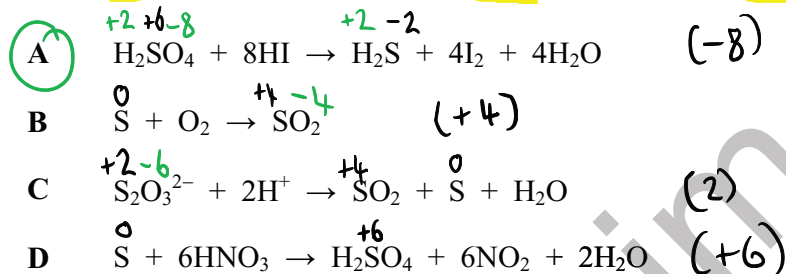


1. Which redox reaction contains the largest change in oxidation state for sulfur?



Your answer

A

- = ox. state of Sulfur

- = ox. state of other elements.

$$0_4 \rightarrow 0 = -2$$

$$-2 \times 4 = -8.$$

[1]

2. Two tests are carried out on an aqueous solution of copper(II) sulfate, $\text{CuSO}_4(\text{aq})$.

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

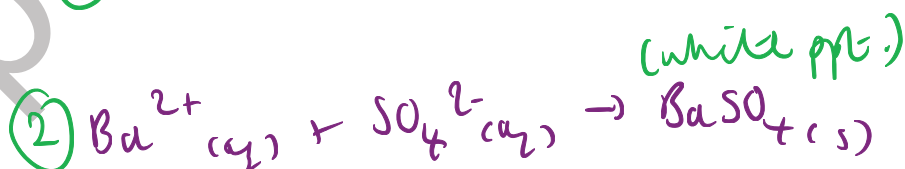
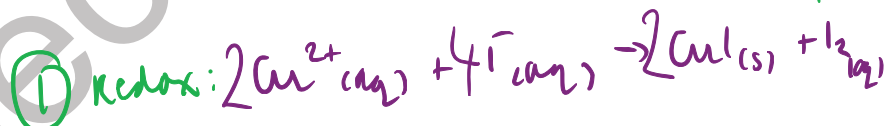
B Only 1 and 2

~~C~~ Only 2 and 3

~~D~~ Only 1

Your answer

B



↳ no change in ox. states ∴
not redox.

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

A +4

B +5

C +6

D +7

Your answer

C

oxidation
state of
potassium

oxidation state of
oxygen

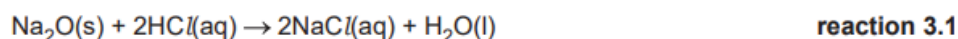
$$(+1 \times 2) + (-2 \times 4) + x = 0$$

$$2 + -8 + x = 0$$

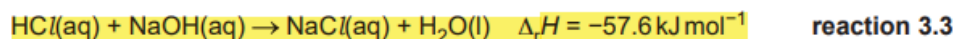
$$x = +6$$

[1]

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



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



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

- Weigh a bottle containing $\text{Na}_2\text{O(s)}$ and weigh a polystyrene cup.
- Add about 25 cm^3 of water to the polystyrene cup and measure its temperature.
- Add the $\text{Na}_2\text{O(s)}$, 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 + $\text{Na}_2\text{O(s)}$	= 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.

$$\Delta H_{3.1} = \Delta H_{3.2} + (\Delta H_{3.3}) \times 2$$

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

Show all your working.

$$mc\Delta T = E \text{ (joules)}$$

$$\text{mass of Na}_2\text{O} = 16.58 - 15.34 \\ = 1.24 \text{ g}$$

$$\text{mass of solution} = 47.33 - 21.58 \\ = 25.75 \text{ g}$$

$$\Delta T = 55.5 - 20.5 = 35^\circ\text{C}$$

$$25.75 \times 4.18 \times 35 = 3767.225 \text{ J} \\ = 3.767225 \text{ kJ}$$

$$\text{mol} = \frac{1.24}{(23 \times 2) + 16} = 0.02 \text{ mol}$$

-ve ΔH value \swarrow
 ΔH 3.2:

$$3.767225 \div 0.02 = 188 \text{ kJ mol}^{-1}$$

$$\Delta H 3.1 = -188 + (2 \times -57.6) = -303.2 \text{ kJ mol}^{-1}$$

(b) The uncertainty in each **temperature** reading is $\pm 0.1^\circ\text{C}$.

The uncertainty in each **mass** reading is $\pm 0.005 \text{ g}$.

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

Show all your working.

$$\text{mass: } \frac{0.005 \times 2}{1.24} \times 100 = 0.81\%$$

→ mass balance was used twice to find mass of Na_2O

$$\text{temperature: } \frac{0.1 \times 2}{35} \times 100 = 0.57\%$$

So mass of Na_2O has the greater percentage uncertainty

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

larger denominator
= smaller number

Explain your reasoning.

greater mass of Na_2O and a
larger ΔT because both would
reduce % uncertainty

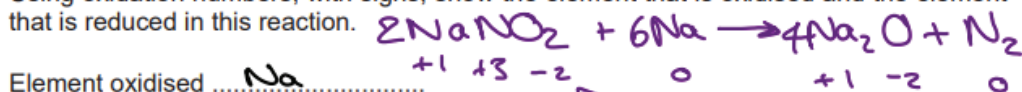
[2]

- (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 ?

Sodium nitrate [1]

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



Oxidation number change from 0 to $+1$

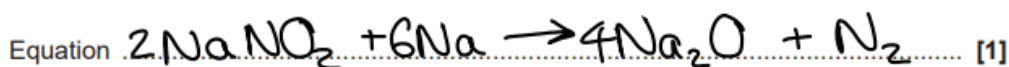
Element reduced N

Oxidation number change from $+3$ to 0

oxidation
numbers in a
compound must
add up to 0

[2]

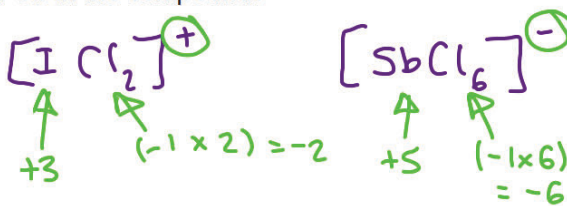
- (iii) Construct the equation for this reaction.



5. In the compound $[\text{ICl}_2]^+ [\text{SbCl}_6]^-$, 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

C

[1]

6. What is the oxidation number of N in $\text{Mg}(\text{NO}_2)_2 \cdot 3\text{H}_2\text{O}$?

A +2

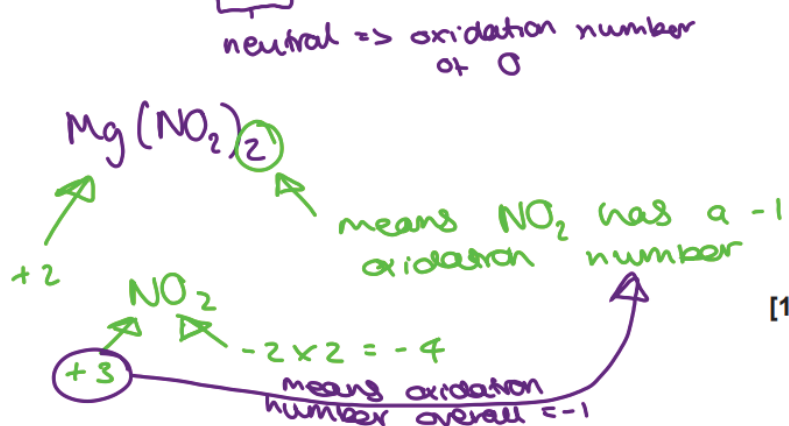
B +3

C +4

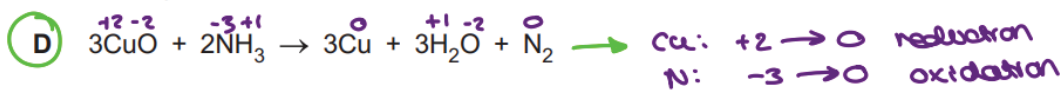
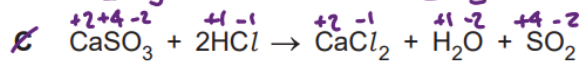
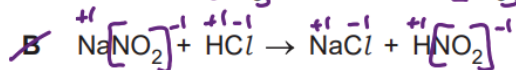
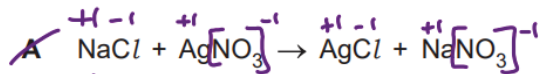
D +5

Your answer

B



7. Which reaction is a redox reaction?

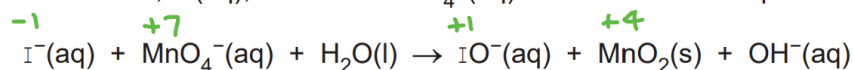


Your answer

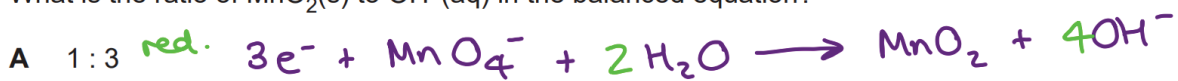
D

[1]

8. 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?

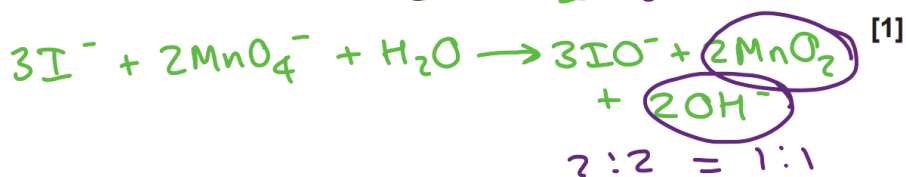
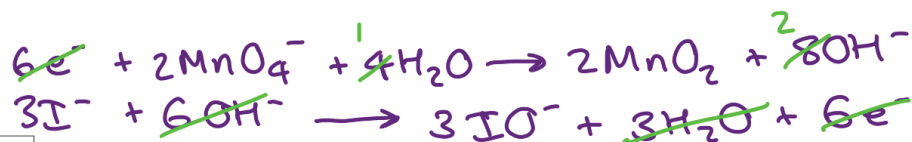


C 1 : 1

D 3 : 2

Your answer

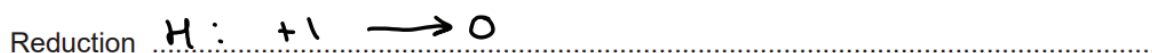
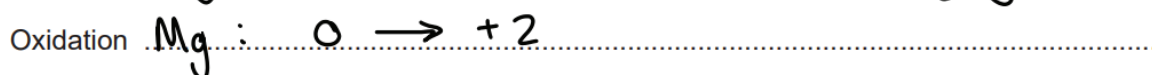
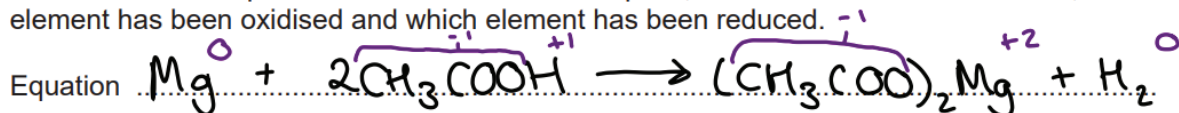
C



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.



[3]

- (b) The K_a values of HCOOH and CH_3COOH are shown in Table 18.1.

stronger acid (written vertically next to HCOOH)

Weak acid	$K_a / \text{mol dm}^{-3}$
<u>HCOOH</u>	1.82×10^{-4}
CH_3COOH	1.78×10^{-5}

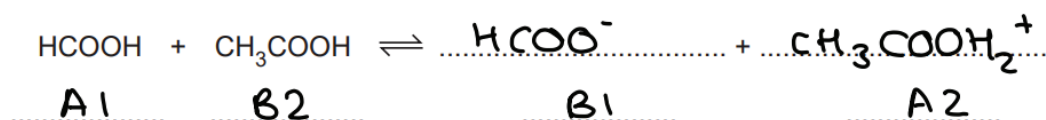
Handwritten notes:
 $\text{p}K_a = \text{pH}$
 $\text{p}K_a = -\log_{10} K_a$
 3.74 (next to 1.82×10^{-4})
 4.75 (next to 1.78×10^{-5})

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.



[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 $0.204 \text{ mol dm}^{-3}$.

$$10^{-\text{pH}} = [\text{H}^+]$$

$$\frac{[\text{H}^+]^2}{[\text{HA}]} = K_a$$

rearrange for $[\text{HA}]$
 $= [\text{CH}_3\text{COOH}]$

$$10^{-2.72} = 1.905 \times 10^{-3} \text{ mol dm}^{-3} = [\text{H}^+]$$

$$[\text{CH}_3\text{COOH}] = \frac{(1.905 \times 10^{-3})^2}{1.78 \times 10^{-5}} = 0.204 \text{ mol dm}^{-3}$$

[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 cm^3 of $0.204 \text{ mol dm}^{-3}$ $\text{CH}_3\text{COOH}(\text{aq})$ with 600 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.

$$10^{-\text{pH}} = [\text{H}^+]$$

part (i) $[\text{H}^+]_{\text{buffer}} = 10^{-4} = 1 \times 10^{-4} \text{ mol dm}^{-3}$

$$\frac{0.204}{1} \times 0.4 = 8.16 \times 10^{-2} = [\text{CH}_3\text{COOH}]_{\text{buffer}}$$

\uparrow
 $= 400 \text{ cm}^3 = 0.4 \text{ dm}^3$
 \uparrow
 $= 1 \text{ dm}^3 = 1000 \text{ cm}^3$

$$\frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]} = K_a$$

$$1.78 \times 10^{-5} = \frac{[1 \times 10^{-4}][\text{CH}_3\text{COO}^-]}{8.16 \times 10^{-2}}$$

$$[\text{CH}_3\text{COO}^-]_{\text{buffer}} = \frac{1.78 \times 10^{-5} \times 8.16 \times 10^{-2}}{1 \times 10^{-4}} = 1.5 \times 10^{-2} \text{ mol dm}^{-3}$$

calculator answer

$$\frac{1.452 \dots \times 10^{-2}}{0.6} \times 1 = 2.4 \times 10^{-2} = [\text{CH}_3\text{COO}^-]_{\text{initial}}$$

opposite actions to part (i)

concentration = $2.4 \times 10^{-2} \text{ mol dm}^{-3}$ [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.

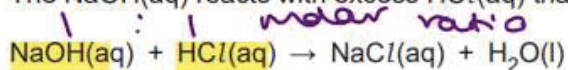
Stage 2

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**:



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 .

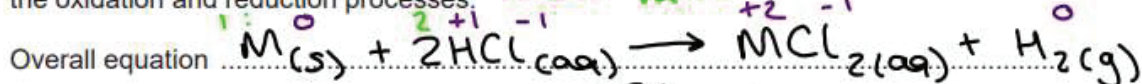
	1	2	3
Final reading / cm^3	27.80	37.55	32.20
Initial reading / cm^3	0.50	10.00	5.00

titre / cm^3 27.30 27.55 27.20

concordant

(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.

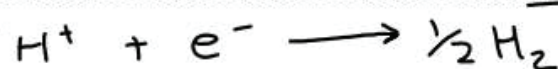
Write an overall equation, with state symbols, for this reaction. Write half-equations for the oxidation and reduction processes.



(increase oxidation state)



(decrease oxidation state)



[3]

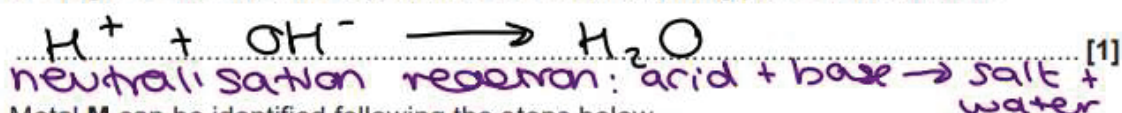
(ii) In Stage 1, suggest two observations that would confirm that all of metal **M** has reacted.

1 bubbles/effervescence stops

2 M/metal disappears

[2]

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



(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**.

$$\frac{27.30 + 27.20}{2} = 27.25 \text{ cm}^3 \text{ mean titre}$$



$$27.25 \times 10^{-3} \times 0.320 = 8.72 \times 10^{-3} \text{ mol in } 25 \text{ cm}^3 \text{ (HCl)}$$

$$8.72 \times 10^{-3} \times 10 = 8.72 \times 10^{-2} \text{ mol in } 250 \text{ cm}^3 \text{ (HCl)}$$

$$0.210 - 8.72 \times 10^{-2} = 0.1228 \text{ mol HCl reacted with M}$$

$$\frac{0.1228}{2} = 0.0614 \text{ mol of M reacted}$$

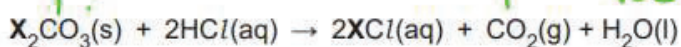
$$\frac{6.90}{0.0614} = 112.4 = \text{Cd}$$



Metal **M** = Cd [6]

- (b) The student is provided with the carbonate of an unknown metal, X_2CO_3 .

The student measures the mass loss when the X_2CO_3 is reacted with an **excess** of hydrochloric acid. The equation is shown below.



molar ratio

The reaction is carried out using this method:

- Step 1** Add 100 cm³ HCl(aq) to a conical flask and weigh.
Step 2 Add 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 + 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.

$$187.50 - 184.75 = 2.75 \text{ g of } CO_2$$

$$\frac{2.75}{12 + (16 \times 2)} = 0.0625$$

$$\text{Amount of } CO_2 = 0.0625 \text{ mol [1]}$$



- (ii) Calculate the molar mass of X_2CO_3 and identify metal X.

$$0.0625 \text{ mol of } X_2CO_3$$

$$187.50 - 172.93 = 14.57 \text{ g of } X_2CO_3$$

$$\frac{14.57}{0.0625} = 233.12 \text{ g mol}^{-1}$$

$$X = Rb$$

$$\frac{233.12 - (12 + (16 \times 3))}{2} = 86.56 = Rb$$

$$\text{Molar mass of } X_2CO_3 = 233.12 \text{ g mol}^{-1}$$

$$\text{Metal X} = Rb \text{ [3]}$$

- (c) After analysing the results, the student was told that their molar mass of 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?

reweigh to constant mass

[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 X_2CO_3 .

- mass (CO_2) loss would be smaller / mass X_2CO_3 reacted seems to be less
- molar mass would be greater

[2]