CHAPTER

12

Chemical Bonding

Section 12.1 *The Chemical Bond Concept*

2.

Atom	Valence Electrons
H	1 valence e^-
Br	7 valence e^-

4.

Atom	Covalent Bond
H	2 valence e^-
Br	8 valence e^-

6.

	Compound	Bond		Compound	Bond
(a)	$ZnBr_2$	ionic	(b)	CO_2	covalent
(c)	IF_7	covalent	(d)	$PbSO_4$	ionic

8.

	Substance	Particle		Substance	Particle
(a)	CH_3OH	molecule	(b)	$CoCl_2$	formula unit
(c)	CH_3COCH_3	molecule	(d)	$SnCO_3$	formula unit

10.

	Substance	Particle		Substance	Particle
(a)	Xe	atom	(b)	P_4	molecule
(c)	XeO_3	molecule	(d)	Fe_3O_4	formula unit

Section 12.2 *Ionic Bonds*

12.

	Ion	Ionic Charge		Ion	Ionic Charge
(a)	Li ion	1+ (Group 1)	(b)	Sr ion	2+ (Group 2)
(c)	Al ion	3+ (Group 13)	(d)	Pb ion	4+ (Group 14)

14.

	Ion	Ionic Charge		Ion	Ionic Charge
(a)	Cl ion	1– (Group 17)	(b)	I ion	1– (Group 17)
(c)	S ion	2– (Group 16)	(d)	P ion	3– (Group 15)

16.

	Ion	Electron Configuration
(a)	Sc^{3+}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
(b)	K^+	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
(c)	Ti^{4+}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
(d)	Ba^{2+}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ \ 5s^2\ 4d^{10}\ 5p^6$

18.

	Ion	Electron Configuration
(a)	Br^-	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$
(b)	O^{2-}	$1s^2\ 2s^2\ 2p^6$
(c)	Se^{2-}	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$
(d)	N^{3-}	$1s^2\ 2s^2\ 2p^6$

20.

	Ion	Isoelectronic Noble Gas
(a)	Se^{2-}	Kr
(b)	Br^-	Kr
(c)	Rb^+	Kr
(d)	Sr^{2+}	Kr

22.

	Ion	Isoelectronic Noble Gas
(a)	Sc^{3+}	Ar
(b)	K^+	Ar
(c)	Ti^{4+}	Ar
(d)	Ba^{2+}	Xe

24.

	Ion	Isoelectronic Noble Gas
(a)	Br^-	Kr
(b)	O^{2-}	Ne
(c)	Se^{2-}	Kr
(d)	N^{3-}	Ne

26. (a) Al atom radius > Al ion radius
(b) Pb atom radius > Pb ion radius
(c) Se atom radius < Se ion radius
(d) N atom radius < N ion radius

28. The true statements are (b) and (c). The corrected statements are:
(a) Aluminum and nitride ions bond by *electrostatic attraction*.
(d) Breaking an ionic bond between aluminum and nitrogen *requires* energy.

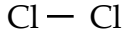
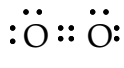
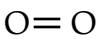
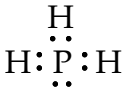
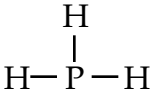
Section 12.3 *Covalent Bonds*

30. (a) The bond length in H–Br is less than the sum of the atomic radii.
(b) The bond length in S=O is less than the sum of the atomic radii.

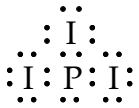
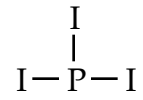
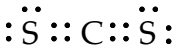
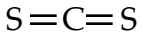
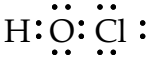
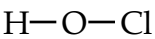
32. The true statements are (b) and (c). The corrected statements are:
(a) Valence electrons are *shared* between carbon and oxygen atoms.
(d) Energy is *required* to break a C—O covalent bond.

Section 12.4 *Electron Dot Formulas of Molecules*

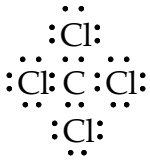
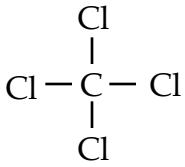
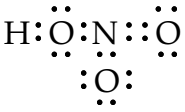
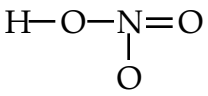
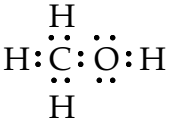
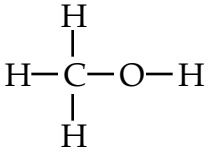
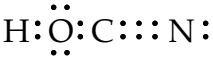
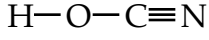
34.

	Molecule	Valence Electrons	Electron Dot	Structural Formula
(a)	$\mathbf{Cl}_2$	$7 + 7 = 14$ e$^-$		
(b)	$\mathbf{O}_2$	$6 + 6 = 12$ e$^-$		
(c)	H**I**	$1 + 7 = 8$ e$^-$		
(d)	$\mathbf{P}H_3$	$5 + 3(1) = 8$ e–		

36.

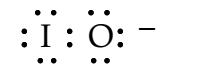
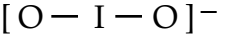
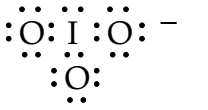
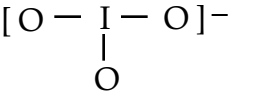
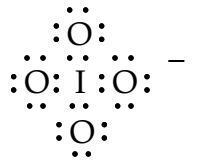
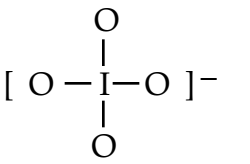
Molecule	Valence Electrons	Electron Dot	Structural Formula
(a) **N**$_2$	2(5) = 10 e$^-$		
(b) **P**I$_3$	5 + 3(7) = 26 e$^-$		
(c) **C**S$_2$	4 + 2(6) = 16 e$^-$		
(d) H**O**Cl	1 + 6 + 7 = 14 e$^-$		

38.

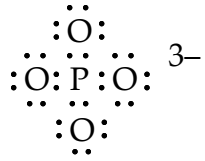
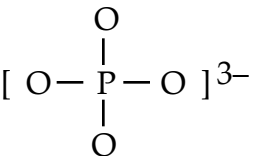
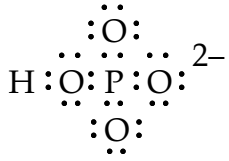
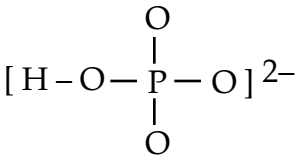
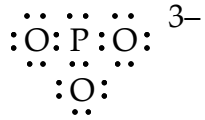
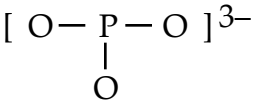
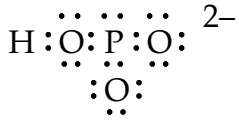
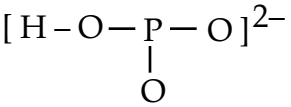
Molecule	Valence Electrons	Electron Dot	Structural Formula
(a) **C**Cl$_4$	4 + 4(7) = 32 e$^-$		
(b) HO**N**O$_2$	1 + 3(6) + 5 = 24 e$^-$		
(c) **C**H$_3$OH	4 + 4(1) + 6 = 14 e$^-$		
(d) HO**C**N	1 + 6 + 4 + 5 = 16 e$^-$		

Section 12.5 *Electron Dot Formulas of Polyatomic Ions*

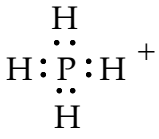
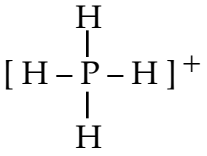
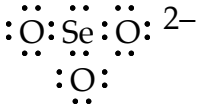
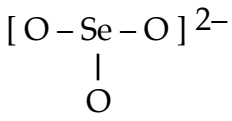
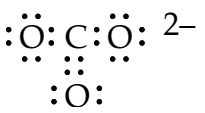
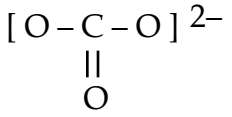
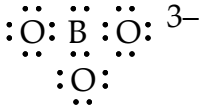
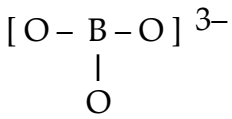
40.

	Polyatomic Ion	Valence Electrons	Electron Dot	Structural Formula
(a)	$\mathbf{I}O^-$	$7 + 6 + 1 = 14\ e^-$		
(b)	$\mathbf{I}O_2^-$	$7 + 2(6) + 1 = 20\ e^-$		
(c)	$\mathbf{I}O_3^-$	$7 + 3(6) + 1 = 26\ e^-$		
(d)	$\mathbf{I}O_4^-$	$7 + 4(6) + 1 = 32\ e^-$		

42.

	Polyatomic Ion	Valence Electrons	Electron Dot	Structural Formula
(a)	$\mathbf{P}O_4^{3-}$	$5 + 4(6) + 3 = 32\ e^-$		
(b)	$H\mathbf{P}O_4^{2-}$	$1 + 5 + 4(6) + 2 = 32\ e^-$		
(c)	$\mathbf{P}O_3^{3-}$	$5 + 3(6) + 3 = 26\ e^-$		
(d)	$H\mathbf{P}O_3^{2-}$	$1 + 5 + 3(6) + 2 = 26\ e^-$		

44.

	Polyatomic Ion	Valence Electrons	Electron Dot	Structural Formula
(a)	**P**H_4^+	$5 + 4(1) - 1 = 8\ e^-$		
(b)	**Se**O_3^{2-}	$6 + 3(6) + 2 = 26\ e^-$		
(c)	**C**O_3^{2-}	$4 + 3(6) + 2 = 24\ e^-$		
(d)	**B**O_3^{3-}	$5 + 3(6) + 3 = 26\ e^-$		

Section 12.6 *Polar Covalent Bonds*

46. Within a period of elements, the electronegativity increases from left to right in the periodic table.

48. Nonmetals are more electronegative than semimetals.

50.

	More Electronegative		More Electronegative
(a)	Se < **Br**	(b)	**C** > B
(c)	Te < **S**	(d)	Ba < **Be**

(Note: The more electronegative element is in bold.)

52.

	Bond	Polarity		Bond	Polarity
(a)	H—Cl	3.0 – 2.1 = 0.9	(b)	H—Br	2.8 – 2.1 = 0.7
(c)	N—O	3.5 – 3.0 = 0.5	(d)	C—O	3.5 – 2.5 = 1.0

54. Polar Bonds Using Delta Notation

(a) δ^- C—H δ^+
(b) δ^+Se—O δ^-
(c) δ^+P—I δ^-
(d) δ^+H—Br δ^-

(Note: δ^- indicates the more electronegative atom and δ^+ indicates the more electropositive atom.)

Section 12.7 *Nonpolar Covalent Bonds*

56.

	Bond	Polarity	Classification
(a)	I—C	2.5 – 2.5 = 0	nonpolar
(b)	C—S	2.5 – 2.5 = 0	nonpolar
(c)	S—H	2.5 – 2.1 = 0.4	polar
(d)	H—Br	2.8 – 2.1 = 0.7	polar

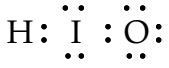
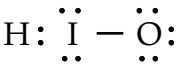
Thus, (a) and (b) are nonpolar.

58. O_2, F_2, and I_2 occur naturally as diatomic molecules.

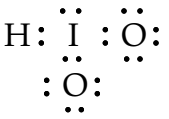
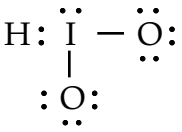
Section 12.8 *Coordinate Covalent Bonds*

(Note: Coordinate covalent bonds are indicated by a dash, —.)

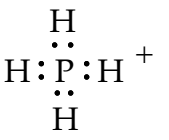
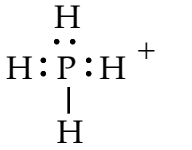
60.

Molecule	Valence Electrons	Electron Dot	Coord. Cov. Bond
H**I**O	1 + 7 + 6 = 14 e⁻		

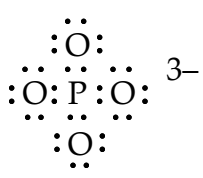
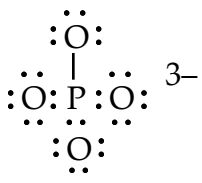
62.

Molecule	Valence Electrons	Electron Dot	Coord. Cov. Bond
H**I**O_2	1 + 7 + 2(6) = 20 e⁻		

64.

Polyatomic Ion	Valence Electrons	Electron Dot	Coord. Cov. Bond
PH_4^+	5 + 4(1) – 1 = 8 e⁻		

66.

Polyatomic Ion	Valence Electrons	Electron Dot	Coord. Cov. Bond
PO_4^{3-}	5 + 4(6) + 3 = 32 e⁻		

Section 12.9 *Hydrogen Bonds*

68. H–F: – – – H–F:

70. A hydrogen bond is ~50% longer than a polar covalent bond.

Section 12.10 *Shapes of Molecules*

72.

Formula	Electron Pair	Molecular Shape	Bond Angle
CBr_4	tetrahedral	tetrahedral	109.5°

74.

Formula	Electron Pair	Molecular Shape	Bond Angle
PH_3	tetrahedral	trigonal pyramidal	107°

76.

Formula	Electron Pair	Molecular Shape	Bond Angle
Cl_2**O**	tetrahedral	bent	104.5°

78. In **C**F_4 each of the four **C**–F bonds is polar, but the four fluorine atoms pull equally in opposite directions to give a nonpolar molecule. The four fluorine atoms are at the corners of a tetrahedron, and the molecular shape is described as *tetrahedral*.

General Exercises

80.

	Substance	Particle
(a)	Pu	atom
(b)	O_2	molecule
(c)	Pu_2O_3	formula unit
(d)	H_2O_2	molecule

82.

	Ions	Chemical Formula
(a)	1 Sc^{3+} and 1 N^{3-}	ScN
(b)	1 Ti^{4+} and 2 O^{2-}	TiO_2
(c)	2 NH_4^+ and 1 CO_3^{2-}	$(NH_4)_2CO_3$
(d)	3 Hg_2^{2+} and 2 PO_4^{3-}	$(Hg_2)_3(PO_4)_2$

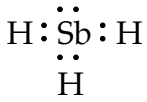
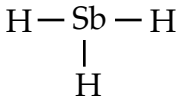
84. A chloride ion has one more electron than a chlorine atom. As a result, the negative electrons in the 3*p* subenergy level repel each other, and the ion becomes larger.

86. Bond: Sb—Cl — Polarity: 3.0 – 1.9 = 1.1 (polar)

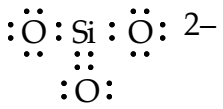
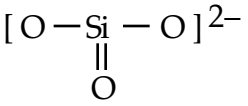
88. Bond: S—I — Polarity: 2.5 – 2.5 = 0 (nonpolar)

90. Polar Bond and Delta Notation: δ^+ As—Cl δ^-

92.

Molecule	Valence Electrons	Electron Dot	Structural Formula
SbH_3	5 + 3(1) = 8 e^-		

94.

Polyatomic Ion	Valence Electrons	Electron Dot	Structural Formula
SiO_3^{2-}	4 + 3(6) + 2 = 24 e^-		

96.

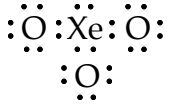
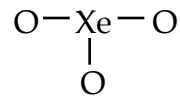
Formula	Electron Pair	Molecular Shape	Bond Angle
SiO_2	linear	linear	180°

98.

Formula	Electron Pair	Molecular Shape	Bond Angle
CO_3^{2-}	trigonal planar	trigonal planar	120°

Challenge Exercises

100.

Molecule	Valence Electrons	Electron Dot	Structural Formula
XeO_3	8 + 3(6) = 26 e–		

Online Exercises

102. In addition to water and ammonia, *hydrogen fluoride, HF,* can also form strong hydrogen bonds between molecules. A hydrogen atom in one HF molecule can bond to a nonbonding electron pair in another HF molecule.

104. The two strands of a DNA molecule that form the double helix are held together by *two hydrogen bonds* between the DNA bases adenine(A) and thymine(T).