Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | Candidate Number

Tuesday 29 October 2019

Morning (Time: 1 hour 40 minutes) | Paper Reference **WCH04/01**

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

Candidates must have: Scientific calculator
Data Booklet

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

Turn over ▶

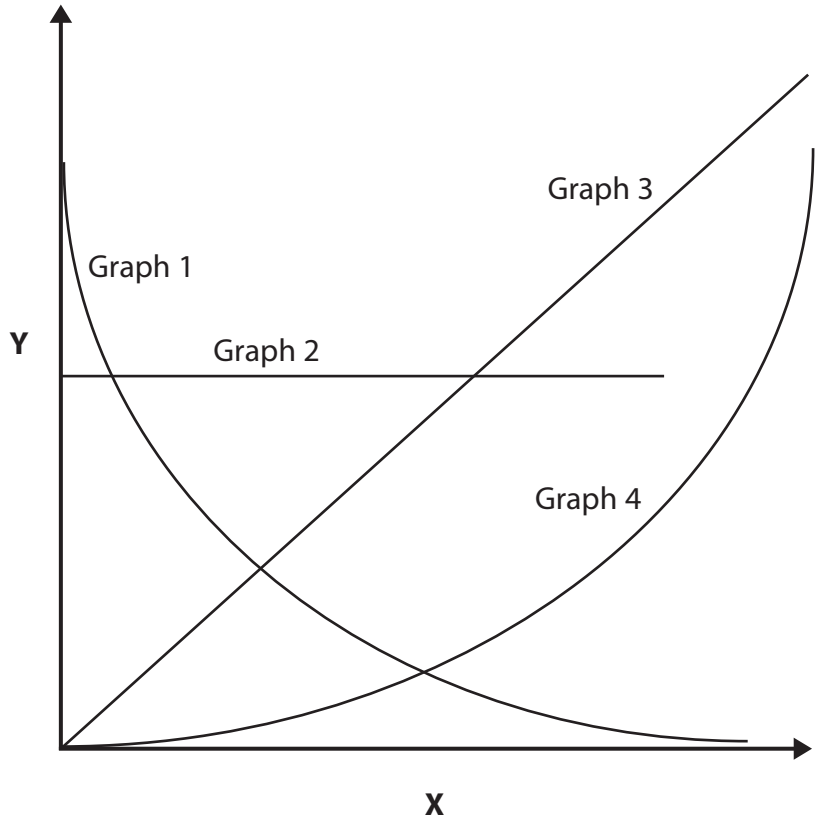
P58273A

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 The diagram shows four graphs in which a quantity **Y** has been plotted against a quantity **X**.



(a) Which graph would be obtained when **X** is reactant concentration and **Y** is rate of reaction for a first order reaction?

(1)

☒ **A** Graph 1

☒ **B** Graph 2

☒ **C** Graph 3

☒ **D** Graph 4

(b) Which graph would be obtained when **X** is time and **Y** is product concentration for a zero order reaction?

(1)

☒ **A** Graph 1

☒ **B** Graph 2

☒ **C** Graph 3

☒ **D** Graph 4

(c) Which graph would be obtained when **X** is temperature and **Y** is rate of reaction?

(1)

☒ **A** Graph 1

☒ **B** Graph 2

☒ **C** Graph 3

☒ **D** Graph 4

(Total for Question 1 = 3 marks)

2 Hydrogen iodide may be formed from the reaction of hydrogen with iodine.

The transition state is the same in both directions of the equilibrium.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H_{reaction} = +53\,kJ\,mol^{-1}$$

The activation energy for the forward reaction is 173 kJ mol^{-1}.

The activation energy, in kJ mol^{-1}, for the reverse reaction is

☒ **A** −53

☒ **B** +120

☒ **C** +173

☒ **D** +226

(Total for Question 2 = 1 mark)

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

3 Sodium chloride dissolves in water.

$$NaCl(s) + aq \rightarrow Na^+(aq) + Cl^-(aq) \qquad \Delta H^{\ominus} = +3.9\,kJ\,mol^{-1}$$

The best explanation for the fact that sodium chloride dissolves in water spontaneously is that the process has a

- ☒ **A** low activation energy.
- ☒ **B** positive enthalpy change.
- ☒ **C** positive entropy change of the surroundings, $\Delta S^{\ominus}_{surroundings}$.
- ☒ **D** positive entropy change of the system, $\Delta S^{\ominus}_{system}$.

(Total for Question 3 = 1 mark)

4 Butane has a higher standard molar entropy than 2-methylpropane at 298 K and 1 atm, when both compounds are gases.

The best explanation for this fact is that butane has

- ☒ **A** a higher boiling temperature.
- ☒ **B** a more positive standard molar enthalpy change of formation.
- ☒ **C** fewer ways of distributing energy quanta.
- ☒ **D** more ways of distributing energy quanta.

(Total for Question 4 = 1 mark)

5 Standard molar entropy is zero for

- ☒ **A** perfect crystals at absolute zero (0 K).
- ☒ **B** ideal gases under standard conditions (298 K and 1 atm).
- ☒ **C** elements in their most stable states under standard conditions.
- ☒ **D** graphite, containing only the carbon-12 isotope, under standard conditions.

(Total for Question 5 = 1 mark)

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

6 Ethanol is manufactured by the hydration of ethene at 500 K and 60 atm.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H^{\ominus} = -53.8\,kJ\,mol^{-1}$$

(a) How does increasing the temperature to 550 K affect the activation energy and equilibrium constant of this reaction?

(1)

	Activation energy	Equilibrium constant
☒ **A**	increases	increases
☒ **B**	decreases	decreases
☒ **C**	unchanged	increases
☒ **D**	unchanged	decreases

(b) How does increasing the pressure to 70 atm affect the rate of the reaction and the equilibrium yield of ethanol?

(1)

	Rate	Equilibrium yield
☒ **A**	increases	increases
☒ **B**	increases	decreases
☒ **C**	decreases	increases
☒ **D**	decreases	decreases

(c) The equilibrium constant for the hydration of ethene is given by the expression

(1)

☒ **A** $K_p = \dfrac{p(C_2H_5OH)}{p(C_2H_4) \times p(H_2O)}$

☒ **B** $K_p = \dfrac{p(C_2H_4) \times p(H_2O)}{p(C_2H_5OH)}$

☒ **C** $K_p = \dfrac{p(C_2H_5OH)}{p(C_2H_4)}$

☒ **D** $K_p = \dfrac{p(C_2H_4)}{p(C_2H_5OH)}$

(Total for Question 6 = 3 marks)

7 The Arrhenius theory defined acids as substances that

- ☒ **A** have a sour taste.
- ☒ **B** react with alkalis to form a salt and water only.
- ☒ **C** produce an excess of hydrogen ions in solution.
- ☒ **D** accept lone pairs of electrons.

(Total for Question 7 = 1 mark)

8 The dissociation constant of water, K_w , increases with increasing temperature.

Under standard conditions pure water is neutral and has a pH = 7.

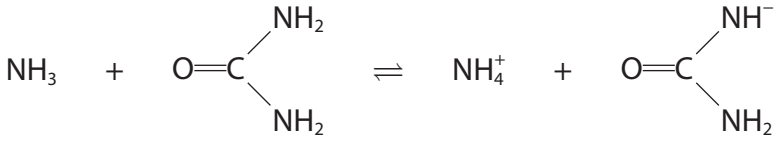
What happens to the acidity and pH of pure water when the temperature is increased?

	Effect of increasing temperature	
	Acidity of water	pH
☒ **A**	increases	increases
☒ **B**	increases	decreases
☒ **C**	remains neutral	increases
☒ **D**	remains neutral	decreases

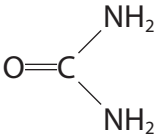
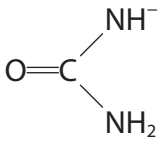
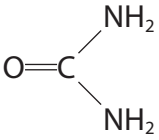
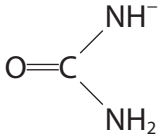
(Total for Question 8 = 1 mark)

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

9 When urea dissolves in liquid ammonia, an acid-base equilibrium is set up.



Which species are the Brønsted-Lowry acids in this equilibrium?

	Acid 1	Acid 2
☒ **A**	NH_3	NH_4^+
☒ **B**		NH_4^+
☒ **C**	NH_3	
☒ **D**		

(Total for Question 9 = 1 mark)

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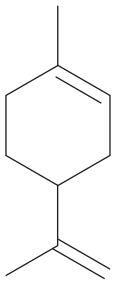
10 Limonene is a major component of the oil found in citrus fruits.



Limonene

Limonene will show

☒ **A** geometric and optical isomerism.

☒ **B** geometric isomerism only.

☒ **C** optical isomerism only.

☒ **D** neither geometric nor optical isomerism.

(Total for Question 10 = 1 mark)

11 Ethanal has a much higher boiling temperature and is much more soluble in water than propane.

These differences in properties are best explained by the fact that, in addition to London forces, ethanal forms

☒ **A** hydrogen bonds in the liquid state and in aqueous solution.

☒ **B** permanent dipole-dipole forces in the liquid state and hydrogen bonds in aqueous solution.

☒ **C** hydrogen bonds in the liquid state and permanent dipole-dipole forces in aqueous solution.

☒ **D** permanent dipole-dipole forces in the liquid state and in aqueous solution.

(Total for Question 11 = 1 mark)

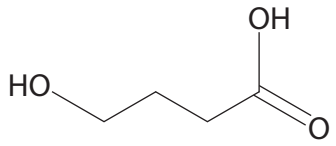
Use this space for any rough working. Anything you write in this space will gain no credit.

12 Butanone may be converted into propanoic acid by

- ☒ **A** refluxing with acidified potassium dichromate(VI).
- ☒ **B** warming with iodine and sodium hydroxide followed by acidifying with sulfuric acid.
- ☒ **C** heating with hydrogen gas in the presence of a nickel catalyst.
- ☒ **D** heating with hydrogen cyanide and potassium cyanide followed by refluxing with sulfuric acid.

(Total for Question 12 = 1 mark)

13 The structure of 4-hydroxybutanoic acid is



(a) The presence of the alcohol functional group and the carboxylic acid functional group may be confirmed by reacting under suitable conditions

(1)

- ☒ **A** a sample of the compound with phosphorus(V) chloride.
- ☒ **B** a sample of the compound with sodium hydrogencarbonate solution.
- ☒ **C** separate samples of the compound with ethanol and with ethanoic acid.
- ☒ **D** separate samples of the compound with acidified potassium dichromate(VI) and with 2,4-dinitrophenylhydrazine.

(b) The high resolution proton nmr spectrum of 4-hydroxybutanoic acid will have

(1)

- ☒ **A** two singlets, two triplets and one quintet.
- ☒ **B** two singlets and three triplets.
- ☒ **C** one singlet, two triplets, one quartet and one quintet.
- ☒ **D** two singlets, two triplets, one quartet and one quintet.

(Total for Question 13 = 2 marks)

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

14 Transesterification involves reactions in which

- ☒ **A** alkyl groups of alcohols replace alkyl groups of esters.
- ☒ **B** alkyl groups of carboxylic acids replace alkyl groups of esters.
- ☒ **C** trans isomers of long-chain esters are formed.
- ☒ **D** diacyl chlorides and diols combine to form polyesters.

(Total for Question 14 = 1 mark)

15 The main characteristic of HPLC is the use of

- ☒ **A** polymeric liquids.
- ☒ **B** high pressures.
- ☒ **C** helium-cadmium lasers.
- ☒ **D** long columns.

(Total for Question 15 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

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

16 Ammonium nitrate, NH_4NO_3, is used as a fertiliser.

(a) When heated gently at 160 °C, ammonium nitrate decomposes.

$$NH_4NO_3(s) \rightarrow N_2O(g) + 2H_2O(g) \qquad \Delta H^{\ominus} = -36.0\,kJ\,mol^{-1}$$

(i) Predict the sign of the entropy change in the system, $\Delta S^{\ominus}_{system}$.
Justify your answer.

(1)

.....

.....

.....

(ii) Calculate the entropy change in the system, $\Delta S^{\ominus}_{system}$, for the decomposition of ammonium nitrate, using data from your Data Booklet.
Include a sign and units with your answer.

(3)

(iii) Calculate the entropy change in the surroundings, $\Delta S^{\ominus}_{surroundings}$, for the decomposition of ammonium nitrate at 160 °C.
Include a sign and units with your answer.

(3)

(iv) Use your answers to (a)(ii) and (a)(iii) to calculate the total entropy change, $\Delta S^{\ominus}_{total}$, for the decomposition of ammonium nitrate.
Give your answer to an appropriate number of significant figures and include a sign and units with your answer.

(2)

(b) When ammonium nitrate is heated rapidly, it decomposes as shown.

$$NH_4NO_3(s) \rightarrow N_2(g) + 2H_2O(g) + \tfrac{1}{2}O_2(g) \qquad \Delta H = -118.0\,kJ\,mol^{-1}$$

(i) The total entropy change, ΔS_{total}, for this decomposition of ammonium nitrate is $+555\,J\,K^{-1}\,mol^{-1}$.

Calculate the equilibrium constant for this decomposition.
Units are not required.

(2)

*(ii) Explain, in terms of entropy, how this equilibrium constant for the complete decomposition of ammonium nitrate would be affected if the temperature was increased. No calculation is required.

(2)

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(Total for Question 16 = 13 marks)

17 The reaction of 2-bromobutane with aqueous alkali is a nucleophilic substitution.

$$C_4H_9Br + NaOH \rightarrow C_4H_9OH + NaBr$$

Depending on the conditions, the mechanism of this reaction may be S_N1 or S_N2.

(a) Experiments were carried out to determine the rate equation for a reaction of 2-bromobutane with aqueous sodium hydroxide.

In each experiment, the reactants were mixed and the concentration of 2-bromobutane was measured at various times as the reaction proceeded.

The initial rate of the reaction was determined using these data.

(i) Describe how the **initial** rate would be determined from the results of one experiment.

(3)

(ii) Give a reason why the concentration of sodium hydroxide used was very much greater than the concentration of 2-bromobutane.

(1)

(b) The results of a set of experiments are shown.

Experiment	Initial $[C_4H_9Br]$ / mol dm^{-3}	Initial [NaOH] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.020	1.0	1.5×10^{-5}
2	0.030	1.0	2.3×10^{-5}
3	0.040	2.0	5.9×10^{-5}

(i) By referring to the data in the table, show that the reaction was first order with respect to both C_4H_9Br and NaOH.

(2)

(ii) Calculate the rate constant for the reaction.
Use the data from experiment 1 and include units with your answer.

(2)

(c) (i) State why the reaction of 2-bromobutane with aqueous sodium hydroxide being second order indicates an S_N2 mechanism.

(1)

.....

.....

.....

(ii) Draw the first step of the mechanism, showing the transition state in the S_N2 mechanism for the reaction of 2-bromobutane with aqueous sodium hydroxide. Include curly arrows, and any relevant dipoles and lone pairs of electrons.

(3)

(d) 2-bromobutane and butan-2-ol are chiral molecules.

(i) State the meaning of the term chiral molecule.

(1)

*(ii) When a single enantiomer (optical isomer) of 2-bromobutane reacts with aqueous alkali, the stereochemistry of the butan-2-ol formed depends on whether the mechanism is S_N1 or S_N2.

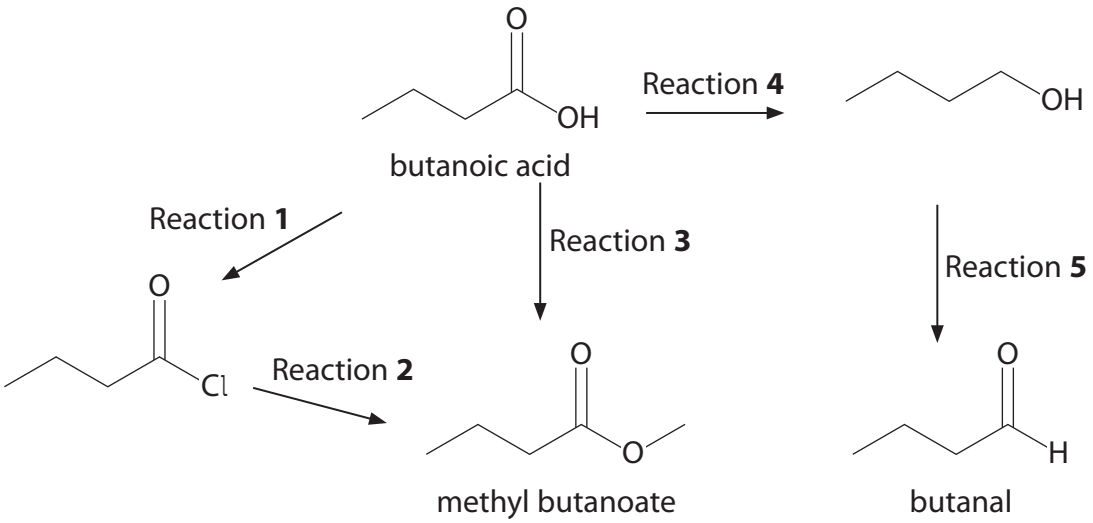
Explain how the stereochemistry of the butan-2-ol differs with the different mechanisms.

(4)

(Total for Question 17 = 17 marks)

18 Butanoic acid is found in milk, butter and cheese and its name comes from the Latin word for butter. It has an unpleasant smell, which can be detected at very low concentrations, whereas the esters of butanoic acid, such as methyl butanoate, have pleasant smells and tastes, and are added to food and perfumes.

(a) Some reactions of butanoic acid are shown.



(i) Identify, by name or formula, the reagents and any essential conditions for Reactions **1** to **4**.

(5)

Reaction **1** .....

Reaction **2** .....

Reaction **3** .....

.....

Reaction **4** .....

.....

(ii) The reagents used in Reaction **5** are potassium dichromate(VI) and sulfuric acid.

State how this reaction must be carried out to ensure that the main product is butanal.

(1)

.....

.....

(iii) Give **one** advantage and **one** disadvantage of preparing methyl butanoate using Reactions **1** and **2** rather than Reaction **3**.

(2)

(iv) Suggest why butanal is **not** made from butanoic acid in a single step.

(1)

(b) Give **two** ways in which the infrared spectra of butanoic acid and methyl butanoate differ, other than in their fingerprint region.
Quote values from your Data Booklet for the wavenumber ranges of specific bonds.

(2)

(c) Butanoic acid can be detected by animals with a good sense of smell at concentrations of 10 parts of butanoic acid vapour per billion (1×10^9) of air at room temperature and pressure (r.t.p.).

Calculate the minimum concentration, in mol dm^{-3}, of butanoic acid that can be detected by these animals.

(2)

[Molar volume of gases at r.t.p. = 24.0 dm^3 mol^{-1}]

(Total for Question 18 = 13 marks)

19 Heating fructose with hydrochloric acid produced an aliphatic compound, **G**, which has five carbon atoms in an **unbranched** chain.

G gave an orange precipitate with 2,4-dinitrophenylhydrazine but **no reaction** when warmed with ammoniacal silver nitrate. Addition of **G** to sodium hydrogencarbonate solution resulted in vigorous effervescence.

In the mass spectrum of **G**, the molecular ion peak was at $m/e = 116$.

Draw the **three** possible structures of **G**. Explain your reasoning.

(7)

(Total for Question 19 = 7 marks)

TOTAL FOR SECTION B = 50 MARKS

SECTION C

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

20 Methanoic acid, HCOOH, is a weak acid that is present in the stings of ants and nettles. It is used as a preservative and antibacterial agent in livestock feed.

(a) An aqueous solution of methanoic acid has a concentration of 30 g dm^{-3}.

(i) Write the equation for the dissociation of methanoic acid in water. State symbols are not required.

(1)

(ii) Write the expression for K_a for methanoic acid.

(1)

(iii) Calculate the pH of a solution of methanoic acid with a concentration of 30 g dm^{-3}.

[K_a of methanoic acid = 1.70×10^{-4} mol dm^{-3}]

(4)

(iv) State **two** approximations used in the calculation of the pH in (a)(iii).

(2)

(b) A solution which contains both methanoic acid and sodium methanoate acts as a buffer.

(i) State the meaning of the term buffer.

(2)

*(ii) Explain how a solution which contains both methanoic acid and sodium methanoate acts as a buffer.

(4)

(c) A buffer solution **Q** is prepared by dissolving 1.25 mol of methanoic acid and 1.50 mol of sodium methanoate in distilled water and making up the solution to 1.00 dm^3.

(i) Calculate the pH of **Q**.

[K_a of methanoic acid = 1.70×10^{-4} mol dm^{-3}]

(3)

(ii) Calculate the pH of **Q** after the addition of 2.0 g of sodium hydroxide. Assume that the volume of **Q** is unchanged at 1.00 dm^3.

(3)

(Total for Question 20 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS

TOTAL FOR PAPER = 90 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key: relative atomic mass / atomic symbol / name / atomic (proton) number									(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

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

Mark Scheme (Results)

October 2019

Pearson Edexcel International Advanced Level In Chemistry (WCH04)
Paper 01 General Principles of Chemistry l – Rates, Equilibria and Further Organic Chemistry

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October 2019
Publications Code WCH04_01_1910_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A (multiple choice)

Question Number	Correct Answer	Mark
1(a)	**The only correct answer is C** (Graph 3) ***A*** *is not correct because this is a graph of concentration of reactant against time for a first order reaction* ***B*** *is not correct because this is a graph of rate against concentration for a zero order reaction.* ***D*** *is not correct because this is a graph of rate against temperature*	**(1)**

Question Number	Correct Answer	Mark
1(b)	**The only correct answer is C** (Graph 3) ***A*** *is not correct because the concentration of product must increase with time. This is a graph of concentration of reactant against time for a first order reaction and shows Y decreasing with time* ***B*** *is not correct because the concentration of product must increase with time. This is a graph of rate against concentration for a zero order reaction and shows Y constant.* ***D*** *is not correct because the concentration of product must increase linearly with time. This is a graph of rate against temperature and shows Y increasing exponentially*	**(1)**

Question Number	Correct Answer	Mark
1(c)	**The only correct answer is D** (Graph 4) ***A*** *is not correct because rate increases exponentially with temperature. This is a graph of concentration of reactant against time for a first order reaction so Y decreases* ***B*** *is not correct because rate increases exponentially with temperature. This is a graph of rate against concentration for a zero order reaction so Y does not change.* ***C*** *is not correct because rate increases exponentially with temperature; it is not directly proportional to temperature*	**(1)**

Question Number	Correct Answer	Mark
2	**The only correct answer is B** (+120) ***A*** *is not correct because this is the enthalpy change of the reverse reaction* ***C*** *is not correct because this is the same as the activation energy of the forward reaction* ***D*** *is not correct because this is the sum of the activation energy and the enthalpy change for the forward reaction*	**(1)**

Question Number	Correct Answer	Mark
3	**The only correct answer is D** (positive entropy change of the system, Δ*S* system) ***A*** *is not correct because activation energy determines rate not thermodynamic feasibility* ***B*** *is not correct because a positive enthalpy change favours the reverse reaction* ***C*** *is not correct because* $\Delta S^{\ominus}_{surroundings}$ *is negative for an endothermic reaction*	**(1)**

Question Number	Correct Answer	Mark
4	**The only correct answer is D** (more ways of distributing energy quanta) ***A*** *is not correct because boiling temperature only affects molar entropy when there is a change of state.* ***B*** *is not correct because standard molar enthalpy change of formation does not affect molar entropy* ***C*** *is not correct because molar entropy increases as the number of ways of distributing energy quanta increases*	**(1)**

Question Number	Correct Answer	Mark
5	**The only correct answer is A** (perfect crystals at absolute zero (0 K)) ***B*** *is not correct because the molar entropy of gases is never zero* ***C*** *is not correct because this refers to standard enthalpies of formation for elements* ***D*** *is not correct because this is not true*	**(1)**

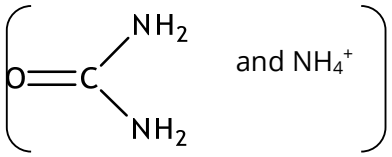
Question Number	Correct Answer	Mark
6(a)	**The only correct answer is D** (unchanged and decreases) ***A*** *is not correct because activation energy does not change with temperature and the equilibrium constant of an exothermic reaction decreases with increasing temperature* ***B*** *is not correct because activation energy does not change with temperature* ***C*** *is not correct because the equilibrium constant of an exothermic reaction decreases with increasing temperature*	**(1)**

Question Number	Correct Answer	Mark
6(b)	**The only correct answer is A** (increases and increases) ***B*** *is not correct because equilibrium yield would increase because 2 mol of reactant gives 1 mol of product* ***C*** *is not correct because rate increases when pressure increases for a gas phase reaction* ***D*** *is not correct because equilibrium yield would increase because 2 mol of reactant gives 1 mol of product and rate increases when pressure increases for a gas phase reaction*	**(1)**

Question Number	Correct Answer	Mark
6(c)	**The only correct answer is A** $\left(K_p = \left(\frac{p(C_2H_5OH)}{p(C_2H_4) \text{ x } p(H_2O)} \right) \right)$ ***B*** *is not correct because this is K_p for the reverse reaction* ***C*** *is not correct because water is in the gas phase so it is included in the K_p expression* ***D*** *is not correct because the expression has been inverted and because water is in the gas phase so it is included in the K_p expression*	**(1)**

Question Number	Correct Answer	Mark
7	**The only correct answer is C** (produce an excess of hydrogen ions in solution) ***A*** *is not correct because this a traditional description of an acid* ***B*** *is not correct because this is just one of a number of typical reactions of acids* ***D*** *is not correct because this is the Lewis definition of acids*	**(1)**

Question Number	Correct Answer	Mark
8	**The only correct answer is D** (remains neutral and decreases) ***A*** *is not correct because water remains neutral and the pH decreases* ***B*** *is not correct because water remains neutral* ***C*** *is not correct because the pH of water decreases*	**(1)**

Question Number	Correct Answer	Mark
9	**The only correct answer is B**  and NH_4^+ ***A*** *is not correct because ammonia is a Brønsted-Lowry base* ***C*** *is not correct because both species are Brønsted-Lowry bases.* ***D*** *is not correct because the deprotonated urea is a Brønsted-Lowry base*	**(1)**

Question Number	Correct Answer	Mark
10	**The only correct answer is C** (optical isomerism only) ***A*** *is not correct because limonene does not have geometric isomers* ***B*** *is not correct because limonene does not have geometric isomers* ***D*** *is not correct because limonene does have a chiral carbon*	**(1)**

Question Number	Correct Answer	Mark
11	**The only correct answer is B** (permanent dipole-dipole forces in the liquid state and hydrogen bonds in aqueous solution) ***A*** *is not correct because ethanal does not form hydrogen bonds in the liquid state* ***C*** *is not correct because ethanal does not form hydrogen bonds in the liquid state and permanent dipole-dipole forces cannot account for the solubility of ethanal in water* ***D*** *is not correct because permanent dipole-dipole forces cannot account for the solubility of ethanal in water*	**(1)**

Question Number	Correct Answer	Mark
12	**The only correct answer is B** (warming with iodine and sodium hydroxide followed by acidifying with sulfuric acid) ***A*** *is not correct because acidified potassium dichromate(VI) does not react with butanone* ***C*** *is not correct because this would not reduce the number of carbon atoms* ***D*** *is not correct because this sequence will give 2-hydroxy-2-methylbutanoic acid*	**(1)**

Question Number	Correct Answer	Mark
13(a)	**The only correct answer is C** (separate samples of the compound with ethanol and with ethanoic acid) ***A*** *is not correct because this reagent does not discriminate between alcohol and carboxylic acid OH groups* ***B*** *is not correct because this reagent will only show that an acid is present* ***D*** *is not correct because 2,4-dinitrophenylhydrazine does not react with the carbonyl group in carboxylic acids*	**(1)**

Question Number	Correct Answer	Mark
13(b)	**The only correct answer is A** (two singlets, two triplets and one quintet) ***B*** *is not correct because this ignores the fact that the protons on C3 are coupled to those on C2* ***and*** *C4* ***C*** *is not correct because this pattern includes the OH group on C4 in the coupling* ***D*** *is not correct because this pattern requires a proton on the carboxylic acid carbon which couples with the C2 protons*	**(1)**

Question Number	Correct Answer	Mark
14	**The only correct answer is A** (alkyl groups of alcohols replace alkyl groups of esters) ***B*** *is not correct because the alkyl groups of esters are replaced by alkyl groups of alcohols.* ***C*** *is not correct because the 'trans' does not refer to geometric isomerism* ***D*** *is not correct because transesterification involves esters reacting with alcohols*	**(1)**

Question Number	Correct Answer	Mark
15	**The only correct answer is B** (high pressures) ***A*** *is not correct because liquid polymers are not used in HPLC* ***C*** *is not correct because lasers are not used in HPLC* ***D*** *is not correct because long columns are not a particular characteristic of HPLC*	**(1)**

(TOTAL FOR SECTION A = 20 MARKS)

Section B

Question Number	Acceptable Answers	Reject	Mark
16(a)(i)	(ΔS^{o}_{system}) is positive **and** because a solid reactant forms gas products OR because gases have higher entropies than solids ALLOW (ΔS^{o}_{system}) is positive **and** because 1 mol goes to 3 mol OR because more moles of products (than reactants) ALLOW molecules for moles IGNORE references to disorder	Explanations with no comparison e.g. because 3 mol of gas are formed incorrect numbers of moles Just 'more products'	**(1)**

Question Number	Acceptable Answers	Reject	Mark
16(a)(ii)	In this question and throughout the paper allow mol^{-} for mol^{-1} and 'J / K / mol' format / J mol^{-1} K^{-1} In parts (ii), (iii) and (iv) penalise omission of sign or omitted / incorrect units for 1 mark only and at the **first** occasion $NH_4NO_3(s) \rightarrow N_2O(g) + 2H_2O(g)$ $S^{\ominus}$/J K^{-1} mol^{-1} 151.1 219.7 188.7 (1) Penalise incorrect values once only ΔS^{o}_{system} = 219.7 + 2 x 188.7 – 151.1 (1) EITHER = +446(.0) J K^{-1} mol^{-1} OR = +0.446(0) kJ K^{-1} mol^{-1} (1) Ignore SF except 1 SF Correct answer with no working scores (3) TE at each stage but no TE if wrong reactants / products used		**(3)**

Question Number	Acceptable Answers	Reject	Mark
16(a)(iii)	$\Delta S^{o}_{surroundings} = -\Delta H/T$ (1) = −(−36 000/(160 + 273) (1) EITHER = +83.1409 J K^{-1} mol^{-1} OR = +0.0831409 kJ K^{-1} mol^{-1} (1) Ignore SF except 1 SF Correct answer with no working scores (3) Omission of 273 (+225.0) scores (2) Sign incorrect (−83.14 J K^{-1} mol^{-1}) scores (2)		**(3)**

Question Number	Acceptable Answers	Reject	Mark
16(a)(iv)	$\Delta S^{\ominus}_{total} = \Delta S^{o}_{system} + \Delta S^{o}_{surroundings}$ = 446.0 + 83.1409 = 529.1409 (1) EITHER =+530 / 529 J K^{-1} mol^{-1} OR = +0.53 / 0.529 kJ K^{-1} mol^{-1} (1) Correct answer with sign and to 2 or 3 SF with no working scores (2) TE on (a)(ii) and (a)(iii) and M1	Answers not given to 2 or 3 SF	**(2)**

Question Number	Acceptable Answers	Reject	Mark
16(b)(i)	$\Delta S_{total} = R \ln K$ ALLOW $\Delta S = R \ln K$ only if ΔS = 555 is used (1) $\ln K = \Delta S_{total} / R$ = 555/8.31 = 66.787 K = 1.0121 x 10^{29} OR K = 9.80104 x 10^{28} if R = 8.314 used (1) Correct answer with no working scores (2) IGNORE units and K_c expressions Ignore SF No TE on incorrect expressions	K = 1.02 x 10^{29}	**(2)**

Question Number	Acceptable Answers	Reject	Mark
***16(b)(ii)**	**Route 1** ΔS_{system} is (approximately) constant (with temperature) (1) (As $\Delta S_{surroundings}$ becomes less positive as T increases) ΔS_{total} becomes less positive / decreases /gets smaller (with increasing temperature) **and** so *K* decreases (1) **Route 2** ΔS_{system} becomes more positive / increases with temperature **and** because the products are gases (1) (As $\Delta S_{surroundings}$ becomes less positive as T increases) cannot tell whether ΔS_{total} increases or decreases (with increasing temperature) so cannot tell whether *K* increases or decreases (1) IGNORE Just 'entropies of substances increase with temperature' Explanations in terms of Le Chatelier's Principle	Just 'ΔS' throughout	**(2)**

(Total for Question 16 = 13 marks)

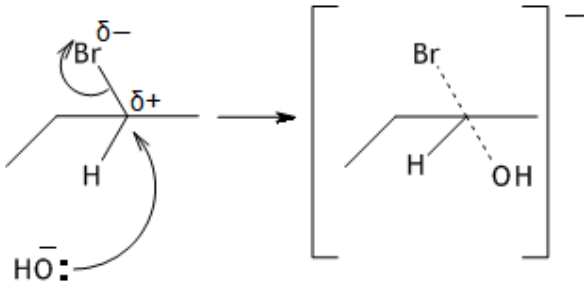
Question Number	Acceptable Answers	Reject	Mark
17(a)(i)	**M1** Plot a graph of [C_4H_9Br] (on the y axis) against time (on the x axis) ALLOW Plot a graph of concentration (of reactant) against time OR Diagram of graph with axes labelled (1) **M2** Draw a tangent at time t = 0 / initial concentration (of 2-bromobutane) ALLOW Diagram from **M1** with tangent clearly labelled (1) **M3** Measure the gradient of the tangent OR Measure the gradient of the graph at time t = 0 / the initial concentration of 2-bromobutane ALLOW Measure the initial gradient (of the graph) (1)	[NaOH] Just 'measure the gradient of the graph'	**(3)**

Question Number	Acceptable Answers	Reject	Mark
17(a)(ii)	So that the concentration of sodium hydroxide would remain (approximately) constant OR Only the concentration of 2-bromobutane would change OR So that the rate of reaction would only vary with the (change in) concentration of 2-bromobutane OR So that the rate of reaction would not be affected by (the change in concentration of) sodium hydroxide IGNORE References to limiting factors	So that all the 2-bromobutane reacts	**(1)**

Question Number	Acceptable Answers	Reject	Mark
17(b)(i)	Standalone marks E1 to E2 [C_4H_9Br] x 1.5 and (initial) rate x 1.5 ([NaOH] constant) so 1st order (wrt [C_4H_9Br]) (1) E1 to E3 [C_4H_9Br] x 2 and [NaOH] x 2 and (initial) rate x 4 so 1st order wrt [NaOH] (1) (so confirms overall second order)		**(2)**

Question Number	Acceptable Answers	Reject	Mark
17(b)(ii)	k = rate /([C_4H_9Br] x [NaOH]) = 1.5 x 10^{-5} / (0.020 x 1.0) = 7.5 x 10^{-4} / 0.00075 ALLOW Use of data from any of the experiments (E2 = 7.667 x 10^{-4}; E3 = 7.375 x 10^{-4}) (1) Correct answer with no working scores (1) dm^3 mol^{-1} s^{-1} ALLOW Units in any order (1) No TE for either mark on incorrect rate equation		**(2)**

Question Number	Acceptable Answers	Reject	Mark
17(c)(i)	[C_4H_9Br] and [NaOH] /[OH^-] are both involved in the rate-determining step ALLOW both reactants /two reactants / two species / two substances in the slow step in the RDS IGNORE References to the rate equation	Two molecules	**(1)**

Question Number	Acceptable Answers	Reject	Mark
17(c)(ii)	Allow skeletal, displayed or semi displayed structures, use of CH_3 and C_2H_5, omission of **one** H from CH_3 and C_2H_5 in a displayed formula  IGNORE Incorrect R groups / stages after the transition state Products even if incorrect Use of 1-bromobutane **M1** Curly arrow from C—Br bond to Br or just beyond **and** dipole ALLOW This curly arrow drawn on the transition state (1) **M2** Curly arrow from **lone pair** of O on OH^- to C atom (1) COMMENT Award MP2 if arrow closer to lone pair than to oxygen / charge **M3** Transition state including partial bonds **and** charge on any part of the transition state (1) IGNORE Dipoles on the transition state S_N1 may score M1 and M2	lone pair shown on H O−H----C in intermediate	**(3)**

Question Number	Acceptable Answers	Reject	Mark
17(d)(i)	(A chiral molecule) has a non-superimposable mirror image ALLOW (A chiral molecule has) an asymmetric carbon atom OR a carbon atom bonded to 4 different atoms / groups OR a carbon atom bonded to 4 different functional groups ALLOW for 'bonded to' Attached to / surrounded by IGNORE References to the rotation of the plane of plane polarised light / optical activity	4 molecules Just 'molecule with four different groups'	**(1)**

Question Number	Acceptable Answers	Reject	Mark
***17(d)(ii)**	**M1** S_N1 gives a racemic mixture **and** S_N2 gives a single enantiomer / optical isomer ALLOW S_N1 gives a mixture with no optical activity / both enantiomers **and** S_N2 gives an optically active mixture / single isomer (1) **M2** In S_N1 the intermediate (carbocation) is planar (about the carbon atom carrying the positive charge) (1) **M3** So the nucleophile / OH^- attacks (equally) from either side / top and bottom (of the carbocation / intermediate) (1) **M4** In S_N2 the nucleophile attacks one side of the molecule only / on the opposite side to the Br (1) If $S_N1$and S_N2 are reversed do not award M1 but max 3 available	molecule / carbonyl is planar Alkali (for nucleophile / OH^-) attacks the carbocation	**(4)**

(Total for Question 17 = 17 marks)

Question Number	Acceptable Answers	Reject	Mark
18(a)(i)	IGNORE use / omission of heat / reflux Reaction **1** (dry) Phosphorus(V) chloride / phosphorus pentachloride / PCl_5 OR Phosphorus(III) chloride / phosphorus trichloride / PCl_3 ALLOW Thionyl chloride $SOCl_2$ (1) Reaction **2** Methanol / CH_3OH (1) Reaction **3** Methanol / CH_3OH **and** (concentrated) sulfuric acid / H_2SO_4 (heat) ALLOW Any strong acid by name or formula Identified dilute strong acids (1) IGNORE H^+ If the same incorrect / unspecified alcohol is used in Reactions **2** and **3** award (1) for otherwise correct answers Reaction **4** Lithium tetrahydridoaluminate((III)) / lithium aluminium hydride / $LiAlH_4$ ALLOW Lithal (1) In **dry** ether /diethyl ether / ethoxyethane (1) IGNORE subsequent hydrolysis	Additional reagents Addition of acid	**(5)**

Question Number	Acceptable Answers	Reject	Mark
18(a)(ii)	Distilling the product directly out of the reaction mixture ALLOW Just distil / distillation IGNORE Controlling temperature Using excess butan-1-ol Using limited amount of oxidising agent	Reflux Fractional distillation Steam distillation	**(1)**

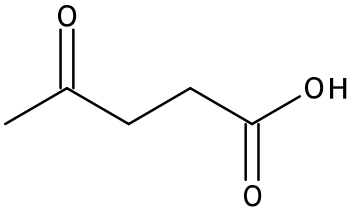
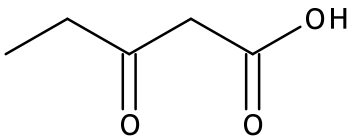
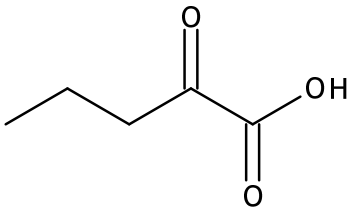
Question Number	Acceptable Answers	Reject	Mark
18(a)(iii)	Advantage: (Overall) reaction goes to completion ALLOW Reaction fast(er) / does not require heat / occurs at room temperature / does not require a catalyst (1) IGNORE (For M1) Reference to purity / yield / ease of reaction / vigorous reaction / reaction not reversible / not equilibrium Disadvantage: (Toxic / corrosive) hydrogen chloride / HCl is formed (1) IGNORE Two-step process / by-products formed	References to cost reaction not reversible / equilibrium	**(2)**

Question Number	Acceptable Answers	Reject	Mark
18(a)(iv)	Butanal is more easily reduced than butanoic acid ALLOW Butan-1-ol / butanol / alcohol is (always) formed OR difficult to stop the reduction at the aldehyde IGNORE References to the strength of the reducing agent References to speed of reaction		**(1)**

Question Number	Acceptable Answers	Reject	Mark
18(b)	Any **two** from Butanoic acid (will have stretching vibrations for) O—H at 3300-2500 (cm^{-1}) (1) OR Butanoic acid (will have stretching vibrations for) C=O at 1725-1700 (cm^{-1}) (1) OR Methyl butanoate (will have stretching vibrations for) C=O at 1750-1735 (cm^{-1}) (1) IGNORE Reference to the fingerprint region C—O at 1200-1180 / 1250-1230 / 1200-1150 (cm^{-1}) If no other mark is awarded two correct wavenumber ranges with no bonds specified scores (1) If no other mark is awarded two correct wavenumbers within the ranges with correct bonds specified scores (1)	3750-3200 (cm^{-1})	**(2)**

Question Number	Acceptable Answers	Reject	Mark
18(c)	10 parts per billion by volume = 10 dm^3 butanoic acid (vapour) per 1 x 10^9 dm^3 of air = 1 x 10^{-8} dm^3 butanoic acid per dm^3 of air (1) IGNORE 1 x 10^{-8} without units / explanation = 1 x 10^{-8} ÷ 24.0 = 4.16667 x 10^{-10} (mol dm^{-3}) (1) Correct answer with no working scores (2) IGNORE SF		**(2)**

(Total for Question 18 = 13 marks)

Question Number	Acceptable Answers	Reject	Mark
19	 (1)  (1)  (1) OR Structural or displayed formulae IGNORE Names even if incorrect / one missing H in displayed structures (then penalise once) **M1** (Orange) ppt with DNPH so carbonyl group (1) **M2** No reaction with Tollen's reagent so ketone / not aldehyde (1) **M3** Effervescence /reaction with $NaHCO_3$ indicates carboxylic acid (group) / carboxyl (group) ALLOW carboxylic (group) /acid (group) (1) **M4** *m / e* of molecular ion / M_r = 116 so must be $C_5H_8O_3$ ALLOW *m / e* of molecular ion = 116 so M_r of **any** structure(s) shown with M_r = 116 gives this peak (1)	Just 'M_r of G must be = 116'	**(7)**

(Total for Question 19 = 7 marks)
TOTAL FOR SECTION B = 50 MARKS

Question Number	Acceptable Answers	Reject	Mark
20(a)(i)	$HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$ OR $HCOOH \rightleftharpoons HCOO^- + H^+$ ALLOW $HCOOH + H_2O \rightleftharpoons HCOO^- + H^+$ → for ⇌ Ignore state symbols even if incorrect	Incorrect formulae (penalise once only in (i), (ii) and (iii)	**(1)**

Question Number	Acceptable Answers	Reject	Mark
20(a)(ii)	$K_a = \frac{[HCOO^-][H^+]}{[HCOOH]}$ OR H_3O^+ for H^+ ALLOW $K_c = \frac{[HCOO^-][H^+]}{[HCOOH]}$ OR H_3O^+ for H^+ IGNORE State symbols even if incorrect $[\ ]_{eq}$ / $[\ ]_{eqm}$ $K_a = \frac{[H^+]^2}{[HCOOH]}$	Other types of bracket Omission of K_a =	**(1)**

Question Number	Acceptable Answers	Reject	Mark
20(a)(iii)	No TE on an incorrect expression in (a)(ii) [HCOOH] = 30/46 = 0.65217 mol dm^{-3} (1) **COMMENT** In M1 penalise multiple errors in calculation of the concentration once only $K_a = 1.70 \times 10^{-4} \approx [H^+]^2 / 0.65217$ (1) $[H^+] = \sqrt{(1.70 \times 10^{-4} \times 0.65217}$ $= 1.0529 \times 10^{-2} / 0.010529$ (1) pH = −log 0.010529 = 1.9776 / 1.98 / 2.0 (1) TE at each stage of the calculation Do not penalise premature <u>correct</u> rounding If 30 is used for the concentration (in mol dm^{-3}) pH = 1.1462 / 1.15 / 1.1 scores (3) If square root not taken pH = 3.9552 scores (3) IGNORE SF except 1 SF Allow other calculation methods	pH = 2 /1.9 / 1.97 pH = 1.2	**(4)**

Question Number	Acceptable Answers	Reject	Mark
20(a)(iv)	IGNORE explanations ALLOW $[H_3O^+]$ for $[H^+]$ throughout Use of HA and A^- **First mark:** HCOOH / methanoic acid ionisation / dissociation negligible ALLOW Acid for HCOOH Slight / partial / incomplete / does not dissociate for negligible dissociation OR $[HCOOH]_{equilibrium} = [HCOOH]_{initial} / 0.65217$ (mol dm^{-3}) (1) **Second mark:** ($[H^+]$ due to) ionisation of water negligible OR $[H^+]$ only due to (ionisation of) HCOOH / methanoic acid OR $[HCOO^-] = [H^+]$ (1) IGNORE references to temperature Penalise omission of [] or use of incorrect acid in discussion once only	Just 'dissociates less'	**(2)**

Question Number	Acceptable Answers	Reject	Mark
20(b)(i)	Standalone marks A buffer resists change in pH OR Maintains a fairly / nearly constant pH ALLOW Negligible change in pH OR resists significant change in pH (1) on the addition of **small** amounts of acid / H^+ **and** of alkali / base / OH^- (1)	prevents change in pH Just constant pH	**(2)**

Question Number	Acceptable Answers	Reject	Mark
***20(b)(ii)**	General answer in terms of HA and A^- scores max 3 (**M2**, **M3** and **M4**) ALLOW use of names for formulae **M1** HCOOH and $HCOO^-$ / HCOONa are present in high concentration / large amount / large excess / form a (large) reservoir (1) **M2** When acid is added the $HCOO^-$ / HCOONa is protonated / reacts, removing the H^+ ion from the solution / forming HCOOH OR $HCOO^- + H^+ \rightarrow HCOOH$ (1) **M3** When alkali is added the HCOOH reacts, removing the OH^- ion (from the solution) OR reacts forming $HCOO^-$ or $HCOO^{(-)}Na^{(+)}$ or water OR OH^- reacts with H^+ **and** HCOOH dissociates to replace the H^+ OR $HCOOH + OH^- \rightarrow HCOO^- + H_2O$ (1) **M4** So [HCOOH] and $[HCOO^-]$ do not change (significantly) OR the ratio [HCOOH] : $[HCOO^-]$ does not change (significantly) ALLOW Use of HCOOH and $HCOO^-$ for [HCOOH] and $[HCOO^-]$ (1) For **M2** and **M3**: Just "acid reacts with $HCOO^-$ and alkali reacts with HCOOH" scores (1)		**(4)**

Question Number	Acceptable Answers	Reject	Mark
20(c)(i)	**Route 1** $K_a = \frac{[H^+] \times [HCOO^-]}{[HCOOH]}$ $[H^+] = K_a \times \frac{[HCOOH]}{[HCOO^-]}$ (1) $= 1.70 \times 10^{-4} \times 1.25/1.50$ (1) $= 1.41667 \times 10^{-4}$ pH = 3.8487 = 3.85 / 3.8 (1) **Route 2** $pH = pK_a + \log \frac{[HCOO^-]}{[HCOOH]}$ (1) $= -\log(1.70 \times 10^{-4}) + \log(1.50/1.25)$ (1) = 3.8487 = 3.85 (1) Correct answer with no working scores (3) Inversion of concentrations pH = 3.69 scores (2) Penalise inversion once only in (i) and (ii) IGNORE SF except 1 SF	pH =3.84 / 3.9 pH =3.84 / 3.9	**(3)**

Question Number	Acceptable Answers	Reject	Mark
20(c)(ii)	Mol NaOH = 2/40 = 0.05 / 5 x 10^{-2} (1) New [HCOOH] = 1.25 – 0.05 = 1.20 **and** New [$HCOO^-$] = 1.50 + 0.05 = 1.55 (1) [H^+] = 1.70 x 10^{-4} x 1.20/1.55 = 1.31613 x 10^{-4} pH = 3.8807 = 3.88 OR pH = −log(1.70 x 10^{-4}) + log(1.55/1.20) (1) Correct answer with no working scores (3) IGNORE SF except 1 SF		**(3)**

(Total for Question 20 = 20 marks)
TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS

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Candidate surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | Candidate Number

Monday 4 November 2019

Afternoon (Time: 1 hour 40 minutes) | Paper Reference **WCH05/01**

Chemistry
Advanced
Unit 5: General Principles of Chemistry II – Transition Metals and Organic Nitrogen Chemistry (including synoptic assessment)

Candidates must have: Scientific calculator
Data Booklet

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

Turn over ▶

P58300A

P 5 8 3 0 0 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 What are the oxidation states of chromium in the ions shown?

	$[Cr(OH)_6]^{3-}$	$[Cr(H_2O)_6]^{2+}$	$Cr_2O_7^{2-}$
☒ **A**	–3	+2	–2
☒ **B**	–3	+6	+2
☒ **C**	+3	+6	+6
☒ **D**	+3	+2	+6

(Total for Question 1 = 1 mark)

2 In which of these compounds does iron have its highest oxidation number?

☒ **A** K_2FeO_4

☒ **B** $(NH_4)_2Fe(SO_4)_2.6H_2O$

☒ **C** $K_3Fe(CN)_6$

☒ **D** $K_4Fe(CN)_6$

(Total for Question 2 = 1 mark)

3 A transition metal **M** forms an octahedral complex in which 3 mol of a ligand **L** combine with 1 mol of **M**.

L is most likely to be

☒ **A** ammonia.

☒ **B** 1,2-diaminoethane.

☒ **C** EDTA.

☒ **D** water.

(Total for Question 3 = 1 mark)

4 What are the shapes of the complexes shown?

	$[CrCl_4]^-$	$[Pt(NH_3)_2Cl_2]$
☒ **A**	tetrahedral	tetrahedral
☒ **B**	square planar	tetrahedral
☒ **C**	tetrahedral	square planar
☒ **D**	square planar	square planar

(Total for Question 4 = 1 mark)

5 One mole of sulfur dioxide reacts exactly with two moles of ions of a metal Q.

The oxidation number of Q in the ions is +4.

The sulfur dioxide is converted to sulfate(VI) ions.

What is the final oxidation number of Q?

☒ **A** +6

☒ **B** +3

☒ **C** +2

☒ **D** 0

(Total for Question 5 = 1 mark)

6 The reaction

$$[Fe(H_2O)_6]^{3+}(aq) + 3OH^-(aq) \rightarrow [Fe(H_2O)_3(OH)_3](s) + 3H_2O(l)$$

is an example of

☒ **A** oxidation.

☒ **B** reduction.

☒ **C** condensation.

☒ **D** ionic precipitation.

(Total for Question 6 = 1 mark)

7 Lithium tetrahydridoaluminate(III), $LiAlH_4$, can be used to convert

- ☒ **A** CH_3CHO to CH_3CH_2OH
- ☒ **B** C_2H_5COOH to CH_3COCH_3
- ☒ **C** C_2H_4 to C_2H_6
- ☒ **D** C_6H_6 to C_6H_{12}

(Total for Question 7 = 1 mark)

8 The electrophile in the preparation of benzenesulfonic acid, $C_6H_5SO_3H$, from benzene is

- ☒ **A** SO_2
- ☒ **B** SO_3
- ☒ **C** SO_4^{2-}
- ☒ **D** HSO_4^-

(Total for Question 8 = 1 mark)

9 Benzenediazonium salts are made by reacting phenylamine with nitrous acid at a temperature of 0–10 °C.

This temperature range must be used because the

- ☒ **A** benzene ring is nitrated at higher temperatures.
- ☒ **B** reaction is highly exothermic.
- ☒ **C** activation energy of the reaction is low.
- ☒ **D** diazonium ion decomposes above 10 °C.

(Total for Question 9 = 1 mark)

10 The solution formed when ethylamine is dissolved in water

- ☒ **A** contains zwitterions.
- ☒ **B** is neutral.
- ☒ **C** is acidic.
- ☒ **D** is alkaline.

(Total for Question 10 = 1 mark)

11 The compound formed when ethanoyl chloride reacts with phenylamine is

- ☒ **A** $CH_3CONHC_6H_5$
- ☒ **B** $C_2H_5CONHC_6H_5$
- ☒ **C** $C_6H_5CONHCH_3$
- ☒ **D** $C_6H_5CONHC_2H_5$

(Total for Question 11 = 1 mark)

12 A white smoke forms when methylamine and hydrogen chloride mix. The formula of the white smoke is

- ☒ **A** NH_4Cl
- ☒ **B** CH_3NH_2Cl
- ☒ **C** CH_3NH_3Cl
- ☒ **D** $CH_3CONHCl$

(Total for Question 12 = 1 mark)

13 The **low** resolution proton nmr spectrum of a compound contains only three peaks.

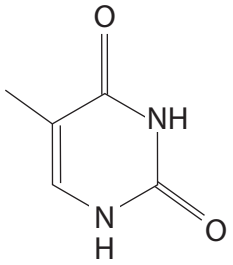
Which of the following compounds could give this spectrum?

- ☒ **A** but-1-ene
- ☒ **B** butanal
- ☒ **C** butanone
- ☒ **D** butanoic acid

(Total for Question 13 = 1 mark)

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

14 Thymine is a naturally occurring compound with the structure shown.



Which of the groups listed is **not** present in its structure?

☒ **A** Alkyl

☒ **B** Alkene

☒ **C** Amide

☒ **D** Ketone

(Total for Question 14 = 1 mark)

15 E_{cell} for a chemical reaction is proportional to both

☒ **A** ΔS_{system} and K

☒ **B** ΔS_{total} and K

☒ **C** ΔS_{system} and $\ln K$

☒ **D** ΔS_{total} and $\ln K$

(Total for Question 15 = 1 mark)

16 Which are correct for a standard hydrogen electrode?

	Temperature / K	Solution
☒ **A**	273	$[H^+(aq)] = 1.00\,mol\,dm^{-3}$
☒ **B**	273	$[OH^-(aq)] = 1.00\,mol\,dm^{-3}$
☒ **C**	298	$[H^+(aq)] = 1.00\,mol\,dm^{-3}$
☒ **D**	298	$[OH^-(aq)] = 1.00\,mol\,dm^{-3}$

(Total for Question 16 = 1 mark)

17 The redox reaction between aqueous iodide ions and aqueous peroxodisulfate ions is slow.

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

Which of these ions catalyses this reaction?

☒ **A** $H^+(aq)$

☒ **B** $Mg^{2+}(aq)$

☒ **C** $Fe^{2+}(aq)$

☒ **D** $OH^-(aq)$

(Total for Question 17 = 1 mark)

18 The repeat units of four polymers are shown

Polymer	Repeat unit
W	—$CH_2CH(CONH_2)$—
X	—$HNCH_2CO$—
Y	—$CH(CH_3)CHCN$—
Z	—$HNCH_2CH_2NHOCCH_2CO$—

(a) Which polymer could be formed from a naturally occurring amino acid?

(1)

☒ **A** W

☒ **B** X

☒ **C** Y

☒ **D** Z

(b) Which formula shows the repeat unit of poly(propenamide)?

(1)

☒ **A** W

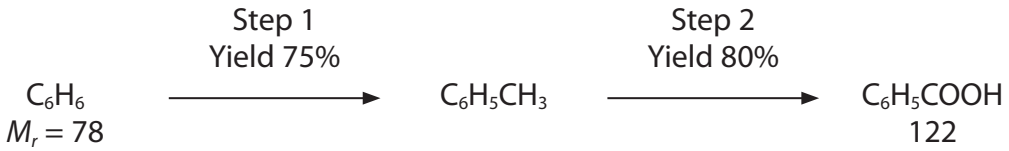
☒ **B** X

☒ **C** Y

☒ **D** Z

(Total for Question 18 = 2 marks)

19 In a laboratory preparation, benzoic acid was produced from benzene in two steps.



The mass of benzoic acid, in grams, obtained from 3.90 g benzene was

- ☒ **A** 1.50
- ☒ **B** 3.66
- ☒ **C** 6.10
- ☒ **D** 10.17

(Total for Question 19 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

20 This question is about the different oxidation states of manganese.

Standard reduction potentials of some electrode reactions involving different oxidation states of manganese are shown.

Electrode reaction	$E^{\ominus}$ / V
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	−1.19
$MnO_4^-(aq) + e^- \rightleftharpoons MnO_4^{2-}(aq)$	+0.56
$MnO_4^{2-}(aq) + 2H_2O(l) + 2e^- \rightleftharpoons MnO_2(s) + 4OH^-(aq)$	+0.59
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51

(a) Use your Data Booklet to select a metal commonly found in the laboratory which would reduce $Mn^{2+}(aq)$ to Mn, but which does **not** react with water at room temperature.

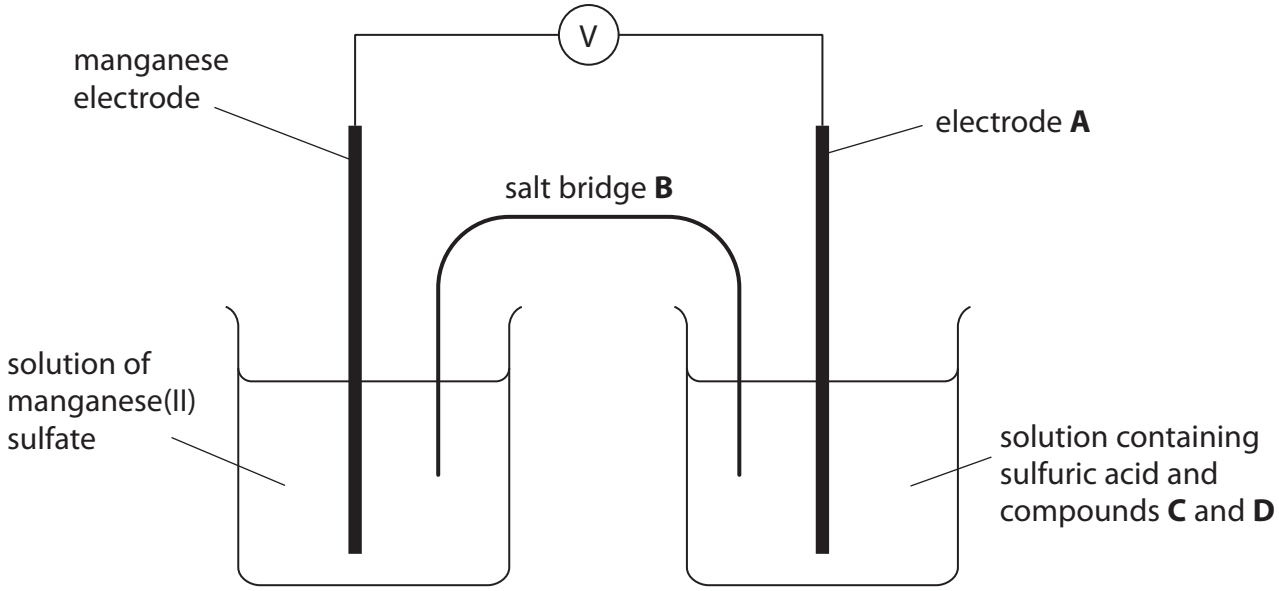
Write an **ionic** equation for this reaction of $Mn^{2+}(aq)$ with the metal you have selected.

State symbols are not required.

(2)

(b) A cell can be used to measure the standard cell potential, $E^{\ominus}_{cell}$, for the reaction of manganate(VII) ions with manganese in acid conditions.

$$2MnO_4^-(aq) + 5Mn(s) + 16H^+(aq) \rightleftharpoons 7Mn^{2+}(aq) + 8H_2O(l)$$



(i) Identify, by name or formula, the substances needed to measure the standard cell potential, $E^{\ominus}_{cell}$.

(4)

Electrode **A** is made of .....

Salt bridge **B** contains a solution of .....

Compound **C** .....

Compound **D** .....

(ii) Calculate the value of the standard cell potential, $E^{\ominus}_{cell}$.
Use the data in the table at the start of the question on page 9.

(1)

(c) Potassium manganate(VI), K_2MnO_4, can be prepared by heating a mixture of potassium manganate(VII), $KMnO_4$, and concentrated potassium hydroxide solution. On cooling, green crystals form.

$$4KMnO_4 + 4KOH \rightarrow 4K_2MnO_4 + O_2 + 2H_2O$$

Write the half-equation that shows hydroxide ions acting as a reducing agent in this reaction.
State symbols are not required.

(1)

(d) Manganate(VI) ions, MnO_4^{2-}, disproportionate into MnO_2 and MnO_4^- in alkaline conditions.

(i) Write the equation for this reaction using appropriate half-equations from the table at the start of the question on page 9.
State symbols are not required.

(2)

(ii) Calculate the $E^{\ominus}_{cell}$ for this reaction and state whether or not this disproportionation is thermodynamically feasible.

(1)

(Total for Question 20 = 11 marks)

21 This question is about copper and zinc.

(a) Complete the electronic configurations for copper and zinc atoms.

(1)

		3d					4s
Copper	(Ar)	↑↓					
Zinc	(Ar)	↑↓					

(b) The first and second ionisation energies of copper and zinc are shown.

	Copper	Zinc
1st ionisation energy / kJ mol^{-1}	746	906
2nd ionisation energy / kJ mol^{-1}	1958	1733

*(i) Suggest why the first ionisation energy of copper is less than the first ionisation energy of zinc.

(2)

*(ii) Suggest why the second ionisation of copper is greater than the second ionisation energy of zinc.

(2)

*(iii) Zinc compounds are usually white, whereas many copper compounds are coloured.

Explain fully why hexaaquazinc ions, $[Zn(H_2O)_6]^{2+}$, are colourless in solution.

(2)

(c) When a few drops of aqueous ammonia are added to a solution of copper(II) sulfate, a precipitate forms. If excess ammonia is then added, the precipitate dissolves.

(i) State the colour of the precipitate and the colour of the solution after the addition of excess ammonia.

(1)

Precipitate .....

Solution .....

(ii) Complete the equation for the reaction of the precipitate with excess ammonia. State symbols are not required.

(2)

$[Cu(H_2O)_4(OH)_2]$ + ... NH_3 →

(d) When aqueous sodium hydroxide is added to a solution of zinc sulfate, a white precipitate forms which is soluble in both excess sodium hydroxide and in dilute sulfuric acid.

(i) State the term used to describe a compound that forms a salt with both sodium hydroxide and sulfuric acid.

(1)

.....

(ii) Write an equation for the reaction of the white precipitate with excess sodium hydroxide.
State symbols are not required.

(1)

(e) Brass is an alloy of copper and zinc.

3.50 g of a sample of brass was reacted with concentrated nitric acid. The resulting solution of copper(II) nitrate and zinc nitrate was neutralised and made up to a volume of 250.0 cm^3.

Excess potassium iodide was reacted with 25.0 cm^3 portions of this solution. Zinc ions do not react with potassium iodide, but copper(II) ions do.

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

The iodine formed was titrated with sodium thiosulfate solution of concentration 0.150 mol dm^{-3}. The mean titre was 24.50 cm^3.

(i) Complete the equation for the reaction of iodine with thiosulfate ions. State symbols are not required.

(1)

$$I_2 + 2S_2O_3^{2-} \rightarrow \text{.....} + \text{.....}$$

*(ii) Calculate the percentage by mass of copper in the sample of brass. Give your answer to **three** significant figures.

(4)

(Total for Question 21 = 17 marks)

22 This question is about some ions and molecules that have delocalised electrons.

(a) Give the meaning of the term **delocalised**, when referring to electrons.

(1)

.....

.....

(b) The carboxylate ion ($—COO^-$) has delocalised electrons.

(i) Draw the displayed formula of a carboxylate ion, indicating the delocalised electrons.

(1)

(ii) Suggest the OCO bond angle.

(1)

.....

(c) Benzene molecules also contain delocalised electrons.

(i) State the number of delocalised electrons in each benzene molecule, **and** identify the type of orbital from which they originate.

(1)

.....

.....

(ii) Name the **physical** method which gives evidence for delocalisation in benzene. State how the result indicates that there is delocalisation.

(2)

.....

.....

.....

.....

.....

*(d) The C—O bond in phenol is shorter than the C—O bond in methanol. Describe how the delocalisation of electrons can be used to explain this.

(2)

.....

.....

.....

.....

.....

.....

(e) Phenol can be nitrated more easily than benzene.

(i) **Name** the reagent which should be used for the nitration of phenol.
Indicate the concentration needed.

(1)

.....

(ii) Give the structure of two possible **isomeric** products of this nitration.

(1)

(iii) State the reagents and conditions needed for the formation of nitrobenzene from benzene.

(2)

.....

.....

.....

.....

(Total for Question 22 = 12 marks)

BLANK PAGE

23 This question is about amino acids.

(a) Explain why amino acids are very soluble in water.

(2)

(b) Name the reagent which is used to detect amino acids on a chromatogram.

(1)

(c) A dipeptide **X** has the molecular formula $C_5H_{10}N_2O_4$.

X was hydrolysed by heating under reflux with hydrochloric acid.
Two naturally occurring amino acids, **Y** and **Z**, were formed.
Only **Z** was optically active.

(i) Deduce the structure of **Y**, which is **not** optically active.

(1)

(ii) The amino acid **Z** has molecular formula $C_3H_7NO_3$.

One mole of **Z** reacts with two moles of phosphorus(V) chloride, PCl_5.

State what can be deduced from this reaction about the structure of **Z**.
Draw the displayed formula of **Z** and circle the chiral centre.

(3)

.....

.....

(iii) **Y** and **Z** were formed by hydrolysis of the compound **X**.

Draw a possible structure of **X**.

(2)

(Total for Question 23 = 9 marks)

TOTAL FOR SECTION B = 49 MARKS

SECTION C

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

24

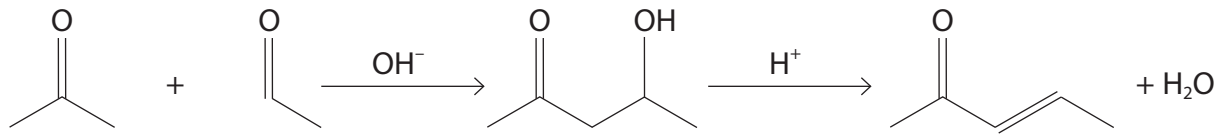
The Importance of Ketones in Organic Synthesis

Naturally occurring ketones are often found in foods. Butane-2,3-dione gives a buttery flavour, and heptan-2-one is found in some blue cheeses. The molecules giving flavour may contain other groups as well as the carbonyl group. Spearmint oil contains C═C bonds and "raspberry ketone" contains a phenolic group.

Camphor is a naturally occurring ketone which reduces itching and is a moth repellent.

Ketones are important in chemical synthesis because they undergo nucleophilic addition reactions. Ketones also react with other carbonyl compounds in condensation reactions. They are used in synthesis to extend the carbon chain in a molecule, for example by reacting with hydrogen cyanide.

"Aldol condensations" are reactions between two carbonyl compounds, such as two ketone molecules, or an aldehyde and a ketone.
One example is the reaction of propanone with ethanal.

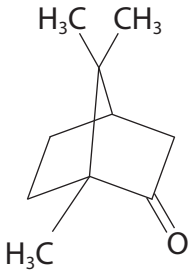


propanone ethanal

Aromatic ketones can be made by reacting benzene with acyl chlorides in the Friedel-Crafts reaction. This produces ketones such as ethyl phenyl ketone which contain the C_6H_5CO group.

2-hydroxycarboxylic acids can be prepared from ketones, and these compounds are intermediates from which many other products can be made.

(a) Camphor is a strong smelling ketone extracted from camphor trees.



Deduce its molecular formula.

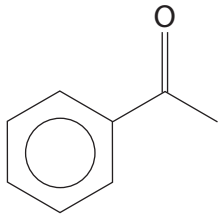
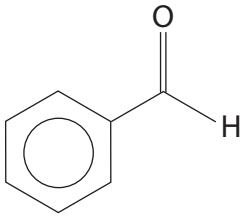
(1)

(b) Benzene reacts with propanoyl chloride in the presence of a catalyst of aluminium chloride to form ethyl phenyl ketone, $C_6H_5COCH_2CH_3$.

Give the mechanism for this reaction, including an equation for the formation of the electrophile.

(4)

(c) Suggest the structure of the **final** product of the aldol condensation reaction between phenylethanone and benzaldehyde.

	
Phenylethanone	Benzaldehyde

(1)

(d) 2-hydroxycarboxylic acids are used as anti-wrinkle products in the cosmetics industry.

2-hydroxy-2-methylpentanoic acid can be made from pentan-2-one in two steps.
Draw the intermediate compound and give the reagent(s) needed in each step.
Reaction conditions are not required.

(3)

pentan-2-one intermediate 2-hydroxy-2-methylpentanoic acid

Reagents for Step 1 .....

Reagents for Step 2 .....

(e) The empirical formula of organic compounds can be found by complete combustion of a known mass of the compound. The mass of each product is then determined.

(i) Water and carbon dioxide are always formed on complete combustion of organic compounds.

Identify the substances that can be used to absorb each of these products so their mass can be measured.

(2)

Water .....

Carbon dioxide .....

(ii) Give a reason why the percentage of oxygen in the compound cannot be found **directly** from the mass of the combustion products.

(1)

.....

.....

(f) The compound known as raspberry ketone was analysed by combustion and the results are shown.

Element	% by mass
C	73.17
H	7.32
O	19.51

(i) Calculate the empirical formula of raspberry ketone.

(2)

(ii) The relative molecular mass of raspberry ketone is 164.

Deduce its molecular formula.

(1)

(iii) Describe how the relative molecular mass of a compound can be found from its mass spectrum.

(1)

.....

.....

(iv) Raspberry ketone is a substituted phenol.

Give a chemical test which distinguishes phenol from benzene and describe the positive result.

(2)

.....

.....

.....

.....

.....

.....

(v) Raspberry ketone reacts with a solution of iodine in sodium hydroxide to give a pale yellow precipitate.

The **high** resolution proton nmr spectrum of raspberry ketone shows peaks due to the phenol group. Outside this region, there are two triplets and a singlet in the spectrum.

Use this information to deduce a structure for raspberry ketone.

Label the atoms which produce the singlet and the atoms which produce the two triplets in the nmr spectrum.

(3)

(Total for Question 24 = 21 marks)

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

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

* Lanthanide series

* Actinide 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
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

Mark Scheme (Results)

October 2019

Pearson Edexcel International Advanced Level In Chemistry (WCH05)
Paper 01 Transition Metals and Organic Nitrogen Chemistry

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October 2019
Publications Code WCH05_01_1910_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A (multiple choice)

Question Number	Answer	Mark
1	**The only correct answer is D (+3, +2, +6)** **A** *is not correct because the oxidation states in columns 1 and 3 are incorrect* **B** *is not correct because the oxidation states in columns 1, 2 and 3 are incorrect* **C** *is not correct because the oxidation state in column 2 is incorrect*	1

Question Number	Answer	Mark
2	**The only correct answer is A (K_2FeO_4)** **B** *is not correct because the oxidation number of iron is +2* **C** *is not correct because the oxidation number of iron is +3* **D** *is not correct because the oxidation number of iron is +2*	1

Question Number	Answer	Mark
3	**The only correct answer is B (1,2-diaminoethane)** ***A** is not correct because ammonia is monodentate so there would be 6 ligands in an octahedral complex* ***C** is not correct because EDTA is hexadentate so there would be 1 ligand in an octahedral complex* **D** *is not correct because water is monodentate so there would be 6 ligands in an octahedral complex*	1

Question Number	Answer	Mark
4	**The only correct answer is C (tetrahedral, square planar)** **A** *is not correct because $[Pt(NH_3)_2Cl_2]$ is not tetrahedral* **B** *is not correct because $[CrCl_4]^-$ is not square planar and $[Pt(NH_3)_2Cl_2]$ is not tetrahedral* **D** *is not correct because $[CrCl_4]^-$ is not square planar*	1

Question Number	Answer	Mark
5	**The only correct answer is B (+3)** **A** *is not correct because the oxidation number of sulfur increases by 2 so the oxidation number of each Q decreases by 1* **C** *is not correct because the oxidation number of sulfur increases by 2 so the oxidation number of each Q decreases by 1* **D** *is not correct because the oxidation number of sulfur increases by 2 so the oxidation number of each Q decreases by 1*	1

Question Number	Answer	Mark
6	**The only correct answer is D (ionic precipitation)** **A** *is not correct because the oxidation number of iron does not change* **B** *is not correct because the oxidation number of iron does not change* **C** *is not correct because the water is not produced from H and OH in different molecules*	1

Question Number	Answer	Mark
7	**The only correct answer is A (CH_3CHO to CH_3CH_2OH)** **B** *is not correct because carboxylic acids cannot be reduced to ketones* **C** *is not correct because hydride ions could not attack an alkene group* **D** *is not correct because hydride ions could not attack a benzene ring*	1

Question Number	Answer	Mark
8	**The only correct answer is B (SO_3)** **A** *is not correct because sulfur dioxide does not react to give benzenesulfonic acid* **C** *is not correct because the negative ion could not attack a benzene ring* **D** *is not correct because the negative ion could not attack a benzene ring*	1

Question Number	Answer	Mark
9	**The only correct answer is D (diazonium ion decomposes above 10°C)** **A** *is not correct because nitrous acid does not nitrate the benzene ring* **B** *is not correct because the reaction is not highly exothermic* **C** *is not correct because the low activation energy does not limit the upper temperature value in the range*	1

Question Number	Answer	Mark
10	**The only correct answer is D (is alkaline)** **A** *is not correct because ethylamine has only one functional group so cannot form a zwitterion* **B** *is not correct because ethylamine has a lone pair on the N atom which attracts protons, lowering* $[H^+]$ *in water* **C** *is not correct because ethylamine has a lone pair on the N atom which attracts protons, lowering* $[H^+]$ *in water*	1

Question Number	Answer	Mark
11	**The only correct answer is A** $(CH_3CONHC_6H_5)$ **B** *is not correct because* $C_2H_5CONHC_6H_5$ *is the product of* C_2H_5COCl *and* $NH_2C_6H_5$ **C** *is not correct because* $C_6H_5CONHCH_3$ *is the product of* C_6H_5COCl *with* NH_2CH_3 **D** *is not correct because* $C_6H_5CONHC_2H_5$ *is the product of* C_6H_5COCl *with* $NH_2C_2H_5$	1

Question Number	Answer	Mark
12	**The only correct answer is C** (CH_3NH_3Cl) **A** *is not correct because this is the product of HCl and ammonia* **B** *is not correct because an H atom is missing from the formula* **D** *is not correct because there is no CO group in methylamine*	1

Question Number	Answer	Mark
13	**The only correct answer is C (butanone)** **A** *is not correct because but-1-ene has four peaks in the low resolution nmr spectrum* **B** *is not correct because butanal has four peaks in the low resolution nmr spectrum* **D** *is not correct because butanoic acid has four peaks in the low resolution nmr spectrum*	1

Question Number	Answer	Mark
14	**The only correct answer is D (ketone)** **A** *is not correct because an alkyl (methyl) group is present* **B** *is not correct because an alkene group is present* **C** *is not correct because an amide group is present*	1

Question Number	Answer	Mark
15	**The only correct answer is D (ΔS_{total} and ln K)** **A** *is not correct because* E_{cell} *for a chemical reaction is proportional to both* ΔS_{total} *and ln K* **B** *is not correct because* E_{cell} *for a chemical reaction is proportional to both* ΔS_{total} *and ln K* ***C*** *is not correct because* E_{cell} *for a chemical reaction is proportional to both* ΔS_{total} *and ln K*	1

Question Number	Answer	Mark
16	**The only correct answer is C (298K and [H^+(aq)] = 1.00 mol dm^{-3})** **A** *is not correct because temperature should not be 273 K* **B** *is not correct because temperature should not be 273 K and hydroxide ions are not 1.00 mol* dm^{-3} **D** *is not correct because hydroxide ions are not 1.00 mol* dm^{-3}	1

Question Number	Answer	Mark
17	**The only correct answer is C ($Fe^{2+}(aq)$)** **A** *is not correct because H^+ is not a catalyst which can be oxidised by one reactant and reduced by the other.* **B** *is not correct because Mg^{2+} is not a catalyst which can be oxidised by one reactant and reduced by the other.* **D** *is not correct because the negative hydroxide ions would repel the reactant ions.*	1

Question Number	Answer	Mark
18(a)	**The only correct answer is B (X)** **A** *is not correct because a polymer formed from an amino acid would contain a CONH (peptide) group* **C** *is not correct because a polymer formed from an amino acid would contain a CONH (peptide) group* **D** *is not correct because this polymer is formed from a diamine and a dicarboxylic acid, not from an amino acid*	1

Question Number	Answer	Mark
18(b)	**The only correct answer is A (W)** **B** *is not correct because the polymer is a condensation polymer and propenamide is an addition polymer* **C** *is not correct because there is no amide group present* **D** *is not correct because the polymer is not formed from an amide*	1

Question Number	Answer	Mark
19	**The only correct answer is B (3.66)** **A** *is not correct because the molar masses have been reversed* **C** *is not correct because the percentage yields have not been used* **D** *is not correct because moles at each stage have been divided by the percentage yields, not multiplied*	1

Total for Section A = 20 marks

Section B

Question Number	Acceptable Answers	Reject	Mark
20(a)	**M1** Al / Mg ALLOW Redox couple eg Mg^{2+}/Mg Al or Mg used in equation (1) **M2** $2Al + 3Mn^{2+} \rightarrow 2Al^{3+} + 3Mn$ OR $Mg + Mn^{2+} \rightarrow Mg^{2+} + Mn$ ALLOW Ba, Ca or V for Mg in **M2** as TE Ce for Al in **M2** as TE $2M + Mn^{2+} \rightarrow 2M^{+} + Mn$ where M= Li, Na, K as TE (1) IGNORE State symbols even if incorrect Reversible arrows but with correct direction	Li, Na, K, Ca, Rb, U, Ce Use of Ba (not based on data) Use of Ca^{2+} or Al^{3+} use of metal below Mn in series (except V which can score a TE in **M2**)	**(2)**

Question Number	Acceptable Answers	Reject	Mark
20(b)(i)	**A** platinum / Pt (1) ALLOW Platinum with platinum black **B** potassium nitrate / KNO_3 / Sodium nitrate / $NaNO_3$ (1) Allow C and D in either order **C** potassium manganate(VII) / $KMnO_4$((aq)) ALLOW Potassium permanganate (1) **D** manganese(II) sulfate / $MnSO_4$ / $MnCl_2$ / Correct formula for other Mn^{2+} salts ALLOW 1 mark for formulae of two ions in C and D Mn^{2+} / Mn^{+2} / manganese(II) ions MnO_4^-((aq)) / Manganate(VII) ions IGNORE Concentrations of solutions (1)	Pt with hydrogen on the surface KBr, KI, KCl, NaCl, KOH, K_2SO_4, just 'nitrate ions' potassium manganate with incorrect oxidation number	**(4)**

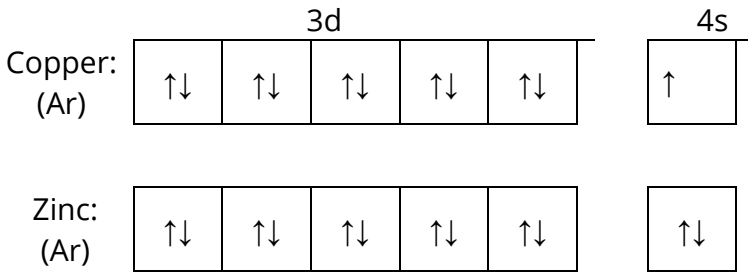
Question Number	Acceptable Answers	Reject	Mark
20(b)(ii)	(+) 2.70(V) / 2.7	Any negative value	**(1)**

Question Number	Acceptable Answers	Reject	Mark
20(c)	$4OH^- \rightarrow O_2 + 2H_2O + 4e^{(-)}$ / $4OH^- - 4e^{(-)} \rightarrow O_2 + 2H_2O$ ALLOW multiples Half equations shown as working before correct final equation IGNORE state symbols even if incorrect reversible arrows	Unbalanced equations Ionic equations including MnO_4^- and MnO_4^{2-} but without electrons	**(1)**

Question Number	Acceptable Answers	Reject	Mark
20(d)(i)	$3MnO_4^{2-} + 2H_2O \rightarrow MnO_2 + 2MnO_4^- + 4OH^-$ ALLOW $3K_2MnO_4 + 2H_2O \rightarrow MnO_2 + 2KMnO_4 + 4KOH$ ALLOW Reversible arrows Correct species including charges on each side of equation OR Two correctly written half equations (2nd and 3rd in the table) (1) Correct balancing (1) Fully correct equation in reverse scores (1) IGNORE state symbols even if incorrect		**(2)**

Question Number	Acceptable Answers	Reject	Mark
20(d)(ii)	$E^\ominus$ = (0.59 – 0.56) = (+) 0.03((V)) **and** thermodynamically feasible (because $E^\ominus$ is positive) ALLOW Spontaneous		**(1)**

(Total for Question 20 = 11 marks)

Question Number	Acceptable Answers	Reject	Mark
21(a)	 ALLOW Half headed arrows		**(1)**

Question Number	Acceptable Answers	Reject	Mark
***21(b)(i)**	**M1** Zinc has one more proton/ more protons (so nuclear attraction is greater) OR Zinc has greater nuclear charge OR Copper has one fewer proton so nuclear attraction is smaller OR Atomic number of zinc is higher than copper (1) **M2** Both have their first electron removed from 4s ALLOW The 4s shell in zinc is full (1) IGNORE Comments on atomic radius Comments about shielding	Cu has lower charge density	**(2)**

Question Number	Acceptable Answers	Reject	Mark
***21(b)(ii)**	In Cu, second electron is taken from 3d subshell / orbital (which must require more energy than from the 4s in zinc) (1) 3d is less well shielded (than 4s in zinc) ALLOW 3d is closer to the nucleus (1)		**(2)**

Question Number	Acceptable Answers	Reject	Mark
***21(b)(iii)**	There are no transitions of electrons (from a lower**)** to a **higher** energy level (in the visible region) ALLOW there are no possible d-d transitions (1) the (3)d sub-shell in zinc is full / there are no empty levels in zinc for transitions to occur / (3)d orbitals are completely full OR Reverse arguments for why other ions are coloured (1)	d orbitals are not split no electrons get excited 3d orbital is full The 3d shell is full Zn has a full d orbital Just "Zn is $3d^{10}$" Zn has no unpaired electrons	**(2)**

Question Number	Acceptable Answers	Reject	Mark
21(c)(i)	precipitate (pale) blue **and** solution dark blue Solution colour must be a darker blue than the precipitate colour IGNORE Gelatinous(precipitate)	Answers where solution is not darker blue than precipitate	**(1)**

Question Number	Acceptable Answers	Reject	Mark
21(c)(ii)	$[Cu(H_2O)_4(OH)_2]+ 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 2H_2O + 2OH^-$ formula of complex ion (1) rest of equation (1) ALLOW Equation with products written $[Cu(NH_3)_4]^{2+} + 4H_2O + 2OH^-$ can score both marks Equation using $6NH_3$ $[Cu(H_2O)_4(OH)_2]+ 6NH_3 \rightarrow [Cu(NH_3)_6]^{2+} + 4H_2O + 2OH^-$ can score for correct balancing (1) IGNORE Order of ligands in complex ions state symbols even if incorrect	$[Cu(H_2O)_4(OH)_2]+ 4NH_3 \rightarrow [Cu(OH)_2(NH_3)_4] + 4H_2O$ scores 0 Equations using $2NH_3$	**(2)**

Question Number	Acceptable Answers	Reject	Mark
21(d)(i)	Amphoteric		**(1)**

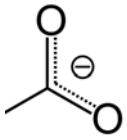
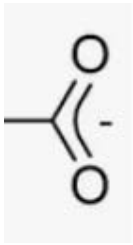
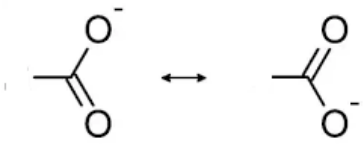
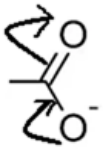
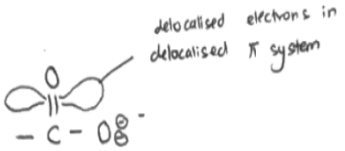
Question Number	Acceptable Answers	Reject	Mark
21d(ii)	$Zn(OH)_2 + 2NaOH \rightarrow Na_2ZnO_2 + 2H_2O$ $Zn(OH)_2 + 2OH^- \rightarrow Zn(OH)_4^{2-}$ ALLOW $Zn(OH)_2 + 2OH^- \rightarrow ZnO_2^{2-} + 2H_2O$ $Zn(OH)_2(H_2O)_4 + 2OH^- \rightarrow Zn(OH)_4(H_2O)_2^{2-} + 2H_2O$ $Zn(OH)_2(H_2O)_4 + 2OH^- \rightarrow Zn(OH)_4^{2-} + 4H_2O$ IGNORE State symbols even if incorrect	$Zn(OH)_3^-$ $Zn(OH)_6^{4-}$	**(1)**

Question Number	Acceptable Answers	Reject	Mark
21(e)(i)	$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$ IGNORE State symbols even if incorrect		**(1)**

Question Number	Acceptable Answers	Reject	Mark
21(e)(ii)	**M1** Mol thiosulfate = ((24.50 x 0.150)/1000) = 3.675×10^{-3} / 0.003675 (1) **M2** (Mol I_2 = ((3.675×10^{-3} /2))= 1.8375×10^{-3}/ 0.0018375) Mol Cu in 25 cm^3 = (($2 \times 1.8375 \times 10^{-3}$)) = 3.675×10^{-3} / 0.003675 (mol) Mass Cu in 25 cm^3 = (0.003675 x 63.5) =2.3336×10^{-1} / 0. 23336 (g) (1) **M3** Mass Cu in 250 cm^3 = M2 × 10 = 2.3336 (g) (1) **M4** % Cu in brass = ((2.3336 x 100/3.50) = 66.675 = 66.7 (1) Allow correct rounding to 2 or more SF e.g. Rounding to 0.00368 in M1 gives final answer 66.7657 = 66.8% Total score (4) Rounding to 2.33 in M3 gives final answer 66.5714 = 66.6% Total score (4) Allow TE at each stage Use of 2:1 ratio only once can give 33.4% scores 3 Correct answer with no working scores 4 The multiplications in M2 and M3 (x 63.5 and x10) can be done in either order.	Use of incorrect ratio Answers > 100% Answers not to 3SF (M4)	**(4)**

(Total for Question 21 = 17 marks)

Question Number	Acceptable Answers	Reject	Mark
22(a)	Electrons are not fixed in a particular **bond** OR not associated with a particular **atom**/ pair of **atoms**/ covalent **bond** OR electrons are shared between three or more **atoms** OR electrons are not found in a fixed position/in one place OR Electrons are free to move from one bond to another OR electrons are free to move from atom to atom ALLOW Electrons are free to move around a system / molecule / ion / compound IGNORE Just 'electrons are free to move'	Just "electrons which can move" Electrons are not bonded Electrons shared between two or more atoms	**(1)**

Question Number	Acceptable Answers	Reject	Mark
22(b)(i)	 OR  OR  OR (with arrows added)  ALLOW Bracketed with charge shown outside IGNORE Lone pairs Bond angles	Diagrams with the bond to the R group of the ion not shown Diagrams with no minus sign or two minus signs Dot and cross diagrams  Only one arrow	**(1)**

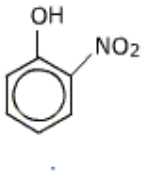
Question Number	Acceptable Answers	Reject	Mark
22(b)(ii)	Angle within the range 120-123 (°) Mark independently from 22(b)(i) IGNORE Name given with angle even if incorrect	Just >120	**(1)**

Question Number	Acceptable Answers	Reject	Mark
22(c)(i)	Number:**6** electrons Type of orbital: p OR 2p / $2p_z$ / $2p_y$ / $2p_x$ IGNORE Hybridised orbitals	pi electrons ϖ electrons ϖ orbitals	**(1)**

Question Number	Acceptable Answers	Reject	Mark
22(c)(ii)	x-ray diffraction / x-ray crystallography (1) bonds (between carbon atoms) would be the same length in benzene / Bond length is intermediate between double and single / Bond angles (in ring) are 120° / the same ALLOW Information in **labelled** diagrams (1) IGNORE It would not show double and single bonds	x-rays x-ray imaging electron density map hydrogenation enthalpy data Bond length is between a pi bond and a sigma bond	**(2)**

Question Number	Acceptable Answers	Reject	Mark
***22(d)**	The lone pair on the O (of phenol) is delocalised / interacts with the delocalised ring (in benzene) / increases the electron density of the ring OR The lone pair on the O of methanol is not delocalised / has no delocalised ring to interact with (1) The (C-O) bond in phenol has a partial double bond character ALLOW The (C-O) bond is stronger (1)	The lone pair on O attracts the delocalised ring	**(2)**

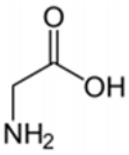
Question Number	Acceptable Answers	Reject	Mark
22(e)(i)	**Dilute /dil** nitric acid OR Nitric acid of concentration between 0.5 and 2 mol dm^{-3} (3% to 12% nitric acid) ALLOW Use of HNO_3 instead of the name Use of concentrated/conc if qualified by a concentration in the correct range e.g conc. HNO_3 of 2.0 mol dm^{-3}	Nitrating mixture Any use of sulfuric acid Dilute / dil nitric acid with incorrect concentration quoted.	**(1)**

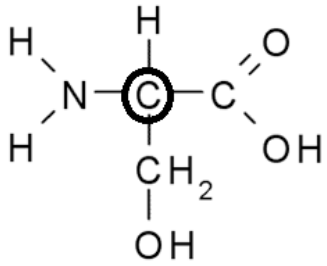
Question Number	Acceptable Answers	Reject	Mark
22(e)(ii)	Any two from   ALLOW any pair of isomeric di, tri, or tetranitrophenols Kekule structures IGNORE Connectivity of OH and NO_2 (1)	NO_3 substituents Any two non-isomeric compounds Substituted cyclohexanes	**(1)**

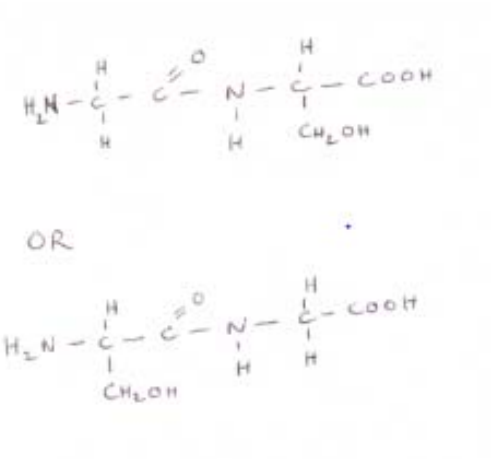
Question Number	Acceptable Answers	Reject	Mark
22(e)(iii)	**Concentrated** nitric acid and **concentrated** sulfuric acid ALLOW **"Concentrated** nitric and sulfuric acids" $H_2SO_4(l)$ $HNO_3(l)$ (1) heat in the range of 50-60 ^oC any temperature in this range ALLOW M2 provided nitric and/or sulfuric acid is mention in M1. (1)	Just "heat" Juse "Heat under reflux"	**(2)**

(Total for Question 22 = 12 marks)

Question Number	Acceptable Answers	Reject	Mark
23(a)	IGNORE Comments about London Forces **M2** in each method depends on which approach is used. Marks from the two methods cannot be mixed. Information may be given in diagrams. **Method 1** **M1** amino acids exist as zwitterions (1) **M2** the charges are attracted to the (polar) water molecules OR the charges are attracted to the $H^{\delta+}$ or $O^{\delta-}$ in water OR There are ion dipole attractions with the water molecules ALLOW There are dipole/dipole attractions with the water molecules (1) **Method 2** **M1** hydrogen bonds can form (with water) from the amine / NH_2 group OR hydrogen bonds can form from the carboxylic acid / COOH / OH group (1) **M2** This compensates for energy required to breaking H bonds between water OR Energy change is larger than lattice energy of acid (1)	Just "both amino acids and water are polar molecules" Ionic bonding with water Just "they form hydrogen bonds" H bonds can form between the H in the amino acid and the H in water	**(2)**

Question Number	Acceptable Answers	Reject	Mark
23(b)	Ninhydrin (solution) ALLOW Ninhydrine (solution) Nin-hydrin (solution)	Nin**o**hydrin Ninhydr**a**n Ninhydr**a**in Ninhydr**ate** Ninhydr**ide**	**(1)**
Question Number	Acceptable Answers	Reject	Mark
23(c)(i)	$^{+}NH_3CH_2COO^-$ / NH_2CH_2COOH OR  OR fully displayed formula		**(1)**

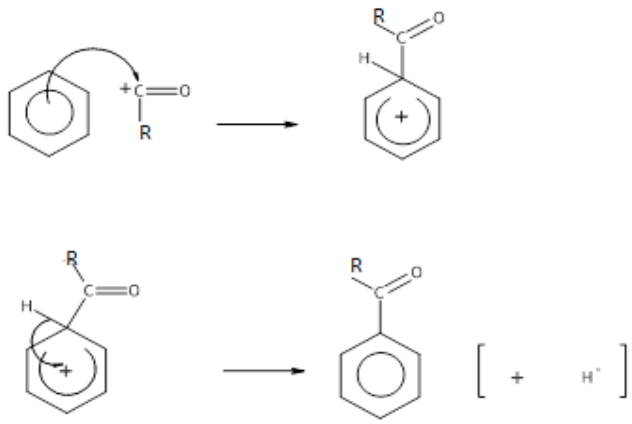
Question Number	Acceptable Answers	Reject	Mark
23(c)(ii)	**M1** Z contains two OH groups OR Z contains an OH / alcohol group as well as the COOH ALLOW OH and COOH shown in formula (1) **M2** formula  **Look carefully for different orientations of this formula.** **Amino group, COOH and an H should be on the same C and CH_2OH in a side chain.** ALLOW undisplayed NH_2, COOH / zwitterion (1) **M3** chiral C circled or highlighted in some way ALLOW TE on a chiral C in an incorrect amino acid NH_2CH_2**C**H(OH)COOH NH_2**C**H(OH)CH_2 COOH (1)	Just "contains COOH" Contains groups other than OH and COOH Contains 2 alcohol groups Answer which does not match formula Eg is an acyl chloride Acid with NH_2 and COOH not on same C: $NH_2CH_2CH(OH)COOH$ $NH_2CH(OH)CH_2COOH$ $NH_2C(OH)(CH_3)COOH$	**(3)**

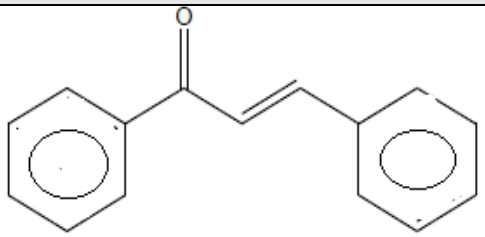
Question Number	Acceptable Answers	Reject	Mark
23(c)(iii)	**You will see different orientations of the dipeptide. Look carefully.** Dipeptide with peptide bond from either COOH of glycine or serine  Correct peptide (CONH) group (1) Rest of dipeptide correct ALLOW TE from $NH_2CH_2CH(OH)COOH$ or $NH_2CH(OH)CH_2COOH$ in (c)(ii) OR from incorrect Y as long as it is an amino If two are given both must be correct (1)	Molecules without CONH (peptide) link	**(2)**

(Total for Question 23 = 9 marks)
Total for Section B = 49 marks

Section C

Question Number	Acceptable Answers	Reject	Mark
24(a)	$C_{10}H_{16}O$ $C_{10}H_{16}O_1$	$C_{10}H_{15}OH$	1

Question Number	Acceptable Answers	Reject	Mark
24(b)	$C_2H_5COCl + AlCl_3 \rightarrow C_2H_5CO^+ + AlCl_4^-$ (1) **Fully correct mechanisms making propyl benzene from chloropropane score max 3**  (R = —CH_2CH_3 / —C_2H_5) Curly arrow from on or within the circle to positively charged carbon ALLOW Curly arrow from anywhere within the hexagon Positive charge on any part of the electrophile Arrow to any part of the $C_2H_5CO^+$ including to the + charge TE on incorrect electrophile eg CH_3CO^+ , $C_3H_7^+$, $C_3H_5O^+$ (1) Intermediate structure including charge with horseshoe covering at least 3 carbon atoms, **and** facing the tetrahedral carbon **and** some part of the positive charge must be within the horseshoe (1) Curly arrow from C—H bond to anywhere in the benzene ring. Correct product shown. TE on incorrect electrophile eg CH_3CO^+, $C_2H_5^+$ (1) Correct Kekulé structures score full marks Ignore any involvement of $AlCl_4^-$ at end	$C_3H_5O^+$ for electrophile Curly arrow on or outside the hexagon All bonds to H and CO dotted **unless** clearly a dots & wedge 3-D structure Bond from benzene ring to C of alkyl group H_2 as product	4

Question Number	Acceptable Answers	Reject	Mark
24(c)	 OR Formula drawn right to left ALLOW Formula written with -COCH=CH- between benzene rings *cis*- / *Z*- isomer IGNORE Reaction intermediate (with OH)		1

Question Number	Acceptable Answers	Reject	Mark
24(d)	Intermediate OR  CN may be shown in either position ALLOW CN represented as ≡N coming from line representing C (1) Step 1: HCN + KCN ALLOW KCN + acid / HCN + alkali / HCN pH 8 IGNORE Ethanol (1) Step 2: (dilute) HCl / other strong acid ALLOW HCl + water Concentrated HCl (1) Step 2 depends on appearance of CN in Step 1 or in the intermediate IGNORE Heat, warm, reflux throughout	Concentrated HCl concentrated H_2SO_4 Carboxylic acids $LiAlH_4$	3

Question Number	Acceptable Answers	Reject	Mark
24(e)(i)	Water: (anhydrous) calcium chloride / magnesium sulfate / sodium sulfate / silica gel/ $CaCl_2$ /$MgSO_4$/ Na_2SO_4 (1) Carbon dioxide: Calcium hydroxide/ lime/ slaked lime /quick lime /soda lime/ sodium hydroxide/ potassium hydroxide/ $Ca(OH)_2$ / CaO / NaOH/ KOH ALLOW Lime water (1)	Name with incorrect formula Copper sulfate /$CuSO_4$ Cobalt chloride / $CoCl_2$ Concentrated sulfuric acid Calcium sulfate Silicon dioxide Concentrated sulfuric acid Sodium carbonate Sodium hydrogencarbonate Lime soda limestone Gas syringe	2

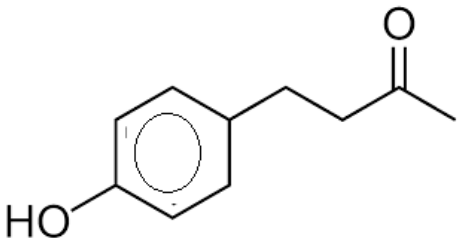
Question Number	Acceptable Answers	Reject	Mark
24(e)(ii)	Mass of oxygen in CO_2 and H_2O includes O in compound and O from air/ atmosphere OR Mass of oxygen in CO_2 and H_2O includes mass provided for combustion ALLOW Oxygen comes from air as well (as from the compound) IGNORE Oxygen is in both carbon dioxide and water	Oxygen is lost Oxygen evaporates	1

Question Number	Acceptable Answers	Reject	Mark
24(f)(i)	Mol C: (73.17/12) = 6.0975 Mol H = 7.32 Mol O: (19.51/16) = 1.219375 (1) Empirical formula C_5H_6O (1) No TE on incorrect moles Answer with no working scores (1) IGNORE sf except 1 sf		2

Question Number	Acceptable Answers	Reject	Mark
24(f)ii)	$C_{10}H_{12}O_2$ Mark independently		1

Question Number	Acceptable Answers	Reject	Mark
24(f)(iii)	Find *m/e* value for the line farthest to the right (of the mass spectrum) (excluding minor isotopes) OR find the line with highest *m/e* value ALLOW *m/z* for *m/e*	m/e of the highest peak / The molecular peak The largest peak Peak with highest molecular mass Just 'position of last peak'	1

Question Number	Acceptable Answers	Reject	Mark
24(f)(iv)	Any matching pair M2 depends on a suitable test in M1 If 2 tests are given both must be correct Add bromine(water) ALLOW Add liquid bromine / $Br_2(l)$ (1) a white precipitate (of tribromophenol) is formed IGNORE Decolorisation Antiseptic smell (1) OR Add sodium (1) Effervescence occurs with phenol (and white solid) ALLOW Hydrogen forms with phenol (1) OR Add iron(III) chloride solution (1) Red/ blue/ purple/ violet colour (1) OR Add ethanoyl chloride/ an acyl chloride (1) Characteristic smell/ fruity smell (1)	use of PCl_5 use of sodium carbonate White solid without gas formation	2

Question Number	Acceptable Answers	Reject	Mark
24(f)(v)	**M1** Structure showing CH_3CO group **M2**  ALLOW Substituents on any position on benzene ring (1) **M3** H in right hand CH_3 labelled as singlet **AND** H in both adjacent CH_2 labelled as triplet (1) Award M3 for correct labelling of positions of singlet and triplet on skeletal formula M3 can be awarded following errors in M2 e.g. missing phenolic group.	Missing phenolic OH	3

(Total for Question 24 = 21 marks)
Total for SECTION C = 21 MARKS
TOTAL FOR PAPER = 80 MARKS

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Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | Candidate Number

Thursday 7 November 2019

Morning (Time: 1 hour 15 minutes) | Paper Reference **WCH06/01**

Chemistry

Advanced

Unit 6: Chemistry Laboratory Skills II

Candidates must have: Scientific calculator

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 50.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- You will be assessed on your ability to organise and present information, ideas, descriptions and arguments clearly and logically, including your use of grammar, punctuation and spelling.
- 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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1/1/1/1/

P 5 8 3 0 1 A 0 1 1 6

Pearson

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

1 A pale green crystalline solid **A** contains two cations and one anion.

(a) When **A** is warmed with aqueous sodium hydroxide, a gas is evolved that turns damp red litmus paper blue.

(i) Identify, by name or formula, the gas evolved.

(1)

.....

(ii) Give the name or formula of the cation in **A** that is identified by this test.

(1)

.....

(b) **A** dissolves in distilled water to form a very pale green solution **B**.

B reacts with aqueous sodium hydroxide to form a green precipitate, which turns into a brown solid **C**, on standing in air.

(i) Give the name or formula of the cation in **B** that is identified by this test.

(1)

.....

(ii) Identify, by name or formula, the brown solid **C**.

(1)

.....

(c) **B** gives a white precipitate when aqueous barium chloride acidified with dilute hydrochloric acid is added.

Give the name or formula of the anion in **B** that is identified by this test.

(1)

.....

(d) Suggest the **formula** of solid **A**. Do not include any water of crystallisation.

(1)

.....

.....

(e) A sample of 0.025 mol of solid **A** with a mass of 9.80 g is heated gently to remove the water of crystallisation and leave 0.025 mol of the anhydrous solid.

The mass of anhydrous solid is 7.10 g.

Calculate the number of moles of water of crystallisation combined with 1 mol of the anhydrous solid.

(2)

(Total for Question 1 = 8 marks)

2 **W** is a white solid with the molecular formula $C_9H_8O_2$.

(a) A series of tests is carried out on **W**.
Complete the table.

Test	Observation	Inference	
(i) Ignite a sample of **W**	Very smoky flame	**W** could be an alkene or ..... compound	(1)
(ii) Add a little **W** to bromine water and shake the mixture	Yellow solution turns into a colourless solution	**W** contains the ..... group	(1)
(iii) Heat **W** until it melts then add phosphorus(V) chloride	Steamy fumes form	**W** contains the ..... group	(1)
(iv) Heat **W** until it melts then add solid	Bubbles of carbon dioxide form	**W** contains the ..... group	(2)

(b) Complete the table, which contains information about the mass spectrum of **W**.

Peak	Inference	
(i) A peak occurs at m/e = ...	The peak is due to $C_6H_5^+$	(1)
(ii) A peak occurs at m/e = 103	The peak is due to an ion with the formula	(1)

(c) The **low** resolution proton nmr spectrum of **W** has four peaks each with relative area 1 and two peaks each with relative area 2.

(i) State the number of proton environments in **W**.

(1)

.....

(ii) State what can be deduced from the relative peak areas.

(1)

.....

.....

.....

(d) **W** exists as two geometric isomers.

Use all the information in this question to deduce the structure of **one** of these isomers.

(2)

(Total for Question 2 = 11 marks)

3 A student used two methods to determine the concentration of vanadium(III) ions in an aqueous solution **X**.

(a) **Method 1** used a titration procedure.

10.0 cm^3 of **X** was titrated with 0.0400 mol dm^{-3} acidified potassium manganate(VII).

The equation for the reaction is

$$5V^{3+}(aq) + 2MnO_4^-(aq) + 2H_2O(l) \rightarrow 5VO_2^+(aq) + 2Mn^{2+}(aq) + 4H^+(aq)$$

The results of four titrations are shown.

Titration	Rough	1	2	3
Final burette reading / cm^3	21.10	41.30	19.85	20.10
Initial burette reading / cm^3	0.50	21.10	0.25	0.00
Titre / cm^3				20.10
Titres used to calculate mean				

(i) Complete the table and calculate the mean titre.
Show which titres you have used in your calculation by putting a tick (✓) in the appropriate boxes in the table.

(2)

Mean titre = ... cm^3

(ii) Calculate the concentration, in mol dm^{-3}, of $V^{3+}(aq)$ ions in solution **X**.
Give your answer to **three** significant figures.

(3)

(iii) Each burette reading was accurate to $\pm 0.05\ cm^3$.

Calculate the percentage uncertainty in the titre value for Titration **3**.

(1)

(b) **Method 2** used an electrochemical cell.

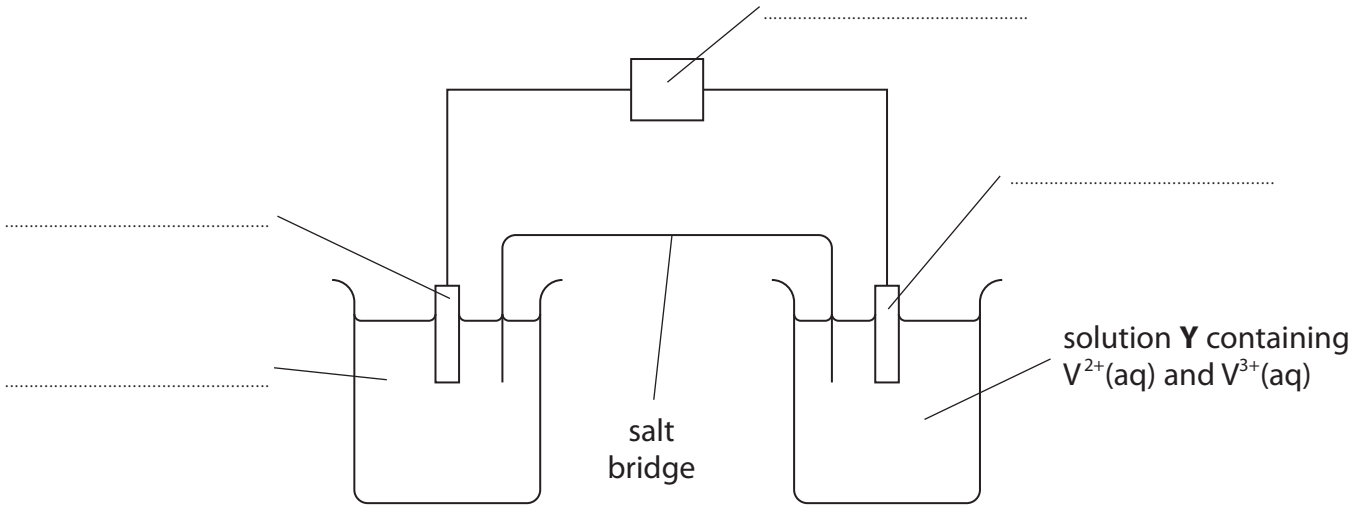
An electrochemical cell was made from the electrode systems represented by these half-equations:

$$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$$

$$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$$

The E_{cell} value was measured using the apparatus shown.

Solution **Y** was made by mixing 50 cm^3 of an aqueous solution of V^{2+} ions with 50 cm^3 of the same solution **X** as used in **Method 1**.



(i) Complete the diagram by adding labels on the dotted lines provided. Conditions are not required.

(4)

(ii) The salt bridge consisted of a strip of filter paper soaked in a saturated solution of potassium nitrate.

Give a reason why potassium hydroxide solution should **not** be used for the salt bridge.

(1)

.....

.....

.....

(iii) In this cell, the zinc half-cell was at standard temperature and concentration. When the cell reaction occurred, the zinc was oxidised and $E_{cell} = +0.44\,V$.

Write the overall equation for the cell reaction.
State symbols are not required.

(1)

(iv) The standard electrode potential, $E^{\ominus}$, for the $Zn^{2+}(aq)|Zn(s)$ half-cell = $-0.76\,V$.

The $V^{3+}(aq)|V^{2+}(aq)$ half-cell was **not** at standard concentration in this experiment.

Calculate the electrode potential, E, for the $V^{3+}(aq)|V^{2+}(aq)$ half-cell in this experiment.

(1)

(v) The **standard** electrode potential, $E^{\ominus}$, for the $V^{3+}(aq)|V^{2+}(aq)$ half-cell = $-0.26\,V$.

Solution **Y** was 1 mol dm^{-3} with respect to $V^{2+}(aq)$.

For the half-cell in this experiment, the electrode potential is given by

$$E = E^{\ominus} + 0.059 \log [V^{3+}(aq)]$$

Use this, and your answer to (b)(iv), to calculate the concentration of $V^{3+}(aq)$ in solution **Y**. You **must** show your working.

(2)

(c) The concentration of $V^{3+}(aq)$ obtained in (a)(ii) was approximately double that obtained in (b)(v).

Explain why these two values were different.

(1)

.....

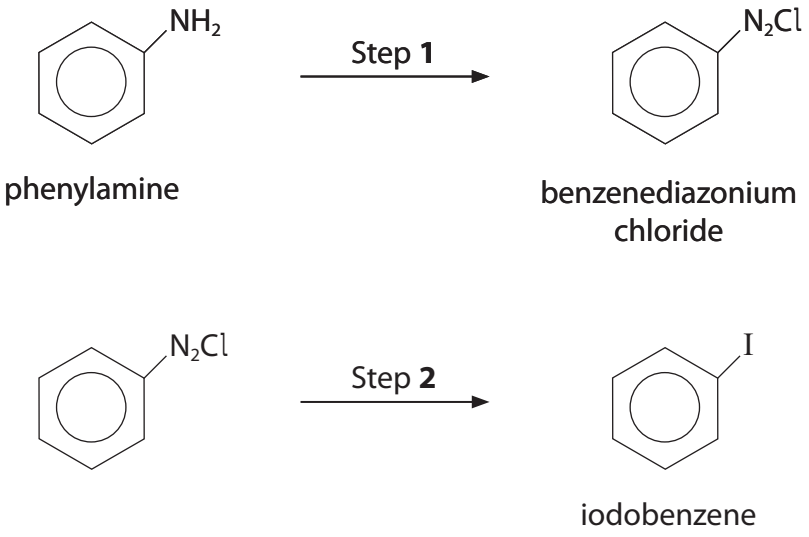
.....

.....

.....

(Total for Question 3 = 16 marks)

4 This question is about the preparation of iodobenzene from phenylamine, and its purification.
The preparation occurs in two steps.



Some data about phenylamine and iodobenzene are given in the table.

Compound	Molar mass / g mol^{-1}	Density / g cm^{-3}	Boiling temperature / °C
Phenylamine	93.0	1.02	184
Iodobenzene	203.9	1.83	188

(a) In Step **1** of the preparation, phenylamine is converted into benzenediazonium chloride.

Give the reagents and condition for Step **1**.

(2)

.....

.....

.....

.....

(b) In Step **2** of the preparation, aqueous potassium iodide is added slowly to the reaction mixture from Step **1**.

The mixture is left to stand for 10 minutes and then it is heated for 20 minutes. The iodobenzene formed is steam distilled from the mixture.

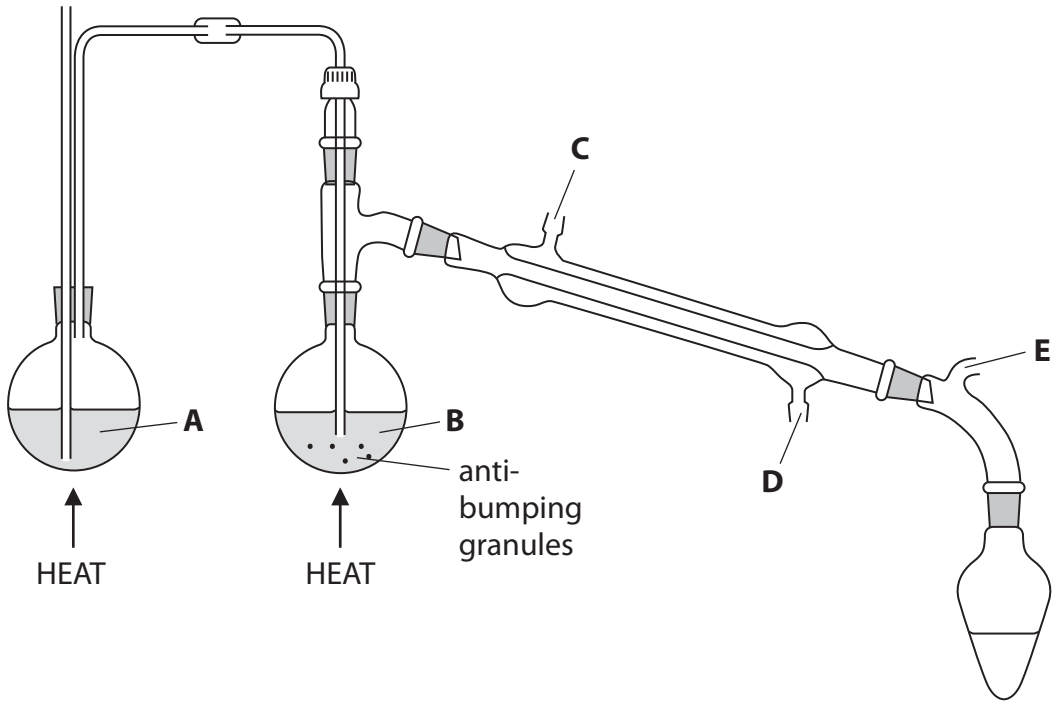
(i) Suggest a reason why the aqueous potassium iodide is added slowly.

(1)

.....

.....

(ii) The apparatus used for steam distillation is shown.



Complete the labelling of the diagram, **A**, **B**, **C** and **D**.

(3)

A .....

B .....

C .....

D .....

(iii) State the purpose of the part of the apparatus labelled **E**.

(1)

.....

.....

(iv) The distillate collected contains iodobenzene and water.

Describe how iodobenzene is obtained from the distillate.

[Refer to the data given at the start of Question 4]

(2)

.....

.....

.....

.....

(v) The iodobenzene obtained from the distillate is a cloudy liquid.

Name a substance that should be added to make the liquid clear.

(1)

.....

.....

(vi) The clear liquid is distilled to obtain pure iodobenzene.

Give a suitable temperature **range** for collecting the pure iodobenzene.

[Refer to the data given at the start of Question 4]

(1)

.....

(c) This preparation and purification process has an expected yield of 70%.

Calculate the **volume** of phenylamine needed to produce 25.0 cm^3 of iodobenzene.

[Refer to the data given at the start of Question 4]

(4)

(Total for Question 4 = 15 marks)

TOTAL FOR PAPER = 50 MARKS

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The Periodic Table of Elements

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

Key: relative atomic mass / **atomic symbol** / name / atomic (proton) number

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