28. Chemistry of transition elements

28.4 Stereoisomerism in transition element complexes

Paper 4

Question Paper

1 **(e)** The $[Fe(C_2O_4)_3]^{3-}$ complex ion shows stereoisomerism.

Complete the three-dimensional diagrams in Fig. 3.1 to show the **two** stereoisomers of $[Fe(C_2O_4)_3]^{3-}$.

The $C_2O_4^{2-}$ ligand can be represented using  .

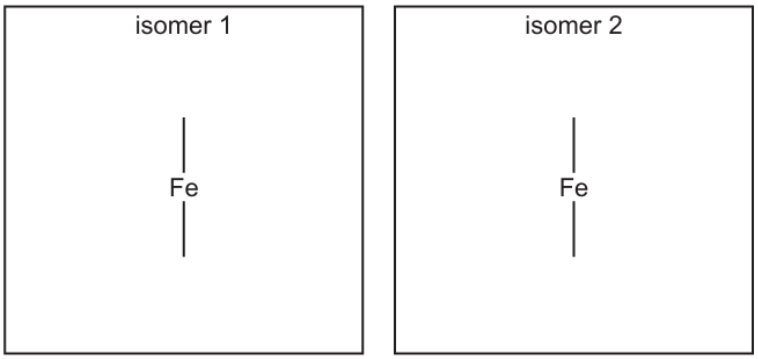


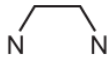
Fig. 3.1

[2]

2 **(e)** Ruthenium(III) ions, Ru^{3+}, form an octahedral complex, $[Ru(dpys)_2Cl_2]^+$, with the ligands *dpys* and chloride ions.

This complex shows the same kind of stereoisomerism as $[Ru(NH_3)_4Cl_2]^+$ but also shows a different type of stereoisomerism.

(i) Complete the three-dimensional diagrams in Fig. 4.3 to show the **three** different stereoisomers of $[Ru(dpys)_2Cl_2]^+$.

The *dpys* ligand can be represented using 

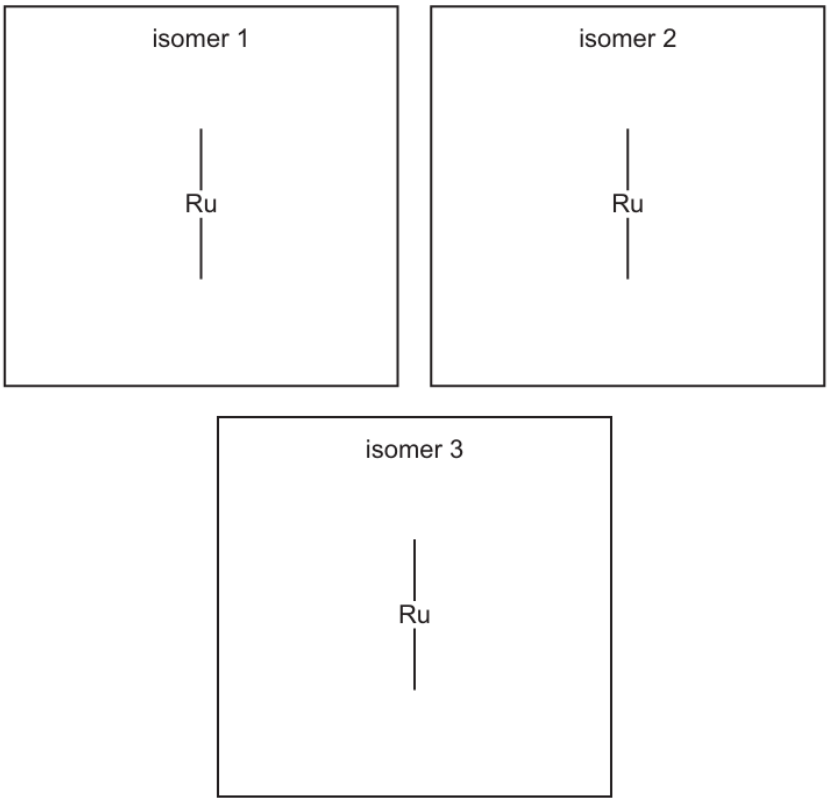


Fig. 4.3

[3]

(ii) State the different types of stereoisomerism shown by $[Ru(dpys)_2Cl_2]^+$.

..... [1]

(iii) Deduce which stereoisomers in **(e)(i)** are **non-polar**. Explain your answer.

.....

..... [1]

3 Ni^{2+} ions form a number of different complex ions, including $[Ni(H_2O)_6]^{2+}$, $[Ni(NH_3)_6]^{2+}$ and $[Ni(en)_3]^{2+}$.

The abbreviation *en* represents 1,2-diaminoethane. The numerical values of two stability constants, K_{stab}, are given in Table 5.1.

Table 5.1

complex	K_{stab}
$[Ni(NH_3)_6]^{2+}$	4.8×10^7
$[Ni(en)_3]^{2+}$	2.0×10^{18}

(c) Complete Fig. 5.1 to show the three-dimensional structures of the two isomers of $[Ni(en)_3]^{2+}$.

Use  to represent the *en* ligand.

Name the type of isomerism shown.

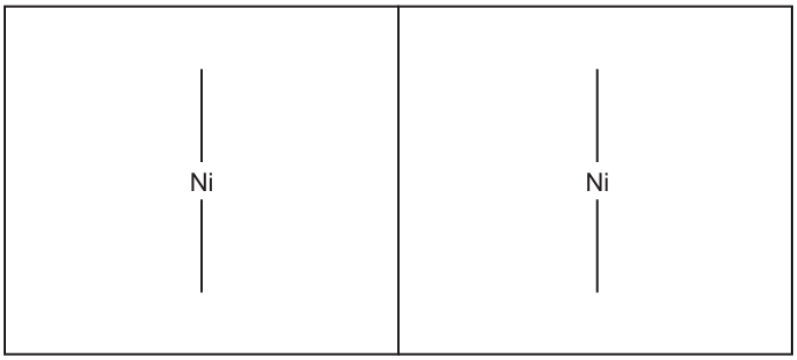


Fig. 5.1

type of isomerism shown .....

[3]

4 **(a)** Some transition element complexes can show stereoisomerism.

State **two** types of stereoisomerism shown by transition element complexes.

1 .....

2 .....

[1]

(c) The complex $[Cr(en)_3]^{2+}$ exists as two stereoisomers whereas the complex $[Cr(OCH_2CH_2NH_2)_3]^-$ exists as four stereoisomers.

Complete the three-dimensional diagrams in Fig. 2.1 to show the four stereoisomers of $[Cr(OCH_2CH_2NH_2)_3]^-$.

Represent the ligand $^-OCH_2CH_2NH_2$ by using 

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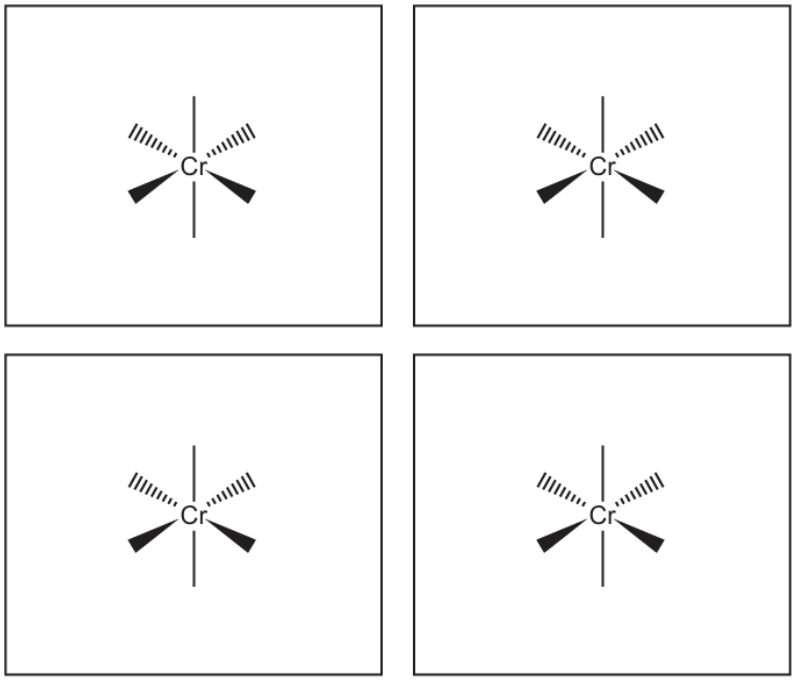


Fig. 2.1

[3]

5 **(c)** The ethanedioate ion, $C_2O_4^{2-}$, can act as a bidentate ligand.

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

.....

.....

..... [2]

(ii) The complex $[Co(H_2O)_2(C_2O_4)BrCl]^-$ exists as stereoisomers.

Complete the three-dimensional diagrams in Fig. 2.2 to show **four** stereoisomers of $[Co(H_2O)_2(C_2O_4)BrCl]^-$.

The $C_2O_4^{2-}$ ligand is represented using O⌒O.

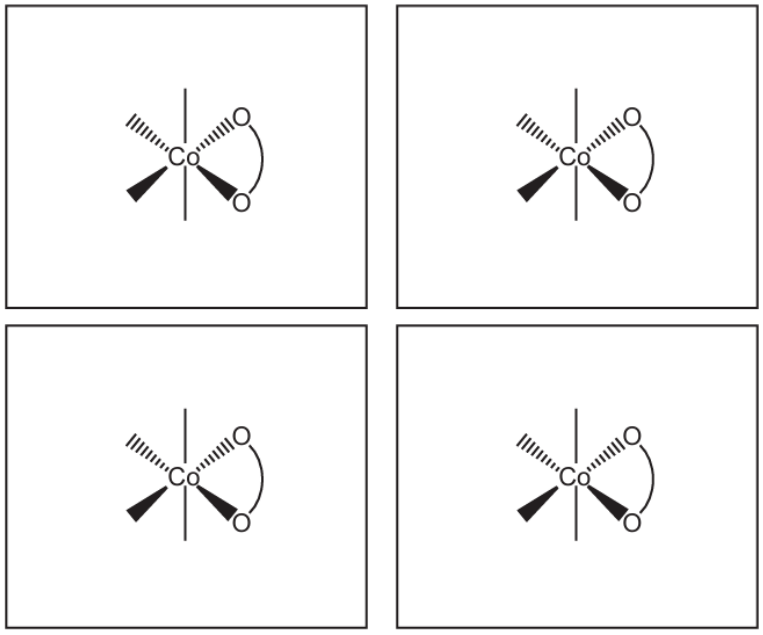


Fig. 2.2

[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]

6 **(b)** Nickel forms the octahedral complex $[Ni(en)_2(H_2O)_2]^{2+}$. This complex can exist in three isomeric forms, listed in Table 6.2.

One of these forms is a trans isomer, the other forms are two different cis isomers.

Table 6.2

isomer	polarity
trans isomer	
cis isomer 1	
cis isomer 2	

(i) Complete Table 6.2 using the terms polar or non-polar.

Each term may be used once, more than once, or not at all. [1]

(ii) Describe the difference between cis isomer 1 and cis isomer 2.

.....

..... [1]

7 **(b)** The formulae of six complexes are given in Table 6.1.

The abbreviation *en* is used for 1,2-diaminoethane.

The abbreviation *dien* is used for the tridentate ligand $H_2NCH_2CH_2NHCH_2CH_2NH_2$.

The *dien* ligand forms three bonds to the gold ion in $[Au(dien)(H_2O)_2Cl]^{2+}$ and $Au(dien)Cl_3$.

These three bonds all lie in the same plane.

The CO ligand coordinates through the carbon atom in $[Rh(CO)_2Cl_2]^+$.

Table 6.1

formula	isomerism shown	geometry
$[Rh(en)_2Cl_2]^+$	yes	
$[Rh(CO)_2Cl_2]^+$	yes	
$[Au(dien)(H_2O)_2Cl]^{2+}$		
$Au(dien)Cl_3$	no	octahedral
$Ni(PH_3)_2Cl_2$	no	
$[Ni(H_2O)_2(NH_3)_4]^{2+}$	yes	

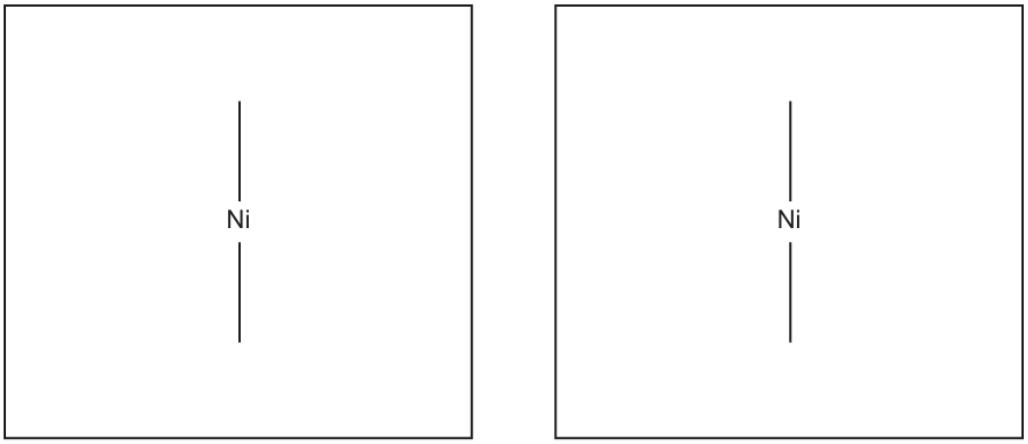
(v) One of the complexes, $[Rh(en)_2Cl_2]^+$ or $[Rh(CO)_2Cl_2]^+$, can exist in three isomeric forms.

Identify this complex and the types of isomerism shown.

.....

..... [1]

(vi) Draw the three-dimensional structures of the two isomers of $[Ni(H_2O)_2(NH_3)_4]^{2+}$ in the boxes and identify the type of isomerism shown.



type of isomerism shown .....

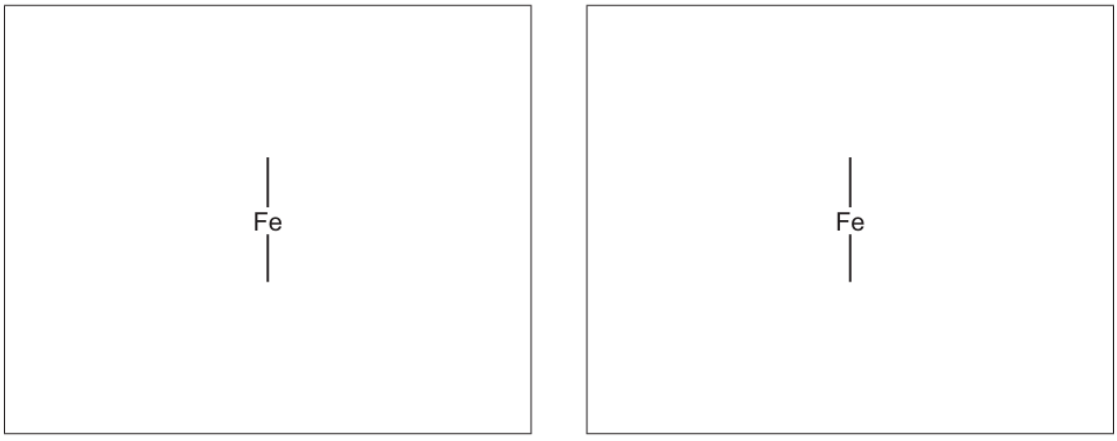
[2]

8 **(b)** **(ii)** The complex $[Fe(bipy)_3]^{2+}$ exists as two stereoisomers.

Complete the three-dimensional diagrams to show the two stereoisomers of $[Fe(bipy)_3]^{2+}$.

State the type of stereoisomerism shown.

Use  to represent bipy in your diagrams.

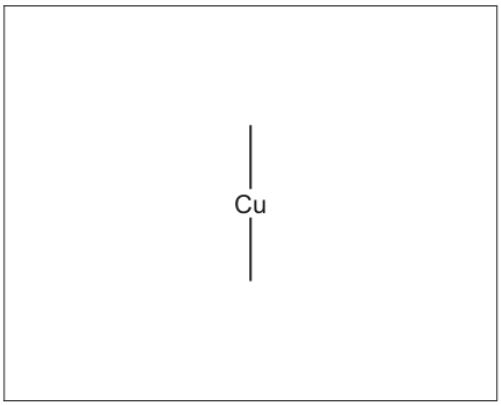


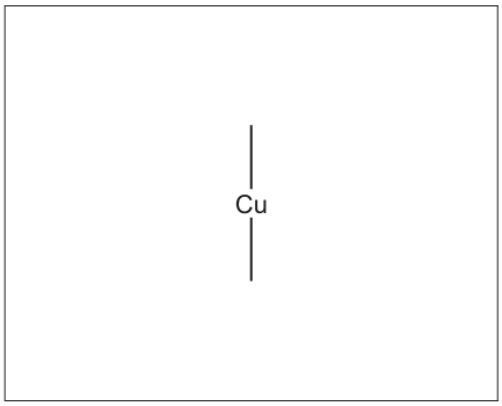
type of stereoisomerism .....

[3]

9 **(e)** There are two possible stereoisomers with the formula $[Cu(NH_3)_4(H_2O)_2]^{2+}$.

Draw three-dimensional diagrams to show the two stereoisomers.





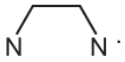
[2]

10 A transition element is a d-block element which forms one or more stable ions with incomplete d-orbitals.

(b) The Ni^{2+} ion forms many different complexes. A solution containing the $[Ni(H_2O)_6]^{2+}$ complex ion is green. When an excess of 1,2-diaminoethane, *en*, $H_2NCH_2CH_2NH_2$, is added, the colour of the solution changes to blue. This is due to the formation of the $[Ni(en)_3]^{2+}$ complex ion.

(ii) The $[Ni(en)_3]^{2+}$ complex can exist as a mixture of two stereoisomers.

Complete the three-dimensional diagram to show one of the stereoisomers.

Each *en* ligand can be represented using 

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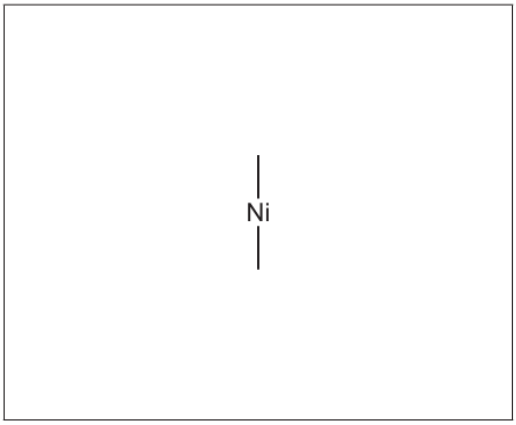


[1]

(iii) Name the geometry of the complex ion drawn in **(b)(ii)** and the type of stereoisomerism shown by $[Ni(en)_3]^{2+}$.

geometry .....

stereoisomerism shown .....

[1]

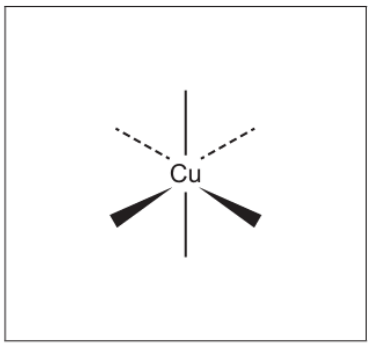
11 An aqueous solution of copper(II) sulfate is a blue colour due to the presence of $[Cu(H_2O)_6]^{2+}$ complex ions.

(b) If an excess of ammonia is added to a solution of $[Cu(H_2O)_6]^{2+}$ a deep blue solution containing $[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex ions is formed.

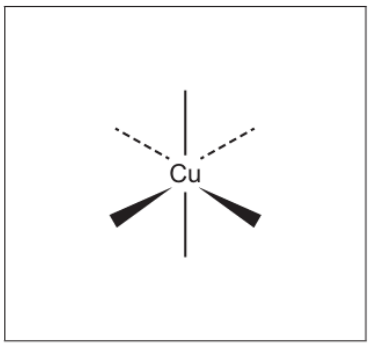
(i) There are two possible stereoisomers with the formula $[Cu(NH_3)_4(H_2O)_2]^{2+}$.

Complete the diagrams to show the two stereoisomers in the boxes below.

isomer 1



isomer 2



[1]

(ii) Use your answer in **(b)(i)** to deduce whether each of these isomers is polar or non-polar.

polarity of isomer 1 .....

polarity of isomer 2 .....

[1]

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

(c) Cu^{2+} forms a complex ion containing water molecules and ethanedioate ions, $C_2O_4^{2-}$, as ligands. The formula of the complex is $[Cu(C_2O_4)_2(H_2O)_2]^{2-}$. The ethanedioate ion is a bidentate ligand.

(i) Explain what is meant by bidentate.

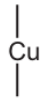
.....

..... [1]

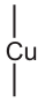
(ii) There are three stereoisomers with the formula $[Cu(C_2O_4)_2(H_2O)_2]^{2-}$.

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

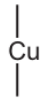
stereoisomer 1



stereoisomer 2



stereoisomer 3



[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]

13 **(c)** The $[Co(NH_3)_3Cl_3]$ complex shows stereoisomerism.

Complete the three-dimensional diagrams to show the two isomers of $[Co(NH_3)_3Cl_3]$.

Suggest the type of stereoisomerism.

type of stereoisomerism .....

[2]

14 **(d)** The complex ion $[NiBr_2(CN)_2]^{2-}$ shows stereoisomerism.

Draw diagrams to show the two isomers of $[NiBr_2(CN)_2]^{2-}$. Name the type of stereoisomerism.

isomer 1	isomer 2

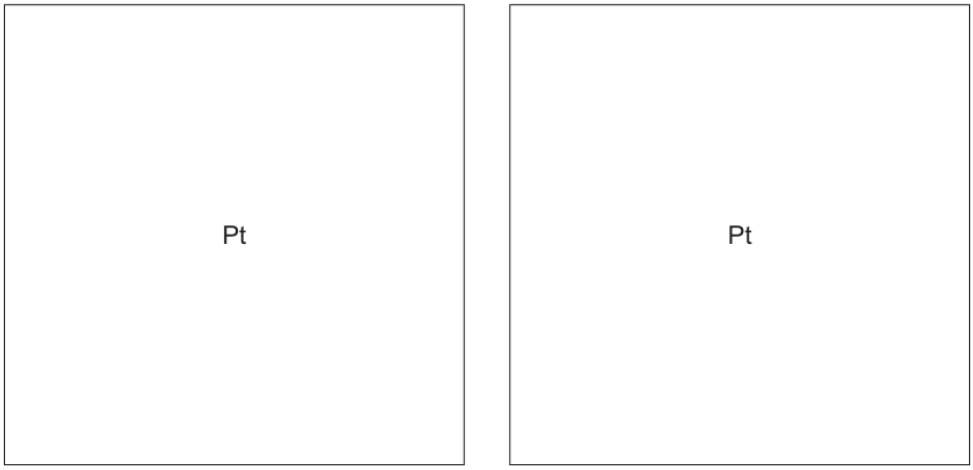
type of stereoisomerism .....

[2]

15 **(c)** Platinum forms a complex ion with the formula $[Pt(CN)_2Cl_2]^{2-}$. In this complex ion the carbon atom of each CN^- ligand bonds to the platinum ion. This complex shows stereoisomerism.

(i) There are only two isomers of this complex.

Draw structures of these two isomers in the boxes below.



[1]

(ii) Describe the geometry of $[Pt(CN)_2Cl_2]^{2-}$.

..... [1]

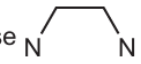
(iii) Name the type of stereoisomerism shown by $[Pt(CN)_2Cl_2]^{2-}$.

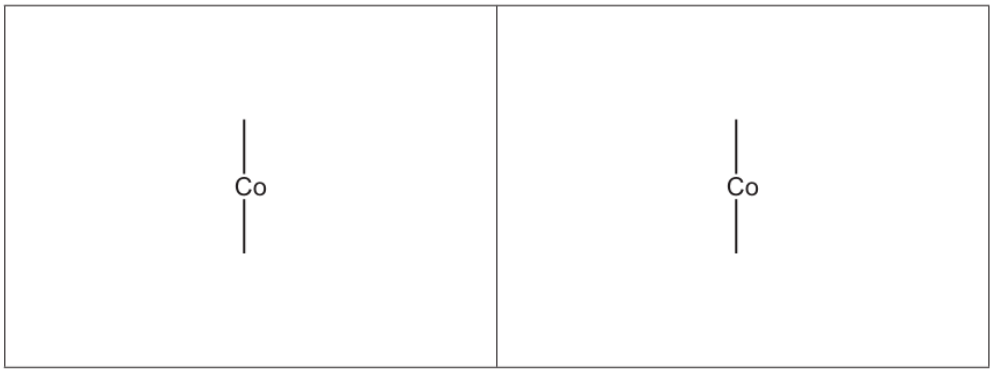
..... [1]

16 **(d)** A solution of the bidentate ligand 1,2-diaminoethane, $H_2NCH_2CH_2NH_2$, is added to an aqueous solution of cobalt(II) sulfate. Oxygen is then bubbled into the mixture forming a complex ion with the formula $[Co(H_2NCH_2CH_2NH_2)_3]^{3+}$.

This complex ion exists as a mixture of two isomers. The geometry of both of these isomeric complexes is octahedral.

(ii) Draw the three-dimensional structures of the two isomeric complexes in the boxes.

You may use  to represent a molecule of $H_2NCH_2CH_2NH_2$.



[2]

(iii) Name the type of stereoisomerism shown by these two isomeric complexes.

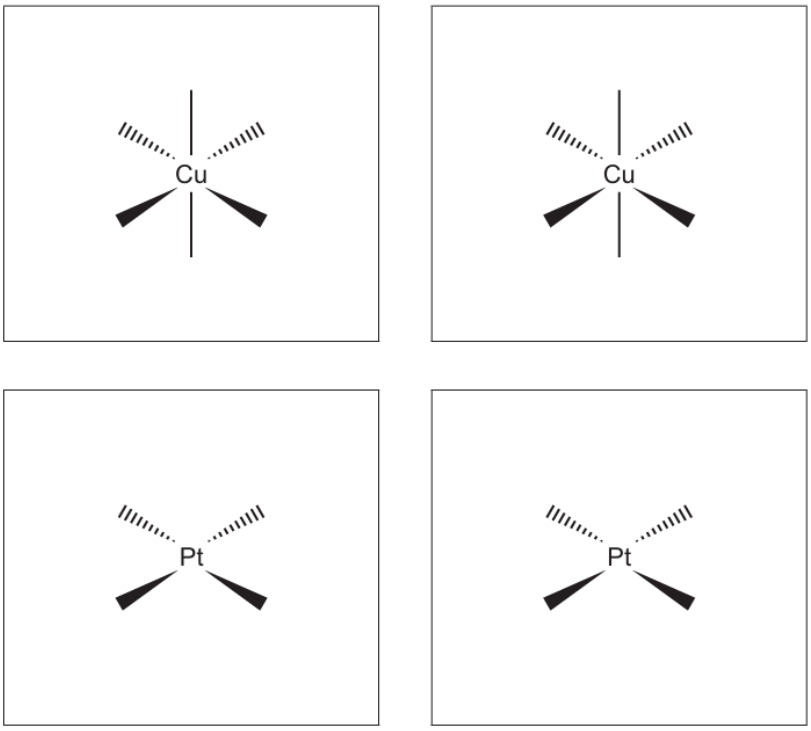
..... [1]

17 **(e)** Transition element complexes can exhibit stereoisomerism. $[Cu(H_2O)_4(NH_3)_2]^{2+}$ and $Pt(NH_3)_2Cl_2$ show the **same** type of isomerism.

(i) Name this type of isomerism.

..... [1]

(ii) Complete the three-dimensional diagrams of the two isomers for $[Cu(H_2O)_4(NH_3)_2]^{2+}$ and $Pt(NH_3)_2Cl_2$.



[2]