Write your name here Surname	Other	names
Pearson Edexcel GCE	Centre Number	Candidate Number
Chemistr	<b>'y</b>	
Advanced Unit 4: General Prir Equilibria a	nciples of Chemis nd Further Organ ynoptic assessme	ic Chemistry
Advanced Unit 4: General Prin Equilibria an (including s Tuesday 14 June 2016 –	nd Further Organ ynoptic assessme Afternoon	ic Chemistry ent)  Paper Reference
Advanced Unit 4: General Prir Equilibria ar (including s	nd Further Organ ynoptic assessme Afternoon	ic Chemistry ent)

### **Instructions**

- Use **black** ink or 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 90.
- The marks for **each** question are shown in brackets
  - use this as a guide as to how much time to spend on each question.
- Questions labelled with an asterisk (\*) are ones where the quality of your written communication will be assessed
  - you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.
- A Periodic Table is printed on the back cover of this paper.

### **Advice**

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

P 4 6 6 6 0 R A 0 1 2 8

Turn over ▶



### **SECTION A**

Answer ALL the questions in this section. You should aim to spend no more than 20 minutes on this section. For each question, select one answer from A to D and put a cross in the box  $\boxtimes$ . If you change your mind, put a line through the box  $\boxtimes$  and then mark your new answer with a cross  $\boxtimes$ .

1 Consider the reaction

$$CH_3COOC_2H_5 + CH_3OH \rightleftharpoons CH_3COOCH_3 + C_2H_5OH$$

This is an example of

- **A** acylation.
- **B** hydrolysis.
- C substitution.
- **D** transesterification.

(Total for Question 1 = 1 mark)

- 2 When a vegetable oil such as palm oil is hydrolysed, the alcohol produced is

  - ☑ B propane-1,2-diol
  - C propane-1,3-diol
  - **D** propane-1,2,3-triol

(Total for Question 2 = 1 mark)

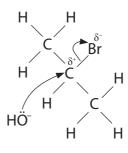
- **3** Which of the following types of radiation can directly result in bond breaking?
  - **A** Infrared
  - **B** Microwave
  - C Radio wave
  - □ Ultraviolet

(Total for Question 3 = 1 mark)

**4** The first steps of two **different** reaction mechanisms are shown.

First Reaction Mechanism

Second Reaction Mechanism



(a) What do **both** reaction mechanism steps have in common?

(1)

- ☑ A They involve addition.
- ☑ B They involve substitution.
- ☑ C As one bond is made, one bond is broken.
- ☑ D The attack is on a planar group.
- (b) Only **one** of the first steps above

(1)

- A leads to the formation of a racemic mixture.
- ☑ B involves initial attack by a nucleophile.
- ☑ C involves initial attack by an electrophile.
- **D** leads to an elimination.

(Total for Question 4 = 2 marks)

Use this space for rough working. Anything you write in this space will gain no credit.

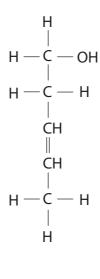


**5** The following molecules are structural isomers with molecular formula  $C_5H_{10}O$ .

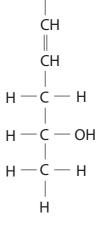
	W	
	H	
Н —	- ¢ —	Н
	$\dot{C} =$	0
н —	- C —	Н
н —	- C —	Н
н —	- C —	Н

Н

X
H 
$\stackrel{ }{C} = O$
$H - \stackrel{\downarrow}{C} - H$
$H - \overset{1}{C} - H$
$H - \overset{\mid}{C} - H$
$H - \overset{1}{C} - H$
H



Υ



Z

(a) Which of the molecules would exhibit optical isomerism?

(1)

- A W
- B X
- D Z

(b) Which of the molecules would exhibit geometric isomerism?

(1)

- A W
- $\square$  B X
- D Z

(c) Which of the molecules would produce iodoform when reacting with iodine in alkaline solution?

(1)

- A W only
- **B** W and X
- C Wand Y
- $\square$  **D** W and Z



(d) Which of the molecules would be oxidized to a carboxylic acid using acidified sodium dichromate(VI)?

(1)

- $extbf{\textbf{\text{\textbf{A}}}}$  X only
- ☑ B Z only
- C X and Y
- $\square$  **D** X, Y and Z
- (e) Which of the molecules would form a crystalline product with 2,4-dinitrophenylhydrazine?

(1)

- A W only
- **B** W and X
- ☑ C W, X and Z
- $\square$  **D** X only

(Total for Question 5 = 5 marks)

Use this space for rough working. Anything you write in this space will gain no credit.

- **6** Chromatography is used to separate the components of a mixture and can be carried out in a range of different ways.
  - (a) A suitable example of a 'carrier gas' in gas chromatography is

(1)

- **A** chlorine.
- **B** nitrogen.
- C steam.
- **D** not possible to state, as there should be a vacuum.
- (b) Separation is achieved in gas chromatography due to the components in the mixture having different

(1)

- **A** interactions with the stationary phase.
- **B** interactions with the mobile phase.
- **C** colours.
- **D** solubility in the moving solvent.

(Total for Question 6 = 2 marks)

Use this space for rough working. Anything you write in this space will gain no credit.

- **7** Polyesters are condensation polymers.
  - (a) PET, polyethylene terephthalate, can be produced from the condensation of ethane-1,2-diol and benzene-1,4-dicarboxylic acid.

Which of the following is the repeat unit of this polymer?

(1)

$$\begin{bmatrix} O & O & \\ \parallel & \parallel & \\ C & -C & -C & -C & +_2 & -C & +_2 & -C \end{bmatrix}$$

$$\begin{array}{c|c} O \\ \parallel \\ C - O - CH_2 - CH_2 - O \end{array}$$

X A

 $\bowtie$  B

$$\begin{bmatrix} O \\ \parallel \\ C - O - CH_2 - CH_2 - O \end{bmatrix}$$

$$\begin{bmatrix} O & O & O \\ \parallel & \parallel & \parallel \\ O & C & CH_2 & CH_2 & C \end{bmatrix}$$

 $\times$  D

X C

(b) The repeat unit of the biodegradable polymer PHB, is shown below.

This is made from a single monomer which could be

(1)

- ☑ A 2-hydroxybutanoic acid.
- ☑ B 3-hydroxybutanoic acid.
- **C** 2-hydroxy-2-methylpropanoic acid.
- ☑ D 3-hydroxy-3-methylpropanoic acid.

(Total for Question 7 = 2 marks)

- The reaction of ammonia with propanoyl chloride, C<sub>2</sub>H<sub>5</sub>COCl, forms
  - $\triangle$  A  $C_2H_5NH_2$
  - B C<sub>2</sub>H<sub>5</sub>CONH<sub>2</sub>
  - C C<sub>2</sub>H<sub>5</sub>CH(OH)NH<sub>2</sub>
  - □ C<sub>2</sub>H<sub>5</sub>CONHC<sub>2</sub>H<sub>5</sub>

(Total for Question 8 = 1 mark)

The dihydrogenphosphate-hydrogenphosphate ion system is an important buffer in the human body.

$$H_{2}PO_{4}^{-} + H_{2}O \rightleftharpoons HPO_{4}^{2-} + H_{3}O^{+}$$

(a) In this system, there are two acid-base conjugate pairs. These are

(1)

acid with its conjugate base

base with its conjugate acid

 $H_2PO_4^- / HPO_4^{2-}$  $\times$  A

$$H_2O / H_3O^+$$

H<sub>2</sub>O / H<sub>3</sub>O<sup>+</sup>  $\mathbb{Z}$  B

$$HPO_4^{2-} / H_2PO_4^{-}$$

X C

$$H_3O^+ / H_2O$$

$$H_2PO_4^- / HPO_4^{2-}$$

 $\times$  D

$$H_2PO_4^- / HPO_4^{2-}$$

$$H_3O^+ / H_2O$$

(b) A formula that can be used for the calculation of the pH of this buffer solution is

$$pH = pK_a + log \left( \frac{\left[ HPO_4^{2-} \right]}{\left[ H_2PO_4^{-} \right]} \right)$$

Calculate the pH of this buffer using

$$pK_a = 7.20$$
 [HPO<sub>4</sub><sup>2-</sup>] = 3.98 × 10<sup>-8</sup> mol dm<sup>-3</sup> [H<sub>2</sub>PO<sub>4</sub>] = 3.89 × 10<sup>-7</sup> mol dm<sup>-3</sup>

$$[H_{3}PO_{4}] = 3.89 \times 10^{-7} \text{ mol dm}^{-3}$$

(1)

- **A** 6.19
- В 6.21
- 7.20
- **■ D** 8.19

(Total for Question 9 = 2 marks)



**10** The Ostwald Process is a method for making nitric acid. The equation for the first stage of this process is

 $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$   $\Delta H = -905 \text{ kJ mol}^{-1}$ 

(a) The equilibrium yield of nitrogen monoxide, NO, is **increased** by

(1)

- ☑ A increasing both the pressure and the temperature.
- **B** decreasing both the pressure and the temperature.
- ☑ C decreasing the pressure and increasing the temperature.
- **D** increasing the pressure and decreasing the temperature.
- (b) For this stage of the process, the catalyst is an alloy of platinum and rhodium. A pressure of between 4 and 10 atm and a temperature of 1150 K are used. Unreacted reactants are recycled.

Which one of the following changes will affect the value of the equilibrium constant,  $K_p$ ?

(1)

- ☑ A Changing the composition of the platinum-rhodium catalyst.
- ☑ B Increasing the pressure above 10 atm.
- ☑ **C** Decreasing the temperature below 1150 K.
- D Not recycling unreacted reactants.

(Total for Question 10 = 2 marks)

Use this space for rough working. Anything you write in this space will gain no credit.



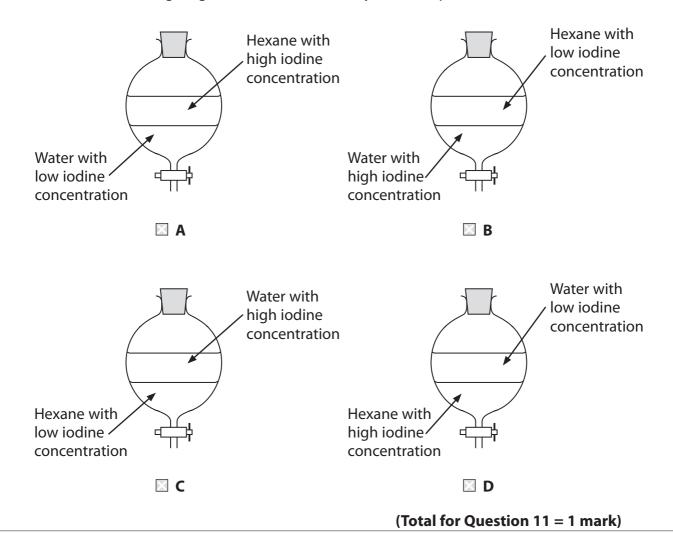
11 lodine is soluble in both water and hexane. If iodine is added to a mixture of the two solvents, then the following equilibrium is set up.

$$I_2(aq) \rightleftharpoons I_2(hexane)$$

The equilibrium constant, known as the partition coefficient, is 85.

The density of hexane is 0.66 g cm<sup>-3</sup>. The density of water is 1.00 g cm<sup>-3</sup>.

Which of the following diagrams is correct for this system at equilibrium?



**TOTAL FOR SECTION A = 20 MARKS** 

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### **SECTION B**

# Answer ALL the questions. Write your answers in the spaces provided.

- **12** Sulfuric acid, H<sub>2</sub>SO<sub>4</sub>, is a well known acid containing sulfur. However, two other sulfur-containing acids are hydrogen sulfide, H<sub>2</sub>S, and sulfurous acid, H<sub>2</sub>SO<sub>3</sub>.
  - (a) Hydrogen sulfide is a weak acid and dissociates in two stages as shown.

Stage 1 
$$H_2S(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$$

$$K_{a1} = 8.91 \times 10^{-8} \text{ mol dm}^{-3}$$

Stage 2 
$$HS^{-}(aq) + H_2O(I) \rightleftharpoons H_3O^{+}(aq) + S^{2-}(aq)$$

$$K_{a2} = 1.20 \times 10^{-13} \text{ mol dm}^{-3}$$

Write the  $K_a$  expressions for

(2)

Stage 1 
$$K_{a1} =$$

Stage 2 
$$K_{a2} =$$

(b) A solution of hydrogen sulfide has an initial concentration of 0.100 mol dm<sup>-3</sup>.

$$K_{a1} = 8.91 \times 10^{-8} \text{ mol dm}^{-3}$$

(i) Use  $K_{a1}$  to calculate the equilibrium concentration, in mol dm<sup>-3</sup>, of the hydrogensulfide ion, HS<sup>-</sup>. Give your answer to **three** significant figures.

(2)

(ii) Use your answer to (b)(i) to calculate the pH of this solution.

(1)

\*(iii) State the **three** assumptions you have made in your calculations in (b)(i) and (b)(ii).

(3)

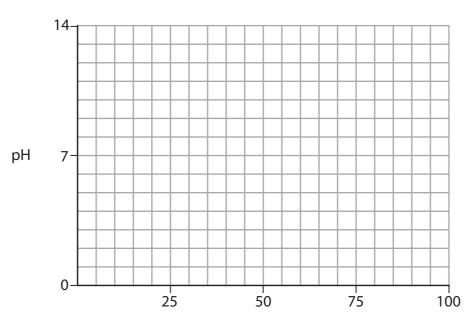
(c) Sulfurous acid,  $H_2SO_3$ , is also a diprotic acid. The values of  $K_{a1}$  and  $K_{a2}$  can be determined from the results of an acid-base titration. Diprotic acids require two OH<sup>-</sup> ions per molecule for complete neutralization.

Sulfurous acid,  $H_2SO_3$ , is a stronger acid than  $H_2S$  and a 0.100 mol dm<sup>-3</sup> solution has a pH of 1.5.

- (i) On the grid below, sketch the likely shape of the titration curve for sulfurous acid,  $H_2SO_3$ , during the neutralization process.
  - 25 cm<sup>3</sup> of sulfurous acid solution with a concentration of 0.100 mol dm<sup>-3</sup> is used
  - 100 cm<sup>3</sup> of the sodium hydroxide solution with a concentration of 0.100 mol dm<sup>-3</sup> is added
  - $pK_{a1} = 1.9$  and  $pK_{a2} = 7.2$

Clearly label any equivalence points in the sketch.

(5)



Volume of sodium hydroxide added / cm<sup>3</sup>

(ii)	Describe	how you	hluow u	use this	graph to	confirm	the va	alue	of $nK$

(1)

(Total for Question 12 = 14 marks)

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**13** This is a question about entropy changes.

Consider the reaction between the two solids, hydrated barium hydroxide and ammonium chloride. When these substances are mixed together, a white paste is formed and the temperature decreases. An equation for this process is given below.

$$Ba(OH)_2.8H_2O(s) \ + \ 2NH_4CI(s) \ \to \ 2NH_3(g) \ + \ 10H_2O(I) \ + \ BaCI_2(s)$$

(a) (i) Identify **one** hazard associated with a named substance in this reaction.

(1)

(ii) Use the standard molar entropies below to calculate the standard entropy change of the system ( $\Delta S_{\text{system}}^{\ominus}$ ) for this reaction at 298 K. Give a sign and units with your answer.

Compound	S <sup>⊕</sup> / J mol <sup>-1</sup> K <sup>-1</sup>
Ba(OH) <sub>2</sub> .8H <sub>2</sub> O(s)	427
NH <sub>4</sub> Cl(s)	95
NH <sub>3</sub> (g)	192
H <sub>2</sub> O(I)	70
BaCl <sub>2</sub> (s)	124

(3)

*(iii) Give <b>two</b> reasons why the sign of your answer to (a)(ii) is as you would expect.	(2)
(b) The standard enthalpy change for this reaction is $\Delta H_r^{\ominus} = +162$ kJ mol <sup>-1</sup> . Use this value to calculate the standard entropy change of the surroundings $(\Delta S_{\text{surroundings}}^{\ominus})$ for this reaction at 298 K. Include a sign and units in your answer.	(2)
(c) Use your answers to (a)(ii) and (b) to calculate the total entropy change ( $\Delta S_{\text{total}}^{\ominus}$ ) for this reaction. Include a sign and units in your answer.	(1)
(d) What would be the effect, if any, on the value of $\Delta S_{\text{total}}^{\ominus}$ from (c) of a small increase in temperature? Justify your answer and state any assumptions that you have made.	(3)



(e) The values of total entropy change and equilibrium constant of a reaction are related by the following equation.

$$\Delta S_{\text{total}} = R \ln K$$

The equation for the dissolving of barium hydroxide is

$$Ba(OH)_2(s) + aq \rightleftharpoons Ba^{2+}(aq) + 2OH^{-}(aq) \qquad \Delta S_{total}^{\ominus} = -44 \text{ J mol}^{-1} \text{ K}^{-1}$$

(i) Calculate the value of the equilibrium constant, *K*, for this equation at 298 K.

$$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$$

(1)

(ii) What does the value of the equilibrium constant suggest about the solubility of barium hydroxide?

Justify your answer.

(1)

(iii) For the dissolving of calcium hydroxide, the value of the total entropy change is -106 J mol $^{-1}$  K $^{-1}$ 

Compare the values of the total entropy changes for these two hydroxides and show that they are consistent with the trend in the solubility of Group 2 hydroxides.

(2)

(Total for Question 13 = 16 marks)

14 This is a question about how 'clock reactions' are used to study reaction kinetics.

The 'bromine clock' involves a reaction between bromide ions and bromate(V) ions in acid solution:

$$5Br^{-}(aq) + BrO_{3}^{-}(aq) + 6H^{+}(aq) \rightarrow 3Br_{2}(aq) + 3H_{2}O(l)$$

In order to monitor this reaction, phenol and methyl orange are added to the reaction mixture.

- A small fixed amount of phenol is present which reacts immediately with the bromine as it is produced, thus removing it from solution.
- Once the bromine produced has reacted with all of the phenol present, then any further bromine produced will bleach the methyl orange solution providing a means to monitor the reaction rate.
- (a) It is assumed that the **initial** rate of reaction is proportional to 1/time taken for the methyl orange to be bleached.

Explain why it is essential for the amount of phenol to be small compared to the amounts of the reactants for this assumption to be valid.

(1)

- (b) A series of experiments was carried out where only the concentration of bromide ions present was varied and the solution contained a large excess of BrO<sub>3</sub><sup>-</sup> and H<sup>+</sup> ions. The total volume of the mixture was kept constant.
  - (i) Why was it important that the solution contained a large excess of  $BrO_3^-$  and  $H^+$  ions?

(1)

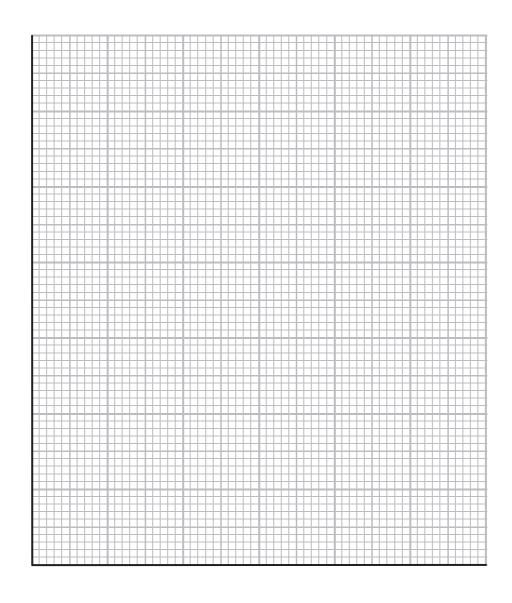


# (ii) The following results were obtained.

Complete the table and use the results to plot a graph of 1/time on the vertical axis against the volume of bromide ions.

(4)

Volume of Br <sup>-</sup> (aq) / cm <sup>3</sup>	10.0	8.0	6.0	5.0	4.0	2.0
Time / s	180	226	300	364	444	900
(1/time) / 10 <sup>-3</sup> s <sup>-1</sup>	5.56	4.42	3.33		2.25	1.11



(iii) Deduce the order of the reaction with respect to bromide ions.	
Justify your answer.	(2)
(iv) The reaction is first order with respect to bromate(V) ions and s with respect to hydrogen ions. Write the overall rate equation f 'bromine clock' reaction and deduce the units of the rate consta	for the
ate equation:	(-/
nits of rate constant	
(c) Another 'clock reaction' is the 'iodine clock' reaction, where hydroge is mixed with a solution containing sodium thiosulfate, potassium i	•
(c) Another 'clock reaction' is the 'iodine clock' reaction, where hydroge	•
(c) Another 'clock reaction' is the 'iodine clock' reaction, where hydroge is mixed with a solution containing sodium thiosulfate, potassium i	iodide and starch.
(c) Another 'clock reaction' is the 'iodine clock' reaction, where hydroge is mixed with a solution containing sodium thiosulfate, potassium in The main reaction is	iodide and starch.
is mixed with a solution containing sodium thiosulfate, potassium is $H_2O_2(aq) \ + \ 2I^-(aq) \ + \ 2H^+(aq) \ \rightarrow \ I_2(aq) \ + \ 2H_2O_2(aq)$ • The thiosulfate ions present react immediately with the iodine of	iodide and starch.  O(I)  as it is
<ul> <li>(c) Another 'clock reaction' is the 'iodine clock' reaction, where hydroge is mixed with a solution containing sodium thiosulfate, potassium is The main reaction is</li></ul>	iodide and starch.  O(I)  as it is
<ul> <li>(c) Another 'clock reaction' is the 'iodine clock' reaction, where hydroge is mixed with a solution containing sodium thiosulfate, potassium is The main reaction is  H₂O₂(aq) + 2I⁻(aq) + 2H⁺(aq) → I₂(aq) + 2H₂O</li> <li>• The thiosulfate ions present react immediately with the iodine a produced, thus removing it from solution.</li> <li>• Once all of the thiosulfate ions are used up, further iodine product with the starch present.</li> </ul>	iodide and starch.  O(I)  as it is luced reacts



(d) 'lodine clock' reactions can be used to determine the activation energy of a reaction using the equation:

In rate = 
$$-\frac{E_a}{R} \times \frac{1}{T}$$
 + constant

(i) State the experimental measurements you would make to provide the numerical data for the calculation of the activation energy.

(1)

(ii) Describe how you would use your experimental measurements to obtain a value for the activation energy.

You should include

- how the data is processed
- the graph you would plot and its expected shape
- how the activation energy of the reaction can be determined from the graph produced.

(6)

(Total for Question 14 = 19 marks)

**TOTAL FOR SECTION B = 49 MARKS** 



### **SECTION C**

## Answer ALL the questions. Write your answers in the spaces provided.

**15** Salicylic acid is the active ingredient in one method of treatment of verrucas, warts and acne. The structure of salicylic acid is shown below.

A laboratory method of preparing salicylic acid is the hydrolysis of the ester, methyl salicylate, which is present in Oil of Wintergreen. A sample of the ester is initially refluxed with sodium hydroxide and salicylic acid is then precipitated by adding a strong acid.

(a) (i) Complete the equation for the alkaline hydrolysis of the ester group in methyl salicylate, using sodium hydroxide.

OH O + NaOH → +

(ii) The salicylic acid is precipitated out of solution by the addition of dilute sulfuric acid until it is in excess.

How could you tell that the sulfuric acid is in excess?

(b) Salicylic acid is sparingly soluble in water. Explain this observation in terms of intermolecular forces.

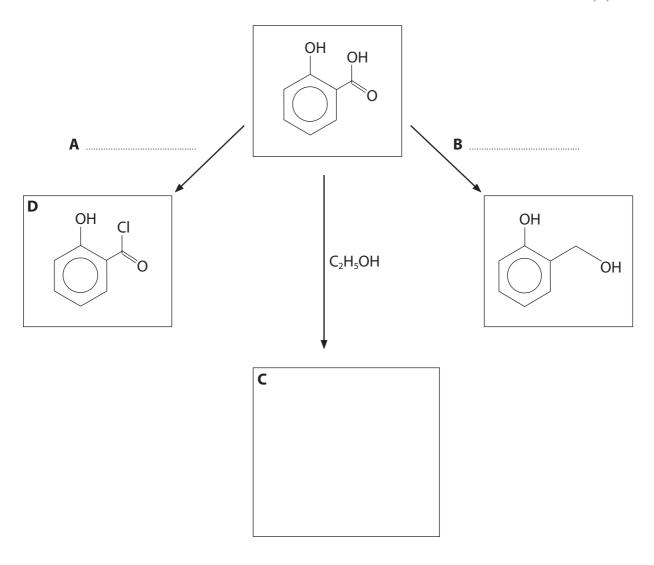
(2)

(1)

(c) State <b>three</b> ways in which the acid hydrolysis of an ester differs from the alkaline hydrolysis of an ester.	
riyurorysis or arr ester.	(3)

- (d) Salicylic acid can undergo various reactions as outlined below.
  - (i) Give the **formula** of the reagents **A** and **B** and the **skeletal** formula of the product **C**.

(3)



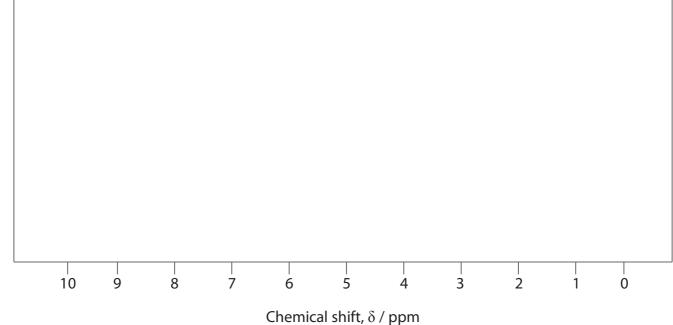
(ii) Both compound **D** and salicylic acid react with ethanol. State **two** differences between these reactions.

(2)

\*(e) Use chemical shift data from the Data Booklet to sketch the **high** resolution proton nmr spectrum for ethanol. The peaks do not overlap.

Explain the number of peaks, their splitting pattern and the ratio of the areas under each set of peaks.

(5)



(f) Tetramethylsilane, $Si(CH_3)_4$ , is used as a reference standard in nmr spectra. Suggest why it gives a very strong signal in the spectrum.	(1)
(g) State the type of radiation that is used to create the nmr spectrum.	(1)
(h) Use the Data Booklet to state <b>two</b> differences between the infrared spectra of salicylic acid and compound <b>D</b> . Include the wave numbers of the relevant groups or bonds.	(2)
(Total for Question 15 = 21 ma	rks)

TOTAL FOR SECTION C = 21 MARKS TOTAL FOR PAPER = 90 MARKS



# The Periodic Table of Elements

	_																							
ted		radon 86	Ru	[222]	54	xenon	Xe	131.3	36	krypton	궇	83.8	18	argon	4	39.9	neon 10	Ne	20.2	2	<b>He</b> helium	4.0	(18)	0 (8)
een repor		astatine 85	Αt	[210]	53	iodine	Ι	126.9	35	bromine	Br	79.9	17	chlorine	ī	35.5	fluorine 9	L	19.0	(17)				7
116 have b iticated		polonium 84	8	[506]	52	tellurium	<u>P</u>	127.6	34	selenium	Se	79.0	16	Sulfur	v	32.1	oxygen 8	0	16.0	(16)				9
tomic numbers 112-116 hav but not fully authenticated		bismuth 83	B	209.0	51	antimony	Sb	121.8	33	arsenic	As	74.9	15	phosphorus	٥	31.0	nitrogen 7	z	14.0	(15)				2
atomic nur but not fi		lead 82	Ъ	207.2	20	tin	Sn	118.7	32	germanium	ge	72.6		_	ï	28.1	carbon 6	U	12.0	(14)				4
Elements with atomic numbers 112-116 have been reported but not fully authenticated		thallium 81	F	204.4	49	mnipui	I	114.8	31	gallium	g	69.7	13	Aliminim	-	27.0	boron 5	В	10.8	(13)				8
Elen		mercury 80	Hg	200.6	48	cadmium	5	112.4	30	zinc	Zu	65.4	(12)											
Rg roentgenium 111	[272]	gold 79	Αn	197.0	47	silver	Ag	107.9	29	copper	J	63.5	(11)											
Ds damstadtium 110	[271]	platinum 78	£	195.1	46	palladium	Pd	106.4	28	nickel	ź	58.7	(10)											
Mt Ds meitnerium damstadtium 109 110	[268]	iridium 77	<u>1</u>	192.2	45	rhodium	R	102.9	27	cobalt	ပိ	58.9	(6)							200			50	
Hs hassium 108	[277]	osmium 76	Os	190.2	44	ruthenium	Ru	101.1	56	iron	Fe	55.8	(8)							-	hydrogen	1.0		
Д	—	rhenium 75	Re	186.2	43	technetium	2	[86]	25	manganese	Wn	54.9	(7)							_				
Sg seaborgium 106	[596]	tungsten 74	>	183.8	42	molybdenum technetium	Wo	95.9	24	vanadium chromium manganese		52.0	(9)				umber	pol	mass					
_	l —	tantalum 73	Та	180.9	41	niobium	g	92.9	23	vanadium	>	50.9	(2)				name atomic (proton) number	atomic symbol	relative atomic mass	Key				
Rf rutherfordium	[261]	hafnium 72		178.5	40	zirconium	Zr	91.2	22	titanium	ï	47.9	(4)				atomic	ato	relati					
AC* actinium 89	[227]	lanthanum 57	La*	138.9	39	yttrium	>	88.9	21	scandium	Sc	45.0	(3)											
Ra radium 88	[526]	barium 56		137.3	38	strontium	Sr	87.6	20	calcium	Ca	40.1	12	magnesti im	-11	24.3	beryllium 4	Be	9.0	(2)				2
Fr francium 87	[223]	caesium 55	S	132.9	37	rubidium	ВЪ	85.5	19	potassium	¥	39.1	11	anipos milipos	14	23.0	lithium 3	ij	6.9	(1)				-
									_	_	_		_	_	_									

\* Lanthanide series

\* Actinide series

175	Ľ	lutetium	71	[257]	ב	lawrencium	103
173	χ	ytterbium	70	[254]	8	nobelium	102
169	T	thulium	69	[256]	ΡW	mendelevium	101
167	ᆸ	erbium	89	[253]	Fn	fermium	100
165	유	holmium	67	[254]	Es	einsteinium	66
163	Dy	dysprosium	99	[251]	უ	californium	86
159	ТÞ	terbium	65	[245]	BK	berkelium	26
157	В	gadolinium	64	[247]	Ę	aurium	96
152	Eu	europium	63	[243]	Am	americium	95
150	Sm	samarium	62	[242]	Pu	plutonium	94
[147]	Pm	promethium	61	[237]	ď	neptunium	93
	P	<u>8</u>		238		uranium	92
141	P	praseodymium	26	232 [231]	Pa	protactinium	91
140	S	cerium	58	232	노	thorium	90