

28.4 STEREOISOMERISM IN COMPLEXES

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Geometric isomers

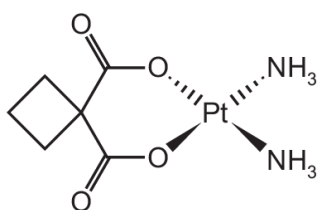
- Some transition element complexes can show stereoisomerism.
State two types of stereoisomerism shown by transition element complexes.

1

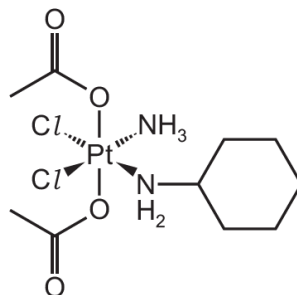
2[1]

- Carboplatin and satraplatin are used as anticancer drugs instead of cisplatin.

carboplatin



satraplatin



- Describe the action of cisplatin as an anticancer drug.

.....

.....

..... [2]

- Suggest the geometry of the platinum centre in the carboplatin complex.

..... [1]

- Suggest why carboplatin does not show cis-trans isomerism.

.....

.....

..... [1]

- Satraplatin is a neutral complex, containing the ligands CH_3CO_2^- , $\text{C}_6\text{H}_{11}\text{NH}_2$, Cl^- and NH_3 .
Deduce the oxidation state of platinum in satraplatin.

..... [1]

- (i) Describe the geometry of $[\text{Pt}(\text{CN})_2\text{Cl}_2]^{2-}$.

..... [1]

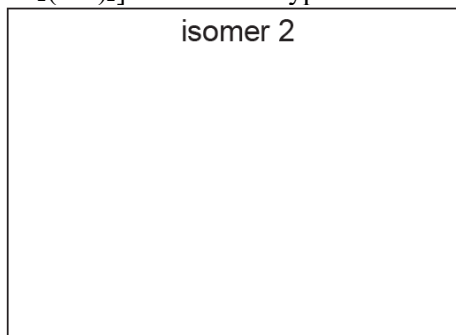
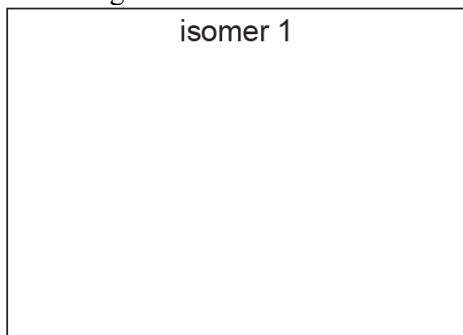
- Name the type of stereoisomerism shown by $[\text{Pt}(\text{CN})_2\text{Cl}_2]^{2-}$.

..... [1]

- The complexes $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ and $[\text{Pt}(\text{en})_2]^{2+}$ have the same geometry (shape) around the metal ion.
 $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ exists as two stereoisomers, whereas $[\text{Pt}(\text{en})_2]^{2+}$ only has one possible structure.
State the geometry around the metal ion.

..... [1]

6. The complex ion $[\text{NiBr}_2(\text{CN})_2]^{2-}$ shows stereoisomerism.
Draw diagrams to show the two isomers of $[\text{NiBr}_2(\text{CN})_2]^{2-}$. Name the type of stereoisomerism.

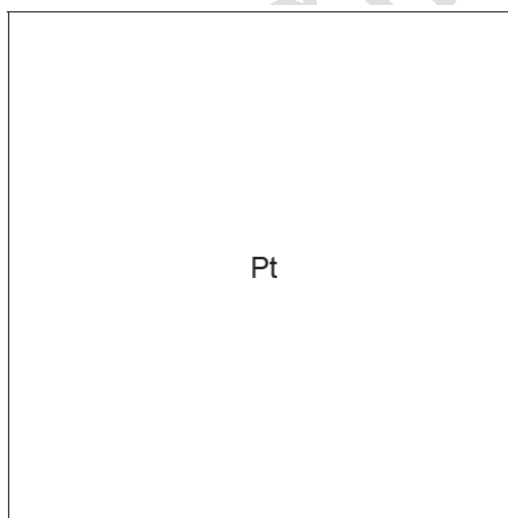
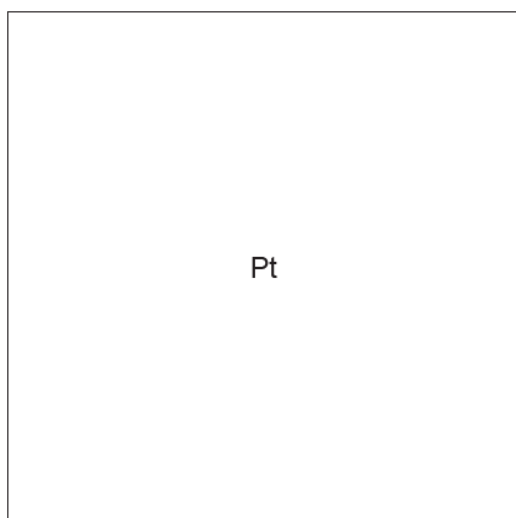


type of stereoisomerism

[2]

7. Platinum forms a complex ion with the formula $[\text{Pt}(\text{CN})_2\text{Cl}_2]^{2-}$. In this complex ion, the carbon atom of each CN^- ligand bonds to the platinum ion. This complex shows stereoisomerism. There are only two isomers of this complex.
Draw structures of these two isomers in the boxes below.

[2]



8. 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 $\text{H}_2\text{NCH}_2\text{CH}_2\text{NHCH}_2\text{CH}_2\text{NH}_2$.
The dien ligand forms three bonds to the gold ion in $[\text{Au}(\text{dien})(\text{H}_2\text{O})_2\text{Cl}]^{2+}$ and $\text{Au}(\text{dien})\text{Cl}_3$.
These three bonds all lie in the same plane.
The CO ligand coordinates through the carbon atom in $[\text{Rh}(\text{CO})_2\text{Cl}_2]^+$.
Table 6.1

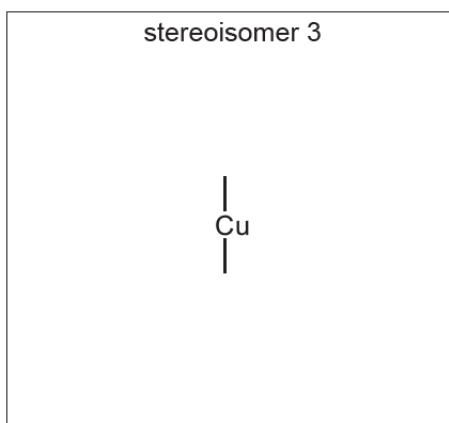
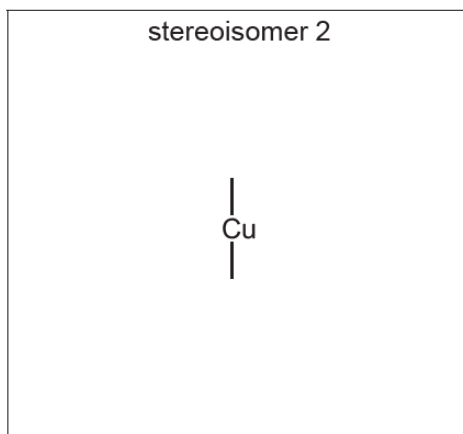
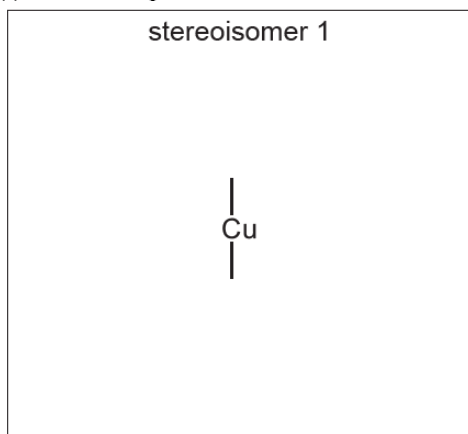
formula	isomerism shown	geometry
$[\text{Rh}(\text{en})_2\text{Cl}_2]^+$	yes	
$[\text{Rh}(\text{CO})_2\text{Cl}_2]^+$	yes	
$[\text{Au}(\text{dien})(\text{H}_2\text{O})_2\text{Cl}]^{2+}$		
$\text{Au}(\text{dien})\text{Cl}_3$	no	octahedral
$\text{Ni}(\text{PH}_3)_2\text{Cl}_2$	no	
$[\text{Ni}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}$	yes	

- (i) Complete Table 6.1 to state the geometry of the first three complexes. Each complex is either square planar, tetrahedral or octahedral.

[1]

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

(i) Complete the three-dimensional diagrams to show these three stereoisomers.



(ii) Use your answer to (i) to answer this question.

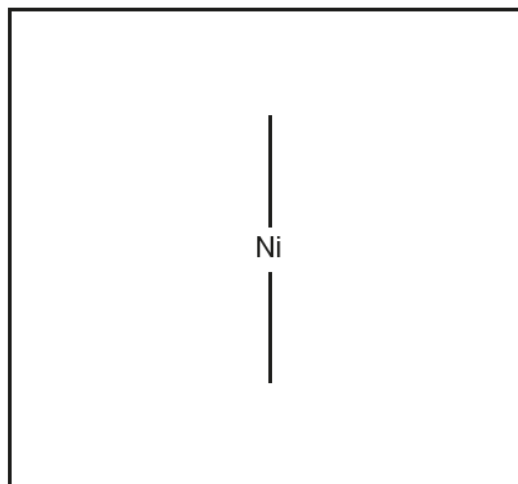
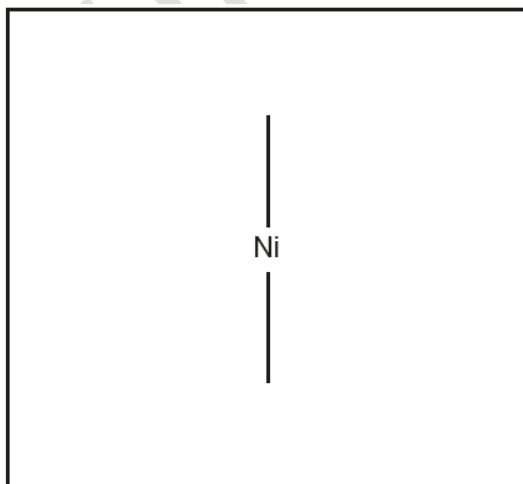
Stereoisomers 1, 2 and 3 show two different types of isomerism.

Name these two types of isomerism.

For each type of isomerism, identify the pair of stereoisomers that demonstrate this isomerism. [2]

type of isomerism	pair of stereoisomers
	and
	and

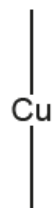
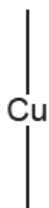
10. Draw the three-dimensional structures of the two isomers of $[\text{Ni}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}$ in the boxes and identify the type of isomerism shown.



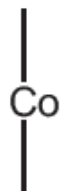
type of isomerism shown

[2]

11. $\text{Cu}^{2+}(\text{aq})$ reacts with CH_3NH_2 to form $[\text{Cu}(\text{CH}_3\text{NH}_2)_2(\text{H}_2\text{O})_4]^{2+}$.
 Draw three-dimensional diagrams to show the two geometrical isomers of $[\text{Cu}(\text{CH}_3\text{NH}_2)_2(\text{H}_2\text{O})_4]^{2+}$. [2]



12. The $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ complex shows stereoisomerism.
 Complete the three-dimensional diagrams to show the two isomers of $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$.
 Suggest the type of stereoisomerism.

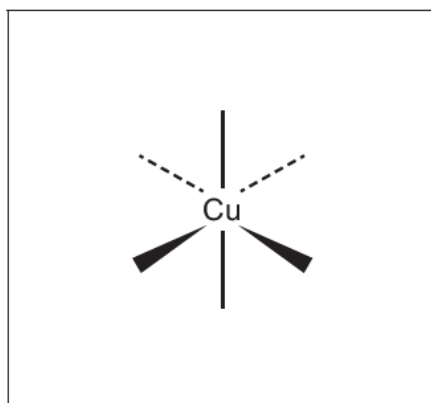
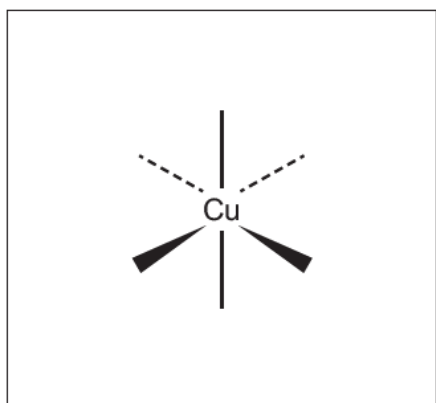


type of stereoisomerism [2]

13. If an excess of ammonia is added to a solution of $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ a deep blue solution containing $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ complex ions is formed.
 (i) There are two possible stereoisomers with the formula $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$.
 Complete the diagrams to show the two stereoisomers in the boxes below. [1]

isomer 1

isomer 2



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

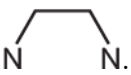
polarity of isomer 1

polarity of isomer 2

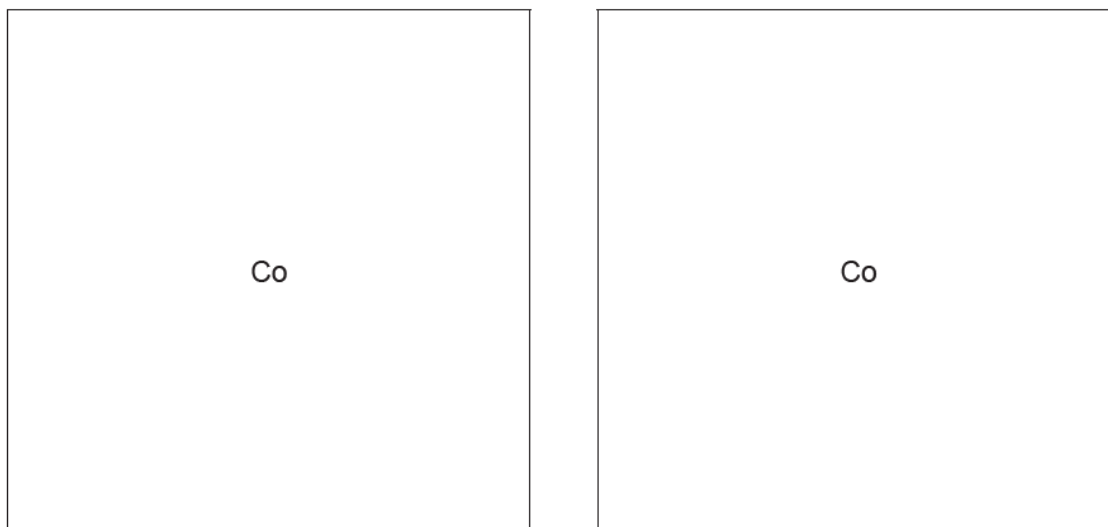
[1]

14. Cobalt forms the complex ion $[\text{Co}(\text{NH}_3)_2(\text{en})_2]^{2+}$. The abbreviation en is used for the bidentate ligand 1,2-diaminoethane, $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$. The complex ion shows both geometrical and optical isomerism.

(i) Draw three-dimensional diagrams for the two **optical** isomers of $[\text{Co}(\text{NH}_3)_2(\text{en})_2]^{2+}$.

Each en ligand can be represented using  N N.

[2]



15. Nickel forms the octahedral complex $[\text{Ni}(\text{en})_2(\text{H}_2\text{O})_2]^{2+}$. 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.

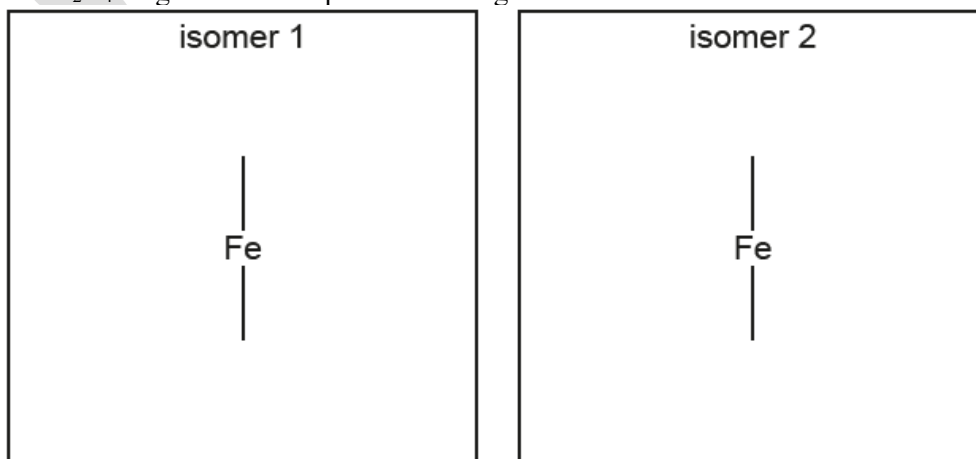
.....
 [1]

16. The $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ complex ion shows stereoisomerism.

Complete the three-dimensional diagrams in Fig. 3.1 to show the two stereoisomers of $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$.

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

[2]



17. 1,2-diaminoethane, $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$, en, can act as a bidentate ligand.

The complex $[\text{Cu}(\text{H}_2\text{O})_2(\text{en})_2]^{2+}$ exists as stereoisomers.

Complete the three-dimensional diagrams in Fig. 1.3 to show the three different stereoisomers of $[\text{Cu}(\text{H}_2\text{O})_2(\text{en})_2]^{2+}$.

The en ligand can be represented using 

[3]

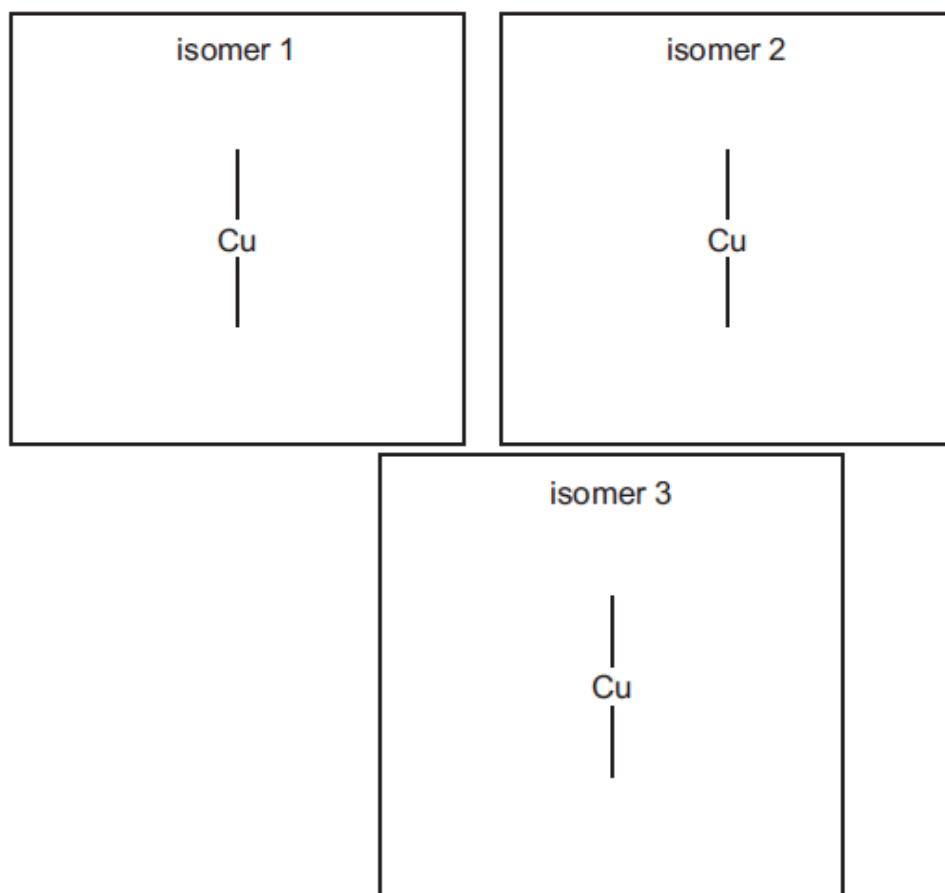


Fig. 1.3

(i) State the different types of stereoisomerism shown by $[\text{Cu}(\text{H}_2\text{O})_2(\text{en})_2]^{2+}$.

..... [1]

(ii) Identify one isomer in (i) that is polar. Explain your answer.

isomer

.....

.....

[1]

18. $\text{Ti}(\text{acac})_2\text{Cl}_2$ shows both optical and geometrical (cis/trans) isomerism. $\text{Ti}(\text{acac})_2\text{Cl}_2$ exists as three stereoisomers. The structure of one stereoisomer of $\text{Ti}(\text{acac})_2\text{Cl}_2$ is shown in Fig. 3.2.

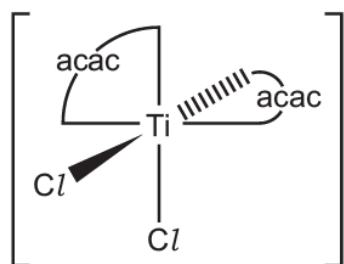
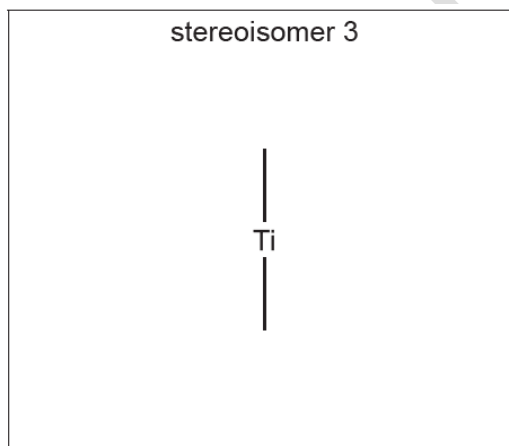
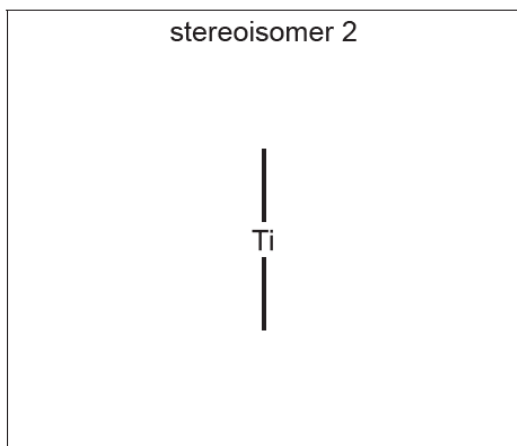


Fig. 3.2

- (i) Complete the structures of the other two stereoisomers of $\text{Ti}(\text{acac})_2\text{Cl}_2$. [2]



- (ii) The acac^- anion is symmetrical. Deduce which, if any, of stereoisomers 1, 2 and 3 in (i) are polar. Explain your answer.

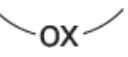
.....

.....

..... [2]

19. **E** is a complex ion, $[\text{Fe}(\text{C}_2\text{O}_4)_2\text{Cl}_2]^{4-}$, containing Fe^{2+} with a coordination number of 6.

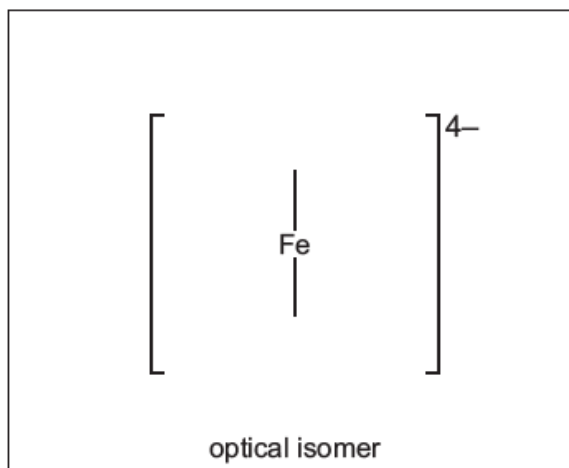
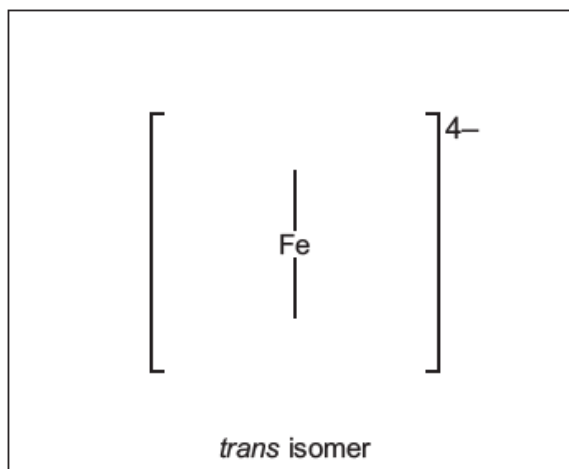
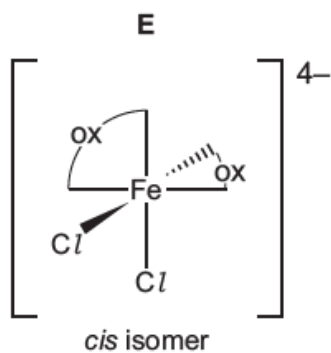
(i) **E** shows both optical isomerism and *cis-trans* isomerism.

One isomer of **E** is shown. The $\text{C}_2\text{O}_4^{2-}$ ion is represented as .

In the boxes, draw three-dimensional diagrams to show:

- the *trans* isomer of **E**
- the optical isomer of **E**.

[2]

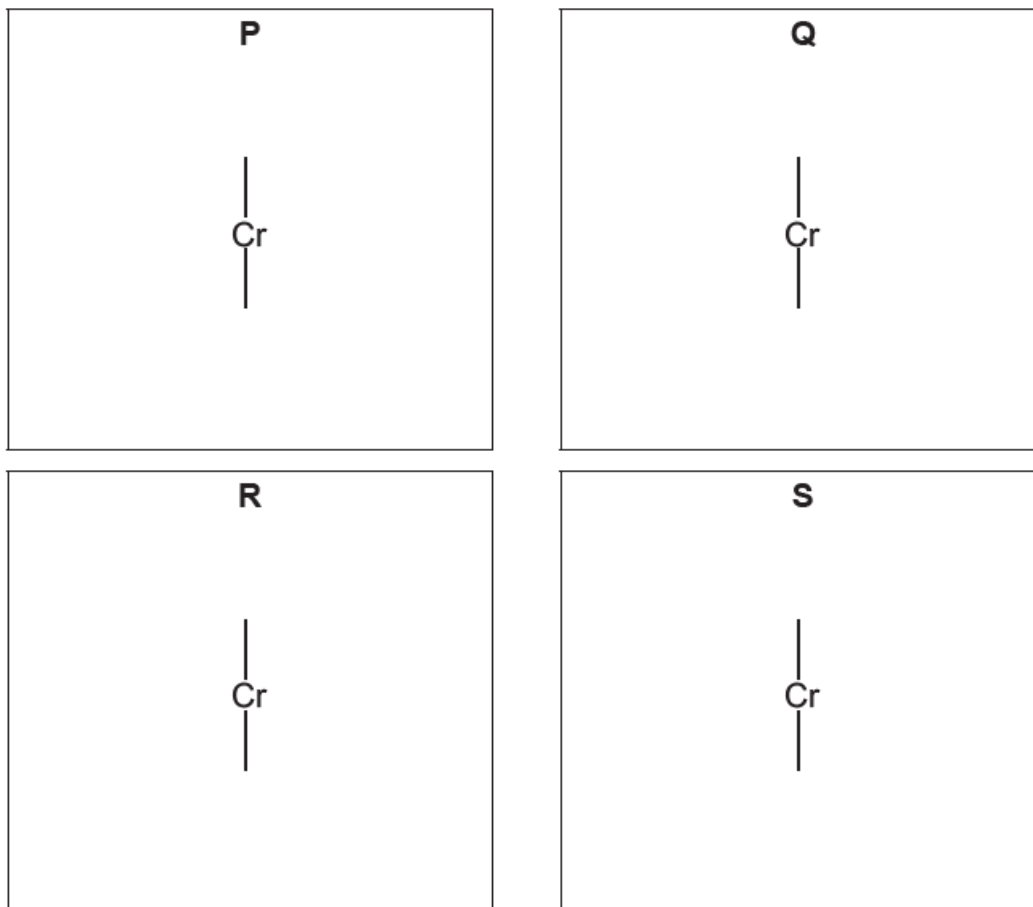


20. (a) Four different compounds can be obtained when anhydrous chromium(III) chloride reacts with water under various conditions. When samples of each compound are reacted separately with aqueous silver nitrate, different amounts of silver chloride are precipitated. The precipitation leaves the complex ions **P**, **Q**, **R** and **S** in solution.

	formula of compound complex ion	moles of AgCl precipitated per mole of complex ion	property of complex ion
P	$\text{CrCl}_3(\text{H}_2\text{O})_6$	3	non-polar
Q	$\text{CrCl}_3(\text{H}_2\text{O})_5$	2	polar
R	$\text{CrCl}_3(\text{H}_2\text{O})_4$	1	polar
S	$\text{CrCl}_3(\text{H}_2\text{O})_4$	1	non-polar

- (i) Draw three-dimensional diagrams for the structures of complex ions **P**, **Q**, **R** and **S**. Include the charges for each complex ion.

[4]



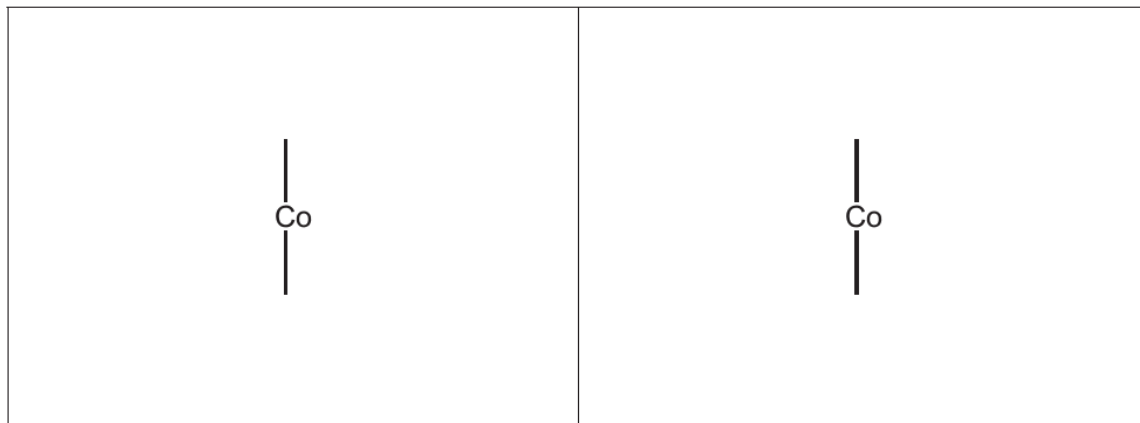
- (ii) Suggest why complex ion **S** is non-polar.

.....
 [1]

21. A solution of the bidentate ligand 1,2-diaminoethane, $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$, is added to an aqueous solution of cobalt(II) sulfate. Oxygen is then bubbled into the mixture, forming a complex ion with the formula $[\text{Co}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{3+}$. This complex ion exists as a mixture of two isomers. The geometry of both of these isomeric complexes is octahedral.

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

You may use $\text{N} \begin{array}{c} \diagup \quad \diagdown \\ \text{ } \end{array} \text{N}$ to represent a molecule of $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$.



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

..... [1]

(iii) State the co-ordination number of cobalt in these two isomeric complexes.

..... [1]

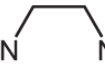
22. An excess of $\text{C}_2\text{O}_4^{2-}$ reacts with VO_2^+ to form a mixture of two octahedral complex ions. The complex ions are stereoisomers of each other. Each complex ion contains a V^{2+} cation and three $\text{C}_2\text{O}_4^{2-}$ ions. Complete the diagram to show the three-dimensional structure of one of the complex ions. Include the charge of the complex ion.

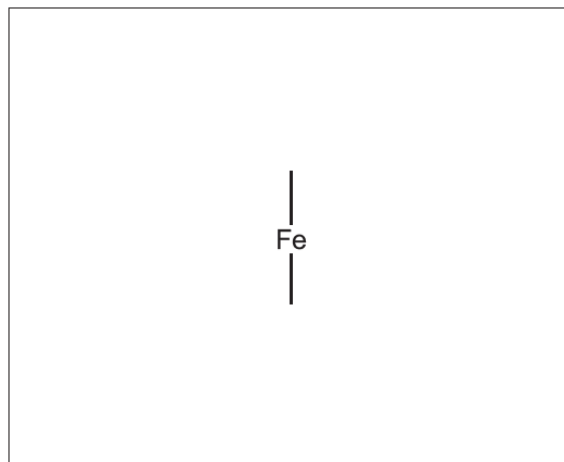
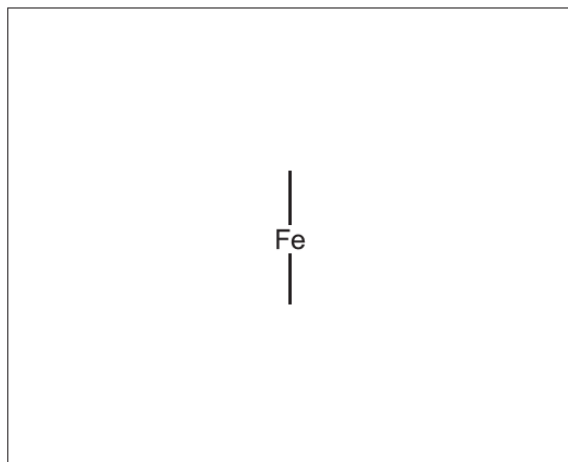
Use $\text{O} \text{---} \text{O}$ to represent a $\text{C}_2\text{O}_4^{2-}$ ion.



23. The complex $[\text{Fe}(\text{bipy})_3]^{2+}$ exists as two stereoisomers.

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

Use  to represent bipy in your diagrams.



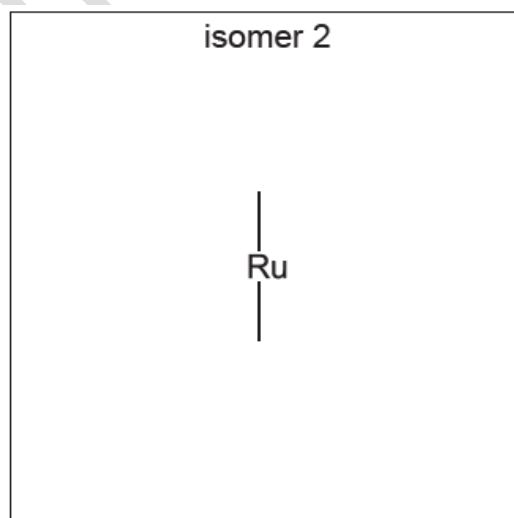
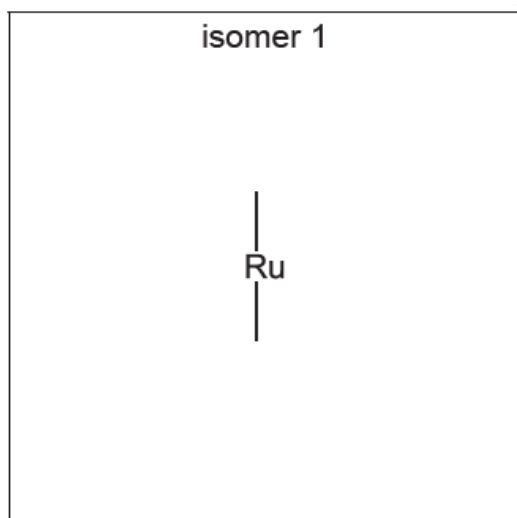
type of stereoisomerism [3]

24. The complex $[\text{Ru}(\text{en})_3]^{3+}$ shows stereoisomerism. The ligand en is bidentate.

Draw three-dimensional diagrams to show the two isomers of $[\text{Ru}(\text{en})_3]^{3+}$. Represent the ligand en by

using 

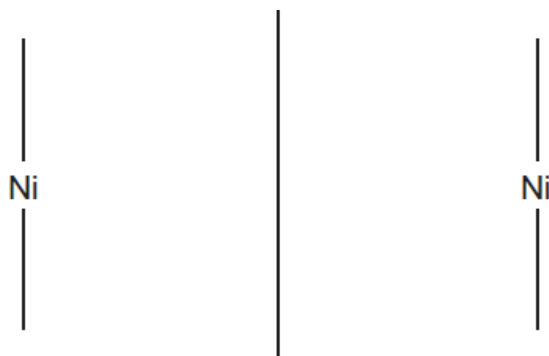
Name the type of stereoisomerism.



type of stereoisomerism [3]

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

Use  to represent the en ligand.
Name the type of isomerism shown.



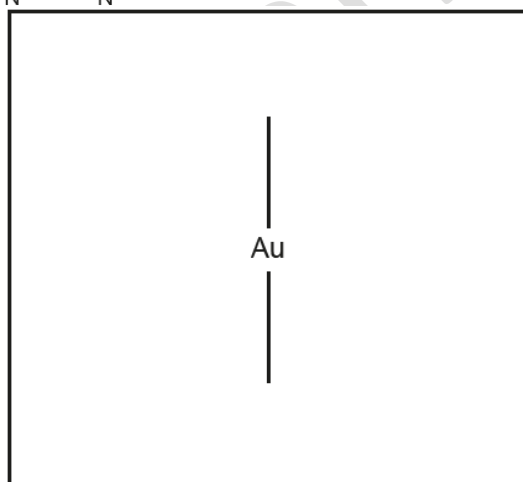
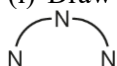
type of isomerism shown [3]

26. Complete Table 1.1 to show the coordination number of each metal ion, and the shapes and overall polarities of the complex ions listed. [2]

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	

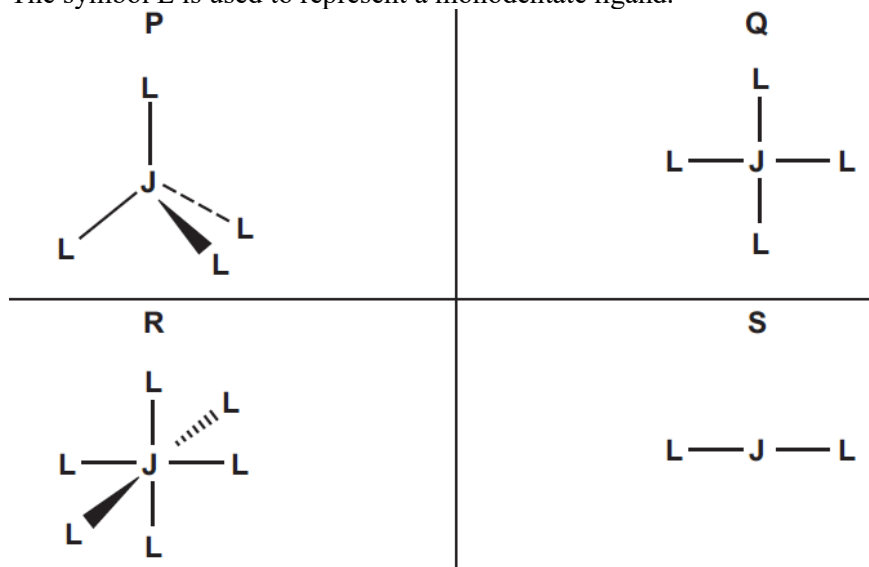
27. (i) Draw the three-dimensional structure of $\text{Au}(\text{dien})\text{Cl}_3$ in the box. The dien ligand can be drawn as



(ii) One of the complexes, $[\text{Rh}(\text{en})_2\text{Cl}_2]^+$ or $[\text{Rh}(\text{CO})_2\text{Cl}_2]^+$, can exist in three isomeric forms. Identify this complex and the types of isomerism shown.

.....
..... [1]

28. The shapes of four different complexes, P, Q, R and S, are shown in Table 5.1. The symbol J represents an atom or ion of a transition element. The symbol L is used to represent a monodentate ligand.



Label one bond angle on each of complexes P, Q, R and S, and identify the size of the angle in degrees. [2]

(b) Identify the shapes of complexes P, Q, R and S.

P

Q

R

S [2]

(c) Two L ligands are exchanged with two different monodentate ligands X and Y in each of complexes P, Q, R and S.

Identify all the complexes which form new complexes that show geometrical isomerism.

..... [1]

(d) Three L ligands are exchanged with three different monodentate ligands X, Y and Z in each of complexes P, Q and R.

Identify all the complexes which form new complexes that show optical isomerism.

..... [1]

29. Ruthenium and osmium are transition metals below iron in Group 8 of the Periodic Table.

(a) Two different complex ions, **X** and **Y**, can form when anhydrous RuCl_3 reacts with water under certain conditions.

X and **Y** have octahedral geometry.

Aqueous samples of **X** and **Y** react separately with an excess of $\text{AgNO}_3(\text{aq})$. Different amounts of AgCl are precipitated:

- 1 mole of complex ion **X** produces 2 moles of AgCl
- 1 mole of complex ion **Y** produces 1 mole of AgCl .

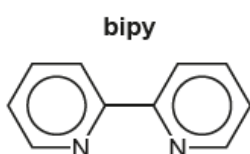
(i) Complete Table 4.1 to suggest formulae for **X** and **Y**.

[2]

Table 4.1

	X	Y
formula of complex		

(ii) Both complexes react with an excess of bipyridine, bipy, to form a mixture of two stereoisomers of $[\text{Ru}(\text{bipy})_3]^{3+}$.

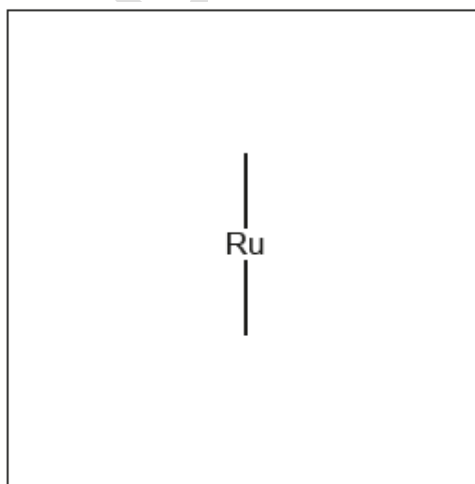
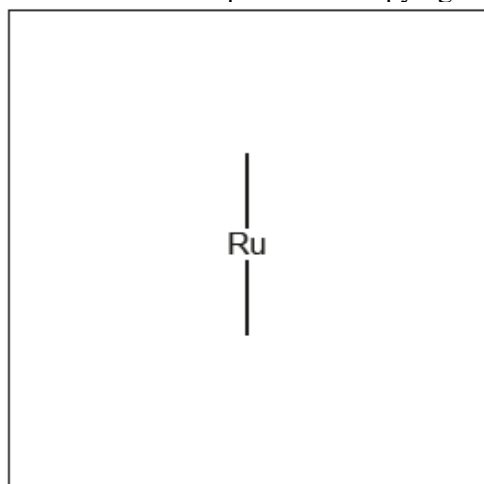


Bipyridine is a bidentate ligand.

Draw three-dimensional diagrams of the two stereoisomers of $[\text{Ru}(\text{bipy})_3]^{3+}$.

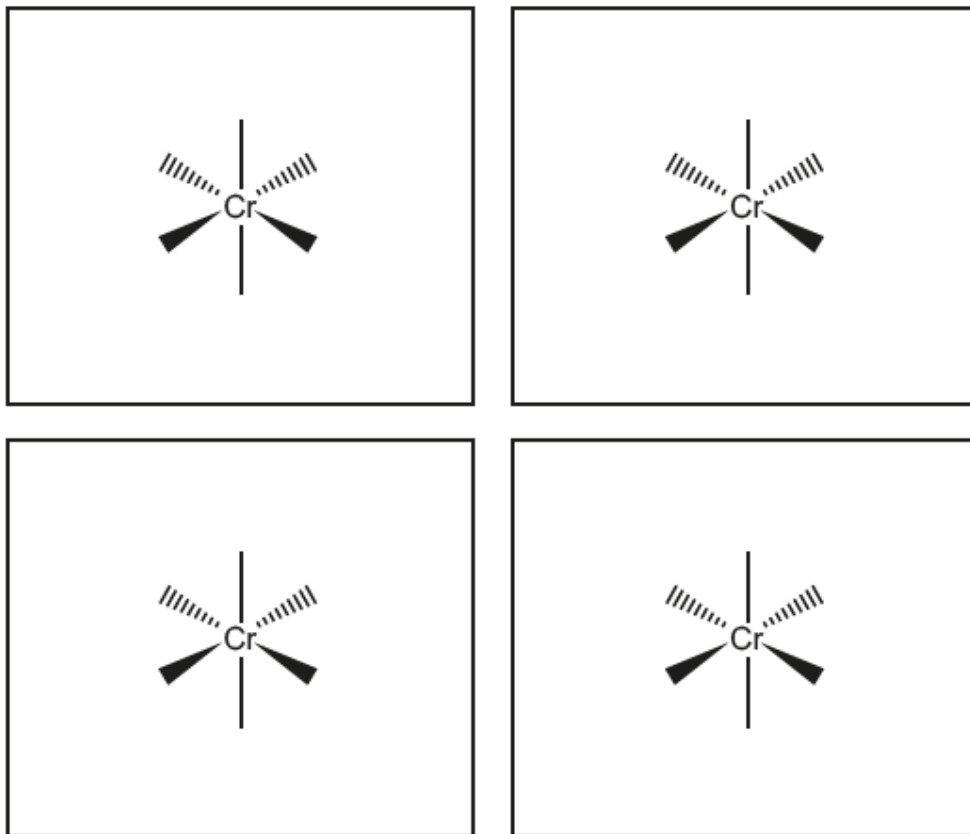
Use $\text{N} \quad \text{N}$ to represent the bipy ligand in your structures.

[2]



30. The complex $[\text{Cr}(\text{en})_3]^{2+}$ exists as two stereoisomers whereas the complex $[\text{Cr}(\text{OCH}_2\text{CH}_2\text{NH}_2)_3]^-$ exists as four stereoisomers. Complete the three-dimensional diagrams in Fig. 2.1 to show the four stereoisomers of $[\text{Cr}(\text{OCH}_2\text{CH}_2\text{NH}_2)_3]^-$.

Represent the ligand $-\text{OCH}_2\text{CH}_2\text{NH}_2$ by using  [3]



.....