CHAPTER 9
BASIC CONCEPTS OF CHEMICAL BONDING

9-1. How many valence electrons are expected for an element that is in group five of the periodic table?

(a) three (b) five
(c) eight (d) ten

9-2. Which of the following elements is <u>most</u> likely to participate in the formation of multiple bonds?

(a) H (b) Na
(c) Cl (d) S

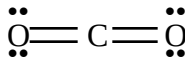
9-3. Which of the following pairs of bonded atoms would be expected to have the longest bond length?

(a) C—N (b) C—S
(c) C—B (d) C—F

9-4. Which of the descriptions below is the best representation of the energy change involved in the process of breaking bonds in a molecule? (Ignore any subsequent bond formation that may occur.)

(a) Always exothermic.
(b) Always endothermic.
(c) The net energy change in breaking a bond is zero.
(d) May be exothermic or endothermic depending on conditions.

9-5. How many sigma (σ) and pi (π) electron pairs are there in a carbon dioxide molecule?



(a) two sigma, zero pi (b) one sigma, one pi
(c) two sigma, two pi (d) two sigma, one pi

9-6. There is a triple bond between the two nitrogen atoms in the nitrogen molecule. How many sigma (σ) and pi (π) electron pairs are present in this nitrogen-nitrogen bond?

(a) one sigma, zero pi
(b) one sigma, one pi
(c) one sigma, two pi
(d) two sigma, one pi

9-7. Which of the following elements is most likely to form compounds involving an expanded valence shell of electrons?

(a) O
(b) Na
(c) P
(d) N

9-8. Which of the following statements best describes the relationship between bond length and bond strength for a series of compounds involving bonds between the same two atoms?

(a) The greater the bond strength, the longer the bond.
(b) The greater the bond strength, the shorter the bond.
(c) Bond length and bond strength are not related.
(d) The relationship between bond length and bond strength depends on other factors.

9-9. Which of the following combinations of two elements is most likely to produce highly ionic bonds?

(a) nitrogen and oxygen
(b) nitrogen and fluorine
(c) boron and nitrogen
(d) lithium and fluorine

9-10. Which of the following combinations of two elements is most likely to produce covalent bonds?

(a) nitrogen and oxygen
(b) nitrogen and fluorine
(c) sodium and nitrogen
(d) lithium and fluorine

9-11. Which of the following salts is expected to have the lowest solubility in water?

(a) NaF
(b) NaCl
(c) NaI
(d) NaBr

9-12. Which of the following salts is expected to have the highest melting point?

(a) NaF (b) NaCl

(c) NaI (d) NaBr

9-13. Predict which of each pair should be more soluble in water.

(i) KCl or KI

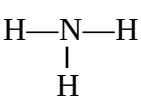
(ii) MgO or BaO

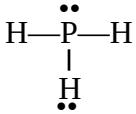
9-14. Predict which compound in each of the following pairs should have the higher melting point.

(i) NaCl or RbCl

(ii) NaCl or $MgCl_2$

9-15. Which of the following is a correct Lewis structure?

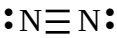
(a) 

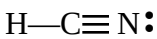
(b) 

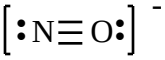
(c)

(d) 

9-16. Which of the following is NOT a correct Lewis dot structure?

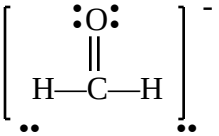
(a) 

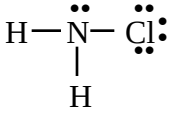
(b) 

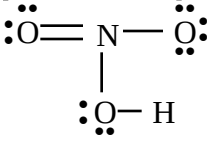
(c) 

(d)

9-17. Which of the following is NOT a correct Lewis dot structure?

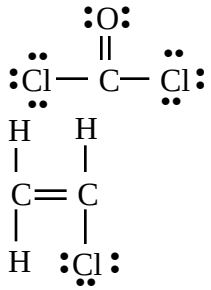
(a) 

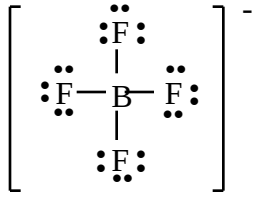
(b) 

(c) 

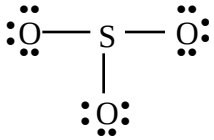
(d) 

9-18. Which of the following is NOT a correct Lewis dot structure?

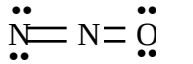
(a) 

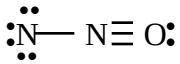
(b) 

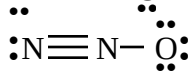
(c)

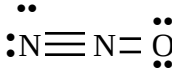
(d) 

9-19. Which of the following is NOT a correct Lewis resonance structure for the N_2O molecule?

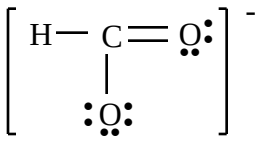
(a) 

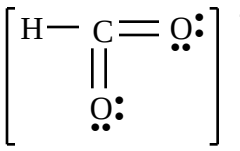
(b) 

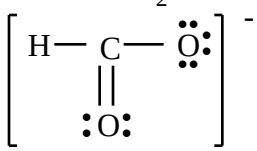
(c) 

(d) 

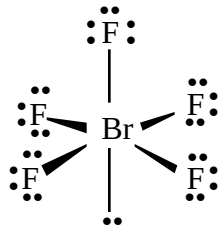
9-20. Which of the following is NOT a correct Lewis resonance structure for the HCO_2^- ion?

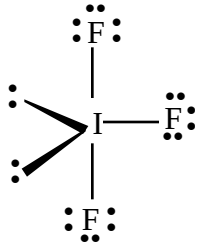
(a) 

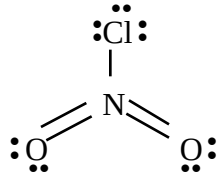
(b) 

(c) 

9-21. Which of the following is NOT a correct Lewis dot structure?

(a) 

(b) 

(c) 

9-22. According to VSEPR Theory, what number of structural electron pairs is normally expected to produce a tetrahedral structural-pair geometry?

(a) three (b) four

(c) five (d) six

9-23. According to VSEPR Theory, what number of structural electron pairs is normally expected to produce a trigonal planar structural-pair geometry?

(a) three (b) four
(c) five (d) six

9-24. According to VSEPR Theory, what number of structural electron pairs is normally expected to produce an octahedral structural-pair geometry?

(a) three (b) four
(c) five (d) six

9-25. Based on the Valence Shell Electron Pair Repulsion Theory (VSEPR), what is the molecular shape of $BeCl_2$?

(a) linear (b) trigonal planar
(c) tetrahedral (d) trigonal bipyramid

9-26. Based on the Valence Shell Electron Pair Repulsion Theory (VSEPR), what is the molecular shape of PCl_5?

(a) linear (b) trigonal planar
(c) tetrahedral (d) trigonal bipyramid

9-27. Based on the Valence Shell Electron Pair Repulsion Theory (VSEPR), what is the molecular shape of CCl_4?

(a) linear (b) trigonal planar
(c) tetrahedral (d) trigonal bipyramid

9-28. Based on the Valence Shell Electron Pair Repulsion Theory (VSEPR), which of the following corresponds most closely to the shape of the IF_2^- ion?

(a) linear (b) “T-shaped"
(c) bent (bond angle 120˚) (d) bent (bond angle 109.5˚)

9-29. Based on the Valence Shell Electron Pair Repulsion Theory (VSEPR), which of the following corresponds most closely to the molecular shape of SCl_2?

(a) linear (b) "T-shaped"

(c) bent (bond angle 120˚) (d) bent (bond angle 109.5˚)

9-30. Based on the Valence Shell Electron Pair Repulsion Theory (VSEPR), which of the following corresponds most closely to the shape of ClF_2^+?

(a) linear (b) "T-shaped"

(c) bent (bond angle 120˚) (d) bent (bond angle 109.5˚)

9-31. Based on the Valence Shell Electron Pair Repulsion Theory (VSEPR), which of the following corresponds most closely to the molecular geometry of ClF_3?

(a) linear (b) "T-shaped"

(c) bent (bond angle 120˚) (d) bent (bond angle 109.5˚)

9-32. A certain molecule has five structural electron pairs and the molecule structure is linear. How many lone pairs are present in this molecule?

(a) none (b) one

(c) two (d) three

9-33. A certain molecule has six structural electron pairs and the molecule structure is a square pyramid. How many lone pairs are present in this molecule?

(a) none (b) one

(c) two (d) three

9-34. What is the approximate Cl-B-Cl angle in BCl_3?

(a) 90^o (b) 109.5^o

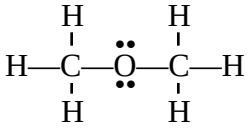
(c) 120^o (d) 180^o

9-35. What is the approximate H-N-H angle in NH_3?

(a) 90^o (b) 109.5^o

(c) 120^o (d) 180^o

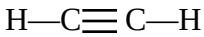
9-36. What is the approximate C-O-C angle in the molecule



(a) 90^o (b) 109.5^o

(c) 120^o (d) 180^o

9-37. What is the approximate C-C-H angle in the acetylene molecule?



(a) 90^o (b) 109.5^o

(c) 120^o (d) 180^o

9-38. What is the approximate I-I-I angle in I_3^-?

(a) 90^o (b) 109.5^o

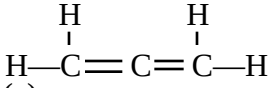
(c) 120^o (d) 180^o

9-39. What is the approximate F-Si-F angle in SiF_6^{2-}?

(a) 90^o (b) 109.5^o

(c) 120^o (d) 180^o

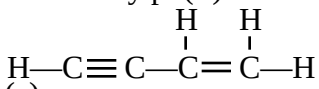
9-40. How many pi (π) bonds are found in the allene molecule?



(a) none (b) one

(c) two (d) three

9-41. How many pi (π) bonds are found in the compound below?



(a) none (b) one
(c) two (d) three

9-42. Which of the following best describes the variation of the electronegativity of the elements with respect to their position on the periodic table?

(a) Increases across a period; increases down a group.
(b) Increases across a period; decreases down a group.
(c) Decreases across a period; increases down a group.
(d) Decreases across a period; decreases down a group.

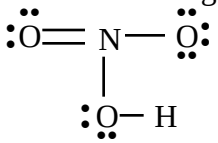
9-43. Which of the following groups of elements is arranged correctly in order of increasing electronegativity?

(a) B < O < Al < F (b) Al < B < O < F
(c) B < O < F < Al (d) F < O < B < Al

9-44. Which of the following groups of elements is arranged correctly in order of increasing electronegativity?

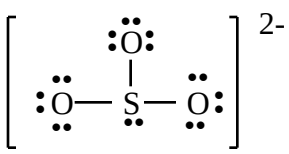
(a) Mg < P < N < F (b) N < Mg < P < F
(c) Mg < N < P < F (d) F < P < Mg < N

9-45. What is the formal charge of the N atom in nitric acid?



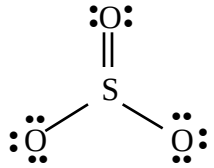
(a) 0 (b) +1
(c) -1 (d) +2

9-46. What is the formal charge on the O atoms in SO_3^{2-}?



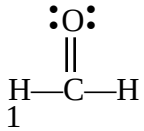
(a) 0 (b) +1
(c) -1 (d) +2

9-47. What is the formal charge of the S atom in SO_3?



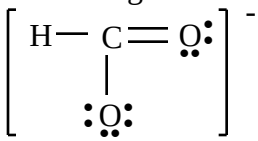
(a) 0 (b) +1
(c) -1 (d) +2

9-48. What is the carbon-oxygen bond order in formaldehyde?



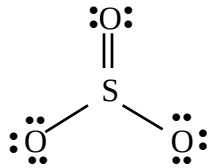
(a) 1 (b) 1 1/2
(c) 2 (d) 2 1/2

9-49. What is the average carbon-oxygen bond order in the formate ion?



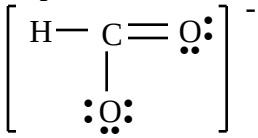
(a) 1 (b) 1 1/2
(c) 2 (d) 2 1/2

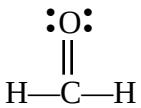
9-50. What is the average sulfur-oxygen bond order in SO_3?



(a) 1 (b) 2
(c) 1/2 (d) 1 1/3

9-51. In which species below is the carbon-oxygen bond longer?

(a) 

(b) 

9-52. Given the bond dissociation energies below, calculate the standard molar enthalpy of formation of ClF_3.

$$1/2\ Cl_2(g) + 3/2\ F_2(g) \rightarrow ClF_3(g)$$

Bond	**Dissociation Energy(kJ/mol)**
Cl—Cl	243
F—F	159
Cl—F	255

(a) 1125 kJ/mol (b) 147 kJ/mol
(c) -363 kJ/mol (d) -405 kJ/mol

9-53. Given the bond dissociation energies below, calculate the standard molar enthalpy of formation of NF_3.

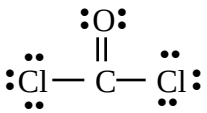
$$1/2\ N_2(g) + 3/2\ F_2(g) \rightarrow NF_3(g)$$

Bond	**Dissociation Energy(kJ/mol)**
N≡N	946
F—F	159
N—F	272

(a) 833 kJ/mol (b) 440. kJ/mol
(c) -104 kJ/mol (d) -578 kJ/mol

9-54. The molar enthalpy of formation of phosgene, Cl_2CO, is -218.8 kJ/mol. What is the C=O bond energy in the molecule?

$$Cl\ (g) + C(graphite) + 1/2\ O\ (g) \rightarrow$$



You know that the enthalpy of vaporization of C(graphite) is 717 kJ/mol and the bond dissociation energies below.

Bond	**Dissociation Energy(kJ/mol)**
Cl—Cl	243
O—O in O_2	498
C—Cl	330

(a) 768 kJ/mol (b) 328 kJ/mol
(c) 1347 kJ/mol (d) 1098 kJ/mol

9-55. Which of the following pairs of bonded atoms would be expected to have the greatest bond polarity?

(a) N—O (b) B—N

(c) K—F (d) S—Cl

9-56. Which of the three bonds below is least polar?

(a) C—O (b) C—F

(c) C—N (d) C—B

9-57. Which of the following molecules is polar?

(a) BCl_3 (b) N_2

(c) CO_2 (d) ClF

9-58. Which of the following molecules is polar?

(a) NCl_3 (b) O_2

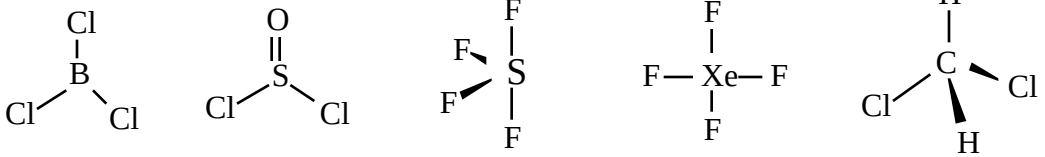
(c) SF_6 (d) CS_2

9-59. Which of the following molecules is most likely to have a dipole moment?

(a) CH_4 (b) BeF_2

(c) SF_6 (d) NF_3

9-60. Which are the *polar* molecules below? (Molecular shapes are indicated. Lone pairs are not indicated)



(a) (b) (c) (d) (e)

9-61. Xenon difluoride is prepared from elemental xenon and fluorine.

$$Xe(g) + F_2(g) \rightarrow XeF_2(g)$$

Calculate the enthalpy change, ΔH, for this reaction knowing that the bond dissociation energies are 131 kJ/mol for Xe—F and 159 kJ/mol for F—F.

(a) 28 kJ (b) -28 kJ

(c) -290. kJ (d) -103 kJ

9-62. Using the thermodynamic information below, estimate the bond dissociation energy for the B—Cl bond.

$D(Cl—Cl) = 243$ kJ/mol

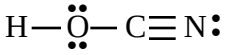
$B(solid) \rightarrow B(gas)$ $\Delta H^\circ_f[B(g)] = 563$ kJ/mol

$B(solid) + 3/2\ Cl_2(g) \rightarrow BCl_3(g)$ $\Delta H^\circ_f[BCl_3(g)] = -403.76$ kJ/mol

(a) 394 kJ (b) 444 kJ

(c) 1210 kJ (d) 1331 kJ

9-63. Cyanic acid has the electron dot structure below.

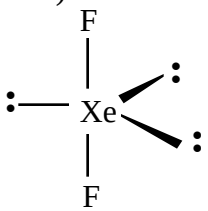


(i) How many sigma (σ) bonds are there in HOCN? _____ π bonds? _____

(ii) What is the value of the C—O—H angle? _____

(iii) What is the value of the N—C—O angle? _____

9-64. Xenon difluoride, XeF_2, has the structure below (where the lone pairs are not included on the F atoms)



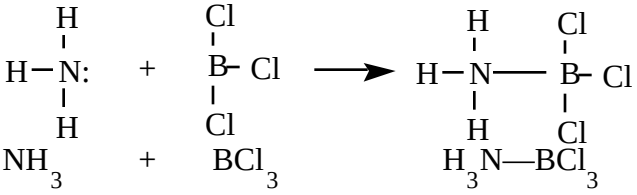
(i) What is the structural pair geometry about the Xe atom? _____

(ii) What is the molecular geometry of the XeF_2 molecule? _____

(iii) What is the value of the F—Xe—F angle? _____

(iv) Is XeF_2 a polar molecule? _____

9-65. Boron trichloride, BCl_3, can accept a pair of electrons from another molecule such as ammonia to form a coordinate covalent bond, as in the following reaction (the lone pairs of electrons around the Cl atoms are not shown):



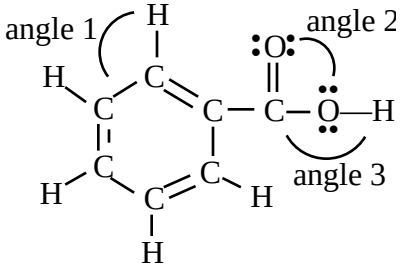
(i) The structural pair geometry of the B atom in BCl_3 is ____ and the Cl-B-Cl angle is _____. When reaction occurs, the Cl-B-Cl angle changes to _____ .

(ii) What is the least polar bond in the molecules above?

(a) N—H (b) B—Cl

(c) N—B (d) All have the same polarity.

9-66. Benzoic acid is a common organic acid.



(i) How many sigma (σ) bonds are there?

(ii) How many pi (π) bonds are there?

(iii) The bond angles are: 1 = ____; 2 = _____; 3 = _____.

(iv) The most polar bonds (or bond) in the molecule are (is):

(a) C—C (b) C—H

(c) C—O (d) O—H

ANSWERS — CHAPTER 9

1.	b	11.	a	21.	c
2.	d	12.	a	22.	b
3.	b	13.	i = KI; ii = BaO	23.	a
4.	a	14.	i = NaCl; ii = $MgCl_2$	24.	d
5.	c	15.	b	25.	a
6.	c	16.	c	26.	d
7.	c	17.	a	27.	c
8.	b	18.	d	28.	a
9.	d	19.	d	29.	d
10.	a	20.	b	30.	d
31.	b	41.	d	51.	a
32.	d	42.	b	52.	d
33.	b	43.	b	53.	c
34.	c	44.	a	54.	a
35.	b	45.	b	55.	c
36.	b	46.	c	56.	d
37.	d	47.	d	57.	d
38.	d	48.	c	58.	a
39.	a	49.	b	59.	d
40.	c	50.	d	60.	b, c, e

61. d
62. b
63. i = 3, 2; ii = 109˚; iii = 180˚
64. i = trigonal bipyramid; ii = linear; iii = 180˚; iv = nonpolar
65. i = trigonal planar, 120˚, 109˚; ii = a
66. i = 15; ii = 4; iii = 120˚, 120˚, 109˚; iv = c