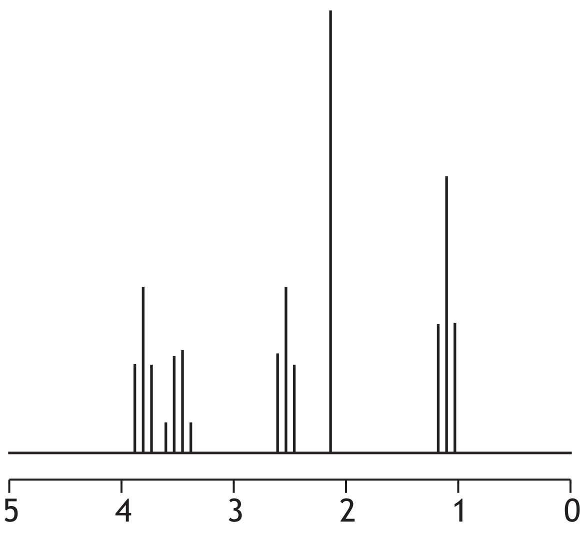
(b) **(i)** Draw the structural formulae of the **two** esters with formula $C_6H_{12}O_2$ that each have only **two** peaks, both singlets, in their high resolution **proton** NMR spectra. The relative peak areas are 3:1 for both esters.

(2)

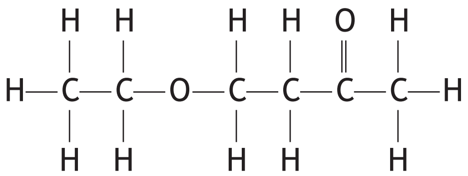
(ii) The high resolution **proton** NMR spectrum of another isomer of $C_6H_{12}O_2$ is shown.



The ratios of the number of protons for the five sets peaks in the spectrum are given in the table.

δ / ppm	3.8	3.5	2.6	2.2	1.2
Ratio of the number of protons	2	2	2	3	3

Show that **all** these data are consistent with the displayed formula shown.
Refer to the five chemical shifts and explain **two** of the splitting patterns.



(5)

(c) (i) There are three other isomers of $C_6H_{12}O_2$ which are carboxylic acids with **five** peaks in their **carbon-13** NMR spectra.

Draw the structural formula of **two** of these isomers.

(2)

a.ellis-frost
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in order to increase the answer space for c(i) by 2cms we have reduced the answer space in c(ii) by 2 cms - please advise if this is ok?

(ii) Draw the **skeletal** formula of a cyclic diol isomer of $C_6H_{12}O_2$ that has only **two** peaks in its **carbon-13** NMR spectrum.

(1)

(Total for Question 4 = 13 marks)

5 This question is about the properties of transition elements, their ions and their complexes.

(a) Give the oxidation state of vanadium in the compound NH_4VO_3.

(1)

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(b) Excess zinc powder is added to an acidified solution of the compound NH_4VO_3. Using the data in the table, explain the sequence of reactions that takes place.

In your answer, include a description of what you would **see**, and the relevant ionic equations with their calculated $E^{\ominus}_{cell}$ values. State symbols are not required.

(7)

Electrode system	$E^{\ominus}$ / V
$V^{2+}(aq) + 2e^- \rightleftharpoons V(s)$	−1.18
$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	−0.26
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.34
$VO_3^-(aq) + 4H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + 2H_2O(l)$	+1.00
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76

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(c) Explain how vanadium(V) oxide acts as a catalyst in one step of the contact process. The equation for this step is

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(2)

*(d) Describe the reactions of separate portions of aqueous copper(II) ions with aqueous sodium hydroxide solution, with excess aqueous ammonia solution and with concentrated hydrochloric acid.

In your answer you should link observations with equations which include the formulae of any copper-containing complex ions. Include state symbols.

(6)

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(Total for Question 5 = 16 marks)

6 This question is about the analysis of an unknown carboxylic acid **X** by three students.

The students analyse the mass spectrum of **X** and find that it has a molecular ion peak at $m / z = 116$.

The three students each propose a different structural formula for compound **X**.

Structure 1 HOOCCH═CHCOOH

Structure 2 $HOCH_2CH{=}CHCH_2COOH$

Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$

(a) The students are given the infrared spectrum of **X**.

(i) State **two** wavenumber ranges of the infrared absorptions providing evidence that compound **X** is a carboxylic acid. Include the bonds responsible.

(2)

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(ii) One of the students suggests that this infrared spectrum and the data in the Data Booklet **alone** could be used to identify which of the three proposed structures is **X**.

Show that this student's suggestion is correct. Include relevant infrared data in your answer.

(3)

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(b) The students decide to carry out an acid-base titration to obtain further information about compound **X**.
Each student uses solid sodium hydroxide, NaOH, to prepare a solution of concentration 0.140 mol dm^{-3}.

Calculate the mass, in grams, of solid sodium hydroxide that each student should weigh out to prepare 250.0 cm^3 of a 0.140 mol dm^{-3} solution.

(2)

(c) Each of the students makes up 250.0 cm^3 of 0.140 mol dm^{-3} sodium hydroxide solution in a volumetric flask and titrates this solution with the same solution of **X** of known concentration.

Student A

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution and pipettes a volume of 10.0 cm^3 of the solution into a conical flask
- fills a burette with the solution of **X** and carries out a titration
- repeats the procedure until obtaining concordant results
- obtains a mean titre of 10.20 cm^3.

Student B

- dissolves the sodium hydroxide in distilled water and transfers the solution to a volumetric flask
- adds more distilled water to the volumetric flask and mixes the solution
- notices that the volumetric flask has been filled with distilled water several cm^3 beyond the graduation mark
- realises the mistake, removes the extra solution and discards it
- pipettes 10.0 cm^3 of the sodium hydroxide solution into a conical flask and titrates this with the solution of **X**.

Student C

- correctly prepares the 0.140 mol dm^{-3} sodium hydroxide solution
- washes a conical flask thoroughly with distilled water and pipettes 10.0 cm^3 of the sodium hydroxide solution into the wet conical flask
- titrates the contents of the conical flask with the solution of **X**.

(i) Explain how, if at all, Student **B**'s mistake affects the value of the titre.

(2)

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(ii) Explain how, if at all, Student **C**'s use of a wet conical flask affects the value of the titre.

(2)

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(iii) Student **A** uses three pieces of apparatus to measure volumes in this experiment.

- The burette has an uncertainty of $\pm 0.05\,cm^3$ for each volume reading
- The volumetric flask has an uncertainty of $\pm 0.30\,cm^3$ for the volume
- The pipette has an uncertainty of $\pm 0.04\,cm^3$ for the volume

Show by calculation which volume measurement has the lowest percentage uncertainty.

(3)

(d) Student **A** calculates the correct value for the molar mass of compound **X**, using the mean titre of 10.20 cm^3. The results indicate that **X** has **structure 1**.

Structure 1 HOOCCH═CHCOOH

Structure 2 $HOCH_2CH{=}CHCH_2COOH$

Structure 3 $CH_3CH_2CH_2CH_2CH_2COOH$

(i) Write the equation for the reaction between **structure 1** and sodium hydroxide solution. State symbols are not required.

(2)

(ii) Deduce the value that would have been obtained for the mean titre if the structural formula of **X** had been **structure 2**.
Justify your answer.

(2)

(e) The students could have identified the three structures using chemical tests.

Complete the table to show whether or not the suggested structures react with bromine water and when heated with acidified potassium dichromate(VI).

Use a tick (✓) if a reaction occurs.

Use a cross (✗) if no reaction occurs.

(2)

Structure	Test with bromine water	Test with acidified potassium dichromate(VI)
HOOCCH═CHCOOH		
$HOCH_2CH{=}CHCH_2COOH$		
$CH_3CH_2CH_2CH_2CH_2COOH$		

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(f) The structure HOOCCH ═CHCOOH has two stereoisomers.

(i) Draw the structures of these stereoisomers.

(2)

***E*-isomer**

***Z*-isomer**

(ii) State why HOOCCH ═CHCOOH has *E*/*Z* isomers.

(2)

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(Total for Question 6 = 24 marks)

7 This question is about weak acids.

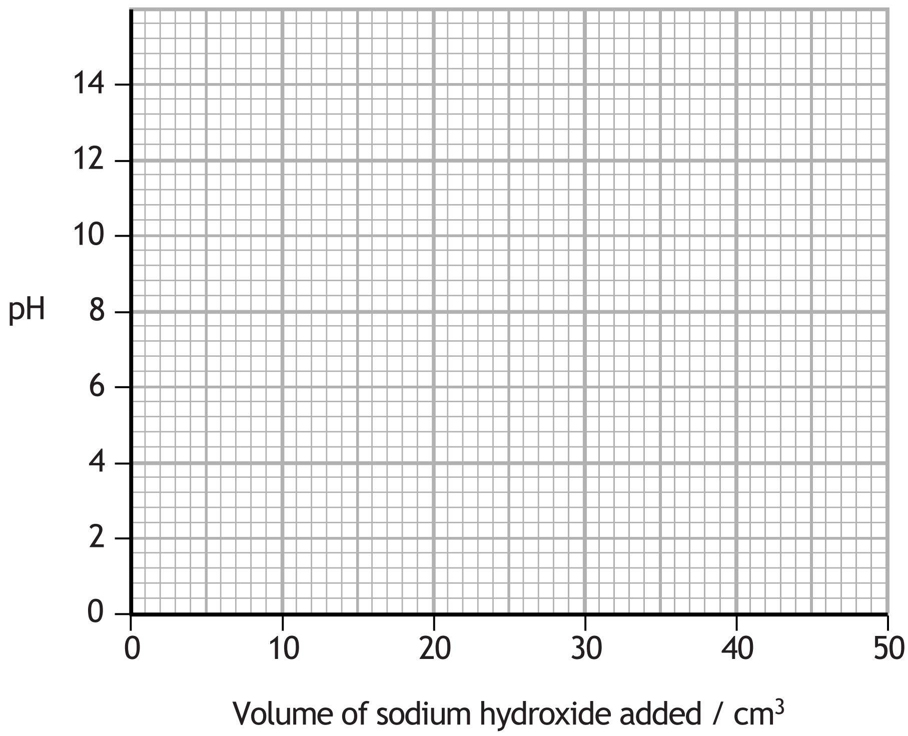
(a) A weak acid, HX, has a K_a value of 5.25×10^{-5} mol dm^{-3}. A solution was formed by mixing 10.5 cm^3 of 0.800 mol dm^{-3} dilute sodium hydroxide with 25.0 cm^3 of 0.920 mol dm^{-3} HX(aq).

Calculate the pH of the solution formed, showing all your working.

(5)

(b) (i) Propanoic acid, CH_3CH_2COOH, is a weak acid.
On the grid below, sketch the change in pH during the addition of 50.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide solution to 25.0 cm^3 of 0.100 mol dm^{-3} propanoic acid solution.

(4)



(ii) Explain how you would use the graph in (b)(i) to obtain the value of the acid dissociation constant, K_a, for propanoic acid.
You are **not** expected to calculate this value.

(2)

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(Total for Question 7 = 11 marks)

8 This question is about an experiment to determine the equilibrium constant, K_c, for an esterification reaction producing propyl ethanoate.
The equation for the reaction is

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l)$$

ethanoic acid   propan-1-ol   propyl ethanoate

In an experiment to determine the equilibrium constant, K_c, the following steps were carried out.

- 6.0 cm^3 of ethanoic acid (0.105 mol), 6.0 cm^3 of propan-1-ol (0.080 mol) and 2.0 cm^3 of dilute hydrochloric acid were mixed together in a sealed boiling tube. In this pre-equilibrium mixture, there is 0.111 mol of water
- The mixture was left for one week, at room temperature and pressure, to reach equilibrium
- The equilibrium mixture and washings were transferred to a volumetric flask and the solution made up to exactly 250.0 cm^3 using distilled water
- 25.0 cm^3 samples of the **diluted** equilibrium mixture were titrated with a solution of sodium hydroxide, concentration 0.200 mol dm^{-3}, using phenolphthalein as the indicator
- The mean titre was 23.60 cm^3 of 0.200 mol dm^{-3} sodium hydroxide solution.

(a) State the role of the hydrochloric acid in the esterification reaction.

(1)

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(b) (i) Calculate the total amount, in moles, of acid present in the **volumetric flask** in the equilibrium mixture.

(2)

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(ii) The 2.0 cm^3 of dilute hydrochloric acid contained 0.00400 mol of $H^+(aq)$ ions. Use this and your answer to part (b)(i) to calculate the amount, in moles, of ethanoic acid present in the equilibrium mixture.

(1)

(c) (i) The initial mixture in the boiling tube contained 0.105 mol of ethanoic acid. Use your answer to (b)(ii) to calculate the amount, in moles, of ethanoic acid that reacted to form the ester in the equilibrium mixture.

(1)

(ii) Use information given in the method, and your answer to (c)(i), to calculate the amounts, in moles, of propan-1-ol, propyl ethanoate and water that are present in the equilibrium mixture.

(3)

Moles of propan-1-ol at equilibrium ....

Moles of propyl ethanoate at equilibrium ....

Moles of water at equilibrium ....

(d) (i) Write the expression for the equilibrium constant, K_c, for this reaction.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l)$$

(1)

(ii) Explain why it is possible, in this case, to calculate K_c using equilibrium amounts in moles, rather than equilibrium concentrations.

(2)

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(iii) Calculate the value of K_c.
Give your answer to an appropriate number of significant figures.

(2)

(e) The pink colour of the phenolphthalein fades after the end-point of the titration has been reached.
Give a possible explanation for this observation.

(2)

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(f) Explain what you could do to confirm that one week is sufficient time for the mixture to reach equilibrium.

(2)

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(g) A student repeated the experiment, but left the mixture in a water bath at 40 °C until equilibrium was reached.

$$CH_3COOH(l) + CH_3CH_2CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_2CH_3(l) + H_2O(l) \qquad \Delta_r H^{\ominus} = +21.4\,kJ\,mol^{-1}$$

Deduce the effect, if any, on this student's value for K_c compared with that obtained in part (d)(iii).

(2)

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(Total for Question 8 = 19 marks)

TOTAL FOR PAPER = 120 MARKS

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The Periodic Table of Elements

Key

relative atomic mass **atomic symbol** name atomic (proton) number

1.0 **H** hydrogen 1

1 (1)	2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	3 (13)	4 (14)	5 (15)	6 (16)	7 (17)	0 (8) (18)
																	4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 74	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103