



Oxford Cambridge and RSA

**Tuesday 06 October 2020 – Afternoon**

**A Level Chemistry A**

**H432/01** Periodic table, elements and physical chemistry

**Time allowed: 2 hours 15 minutes**

**You must have:**

- the Data Sheet for Chemistry A

**You can use:**

- a scientific or graphical calculator
- an HB pencil



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

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Candidate number

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First name(s)

Last name

### INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

### INFORMATION

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

### ADVICE

- Read each question carefully before you start your answer.

## SECTION A

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

Write your answer to each question in the box provided.

Answer **all** the questions.

- 1 Several students titrate  $25.00\text{ cm}^3$  of the same solution of sodium hydroxide,  $\text{NaOH(aq)}$  with hydrochloric acid,  $\text{HCl(aq)}$ .

One student obtains a smaller titre than the other students.

Which procedure explains the smaller titre?

- A The burette readings are taken from the top of the meniscus instead of the bottom of the meniscus.
- B The conical flask is rinsed with water before carrying out the titration.
- C An air bubble is released from the jet of the burette during the titration.
- D The pipette is rinsed with water before filling with  $\text{NaOH(aq)}$ .

Your answer

[1]

- 2 Which statement gives the numerical value of the Avogadro constant?

- A The number of moles in 12g of carbon-12.
- B The number of electrons lost by 20.05g of calcium when it reacts with oxygen.
- C The number of molecules in 16.0g of oxygen.
- D The number of atoms in 1 mole of chlorine molecules.

Your answer

[1]

- 3 0.80 g of element **X** is reacted with 0.40 g of  $O_2$  to form an oxide with the formula  $X_2O_3$ .

What is the identity of element **X**?

- A Aluminium
- B Titanium
- C Germanium
- D Molybdenum

Your answer

[1]

- 4 Phosphoric acid is a tribasic acid.

What is the mass of  $Ca(OH)_2$  that completely neutralises  $100\text{ cm}^3$  of  $0.100\text{ mol dm}^{-3}$  phosphoric acid?

- A 0.49 g
- B 0.74 g
- C 1.11 g
- D 2.22 g

Your answer

[1]

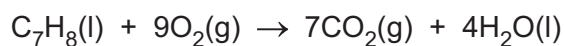
- 5 Which statement about elements in the d block of Period 4 of the periodic table is correct?

- A Cr atoms have the electron configuration:  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$ .
- B  $Cu^+$  ions contain an incomplete 3d sub-shell.
- C  $Fe^{2+}$  ions contain 3 unpaired electrons.
- D Sc forms ions with different oxidation states.

Your answer

[1]

- 6 The equation for the combustion of  $C_7H_8$  is shown in the following equation.



Enthalpy changes of formation are shown in the table.

Substance	$C_7H_8(l)$	$CO_2(g)$	$H_2O(l)$
$\Delta_f H / kJ mol^{-1}$	+12	-394	-286

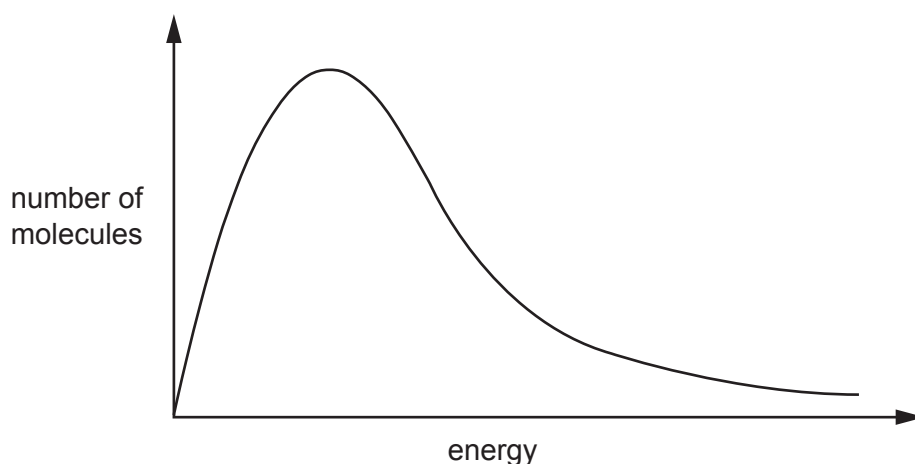
Calculate the enthalpy of combustion, in  $kJ mol^{-1}$ , for the hydrocarbon  $C_7H_8$ .

- A -3914  
 B -692  
 C +692  
 D +3914

Your answer

[1]

- 7 The diagram represents a Boltzmann distribution curve of molecules at a given temperature.



Which statement for this Boltzmann distribution curve is correct at a higher temperature?

- A The peak increases in height and moves to the left.  
 B The peak increases in height and moves to the right.  
 C The peak decreases in height and moves to the left.  
 D The peak decreases in height and moves to the right.

Your answer

[1]

- 8 A graph is plotted of  $\ln(k)$  against  $1/T$ .  
( $k$  = rate constant,  $T$  = temperature in K)

The gradient has the numerical value of  $-55\,000$ .

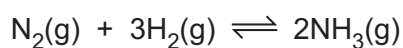
What is the activation energy, in  $\text{kJ mol}^{-1}$ ?

- A  $+1.5 \times 10^{-7}$   
B  $+2.22 \times 10^{-6}$   
C  $+6.62$   
D  $+457$

Your answer

[1]

- 9 The reversible reaction of nitrogen and hydrogen to form ammonia is shown below.



In the equilibrium mixture, the partial pressure of  $\text{N}_2$  is  $18.75\text{ MPa}$  and the partial pressure of  $\text{H}_2$  is  $2.50\text{ MPa}$ .

The total pressure is  $25\text{ MPa}$ .

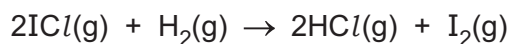
What is the value of  $K_p$ , in  $\text{MPa}^{-2}$ ?

- A  $1.2 \times 10^{-4}$   
B  $0.048$   
C  $0.075$   
D  $21$

Your answer

[1]

- 10 The equation for the reaction of  $\text{ICl}$  and  $\text{H}_2$  is shown below.



The rate constant  $k$  for this reaction is  $1.63 \times 10^{-6} \text{ dm}^3 \text{ mol}^{-1} \text{ s}^{-1}$ .

What is the overall order of the reaction?

- A 0
- B 1
- C 2
- D 3

Your answer

[1]

- 11  $20 \text{ cm}^3$  of  $0.10 \text{ mol dm}^{-3}$  hydrochloric acid is added to  $10 \text{ cm}^3$  of  $0.10 \text{ mol dm}^{-3}$  sodium hydroxide.

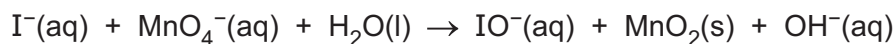
What is the pH of the resulting mixture?

- A 1.00
- B 1.18
- C 1.30
- D 1.48

Your answer

[1]

- 12 Iodide ions,  $\text{I}^-(\text{aq})$ , react with  $\text{MnO}_4^-(\text{aq})$ . The unbalanced equation is shown below.



What is the ratio of  $\text{MnO}_2(\text{s})$  to  $\text{OH}^-(\text{aq})$  in the balanced equation?

- A 1 : 3
- B 1 : 2
- C 1 : 1
- D 3 : 2

Your answer

[1]

**13** Which statement(s) is/are correct when a catalyst is added to a system in dynamic equilibrium?

- 1 The rates of the forward and reverse reactions increase by the same amount.
- 2 The concentrations of the reactants and products do not change.
- 3 The value of  $K_c$  increases.

- A** 1, 2 and 3  
**B** Only 1 and 2  
**C** Only 2 and 3  
**D** Only 1

Your answer

☐

[1]

**14** Which statement(s) for Group 2 elements is/are correct?

- 1 The 2nd ionisation energy of magnesium is greater than the 2nd ionisation energy of calcium.
- 2 A strontium ion,  $\text{Sr}^{2+}$ , contains a total of 6 electrons in s orbitals.
- 3 The equation for the reaction of barium with water is:  
$$2\text{Ba} + 2\text{H}_2\text{O} \rightarrow 2\text{BaOH} + \text{H}_2.$$

- A** 1, 2 and 3  
**B** Only 1 and 2  
**C** Only 2 and 3  
**D** Only 1

Your answer

☐

[1]

15 Which statement(s) for the complex ion  $[\text{Co}(\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2)_3]^{2+}$  is/are correct?

- 1 It has *cis* and *trans* isomers.
- 2 It has optical isomers.
- 3 It is six-fold coordination.

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]



## SECTION B

Answer **all** the questions.

**16** This question is about magnesium, bromine and magnesium bromide.

- (a) Relative atomic mass is defined as ‘the weighted mean mass compared with 1/12th mass of carbon-12’.

Explain what is meant by the term **weighted mean mass**.

.....

.....

.....

..... [1]

- (b) (i) Draw a ‘dot-and-cross’ diagram for  $\text{MgBr}_2$ .

Show outer electron shells only.

[2]

- (ii) Calculate the total number of **ions** in 1.74 g of magnesium bromide,  $\text{MgBr}_2$ .

Give your answer to **3** significant figures.

number of ions = ..... [3]

### Table 16.1

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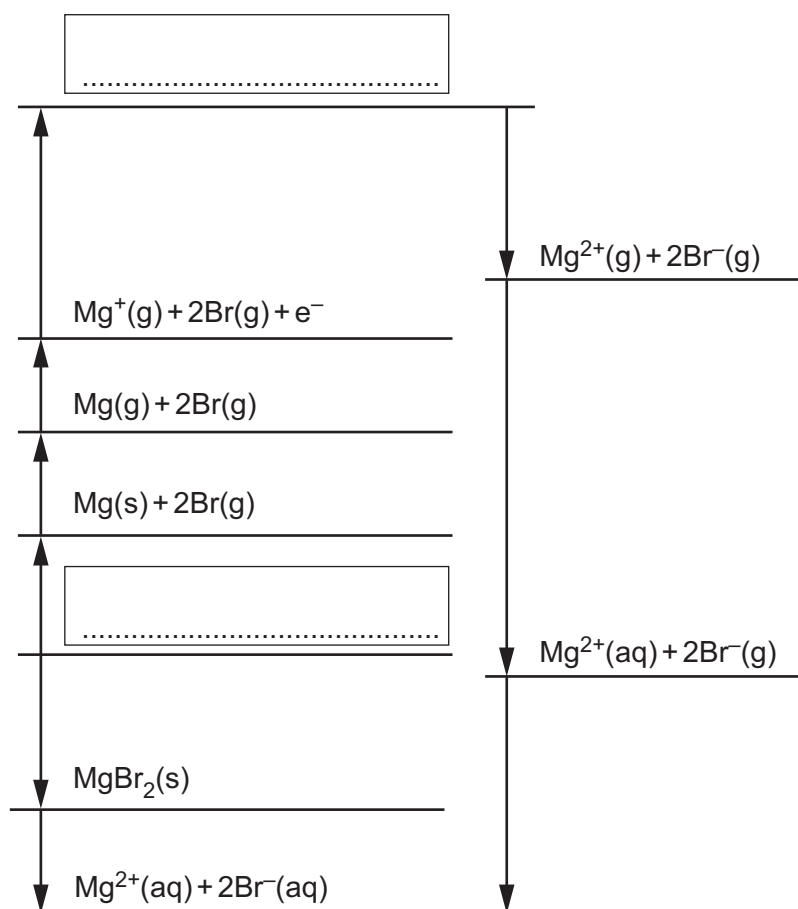
- (d) The enthalpy change of hydration of bromide ions can be determined using the enthalpy changes in **Table 16.2**.

Enthalpy change	Energy / $\text{kJ mol}^{-1}$
1st ionisation energy of magnesium	+736
2nd ionisation energy of magnesium	+1450
atomisation of bromine	+112
atomisation of magnesium	+148
electron affinity of bromine	-325
formation of magnesium bromide	-525
hydration of bromide ion	to be calculated
hydration of magnesium ion	-1926
solution of magnesium bromide	-186

**Table 16.2**

- (i) An incomplete energy cycle based on **Table 16.2** is shown below.

On the dotted lines, add the species present, including state symbols.



[2]

- (ii) Using your completed energy cycle in **16(d)(i)**, calculate the enthalpy change of hydration of bromide ions.

enthalpy change of hydration = .....  $\text{kJ mol}^{-1}$  [2]

- (iii) Write the equation for the lattice enthalpy of magnesium bromide and calculate the lattice enthalpy of magnesium bromide.

Equation .....

Calculation

lattice enthalpy = .....  $\text{kJ mol}^{-1}$  [3]

- 17 Methanol,  $\text{CH}_3\text{OH}$ , can be made industrially by the reaction of carbon monoxide with hydrogen, as shown in **equilibrium 1**.



- (a) Predict the conditions of pressure and temperature that would give the maximum equilibrium yield of  $\text{CH}_3\text{OH}$  in **equilibrium 1**.

Explain your answer.

.....

.....

.....

.....

..... [3]

- (b) A catalyst is used in the production of methanol in **equilibrium 1**.

State **two** ways that the use of catalysts helps chemical companies to make their processes more sustainable and less harmful to the environment.

1 .....

.....

2 .....

.....

[2]

A chemist proposed producing methanol at 525 K using **equilibrium 1**.

Explain, with a calculation, whether the production of methanol is feasible at 525 K.

..... [5]

- $\Delta G$  is linked to  $K_p$  by the relationship:  $\Delta G = -RT \ln K_p$ .

Calculate  $K_p$  for **equilibrium 1** at 298 K.

Give your answer to **3** significant figures.

$$K_p = \dots \text{ units} \dots [3]$$

- 18** This question is about reactions and uses of the weak acids methanoic acid,  $\text{HCOOH}$ , and ethanoic acid,  $\text{CH}_3\text{COOH}$ .

- (a)** A student adds magnesium metal to an aqueous solution of ethanoic acid,  $\text{CH}_3\text{COOH}$ . A redox reaction takes place.

Write the overall equation for this reaction and explain, in terms of oxidation numbers, which element has been oxidised and which element has been reduced.

Equation .....

Oxidation .....

.....

Reduction .....

.....

**[3]**

- (b)** The  $K_a$  values of  $\text{HCOOH}$  and  $\text{CH}_3\text{COOH}$  are shown in **Table 18.1**.

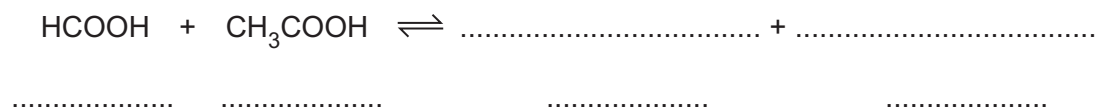
Weak acid	$K_a / \text{mol dm}^{-3}$
$\text{HCOOH}$	$1.82 \times 10^{-4}$
$\text{CH}_3\text{COOH}$	$1.78 \times 10^{-5}$

**Table 18.1**

A student adds methanoic acid to ethanoic acid.

An equilibrium is set up containing two acid-base pairs.

Complete the equilibrium and label the conjugate acid-base pairs as **A1**, **B1** and **A2**, **B2**.



**[2]**



(c) Use **Table 18.1** to answer the following questions.

- (i) The student measures the pH of  $\text{CH}_3\text{COOH}(\text{aq})$  as 2.72.

Show that the concentration of the  $\text{CH}_3\text{COOH}(\text{aq})$  is  $0.204 \text{ mol dm}^{-3}$ .

[2]

- (ii) The student plans to make a buffer solution of pH 4.00 from a mixture of  $\text{CH}_3\text{COOH}(\text{aq})$  and sodium ethanoate,  $\text{CH}_3\text{COONa}(\text{aq})$ .

The student mixes  $400 \text{ cm}^3$  of  $0.204 \text{ mol dm}^{-3}$   $\text{CH}_3\text{COOH}(\text{aq})$  with  $600 \text{ cm}^3$  of  $\text{CH}_3\text{COONa}(\text{aq})$ .

Calculate the concentration of  $\text{CH}_3\text{COONa}(\text{aq})$  needed to prepare this buffer solution of pH 4.00.

concentration = .....  $\text{mol dm}^{-3}$  [4]

19 Standard electrode potentials for four redox systems are shown in **Table 19.1**.

Redox system	Half-equation	$E^\circ/\text{V}$
1	$\text{CO}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{HCOOH}(\text{aq})$	-0.11
2	$\text{HCOOH}(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{HCHO}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	-0.03
3	$\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$	+0.80
4	$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51

**Table 19.1**

(a) A student sets up a standard cell in the laboratory based on redox systems **3** and **4**.

Draw a labelled diagram to show how this cell could be set up to measure its standard cell potential at 298 K.

[3]

Explain this observation in terms of electrode potentials and equilibria.

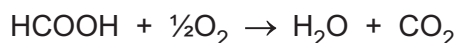
Include overall equations in your answer.

[4]

- (c) Methanoic acid,  $\text{HCOOH}$ , can be used in a fuel cell. As with all fuel cells, the fuel ( $\text{HCOOH}$ ) is supplied at one electrode and the oxidant (oxygen) at the other electrode.

The standard cell potential for this fuel cell is 1.34 V.

The overall reaction is shown below.

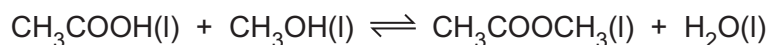


Using the information in **Table 19.1**, deduce the half-equation for the reaction at the oxygen electrode, and calculate the standard electrode potential for the oxygen half-cell.

half-equation .....

standard electrode potential = ..... V

- 20 A student investigates the reaction between ethanoic acid,  $\text{CH}_3\text{COOH}(\text{l})$  and methanol,  $\text{CH}_3\text{OH}(\text{l})$ , in the presence of an acid catalyst. The equation is shown below.

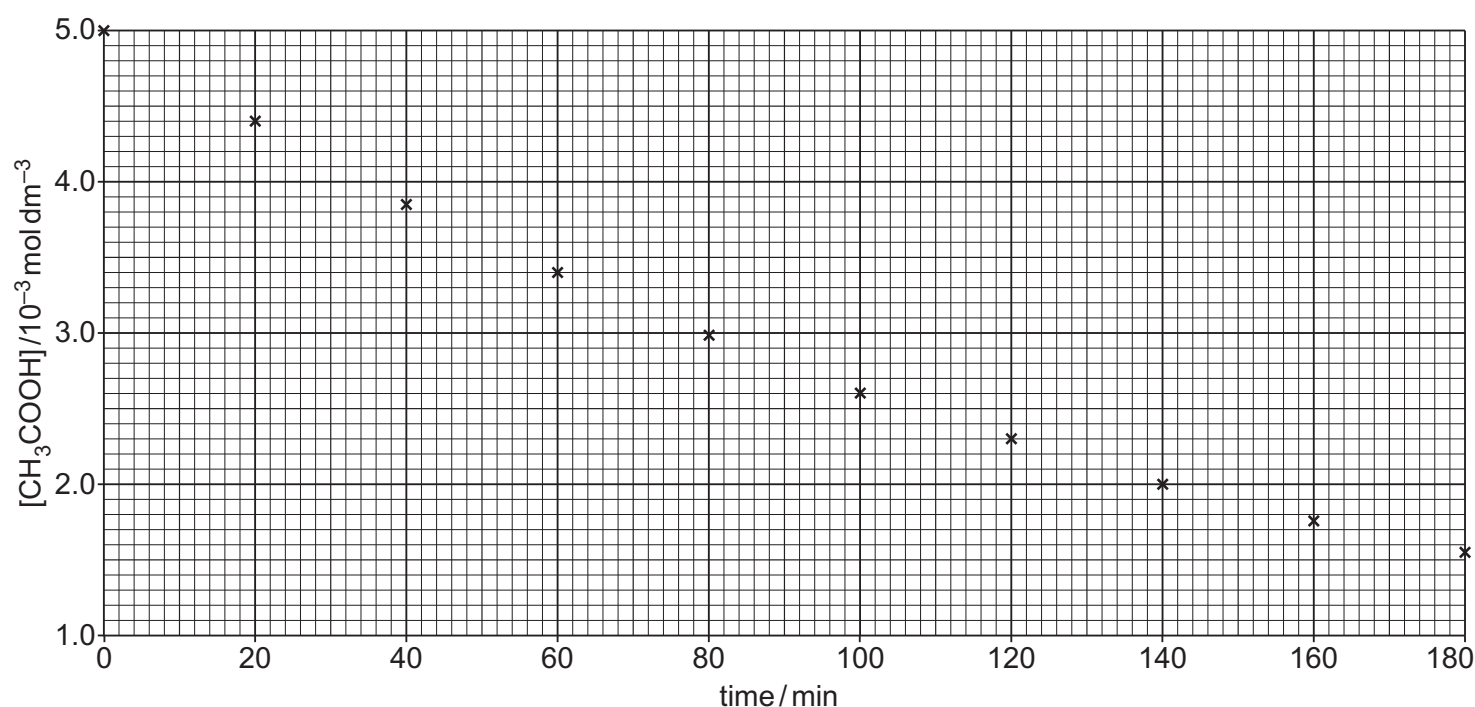


- (a) The student carries out an experiment to determine the order of reaction with respect to  $\text{CH}_3\text{COOH}$ .

The student uses a large excess of  $\text{CH}_3\text{OH}$ . The temperature is kept constant throughout the experiment.

The student takes a sample from the mixture every 20 minutes, and then determines the concentration of the ethanoic acid in each sample.

From the experimental results, the student plots the graph below.



- (i) Explain why the student uses a large excess of methanol in this experiment.

.....  
 ..... [1]

- (ii) Use the half-life of this reaction to show that the reaction is first order with respect to  $\text{CH}_3\text{COOH}$ .

Show your working on the graph and below.

.....  
 ..... [2]

- (iii) Determine the initial rate of reaction.

initial rate = .....  $\text{mol dm}^{-3} \text{ min}^{-1}$  [2]

- (b) The student carries out a second experiment to determine the value of  $K_c$  for this reaction.

The student mixes 9.6 g of  $\text{CH}_3\text{OH}$  with 12.0 g of  $\text{CH}_3\text{COOH}$  and adds the acid catalyst.

When the mixture reaches equilibrium, 0.030 mol of  $\text{CH}_3\text{COOH}$  remains.

Calculate  $K_c$  for this equilibrium.

$K_c =$  ..... [4]

- The student adds aqueous sodium chloride to one test tube, and aqueous sodium iodide to the other test tube.

Sodium halide	Colour of organic layer
Sodium chloride	orange
Sodium iodide	violet

Use your chemical knowledge to explain the trend in reactivity.

[5]

- (b) Chlorine is used in water treatment.

State **one** benefit and **one** risk of using chlorine in water treatment.

Benefit .....

.....

Risk .....

.....

[1]

- (c) Compound **A** contains bromine and fluorine only, and has a boiling point of 41 °C.

1.26 g of compound **A** is heated to 80 °C.  
The volume of gas produced is 0.209 dm<sup>3</sup>.

Under the conditions used, 1 mol of gas molecules has a volume of 29.0 dm<sup>3</sup>.

Determine the molecular formula of compound **A**.

molecular formula = ..... [3]

	Test	B(aq)	C(aq)
1	NH <sub>3</sub> (aq) added dropwise	green precipitate <b>D</b>	grey-green precipitate <b>E</b>
	excess NH <sub>3</sub> (aq) added	no further change	purple solution <b>F</b>
2	HNO <sub>3</sub> (aq)	no change	no change
	followed by Ba(NO <sub>3</sub> ) <sub>2</sub> (aq)	white precipitate <b>G</b>	no change
3	HNO <sub>3</sub> (aq)	no change	no change
	followed by AgNO <sub>3</sub> (aq)	no change	white precipitate <b>H</b>

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Additional answer space if required

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- (b)** A compound of nickel, **J**, has the formula  $(\text{NH}_4)_2[\text{Ni}(\text{SCN})_x(\text{NH}_3)_y]$  and contains  $\text{SCN}^-$  and  $\text{NH}_3$  ligands.

The percentage by mass of three of the elements in compound **J** is shown below:  
 Ni, 16.26%; S, 35.56%; N, 31.00%.

- (i)** Calculate the values of  $x$  and  $y$  in the formula of compound **J**.

$x =$  .....

$y =$  .....

**[3]**

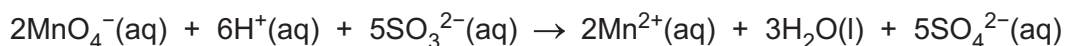
- (ii)** Determine the oxidation number of nickel in compound **J**.

oxidation number: ..... **[1]**

- (c) Sodium sulfite(IV),  $\text{Na}_2\text{SO}_3$ , is used as a preservative in some foods. Food safety legislation allows a maximum of 850 mg  $\text{Na}_2\text{SO}_3$  per kg of burger meat.

A chemist determines the amount of  $\text{Na}_2\text{SO}_3$  in a sample of burger meat using a manganate(VII) titration.

- Step 1** The  $\text{Na}_2\text{SO}_3$  from 525 g of burger meat is extracted to form a solution containing  $\text{SO}_3^{2-}(\text{aq})$  ions.
- Step 2** The solution from **step 1** is made up to  $250.0\text{ cm}^3$  in a volumetric flask with water.  $25.0\text{ cm}^3$  of this diluted solution is pipetted into a conical flask.
- Step 3** The pipetted solution from **step 2** is acidified with dilute sulfuric acid and then titrated with  $0.0100\text{ mol dm}^{-3}$  potassium manganate(VII),  $\text{KMnO}_4$ .



$12.60\text{ cm}^3$  of  $\text{KMnO}_4(\text{aq})$  is required to reach the endpoint.

Analyse the results to determine whether the burger meat complies with food safety legislation.

[5]

END OF QUESTION PAPER

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