

## Chapter Summary and Review

### Key Learning Outcomes

CHAPTER OBJECTIVES	ASSESSMENT
<b>Write Electronic Configurations for Transition Metals and Their Ions (22.2)</b>	<ul style="list-style-type: none"> <li>Examples 22.1, 22.2 For Practice 22.1, 22.2 Exercises 19, 20, 57, 58</li> </ul>
<b>Name Coordination Compounds (22.3)</b>	<ul style="list-style-type: none"> <li>Examples 22.3, 22.4 For Practice 22.3, 22.4 Exercises 23, 24, 25, 26, 27, 28</li> </ul>
<b>Identify and Draw Geometric Isomers (22.4)</b>	<ul style="list-style-type: none"> <li>Examples 22.5, 22.6 For Practice 22.5, 22.6 Exercises 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 61, 62</li> </ul>
<b>Recognize and Draw Optical Isomers (22.4)</b>	<ul style="list-style-type: none"> <li>Example 22.7 For Practice 22.7 Exercises 39, 40, 61, 62</li> </ul>
<b>Estimate Crystal Field Splitting Energy (22.5)</b>	<ul style="list-style-type: none"> <li>Example 22.8 For Practice 22.8 Exercises 43, 44, 45, 46</li> </ul>
<b>Determine the Number of Unpaired Electrons in Octahedral Complexes (22.5)</b>	<ul style="list-style-type: none"> <li>Examples 22.9, 22.10 For Practice 22.9, 22.10 Exercises 49, 50, 51, 52, 65</li> </ul>

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### Key Terms













#### Section 22.1

crystal field theory







#### Section 22.2

lanthanide contraction





## Section 22.3

complex ion   
ligand   
coordination compound   
primary valence   
secondary valence   
coordination number (secondary valence)   
coordinate covalent bond   
monodentate   
bidentate   
polydentate   
chelate   
chelating agent 

## Section 22.4

structural isomers   
stereoisomers   
coordination isomers   
linkage isomers   
geometric isomers   
optical isomers 

## Section 22.5

strong-field complex   
weak-field complex   
low-spin complex   
high-spin complex 

## Key Concepts

### Electron Configurations (22.2)

- As we move across a row of transition elements, we add electrons to the  $(n - 1)d$  orbitals, resulting in a general electron configuration for first- and second-row transition elements of [noble gas]  $ns^2(n - 1)d^x$  and for the third and fourth rows of [noble gas]  $ns^2(n - 2)f^{14}(n - 1)d^x$ , where  $x$  ranges from 1 to 10.
- A transition element forms a cation by losing electrons from the  $ns$  orbitals before losing electrons from the  $(n - 1)d$  orbitals.

### Periodic Trends (22.2)

- The variations in atomic size, ionization energy, and electronegativity across a row in the periodic table for transition metals are similar to those of main-group elements (although the trends are less pronounced and less regular). As we move down a group, however, atomic size increases from the first row of transition metals to the second but stays roughly constant from the second row to the third because of the lanthanide contraction. This contraction results in ionization energy and electronegativity trends as we move down a column for transition metals that are opposite of the main-group elements.

### Composition and Naming of Coordination Compounds (22.3)

- A coordination compound is composed of a complex ion and a counterion.
- A complex ion contains a central metal ion bound to one or more ligands. The number of ligands directly bound to the metal ion is called the coordination number.
- The ligand forms a coordinate covalent bond to the metal ion by donating a pair of electrons to an empty

orbital on the metal.

- Ligands that donate a single pair of electrons are monodentate. A ligand that donates two pairs of electrons is bidentate, and a ligand that donates more than two pairs is polydentate.
- In naming coordination compounds, we use the name of the cation followed by the name of the anion. To name a complex ion, we use the guidelines outlined in [Section 22.3](#).

## Types of Isomers (22.4)

- We broadly divide the isomerism observed in coordination compounds into two categories: structural isomers, in which atoms are connected differently to one another, and stereoisomers, in which atoms are connected in the same way but the ligands have a different spatial arrangement about the metal atom.
- Structural isomers are either coordination isomers (a coordinated ligand exchanges places with an uncoordinated counterion) or linkage isomers (a particular ligand has the ability to coordinate to the metal in different ways).
- Stereoisomers are either geometric isomers (the ligands bonded to the metal have a different spatial arrangement relative to each other, leading to cis–trans or fac–mer isomers) or optical isomers (nonsuperimposable mirror images of one another).

## Bonding in Coordination Compounds (22.5)

- Crystal field theory is a bonding model for transition metal complex ions. The model describes how the degeneracy of the  $d$  orbitals is broken by the repulsive forces between the electrons on the ligands around the metal ion and the  $d$  orbitals in the metal ion.
- The energy difference between the split  $d$  orbitals is the crystal field splitting energy ( $\Delta$ ). The magnitude of  $\Delta$  depends in large part on the ligands bound to the metal.
- Octahedral complexes with a  $d^4$ ,  $d^5$ ,  $d^6$ , or  $d^7$  metal ion can have two possible electronic configurations with different numbers of unpaired electrons. The first, called high-spin, has the same number of unpaired electrons as the free metal ion and is usually the result of a weak crystal field. The second, called low-spin, has fewer unpaired electrons than the free metal ion and is usually the result of a strong crystal field.

## Key Equations and Relationships

### Crystal Field Splitting Energy (22.5)

$$\Delta = hc/\lambda \text{ (where } \lambda \text{ is the wavelength of maximum absorption)}$$

*Not for Distribution*