

AQA A2 CHEMISTRY

TOPIC 5.4

TRANSITION METALS

PART 1 – COMPLEX IONS

BOOKLET OF PAST EXAMINATION QUESTIONS

1. (a) Vanadium is a transition element. State **three** characteristic features of the chemistry of vanadium and its compounds.

Feature 1

Feature 2

Feature 3

(3)

- (b) Predict, with a reason in **each** case, whether or not vanadium(IV) chloride would react with hexane or with ethanol.

Prediction for hexane

Reason

Prediction for ethanol

Reason

(4)

(Total 7 marks)

2. Complete the electronic arrangement of the Co^{2+} ion.

[Ar]

(1)

(Total 1 mark)

3. Explain why complex ions with partially filled d sub-levels are usually coloured.

.....

.....

(2)

(Total 2 marks)

4. (a) (i) What is meant by the term *co-ordinate bond*?

.....
.....

(ii) Explain why co-ordinate bonds can be formed between transition metal ions and water molecules.

.....
.....

(iii) What name is given to any ligand that can form two co-ordinate bonds to one metal ion? Give an example of such a ligand.

Name

Example

(5)

(b) Titanium(IV) chloride reacts with propanone to form a complex compound in which two molecules of propanone have combined with one molecule of titanium(IV) chloride.

Draw a possible structure for the complex formed, indicating clearly which atoms are bonded to titanium.

(2)

(Total 7 marks)

5. (a) What is a *transition element*?

.....
.....

(1)

(b) Give, by name or formula, a transition metal complex which

(i) occurs in the body;.....

(ii) is used as an anti-cancer drug

(2)

- (c) (i) Suggest one feature of silver chemistry which is characteristic of the transition elements.

.....

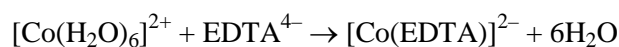
- (ii) Suggest one feature of silver chemistry which is **not** characteristic of the transition elements.

.....

(2)

(Total 5 marks)

6. In order to determine the concentration of a solution of cobalt(II) chloride, a 25.0 cm³ sample was titrated with a 0.0168M solution of EDTA⁴⁻; 36.2 cm³ were required to reach the end-point. The reaction occurring in the titration is



- (i) What type of ligand is EDTA⁴⁻?

.....

- (ii) Calculate the molar concentration of the cobalt(II) chloride solution.

.....

.....

.....

.....

.....

.....

.....

- (iii) Suggest an alternative analytical method for determining the concentration of a solution which contains only cobalt(II) chloride.

.....

.....

.....

(7)

(Total 7 marks)

7. (a) Give the full electronic configuration of a copper atom
 (1)
- (b) Explain why some copper (I) compounds are colourless but most copper (II) compounds are coloured.

 (2)
- (Total 3 marks)**

8. Complete the following electron configurations.
- (i) Cu $1s^2 2s^2 2p^6 3s^2 3p^6$ (1)
- (ii) Cu^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6$ (1)
- (Total 2 marks)**

9. (a) Complete the electronic configuration of a cobalt (II) ion
 Co^{2+} [Ar]..... (1)
- (b) When cobalt (II) chloride is treated, under certain conditions, with the bidentate ligand, $NH_2CH_2CH_2NH_2$, (which can be represented by the symbol “en”), the compound $[CoCl_2(en)_2]Cl$ is formed.
- (i) What is the oxidation state of cobalt in the compound formed?
 (1)
- (ii) What is meant by the term *bidentate* as applied to a ligand?

- (iii) What is the co-ordination number of cobalt in this compound?

- (iv) When this compound is treated with aqueous silver nitrate, only one mole of silver chloride is produced per mole of compound. Explain this observation.

 (5)

- (c) When hydrazine, NH_2NH_2 , reacts with cobalt (II) chloride in aqueous solution, the compound $\text{CoCl}_2(\text{NH}_2\text{NH}_2)_2$ is formed. This compound has a polymeric structure in which cobalt is six co-ordinate and the cobalt ions are linked by hydrazine molecules. Draw the structure of the repeating unit of the polymer.

(2)
(Total 8 marks)

10. Locate the element zirconium (Zr) in the Periodic Table and use its position to help you to answer the following questions.

- (a) Give three characteristic features of zirconium chemistry.

Feature 1

Feature 2

Feature 3

(3)

- (b) Give the formula of the chloride of zirconium in its highest oxidation state.

.....

(1)

(Total 4 marks)

11. (a) When titanium dissolves in concentrated hydrochloric acid, the violet $[\text{Ti}(\text{H}_2\text{O})_4\text{Cl}_2]^+$ ion is formed. Deduce the oxidation state and co-ordination number of titanium in this ion.

Oxidation state.....

Co-ordination number.....

(2)

- (b) Draw the structures of the two isomers of $[\text{Ti}(\text{H}_2\text{O})_4\text{Cl}_2]^+$.

(1)
(Total 3 marks)

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

(i) What is meant by the term *bidentate ligand*?

.....
.....

(ii) This ligand forms an octahedral complex with iron(III) ions. Deduce the formula of this complex and draw its structure showing all the atoms present.

Formula

Structure

(5)

(b) (i) Give the name of a naturally-occurring complex compound which contains iron.

.....

(ii) What is an important function of this complex compound?

.....

(2)

(Total 7 marks)

13. (a) Define the terms *co-ordinate bond* and *co-ordination number*.

Co-ordinate bond

.....

Co-ordination number

.....

(2)

(b) Consider the complex compound $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$

(i) What is the oxidation state of cobalt in this compound?

.....

(ii) Explain why the chloride ions are not considered to be acting as ligands in this complex.

.....

(iii) Give the formula of a complex ion of cobalt which does contain chloride ions acting as ligands.

.....

(iv) Deduce the structural formula of the complex compound $\text{CoCl}_3 \cdot 4\text{NH}_3$, in which cobalt has the same oxidation state and co-ordination number as in $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$

.....

(4)

(Total 6 marks)

14. (a) Give **one** example of a bidentate ligand.

.....

(1)

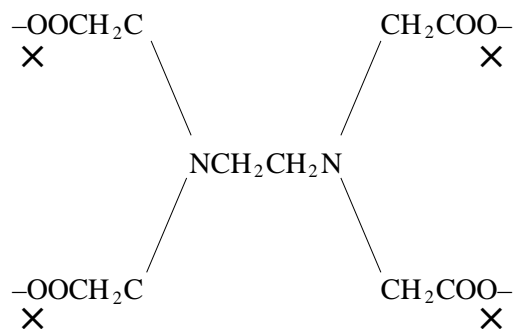
(b) Give **one** example of a linear complex ion formed by a transition metal.

.....

(1)

(Total 2 marks)

15. The multidentate ligand represented as EDTA⁴⁻ has the structural formula shown below. Four of the atoms which can bond to a metal ion are marked with crosses.



- (a) On the formula above, mark with crosses, two other atoms which bond to metal ions when EDTA⁴⁻ forms complexes. (1)

- (b) Explain what is meant by a *multidentate ligand*.

.....

(2)

- (c) The EDTA⁴⁻ ion reacts with metal(II) ions according to the equation



In a titration, using a suitable indicator, a solution containing 0.0624g of hydrated copper(II) sulphate reacted exactly with 25.00 cm³ of 0.0100 M EDTA⁴⁻ solution.

Use the data above to calculate the value of n in the formula of the hydrated copper(II) sulphate, CuSO₄.nH₂O.

.....

(6)

(Total 9 marks)

16. (a) State what is meant by the term *co-ordinate bond*.

.....
.....

(2)

(b) State what is meant by the term *bidentate ligand*.

.....
.....

(2)

(c) Deduce the formula of the compound formed when ethane-1,2-diamine is treated with an excess of hydrochloric acid.

.....

(1)

(Total 5 marks)

17. (a) The compound $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ contains both chloride ions and ammonia molecules as ligands.

(i) State why chloride ions and ammonia molecules can behave as ligands.

.....

(ii) What is the oxidation state and the co-ordination number of cobalt in this complex compound?

Oxidation state of cobalt

Co-ordination number of cobalt

(iii) Suggest why the compound $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$ has a different colour from that of $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$.

.....

(4)

(b) Name and give the formula of an ammonia complex used to distinguish between aldehydes and ketones.

Name

Formula

(2)

(c) Deduce the formulae of the following complexes which contain only chloride ions as ligands.

(i) a tetrahedral complex ion of nickel(II)

.....

(ii) an octahedral complex ion of titanium(IV)

.....

(iii) a linear complex ion of copper(I)

.....

(3)

(d) Chloride ions form the tetrahedral complex ion $[\text{AlCl}_4]^-$ but fluoride ions form the octahedral complex ion $[\text{AlF}_6]^{3-}$. Suggest a reason for this difference.

.....

(1)

(Total 10 marks)

18. (a) Octahedral and tetrahedral complex ions are produced by the reaction of transition metal ions with ligands which form co-ordinate bonds with the transition metal ion. Define the term *ligand* and explain what is meant by the term *co-ordinate bond*. (3)

(a) The frequency, ν , of light absorbed by a transition metal complex ion can be determined using the relationship $\Delta E = h\nu$. State what is meant by the symbols ΔE and h . Give **three** factors which result in a change in the frequency of light absorbed as a result of the reaction of a complex ion. (5)

(Total 8 marks)

19. Transition metals form complex ions. Using actual examples of complex ions formed by transition metal ions, give the formula of

- a linear complex ion,
- a tetrahedral complex ion and
- an octahedral complex ion formed by using a bidentate ligand.

(Total 4 marks)

20. (a) Name the two shapes most commonly found in transition metal complexes and state their bond angles. For each shape, suggest the formula of a nickel(II) complex having that shape. (4)

(b) State three factors which cause a colour change in reactions of transition metal complexes. (3)

(c) Draw structures for each of the following species.

(i) $[\text{Ni}(\text{CN})_5]^{3-}$ which is trigonal bipyramidal.

(ii) $\text{Nb}_2\text{Cl}_{10}$ in which niobium is six co-ordinate and in which some chlorine atoms are bonded to both niobium atoms.

(iii) $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ in which the ethanedioate ions are bidentate.

(iv) $[\text{cis-PtCl}_2(\text{NH}_3)_2]$ which is square-planar. (8)

(Total 15 marks)