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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	$TiCl_4(l)$	$H_2O(l)$	$TiO_2(s)$	$HCl(g)$
$\Delta_f H$ / 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 1st to 8th 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

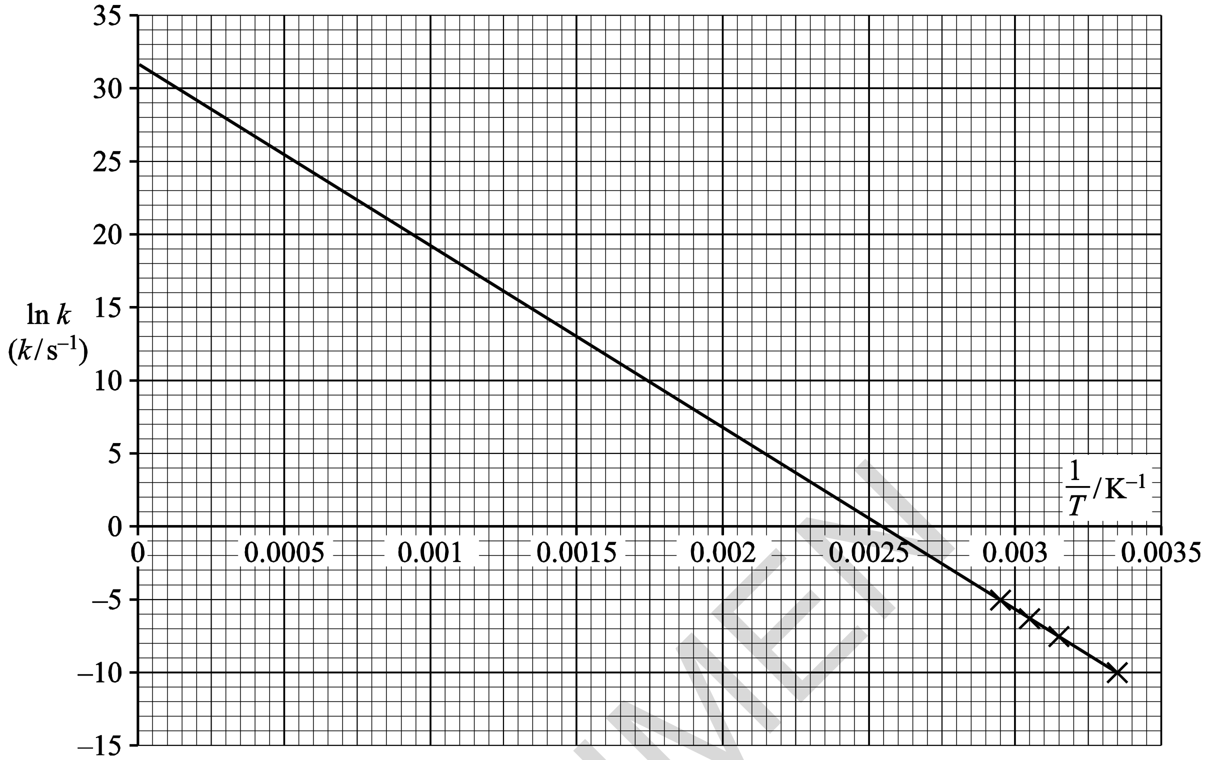
D S

Your answer ☐

[1]

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

$2N_2O_5(g) \rightarrow 4NO(g) + O_2(g)$



A $3.45\ s^{-1}$

B $31.5\ s^{-1}$

C $1.04 \times 10^{5}\ s^{-1}$

D $4.79 \times 10^{13}\ s^{-1}$

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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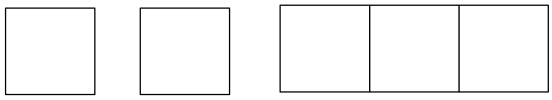
SECTION B

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.

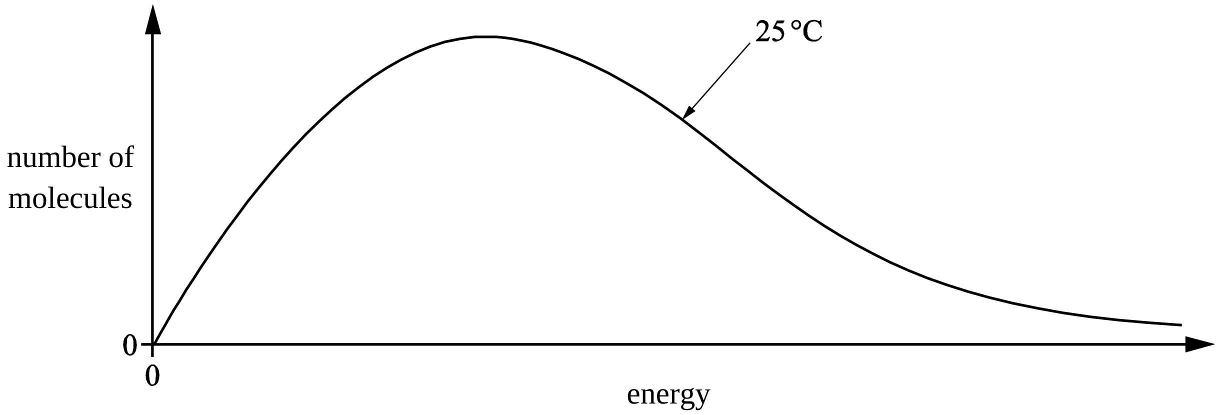

Fig. 17.1

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.

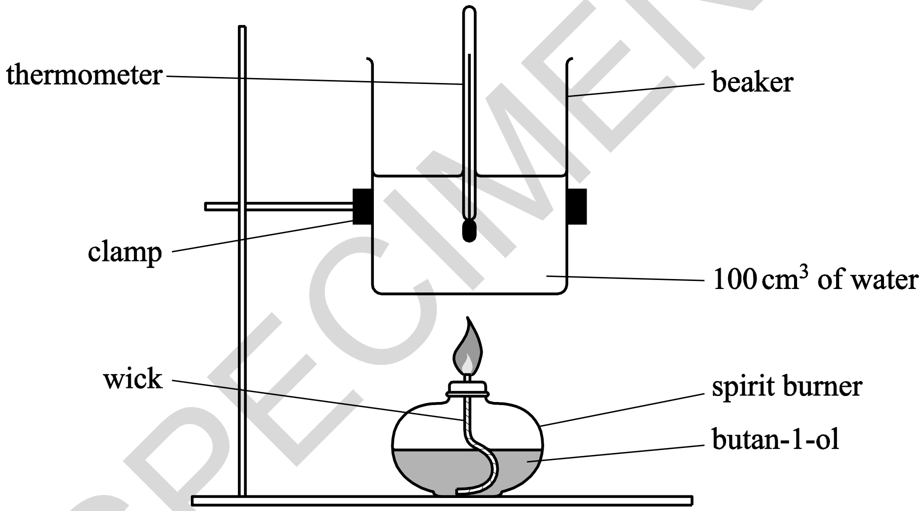
- The equation for the combustion of butan-1-ol.

$$CH_3(CH_2)_3OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$ **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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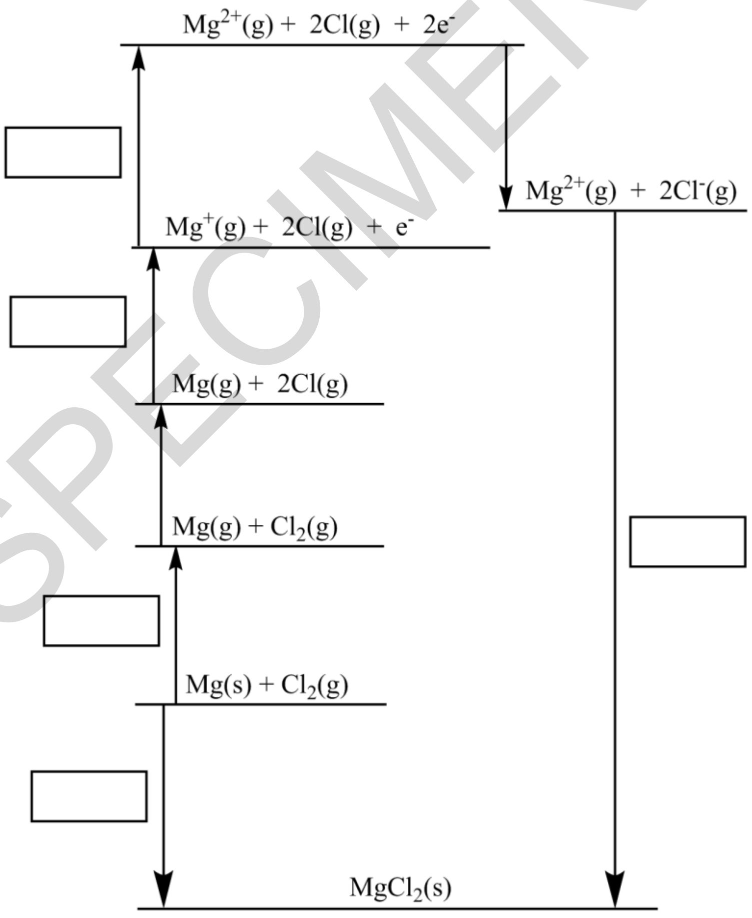
………………………………………………………………………………………………… **[3]**

(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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.... **[8]**

(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	$E^{\ominus}$/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