Write your name here

Surname	Other names

Pearson Edexcel GCE

Centre Number

Candidate Number

Chemistry

Advanced

Unit 4: General Principles of Chemistry I – Rates, Equilibria and Further Organic Chemistry (including synoptic assessment)

Wednesday 10 June 2015 – Afternoon

Time: 1 hour 40 minutes

Paper Reference **6CH04/01**

You must have: Data Booklet

Candidates may use a calculator.

Total Marks

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.

Turn over

P42978A

5/5/6/5/1/1/1/

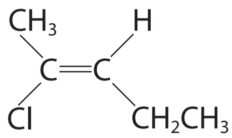
P 4 2 9 7 8 A 0 1 2 8

PEARSON

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 ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Name the compound below.



☐ **A** *E*-2-chloropent-2-ene

☐ **B** *Z*-2-chloropent-3-ene

☐ **C** *E*-2-chloropent-3-ene

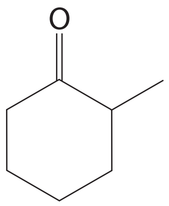
☐ **D** *Z*-2-chloropent-2-ene

(Total for Question 1 = 1 mark)

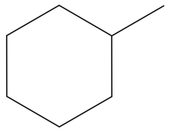
Use this space for any rough working. Anything you write in this space will gain no credit.

2 Which of the following compounds is **not** chiral?

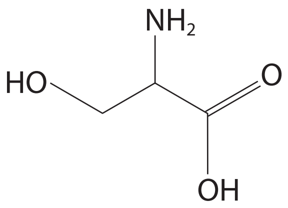
☒ **A**



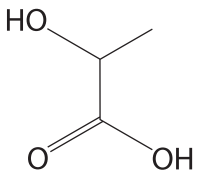
☒ **B**



☒ **C**



☒ **D**



(Total for Question 2 = 1 mark)

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

Turn over ▶

3 Calculate the pH of a solution of HCl, of concentration 0.25 mol dm^{-3}.

☒ **A** –0.60

☒ **B** 0.25

☒ **C** 0.60

☒ **D** 1.39

(Total for Question 3 = 1 mark)

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4 Which gas is the **least** suitable as a carrier gas in Gas-Liquid Chromatography?

☒ **A** Argon

☒ **B** Carbon dioxide

☒ **C** Oxygen

☒ **D** Nitrogen

(Total for Question 4 = 1 mark)

---

5 What are the units of the equilibrium constant (K_c) for the hypothetical reaction below?

$$2A(aq) + B(aq) \rightleftharpoons 4C(aq) + D(aq)$$

☒ **A** $mol^{2}\,dm^{-9}$

☒ **B** $mol^{-2}\,dm^{9}$

☒ **C** $mol^{2}\,dm^{-6}$

☒ **D** $mol^{-2}\,dm^{6}$

(Total for Question 5 = 1 mark)

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

6 This question is about the reversible reaction below.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

(a) A chemist investigating this reaction started with 10 moles of NO_2 and allowed the system to reach equilibrium. If 3 moles of N_2O_4 are formed, the number of moles of NO_2 at equilibrium is

(1)

☒ **A** 8.5

☒ **B** 7

☒ **C** 6

☒ **D** 4

(b) Under different conditions, 40% of the moles present at equilibrium is N_2O_4. If the total pressure of the system is 2.0 atm, the numerical value of the equilibrium constant, K_p is

(1)

☒ **A** 0.56

☒ **B** 0.67

☒ **C** 1.5

☒ **D** 1.8

(Total for Question 6 = 2 marks)

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

7 Carbon monoxide and chlorine react together and reach equilibrium:

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$$

If the pressure of the system is then **increased** at constant temperature, which of the following statements is correct?

☒ **A** The equilibrium moves to the left and K_p decreases.

☒ **B** The equilibrium moves to the right and K_p increases.

☒ **C** The equilibrium moves to the right, then back to the left and K_p remains the same.

☒ **D** The equilibrium moves to the right and K_p remains the same.

(Total for Question 7 = 1 mark)

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8 The table shows some data about metal ions, non-metal ions and their compounds.

Ion	Enthalpy change of hydration / kJ mol^{-1}	Compound	Lattice energy / kJ mol^{-1}
$Mg^{2+}(g)$	–1921	$MgCl_2(s)$	–2526
$Cl^-(g)$	–340		
$Cs^+(g)$	–276	CsF(s)	–747
$F^-(g)$	–483		

Use the data to calculate

(a) the standard enthalpy change, in kJ mol^{-1}, for the following process.

$$Mg^{2+}(g) + 2Cl^-(g) \rightarrow Mg^{2+}(aq) + 2Cl^-(aq)$$

(1)

☒ **A** –1241

☒ **B** –1581

☒ **C** –2261

☒ **D** –2601

(b) the standard enthalpy change of solution, in kJ mol^{-1}, of caesium fluoride, CsF.

(1)

☒ **A** −12

☒ **B** +12

☒ **C** −1506

☒ **D** +1506

(Total for Question 8 = 2 marks)

9 Which of these solvents is most likely to be warmed by microwave radiation?

☒ **A** Hexane

☒ **B** Cyclohexane

☒ **C** Cyclohexanol

☒ **D** Cyclohexene

(Total for Question 9 = 1 mark)

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

10 Some chemical tests are described below.

A Warm with Fehling's (or Benedict's) solution

B Warm with acidified potassium dichromate(VI) solution

C Add sodium carbonate solution

D Add 2,4-dinitrophenylhydrazine solution

(a) Which test always gives a positive result with carbonyl compounds?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) Which test would give a positive result with ethane-1,2-diol?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) Which test would result in effervescence with ethanoic acid?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 10 = 3 marks)

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

11 Consider the four compounds shown below.

A CH_3COOCH_3

B CH_3COOH

C $CH_3CONHCH_2CH_3$

D CH_3COCl

Which of these compounds

(a) will react most vigorously with water?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(b) forms methanol when refluxed with aqueous sodium hydroxide?

(1)

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(c) has at least one triplet in its high resolution proton nmr spectrum?

(1)

☒ **A**

☒ **B**

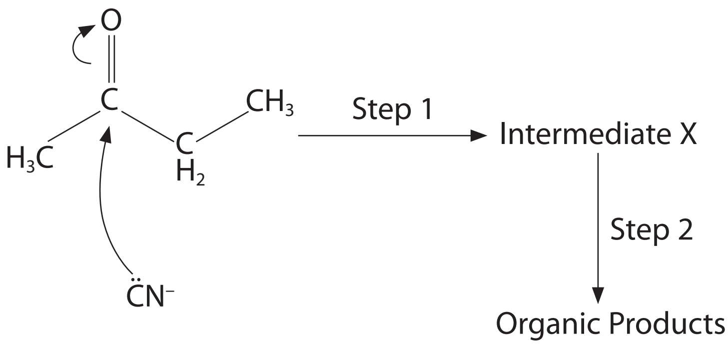
☒ **C**

☒ **D**

(Total for Question 11 = 3 marks)

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

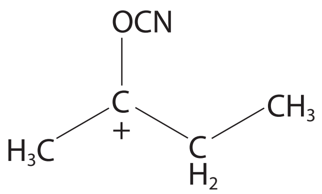
12 The diagram below shows part of the mechanism for the nucleophilic addition of hydrogen cyanide to butanone.



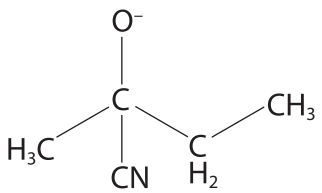
(a) The formula of the intermediate X is

(1)

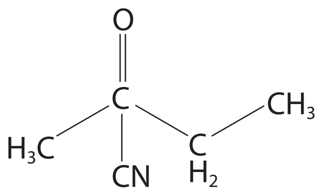
☒ **A**



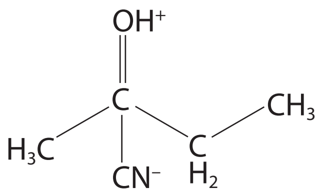
☒ **B**



☒ **C**



☒ **D**



(b) Consider the dissociation of the weak acid, HCN.

$$HCN(aq) \rightleftharpoons H^+(aq) + CN^-(aq)$$

Which of the following reagents would shift the position of the equilibrium towards formation of the nucleophile, CN^-?

(1)

☒ **A** KOH

☒ **B** KCN

☒ **C** H_2SO_4

☒ **D** CH_3COOH

(c) Which statement about the mixture of organic products formed is **not** correct?

(1)

☒ **A** The mixture contains products with chiral molecules.

☒ **B** The mixture rotates the plane of plane-polarized light.

☒ **C** The mixture contains products with the nitrile functional group.

☒ **D** The mixture contains products each of which has four carbon atoms in a straight chain.

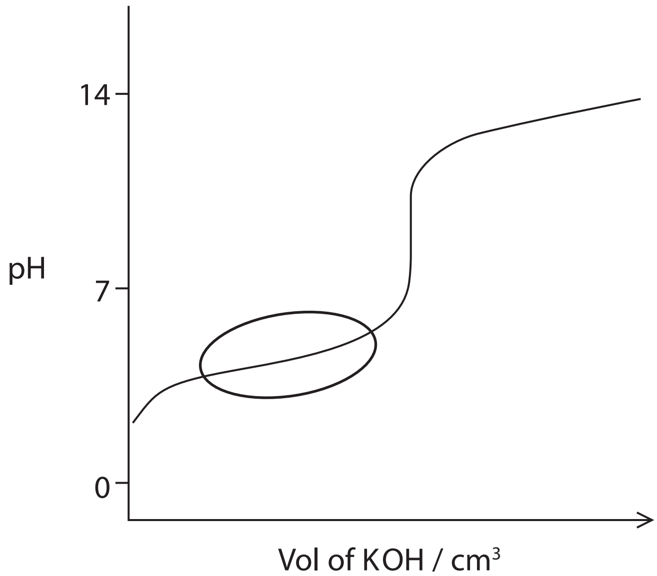
(Total for Question 12 = 3 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

13 A student carried out a titration by adding 0.032 mol dm^{-3} potassium hydroxide solution to 25.0 cm^3 of 0.024 mol dm^{-3} propanoic acid. A sketch graph of pH against volume of potassium hydroxide solution added is shown below.



(a) *(i) Describe and explain the behaviour of the solution formed in the region circled on the sketch graph.

(3)

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*(ii) Explain why the pH at the equivalence point of this titration is greater than 7.

(3)

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(iii) By considering the amount of excess alkali remaining, calculate the pH of the solution formed when 40 cm^3 of 0.032 mol dm^{-3} potassium hydroxide solution has been added to 25.0 cm^3 of 0.024 mol dm^{-3} propanoic acid.

$$K_w = 1.0 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6} \text{ at 298 K}$$

(5)

(b) The student made the following statement:

'The pH of pure water is always 7.0'

Is the student correct? Use the following information to justify your answer.

- $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
- $K_w = 1.0 \times 10^{-14}$ mol^2 dm^{-6} at 298 K
- ΔH is positive for the forward reaction in the equilibrium.

(3)

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(Total for Question 13 = 14 marks)

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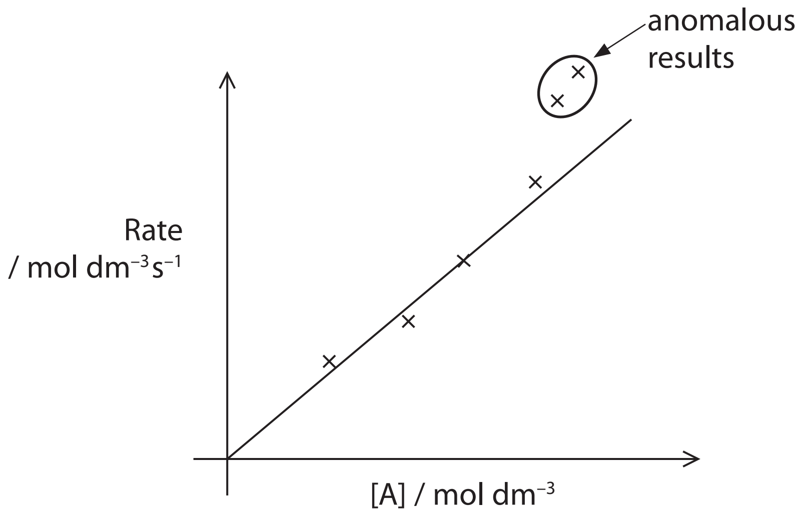
14 The kinetics of the fast reaction below were investigated in a series of experiments.

$$\mathbf{A} + \mathbf{B} \xrightarrow{\text{catalyst } \mathbf{X}} \mathbf{C} + \mathbf{D} \qquad \Delta H \text{ is negative}$$

(a) Outline a titrimetric method that could be used to measure the change in concentration of compound **A** with time. Compound **A** is an alkali, whereas compounds **B**, **C** and **D** are neutral.

(3)

(b) The rate of the reaction was measured at several different concentrations of **A**, in the presence of a large excess of compound **B** and a constant amount of catalyst **X**, to find the order of reaction with respect to **A**. The results are shown on the graph below.



(i) Explain how the graph confirms that the reaction is first order with respect to **A**.

(1)

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(ii) Suggest an explanation, other than human error, for the two anomalous results circled on the graph.

(3)

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(c) In a second series of experiments, further data were collected using an initial rates method. These results are summarised in the table below.

Experiment	Initial concentration / mol dm^{-3}			Initial rate / mol dm^{-3} s^{-1}
	A	**B**	**X**	
1	0.020	0.005	0.500	2.1×10^{-3}
2	0.040	0.005	0.500	4.2×10^{-3}
3	0.060	0.010	0.500	6.3×10^{-3}
4	0.080	0.010	0.250	4.2×10^{-3}

(i) Give **one** reason why obtaining these further data may be considered useful.

(1)

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(ii) Deduce the rate equation for this reaction, explaining how you arrived at your answer.

(5)

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(iii) Use your answer from (c)(ii), and appropriate data from **Experiment 4**, to calculate the value of the rate constant, *k*. Include units in your answer.

(2)

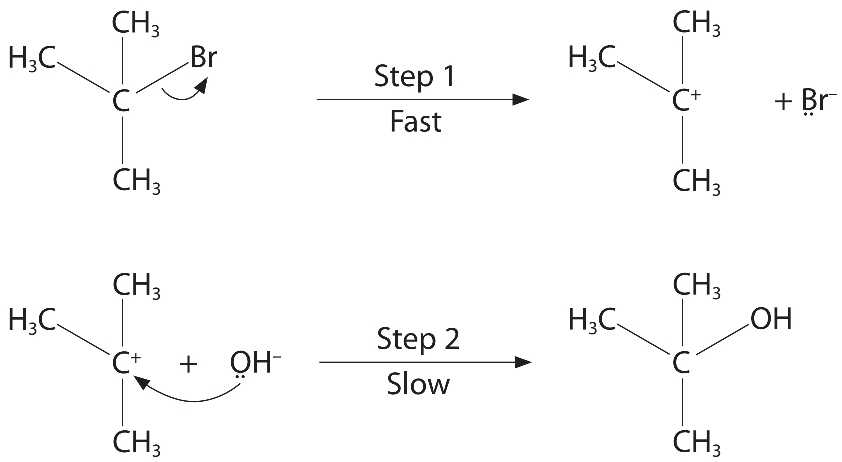
(d) A student carried out a similar investigation into the kinetics of the reaction between 2-bromomethylpropane and hydroxide ions. A summary of the student's findings is shown below.

<u>Kinetics Investigation - Summary of Key Findings</u>

Reaction is first order with respect to 2-bromomethylpropane

<u>Suggested Mechanism</u>

S_N2 - as two steps in process



Use your knowledge of the mechanism of nucleophilic substitution reactions to suggest one feature of the summary, including the student's mechanism, that you agree with and two features you think are incorrect.

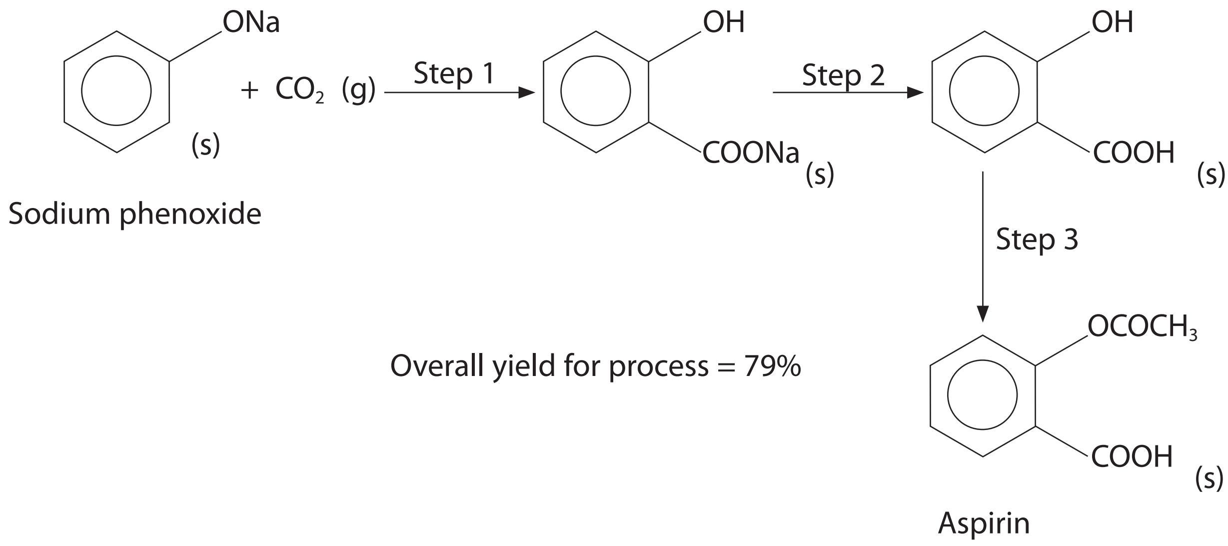
(3)

One feature you agree with.

Two features you think are incorrect.

(Total for Question 14 = 18 marks)

15 Aspirin can be manufactured from sodium phenoxide using the process shown below.



(a) Explain **one** effect of an increase in pressure on the reaction in Step 1.

(2)

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(b) The overall yield for this process is 79%.

Calculate the mass, in tonnes, of aspirin that would be formed from 2.5 tonnes of sodium phenoxide. Give your answer to **two** significant figures.

[Molar masses / g mol^{-1}: sodium phenoxide = 116; aspirin = 180]

(3)

(c) Classify the reaction type in Step 3 and suggest a suitable reagent.

(2)

Reaction type ....

Reagent ....

(Total for Question 15 = 7 marks)

16 Fresh coffee is made by adding hot water to ground coffee beans.

Chemists at the University of Nevada have produced bio-diesel fuel from used coffee grounds. The grounds contain approximately 10–15% oil by mass. This oil can be extracted, using standard chemical techniques, and then converted to bio-diesel by the reaction with methanol in the presence of a suitable catalyst.

(a) (i) A solvent is added to the solid coffee grounds to dissolve the oil. Suggest how the oil is then obtained from this mixture.

(2)

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(ii) Complete the equation below for the formation of a bio-diesel from the reaction of an oil with methanol.

(2)

$$3CH_3OH \quad + \quad \begin{array}{l} CH_2OOCR' \\ | \\ CHOOCR'' \\ | \\ CH_2OOCR''' \end{array} \quad \longrightarrow$$

(iii) Suggest a suitable catalyst for the reaction in (a)(ii).

(1)

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*(b) Another source of oil for bio-diesel production is palm oil, obtained from the fruit of palm trees grown on large plantations across many tropical regions.

Consider **one** advantage and **one** disadvantage of each source to decide which oil may provide a potentially greener and more sustainable supply of bio-diesel.

(4)

(Total for Question 16 = 9 marks)

TOTAL FOR SECTION B = 48 MARKS

SECTION C

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

17 Adipic acid, $HOOC(CH_2)_4COOH$, is a dicarboxylic acid used in the production of polymers. It can be made by the reaction of buta-1,3-diene with carbon monoxide and water.

$$CH_2CHCHCH_2(g) + 2CO(g) + 2H_2O(l) \rightarrow HOOC(CH_2)_4COOH(s)$$

(a) (i) Use the Data Booklet to complete the table below.

(2)

	$CH_2CHCHCH_2(g)$	$CO(g)$	$H_2O(l)$	$HOOC(CH_2)_4COOH(s)$
$\Delta H_f^\ominus$ / kJ mol^{-1}	+109.9			–994.3
$S^\ominus$ / J mol^{-1} K^{-1}	278.7			250.0

(ii) Use data from the table to calculate the standard enthalpy change, in kJ mol^{-1}, when adipic acid is formed from buta-1,3-diene, carbon monoxide and water.

(2)

(iii) Use data from the table to calculate the standard entropy change of the system, in J mol^{-1} K^{-1}, when adipic acid is formed from buta-1,3-diene, carbon monoxide and water.

(2)

(iv) Use your answers to (a)(ii) and (a)(iii) to calculate $\Delta S_{surroundings}$ and ΔS_{total} for the reaction at 298 K.

(3)

(v) It was suggested that **decreasing** the temperature of the reaction to less than 298 K would produce a greater yield of adipic acid.

Explain, in terms of the effect on ΔS_{system}, $\Delta S_{surroundings}$ and hence ΔS_{total}, whether this would be the case.

(3)

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(b) Infrared spectroscopy can be used to follow the progress of reactions. During the reaction to produce adipic acid, suggest **one** peak which diminishes and **one** peak which appears.

Use information from the Data Booklet to identify two such possible peaks, giving their wave numbers and the bonds involved.

(2)

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(c) Adipic acid is used as an additive in some fruit jellies. Suggest what effect the adipic acid will have on the flavour of the jelly.

(1)

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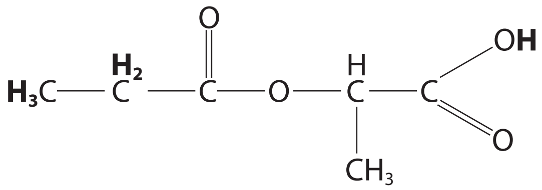
....

(d) An organic compound, **Q**, is found to contain 49.3% carbon and 6.8% hydrogen by mass.

(i) Use these data to confirm its empirical formula is $C_3H_5O_2$.

(3)

(ii) The structure of **Q** is shown below.



The table below summarises some information about parts of the nmr spectrum of compound **Q**.

Use the Data Booklet, and your knowledge of splitting patterns, to complete the table with respect to the features of compound **Q** shown in bold.

(4)

Feature of compound **Q**	Chemical shift / ppm	Splitting pattern
$C\mathbf{H}_3$	0.1 – 1.9	
$C\mathbf{H}_2$		
$COO\mathbf{H}$		singlet

(Total for Question 17 = 22 marks)

TOTAL FOR SECTION C = 22 MARKS
TOTAL FOR PAPER = 90 MARKS

The Periodic Table of Elements

Key

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

1	2											3	4	5	6	7	0 (8)
							1.0 **H** hydrogen 1										*(18)* 4.0 **He** helium 2
(1)	*(2)*											*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	
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	*(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

* 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