Accredited

A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

Sample Question Paper

Date – Morning/Afternoon

Version 2.0

Time allowed: 2 hours 15 minutes

You must have:
- the Data Sheet for Chemistry A

You may use:
- a scientific or graphical calculator

First name	
Last name	

Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided.
- Additional paper may be used if required but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **28** pages.

SECTION A

You should spend a maximum of 20 minutes on this section.

Answer **all** the questions.

1 Which row shows the atomic structure of $^{55}Mn^{2+}$?

	Protons	Neutrons	Electrons
A	25	30	23
B	25	55	23
C	27	30	25
D	30	25	28

Your answer ☐

[1]

2 The Group 2 elements react with water, forming a solution and a gas.

Which statement is correct?

A The reactivity of the elements decreases down Group 2.

B The pH of the solution formed increases down Group 2.

C The reaction is a neutralisation.

D The equation for the reaction of strontium with water is:

$$2Sr + 2H_2O \rightarrow 2SrOH + H_2$$

Your answer ☐

[1]

3 Chloroethene, $CH_2{=}CHCl$, is prepared in the presence of a solid catalyst using the equilibrium reaction below.

$$CH_2ClCH_2Cl(g) \rightleftharpoons CH_2{=}CHCl(g) + HCl(g) \qquad \Delta H = +51\ \text{kJ mol}^{-1}$$

Which change would result in an increased equilibrium yield of chloroethene?

A increasing the pressure

B increasing the surface area of the catalyst

C increasing the temperature

D use of a homogeneous catalyst

Your answer

[1]

4 The table below shows enthalpy changes of formation, $\Delta_f H$.

Compound	$TiCl_4(l)$	$H_2O(l)$	$TiO_2(s)$	$HCl(g)$
$\boldsymbol{\Delta_f H}$ **/ kJ mol^{-1}**	–804	–286	–945	–92

What is the value of the enthalpy change of reaction, $\Delta_r H$, for the reaction in the following equation?

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(g)$$

A –63 kJ mol^{-1}

B –53 kJ mol^{-1}

C +53 kJ mol^{-1}

D +63 kJ mol^{-1}

Your answer

[1]

5 Zinc reacts with copper(II) sulfate solution, $CuSO_4(aq)$.

Which apparatus could be used to determine the effect of the concentration of $CuSO_4(aq)$ on the rate of reaction?

A balance

B gas syringe

C colorimeter

D pH meter

Your answer ☐

[1]

6 The boiling point of hydrogen bromide is –67 ºC.
The boiling point of hydrogen iodide is –34 ºC.

The different boiling points can be explained in terms of the strength of bonds or interactions.

Which bonds or interactions are responsible for the higher boiling point of hydrogen iodide?

A covalent bonds

B hydrogen bonds

C permanent dipole–dipole interactions

D induced dipole–dipole interactions

Your answer ☐

[1]

7 The 1^{st} to 8^{th} successive ionisation energies, in kJ mol^{-1}, of an element in period 3 are:

1012 1903 2912 4957 6274 21 269 25 398 29 855

What is the element?

A Al

B Si

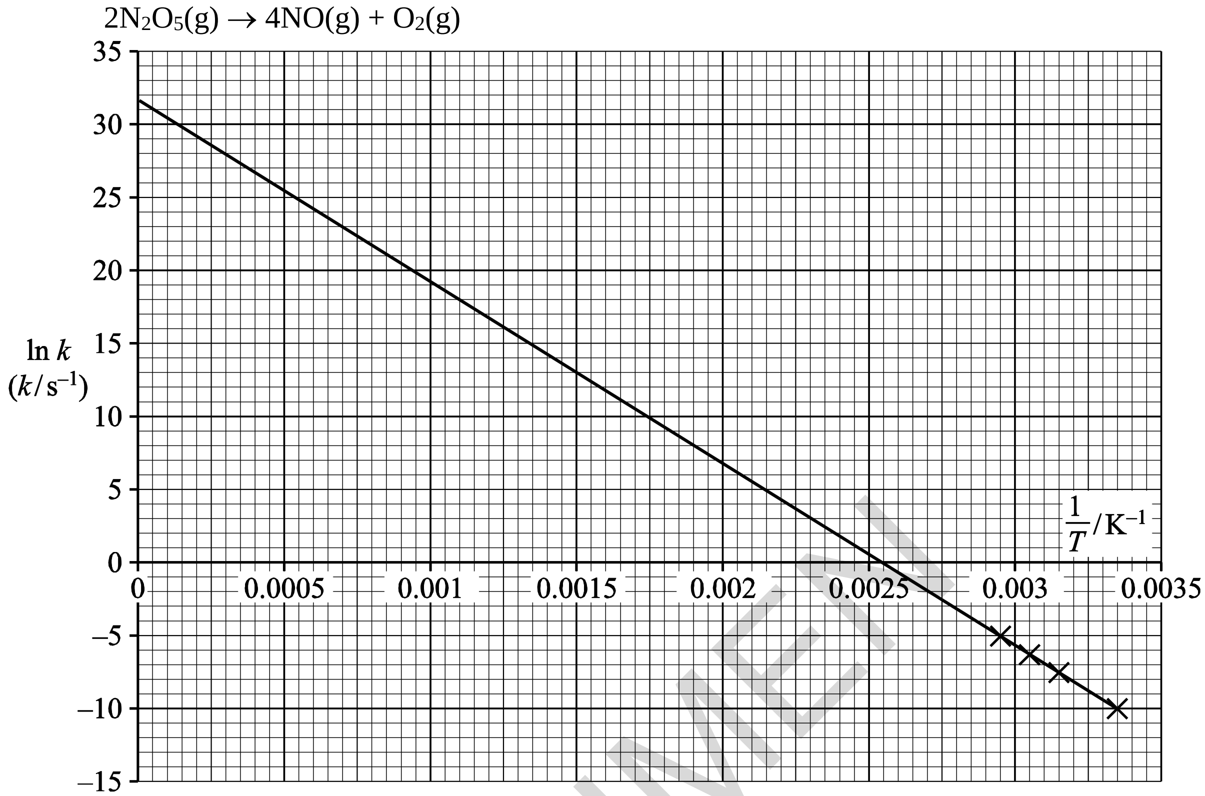
C P

D S

Your answer ☐

[1]

8 Using the graph, what is the value of the pre-exponential factor, *A*, for the decomposition of N_2O_5?



A 3.45 s^{-1}

B 31.5 s^{-1}

C 1.04×10^{5} s^{-1}

D 4.79×10^{13} s^{-1}

Your answer

[1]

9 A solution of propanoic acid, CH_3CH_2COOH, has a pH of 2.89 at 25 °C.

What is $[H^+]$ in this solution?

A 1.7×10^{-6} mol dm^{-3}

B 4.6×10^{-4} mol dm^{-3}

C 1.3×10^{-3} mol dm^{-3}

D 0.46 mol dm^{-3}

Your answer

[1]

10 The lattice enthalpy of calcium chloride can be calculated using **three** of the enthalpy changes below.

Which enthalpy change is **not** required?

A enthalpy change of solution of calcium chloride

B enthalpy change of hydration of Cl^- ions

C enthalpy change of formation of calcium chloride

D enthalpy change of hydration of Ca^{2+} ions

Your answer ☐

[1]

11 Which redox reaction contains the largest change in oxidation state for sulfur?

A $H_2SO_4 + 8HI \rightarrow H_2S + 4I_2 + 4H_2O$

B $S + O_2 \rightarrow SO_2$

C $S_2O_3^{2-} + 2H^+ \rightarrow SO_2 + S + H_2O$

D $S + 6HNO_3 \rightarrow H_2SO_4 + 6NO_2 + 2H_2O$

Your answer ☐

[1]

12 NO(g), H_2(g), N_2(g) and H_2O(g) exist in equilibrium:

$$2NO(g) + 2H_2(g) \rightleftharpoons N_2(g) + 2H_2O(g)$$

At room temperature and pressure, the equilibrium lies well to the right-hand side.

Which of the following could be the equilibrium constant for this equilibrium?

A 1.54×10^{-3} mol dm^{-3}

B 6.50×10^{2} mol dm^{-3}

C 1.54×10^{-3} dm^{3} mol^{-1}

D 6.50×10^{2} dm^{3} mol^{-1}

Your answer ☐

[1]

13 Copper(II) ions form an aqueous complex ion, **X**, with chloride ions.

Which statement about **X** is true?

A **X** has optical isomers

B **X** has a square planar shape

C **X** has the formula $CuCl_4^{2+}$

D **X** has a yellow colour

Your answer ☐

[1]

14 Two tests are carried out on an aqueous solution of copper(II) sulfate, $CuSO_4$(aq).

Test 1: Addition of potassium iodide solution
Test 2: Addition of barium chloride solution

Which of the following statements is/are true?

1: **Test 1** produces an off-white precipitate and a brown solution.

2: **Test 2** produces a white precipitate.

3: **Test 1** and **Test 2** are both redox reactions.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]

15 Two students set up the equilibrium system below.

$$CH_3COOC_2H_5(l) + H_2O(l) \rightleftharpoons C_2H_5OH(l) + CH_3COOH(l)$$

The students titrated samples of the equilibrium mixture with sodium hydroxide, NaOH(aq), to determine the concentration of CH_3COOH.

The students used their results to calculate a value for K_c.

The students' values for K_c were different.

Which of the reason(s) below could explain why the calculated values for K_c were different?

1: Each student carried out their experiment at a different temperature.

2: Each student used a different concentration of NaOH(aq) in their titration.

3: Each student titrated a different volume of the equilibrium mixture.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]

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SECTION B

Answer **all** the questions.

16 Ammonia is a gas with covalently-bonded molecules consisting of nitrogen and hydrogen atoms.

(a) Show the electron configuration of a nitrogen atom using '*electron-in-box*' diagrams.

Label each sub-shell.

1s ……… ………

[2]

(b) Ammonia can be made from the reaction of nitrogen and hydrogen in the Haber process.

$$N_2(g) \; + \; 3H_2(g) \underset{450\ °C\ \text{and}\ 200\ kPa}{\overset{\text{Fe catalyst}}{\rightleftharpoons}} 2NH_3(g) \qquad \Delta H = -92\ kJ\ mol^{-1}$$ **Equation 1**

What effect will increasing the temperature have on the composition of the equilibrium mixture **and** on the value of the equilibrium constant?

Explain your answer.

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……………………………………………………………………………………………… **[2]**

(c) A chemist mixes together 0.450 mol N_2 with 0.450 mol H_2 in a sealed container.

The mixture is heated and allowed to reach equilibrium.

At equilibrium, the mixture contains 0.400 mol N_2 and the total pressure is 500 kPa.

Calculate K_p.

Include units in your answer.

K_p = ………………………… units ………………………… **[5]**

(d) A chemical company receives an order to supply 1.96×10^{10} dm^3 of ammonia at room temperature and pressure. The Haber process produces a 95.0% yield.

Calculate the mass of hydrogen, in tonnes, required to produce the ammonia.

Give your answer to **three** significant figures.

required mass of hydrogen = **…………………………** tonnes **[3]**

(e) **(i)** Hydrazine, N_2H_4, is used as a rocket fuel. Hydrazine can be prepared from the reaction of ammonia with sodium chlorate(I). There are two other products in the reaction.

Write an equation for this reaction.

[1]

(ii) Using the electron pair repulsion theory, draw a 3-D diagram of a molecule of hydrazine.

Predict the H–N–H bond angle around each nitrogen atom.

H–N–H bond angle: **………………………………** **[2]**

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17 Iodine monochloride, ICl, can react with hydrogen to form iodine.

$$2ICl + H_2 \rightarrow 2HCl + I_2$$

This reaction was carried out several times using different concentrations of ICl or H_2. The initial rate of each experiment was calculated and the results are shown below. Initial concentrations are shown for each experiment.

	[ICl] / mol dm^{-3}	**[H_2] / mol dm^{-3}**	**Rate / mol dm^{-3} s^{-1}**
Experiment 1	0.250	0.500	2.04×10^{-2}
Experiment 2	0.500	0.500	4.08×10^{-2}
Experiment 3	0.125	0.250	5.10×10^{-3}

(a) (i) Calculate the rate constant, *k*, for this reaction. Include units in your answer.

k = ... units .... **[4]**

(ii) Calculate the rate of reaction when ICl has a concentration of 3.00×10^{-3} mol dm^{-3} and H_2 has a concentration of 2.00×10^{-3} mol dm^{-3}.

rate = ... mol dm^{-3} s^{-1} **[1]**

(b) Reaction rates can be increased or decreased by changing the temperature of the reaction. **Fig. 17.1** below shows the energy distribution of the reactant molecules at 25 °C.

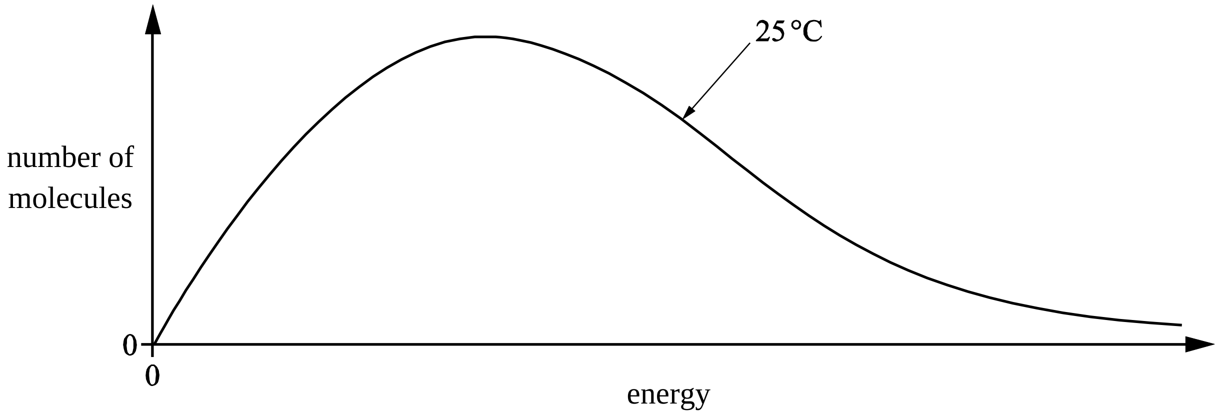

Fig. 17.1

Draw a second curve on **Fig. 17.1**, to represent the distribution of the same number of molecules at a higher temperature.

Use your curve to explain how increasing the temperature increases the rate of reaction.

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…………………………………………………………………………………………… **[2]**

18 A student is asked to calculate ΔG at 25 ºC for the combustion of butan-1-ol. The teacher provides two pieces of information.

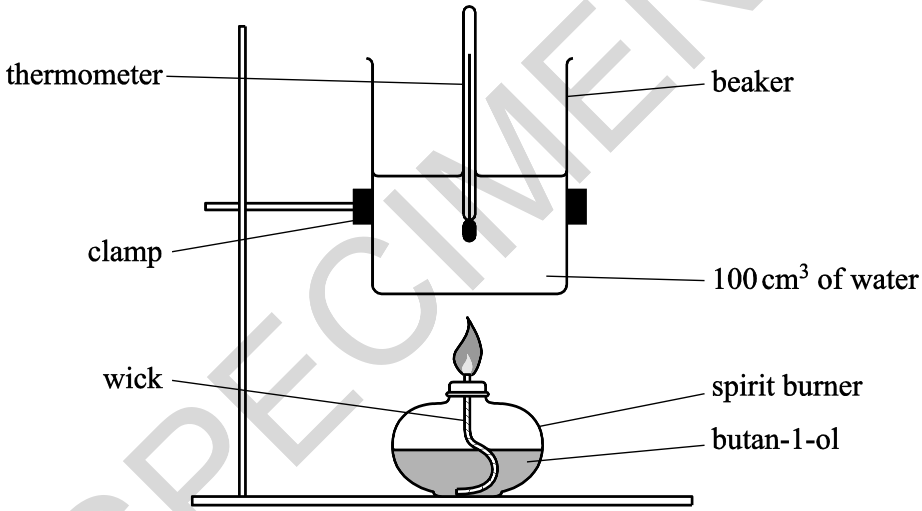
- The equation for the combustion of butan-1-ol.

$$CH_3(CH_2)_3OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l) \qquad \textbf{Equation 2}$$

- Standard entropies of butan-1-ol, oxygen, carbon dioxide and water.

	$CH_3(CH_2)_3OH(l)$	$O_2(g)$	$CO_2(g)$	$H_2O(l)$
S°/ J K^{-1} mol^{-1}	228	205	214	70

The student carries out an experiment using the apparatus below and obtains the following results. The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.



Mass of burner and butan-1-ol before burning / g	98.997
Mass of burner and butan-1-ol after burning / g	98.738
Initial temperature / ºC	18.5
Maximum temperature reached / ºC	39.0

Use the information on the previous page to calculate ΔG, in kJ mol^{-1}, for the combustion of butan-1-ol according to **Equation 2** at 25 °C.

ΔG = ………………………… kJ mol^{-1} **[7]**

19 This question is about the chemistry of the elements in Group 2 and the halogens.

(a) A student prepares an aqueous solution of magnesium chloride by reacting magnesium with excess hydrochloric acid.

Write an equation, including state symbols, for this reaction and state the observation(s) the student should make whilst carrying out this experiment.

equation: ……………………………………………………………………………………….

observation(s): ………………………………………………………………………………….

[2]

(b) Lattice enthalpies give an indication of the strength of ionic bonding.

How would the lattice enthalpies of magnesium chloride and calcium chloride differ?

Explain your answer.

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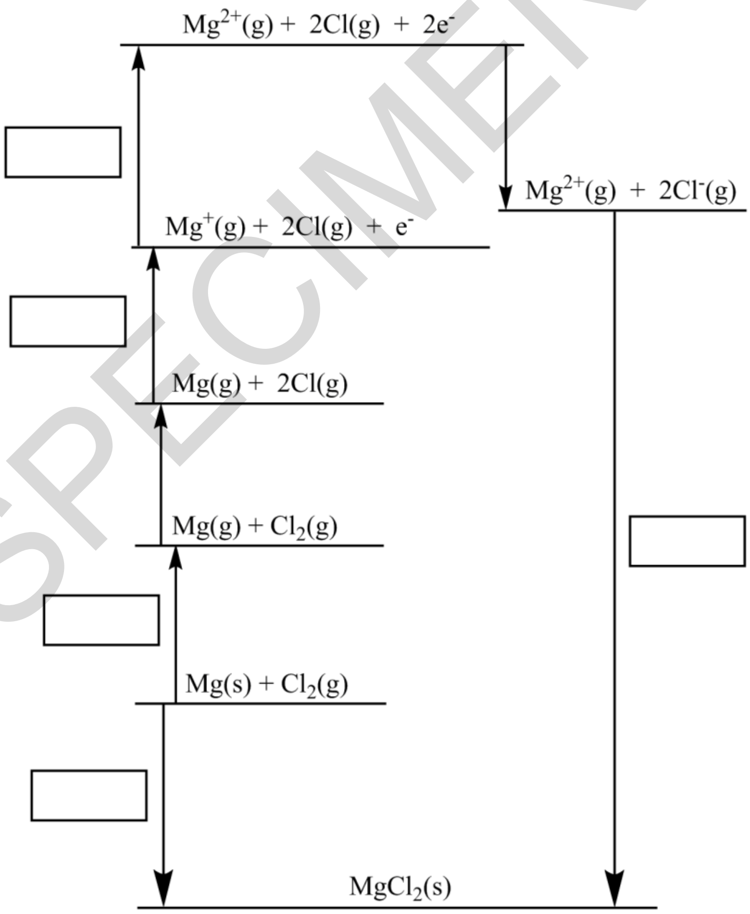
………………………………………………………………………………………… **[3]**

(c) The table below shows the enthalpy changes that are needed to determine the lattice enthalpy of magnesium chloride, $MgCl_2$.

Letter	**Enthalpy change**	**Energy / kJ mol^{-1}**
A	1st electron affinity of chlorine	–349
B	1st ionisation energy of magnesium	+736
C	atomisation of chlorine	+150
D	formation of magnesium chloride	–642
E	atomisation of magnesium	+76
F	2nd ionisation energy of magnesium	+1450
G	lattice enthalpy of magnesium chloride	

(i) On the cycle below, write the correct letter in each box.



[3]

(ii) Use the Born–Haber cycle to calculate the lattice enthalpy of magnesium chloride.

lattice enthalpy = ... kJ mol^{-1} **[2]**

(d)* Describe and explain the relative reactivity of the halogens, chlorine, bromine and iodine, in their redox reactions with halides, using reactions on a test-tube scale.

Include reaction equations and observations in your answer. **[6]**

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Additional answer space if required.

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20 A student investigates the reactions of two weak monobasic acids: 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$, and butanoic acid, $CH_3CH_2CH_2COOH$.

(a) The student wants to prepare a standard solution of 2-hydroxypropanoic acid that has a pH of 2.19.

Plan how the student could prepare 250 cm^3 of this standard solution from solid 2-hydroxypropanoic acid.

In your answer you should provide detail of the practical procedure that would be carried out, including appropriate quantities and necessary calculations.

K_a for 2-hydroxypropanoic acid is 1.38×10^{-4} mol dm^{-3} at 25 °C.

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(b) 2-Hydroxypropanoic acid is a slightly stronger acid than butanoic acid. The two acids are mixed together and an acid–base equilibrium is set up.

Suggest the equilibrium equation and identify the conjugate acid–base pairs.

$CH_3CH(OH)COOH + CH_3CH_2CH_2COOH \rightleftharpoons$ ....

[2]

(c) To prepare a buffer solution, 75.0 cm^3 of 0.220 mol dm^{-3} butanoic acid is reacted with 50.0 cm^3 of 0.185 mol dm^{-3} sodium hydroxide.

K_a for butanoic acid is 1.5×10^{-5} mol dm^{-3} at 25 °C.

(i) Calculate the pH of 0.185 mol dm^{-3} sodium hydroxide at 25 °C.

Give your answer to **two** decimal places.

pH = ... **[2]**

(ii) Calculate the pH of the buffer solution at 25 °C.

Give your answer to **two** decimal places.

pH = ... **[4]**

21 **Table 21.1** below gives the standard electrode potentials for seven redox systems.
You need to use this information to answer the questions below.

Redox system	Equation	E°/V
1	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
2	$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
3	$Br_2(aq) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
4	$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
5	$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
6	$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
7	$Ce^{3+}(aq) + 3e^- \rightleftharpoons Ce(s)$	–2.33

Table 21.1

(a) **(i)** Outline an experimental setup that could be used in the laboratory to measure the standard cell potential of an electrochemical cell based on redox systems **4** and **5**.

In your answer you should include details of the apparatus, solutions and the standard conditions required to measure this standard cell potential.

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.... **[4]**

(ii) An electrochemical cell can be made based on redox systems **2** and **4**.
The standard cell potential is +0.53 V.

State and explain the effect on the cell potential of this cell if the concentration of silver ions is increased.

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.... **[2]**

(b) From **Table 21.1**, predict the oxidising agent(s) that **will not** oxidise Fe^{2+}(aq) to Fe^{3+}(aq).

.... **[1]**

(c) An aqueous solution of iron(II) bromide is mixed with an excess of acidified solution containing manganate(VII) ions.

Using **Table 21.1**, give the formulae of the products of any reactions that take place.

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....

.... **[2]**

22 A student carries out a number of experiments on transition metal compounds.

4.800 g of a green hydrated crystalline solid **A** are heated in a crucible to remove the water of crystallisation. 1.944 g of water are removed to leave 0.0180 mol of solid residue **B**.

Solid **B** contains 32.8%, by mass, of the transition metal.

All of **B** is reacted with $AgNO_3(aq)$ to form 7.695 g of a white precipitate, **C**.

The green crystalline solid **A** is dissolved in water to produce a green solution containing a complex ion, **D**.

When aqueous sodium hydroxide is added to solution of **D**, a grey–green precipitate, **E**, is observed, which dissolves in excess aqueous sodium hydroxide to form a green solution.

(a) Determine the formulae of **A, B, D** and **E**.

A = …………………………… **D =** ……………………………

B = …………………………… **E =** …………………………… **[9]**

(b)* Transition metal complexes often have different shapes and may form a number of stereoisomers.

Describe the different shapes and the different types of stereoisomerism found in transition metal chemistry.

Use suitable examples and diagrams in your answer. **[6]**

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Additional answer space if required.

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END OF QUESTION PAPER

…day June 20XX – Morning/Afternoon

A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

SAMPLE MARK SCHEME

Duration: 2 hours 15 minutes

MAXIMUM MARK 100

This document consists of 24 pages

MARKING INSTRUCTIONS

PREPARATION FOR MARKING

SCORIS

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *scoris assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to scoris and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the scoris 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the scoris messaging system.

5. Work crossed out:

   a. where a candidate crosses out an answer and provides an alternative response, the crossed out response is not marked and gains no marks

   b. if a candidate crosses out an answer to a whole question and makes no second attempt, and if the inclusion of the answer does not cause a rubric infringement, the assessor should attempt to mark the crossed out answer and award marks appropriately.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.

7. There is a NR (No Response) option. Award NR (No Response)

   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (e.g. ‘can’t do’, ‘don’t know’)
   - OR if there is a mark (e.g. a dash, a question mark) which isn’t an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The scoris **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

   If you have any questions or comments for your Team Leader, use the phone, the scoris messaging system, or email.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:

Read through the whole answer from start to finish, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance.

Using a 'best-fit' approach based on the science content of the answer, first decide which set of level descriptors, Level 1, Level 2 or Level 3, **best** describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme.

Once the level is located, award the higher or lower mark.

The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met.

The lower mark should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.

In summary:

- **The science content determines the level.**
- **The communication statement determines the mark within a level.**

Level of response questions on this paper are **19(d)** and **22(b)**.

11. **Annotations**

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

12. **Subject-specific Marking Instructions**

INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

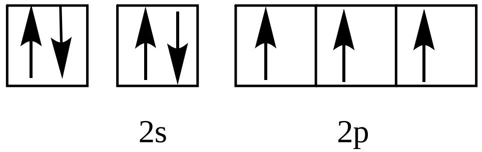
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

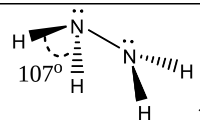
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

SECTION A

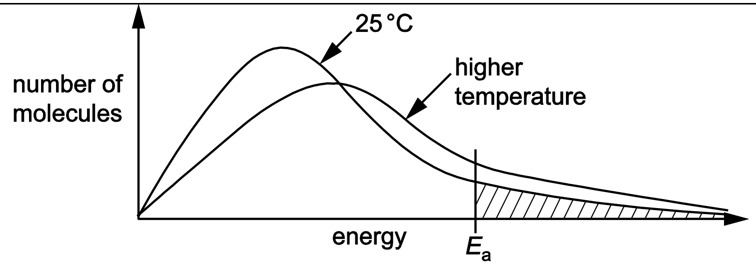
Question	Answer	Marks	Guidance
1	A	**1**	
2	B	**1**	
3	C	**1**	
4	D	**1**	
5	C	**1**	
6	D	**1**	
7	C	**1**	
8	D	**1**	
9	C	**1**	
10	C	**1**	
11	A	**1**	
12	D	**1**	
13	D	**1**	
14	B	**1**	
15	D	**1**	
	Total	**15**	

SECTION B

Question			Answer	Marks	Guidance
16	(a)		 ✓ ✓	2	**ALLOW** half headed arrows
	(b)		The forward reaction is exothermic, so an increase in temperature favours the backward reaction (*owtte*) … ✓ … therefore there will be more N_2 and H_2 **OR** less NH_3 in the equilibrium mixture, **AND** therefore the value of the equilibrium constant will decrease (*owtte*) ✓	2	**ALLOW** names of compounds **ALLOW** reactants/product instead of compounds 2nd mark only available if deduced from 1st mark **ALLOW ECF** for 2nd mark
	(c)		**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 2.37×10^{-6} kPa^{-2} award 5 marks **IF** answer = 2.37×10^{-6} with incorrect units award 4 marks At equilibrium, $n(H_2)$ = 0.300 (mol) **AND** $n(NH_3)$ = 0.100 (mol) ✓ $p(N_2) = \frac{0.400}{0.800} \times 500 = 250$ kPa **AND** $p(H_2) = \frac{0.300}{0.800} \times 500 = 187.5$ kPa **AND** $p(NH_3) = \frac{0.100}{0.800} \times 500 = 62.5$ kPa ✓ $K_p = \frac{p(NH_3)^2}{p(N_2) \times p(H_2)^3} = \frac{62.5^2}{250 \times 187.5^3}$ ✓ $= 2.37 \times 10^{-6}$ ✓ kPa^{-2} ✓	5	Final answer must be correct and have the correct units to score all five marks **ALLOW** calculator value for K_p correctly rounded to three or more significant figures. **If there is an alternative answer, check to see if there is any ECF credit possible using working below** Correct values substituted into correct expression for K_p gains first three marks.

Question			Answer	Marks	Guidance
	(d)		**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 2580 (tonnes) award 3 marks $n(NH_3) = \frac{1.96 \times 10^{10}}{24}$ **OR** 8.167×10^8 (mol) **AND** $n(H_2) = \frac{8.167 \times 10^8}{2} \times 3 = 1.225 \times 10^9$ (mol) ✓ Mass of $H_2 = \frac{2.450 \times 10^9}{1 \times 10^6} = 2450$ (tonnes) ✓ Mass of H_2 for 95% yield = $\frac{2450 \times 100}{95} = 2580$ (tonnes) ✓	3	**If there is an alternative answer, check to see if there is any ECF credit possible using working below** **ALLOW** 2.58×10^3 tonnes **AW** 100% yield = 2.063×10^{10} dm^3 ✓ Amount of $NH_3 = 8.596 \times 10^8$ mol **AND** Amount of $H_2 = 1.289 \times 10^9$ mol ✓ Mass of H_2 = 2580 (tonnes) ✓ **ALLOW** 2579 (tonnes) (calculator answer rounded to nearest whole number)
	(e)	(i)	$2NH_3 + NaOCl \rightarrow N_2H_4 + NaCl + H_2O$ ✓	1	
		(ii)	 ✓ Bond angle 107° ✓	2	Diagram must attempt to show geometry around the nitrogen atom to be pyramidal **ALLOW** 106–108°
			Total	15	

Question			Answer	Marks	Guidance
17	(a)	(i)	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 0.163 $dm^3\ mol^{-1}\ s^{-1}$ **OR** 0.1632 $dm^3\ mol^{-1}\ s^{-1}$ award 4 marks **IF** answer = 0.163 **OR** 0.1632 with incorrect units award 3 marks Order w.r.t. ICl = 1 and order w.r.t H_2 = 1 ✓ rate = $k[ICl][H_2]$ ✓ $k = \frac{2.04 \times 10^{-2}}{0.250 \times 0.500}$ = 0.163 **OR** 0.1632 ✓ $dm^3\ mol^{-1}\ s^{-1}$ ✓	4	**If there is an alternative answer, check to see if there is any ECF credit possible using working below** Both orders = 1 mark Correct rate equation or rearranged form = 1 mark Candidates may use experimental data from experiments 2 or 3 to calculate the rate constant **DO NOT ALLOW** 0.16
		(ii)	rate = $k[ICl][H_2]$ (from **(i)**) $= 0.163 \times 3 \times 10^{-3} \times 2 \times 10^{-3} = 9.78 \times 10^{-7}$ ($mol\ dm^{-3}\ s^{-1}$) ✓	1	**ALLOW ECF** from **(i)** Note use of 0.1632 from **(i)** gives $9.79(2) \times 10^{-7}$

Question			Answer	Marks	Guidance
	(b)		 Correct curve for higher temperature ✓ Activation energy shown on diagram **AND** graph shows that at higher temperature (*owtte*) more molecules have energy above activation energy **OR** more molecules have enough energy to react ✓	2	Boltzmann distribution – must start at origin and must not end up at 0 on *y*-axis i.e. must not touch *x*-axis at high energy Maximum of curve to right **AND** lower than maximum of lower temperature curve **AND** above lower temp line at higher energy as shown in diagram link to graph required for mark
			Total	**7**	

Question			Answer	Marks	Guidance
18			***ΔH calculation from experiment*** q = 100 × 4.18 × 20.5 **OR** 8569 J **OR** 8.569 kJ ✓ Amount of butan-1-ol = $\frac{0.259}{74}$ = 3.5 × 10^{-3} mol ✓ Δ*H* = –2448 kJ mol^{-1}✓ ***ΔS calculation*** Δ*S* = $S_{products}$ – $S_{reactants}$ Δ*S* = (4 × 214) + (5 × 70) – [(228) + (6 × 205)] **OR** Δ*S* = 1206 – 1458 ✓ Δ*S* = –252 J K^{-1} mol^{-1} **OR** –0.252 kJ K^{-1} mol^{-1} ✓ ***ΔG calculation*** Δ*G* = Δ*H* – *T*Δ*S* Δ*G* = –2448 – (298 × –0.252) ✓ Δ*G* = –2373 (kJ mol^{-1}) ✓	7	**ALLOW** Calculator value for Δ*H* = –2448.285714 correctly rounded to three or more significant figures Mark for use of correct expression with Δ*S* in kJ K^{-1} mol^{-1} **ALLOW** three or more sig figs for Δ*G*
			Total	7	

Question			Answer	Marks	Guidance
19	(a)		$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ ✓ Effervescence **AND** solid dissolves ✓	2	State symbols are required **ALLOW** solid disappears
	(b)		Lattice enthalpy of $MgCl_2$ is more exothermic than $CaCl_2$ … ✓ because magnesium ion/Mg^{2+} is smaller (than calcium ions/Ca^{2+}) **OR** Mg^{2+} has a greater charge density … ✓ … therefore the attraction between Mg^{2+} and Cl^- is greater (than between Ca^{2+} and Cl^-) ✓	3	**ORA** throughout **ALLOW** 'charge density' here **only** **ALLOW** magnesium/Mg is smaller **DO NOT ALLOW** Mg^{2+} has a smaller **atomic** radius **DO NOT ALLOW** chlorine ions **DO NOT ALLOW** Mg has greater attraction **ALLOW** 'attracts with more force' for greater attraction but **DO NOT ALLOW** 'greater force' (could be repulsion)
	(c)	(i)	**F** **B** **G** **E** **D** **FIVE** correct ✓✓✓ **FOUR** correct ✓✓ **THREE** correct ✓	3	**ALLOW** 1450 736 **G** 76 –642 **IF** only one or two correct, award 0 marks.
		(ii)	$-642 - (+76 + (2 \times 150) + 736 + 1450 + (2 \times -349))$ ✓ $-642 - 1864 = -2506$ ✓ (kJ mol^{-1})	2	**ALLOW** for 1 mark: –2705 (2 x 150 and 2 x 349 not used for Cl) –2356 (2 x 150 not used for Cl) –2855 (2 x 349 not used for Cl) +2506 (wrong sign) **DO NOT ALLOW** any other answers

Question			Answer	Marks	Guidance
	(d)*		*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Describes and explains concisely the trend in reactivity of the halogens **AND** Full observations of redox reactions backed up by at least two equations *There is a well-developed explanation which is clear and logically structured. The observations and equations are relevant to those trends explained.* *Clear and confident knowledge of relevant technical language.* **Level 2 (3–4 marks)** Describes and explains the trend in reactivity of the halogens **AND** Is able to recall a redox reaction by suitable observations and correctly link to an equation *There is an explanation with some structure. The observations and equations are in the most-part relevant to the trend explained.* *Sound grasp of relevant technical language.* **Level 1 (1–2 marks)** Describes the trend in reactivity of the halogens with some attempt at explanation **AND** Is able to recall a redox reaction either by suitable observation or by equation	6	**Indicative scientific points may include:** **Trend in reactivity** • More shells or increasing radius down the group • Increased shielding down the group • More difficult to gain an electron **Observations** • Reaction of Cl_2 or Br_2 with I^-: orange/brown solution **OR** purple in organic • Reaction of Cl_2 with Br^-: yellow solution **OR** orange in organic **Reaction equations** • $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ • $Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$ **OR** $Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ • Order of reactivity linked to observations

Question			Answer	Marks	Guidance
			There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. **0 marks** No response or no response worthy of credit.		
			Total	**16**	

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>20</td><td>(a)</td><td></td><td>$[H^+] = 10^{-pH} = 10^{-2.19} = 6.46 \times 10^{-3}$ (mol dm^{-3}) ✓

$[CH_3CH(OH)COOH] = \frac{[H^+]^2}{K_a} = \frac{(6.46 \times 10^{-3})^2}{1.38 \times 10^{-4}}$ ✓
= 0.0302 (mol dm^{-3}) ✓

$n(CH_3CH(OH)COOH) = \frac{0.302 \times 250}{1000} = 0.0755$ mol ✓

Mass of $CH_3CH(OH)COOH = 0.0755 \times 90 = 6.80$ g ✓

Dissolve 6.80 g of the solid in distilled water (less than 250 cm^3) in a beaker ✓

(then) transfer the solution to a 250 cm^3 volumetric flask AND ensure that all solution is washed out of beaker (washings transferred to volumetric flask) ✓

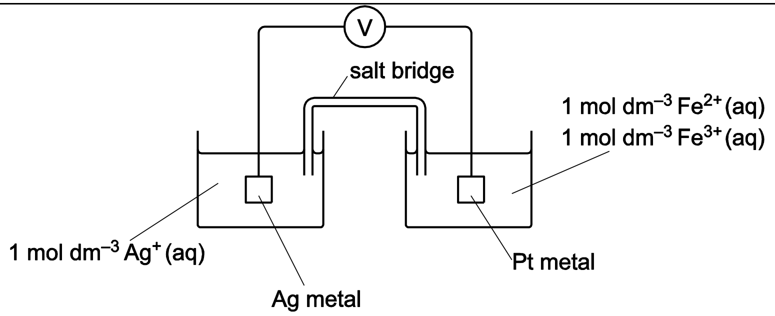
(then) make solution up to 250 cm^3 with distilled water AND ensure thorough mixing by inverting the flask several times ✓</td><td>8</td><td>ALLOW 5 marks for 6.80 g through any calculation.

ALLOW ECF for incorrect calculation of mass. Mass used must be linked to calculation.</td></tr>
<tr><td></td><td>(b)</td><td></td><td>$CH_3CH(OH)COO^- + CH_3CH_2CH_2COOH_2^+$ ✓

$CH_3CH(OH)COOH$ AND $CH_3CH(OH)COO^-$
$CH_3CH_2CH_2COOH$ AND $CH_3CH_2CH_2COOH_2^+$
Both pairs identified ✓</td><td>2</td><td>State symbols NOT required

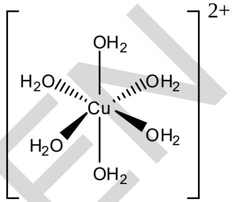
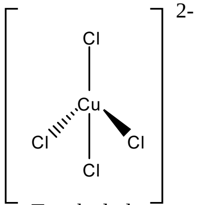
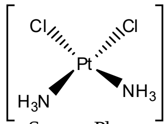
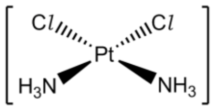
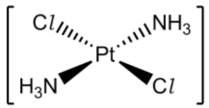
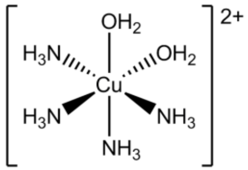
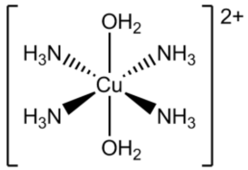
ALLOW labels ‘acid 1’, ‘base 1’ etc.
ALLOW ECF for second mark</td></tr>
</table>

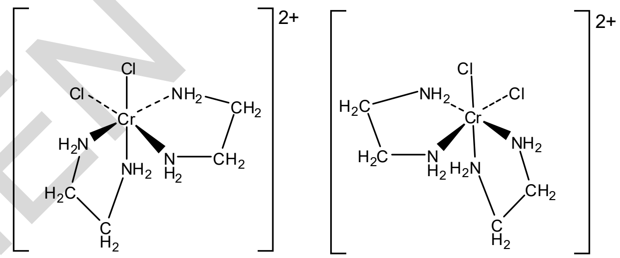
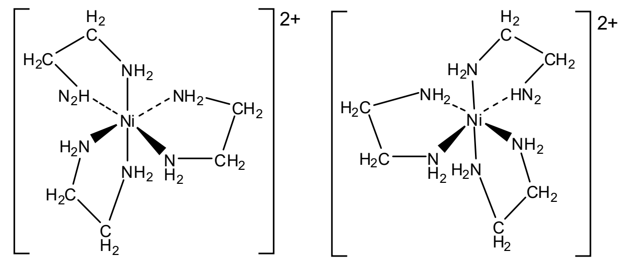
Question			Answer	Marks	Guidance
	(c)	**(i)**	$[H^+] = \dfrac{1 \times 10^{-14}}{0.185} = 5.405 \times 10^{-14}$ (Use of K_w) ✓ pH = $-\log(5.405 \times 10^{-14})$ = 13.27 ✓	2	**ALLOW** $5.405405405 \times 10^{-14}$ and correct rounding to 5.4×10^{-14} **ALLOW** alternative approach using pOH: pOH = –log(0.185) = 0.73 pH = 14 – 0.73 = 13.27 Correct answer scores **BOTH** marks **ALLOW** 13.267
		(ii)	$n(A^-) = 9.25 \times 10^{-3}$ (mol) ✓ $n(HA) = 0.0165 - 9.25 \times 10^{-3} = 7.25 \times 10^{-3}$ (mol) ✓ $[H^+] = K_a \times \dfrac{[HA]}{[A^-]}$ ✓ pH = $-\log(1.5 \times 10^{-5} \times \dfrac{0.058}{0.074})$ = 4.93 **OR** pH = $-\log(1.5 \times 10^{-5} \times \dfrac{1000 \times \frac{7.25 \times 10^{-3}}{125}}{1000 \times \frac{9.25 \times 10^{-3}}{125}})$ = 4.93 ✓ **Final mark** also via Henderson–Hasselbalch equation: pH = pK_a – log $\dfrac{[HA]}{[A^-]}$ = 4.82 – (–0.11) = 4.93 **OR** pH = pK_a + log $\dfrac{[A^-]}{[HA]}$ = 4.82 + 0.11 = 4.93 ✓	4	**ALLOW** HA/acid and A^-/salt throughout for butanoate and butanoic acid **ALLOW** pK_a = –log K_a **OR** $-\log 1.5 \times 10^{-3}$ **OR** 4.82 **ALLOW ECF** from incorrect values of $n(A^-)$ or $n(HA)$ **ALLOW** pH = $-\log(1.5 \times 10^{-5} \times \dfrac{7.25 \times 10^{-3}}{9.25 \times 10^{-3}})$ = 4.93
			Total	**16**	

Question			Answer	Marks	Guidance
21	(a)	(i)	 **Half-cells (2 marks)** Ag(s) and 1 mol dm^{-3} Ag^{+}(aq) ✓ 1 mol dm^{-3} Fe^{2+}(aq) **AND** 1 mol dm^{-3} Fe^{3+}(aq) **AND** Pt metal ✓ **Complete circuit (1 mark)** salt bridge **AND** voltmeter **AND** wires ✓ **Standard conditions (1 mark)** 298 K / 25 ºC **AND** 100 kPa / 101 kPa pressure ✓	4	**ALLOW** 1 atm
		(ii)	(Electrode potential of) Ag^{+}/Ag becomes more positive … ✓ therefore, E_{cell} becomes smaller **OR** less positive. ✓	2	**ALLOW** equilibrium Ag/Ag^{+} shifts to right **ALLOW** more negative 2nd mark only available if deduced from 1st mark **ALLOW ECF** for 2nd mark

Question			Answer	Marks	Guidance
	(b)		Ce^{3+} and Zn^{2+} ✓	1	
	(c)		Mn^{2+}, H_2O, Fe^{3+}, Br_2 Three species correct ✓ Four species correct ✓	2	
			Total	9	

Question			Answer	Marks	Guidance
22	(a)		1. $n(AgCl)$ formed $= \frac{7.695}{143.5} = 0.05362$ (mol) ✓ 2. 0.0180 mol of **B** forms 0.05362 mol of Cl^- No of Cl^- ions in formula of **B** $= \frac{0.05362}{0.0180} = 3$ ✓ 3. Molar mass of **B** $= \frac{2.856}{0.0180} = 158.7$ (g mol^{-1}) ✓ 158.7 – (3 × 35.5) = 52.2 which is chromium ✓ 4. $n(H_2O) = \frac{1.944}{18} = 0.108$ (mol) 0.0180 mol $CrCl_3$: 0.108 mol H_2O **OR** 1 mol $CrCl_3$: 6 mol H_2O ✓ **A** $CrCl_3$•$6H_2O$ (from points 2, 3 and 4) ✓ **B** $CrCl_3$ (from points 2 and 3) ✓ **D** $[Cr(H_2O)_6]^{3+}$ (from determination of **A** and understanding of reaction with water) ✓ **E** $Cr(OH)_3$ (from understanding of reaction of **D** with aqueous hydroxide) ✓	9	**ALLOW** Alternative working throughout

Question	Answer	Marks	Guidance
(b)*	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Links together names of shapes with correct 3-D diagrams **AND** Appreciates the two different types of isomerism and labels diagrams appropriately *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* *Demonstrates clear and confident knowledge of relevant technical language using the terms* • *non-superimposable mirror images within optical isomerism* • *opposite and adjacent/same side in cis–trans* **Level 2 (3–4 marks)** Names and labels at least two of the shapes appropriately giving 3-D diagrams **AND** Appreciates that two types of isomerism exist in transition metal chemistry, gives diagrams to illustrate at least one pair of isomers and names them correctly *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* *Answers question with a sound grasp of relevant technical language using the terms*	6	**Indicative scientific points may include:** **Shapes of complex ions** • six coordinate bonds: octahedral • four coordinate bonds: tetrahedral or square planar • 3-D diagrams with charges linked to shapes  Octahedral  Tetrahedral  Square Planar ***cis–trans* isomerism** • found in octahedral and square planar complexes • *trans* – opposite; *cis* – adjacent / same side • 3-D diagrams to illustrate  *cis*  *trans* **OR**  *cis*  *trans*

Question			Answer	Marks	Guidance
			• *tetrahedral, octahedral* • *cis–trans* ***OR*** *optical* **Level 1 (1–2 marks)** Names and draws structures of two of the shapes **AND** Appreciates one type of isomerism that can be seen in transition metal chemistry *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* *Answers question with a basic grasp of relevant technical language* • *links octahedral to six ligands and tetrahedral to four ligands either in word or by diagram* • *correctly links one type of isomerism to a structure* **0 marks** No response or no response worthy of credit.		**Optical isomerism** • Found in octahedral complexes when bidentate ligands are present • Isomers are non-superimposable mirror images • 3-D diagrams to illustrate  **OR** 
			Total	**15**	

Summary of updates

Date	Version	Change
January 2019	2.0	Minor accessibility changes to the paper: i) Additional answer lines linked to Level of Response questions ii) One addition to the rubric clarifying the general rule that working should be shown for any calculation questions

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