1. 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]

2. 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]

3. What is the oxidation number of Mn in K_2MnO_4?

A +4

B +5

C +6

D +7

Your answer ☐

[1]

4. A student plans to determine the enthalpy change of **reaction 3.1** shown below.

$$Na_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) \qquad \textbf{reaction 3.1}$$

This enthalpy change can be determined indirectly using Hess' Law from the enthalpy changes of **reaction 3.2** and **reaction 3.3** shown below.

$$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq) \qquad \textbf{reaction 3.2}$$

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) \quad \Delta_r H = -57.6\,kJ\,mol^{-1} \qquad \textbf{reaction 3.3}$$

The student will determine the enthalpy change of **reaction 3.2** as outlined below.

- Weigh a bottle containing $Na_2O(s)$ and weigh a polystyrene cup.
- Add about 25 cm^3 of water to the polystyrene cup and measure its temperature.
- Add the $Na_2O(s)$, stir the mixture, and measure the maximum temperature reached.
- Weigh the empty bottle and weigh the polystyrene cup with the final solution.

Mass readings

Mass of bottle + $Na_2O(s)$	= 16.58 g
Mass of empty bottle	= 15.34 g
Mass of empty polystyrene cup	= 21.58 g
Mass of polystyrene cup + final solution	= 47.33 g

Temperature readings

Initial temperature of water	= 20.5 °C
Maximum temperature of final solution	= 55.5 °C

The density and specific heat capacity, *c*, of the solution are the same as for water.

(a)* Calculate the enthalpy change of **reaction 3.2** and the enthalpy change of **reaction 3.1**.

Show all your working.

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..... **[6]**

(b) The uncertainty in each temperature reading is ±0.1 °C.

The uncertainty in each mass reading is ±0.005 g.

Determine whether the mass of Na_2O or the temperature change has the greater percentage uncertainty.

Show all your working.

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

(c) Suggest a modification to this experiment, using the **same** apparatus, which would reduce the percentage errors in the measurements.

Explain your reasoning.

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

(d) Sodium oxide, Na_2O, can be prepared by the redox reaction of $NaNO_2$ and sodium metal. Nitrogen gas is also formed.

(i) What is the systematic name for $NaNO_2$?

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

(ii) Using oxidation numbers, with signs, show the element that is oxidised and the element that is reduced in this reaction.

Element oxidised .....

Oxidation number change from ..... to .....

Element reduced .....

Oxidation number change from ..... to .....

[2]

(iii) Construct the equation for this reaction.

Equation ..... **[1]**

5. In the compound $[ICl_2]^+ [SbCl_6]^-$, the oxidation number of chlorine is –1.

What are the oxidation numbers of I and Sb in the compound?

	I	Sb
A	+1	+5
B	+1	+7
C	+3	+5
D	+3	+7

Your answer ☐ **[1]**

6. What is the oxidation number of N in $Mg(NO_2)_2 \cdot 3H_2O$?

A +2

B +3

C +4

D +5

Your answer ☐ **[1]**

7. Which reaction is a redox reaction?

A $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

B $NaNO_2 + HCl \rightarrow NaCl + HNO_2$

C $CaSO_3 + 2HCl \rightarrow CaCl_2 + H_2O + SO_2$

D $3CuO + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$

Your answer ☐ **[1]**

8. Iodide ions, $I^-(aq)$, react with $MnO_4^-(aq)$. The unbalanced equation is shown below.

$I^-(aq) + MnO_4^-(aq) + H_2O(l) \rightarrow IO^-(aq) + MnO_2(s) + OH^-(aq)$

What is the ratio of $MnO_2(s)$ to $OH^-(aq)$ in the balanced equation?

A 1 : 3

B 1 : 2

C 1 : 1

D 3 : 2

Your answer ☐ **[1]**

9. This question is about reactions and uses of the weak acids methanoic acid, HCOOH, and ethanoic acid, CH_3COOH.

(a) A student adds magnesium metal to an aqueous solution of ethanoic acid, CH_3COOH.
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 HCOOH and CH_3COOH are shown in **Table 18.1**.

Weak acid	**K_a / mol dm^{-3}**
HCOOH	1.82×10^{-4}
CH_3COOH	1.78×10^{-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**.

HCOOH + CH_3COOH $\rightleftharpoons$ ..... + ...

....

[2]

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

(i) The student measures the pH of $CH_3COOH(aq)$ as 2.72.

Show that the concentration of the $CH_3COOH(aq)$ is 0.204 mol dm^{-3}.

[2]

(ii) The student plans to make a buffer solution of pH 4.00 from a mixture of $CH_3COOH(aq)$ and sodium ethanoate, $CH_3COONa(aq)$.

The student mixes 400 cm^3 of 0.204 mol dm^{-3} $CH_3COOH(aq)$ with 600 cm^3 of $CH_3COONa(aq)$.

Calculate the concentration of $CH_3COONa(aq)$ needed to prepare this buffer solution of pH 4.00.

concentration = ... mol dm^{-3} **[4]**

10. A student carries out an investigation to identify two metals, **M** and **X**, by two different methods.

(a) The student is provided with a sample of metal **M**.

The student analyses metal **M** using a 'back-titration' technique:

- The metal is reacted with excess acid.
- The resulting solution is titrated to determine the amount of acid remaining after the reaction.

Stage 1
The student adds 100 cm^3 of 2.10 mol dm^{-3} HCl(aq) to 6.90 g of **M**.
An excess of HCl(aq) has been used to ensure that all of metal **M** reacts.

A redox reaction occurs, forming a solution containing **M** in the +2 oxidation state.

Stage 2
The resulting solution from **Stage 1** is made up to 250.0 cm^3 with distilled water.

Stage 3
A 25.00 cm^3 sample of the diluted solution from **Stage 2** is titrated with 0.320 mol dm^{-3} NaOH(aq).

The NaOH(aq) reacts with excess HCl(aq) that remains in **Stage 1**:

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

The student repeats the titration to obtain concordant titres.

Titration results (The trial titre has been omitted.)
The burette readings have been recorded to the nearest 0.05 cm^3.

	1	**2**	**3**
Final reading / cm^3	27.80	37.55	32.20
Initial reading / cm^3	0.50	10.00	5.00

(i) In **Stage 1**, a redox reaction takes place between **M** and HCl(aq), forming hydrogen and a solution containing **M** in the +2 oxidation state.

Write an overall equation, with state symbols, for this reaction. Write half-equations for the oxidation and reduction processes.

Overall equation .....

Oxidation half-equation .....

Reduction half-equation .....

[3]

(ii) In **Stage 1**, suggest **two** observations that would confirm that all of metal **M** has reacted.

1 .....

.....

2 .....

.....

[2]

(iii) In **Stage 3**, write the ionic equation for the reaction taking place in the titration.

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

(iv) Metal **M** can be identified following the steps below.

1. The amount, in mol, of excess HCl(aq) that remains after the reaction of **M** with HCl(aq).
2. The amount, in mol, of HCl(aq) that reacted with **M**.
3. The identity of metal **M**.

Analyse the results to identify metal **M**.

Metal **M** = ... **[6]**

(b) The student is provided with the carbonate of an unknown metal, $\mathbf{X}_2CO_3$.

The student measures the mass loss when the $\mathbf{X}_2CO_3$ is reacted with an **excess** of hydrochloric acid. The equation is shown below.

$\mathbf{X}_2CO_3(s) + 2HCl(aq) \rightarrow 2\mathbf{X}Cl(aq) + CO_2(g) + H_2O(l)$

The reaction is carried out using this method:

Step 1 Add 100 cm^3 $HCl(aq)$ to a conical flask and weigh.

Step 2 Add $\mathbf{X}_2CO_3$ to the conical flask and immediately reweigh.

Step 3 After 5 minutes, reweigh the conical flask and contents.

Results

Mass of conical flask + $HCl(aq)$	172.93 g
Mass of conical flask + $\mathbf{X}_2CO_3$ + $HCl(aq)$ before reaction	187.50 g
Mass of conical flask + contents after 5 minutes	184.75 g

(i) Calculate the amount, in mol, of CO_2 released in the reaction.

Amount of CO_2 = ... mol **[1]**

(ii) Calculate the molar mass of $\mathbf{X}_2CO_3$ and identify metal **X**.

Molar mass of $\mathbf{X}_2CO_3$ = ... $g\,mol^{-1}$ Metal **X** = ...**[3]**

(c) After analysing the results, the student was told that their molar mass of $\mathbf{X}_2CO_3$ was incorrect.

The student evaluated the experiment for possible reasons for the incorrect result.

(i) The student wondered whether the reaction was complete when the mass was recorded after 5 minutes (**Step 3**).

How could the student modify the experimental procedure to be confident that the reaction was complete?

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

(ii) The student finds out that carbon dioxide is slightly soluble in water.

State and explain how the solubility of CO_2 would affect the calculated molar mass of $\mathbf{X}_2CO_3$.

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