

# Transition Metals

2003 AH MC7 (60%)

7. The electronic configuration of  $\text{Co}^{2+}(\text{g})$  is

- A  $[\text{Ar}] 4s^2 3d^7$   
 B  $[\text{Ar}] 4s^2 3d^5$   
 C  $[\text{Ar}] 3d^9$   
 D  $[\text{Ar}] 3d^7$ .

**Note:**  $[\text{Ar}]$  denotes the electronic configuration of argon.

2004 AH MC8 (47%) and 2008 AH MC11 (53%)

8. The number of unpaired electrons in a gaseous  $\text{Ni}^{2+}$  ion is

- A 0  
 B 2  
 C 4  
 D 6.

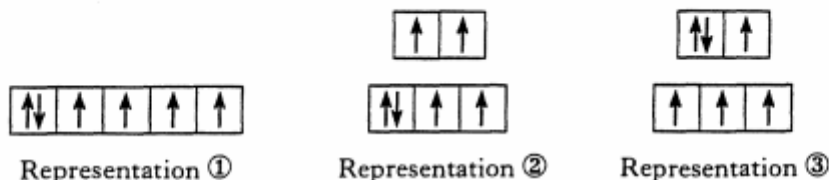
2012 AH MC2 (46%)

2. An ion,  $\text{X}^{3+}$ , contains 55 electrons.

In which block of the Periodic Table would element **X** be found?

- A s  
 B p  
 C d  
 D f

2001 AH L1a+b

1. Under certain conditions the 3d electrons in the  $\text{Fe}^{2+}$  ion can be represented as

- (a) Give the full electronic configuration for the  $\text{Fe}^{2+}$  ion in terms of s, p and d electrons. 1
- (b) The orbitals shown in representation ① are degenerate.  
 What is meant by the term "degenerate"? 1

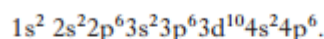
2012 AH MC3 (76%)

3. Which of the following statements is **true** about a  $\text{Co}^{2+}(\text{g})$  ion?

- A It has 5 unpaired electrons.  
 B It has 8 electrons in s orbitals.  
 C It has 13 electrons in the third shell.  
 D Its electrons with the highest energy are in 3d orbitals.

2015 AH MC2 (92%)

2. The electronic configuration of a krypton atom is



Which of the following ions does **not** have this configuration?

- A  $\text{Sr}^{2+}$   
 B  $\text{Se}^{2-}$   
 C  $\text{As}^{3-}$   
 D  $\text{Zr}^{3+}$

## 2002 AH L1c

1. At room temperature, titanium(III) chloride is a solid which dissolves in water to give a purple solution. However, titanium(IV) chloride is a liquid at room temperature which reacts vigorously with water giving off white fumes.

(c) Write the electronic configuration of the titanium(III) ion in terms of s, p and d orbitals. 1

## 2005 AH L3b

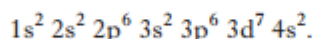
3. Different ligands may affect the redox properties of metal ions.



(b) Write the electronic configuration of the  $\text{Co}^{3+}$  ion in terms of s, p and d orbitals. 1

## 2007 AH L7a

7. The electronic configuration for cobalt, Co, in its ground state, is



(a) In terms of s, p and d orbitals, write down the electronic configurations of

(i) Cu 1

(ii)  $\text{Co}^{2+}$  1

in their ground states.

## 2008 AH L2(iii)

2. An aqueous solution of the compound  $[\text{CoCl}_2(\text{NH}_3)_4]\text{Cl}$  gave the following **transmittance** spectrum.

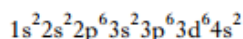
(b) The solution contains the complex ion  $[\text{CoCl}_2(\text{NH}_3)_4]^+$ .

(iii) Write down the electronic configuration of cobalt in this complex ion in terms of s, p and d orbitals. 1

## 2011 AH L4a

4. Iron and manganese are transition metals which have many uses in industry.

The electronic configuration for iron, in its ground state, is



(a) In terms of s, p and d orbitals write down the electronic configurations of

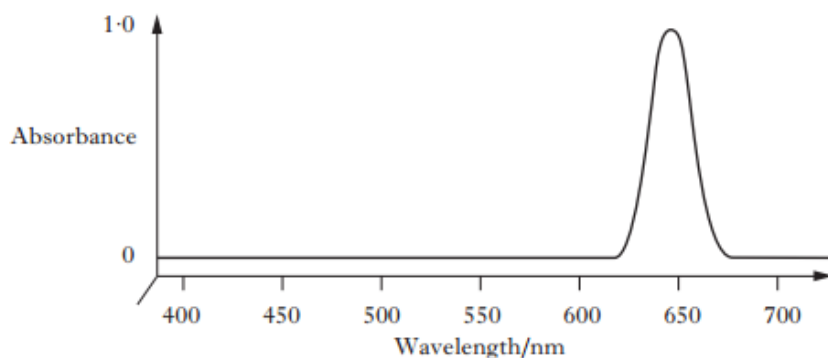
(i)  $\text{Fe}^{3+}$

(ii)  $\text{Mn}^{3+}$

in their ground states. 2

(iii) Explain why the  $\text{Fe}^{3+}$  ion is more stable than the  $\text{Mn}^{3+}$  ion. 1

5.



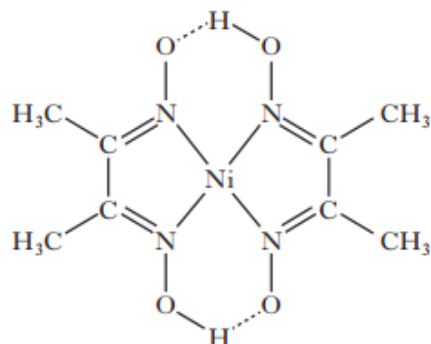
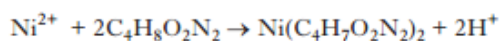
The absorption spectrum of a solution of sodium tetrachlorocobaltate(II) is shown above.

(b) Write the electronic configuration for a cobalt(II) ion in terms of s, p and d orbitals.

1

2013 revAH L5c(ii)

5. Nickel(II) ions react quantitatively with dimethylglyoxime ( $C_4H_8O_2N_2$ ) forming a complex which precipitates out as a red solid. The equation for the reaction and the structure of the complex are shown below.



Relative formula mass = 288.7

(c) The formulae of two very common ions of nickel are  $[Ni(H_2O)_6]^{2+}$  and  $[Ni(NH_3)_6]^{2+}$ .

(ii) In terms of s, p and d orbitals, write down the electronic configuration of the nickel ion in  $[Ni(H_2O)_6]^{2+}$ .

1

## Complexes

2002 AH MC18 (57%)

18. A complex ion with the name hexaammine nickel(II) will have the formula

- A  $[\text{Ni}(\text{NH}_2)_6]^{2+}$   
 B  $[\text{Ni}(\text{NH}_3)_6]^{2+}$   
 C  $[\text{Ni}(\text{NH}_3)_6]^{4+}$   
 D  $[\text{Ni}(\text{NH}_4)_6]^{2+}$ .

2009 AH MC8 (46%) and 2015 AH MC9 (55%)

8. The correct formula for the tetraamminedichlorocopper(II) complex is

- A  $[\text{Cu}(\text{NH}_3)_4\text{Cl}_2]^{2-}$   
 B  $[\text{Cu}(\text{NH}_3)_4\text{Cl}_2]$   
 C  $[\text{Cu}(\text{NH}_3)_4\text{Cl}_2]^{2+}$   
 D  $[\text{Cu}(\text{NH}_3)_4\text{Cl}_2]^{4+}$ .

2016 AH MC5 (67%)

5. The complex ion  $[\text{Cu}(\text{CN})_6]^{4-}$  is called

- A hexacyanocopper(II)  
 B hexacyanocopper(IV)  
 C hexacyanocuprate(II)  
 D hexacyanocuprate(IV).

2001 AH MC9 (64%)

9. Salts having the empirical formula  $\text{CrCl}_3(\text{H}_2\text{O})_6$  have been isolated in three isomeric forms. Analysis of one isomer showed one third of the total chlorine content was precipitated as silver(I) chloride by the addition of excess silver(I) nitrate solution.

The formula of the isomer is

- A  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{Cl}^-)_3$   
 B  $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]^{2+}(\text{Cl}^-)_2 \cdot \text{H}_2\text{O}$   
 C  $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+(\text{Cl}^-)_2 \cdot 2\text{H}_2\text{O}$   
 D  $[\text{Cr}(\text{H}_2\text{O})_3\text{Cl}_3] \cdot 3\text{H}_2\text{O}$ .

2012 AH MC7 (46%)

7. Which of the following ligands is bidentate?

- A  $\text{CN}^-$   
 B  $\text{NH}_3$   
 C  $\text{H}_2\text{O}$   
 D  $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$

2015 revAH MC7 (66%)

7. Which of the following would **not** act as a ligand in the formation of a complex with a transition metal ion?

- A  $\text{O}^{2-}$   
 B  $\text{NH}_2\text{C}_2\text{H}_4\text{NH}_2$   
 C  $\text{C}_2\text{H}_5\text{NH}_3^+$   
 D  $\begin{array}{c} \text{COO}^- \\ | \\ \text{COO}^- \end{array}$

2015 revAH MC8 (65%)

8. What is the co-ordination number of the transition metal in  $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})_2]\text{Cl}_3$ ?

- A 3  
 B 4  
 C 6  
 D 9

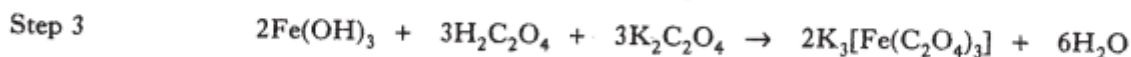
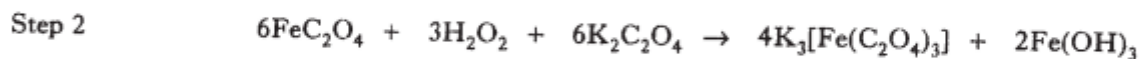
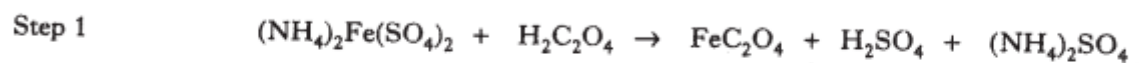
2003 AH MC5 (63%)

5. A  $0.1 \text{ mol l}^{-1}$  solution of metal ions ( $\text{M}^+$ ) was mixed in varying proportions with a  $0.1 \text{ mol l}^{-1}$  solution of a neutral ligand (L) giving coloured solutions. Each mixture was placed in a colorimeter and the absorbance measured.

Maximum absorbance was obtained when  $3.5 \text{ cm}^3$  of the metal ion solution was mixed with  $7.0 \text{ cm}^3$  of the ligand solution. The formula of the complex ion formed is most likely to be

- A  $[\text{ML}_2]^+$   
 B  $[\text{ML}_2]^{2+}$   
 C  $[\text{M}_2\text{L}]^+$   
 D  $[\text{M}_2\text{L}]^{2+}$ .

4. The bright green compound, potassium trioxalatoferrate(III), has the formula  $K_3[Fe(C_2O_4)_3]$ . It can be prepared from ammonium iron(II) sulphate,  $(NH_4)_2Fe(SO_4)_2$ , in three steps as shown by the equations below.

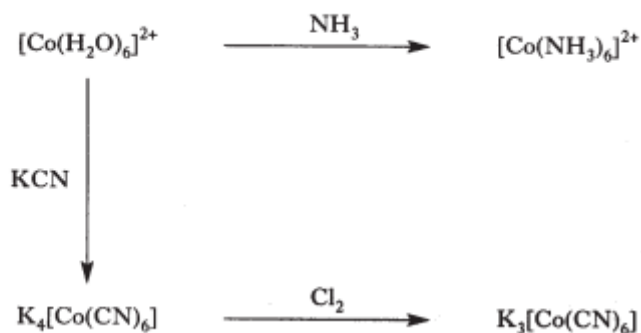


A student, starting with 5.0 g of hydrated ammonium iron(II) sulphate,  $(NH_4)_2Fe(SO_4)_2 \cdot 6H_2O$ , obtained 1.2 g of the hydrated product  $K_3[Fe(C_2O_4)_3] \cdot 3H_2O$ .

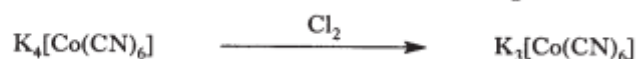
- (a) What is the value of the co-ordination number of the iron ion in the final product? 1

2004 AH L5b+c

5. Consider the following reactions.



- (b) Name the  $[Co(NH_3)_6]^{2+}$  ion. 1  
 (c) What is the function of the chlorine in the following reaction?



2005 AH L3a

3. Different ligands may affect the redox properties of metal ions.



- (a) Why can ammonia and water molecules act as ligands? 1

2008 AH L2b(ii)

2. An aqueous solution of the compound  $[CoCl_2(NH_3)_4]Cl$  gave the following **transmittance** spectrum.

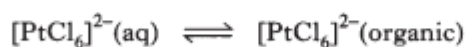
- (b) The solution contains the complex ion  $[CoCl_2(NH_3)_4]^+$ .

- (ii) Name this complex ion. 1

2005 AH L5a(i)

5. Solvent extraction is a technique used in the extraction of platinum from its ore. This extraction makes use of the fact that platinum complexes have different solubilities in aqueous hydrochloric acid and in organic solvents.

(a) When platinum complexes are extracted, an equilibrium is established.

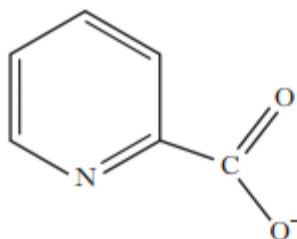


(i) Name the  $[\text{PtCl}_6]^{2-}$  ion.

1

2007 AH L9a+c

9. A common dietary supplement taken by athletes and slimmers is called chromium picolinate  $[\text{Cr}(\text{pic})_3]$ . The structure of the picolinate ion, pic, is



(a) What feature of the picolinate ion makes it suitable for use as a ligand?

1

(c) A simpler complex of chromium is  $[\text{Cr}(\text{CN})_6]^{4-}$ . What is its systematic name?

1

2010 AH L2

2. Complex ions **A** and **B** are isomeric and have the formula  $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+$ .

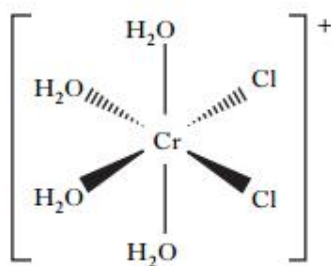
(a) Calculate the oxidation number of chromium in the complex ion.

1

(b) Name the complex ion.

1

(c) The structural formula for complex ion **A** is



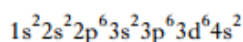
Draw the structural formula for complex ion **B**.

1

2011 AH 4c

4. Iron and manganese are transition metals which have many uses in industry.

The electronic configuration for iron, in its ground state, is



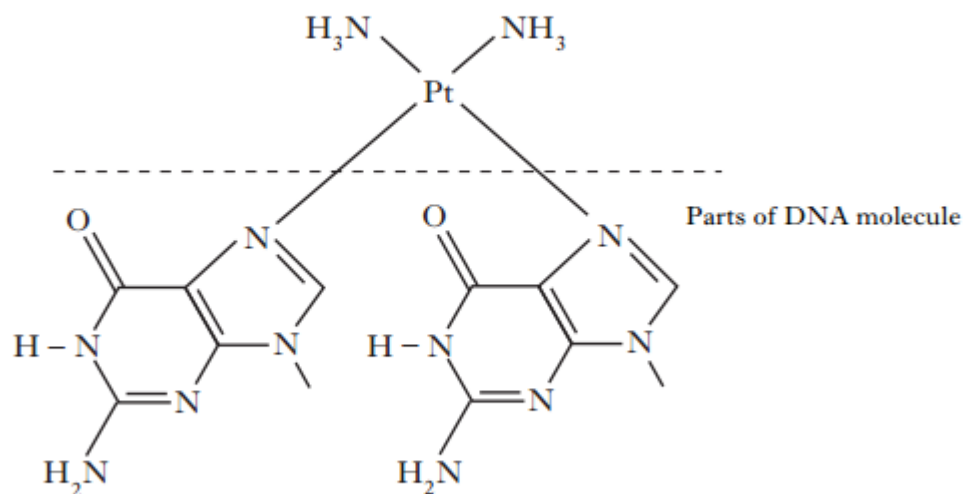
(c) Transition metals can form a wide variety of complexes. One such complex is ammonium tetrachlorocuprate(II).

Write the formula for this complex.

1

4. *cis*-Platin is a highly successful anti-cancer drug. The formula for *cis*-platin is  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ .

(a) *cis*-Platin works by forming a complex with parts of a DNA molecule. These parts of the DNA form bonds through nitrogen atoms to  $\text{Pt}(\text{NH}_3)_2$  as shown below.



- (i) Explain why DNA can be classified as a bidentate ligand in this complex. 1
- (ii) What feature of the DNA makes it suitable as a ligand? 1

2012 AH L2c

2. The nitrate ion,  $\text{NO}_3^-$ , can be converted into either nitrous acid,  $\text{HNO}_2$  or nitrogen monoxide,  $\text{NO}$ . The oxidation state of nitrogen in  $\text{NO}$  is +2.

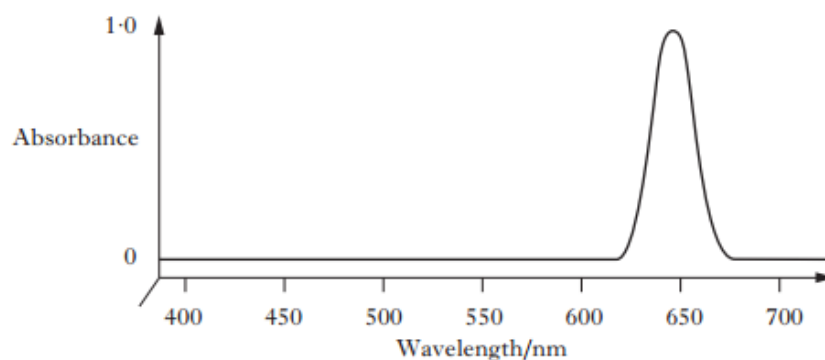
(c) Nitrogen is also present in the cyanide ion,  $\text{CN}^-$ .

Name the complex ion  $[\text{Cu}(\text{CN})_2]^-$ .

1

2013 AH L5c

5.



The absorption spectrum of a solution of sodium tetrachlorocobaltate(II) is shown above.

(c) Write the formula for the tetrachlorocobaltate(II) ion.

1

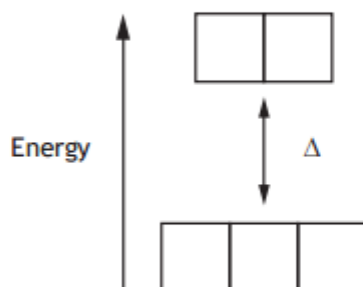
3. Iron can form a variety of complexes with different ligands. Each complex has different properties.

(a) Some iron complex ions are paramagnetic. Paramagnetic substances are substances that are weakly attracted by a magnetic field.

Paramagnetism is caused by the presence of unpaired electrons.

In both  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  and  $[\text{Fe}(\text{CN})_6]^{4-}$ , the  $\text{Fe}^{2+}$  ion has six d-electrons, but only  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  is paramagnetic.

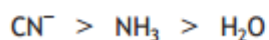
(i) Complete the d-orbital box diagram for the complex ion  $[\text{Fe}(\text{CN})_6]^{4-}$ . 1



(An additional diagram, if required, can be found on *Page 28*)

(ii) The relative ability of a ligand to split the d-orbitals when forming a complex ion is given by the spectrochemical series.

The spectrochemical series for some ligands is shown below.



The  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  ion has unpaired electrons and is therefore paramagnetic.


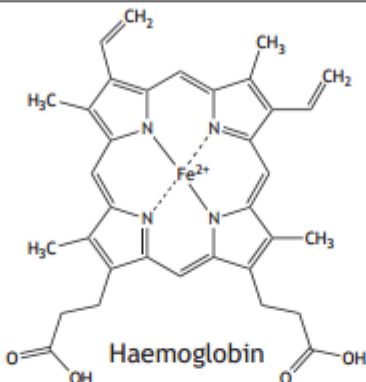

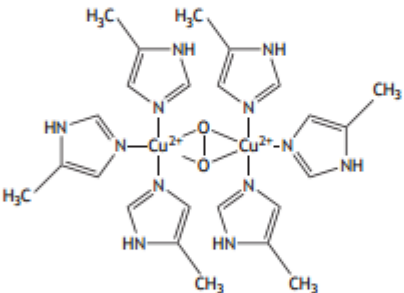

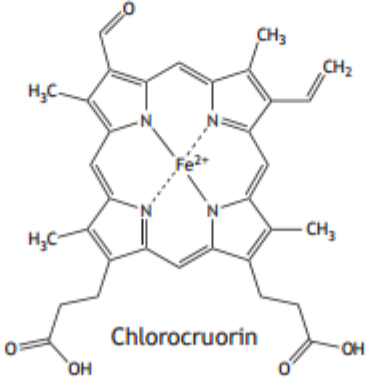
Explain how unpaired electrons can arise in this complex ion. 2

(iii) Explain why all of the complex ions formed by the  $\text{Fe}^{3+}$  ion are paramagnetic. 1



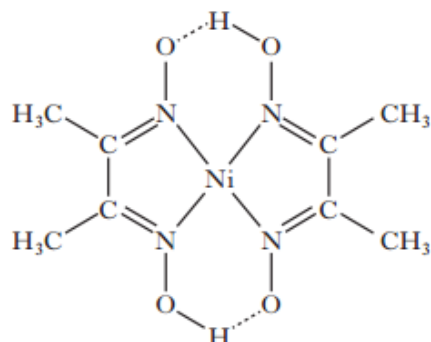
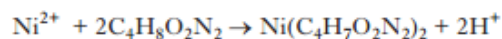
## 3. (continued)

- (b) Human blood is red due to the presence of haemoglobin bonded to oxygen. Other animals have different coloured blood due to the presence of different complex ions bonded to oxygen.

Animal	Complex ion	Colour of blood
 Human	 Haemoglobin	RED
 Spider	 Oxyhaemocyanin	BLUE
 Leech	 Chlorocruorin	GREEN

- (i) State the co-ordination number of the  $\text{Fe}^{2+}$  ion in haemoglobin. 1
- (ii) Spiders' blood contains the oxyhaemocyanin complex ion. Oxyhaemocyanin contains copper ions.  
Suggest an analytical technique that could be used to determine the presence of copper ions in spiders' blood. 1
- (iii) Using your knowledge of chemistry, comment on why these animals have different coloured blood. 3

5. Nickel(II) ions react quantitatively with dimethylglyoxime ( $C_4H_8O_2N_2$ ) forming a complex which precipitates out as a red solid. The equation for the reaction and the structure of the complex are shown below.

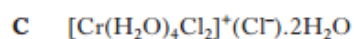
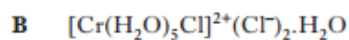
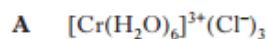


Relative formula mass = 288.7

- (a) What is the coordination number of nickel in the complex? 1
- (c) The formulae of two very common ions of nickel are  $[Ni(H_2O)_6]^{2+}$  and  $[Ni(NH_3)_6]^{2+}$ .
- (i) Name the complex ion  $[Ni(H_2O)_6]^{2+}$ . 1

## 2014 AH L4a+b

4. A chromium compound is known to exist in the following three isomeric forms. The co-ordination number of chromium is the same in each isomer.



- (a) State the co-ordination number. 1
- (b) Name the complex ion in isomer **A**. 1

# Oxidation State

2002 AH MC19 (75%) and 2014 AH MC8 (82%) and 2014 revAH MC11 (83%)

19. The highest oxidation state of chlorine is present in

- A HClO
- B HClO<sub>2</sub>
- C HClO<sub>3</sub>
- D HClO<sub>4</sub>.

2013 AH MC14 (69%) and 2013 revAH MC10 (71%)

14. In which of the following reactions does the oxidation state of copper neither increase nor decrease?

- A  $\text{Zn} + \text{CuSO}_4 \rightarrow \text{ZnSO}_4 + \text{Cu}$
- B  $\text{CuSO}_4 + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4]\text{SO}_4$
- C  $\text{FeCl}_2 + \text{CuCl}_2 \rightarrow \text{FeCl}_3 + \text{CuCl}$
- D  $\text{Cu} + 4\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{H}_2\text{O} + 2\text{NO}_2$

2001 AH MC5 (85%)

5. Manganese is in oxidation state +5 in

- A  $\text{MnO}_4^-$
- B  $\text{MnO}_4^{2-}$
- C  $\text{MnO}_4^{3-}$
- D  $[\text{Mn}(\text{CN})_6]^{3-}$ .

2008 AH MC10 (74%)

10. Which of the following involves oxidation?

- A  $\text{MnO}_4^- \rightarrow \text{MnO}_4^{2-}$
- B  $\text{Ag}^+ \rightarrow [\text{Ag}(\text{NH}_3)_2]^+$
- C  $[\text{Fe}(\text{CN})_6]^{4-} \rightarrow [\text{Fe}(\text{CN})_6]^{3-}$
- D  $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} \rightarrow [\text{Ni}(\text{CN})_4]^{2-}$

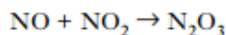
2003 AH MC4 (55%)

4. In which species does vanadium have the highest oxidation state?

- A  $\text{VOF}_3$
- B  $\text{V}(\text{OH})_2$
- C  $\text{VCl}_4$
- D  $\text{VSO}_4 \cdot 7\text{H}_2\text{O}$

2011 AH L3a

3. When a mixture of nitrogen monoxide and nitrogen dioxide is cooled to  $-20^\circ\text{C}$  they react to form the clear blue liquid, dinitrogen trioxide.



(a) The oxidation state of nitrogen is **different** in each of these three compounds.

Calculate the oxidation states of the nitrogen in NO and NO<sub>2</sub> respectively.

**1**

2012 AH L2a

2. The nitrate ion, NO<sub>3</sub><sup>-</sup>, can be converted into either nitrous acid, HNO<sub>2</sub> or nitrogen monoxide, NO.

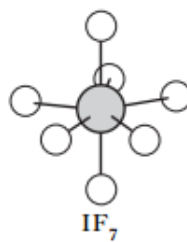
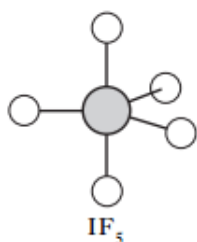
The oxidation state of nitrogen in NO is +2.

(a) Calculate the oxidation state of nitrogen in

- (i) NO<sub>3</sub><sup>-</sup>
- (ii) HNO<sub>2</sub>.

**1**

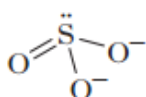
12. Many interhalogen compounds exist. Two of these are iodine pentafluoride and iodine heptafluoride.



- (a) What are the oxidation states of iodine in iodine pentafluoride and iodine heptafluoride? 1

2014 AH L2c

2. A resonance structure for the sulphite ion is



- (c) What is the oxidation number of sulphur in the sulphite ion? 1

2015 AH L3b and 2015 revAH L5

3. Vanadium is a transition metal which exhibits different oxidation states. This property allows it to be used in electrochemical cells and also gives rise to different coloured solutions.

- (b) A classic chemistry demonstration involves vanadium changing oxidation states.

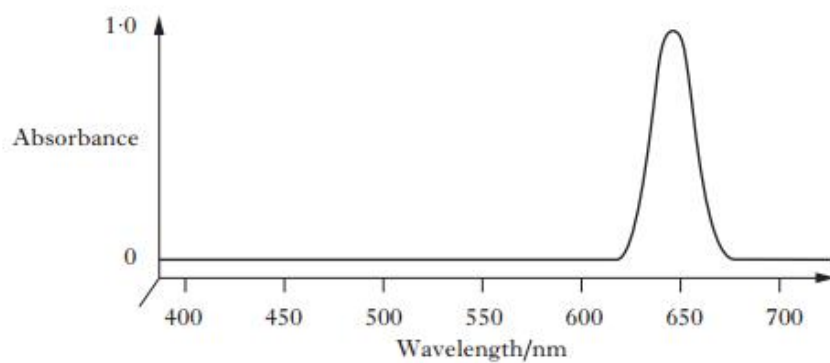
Some zinc metal is added to a flask containing an acidified solution of the dioxovanadium(V) ion, VO<sub>2</sub><sup>+</sup>(aq). The flask is stoppered with some cotton wool and gently swirled. The colour of the solution turns from yellow to blue. Further swirling turns the solution from blue to green. Finally, the flask is shaken vigorously and a violet colour is produced.



- (i) Determine the oxidation number of vanadium in the blue VO<sup>2+</sup>(aq) ion. 1
- (ii) It was observed during the demonstration that the yellow solution turned green before turning blue in reaction  $\textcircled{1}$ .  
Suggest a reason for this. 1
- (iii) In reaction  $\textcircled{3}$  V<sup>2+</sup>(aq) ions are produced.  
How many d electrons does a V<sup>2+</sup>(aq) ion have? 1
- (iv) When the cotton wool stopper is removed the violet solution slowly changes back to blue.  
Suggest why this happens. 1

2013 AH L5a

5.

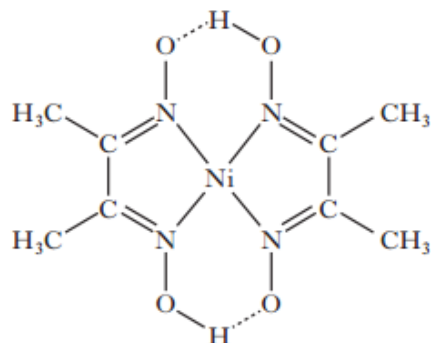
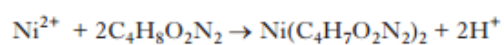


The absorption spectrum of a solution of sodium tetrachlorocobaltate(II) is shown above.

(a) Predict the most likely colour of the solution.

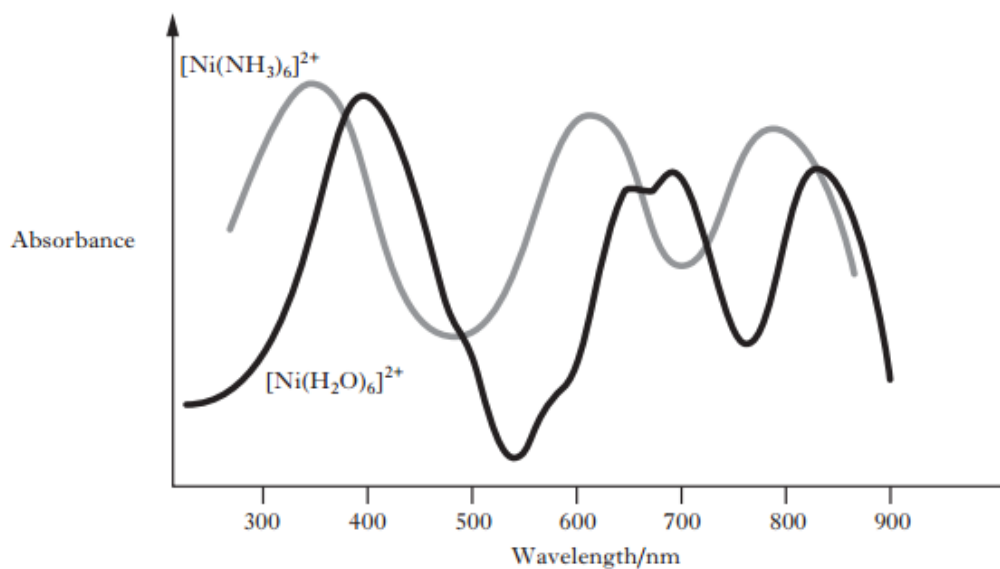
1

5. Nickel(II) ions react quantitatively with dimethylglyoxime ( $C_4H_8O_2N_2$ ) forming a complex which precipitates out as a red solid. The equation for the reaction and the structure of the complex are shown below.



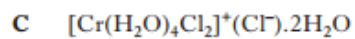
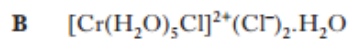
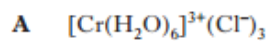
Relative formula mass = 288.7

5. (d)



- (i) Why is  $[Ni(H_2O)_6]^{2+}(Cl^-)_2(aq)$  likely to be green? 1
- (ii) Explain why the peaks in the absorption spectrum of  $[Ni(NH_3)_6]^{2+}$  are at shorter wavelengths. 2
- (iii) Predict the colour of  $[Ni(NH_3)_6]^{2+}(Cl^-)_2(aq)$ . 1

4. A chromium compound is known to exist in the following three isomeric forms. The co-ordination number of chromium is the same in each isomer.



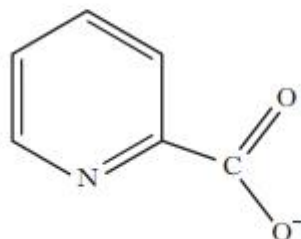
- (c) All three forms have different colours in solution.

(i) Explain how colour arises in transition metal compounds such as those above. 2

(ii) Suggest why the three solutions have different colours. 1

2007 AH MC9

9. A common dietary supplement taken by athletes and slimmers is called chromium picolinate  $[\text{Cr}(\text{pic})_3]$ . The structure of the picolinate ion, pic, is



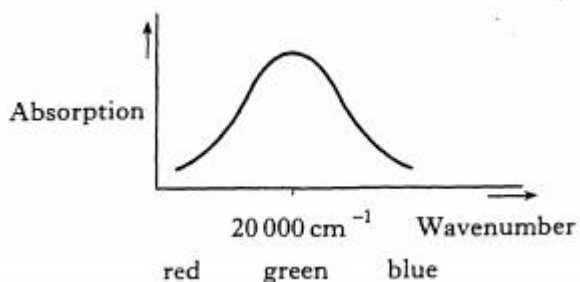
- (b) In the body, it is thought that the chromium in  $[\text{Cr}(\text{pic})_3]$  is changed into chromium(VI) by the action of hydrogen peroxide.
- (i) What is the oxidation state of chromium in  $[\text{Cr}(\text{pic})_3]$ ? 1
- (ii) What is the role of hydrogen peroxide in this reaction? 1

2008 AH L2b(i)

2. An aqueous solution of the compound  $[\text{CoCl}_2(\text{NH}_3)_4]\text{Cl}$  gave the following **transmittance** spectrum.
- (b) The solution contains the complex ion  $[\text{CoCl}_2(\text{NH}_3)_4]^+$ .
- (i) What is the oxidation number of cobalt in this complex ion? 1



2001 AH MC2 (88%)



2. The colour which would be observed is
- A blue
  - B green
  - C purple
  - D yellow.

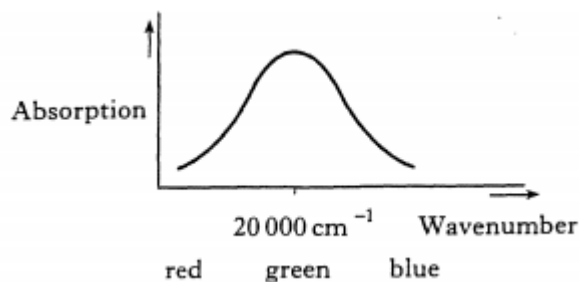
2003 AH MC2 (80%)

2. An aqueous solution of potassium permanganate is coloured purple. In which region of the visible spectrum is it absorbing?
- A Red
  - B Orange
  - C Green
  - D Violet

2015 revAH MC9 (62%)

9. Which of the following solids would form a colourless aqueous solution?
- A  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$
  - B  $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$
  - C  $\text{K}_2\text{CrO}_4$
  - D  $\text{CoCl}_2$

2001 AH MC3 (65%)



3. The colour is caused by
- A electrons absorbing energy to jump from one d orbital to another d orbital
  - B excited electrons dropping to the ground state
  - C electrons absorbing energy to jump from the first to the second shell
  - D electrons absorbing energy to jump from the second to the third shell.

2004 AH MC9 (54%) and 2011 AH MC10 (52%)

9. Which of the following ions is **least** likely to be coloured?
- A  $\text{Ti}(\text{H}_2\text{O})_6^{3+}$
  - B  $\text{Cr}(\text{NH}_3)_6^{3+}$
  - C  $\text{Ni}(\text{H}_2\text{O})_6^{2+}$
  - D  $\text{Zn}(\text{NH}_3)_4^{2+}$

2011 AH MC2 (81%)

2. In colorimetry, as the concentration of a coloured solution decreases
- A the absorbance increases
  - B the absorbance decreases
  - C the radiation wavelength increases
  - D the radiation wavelength decreases.

2014 revAH MC4 (92%)

4. The colour of a highly concentrated ionic solution which absorbs light only in the ultra-violet region of the electromagnetic spectrum is
- A red
  - B black
  - C violet
  - D colourless.

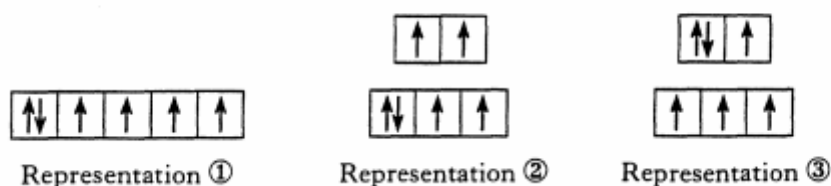
2012 AH MC4 (37%)

4. In absorption spectroscopy, as the concentration of an ionic solution decreases, the radiation transmitted
- A increases in intensity
  - B decreases in intensity
  - C increases in wavelength
  - D decreases in wavelength.

2014 AH MC4 (76%) and 2014 revAH MC7 (82%)

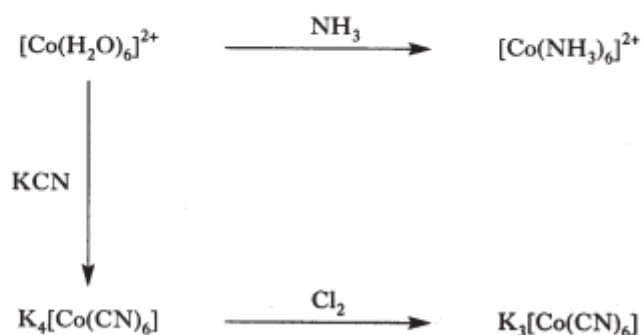
4. In absorption spectroscopy, as the concentration of an ion in solution increases, there is an increase in the
- A wavelength of radiation absorbed
  - B frequency of radiation absorbed
  - C intensity of radiation absorbed
  - D intensity of radiation transmitted.

1. Under certain conditions the 3d electrons in the  $\text{Fe}^{2+}$  ion can be represented as



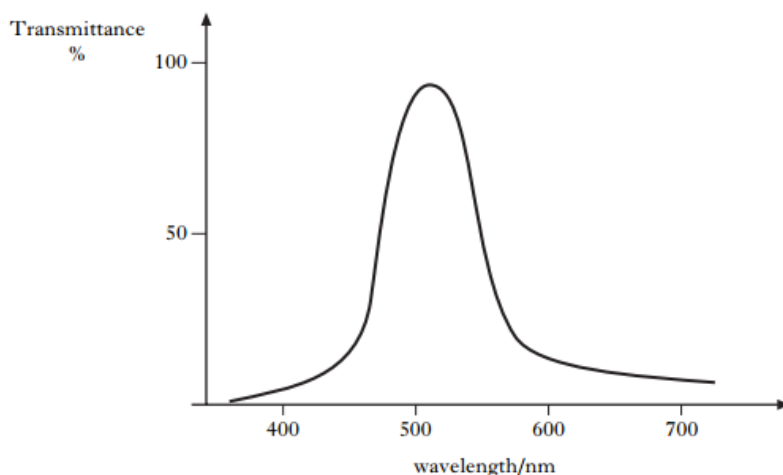
- (c) (i) Under which conditions could representation ① exist? 1
- (ii) Under which conditions could representation ② exist? 1
- (iii) What could cause the electronic configuration of the  $\text{Fe}^{2+}$  ion to change from representation ② to representation ③? 1

5. Consider the following reactions.



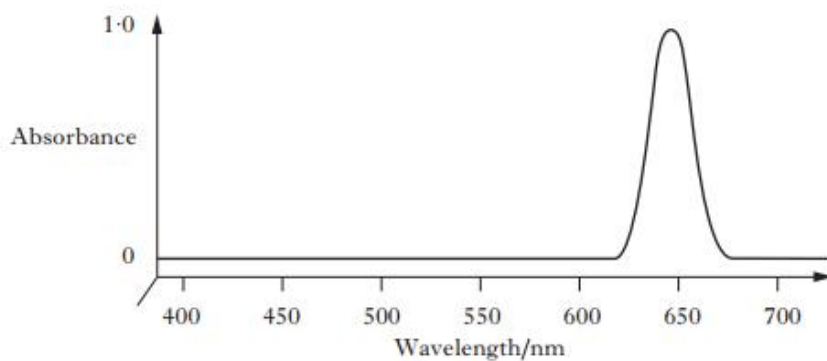
- (d) There is a colour change when  $\text{NH}_3$  is added to  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ .  
 Why does this change of ligand result in different wavelengths of light being absorbed? 1

2. An aqueous solution of the compound  $[\text{CoCl}_2(\text{NH}_3)_4]\text{Cl}$  gave the following **transmittance** spectrum.



- (a) From the above spectrum, deduce the colour of the solution. 1

5.



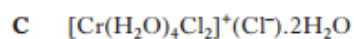
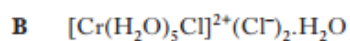
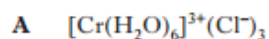
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1

## 2014 AH L4

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(c) All three forms have different colours in solution.

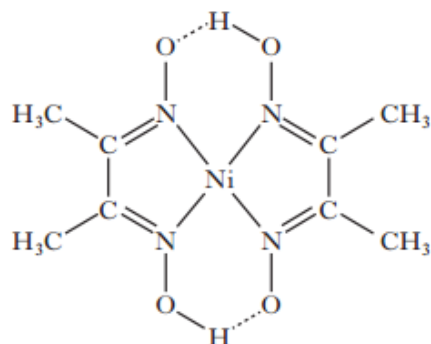
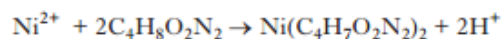
(i) Explain how colour arises in transition metal compounds such as those above.

2

(ii) Suggest why the three solutions have different colours.

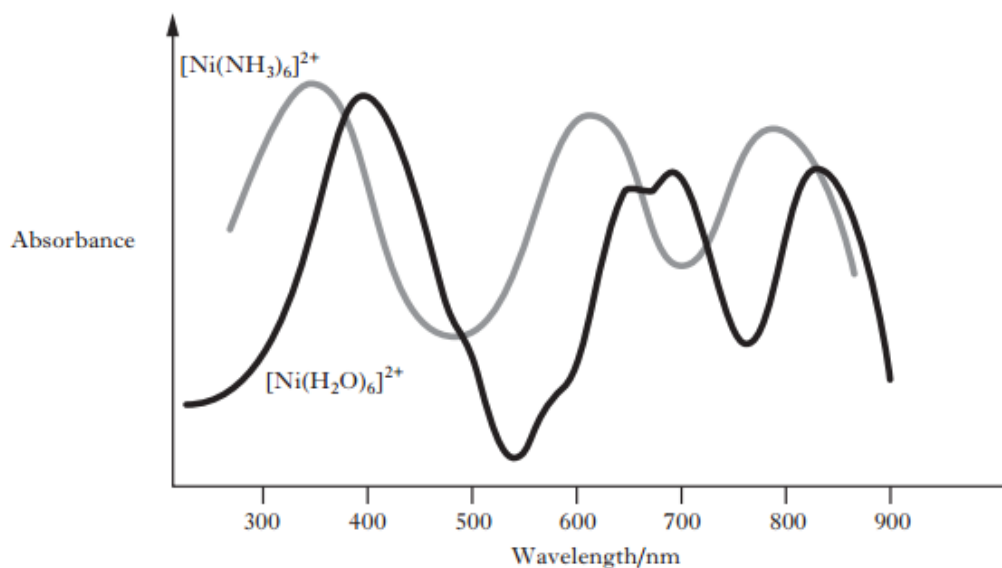
1

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