

Revision Sheet

A-Level Chemistry · Unit 28 Chemistry of transition elements

6 vocabulary items · 59 marks of exam questions (4 questions)

Part 1 · Vocabulary review (6 items). The terms this unit is examined on most. Mark it yourself from the answer key.

Section A · Chinese to English

Write the English word.

1. _____ [1]
2. _____ [1]
3. _____ [1]
4. _____ [1]
5. _____ [1]
6. _____ [1]

Part 2 · Exam questions (59 marks, 4 questions) begins on the next page. They are ordered easy to difficult and none of them has been set before.

7 (a) State **two** typical chemical properties of a transition element.

- 1
- 2 [1]

(b) Aqueous solutions of cobalt(II) salts contain the complex ion $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.

(i) Define complex ion.

- [1]

(ii) Samples of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ are reacted separately with an excess of aqueous ammonia, with an excess of concentrated HCl and with an excess of aqueous sodium hydroxide, as shown in Fig. 2.1.

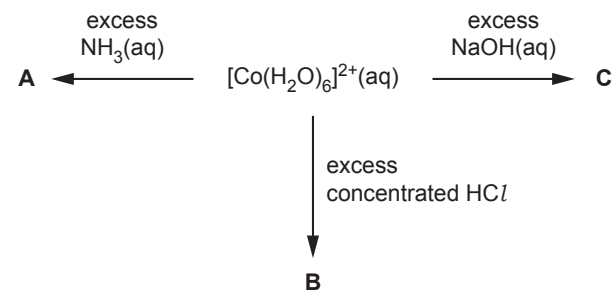


Fig. 2.1

Complete Table 2.1 about the reactions shown by $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.

Table 2.1

reagent added to $[\text{Co}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$	formula of cobalt species formed	colour and state of cobalt species formed	type of reaction
an excess of $\text{NH}_3(\text{aq})$	A =		
an excess of concentrated HCl	B =		
an excess of $\text{NaOH}(\text{aq})$	C =		

(c) The ethanedioate ion, $\text{C}_2\text{O}_4^{2-}$, can act as a bidentate ligand.

(i) Explain what is meant by a bidentate ligand.

.....

 [2]

(ii) The complex $[\text{Co}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)\text{BrCl}]^-$ exists as stereoisomers.

Complete the three-dimensional diagrams in Fig. 2.2 to show **four** stereoisomers of $[\text{Co}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)\text{BrCl}]^-$.

The $\text{C}_2\text{O}_4^{2-}$ ligand is represented using .

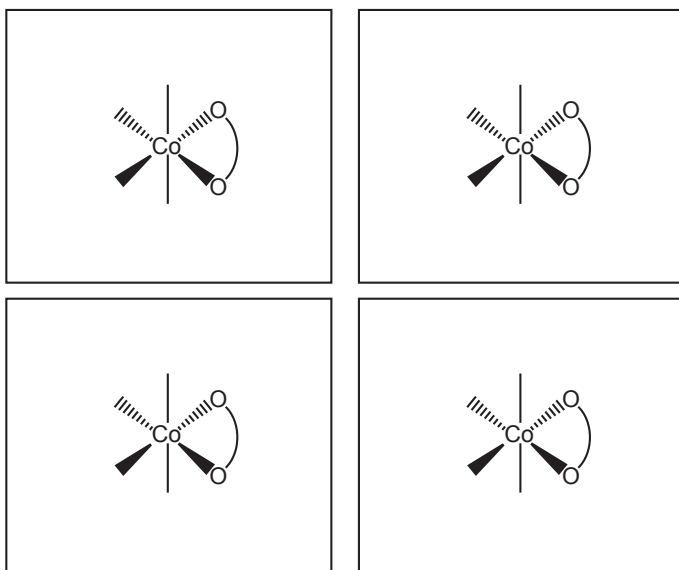


Fig. 2.2

[3]

(iii) State the oxidation state of cobalt in this complex and a type of stereoisomerism shown.

oxidation state of cobalt

type of stereoisomerism

[1]

[Total: 12]

8 Transition elements form complexes.

(a) Molybdenum, Mo, forms an octahedral complex consisting of one Mo atom surrounded by carbon monoxide, CO, molecules. CO is a monodentate ligand. Iron forms an octahedral complex consisting of one Fe^{3+} and a number of cyanide, CN^- , ions. CN^- is a monodentate ligand.

(i) Define the term *monodentate ligand*.

.....
 [1]

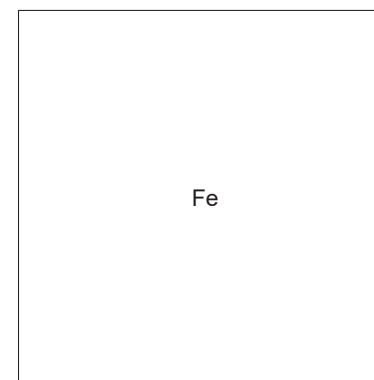
(ii) Complete the table by stating the formulae and charges of the complexes described.

	formula	charge
molybdenum complex		
iron(III) complex		

[2]

(iii) Draw a three-dimensional diagram to show the shape of this iron(III) complex.

Label one 180° bond angle on your diagram.



[1]

(b) An excess of aqueous ammonia is added to dilute copper(II) sulfate solution. A dark blue complex, $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$, is formed.

(i) Write an ionic equation for this reaction.

..... [1]

(ii) Explain the origin of colour in copper(II) complexes.

.....

.....

.....

.....

.....

.....

..... [4]

(c) An excess of concentrated hydrochloric acid is added to the dark blue solution of $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$. A new complex, **Z**, is formed. The colour of the solution changes.

(i) Write an equation for the formation of **Z** from the solution of $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$. Include the formula and charge of **Z**.

..... [2]

(ii) Name the type of reaction when **Z** forms from $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$.

..... [1]

(iii) State the geometry of **Z**.

..... [1]

(iv) State the colour of a solution of **Z**.

..... [1]

(v) Explain why the colour of a solution of $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ is different from the colour of a solution of **Z**. You should refer to the energies of the orbitals involved in your answer.

.....

..... [1]

[Total: 15]

9 Copper is a transition element. It forms a wide variety of compounds.

(a) Define transition element.

.....

..... [1]

(b) An aqueous solution of copper(II) sulfate, CuSO_4 , contains $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ complex ions. If an excess of concentrated hydrochloric acid is added to this solution a ligand exchange reaction occurs and $[\text{CuCl}_4]^{2-}$ complex ions are formed.

(i) Complete Table 5.1 to state the geometry, the coordination number of copper, and one bond angle in each of the two complex ions.

Table 5.1

complex ion	geometry	coordination number	bond angle
$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$			
$[\text{CuCl}_4]^{2-}$			

[3]

(ii) In an isolated Cu^{2+} ion the d-orbitals are all degenerate. In a complex ion such as $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ the d-orbitals are non-degenerate.

Define degenerate and non-degenerate in this context.

degenerate

non-degenerate

[1]

(iii) Explain why the solutions of the two complex ions in Table 5.1 are **different** colours.

.....

..... [1]

(c) Cu^{2+} forms a complex ion containing water molecules and ethanedioate ions, $\text{C}_2\text{O}_4^{2-}$, as ligands. The formula of the complex is $[\text{Cu}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^{2-}$. The ethanedioate ion is a bidentate ligand.

(i) Explain what is meant by bidentate.

.....

..... [1]

- (ii) There are three stereoisomers with the formula $[\text{Cu}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^{2-}$.

Complete the three-dimensional diagrams to show these three stereoisomers.

stereoisomer 1

$\begin{array}{c} | \\ \text{Cu} \\ | \end{array}$

stereoisomer 2

$\begin{array}{c} | \\ \text{Cu} \\ | \end{array}$

stereoisomer 3

$\begin{array}{c} | \\ \text{Cu} \\ | \end{array}$

[2]

- (iii) Use your answer to (c)(ii) to answer this question.

Stereoisomers 1, 2 and 3 show two different types of isomerism.

Name these two types of isomerism.

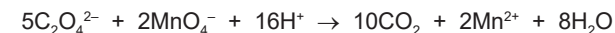
For each type of isomerism identify the pair of stereoisomers that demonstrate this isomerism.

type of isomerism	pair of stereoisomers
	and
	and

[2]

- (d) A solution contains 3.70 g of $\text{Na}_2[\text{Cu}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]$ dissolved in 100 cm^3 of solution. A 25.0 cm^3 sample of this solution is warmed and then oxidised by $0.0100\text{ mol dm}^{-3}$ acidified potassium manganate(VII).

The equation for the redox reaction is shown.



Calculate the minimum volume of $0.0100\text{ mol dm}^{-3}$ acidified potassium manganate(VII) needed to oxidise all of the ethanedioate ions, $\text{C}_2\text{O}_4^{2-}$, in the 25.0 cm^3 sample. Show all your working.

$[M_r: \text{Na}_2[\text{Cu}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2], 321.5]$

minimum volume = cm^3 [3]

- (e) Copper(II) nitrate, $\text{Cu}(\text{NO}_3)_2$, and barium nitrate, $\text{Ba}(\text{NO}_3)_2$, both decompose when heated.

Copper(II) nitrate decomposes at a lower temperature than barium nitrate.

Suggest a reason for this difference. Explain your answer.

.....

.....

.....

..... [2]

[Total: 16]

- 10 (a) The solubility of the Group 2 hydroxides increases down the group.

Explain this trend.

.....

 [3]

- (b) The solubility of $\text{Be}(\text{OH})_2$ in water is $2.40 \times 10^{-6} \text{ g dm}^{-3}$ at 298 K.

- (i) Write an expression for the solubility product, K_{sp} , of $\text{Be}(\text{OH})_2$ and state its units.

$$K_{\text{sp}} =$$

units = [2]

- (ii) Calculate the numerical value of K_{sp} for $\text{Be}(\text{OH})_2$ at 298 K.

$$K_{\text{sp}} = \dots\dots\dots [2]$$

- (c) $\text{Be}(\text{OH})_2$ is soluble in aqueous solutions containing an excess of hydroxide ions and forms the complex ion $[\text{Be}(\text{OH})_4]^{2-}$. This complex ion has a similar shape to that of $[\text{CuCl}_4]^{2-}$.

- (i) Define the term complex ion.

.....
 [1]

- (ii) Draw a three-dimensional diagram to show the structure of the complex ion $[\text{Be}(\text{OH})_4]^{2-}$. Name the shape of the $[\text{Be}(\text{OH})_4]^{2-}$ complex ion.

shape [1]

- (d) (i) Explain why transition elements can form complex ions.

.....
 [1]

- (ii) Complete Table 1.1 to show the coordination number of each metal ion, and the shapes and overall polarities of the complex ions listed.

Table 1.1

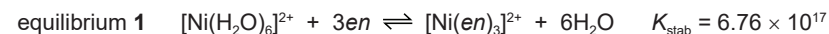
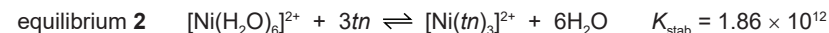
complex ion	shape	coordination number	polar or non-polar
<i>cis</i> - $[\text{Pt}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)\text{Cl}_2]$	square planar		
$[\text{Ag}(\text{NH}_3)_2]^+$			non-polar
$[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$		6	

[2]

- (e) (i) Define stability constant, K_{stab} .

.....
 [1]

- (ii) Nickel can form complexes with the ligands *en*, $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$, and *tn*, $\text{H}_2\text{NCH}_2\text{CH}_2\text{CH}_2\text{NH}_2$, as shown.



Construct an expression for the stability constant, K_{stab} , for equilibrium 1.
 State the units for K_{stab} .

$$K_{\text{stab}} =$$

units = [2]

- (iii) Describe what the K_{stab} values indicate about the position of equilibrium for equilibrium 1 and 2. Use the K_{stab} values to deduce which complex, $[\text{Ni}(\text{en})_3]^{2+}$ or $[\text{Ni}(\text{tn})_3]^{2+}$, is more stable.

.....
 [1]

[Total: 16]