Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number | | | | | |

Candidate Number | | | | |

Wednesday 17 June 2020

Morning (Time: 2 hours 30 minutes) | Paper Reference **9CH0/03**

Chemistry

Advanced

Paper 3: General and Practical Principles in Chemistry

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.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

Turn over ▶

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Pearson

Answer ALL questions.

1 Aqueous sodium carbonate and aqueous sodium sulfate are both colourless solutions.

(a) Give the reagent and the observation to show the presence of carbonate ions.

(2)

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(b) Give the reagent and the observation to show the presence of sulfate ions.

(2)

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(Total for Question 1 = 4 marks)

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2 This question is about flame tests for Group 1 and 2 metal ions.

(a) (i) State the colour of the flame produced by separate samples of potassium and strontium ions.

(1)

Potassium ions .....

Strontium ions .....

(ii) Give a reason why carrying out a flame test on a mixture of potassium chloride and strontium chloride does not clearly show that two different metal ions are present.

(1)

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(b) In the first stage of the flame test, the nichrome wire is dipped into concentrated hydrochloric acid and then heated in a Bunsen flame.

In the second stage, this nichrome wire is dipped into fresh hydrochloric acid and then into the metal salt to be tested before being reheated in the Bunsen flame.

(i) Give **two** reasons why the wire is made of nichrome and not iron.

(2)

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(ii) Give a reason why the wire is dipped into acid and then heated in the first stage.

(1)

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(iii) State why **fresh** concentrated hydrochloric acid is used in the second stage of the flame test.

(1)

(iv) State why **hydrochloric acid** is used in the second stage of the flame test.

(1)

(c) Explain, with reference to electron transitions, the formation of the colour in a flame test.

(3)

(Total for Question 2 = 10 marks)

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3 This question is about a titration experiment carried out by a group of students to determine the concentration of a solution of ethanoic acid using sodium hydroxide.

(a) A student weighed about 4.00 g of sodium hydroxide pellets and added them to a beaker containing 50 cm^3 of deionised water.

The mixture was stirred with a glass rod to dissolve the pellets and to give a homogenous solution.

The solution was poured through a funnel into a 250.0 cm^3 volumetric flask and deionised water was added up to the mark and then the flask was shaken.

(i) Describe how you would ensure that all the sodium hydroxide was transferred to the volumetric flask.

(2)

(ii) A student adds deionised water above the mark and shakes the flask.

State why the procedure has to be restarted rather than using a teat pipette to remove the excess water.

(1)

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(b) Two students each cleaned a burette, then poured sodium hydroxide solution into their burettes.

(i) Student 1 used a funnel to pour sodium hydroxide solution into the burette.

Give **two** steps needed before the student takes the initial burette reading.

(2)

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(ii) Student 2 cleaned the burette by rinsing it with deionised water immediately before filling it with the sodium hydroxide solution.

Give the effect, if any, on the value of the first titre. Justify your answer.

(1)

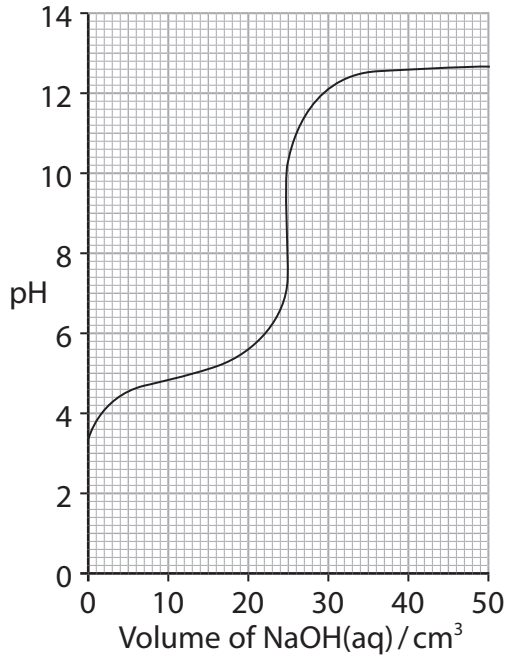
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(c) The sketch shows the pH changes during a titration of 25.0 cm^3 of ethanoic acid with sodium hydroxide of the same concentration.



The ideal indicator for this titration will change colour on the addition of a very small volume of sodium hydroxide solution at a titre value very close to the equivalence point of the reaction.

(i) Assess the suitability of methyl red as an indicator for this titration. Make use of the Data Booklet in answering this question.

(4)

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(ii) Complete the table, with a tick (✓) or a cross (✗), to show whether or not the indicator would be suitable for use in this titration.

(1)

Indicator	pH range	Tick or Cross
Bromocresol purple	5.2 – 6.8	
Thymol blue	8.0 – 9.6	
Thymolphthalein	8.3 – 10.6	
Alizarin yellow R	10.1 – 13.0	

(d) Each student used a pipette to measure 25.0 cm^3 of the ethanoic acid solution into four separate conical flasks and added an indicator.

The results of one student's titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	13.00	25.50	37.90	50.00
Initial burette reading / cm^3	0.25	13.00	25.50	37.90
Titre / cm^3				
Concordant titres (✓)				

(i) Complete the table.

(1)

(ii) The low titre for titration **4** was queried by the teacher. The student had wanted to refill the burette and continue the titration but had been told the measurement uncertainty would increase if this was done.

Calculate the total percentage measurement uncertainty if the burette had been refilled to 0.00, and then a further 0.30 cm^3 had been added from the burette, to the conical flask.

The measurement uncertainty for each burette reading is ±0.05 cm^3.

(1)

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(e) The teacher carried out the experiment and obtained the following results.

Mass of sodium hydroxide used to make 250.0 cm^3 solution = 3.80 g

Volume of ethanoic acid solution = 25.00 cm^3

Mean titre of sodium hydroxide = 11.90 cm^3

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

Calculate the concentration of the ethanoic acid solution in **g dm^{-3}**.
Give your answer to an appropriate number of significant figures.

(5)

(Total for Question 3 = 18 marks)

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4 Hess's law can be used to determine enthalpy changes for reactions which cannot be obtained directly.
An example is the reaction of anhydrous copper(II) sulfate with water to form hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

The following outline procedure was carried out.

Step **1** 42.75 g of deionised water was weighed out in a polystyrene cup and the temperature measured.

Step **2** 0.0250 mol of hydrated copper(II) sulfate was added to the water in the polystyrene cup with stirring, making a total of 45.00 g of water.

Step **3** The temperature change was recorded.

Step **4** Steps **1** to **3** were repeated using 45.00 g of deionised water and 0.0250 mol of anhydrous copper(II) sulfate.

(a) Calculate the mass of 0.0250 mol of hydrated copper(II) sulfate, $CuSO_4.5H_2O$.

(2)

(b) The reaction of hydrated copper(II) sulfate with water is shown.

$$CuSO_4.5H_2O(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H_1 = +18.2\,kJ\,mol^{-1}$$

Calculate the temperature change that would have given this enthalpy change for the stated experimental procedure.
Give your answer to a measurable number of significant figures and state whether the temperature increases or decreases.

[Specific heat capacity of the solution = 4.18 J g^{-1} $^oC^{-1}$]

(3)

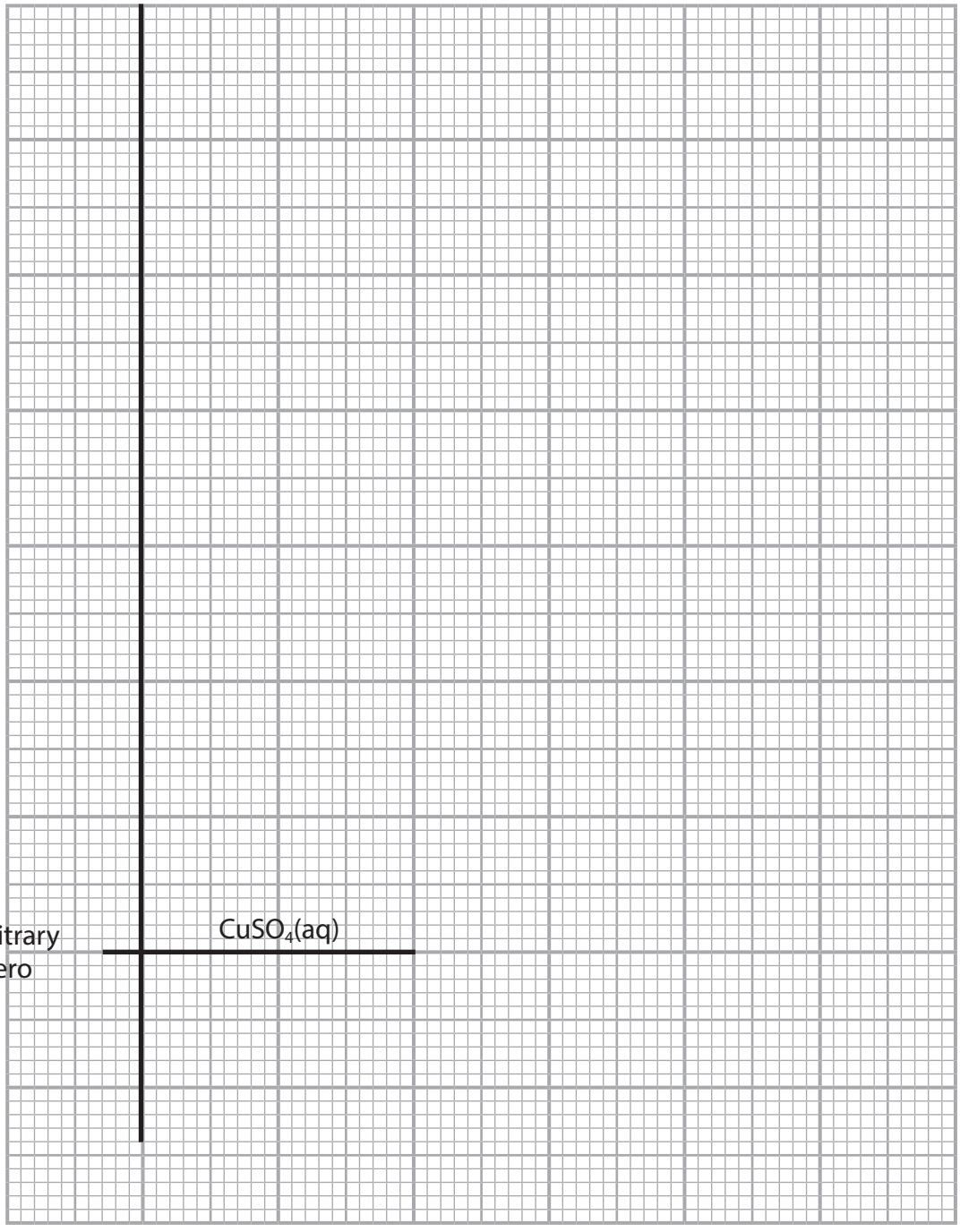
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(c) The reaction of anhydrous copper(II) sulfate with water is shown.

$$CuSO_4(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H_2 = -84.5\ kJ\ mol^{-1}$$

(i) Draw to scale, on the graph paper, a labelled enthalpy level diagram which shows the enthalpy changes for the reactions of water with hydrated copper(II) sulfate (ΔH_1) and anhydrous copper(II) sulfate (ΔH_2).

(3)



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(ii) Use your enthalpy level diagram in (c)(i) to determine the enthalpy change, $\Delta_r H$, for the reaction

$$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4.5H_2O(s)$$

You **must** show your working on the diagram.

(1)

$\Delta_r H$.....

(d) State why the enthalpy change for the reaction of one mole of anhydrous copper(II) sulfate with five moles of water to form hydrated copper(II) sulfate, $CuSO_4.5H_2O$, cannot be measured directly.

(1)

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(Total for Question 4 = 10 marks)

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5 This question is about extracting benzoic acid from a mixture of benzoic acid, C_6H_5COOH, and phenol, C_6H_5OH.

The following steps were carried out.

Step **1** A suitable mass of the mixture was placed in a separating funnel and some ether added. The funnel was shaken to dissolve the mixture.

Step **2** Aqueous sodium hydrogencarbonate was added to the separating funnel, and the contents shaken.

Step **3** Once the reaction was complete, the two layers were allowed to separate.

Step **4** The lower aqueous layer was removed and placed in a beaker.

Step **5** The ether layer in the separating funnel was washed with deionised water and the washings added to the beaker.

Step **6** Hydrochloric acid was added to the aqueous solution in the beaker to precipitate the benzoic acid.

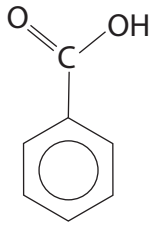
Step **7** The impure benzoic acid was filtered under reduced pressure.

Step **8** The impure benzoic acid was purified by recrystallisation.

Step **9** The melting temperature of the purified benzoic acid was measured and compared with the literature value of 122 °C.

(a) Complete the equation for the reaction between benzoic acid and sodium hydrogencarbonate.

(2)



+ ..... → ..... + ... + ...

(b) In Step **2** there is a pressure build-up in the separating funnel.

Describe how you would lower the pressure.

(1)

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(c) State why, in Step **4**, the aqueous layer was the lower of the two layers.

(1)

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(d) Give a reason why, in Step **5**, the ether layer was washed with deionised water.

(1)

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(e) Explain why the addition of hydrochloric acid in Step **6** results in the precipitation of benzoic acid.

(2)

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(f) Draw a diagram of the apparatus used in Step **7** to filter under reduced pressure.

(2)

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(g) Benzoic acid can be purified in Step **8** because of its high solubility in hot water and low solubility in cold water.

Calculate the maximum number of benzoic acid molecules that can dissolve in 50.0 cm^3 of cold water if the solubility is 1.70 g per 1000 cm^3.

(3)

(h) The melting temperature range of the purified benzoic acid in Step **9** was 116–121 °C.

Compare this result with the literature value, giving a reason for any differences.

(2)

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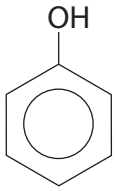
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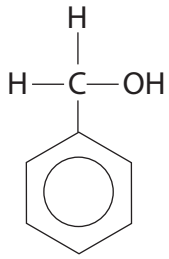
(Total for Question 5 = 14 marks)

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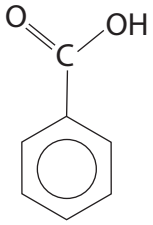
6 This is a question about the analysis of three aromatic substances with —OH groups.



phenol



phenylmethanol



benzoic acid

(a) Write the equation for the **complete** combustion of phenol.
State symbols are not required.

(2)

(b) When burned in air, these aromatic compounds undergo **incomplete** combustion.

(i) Calculate the percentage composition by mass of carbon in both phenylmethanol and benzoic acid.

(3)

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(ii) Give the expected observation when these aromatic compounds undergo incomplete combustion.

(1)

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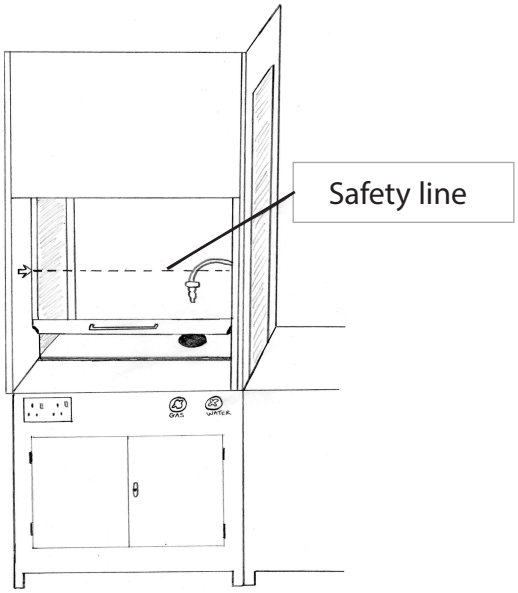
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(iii) Identify another **type** of organic compound which will also produce the same observation as in (b)(ii).

(1)

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(iv) These combustion experiments must be carried out in a fume cupboard.



Explain why the front window of the fume cupboard must be below the safety line even with the exhaust fan switched on.

(2)

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(c) Spectroscopy is an effective means of distinguishing between molecules.

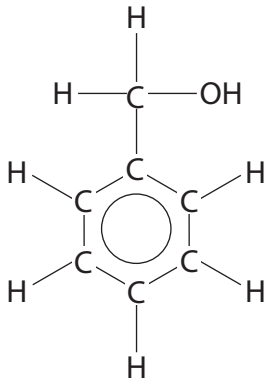
(i) Compare and contrast the infrared spectra of phenol, phenylmethanol and benzoic acid.
Include relevant bonds and their wavenumber ranges using the Data Booklet.

(5)

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(ii) Predict the number of peaks present, and their chemical shifts, in the ^{13}C nuclear magnetic resonance (NMR) spectrum of phenylmethanol. Use the information in the Data Booklet to help you.

(3)



phenylmethanol

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(iii) Give the formula of a fragment ion, with its *m/z* value, that you would expect to be present in the mass spectrum of benzoic acid but **not** in the mass spectrum of phenol or the mass spectrum of phenylmethanol.

(2)

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(Total for Question 6 = 19 marks)

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***7** "Cobalt(II) ions combine with substances in solution to form complex ions with different coordination numbers."

Discuss this statement by referring to **two** complex ions containing cobalt(II).

Include

- reference to any difference in colour
- a definition of any terms used
- an explanation of the different shapes

(6)

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(Total for Question 7 = 6 marks)

8 This is a question about chromium(III) and chromium(VI) compounds.

(a) Describe the observations when aqueous sodium hydroxide is added drop by drop until in excess to a solution of chromium(III) ions.

(2)

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(b) The chromium(III) complex, $[Cr(OH)_6]^{3-}$, can be oxidised to chromate(VI) ions, CrO_4^{2-}, by hydrogen peroxide solution.

(i) Deduce the oxidation half-equation for this reaction, which takes place in alkaline conditions. State symbols are not required.

(2)

(ii) If the solution of chromate(VI) ions is then acidified, the colour of the solution changes to orange as dichromate(VI) ions form.

Write the equation for this change. State symbols are not required.

(1)

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(iii) In acidic conditions, dichromate(VI) ions can also be reduced to chromium(III) ions using hydrogen peroxide.

The value of $E^{\ominus}_{cell} = +0.65\,V$ for which the cell diagram is

$$Pt(s) \mid H_2O_2(aq), [2H^+(aq)+O_2(g)] \,\vdots\, [Cr_2O_7^{2-}(aq)+14H^+(aq)], [2Cr^{3+}(aq)+7H_2O(l)] \mid Pt(s)$$

Deduce from the cell diagram the oxidation and the reduction half-equations, and thus the overall equation for this reaction.
State symbols are not required.

(3)

(c) Draw a labelled diagram of the apparatus that you would use to measure the standard emf of a cell with a zinc-zinc(II) electrode system and a chromium(III)-dichromate(VI) electrode system.

Include the **formulae** of all the compounds required and the concentrations of the solutions.

(7)

(Total for Question 8 = 15 marks)

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9 This question is about amines.

(a) Phenylamine is an aromatic amine and butylamine is an aliphatic amine.

Phenylamine can be prepared from nitrobenzene.



Butylamine can be prepared from butanenitrile.

$$C_3H_7CN \rightarrow C_4H_9NH_2$$

Compare and contrast these two preparations of amines.

(3)

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(b) Compare and contrast the basicity of phenylamine and butylamine.

(3)

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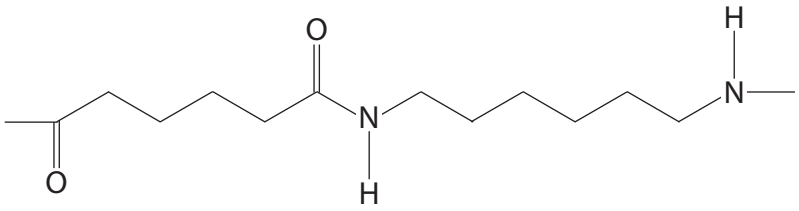
(c) Write the equation for the reaction between propanoyl chloride and pentylamine. Include the name of the amide formed.

State symbols are not required.

(2)

Name of amide .....

(d) A section of a polyamide is shown.



Identify, by name or formula, the amine monomer that reacts to form this polyamide.

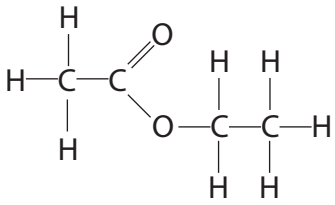
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(Total for Question 9 = 9 marks)

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10 Ethyl ethanoate is an ester.



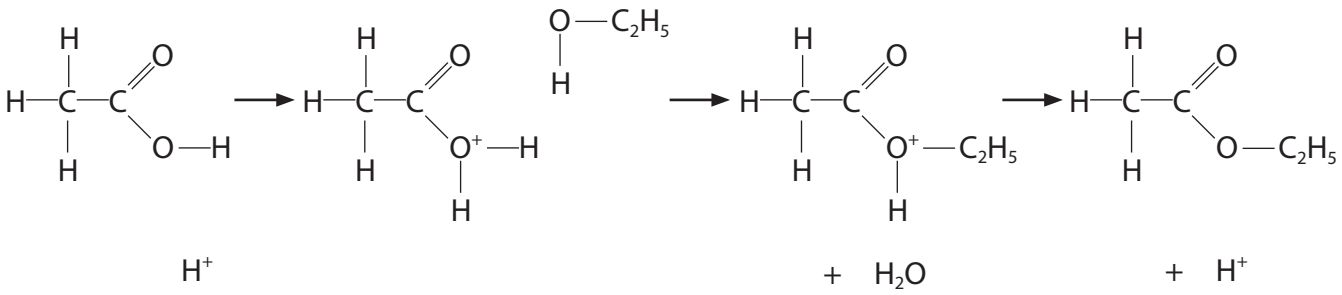
(a) One method for the formation of ethyl ethanoate is the reaction between ethanol and ethanoic acid, which is catalysed by hydrogen ions.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

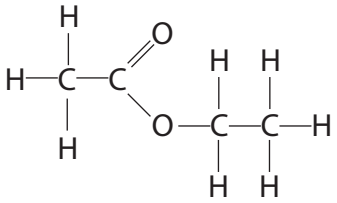
An incomplete simplified mechanism for this reaction is shown.

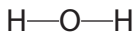
(i) Add curly arrows and relevant lone pairs of electrons to complete the mechanism.

(4)



(ii) In an experiment, the oxygen atom in ethanol is replaced by the oxygen-18 isotope, ^{18}O.
The products of the esterification are



and 

Label the ^{18}O oxygen atom in one of the products.
Justify your answer.

(2)

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(iii) Calculate the standard molar entropy of ethyl ethanoate using your knowledge of Gibbs free energy, ΔG, and the data in the table.

Include sign and units in your answer.

Use $\Delta G = -RT \ln K$ and other appropriate equations.

Quantity	Value
Gas constant, R	8.31 J mol^{-1} K^{-1}
Temperature, T	298 K
Equilibrium constant of esterification reaction, K	4.0
Enthalpy change of esterification reaction, ΔH	–6.0 kJ mol^{-1}
Standard molar entropy of ethanoic acid, S^{O}	159.8 J K^{-1} mol^{-1}
Standard molar entropy of ethanol, S^{O}	160.7 J K^{-1} mol^{-1}
Standard molar entropy of water, S^{O}	69.9 J $K^{-1}mol^{-1}$

(6)

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(b) Ethyl ethanoate can also be formed by reacting ethanol with ethanoyl chloride, CH_3COCl.

Identify **three** differences in the esterification reaction when ethanoyl chloride is used instead of ethanoic acid.

(3)

(Total for Question 10 = 15 marks)

TOTAL FOR PAPER = 120 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									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	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(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

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
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

* Lanthanide series

* Actinide series

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