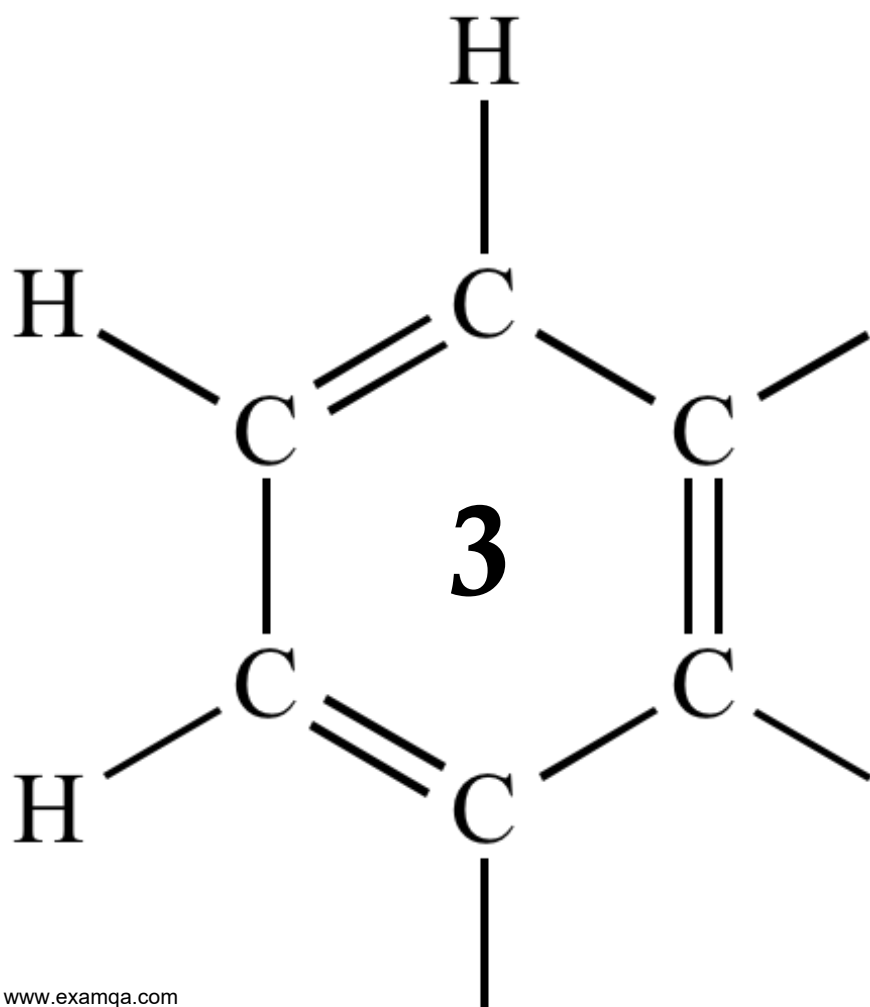


AQA A2 CHEMISTRY
TRANSITION METALS



- (b) Describe what you would observe when dilute aqueous sodium hydroxide is added, dropwise until in excess, to a dilute aqueous solution containing chromium(III) ions.

Write **two** equations to illustrate your observations.

In these equations you should give the full formula of each of the complexes, for example $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$.

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(4)

- (c) When an aqueous solution containing $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ ions is warmed in the presence of Cl^- ions, $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]^{2+}$ ions are formed and the colour of the solution changes.

Name this type of reaction.

Suggest, in terms of electrons, why the colours of the complex ions are different.

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(3)

(d) The chromium(II) ion $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$ has different properties from the $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ ion.

Use data from the table above to explain why, in an open container, $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ ions change into $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ions.

Suggest the identity of the products formed in each case when sodium carbonate solution is added to separate solutions containing $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ ions and $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ions.

- (b) A flue-gas desulfurisation process involves the oxidation, by oxygen, of aqueous sulfate(IV) ions (SO_3^{2-}) into aqueous sulfate(VI) ions (SO_4^{2-}). This reaction is catalysed by Co^{2+} ions in an acidic aqueous solution.

Write an equation for the overall reaction of sulfate(IV) ions with oxygen to form sulfate(VI) ions.

Suggest why this overall reaction is faster in the presence of Co^{2+} ions.

Suggest a mechanism for the catalysed reaction by writing **two** equations involving Co^{2+} and Co^{3+} ions. You will need to use H^+ ions and H_2O to balance these two equations.

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(4)
(Total 16 marks)

3

An experiment was carried out to determine the original concentration of iron(II) ions in a solution that had been stored in air. An excess of zinc and acid was added to this solution. The mixture was then filtered to remove the excess zinc before titration.

- (a) Suggest why the zinc and acid were added.

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(1)

(b) Explain why it was necessary to remove the excess zinc.

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(1)
(Total 2 marks)

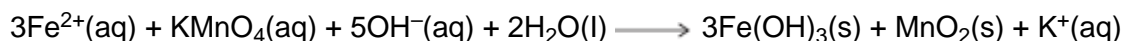
4

(a) The iron(II) ions in well-water can be removed by oxidation using potassium manganate(VII) in **alkaline** solution. A mixture containing solid iron(III) hydroxide and solid manganese(IV) oxide is formed. These solid products can be removed by filtration under reduced pressure.

(i) Draw a diagram of the apparatus used for this filtration. Do **not** include the apparatus used to reduce the pressure.

(2)

(ii) An equation representing the oxidation reaction is given below.



Calculate the mass, in grams, of KMnO_4 required to react with the iron(II) ions in 1.00 dm^3 of well-water that has an iron(II) concentration of $0.225 \text{ mol dm}^{-3}$.
Give your answer to the appropriate precision.
Show your working.

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(3)

- (iii) In practice, a slight excess of potassium manganate(VII) is used to treat the well-water.
Although this treated water is safe to drink, this excess of potassium manganate(VII) is undesirable. Suggest **one** reason, other than colour, why the excess is undesirable.

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(1)

- (b) Suggest **one** reason why the colour of potassium manganate(VII) solution can be a source of error when using a volumetric (graduated) flask to prepare a standard solution.

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(1)

(Total 7 marks)

5

- (a) Use data from the table below to explain why dilute hydrochloric acid cannot be used to acidify potassium manganate(VII) in a titration.

	E^\ominus / V
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$Cl_2(aq) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$2H^+(aq) + 2e^- \rightarrow H_2(aq)$	0.00

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(2)

- (b) Use information from the table in part (a) to determine the minimum volume, in cm^3 , of $0.500 \text{ mol dm}^{-3}$ sulfuric acid that is required for a titre of 25.0 cm^3 of $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII) solution.
Show your working.

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(3)

- (c) In each titration using potassium manganate(VII), a large excess of dilute sulfuric acid is used to avoid any possibility of the brown solid MnO_2 forming.

- (i) Deduce a half-equation for the reduction of MnO_4^- ions in acidic solution to form MnO_2 .

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(1)

- (ii) Give **two** reasons why it is essential to avoid this reaction in a titration between potassium manganate(VII) and iron(II) ions.

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(2)

- (d) Potassium manganate(VII) is an oxidising agent.
Suggest **one** reason why a $0.0200 \text{ mol dm}^{-3}$ solution of potassium manganate(VII) does **not** need to be kept away from flammable material.

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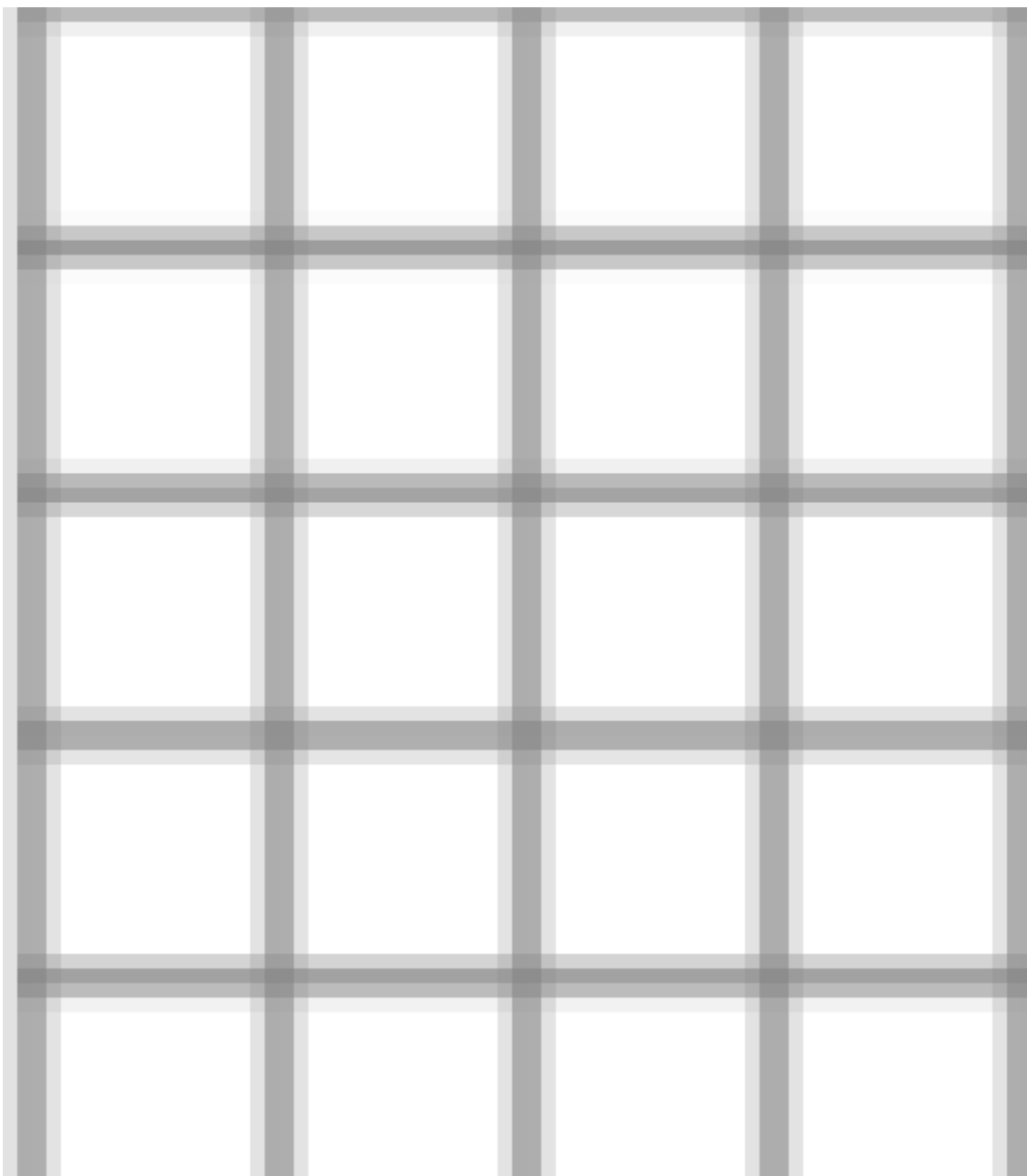
(1)
(Total 9 marks)

6

- (a) The concentration of iron(III) ions in a dilute solution can be determined by visible spectrometry. The absorption of light by a number of solutions of iron(III) sulfate, $\text{Fe}_2(\text{SO}_4)_3(\text{aq})$, was measured. The results are shown in the table below.

Concentration of $\text{Fe}_2(\text{SO}_4)_3(\text{aq}) / \text{mol dm}^{-3}$	Absorbance / %
0.020	2.2
0.040	4.7
0.060	7.0
0.080	9.4
0.100	11.8

- (i) Use these results to plot a graph of percentage absorbance (y-axis) against concentration of iron(III) sulfate solution on the grid below. Draw a straight line of best fit.



(2)

- (ii) Use your graph to determine the concentration of iron(III) ions in a solution of $\text{Fe}_2(\text{SO}_4)_3$ that has an absorbance of 5.4%.

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(2)

- (iii) Calculate the volume of water that should be added to 100 cm³ of a 0.10 mol dm⁻³ solution of iron(III) sulfate to make a 0.040 mol dm⁻³ solution.
Show your working.

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(2)

- (b) Give **one** reason why well-water may be more beneficial to health than pure water.

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(1)

(Total 7 marks)

7

When using potassium manganate(VII) in redox titrations with iron(II) ions it is essential that the reaction mixture is acidified. Normally, dilute sulfuric acid is used.

- (a) State why an excess of hydrogen ions is added to the reaction mixture.

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(1)

- (b) State why the acid used must **not** be ethanoic acid.

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(1)

- (c) Explain why an indicator is **not** needed in this redox titration.

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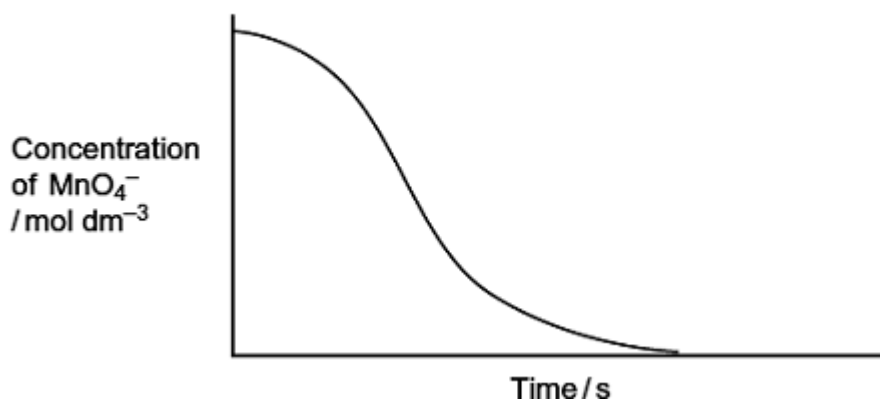
(1)

(Total 3 marks)

8

An acidified solution of potassium manganate(VII) was reacted with a sample of sodium ethanedioate at a constant temperature of 60 °C. The concentration of the manganate(VII) ions in the reaction mixture was determined at different times using a spectrometer to measure the light absorbed.

The following results were obtained.



(a) Write an equation for the reaction between manganate(VII) ions and ethanedioate ions in acidic solution.

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(2)

(b) By considering the properties of the reactants and products, state why it is possible to use a spectrometer to measure the concentration of the manganate(VII) ions in this reaction mixture.

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(2)

- (c) This reaction is autocatalysed. Give the meaning of the term *autocatalyst*.
Explain how the above curve indicates clearly that the reaction is autocatalysed.

Meaning of *autocatalyst*

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Explanation

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(3)

- (d) Identify the autocatalyst in this reaction.

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(1)

- (e) Write **two** equations to show how the autocatalyst is involved in this reaction.

Equation 1

Equation 2

(2)

(Total 10 marks)

9

Due to their electron arrangements, transition metals have characteristic properties including catalytic action and the formation of complexes with different shapes.

- (a) Give **two other** characteristic properties of transition metals. For each property, illustrate your answer with a transition metal of your choice.

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(4)

- (b) Other than octahedral, there are several different shapes shown by transition metal complexes. Name **three** of these shapes and for each one give the formula of a complex with that shape.

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(6)

(c) It is possible for Group 2 metal ions to form complexes. For example, the $[\text{Ca}(\text{H}_2\text{O})_6]^{2+}$ ion in hard water reacts with EDTA^{4-} ions to form a complex ion in a similar manner to hydrated transition metal ions. This reaction can be used in a titration to measure the concentration of calcium ions in hard water.

(i) Write an equation for the equilibrium that is established when hydrated calcium ions react with EDTA^{4-} ions.

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(1)

(ii) Explain why the equilibrium in part (c)(i) is displaced almost completely to the right to form the EDTA complex.

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(3)

(iii) In a titration, 6.25 cm^3 of a $0.0532 \text{ mol dm}^{-3}$ solution of EDTA reacted completely with the calcium ions in a 150 cm^3 sample of a saturated solution of calcium hydroxide. Calculate the mass of calcium hydroxide that was dissolved in 1.00 dm^3 of the calcium hydroxide solution.

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(Extra space)

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(3)

(Total 17 marks)

10

In its reactions with transition metal ions, ammonia can act as a Brønsted–Lowry base and as a Lewis base.

(a) Define the term *Lewis base*.

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(1)

(b) Write an equation for a reaction between aqueous copper(II) ions ($[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$) and ammonia in which ammonia acts as a Brønsted–Lowry base. State what you would observe.

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(Extra space)

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(2)

(c) Write an equation for a different reaction between aqueous copper(II) ions ($[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$) and ammonia in which ammonia acts as a Lewis base but **not** as a Brønsted–Lowry base. State what you would observe.

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(Extra space)

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(2)

- (d) An excess of dilute ammonia solution is added to an aqueous solution containing iron(II) ions in a test tube that is then left to stand for some time.

State and explain what you would observe.

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(Extra space)

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(4)

- (e) Diaminoethane ($\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$), like ammonia, can react as a base and as a ligand.

- (i) Write an equation for the reaction that occurs between an aqueous solution of aluminium chloride and an excess of aqueous diaminoethane.
Describe the appearance of the aluminium-containing reaction product.

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(Extra space)

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(3)

- (ii) Write an equation for the reaction that occurs between an aqueous solution of cobalt(II) sulfate and an excess of aqueous diaminoethane.
Draw a diagram to show the shape of and bonding in the complex product.
Write an equation for the reaction that would occur if the complex product of this reaction were allowed to stand in contact with oxygen gas.

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(5)
(Total 17 marks)

11

Transition metals and their complexes have characteristic properties.

- (a) Give the electron configuration of the Zn^{2+} ion.
Use your answer to explain why the Zn^{2+} ion is **not** classified as a transition metal ion.

Electron configuration

Explanation

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(2)

(b) In terms of bonding, explain the meaning of the term *complex*.

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(2)

(c) Identify **one** species from the following list that does **not** act as a ligand. Explain your answer.

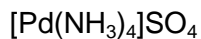


Not a ligand.....

Explanation

(2)

(d) The element palladium is in the d block of the Periodic Table. Consider the following palladium compound which contains the sulfate ion.



(i) Give the oxidation state of palladium in this compound.

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(1)

(ii) Give the names of two possible shapes for the complex palladium ion in this compound.

Shape 1

Shape 2

(2)

(Total 9 marks)