



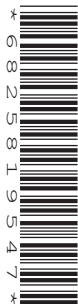
Oxford Cambridge and RSA

A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

Tuesday 13 June 2017 – Afternoon

Time allowed: 2 hours 15 minutes



You must have:

- the Data Sheet for Chemistry A (sent with general stationery)

You may use:

- a scientific or graphical calculator



First name

Last name

StemUp Model Solution

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.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

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.

2
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** Which atom is **not** an isotope of iodine?

	Number of neutrons	Mass number
A	72	125
B	74	127
C	75	128
D	77	129

Your answer

D

[1]

- 2** What is the bonding between the ligands and the metal ion in $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$?

- A** Metallic
B Ionic
C Hydrogen
D Dative covalent

Your answer

D

[1]

- 3** What is the oxidation number of Mn in K_2MnO_4 ?

- A** +4
B +5
C +6
D +7

Your answer

C

[1]

4 Which calcium compound contains the **greatest** percentage by mass of calcium?

- A calcium carbonate
- B calcium nitrate
- C calcium hydroxide
- D calcium sulfate

Your answer

C

[1]

5 0.0200 mol of calcium oxide is reacted completely with $2.00 \text{ mol dm}^{-3} \text{ HCl}$.

What is the volume, in cm^3 , of $2.00 \text{ mol dm}^{-3} \text{ HCl}$ required for this reaction?

- A 15
- B 20
- C 30
- D 60

Your answer

B

[1]

6 How many electrons are removed from $2.02 \times 10^{-2} \text{ g}$ of Ne(g) atoms to form $\text{Ne}^+(\text{g})$ ions?

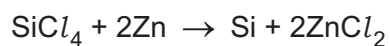
- A 3.36×10^{-26}
- B 1.66×10^{-27}
- C 6.02×10^{20}
- D 1.22×10^{22}

Your answer

C

[1]

- 7 Silicon can be made by heating silicon tetrachloride, SiCl_4 , with zinc.



8.50 g of SiCl_4 is reacted with an excess of zinc. The percentage yield of silicon is 90%.

What is the mass of silicon made?

- A 1.26 g
- B 1.31 g
- C 1.40 g
- D 1.55 g

Your answer

A

[1]

- 8 Four pairs of solutions are mixed.

Which pair of solutions forms a white precipitate?

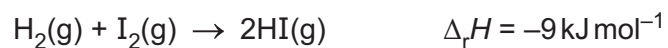
- A $\text{NH}_4\text{Cl}(\text{aq})$ and $\text{NaOH}(\text{aq})$
- B $\text{KBr}(\text{aq})$ and $\text{AgNO}_3(\text{aq})$
- C $\text{FeCl}_3(\text{aq})$ and $\text{NH}_3(\text{aq})$
- D $\text{Cr}_2(\text{SO}_4)_3(\text{aq})$ and $\text{BaCl}_2(\text{aq})$

Your answer

D

[1]

9 Enthalpy values are provided below.



Bond	Bond enthalpy / kJ mol^{-1}
H–H	+436
I–I	+151

What is the bond enthalpy, in kJ mol^{-1} , of the H–I bond?

- A –596
- B –298
- C +298
- D +596

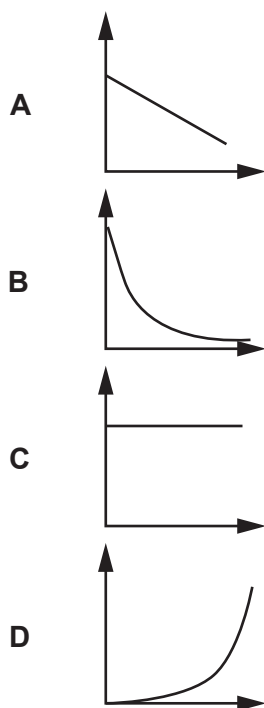
Your answer

C

[1]

10 A reaction is zero order with respect to a reactant **A**.

Which concentration–time graph for reactant **A** is the correct shape?



Your answer

A

[1]

- 11 Aqueous Cr^{3+} ions are reacted with an excess of aqueous sodium hydroxide.

Which product is formed?

- A $\text{Cr}(\text{OH})_6^{3-}$
B $\text{Cr}(\text{OH})_3$
C $[\text{Cr}(\text{OH})_4(\text{H}_2\text{O})_2]^-$
D $[\text{Cr}(\text{OH})_4]^{3-}$

Your answer

A

[1]

- 12 **HA** and **HB** are two strong monobasic acids.
 25.0 cm^3 of 6.0 mol dm^{-3} **HA** is mixed with 45.0 cm^3 of 3.0 mol dm^{-3} **HB**.

What is the $\text{H}^+(\text{aq})$ concentration, in mol dm^{-3} , in the resulting solution?

- A 1.9
B 2.1
C 4.1
D 4.5

Your answer

C

[1]

- 13 A mixture of N_2 and O_2 gases has a total pressure of 1.42 atm.
The mole fraction of N_2 is 0.700.

What is the partial pressure, in atm, of O_2 in the mixture?

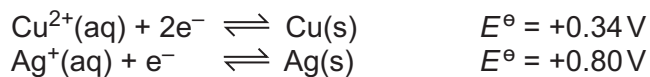
- A 0.211
B 0.426
C 0.493
D 0.994

Your answer

B

[1]

14 A cell is constructed from the two redox systems below.



Which statement(s) is/are correct for the cell?

- 1 The cell potential is 1.14 V.
- 2 The reaction at the copper electrode is $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-}$.
- 3 The silver electrode increases in mass.

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

Your answer

C

[1]

15 Which electron configuration(s) is/are correct?

- 1 Cr atom: $1\text{s}^2 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6 3\text{d}^5 4\text{s}^1$
- 2 Cu atom: $1\text{s}^2 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6 3\text{d}^{10} 4\text{s}^1$
- 3 Fe^{2+} ion: $1\text{s}^2 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6 3\text{d}^5 4\text{s}^1$

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

Your answer

B

[1]

SECTION B

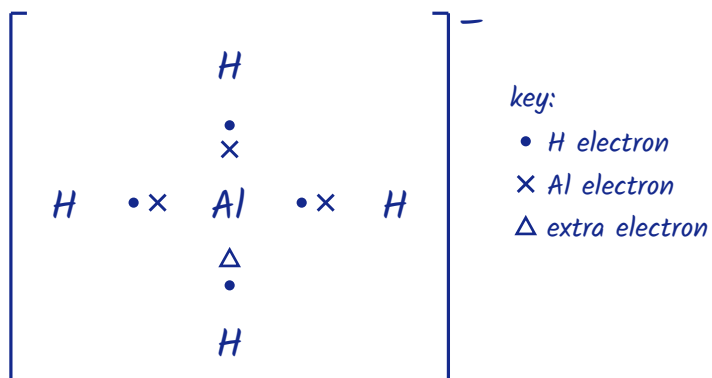
Answer **all** the questions.

16 This question is about ions and compounds containing hydrogen.

(a) Lithium aluminium hydride, LiAlH_4 , contains the AlH_4^- ion.

Draw a 'dot-and-cross' diagram to show the bonding in an AlH_4^- ion.

Show outer electrons only.



[1]

(b) Nitrogen forms NH_4^+ and NH_2^- ions.

Predict the name of the shape of, and H–N–H bond angle in, NH_4^+ and NH_2^- .

Ion	Name of shape	H–N–H bond angle
NH_4^+	<i>tetrahedral</i>	<i>109.5°</i>
NH_2^-	<i>non-linear (bent)</i>	<i>104.5°</i>

[2]

- (c) Nitrogen, phosphorus and arsenic are in Group 15 (5) of the periodic table.

The boiling points of their hydrides are shown below.

Element	Hydride	Boiling point/°C
N	NH ₃	-33
P	PH ₃	-88
As	AsH ₃	-55

- (i) Explain why the boiling point of PH₃ is lower than the boiling point of NH₃.

NH₃ has hydrogen bonding between its molecules (N is very electronegative and has a lone pair), but PH₃ does not have hydrogen bonding.
Hydrogen bonds are stronger than the induced dipole-dipole interactions in PH₃, so more energy is needed to overcome the intermolecular forces in NH₃.

[2]

- (ii) Explain why the boiling point of PH₃ is lower than the boiling point of AsH₃.

AsH₃ has more electrons than PH₃ (As has more electrons than P). So AsH₃ has stronger induced dipole-dipole interactions (London forces) between its molecules, and more energy is required to overcome them.

[2]

17 This question is about Group 2 and Group 17 (7).

- (a) Barium chloride can be prepared from barium hydroxide in a neutralisation reaction.

Write the equation for this reaction. State symbols are **not** required.



- (b) The reactivity of the Group 2 elements Mg–Ba increases down the group.

Explain why.

Down the group the atomic radius increases: there are more shells and more electron shielding of the outer electrons.

So the nuclear attraction on the outer electrons decreases.

Therefore the ionisation energy decreases: less energy is needed to remove the outer electrons, so the elements react more readily.

..... [3]

- (c) On gently heating, the compound $KClO_3$ reacts as shown in the equation.



This reaction is an example of disproportionation.

- (i) State what is meant by *disproportionation* and use oxidation numbers to show that disproportionation has taken place.

Disproportionation is the oxidation and reduction of the same element in one reaction.

Cl is oxidised from +5 in $KClO_3$ to +7 in $KClO_4$.

Cl is reduced from +5 in $KClO_3$ to -1 in KCl .

..... [3]

- (ii) What is the systematic name for $KClO_4$?

potassium chlorate(VII) [1]

(d) Two changes are described below.

For each change,

- write an equation, including state symbols,
- state and explain how the entropy changes.

(i) The reaction of aqueous barium nitrate with aqueous sodium sulfate.

Full equation with state symbols



Explanation of entropy change *Entropy decreases (ΔS negative):*

a solid precipitate, $\text{BaSO}_4(\text{s})$, forms from aqueous ions, and the solid has less disorder (fewer ways of arranging energy).

[2]

(ii) The change that accompanies the standard enthalpy change of atomisation of iodine.

Equation with state symbols



Explanation of entropy change *Entropy increases (ΔS positive):*

solid iodine changes into gaseous atoms, and a gas has much more disorder (more ways of arranging energy).

[2]

18 This question is about free energy changes, ΔG , enthalpy changes, ΔH , and temperature, T .

(a) The Gibbs' equation is shown below.

$$\Delta G = \Delta H - T\Delta S$$

A chemist investigates a reaction to determine how ΔG varies with T . The results are shown in **Fig. 18.1**.

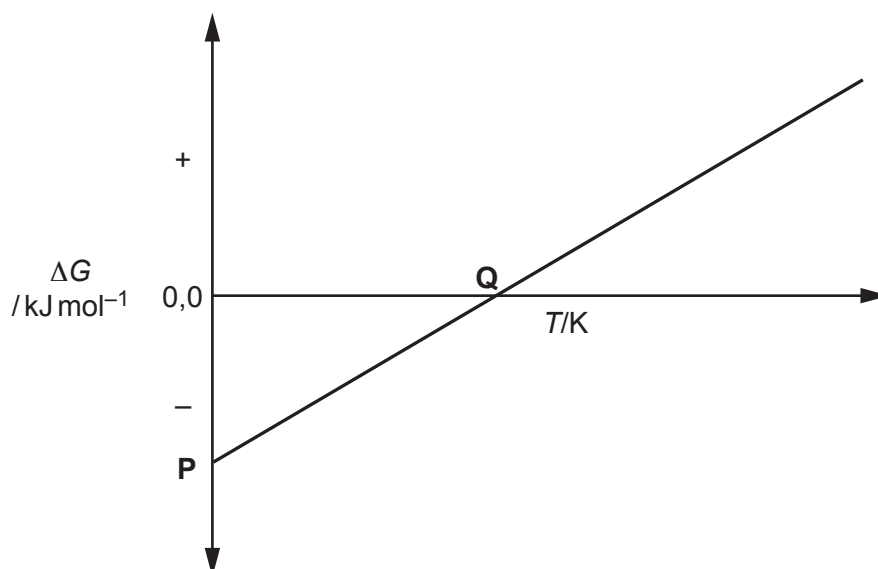


Fig. 18.1

What is significant about the gradient of the line and the values **P** and **Q** shown in **Fig. 18.1**? Explain your reasoning.

$\Delta G = \Delta H - T\Delta S$ can be written as $\Delta G = -\Delta S T + \Delta H$, which is in the form

$y = mx + c$.

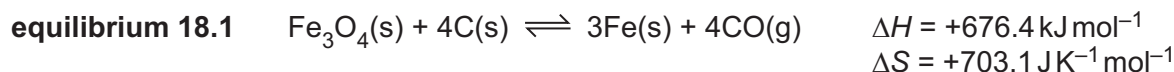
So the gradient of the line = $-\Delta S$ (the gradient is positive, so ΔS is negative).

P is the intercept on the ΔG axis (where $T = 0$), so $P = \Delta H$, the enthalpy change (negative, exothermic).

Q is the temperature at which feasibility changes: at **Q**, $\Delta G = 0$. Below **Q**, $\Delta G < 0$ and the reaction is feasible; above **Q**, $\Delta G > 0$ and it is not feasible.

[4]

- (b) Iron can be extracted from its ore Fe_3O_4 using carbon.
Several equilibria are involved including **equilibrium 18.1**, shown below.



- (i) Why is **equilibrium 18.1** a *heterogeneous* equilibrium?

*The species are in different states (phases): Fe_3O_4 , C and Fe are solids
 but CO is a gas.* [1]

- (ii) Write the expression for K_p for **equilibrium 18.1**.

$$K_p = p(\text{CO})^4$$

[1]

- (iii) The forward reaction in **equilibrium 18.1** is only feasible at high temperatures.

- Show that the forward reaction is **not** feasible at 25°C .
- Calculate the minimum temperature, in K, for the forward reaction to be feasible.

$$\Delta S = +703.1 \text{ J K}^{-1} \text{ mol}^{-1} = +0.7031 \text{ kJ K}^{-1} \text{ mol}^{-1}$$

$$\text{At } 25^\circ\text{C}, T = 298 \text{ K:}$$

$$\Delta G = \Delta H - T\Delta S = 676.4 - (298 \times 0.7031)$$

$$\Delta G = +467 \text{ kJ mol}^{-1}$$

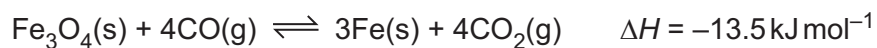
$$\Delta G > 0 (\Delta H > T\Delta S), \text{ so the forward reaction is not feasible at } 25^\circ\text{C}.$$

$$\text{Feasible when } \Delta G \leq 0, \text{ so the minimum temperature is when } \Delta G = 0:$$

$$T = \Delta H \div \Delta S = 676.4 \div 0.7031 = 962 \text{ K}$$

minimum temperature = ...962..... K [3]

(iv) Another equilibrium involved in the extraction of iron from Fe_3O_4 is shown below.



Enthalpy changes of formation, $\Delta_f H$, for $\text{Fe}_3\text{O}_4(\text{s})$ and $\text{CO}_2(\text{g})$ are shown in the table.

Compound	$\Delta_f H / \text{kJ mol}^{-1}$
$\text{Fe}_3\text{O}_4(\text{s})$	-1118.5
$\text{CO}_2(\text{g})$	-393.5

Calculate the enthalpy change of formation, $\Delta_f H$, for $\text{CO}(\text{g})$.

$$\Delta H = \Sigma \Delta_f H(\text{products}) - \Sigma \Delta_f H(\text{reactants})$$

$$-13.5 = (4 \times -393.5) - (-1118.5 + 4 \times \Delta_f H(\text{CO}))$$

$$4 \times \Delta_f H(\text{CO}) = (4 \times -393.5) - (-1118.5) + 13.5$$

$$4 \times \Delta_f H(\text{CO}) = -1574.0 + 1118.5 + 13.5 = -442.0$$

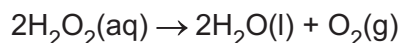
$$\Delta_f H(\text{CO}) = -442.0 \div 4 = -110.5 \text{ kJ mol}^{-1}$$

$$\Delta_f H, \text{ for CO(g)} = \dots\dots\dots -110.5 \dots\dots\dots \text{ kJ mol}^{-1} \text{ [3]}$$

15
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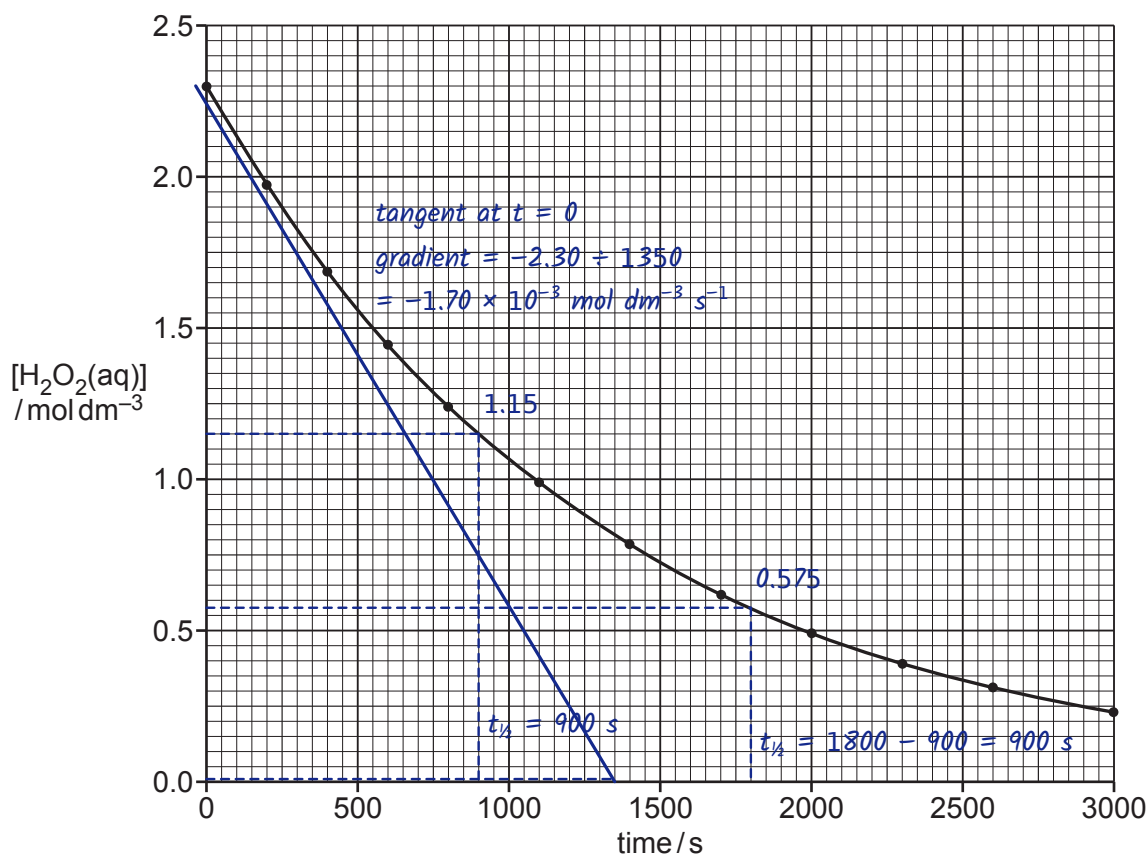
- 19 Aqueous solutions of hydrogen peroxide, $\text{H}_2\text{O}_2(\text{aq})$, decompose as in the equation below.



A student investigates the decomposition of $\text{H}_2\text{O}_2(\text{aq})$ by measuring the volume of oxygen gas produced over time. All gas volumes are measured at room temperature and pressure.

The student uses 25.0 cm^3 of 2.30 mol dm^{-3} H_2O_2 .

From the results, the student determines the concentration of $\text{H}_2\text{O}_2(\text{aq})$ at each time. The student then plots a concentration–time graph.



- (a) Determine the total volume of oxygen, measured at room temperature and pressure, that the student should be prepared to collect in this investigation.

Suggest apparatus that would allow this gas volume to be collected, indicating clearly the scale of working.

$$n(\text{H}_2\text{O}_2) = 2.30 \times 25.0/1000 = 0.0575 \text{ mol}$$

$$n(\text{O}_2) = 0.0575 \div 2 = 0.02875 \text{ mol}$$

$$\text{volume of O}_2 = 0.02875 \times 24\,000 = 690 \text{ cm}^3$$

Collect the gas in a 1000 cm^3 (1 dm^3) measuring cylinder, inverted over water (or in a 1 dm^3 gas syringe).

[3]

- (b) Suggest a different experimental method that would allow the rate of this reaction to be followed over time.

Measure the loss in mass of the reaction mixture over time (on a balance),
as O_2 escapes.

[1]

- (c)* Determine the initial rate of reaction, the order with respect to H_2O_2 , and the rate constant.

Your answer must show full working on the graph and on the lines below.

Initial rate: I drew a tangent to the curve at $t = 0$ s (on the graph).

Gradient = $-2.30 \div 1350 = -1.70 \times 10^{-3}$, so the initial rate = 1.70×10^{-3}
 $\text{mol dm}^{-3} \text{ s}^{-1}$.

Order: half-lives are shown on the graph. $[H_2O_2]$ falls from 2.30 to 1.15 mol dm^{-3} in 900 s, and from 1.15 to 0.575 mol dm^{-3} in a further 900 s (1800 – 900 s).

The half-life is constant (900 s), so the reaction is first order with respect to H_2O_2 .

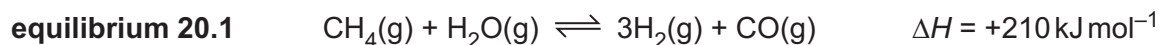
Rate constant: rate = $k[H_2O_2]$, so $k = \text{rate} \div [H_2O_2] = 1.70 \times 10^{-3} \div 2.30$
 $= 7.4 \times 10^{-4} \text{ s}^{-1}$.

Check using the half-life: $k = \ln 2 \div t_{1/2} = 0.693 \div 900 = 7.7 \times 10^{-4} \text{ s}^{-1}$,
which agrees.

[6]

20 This question is about equilibrium reactions.

- (a) Hydrogen gas is manufactured by the chemical industry using the reaction of methane and steam. This is a reversible reaction, shown in **equilibrium 20.1** below.



Explain, in terms of le Chatelier's principle, the conditions of pressure and temperature for a maximum yield of hydrogen from **equilibrium 20.1**, and explain why the operational conditions used by the chemical industry may be different.

For a maximum yield of hydrogen: low pressure and high temperature.

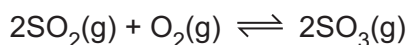
Pressure: the right-hand side has more gaseous moles (4 mol) than the left-hand side (2 mol), so a low pressure shifts the equilibrium position to the right.

Temperature: the forward reaction is endothermic (takes in heat), so a high temperature shifts the equilibrium position to the right.

Industry may use different conditions: a low pressure gives a slow rate, and a very high temperature uses a large amount of energy (fuel).

[4]

- (b) A chemist investigates the equilibrium reaction between sulfur dioxide, oxygen, and sulfur trioxide, shown below.



- The chemist mixes together SO_2 and O_2 with a catalyst.
- The chemist compresses the gas mixture to a volume of 400 cm^3 .
- The mixture is heated to a constant temperature and is allowed to reach equilibrium without changing the total gas volume.

The equilibrium mixture contains 0.0540 mol SO_2 and 0.0270 mol O_2 .

At the temperature used, the numerical value for K_c is $3.045 \times 10^4\text{ dm}^3\text{ mol}^{-1}$.

- (i) Write the expression for K_c and the units of K_c for this equilibrium.

$$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]} \quad \text{units: } \text{dm}^3 \text{ mol}^{-1}$$

[2]

- (ii) Determine the amount, in mol, of SO_3 in the equilibrium mixture at this temperature.

Give your final answer to an **appropriate** number of significant figures.

Show all your working.

$$[\text{SO}_2] = 0.0540 \div 0.400 = 0.135 \text{ mol dm}^{-3}$$

$$[\text{O}_2] = 0.0270 \div 0.400 = 0.0675 \text{ mol dm}^{-3}$$

$$[\text{SO}_3]^2 = K_c \times [\text{SO}_2]^2 \times [\text{O}_2] = 3.045 \times 10^4 \times 0.135^2 \times 0.0675$$

$$[\text{SO}_3]^2 = 37.46, \text{ so } [\text{SO}_3] = \sqrt{37.46} = 6.12 \text{ mol dm}^{-3}$$

$$n(\text{SO}_3) = 6.12 \times 0.400 = 2.45 \text{ mol (3 s.f.)}$$

equilibrium amount of $\text{SO}_3 = \dots\dots\dots 2.45 \dots\dots\dots \text{ mol [4]}$

- 21 This question is about the properties and reactions of ethanoic acid, CH_3COOH . Ethanoic acid is a weak acid with an acid dissociation constant, K_a , of $1.75 \times 10^{-5} \text{ mol dm}^{-3}$ at 25°C .

- (a) A student uses a pH meter to measure the pH of a solution of CH_3COOH at 25°C . The measured pH is 2.440.

Calculate the concentration of ethanoic acid in the solution.

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

$$[\text{H}^+] = 10^{-\text{pH}} = 10^{-2.440} = 3.63 \times 10^{-3} \text{ mol dm}^{-3}$$

$$K_a = [\text{H}^+]^2 \div [\text{CH}_3\text{COOH}]$$

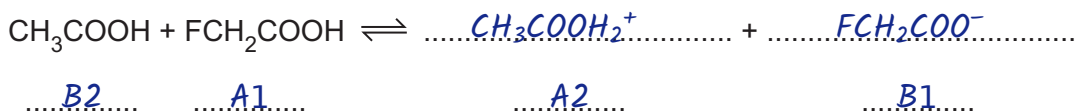
$$[\text{CH}_3\text{COOH}] = [\text{H}^+]^2 \div K_a = (3.63 \times 10^{-3})^2 \div (1.75 \times 10^{-5})$$

$$[\text{CH}_3\text{COOH}] = 0.753 \text{ mol dm}^{-3}$$

concentration = ...0.753..... mol dm^{-3} [3]

- (b) Ethanoic acid is added to another weak acid, fluoroethanoic acid, FCH_2COOH ($K_a = 2.19 \times 10^{-3} \text{ mol dm}^{-3}$). 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) The student plans to prepare a buffer solution that has a pH of 4.50. The buffer solution will contain ethanoic acid, CH_3COOH , and sodium ethanoate, CH_3COONa .

The student plans to add 9.08 g CH_3COONa to 250 cm^3 of 0.800 mol dm^{-3} CH_3COOH . The student assumes that the volume of the solution does not change.

- (i) Show by calculation whether, or not, the student's experimental method would produce the required pH.

Show **all** your working.

$$n(\text{CH}_3\text{COONa}) = 9.08 \div 82.0 = 0.111 \text{ mol}$$

$$[\text{CH}_3\text{COO}^-] = 0.111 \times 1000/250 = 0.443 \text{ mol dm}^{-3}$$

$$[\text{CH}_3\text{COOH}] = 0.800 \text{ mol dm}^{-3}$$

$$[\text{H}^+] = K_a \times [\text{CH}_3\text{COOH}] \div [\text{CH}_3\text{COO}^-]$$

$$[\text{H}^+] = 1.75 \times 10^{-5} \times 0.800 \div 0.443 = 3.16 \times 10^{-5} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log(3.16 \times 10^{-5}) = 4.50$$

So the student's method does produce the required pH of 4.50.

[5]

- (ii) When the student prepares the buffer solution, the volume of solution increases slightly.

Suggest whether the pH of the buffer solution would be the same, greater than, or less than your calculated value in (c)(i).

Explain your reasoning.

The pH stays the same.

The ratio $[\text{CH}_3\text{COOH}] \div [\text{CH}_3\text{COO}^-]$ is the same, as both concentrations decrease by the same proportion, so $[\text{H}^+] = K_a \times \text{ratio}$ does not change.

[2]

22 This question is about redox, electrode potentials and feasibility.

Table 22.1 shows standard electrode potentials for four redox systems. You need to use this information to answer the questions below.

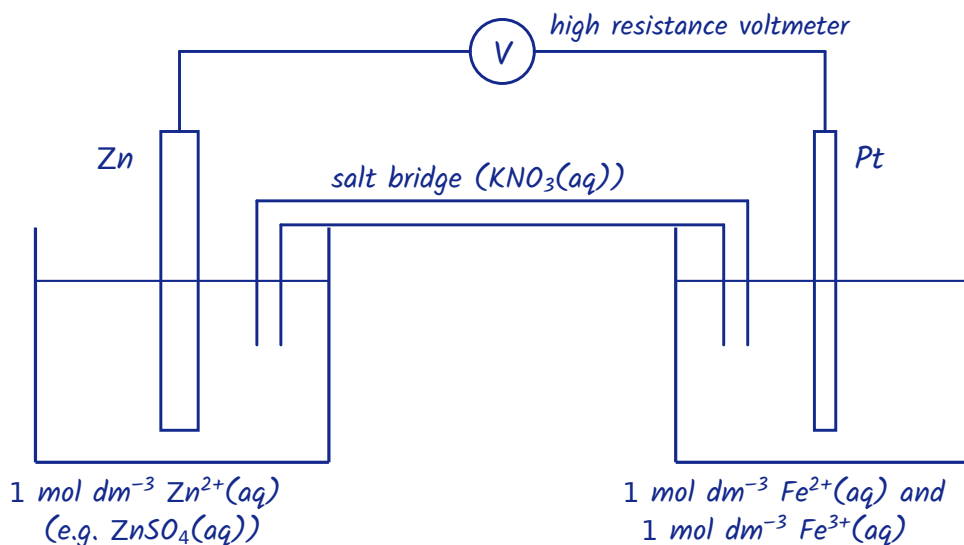
Redox system	Equation	E°/V
1	$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
2	$\text{SO}_4^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{SO}_3^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.17
3	$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
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 22.1

(a) A standard cell is set up in the laboratory based on redox systems **1** and **3** and the standard cell potential is measured.

(i) Draw a labelled diagram to show how this cell could be set up to measure its standard cell potential.

Include details of the apparatus, solutions and the standard conditions required to measure this standard cell potential.



Standard conditions 298 K (25 °C), all solutions 1 mol dm⁻³

(Fe²⁺ and Fe³⁺ both 1 mol dm⁻³); 100 kPa pressure.

..... [4]

(ii) Predict the standard cell potential of this cell.

$$E_{\text{cell}} = 0.77 - (-0.76)$$

standard cell potential = 1.53 V [1]

(b) In **Table 22.1**, what is the strongest reducing agent and the strongest oxidising agent?

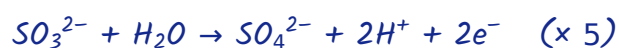
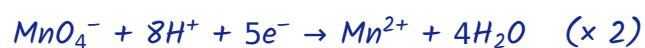
Strongest reducing agent Zn.....

Strongest oxidising agent MnO₄⁻.....

[2]

(c) Electrode potentials can be used to predict the feasibility of reactions.

Construct an overall equation for the predicted reaction between the species in redox systems **2** and **4**.



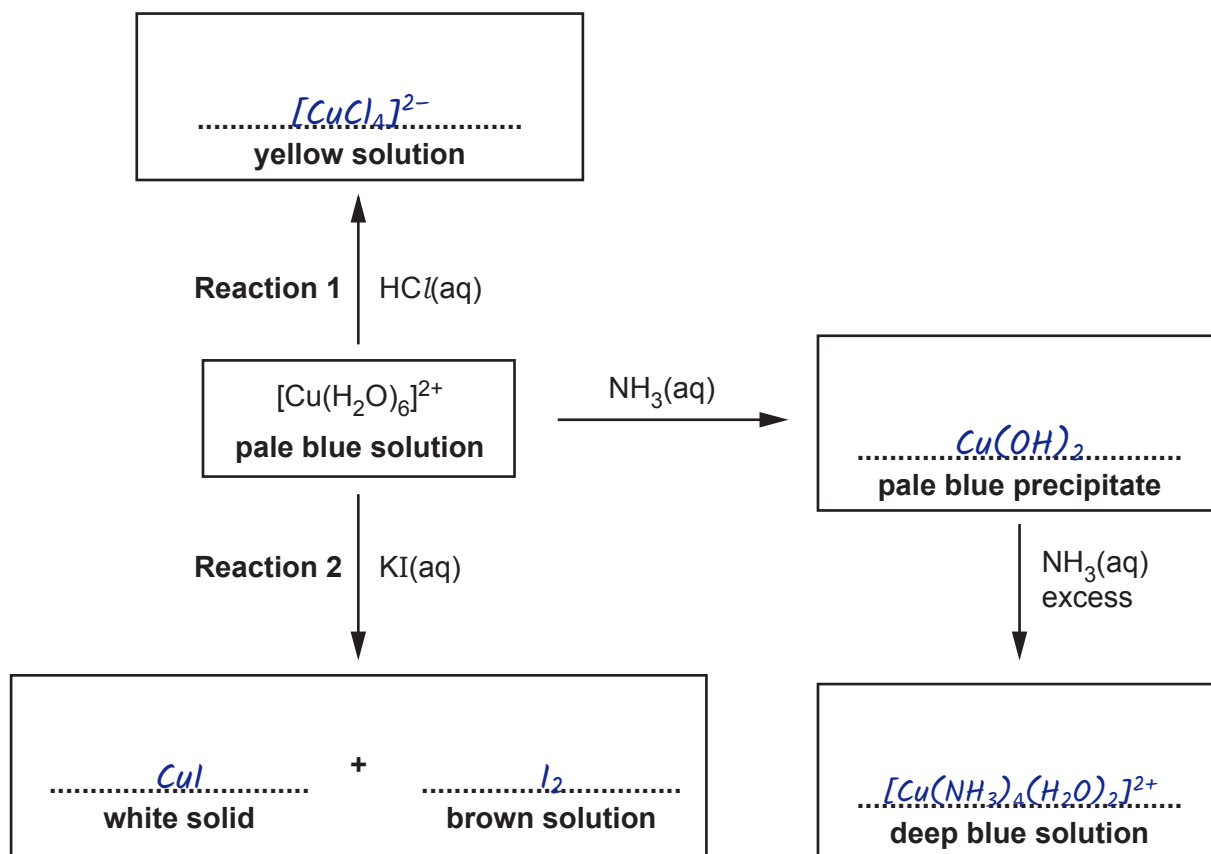
24
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23 This question is about reactions of ions and compounds of transition elements.

(a) The flowchart shows reactions of the complex ion $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$.

(i) In the boxes, write down the formulae of the species responsible for the observations.



[5]

(ii) Name the type of reaction for **Reaction 1** and **Reaction 2**.

Reaction 1 ligand substitution

Reaction 2 redox

[2]

- (b)* A hydrated nickel(II) complex, **A**, is heated in a crucible to remove the water of crystallisation. The anhydrous complex **B** is formed. The results are shown below.

Mass of crucible + hydrated complex A	= 59.554 g
Mass of crucible + anhydrous complex B	= 58.690 g
Mass of crucible	= 51.257 g

The anhydrous complex **B** is analysed and found to have a molar mass of 309.7 g mol^{-1} and to contain the following percentage composition by mass:

Ni, 18.95%; C, 23.25%; N, 27.12%; H, 7.75%; Cl, 22.93%.

The anhydrous complex **B** contains a cation **C** comprising Ni, C, N and H only.

Cation **C** is six-coordinate, contains three molecules of the bidentate ligand **D**, and exists as optical isomers.

Determine the formula of **A**, **B**, **C** and **D** and show the 3D structures for the optical isomers of **C**.

Show **all** your working.

$$\text{Mass of B} = 58.690 - 51.257 = 7.433 \text{ g; mass of H}_2\text{O} = 59.554 - 58.690 = 0.864 \text{ g}$$

$$n(\text{B}) = 7.433 \div 309.7 = 0.02400 \text{ mol; } n(\text{H}_2\text{O}) = 0.864 \div 18.0 = 0.04800$$

$$\text{mol, so B : H}_2\text{O} = 1 : 2$$

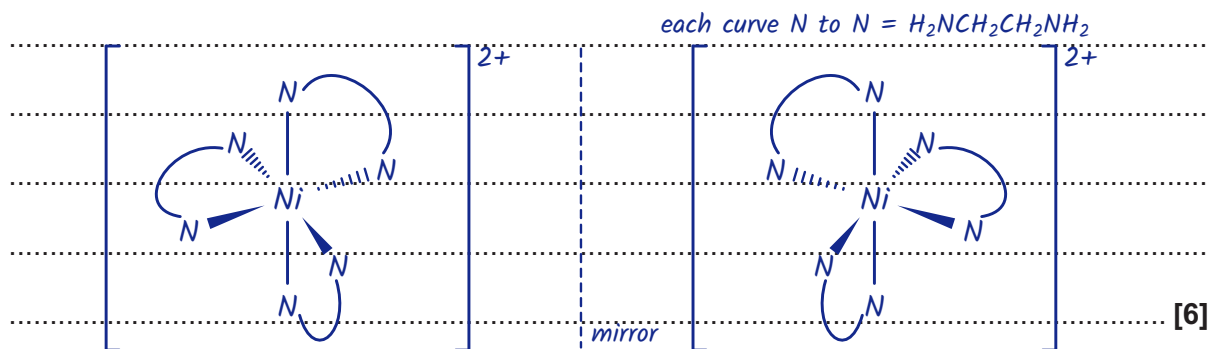
$$\text{Ni : C : N : H : Cl} = 18.95/58.7 : 23.25/12.0 : 27.12/14.0 : 7.75/1.00 :$$

$$22.93/35.5 = 0.323 : 1.94 : 1.94 : 7.75 : 0.646 = 1 : 6 : 6 : 24 : 2$$

$$\text{B} = \text{NiC}_6\text{N}_6\text{H}_{24}\text{Cl}_2 \text{ (M} = 309.7) = [\text{Ni}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]\text{Cl}_2$$

$$\text{A} = [\text{Ni}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]\text{Cl}_2 \cdot 2\text{H}_2\text{O} \quad \text{C} = [\text{Ni}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{2+}$$

$$\text{D} = \text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2 \text{ (bidentate). Optical isomers of C (mirror images):}$$



END OF QUESTION PAPER

This image shows a blank sheet of white paper designed for handwriting practice. It features a solid black vertical line on the left side, creating a narrow margin. The rest of the page is filled with evenly spaced, horizontal dashed lines for writing. There are no other markings or text on the page.

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