



Coordinat	ion Co	ompour <u>Alfred</u>	nds of Cobalt <u>Werner</u>	Studied by
Traditional Formula	<u>Werner</u> Total Ions	<u>''s Data*</u> Free Cl [.]	Modern Formula	Charge of Complex Ion
$CoCl_3 \cdot 6 NH_3$	4	3	[Co(NH ₃) ₆]Cl ₃	3+
CoCl ₃ • 5 NH ₃	3	2	[Co(NH ₃) ₅ Cl]Cl ₂	2+
CoCl ₃ · 4 NH ₃	2	1	[Co(NH ₃) ₄ Cl ₂]Cl	1+
CoCl ₃ • 3 NH ₃	0	0	[Co(NH ₃) ₃ Cl ₃]	
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- CoCl₃·nNH₃ (n = 1 4) can exist as four different compounds with different numbers of "free" Cl⁻ ions per formula unit.
- The NH₃ ligands are covalently bonded to the central Co^{3+} ion.
- A maximum of six ligands can be bonded to the central cobalt atom.
- There are two isomers for the Cl ligands attached to cobalt of $CoCl_3 \cdot 4NH_3$.





Isomerism

- Isomers: two compounds with the same formulas but different arrangements of atoms.
- Coordination-sphere isomers and linkage isomers: have different structures (i.e. different bonds).
- Geometrical isomers and optical isomers are stereoisomers (i.e. have the same bonds, but different spatial arrangements of atoms).
- Structural isomers have different connectivity of atoms.
- Stereoisomers have the same connectivity but different spatial arrangements of atoms.





QUESTION

Which of the following ligands might give linkage isomers?

A. NO_2^- B. SCN^- C. $H_2NHC_2CH_2NH_2$ D. A and B E. A, B, and C











QUESTION

What is the sum of the geometric and optical isomers that the complex ion $Co(en)_2Cl_2^+$ exhibits?

A) 0

B) 1 C) 2

D) 3 E) 4

Stereoisomerism

- Enantiomers are chiral: i.e. They are non-superimposable mirror images.
- Enantiomers are "optical isomers." eg. (+) and (-) carvone
- Most physical and chemical properties of enantiomers are identical.
- Therefore, enantiomers are very difficult separate eg. Tartaric acid...ask Louis Pasteur.



► Enantiomers can have very different physiological effects: eg. (+) and (-) carvone





"I call any geometrical figure, or group of points, *chiral*, and say that it has chirality, if its image in a plane mirror ... cannot be brought to coincide with itself. Two equal and similar right hands are homochirally similar."

Sir William Thomson (Lord Kelvin) The Baltimore Lectures, 1904















Color and Magnetism

- Color of a complex depends on: (i) the metal and (ii) its oxidation state.
- Pale blue [Cu(H₂O)₆]²⁺ can be converted into dark blue [Cu(NH₃)₆]²⁺ by adding NH₃(*aq*).
- A partially filled *d* orbital is usually required for a complex to be colored.
- So, *d*⁰ metal ions are usually colorless. *Exceptions: MnO*₄⁻ and CrO₄²⁻.
- Colored compounds absorb visible light.
- The color our eye perceives is the sum of the light not absorbed by the complex.





Absorbed Color	λ(nm)	Observed Color	λ(nm)
Violet	400	Green-yellow	560
Blue	450	Yellow	600
Blue-green	490	Red	620
Yellow-green	570	Violet	410
Yellow	580	Dark blue	430
Orange	600	Blue	450
Red	650	Green	520



Colors of Transition Metal Complexes

- Absorption of UV-visible radiation by atom, ion, or molecule:
 - Occurs only if radiation has the energy needed to raise an e⁻ from its ground state to an excited state
 - · i.e., from lower to higher energy orbital
 - light energy absorbed = energy difference between the ground state and excited state
 - · "electron excitation"



















Magnetism

- Paramagnetic metal complexes have unpaired electrons.
- Diamagnetic metal complexes have paired electrons.
- There are some interesting observations. Consider a *d*⁶ metal ion:
 - [Co(NH₃)₆]³⁺ has no unpaired electrons, but [CoF₆]³⁻ has four unpaired electrons per ion.
- Crystal Field Theory provides an explanation.