Energetics – A2 2022 Chemistry P1&P3

1. June/2022/Paper_7405/1/No.3

0 3 This question is about hydrogen peroxide, H_2O_2

The half-equation for the oxidation of hydrogen peroxide is

$$H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$$

Hair bleach solution contains hydrogen peroxide.

A sample of hair bleach solution is diluted with water.
The concentration of hydrogen peroxide in the diluted solution is 5.00% of that in the original solution.
A 25.0 cm^3 sample of the diluted hair bleach solution is acidified with dilute sulfuric acid.
This acidified sample is titrated with 0.0200 mol dm^{-3} potassium manganate(VII) solution.
The reaction is complete when 35.85 cm^3 of the potassium manganate(VII) solution are added.

0 3 . 1 Give an ionic equation for the reaction between potassium manganate(VII) and acidified hydrogen peroxide.

Calculate the concentration, in mol dm^{-3}, of hydrogen peroxide in the original hair bleach solution.

(If you were unable to write an equation for the reaction you may assume that the mole ratio of potassium manganate(VII) to hydrogen peroxide is 3:4
This is **not** the correct mole ratio.)

[5 marks]

Concentration _____ mol dm^{-3}

0 3 . 2 State why an indicator is **not** added in this titration.

[1 mark]

0 3 . 3 Give the oxidation state of oxygen in hydrogen peroxide.

[1 mark]

0 3 . 4 Hydrogen peroxide decomposes to form water and oxygen.

Give an equation for this reaction.

Calculate the amount, in moles, of hydrogen peroxide that would be needed to produce 185 cm^3 of oxygen gas at 100 kPa and 298 K

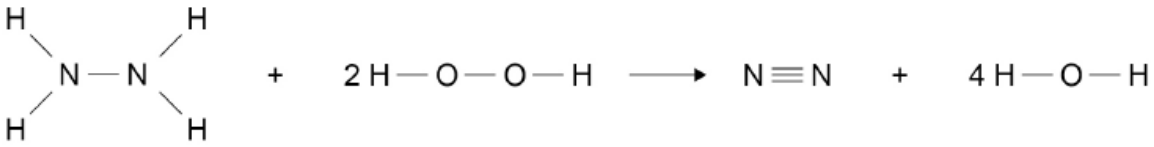
The gas constant, R = 8.31 J K^{-1} mol^{-1}

[5 marks]

Equation

Amount _____ mol

0 3 . 5 Hydrazine (N_2H_4) is used as a rocket fuel that is oxidised by hydrogen peroxide. The equation for this reaction in the gas phase is



The enthalpy change for this reaction, $\Delta H = -789$ kJ mol^{-1}

Table 3 shows some mean bond enthalpy values.

Table 3

	N–H	**N–N**	**N≡N**	**O–H**
Mean bond enthalpy / kJ mol^{-1}	388	163	944	463

Define the term mean bond enthalpy.

Use the equation and the data in **Table 3** to calculate a value for the O–O bond enthalpy in hydrogen peroxide.

[5 marks]

Definition _____

_____

Bond enthalpy _____ kJ mol^{-1}

2. June/2022/Paper_7405/3/No.1

0 1 A value for enthalpy of solution can be determined in two ways:

- from a cycle, using lattice enthalpy and enthalpies of hydration
- from the results of a calorimetry experiment.

0 1 . 1 Define the term enthalpy of lattice dissociation.

[2 marks]

0 1 . 2 The enthalpy of solution for ammonium nitrate is the enthalpy change for the reaction shown.

$$NH_4NO_3(s) + aq \rightarrow NH_4^+(aq) + NO_3^-(aq) \quad \Delta H = +26\,kJ\,mol^{-1}$$

Table 1

	$NH_4^+(g)$	$NO_3^-(g)$
Enthalpy of hydration $\Delta_{hyd}H$ / kJ mol^{-1}	–307	–314

Draw a suitably labelled cycle and use it, with data from **Table 1**, to calculate the enthalpy of lattice dissociation for ammonium nitrate.

[3 marks]

Enthalpy of lattice dissociation _____ kJ mol^{-1}

0 1 . 3 A student does an experiment to determine a value for the enthalpy of solution for ammonium nitrate.

The student uses this method.

- Measure 25.0 cm^3 of distilled water in a measuring cylinder.
- Pour the water into a beaker.
- Record the temperature of the water in the beaker.
- Add 4.00 g of solid NH_4NO_3 to the water in the beaker.
- Stir the solution and record the lowest temperature reached.

Table 2 shows the student's results.

Table 2

Initial temperature / °C	20.2
Lowest temperature / °C	12.2

Calculate the enthalpy of solution, in kJ mol^{-1}, for ammonium nitrate in this experiment.

Assume that the specific heat capacity of the solution, c = 4.18 $J K^{-1} g^{-1}$

Assume that the density of the solution = 1.00 $g\,cm^{-3}$

[3 marks]

Enthalpy of solution _____ kJ mol^{-1}

0 1 . 4 The uncertainty in each of the temperature readings from the thermometer used in this experiment is ±0.1°C

Calculate the percentage uncertainty in the temperature change in this experiment.

[1 mark]

Percentage uncertainty _____

0 1 . 5 Suggest a change to the student's method, using the same apparatus, that would reduce the percentage uncertainty in the temperature change.

Give a reason for your answer.

[2 marks]

Change _____

_____

Reason _____

_____

0 1 . 6 Another student obtained a value of +15 kJ mol^{-1} using the same method.

Suggest the main reason for the difference between this experimental value for the enthalpy of solution and the correct value of +26 kJ mol^{-1}

[1 mark]

_____

_____

0 1 . 7 **Table 3** shows some entropy data at 298 K

Table 3

	Entropy S / J K^{-1} mol^{-1}
$NH_4NO_3(s)$	151
$NH_4^+(aq)$	113
$NO_3^-(aq)$	146

Calculate a value for the Gibbs free-energy change (ΔG), at 298 K, for the reaction when ammonium nitrate dissolves in water.

$$NH_4NO_3(s) + aq \rightarrow NH_4^+(aq) + NO_3^-(aq) \quad \Delta H = +26 \text{ kJ mol}^{-1}$$

Use data from **Table 3** and the value of ΔH from the equation.
Assume for the solvent, water, that the entropy change, $\Delta S = 0$

Explain what the calculated value of ΔG indicates about the feasibility of this reaction at 298 K

[4 marks]

ΔG _____ kJ mol^{-1}

Explanation _____

_____

_____

0 1 . 8 Ammonium nitrate decomposes as shown.

$$NH_4NO_3(s) \rightarrow N_2(g) + \frac{1}{2}O_2(g) + 2H_2O(g) \quad \Delta H = +123 \text{ kJ mol}^{-1}$$

The entropy change (ΔS) for this reaction is +144 J K^{-1} mol^{-1}

Calculate the temperature at which this reaction becomes feasible.

[2 marks]

Temperature _____ K

3. June/2022/Paper_7405/3/No.4

0 4 Hydrogen peroxide solution decomposes to form water and oxygen.

$$2\,H_2O_2(aq) \rightarrow 2\,H_2O(l) + O_2(g)$$

The reaction is catalysed by manganese(IV) oxide.

A student determines the order of this reaction with respect to hydrogen peroxide. The student uses a continuous monitoring method in the experiment.

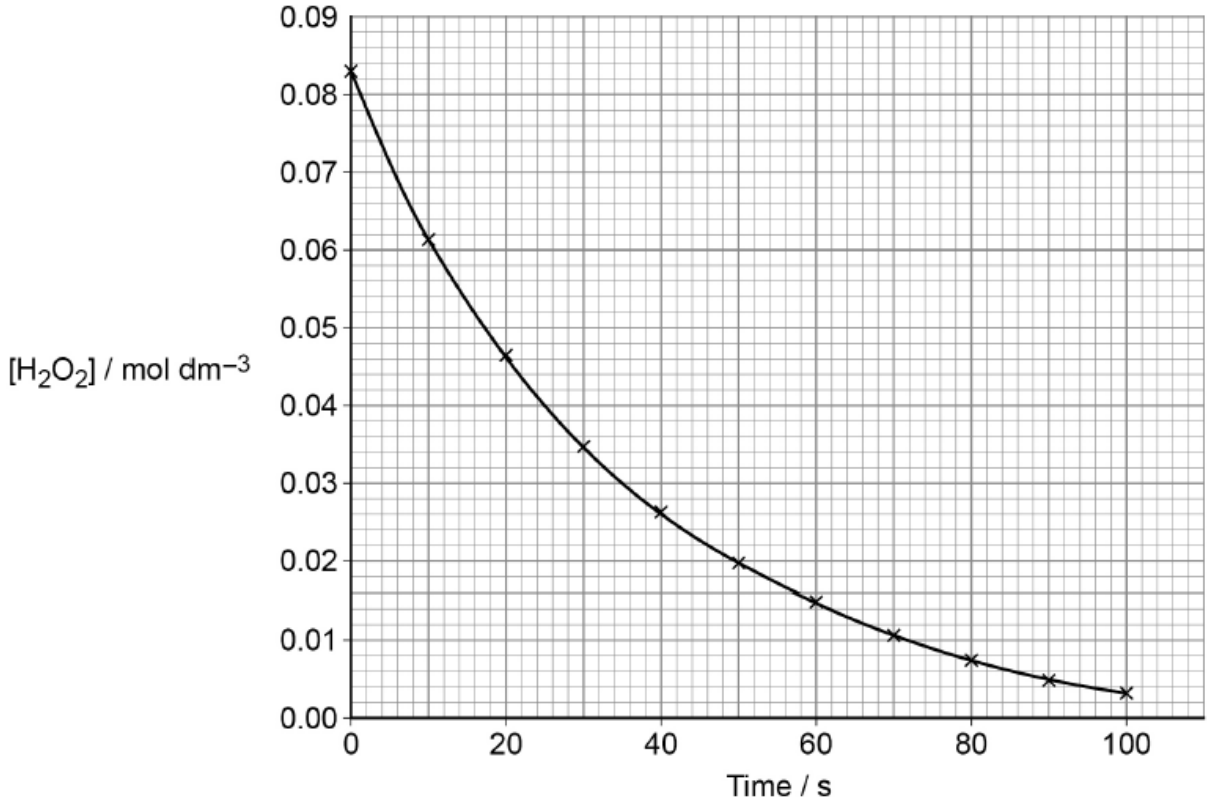
The student places hydrogen peroxide solution in a conical flask with the catalyst and uses a gas syringe to collect the oxygen formed. The student records the volume of oxygen every 10 seconds for 100 seconds.

0 4 . 1 Explain why the reaction is fastest at the start.

[2 marks]

0 4 . 2 The graph in **Figure 1** shows how the concentration of hydrogen peroxide changes with time in this experiment.

Figure 1



Tangents to the curve in **Figure 1** can be used to determine rates of reaction.

Draw a tangent to the curve when the concentration of hydrogen peroxide solution is 0.05 mol dm^{-3}

Use your tangent to calculate the gradient of the curve at this point.

[2 marks]

Gradient _____ mol dm^{-3} s^{-1}

0 4 . 3 The concentration of hydrogen peroxide solution at time t during the experiment can be calculated using this expression.

$$[H_2O_2]_t = [H_2O_2]_{initial}\left(\frac{V_{max} - V_t}{V_{max}}\right)$$

$[H_2O_2]_t$ = concentration of hydrogen peroxide solution at time t / mol dm^{-3}

$[H_2O_2]_{initial}$ = concentration of hydrogen peroxide solution at the start / mol dm^{-3}

V_{max} = total volume of oxygen gas collected during the whole experiment / cm^3

V_t = volume of oxygen gas collected at time t / cm^3

In this experiment, V_{max} = 100 cm^3

Use **Figure 1** and the expression to calculate $[H_2O_2]_t$ when 20 cm^3 of oxygen has been collected.

[2 marks]

$[H_2O_2]_t$ _____ mol dm^{-3}

Table 5 shows data from a similar experiment.

Table 5

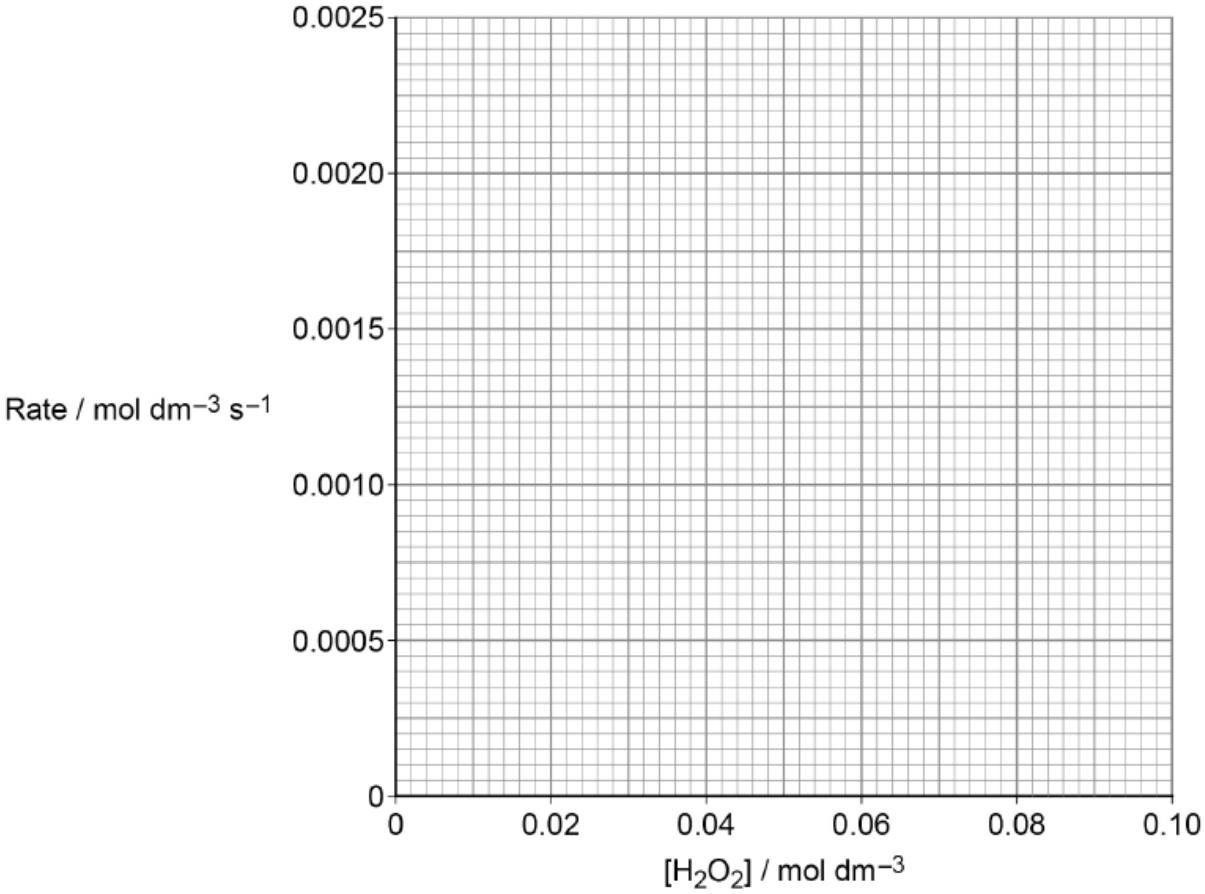
$[H_2O_2]$ / mol dm^{-3}	0.02	0.03	0.05	0.07	0.09
Rate / mol dm^{-3} s^{-1}	0.00049	0.00073	0.00124	0.00168	0.00219

0 4 . 4 Plot the data from **Table 5** on the grid in **Figure 2**.

Draw a line of best fit.

[2 marks]

Figure 2



0 4 . 5 Use **Figure 2** to determine the order of reaction with respect to H_2O_2

State how the graph shows this order.

[2 marks]

Order _____

How the graph shows this order _____

_____

_____

4. June/2022/Paper_7405/3/No.17

Which statement is correct about the Group 1 elements?

[1 mark]

A The Cs^+ ion has a more negative enthalpy of hydration than the Rb^+ ion. ⬭

B The enthalpy of atomisation for potassium is greater than the enthalpy of atomisation for sodium. ⬭

C The melting point of potassium is higher than the melting point of sodium. ⬭

D The second ionisation energy of rubidium is lower than the second ionisation energy of lithium. ⬭