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Focus 2: Molecules

1. Use the expression for the Coulomb potential energy to calculate the energy for formation of 1 mole of sodium chloride ion-pairs, that is, the energy change for the following reaction:
   $Na^+(g) + Cl^-(g) \rightarrow Na^+Cl^-(g)$
   Use r_{12} = 283 pm.
   Ans: –491 $kJ \cdot mol^{-1}$

2. If 491 $kJ \cdot mol^{-1}$ is released in the reaction $Na^+(g) + Cl^-(g) \rightarrow Na^+Cl^-(g)$, what is the energy change for the reaction $Na(g) + Cl(g) \rightarrow Na^+Cl^-(g)$? (Hint: See the discussion in the text and apply Hess's Law.)
   Ans: –346 $kJ \cdot mol^{-1}$

3. If 346 $kJ \cdot mol^{-1}$ is released in the reaction $Na(g) + Cl(g) \rightarrow Na^+Cl^-(g)$, is the energy change for the reaction $Na^+Cl^-(g) \rightarrow NaCl(s)$ endothermic or exothermic?
   Ans: Exothermic

4. The Madelung constant is different for all crystals. True or false?
   Ans: True

5. Use the expression for the Coulomb potential energy to calculate the energy for formation of 1 mole of rubidium chloride ion-pairs, that is, the energy change for the following reaction:
   $Rb^+(g) + Cl^-(g) \rightarrow Rb^+Cl^-(g)$
   Use r_{12} = 330 pm.
   Ans: –421 $kJ \cdot mol^{-1}$

6. Which of the following has the lowest lattice energy?
   A) KCl B) LiCl C) KBr D) NaCl E) KI
   Ans: E

7. Which of the following has the highest lattice energy?
   A) NaCl B) KI C) MgO D) BaO E) CaO
   Ans: C

8. Which of the following has the highest melting point?
   A) KF B) KI C) RbF D) KBr E) KCl
   Ans: A

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9. Metals rarely lose electrons in chemical reactions because
   A) their electron affinities are too high.
   B) their ionic radii become too small.
   C) their ionization energies are too small.
   D) their size is too small.
   E) their ionization energies are too high.
   Ans: E

10. An element, E, has the electronic configuration [Ne] $3s^2 3p^1$. Write the formula of its compound with sulfate.
    Ans: $E_2(SO_4)_3$

11. Predict the electronic configuration in the oxide ion in CaO.
    A) [He]$2s^2 2p^6$ or [Ne]
    B) [He]$2s^2 2p^5$
    C) [He]$2s^2 2p^6 3s^2$
    D) [Ne]$3s^1 3p^3$
    E) [Ne]$3s^2 3p^3$
    Ans: A

12. Write the formula of magnesium phosphide.
    Ans. Mg_3P_2

13. Which of the following metal ions has the ground-state electron configuration [Ar]$3d^6$?
    A) Ni^{3+} B) Fe^{2+} C) Mn^{2+} D) Cu^{+} E) Ca^{2+}
    Ans: B

14. For the ground-state ion Pb^{2+}, what type of orbital do the electrons with highest energy reside in?
    A) 6p B) 5p C) 4f D) 6s E) 5d
    Ans: D

15. For the ground-state ion Sn^{4+}, what type of orbital do the electrons with highest energy reside in?
    A) 4p B) 5p C) 4f D) 4d E) 5s
    Ans: D

16. For the ground-state ion Bi^{3+}, what type of orbital do the electrons with highest energy reside in?
    A) 5d B) 6s C) 4f D) 5p E) 6p
    Ans: B

17. For the ground-state ion I^-, what type of orbital do the electrons with highest energy reside in?
    A) 4d B) 6s C) 5p D) 5d E) 5s
    Ans: C

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18. Because of the octet rule, the gaseous O^{2-} ion is stable. True or false?
Ans: False

19. All the following elements exist as diatomic gases at room temperature and atmospheric pressure except
A) H. B) Ar. C) N. D) Cl. E) O.
Ans: B

20. How many lone pairs of electrons are found in the Lewis structure of the interhalogen compound ICl_3?
A) 10 B) 4 C) 8 D) 6 E) 7
Ans: A

21. How many lone pairs of electrons are found in the Lewis structure of urea, $(NH_2)_2CO$?
A) 2 B) 3 C) 6 D) 4 E) 8
Ans: D

22. How many lone pairs of electrons are found in the Lewis structure of hydrazine, H_2NNH_2?
A) 8 B) 4 C) 1 D) 0 E) 2
Ans: E

23. Draw the Lewis structure of xenon difluoride and give the number of lone pairs electrons around the central atom.
Ans: Three

24. Draw the Lewis structure of the formate ion and indicate whether resonance forms are possible.
Ans: Two resonance forms are possible.

25. Draw the "best" Lewis structures of hydrogen azide, $HN_1N_2N_3$, and the azide ion, $N_1N_2N_3^-$. The subscripts are used for identification. For each, match the following bond lengths to the correct N–N bond. The bond lengths can be used more than once.

	N–N bond	Bond length, pm
hydrogen azide	N_1–N_2	113
	N_2–N_3	116
azide ion	N_1–N_2	124
	N_2–N_3	

Ans: hydrogen azide: N_1–N_2, 124 pm; N_2–N_3, 113 pm; azide ion: N_1–N_2, 116 pm; N_2–N_3, 116 pm

26. Which of the following do not have resonance structures?
A) CH_3CONH^- B) $CH_2COCH_3^-$ C) H_2CO D) All have resonance structures.
Ans: C

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27. For dinitrogen monoxide, the arrangement of the atoms is N-N-O. In the Lewis structure with a double bond between NN and NO, the formal charges on N, N, and O, respectively, are
A) 0, −1, +1. B) −1, +1, 0. C) 0, +1, −1. D) 0, 0, 0. E) −2, +1, +1.
Ans: B

28. For dinitrogen monoxide, the arrangement of the atoms is N-N-O. In the Lewis structure with a single bond between NN and a triple bond between NO, the formal charges on N, N, and O, respectively, are
A) −1, +1, 0. B) 0, 0, 0. C) 0, +1, −1. D) 0, −1, +1. E) −2, +1, +1.
Ans: E

29. In the "best" Lewis structure of XeO_4, there are two double bonds and the formal charge on Xe is zero. True or false?
Ans: False

30. Write three Lewis structures for the cyanate ion, NCO^-, where the arrangement of atoms is N-C-O. In the most plausible structure,
A) there is a triple bond between N and C.
B) there are two double bonds.
C) there is a triple bond between C and O.
D) the formal charge on O is +1.
E) the formal charge on N is −1.
Ans: A

31. Predict the N-O bond lengths in NO_2^-, given the N-O and N=O bond lengths of 140 and 120 pm, respectively.
Ans: Both ~ 130 pm

32. Why are the N-O bond lengths in NO_3^- the same?
Ans: The explanation is resonance.

33. Which of the following species are radicals?
A) CO_2 B) HNO_3 C) NO_2 D) NO_3^- E) HNO_3
Ans: C only.

34. Which of the following species are radicals?
A) CH_2O B) HCN C) HclO D) $ClONO_2$ E) ClO
Ans: E only.

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35. In the most plausible Lewis structure of $XeOF_2$, there are
    A) 2 single bonds, 1 double bond, and 1 lone pair of electrons around Xe.
    B) 3 single bonds and 1 lone pair of electrons around Xe.
    C) 2 single bonds, 1 double bond, and 3 lone pairs of electrons around Xe.
    D) 2 single bonds, 1 double bond, and 2 lone pairs of electrons around Xe.
    E) 3 single bonds and 2 lone pairs of electrons around Xe.
    Ans: D

36. How many electrons are in the expanded valence in $XeOF_2$?
    A) 14 B) 12 C) 8 D) 10 E) 6
    Ans: B

37. How many electrons are in the expanded valence in I_3^-?
    A) 12 B) 6 C) 10 D) 14 E) 8
    Ans: C

38. How many electrons are in the expanded valence in H_2SO_4?
    A) 12 B) 14 C) 8 D) 6 E) 10
    Ans: A

39. How many electrons are in the expanded valence in XeO_4?
    Ans: 16

40. Consider the following equilibrium:
    $S_2O_4^{2-}(aq) \leftrightarrow 2SO_2^-(aq)$ $K \sim 10^{-9}$
    Write a Lewis structure for each species.
    Ans: The arrangement of atoms in $S_2O_4^{2-}$ is $O_2S—SO_2$. The latter has a Lewis structure that obeys the octet rule, but SO_2^- is a radical.

41. Which of the following species has bonds with the most ionic character?
    A) SiO_2 B) PCl_3 C) P_4O_{10} D) CO_2 E) NO_2
    Ans: A

42. Write all possible Lewis structures of sulfur dioxide. Which structure is most feasible?
    Ans: The structure with the expanded valence is favored.

43. Which of the following species has bonds with the most ionic character?
    A) CO_2 B) NO_2 C) SnO_2 D) P_4O_{10} E) PCl_3
    Ans: C

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44. Which of the following statements is true?
    A) Atoms with high ionization energies and high electron affinities are highly electronegative.
    B) Atoms with high ionization energies and high electron affinities have low electronegativities.
    C) The electronegativity of an atom depends only on the value of the ionization energy of the atom.
    D) Atoms with low ionization energies and low electron affinities have high electronegativities.
    E) The electronegativity of an atom is defined as half the electron affinity of the atom.
    Ans: A

45. Which of the following statements is true?
    A) The electronegativity of an atom is defined as electron affinity of the atom.
    B) The electronegativity of an atom depends only on the value of the ionization energy of the atom.
    C) Atoms with high ionization energies and high electron affinities have low electronegativities.
    D) Atoms with low ionization energies and low electron affinities have low electronegativities.
    E) Atoms with low ionization energies and low electron affinities have high electronegativities.
    Ans: D

46. Which of the compounds below has bonds with the least covalent character?
    A) AgI B) AgCl C) AgF D) $AlCl_3$ E) $BeCl_2$
    Ans: C

47. Which of the compounds below has bonds with the most covalent character?
    A) NaCl B) LiCl C) $CaCl_2$ D) $BeCl_2$ E) $MgCl_2$
    Ans: D

48. Which of the compounds below has bonds with the most covalent character?
    A) CaO B) Li_2O C) MgO D) MgS E) CaS
    Ans: D

49. Use the bond enthalpies given to estimate the heat released when 1-bromobutene, $CH_3CH_2CH{=}CH_2$, reacts with bromine to give $CH_3CH_2CHBrCH_2Br$. Bond enthalpies ($kJ{\cdot}mol^{-1}$): C-H, 412; C-C, 348; C=C, 612; C-Br, 276; Br-Br, 193.
    A) 181 $kJ{\cdot}mol^{-1}$
    B) 317 $kJ{\cdot}mol^{-1}$
    C) 288 $kJ{\cdot}mol^{-1}$
    D) 95 $kJ{\cdot}mol^{-1}$
    E) 507 $kJ{\cdot}mol^{-1}$
    Ans: D

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50. Use the bond enthalpies given to estimate the heat released when ethene, $CH_2=CH_2$, reacts with HBr to give CH_3CH_2Br. Bond enthalpies ($kJ \cdot mol^{-1}$): C-H, 412; C-C, 348; C=C, 612; C-Br, 276; Br-Br, 193; H-Br, 366.
A) 1036 $kJ \cdot mol^{-1}$
B) 200 $kJ \cdot mol^{-1}$
C) 470 $kJ \cdot mol^{-1}$
D) 424 $kJ \cdot mol^{-1}$
E) 58 $kJ \cdot mol^{-1}$
Ans: E

51. Use the bond enthalpies given to estimate the heat released when 2-methyl-1-propene, $(CH_3)_2C=CH_2$, reacts with HBr to give $(CH_3)_2CBrCH_3$. Bond enthalpies ($kJ \cdot mol^{-1}$): C-H, 412; C-C, 348; C=C, 612; C-Br, 276; H-Br, 366.
A) 58 $kJ \cdot mol^{-1}$
B) 507 $kJ \cdot mol^{-1}$
C) 317 $kJ \cdot mol^{-1}$
D) 288 $kJ \cdot mol^{-1}$
E) 181 $kJ \cdot mol^{-1}$
Ans: A

52. Use the bond enthalpies given to estimate the heat released when ethene, $CH_2=CH_2$, reacts with hydrogen to give CH_3CH_3. Bond enthalpies ($kJ \cdot mol^{-1}$): C-H, 412; C-C, 348; C=C, 612; C-Br, 276; H-H, 436.
A) 124 $kJ \cdot mol^{-1}$
B) 342 $kJ \cdot mol^{-1}$
C) 288 $kJ \cdot mol^{-1}$
D) 148 $kJ \cdot mol^{-1}$
E) 560 $kJ \cdot mol^{-1}$
Ans: A

53. Which of the following compounds contains the weakest bonds to hydrogen?
A) CH_4 B) H_2O C) SiH_4 D) HF E) H_2S
Ans: C

54. Which of the following compounds contains the strongest bonds to hydrogen?
A) SiH_4 B) CH_4 C) HF D) H_2S E) H_2O
Ans: C

55. Which of the following compounds is the least stable?
A) CH_4 B) SnH_4 C) SiH_4 D) GeH_4 E) PbH_4
Ans: E

56. Estimate the CO bond length in acetone, CH_3COCH_3. Given: covalent radii (pm) of C–, 77; C=, 67; O–, 74; O=, 60; H, 37.
A) 75.5 pm B) 127 pm C) 63.5 pm D) 151 pm E) 137 pm
Ans: B

57. Estimate the CN bond length in urea, NH_2CONH_2. Given: covalent radii (pm) of C–, 77; C=, 67; N–, 75; N=, 60; O–, 74; O=, 60; H, 37.
A) 71 pm B) 127 pm C) 76 pm D) 152 pm E) 142 pm
Ans: D

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58. If the following all crystallize in the same type of structure, which has the highest lattice energy?
A) LiCl B) KF C) KBr D) KCl E) LiF
Ans: E

59. If the following all crystallize in the same type of structure, which has the highest lattice energy?
A) NaCl B) NaF C) KF D) NaBr E) NaI
Ans: B

60. If the following all crystallize in the same type of structure, which has the lowest lattice energy?
A) CaO B) BaS C) SrO D) SrS E) BaO
Ans: B

61. If the following all crystallize in the same type of structure, which has the lowest lattice energy?
A) LiCl B) NaI C) NaCl D) KCl E) KI
Ans: E

62. White phosphorus is composed of tetrahedral molecules of P_4 in which every P atom is connected to three other P atoms. In the Lewis structure of P_4, there are
A) 3 bonding pairs and 4 lone pairs of electrons.
B) 6 bonding pairs and 2 lone pairs of electrons.
C) 5 bonding pairs and 4 lone pairs of electrons.
D) 6 bonding pairs and no lone pairs of electrons.
E) 6 bonding pairs and 4 lone pairs of electrons.
Ans: E

63. Which of the following is a radical?
A) BrO B) CH_3^+ C) CH_3^- D) BF_4^-
Ans: A

64. If dinitrogen oxide has a dipole moment, what is the arrangement of atoms?
Ans: N-N-O

65. The electronegativity of an element can be expressed as $\frac{1}{2}(I + E_a)$ where I is the ionization energy and E_a is the electron affinity. True or false?
Ans: True

66. The best Lewis structures of SO_2 and O_3 include expanded valence structures such as O=S=O and O=O=O. True or false?
Ans: False

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67. Which of the following has resonance structures?
A) $XeOF_2$ B) N_2H_4 C) CH_3CONH^- D) H_2CO
Ans: C

68. How many resonance structures can be drawn for N_2O?
A) 0 B) 3 C) 2 D) 1
Ans: B

69. What is the formal charge on the Xe atom in XeF_4?
A) 0 B) –4 C) +2 D) +4
Ans: A

70. There are three resonance structures of the sulfate ion. A resonance structure can be written where the formal charge on sulfur is 0. True or false?
Ans: True

71. How many double bonds are present in the "best" resonance structure of the phosphate ion?
A) 2 B) 3 C) 1 D) 0
Ans: C

72. How many lone pairs of electrons are there in the Lewis structure of Al_2Cl_6?
A) 24 B) 12 C) 4 D) 16
Ans: D

73. Match each of the following compounds with its lattice energy.
KI, LiF, MgF_2, LiI 2961, 1046, 759, 645 kJ/mol
Ans: MgF_2 (2961), LiF (1046), LiI (759), KI (645 kJ/mol)

74. White phosphorus is composed of tetrahedral molecules of P_4 in which each P atom is bonded to three others. In this molecule the formal charge on each P atom is ___.
Ans: 0

75. Of the following molecules, which has the strongest bonds?
A) H_2O B) H_2Se C) H_2Te D) H_2S
Ans: A

76. An element E has the electronic configuration $1s^2 2s^2 2p^4$. What is the formula of its compound with lithium?
A) LiE_2 B) LiE C) Li_2E D) Li_4E
Ans: C

77. How many valence electrons are present in W^{4+}?
Ans: 2

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78. What is wrong with the following Lewis structure?
$O-C\equiv O$
A) The valence electron count
B) The positioning of the carbon atom
C) The distribution of valence electrons
D) The charge on the carbon atom
E) The dipole of the molecule
Ans: C

79. Sulfur is more electronegative than oxygen. True or false?
Ans: False

80. What is the electronic configuration of Ag?
Ans: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^1\ 4d^{10}$

81. What is the formal charge of S in the molecule H_2SO_4?
Ans: 0

82. Why is the bond dissociation energy of C—C greater than that of C—H?
A) Because of enhanced sigma bond overlap
B) Because the bond is electrostatically stronger
C) Because multiple bonds are always stronger than single bonds
D) Because of the decreased bond dipole
E) It isn't, the dissociation energy is greater for C—H
Ans: E

83. List the chalcogens in order of increasing electronegativity.
Ans: tellurium < selenium < sulfur < oxygen.

84. Which has the greater ionic character: H_2S or H_2O?
Ans: H_2O

85. Name all the angles in a trigonal bipyramidal geometry.
Ans: 90°, 120°, and 180°

86. Name all the angles in a trigonal planar geometry.

Ans: 120°

87. Predict the HNH bond angle in NH_2^-.
Ans: ~109°

88. Predict the electron arrangement in NO_2^-.
Ans: trigonal planar

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89. The electron arrangement and shape in IF_4^+, respectively, are
Ans: trigonal bipyramidal; seesaw.

90. Predict the electron arrangement in ClF_3.
Ans: Trigonal bipyramidal

91. Predict the electron arrangement in IF_5.
Ans: Octahedral

92. What is the shape of AlH_4^-?
A) Tetrahedral
B) Trigonal bipyramidal
C) Seesaw
D) T-shaped
E) Square planar
Ans: A

93. What is the shape of BrO_4^-?
A) Tetrahedral
B) Trigonal bipyramidal
C) Seesaw
D) T-shaped
E) Square planar
Ans: A

94. What is the shape of AsF_3?
A) T-shaped
B) Trigonal planar
C) Trigonal pyramidal
D) Tetrahedral
E) Seesaw
Ans: C

95. What is the shape of SO_3^{2-}?
A) T-shaped
B) Trigonal pyramidal
C) Seesaw
D) Tetrahedral
E) Trigonal planar
Ans: B

96. What is the shape of CS_3^{2-}?
A) Trigonal pyramidal
B) Trigonal planar
C) T-shaped
D) Tetrahedral
E) Seesaw
Ans: B

97. What is the shape of $COCl_2$?
A) T-shaped
B) Trigonal planar
C) Trigonal pyramidal
D) Tetrahedral
E) Seesaw
Ans: B

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98. What is the shape of XeF_4?
A) Square planar
B) Tetrahedral
C) Trigonal bipyramidal
D) Seesaw
E) T-shaped
Ans: A

99. What is the shape of ICl_4^-?
A) T-shaped
B) Trigonal bipyramidal
C) Seesaw
D) Tetrahedral
E) Square planar
Ans: E

100. What is the shape of IF_4^+?
A) Tetrahedral
B) Seesaw
C) Trigonal bipyramidal
D) Square planar
E) T-shaped
Ans: B

101. What is the shape of ClF_3?
A) Tetrahedral
B) Seesaw
C) Trigonal bipyramidal
D) T-shaped
E) Square planar
Ans: D

102. All the following have a linear shape except
A) $BeCl_2$. B) O_3. C) I_3^-. D) XeF_2. E) CS_2.
Ans: B

103. All the following have an angular shape except
A) HOCl. B) S_3^{2-}. C) I_3^-. D) ClO_2^-. E) NH_2^-.
Ans: C

104. All the following have a linear shape except
A) IF_2^-. B) CS_2. C) XeF_2. D) I_3^-. E) I_3^+.
Ans: E

105. All the following have an angular shape except
A) N_3^-. B) ClO_2^-. C) S_3^{2-}. D) HOCl. E) NH_2^-.
Ans: A

106. Which of the following has bond angles slightly less than 109°?
A) NH_4^+ B) ClO_4^- C) BrO_3^- D) PO_4^{3-} E) BH_4^-
Ans: C

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107. Which of the following has bond angles of 180°?
A) I_3^- B) ClO_2^- C) O_3 D) NH_2^- E) HO_2^-
Ans: A

108. Which of the following has bond angles of 180°?
A) N_2O B) ClO_2^- C) O_3 D) HO_2^- E) NH_2^-
Ans: A

109. Which of the following has bond angles slightly less than 120°?
A) SO_3 B) SF_2 C) I_3^- D) NO_3^- E) O_3
Ans: E

110. Which of the following has bond angles slightly less than 109°?
A) NO_2^- B) I_3^- C) HOCl D) O_3 E) CH_2^-
Ans: C

111. Which of the following has bond angles slightly less than 109°?
A) CS_3^{2-} B) AsF_3 C) SO_2 D) $COCl_2$ E) COS
Ans: B

112. Which of the following has bond angles slightly less than 120°?
A) NO_3^- B) HO_2^- C) NO_2^- D) CS_3^{2-} E) I_3^+
Ans: C

113. Which of the following has bond angles of 120°?
A) HO_2^- B) CS_3^{2-} C) S_3^{2-} D) O_3 E) NO_2^-
Ans: B

114. Which of the following has bond angles of 90°, 120°, and 180°?
A) PF_6^- B) IF_5 C) XeF_4 D) ICl_4^- E) SF_4
Ans: E

115. Which of the following only has bond angles of 90°?
A) IF_5 B) IF_4^+ C) XeF_2 D) SF_4 E) IO_2F_3
Ans: A

116. Which of the following only has bond angles of 90° and 180°?
A) IF_5 B) BrF_3 C) BCl_3 D) NO_3^- E) ICl_4^+
Ans: B

117. Which of the following is polar?
A) CO_3^{2-} B) O_3 C) XeF_2 D) I_3^- E) NON
Ans: B

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118. Which of the following is polar?
A) NON B) XeF_2 C) XeO_2 D) ICl_4^- E) I_3^-
Ans: C

119. Which of the following is polar?
A) XeF_4 B) PCl_5 C) ICl_4^- D) SF_6 E) IF_5
Ans: E

120. All the following are polar except
A) S_3^{2-}. B) NH_2^-. C) I_3^-. D) O_3. E) I_3^+.
Ans: C

121. All of the following are polar except
A) SF_4. B) ClO_2^-. C) IF_4^+. D) XeF_4. E) ClF_3.
Ans: D

122. Which of the following is polar?
A) SF_6 B) ICl_4^- C) SF_4 D) AsF_6^- E) XeF_4
Ans: C

123. All the following are polar except
A) ClF_3. B) $COCl_2$. C) BO_3^{3-}. D) BrO_3^-. E) O_3.
Ans: C

124. All the following are polar except
A) O_3. B) ClF_3. C) $COCl_2$. D) BrO_3^-. E) CS_3^{2-}.
Ans: E

125. All the following are polar except
A) XeO_2. B) ClF_3. C) XeF_4. D) $SOCl_2$. E) XeO_3.
Ans: C

126. The molecule *cis*-dichloroethene is nonpolar. True or false?
Ans: False

127. How many σ- and π-bonds, respectively, are there in acrolein, CH_2=CHCHO?
A) 4 and 2 B) 7 and 2 C) 5 and 2 D) 5 and 4 E) 7 and 1
Ans: B

128. How many σ- and π-bonds, respectively, are there in peroxyacetylnitrate, $CH_3C(O)O$-ONO_2?
A) 9 and 2 B) 10 and 2 C) 10 and 1 D) 8 and 4 E) 8 and 2
Ans: B

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129. How many σ- and π-bonds are present in diazomethane, CH_2NN?
Ans: 4 σ-bonds and 2 π-bonds

130. Draw the Lewis structure of formamide, NH_2CHO, and give the number of lone pairs of electrons, and the number of σ- and π-bonds.
Ans: 3 lone pairs, 5 σ-bonds, and 1 π-bond

131. Draw the Lewis structure of the cyanamide ion, $NCNH^-$, and give the number of lone pairs of electrons and the number of σ- and π-bonds.
Ans: 3 lone pairs, 3 σ-bonds, and 2 π-bonds

132. Identify the hybrid orbitals used by the underlined atom in acetone, $CH_3\underline{C}OCH_3$.
A) sp^3d B) sp^2 C) None; pure p_z-orbitals are used in bonding. D) sp^3 E) sp
Ans: B

133. The hybrid orbitals used by the underlined atoms in $CH_3\underline{C}HCH\underline{C}N$, from left to right, respectively, are
A) sp^3 and sp.
B) sp^2 and sp.
C) sp^2 and sp^3.
D) sp^2 and sp^2.
E) sp and sp^3.
Ans: B

134. The hybrid orbitals used by the underlined atoms in $CH_3\underline{C}H_2\underline{O}CH_2CH_3$, from left to right, respectively, are
A) sp and sp. B) sp^3 and sp. C) sp^3 and sp^3. D) sp and sp^3. E) sp^2 and sp^3.
Ans: C

135. The hybrid orbitals used by the underlined atoms in $\underline{C}H_2CH\underline{C}HO$, from left to right, respectively, are
A) sp^3 and sp^2. B) sp^2 and sp^2. C) sp^2 and sp. D) sp and sp. E) sp^3 and sp.
Ans: B

136. For the Lewis structure of the cyanamide ion that contains two double bonds, $\underline{N}=C=NH^-$, the hybrid orbitals used by the underlined nitrogen atom and the carbon atom, respectively, are
A) sp^2 and sp^3. B) sp and sp. C) sp^2 and sp^2. D) sp and sp^3. E) sp^2 and sp.
Ans: E

137. The NCO bond angle in formamide, H_2NCHO, is _____.
Ans: ~ 120° (120° is an acceptable answer)

138. All the following are paramagnetic except
A) O_2^+. B) O_2^-. C) N_2^{2+}. D) N_2^{2-}. E) O_2.
Ans: C

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139. Which of the following is diamagnetic?
A) O_2^{2-} B) S_2 C) O_2^- D) O_2^+
Ans: A

140. What is the ground-state electron configuration of O_2^-?
Ans: $(\sigma_{2s})^2(\sigma_{2s}^*)^2(\sigma_{2p})^2(\pi_{2p})^4(\pi_{2p}^*)^2(\pi_{2p}^*)^1$

141. Which of the following is paramagnetic?
A) N_2 B) B_2 C) O_2^{2-} D) C_2^{2-} E) B_2^{2-}
Ans: B

142. Which of the following would have the longest bond?
A) B_2 B) C_2 C) N_2 D) C_2^{2-} E) N_2^{2-}
Ans: A (bond order = 1)

143. The bond order of N_2^{2+} is
A) 2.5. B) 1. C) 2. D) 1.5. E) 3.
Ans: C

144. The bond order of O_2^{2+} is
A) 1. B) 2. C) 3. D) 2.5. E) 1.5.
Ans: D

145. Which of the following has the longest bond?
A) N_2 B) NO^- C) N_2^{2+} D) N_2^{2-} E) O_2^{2-}
Ans: E

146. Which of the following is paramagnetic?
A) N_2 B) N_2^{2+} C) O_2^{2-} D) N_2^{2-} E) NO^+
Ans: D

147. Which of the following species has the shortest bond length?
A) NO^{2-} B) NO^{2+} C) NO^- D) NO E) NO^+
Ans: E

148. Which of the following species has two unpaired electrons?
A) OF^+ B) NO^+ C) CO^+ D) NF^+ E) CF^+
Ans: A

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149. Which of the following is a p-type semiconductor?
A) Selenium doped with indium
B) Silicon doped with arsenic
C) GaAs with arsenic in excess of gallium
D) Germanium doped with arsenic
E) Silicon doped with phosphorus
Ans: A

150. Which of the following is an n-type semiconductor?
A) Silicon doped with phosphorus
B) Silicon doped with boron
C) GaAs with gallium in excess of arsenic
D) Selenium doped with indium
E) Germanium doped with indium
Ans: A

151. Germanium is a semiconductor. Which of the following should be added in small amounts to produce a p-type semiconductor?
A) Bi B) As C) P D) Sb E) B
Ans: E

152. Gallium is a semiconductor. Which of the following should be added in small amounts to produce a p-type semiconductor?
A) Si B) Sb C) B D) P E) As
Ans: C

153. How many lone pairs of electrons are there in the Lewis structure of azidocarbonamide, $H_2NC(O)NNC(O)NH_2$?
A) 8 B) 12 C) 10 D) 16 E) 6
Ans: A

154. What is the approximate **NNC** bond angle in azidocarbonamide, $H_2NC(O)\mathbf{NNC}(O)NH_2$?
A) 118° B) 180° C) 90° D) 107° E) 109°
Ans: A

155. What is the hybridization of the bolded atoms **NNC,** from left to right, in azidocarbonamide, $H_2NC(O)\mathbf{NNC}(O)NH_2$?
A) sp^3, sp, sp^2
B) sp^2, sp, sp^3
C) sp^2, sp, sp^2
D) sp, sp, sp^2
E) sp^2, sp^2, sp^2
Ans: E

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156. How many σ- and π-bonds, respectively, are there in the Lewis structure of azidocarbonamide, $H_2NC(O)NNC(O)NH_2$?
A) 14 and 3 B) 15 and 3 C) 14 and 2 D) 8 and 3 E) 11 and 3
Ans: E

157. Two Lewis structures can be written for diazomethane, where the arrangement of atoms is H_2**C**-**N**-N. The hybrid orbitals used by the bold atoms in these Lewis structures are
A) sp^3 or sp^2, and sp. B) sp^2 and sp. C) sp^3 and sp. D) sp^3 or sp^2, and sp^2.
Ans: A

158. The fact that B_2 has two unpaired electrons means the $2p_\pi$ molecular orbitals have higher energy than the $2p_\sigma$ molecular orbitals. True or false?
Ans: False

159. How many peaks would you predict for the photoelectron spectrum of water using 1) the molecular orbital model and 2) the VSEPR model?
Ans: molecular orbital, 4; VSEPR, 2; the experimental result is 4 peaks

160. The OSO bond angle in the sulfite ion is _____ (greater than/equal to/ less than) 109.5°.
Ans: less than

161. An AX_3E_2 molecule has a trigonal planar shape. True or false?
Ans: False

162. Which of the following molecules is (are) polar?
(a) $AsCl_4^+$ (b) I_3^+ (c) I_3^- (d) N_3^- (e) S_3^{2-}
A) (b) and (e) B) (b) and (c) C) (c) and (e) D) only (e)
Ans: A

163. What is the bond order in the OH radical?
Ans: 0.5

164. When two atoms are brought together along the *x*-axis, what is the number of σ bonds that can be formed by overlap of *p*-orbitals on each atom?
A) 0 B) 1 C) 2 D) 3
Ans: B

165. What hybrid orbitals are used by the N atoms in urea, H_2NCONH_2?
A) sp B) sp^2 C) sp^3 D) dsp^3
Ans: C

166. In the NO molecule, which atom makes the larger contribution to the lowest energy molecular orbital?
Ans: O

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167. For A_2, the LCAO-MO, $\psi = c_A\psi_A + c_B\psi_B$, has $c_A = c_B$. True or false?
Ans: True

168. For HF, the LCAO-MO, $\psi = c_H\psi_H + c_F\psi_F$, has $c_H = c_F$. True or false?
Ans: False

169. For peroxyacetylnitrate, $CH_3C(O)\mathbf{O}—ONO_2$, what hybrid orbitals are used by the oxygen atom in bold?
A) *dsp* B) *sp* C) sp^2 D) sp^3
Ans: D

170. The molecules OF_2 and O_3 both have bent shapes. What are the approximate bond angles in OF_2 and O_3, respectively?
A) 109^o and 120^o
B) Both 109^o
C) Both 120^o
D) Both 180^o
E) 109^o and 180^o
Ans: A

171. What are the electron arrangements around the central atom and the shape, respectively, of SF_4?
A) Trigonal bipyramidal and seesaw
B) Both tetrahedral
C) Octahedral and square pyramidal
D) Both square pyramidal
E) Seesaw
Ans: A

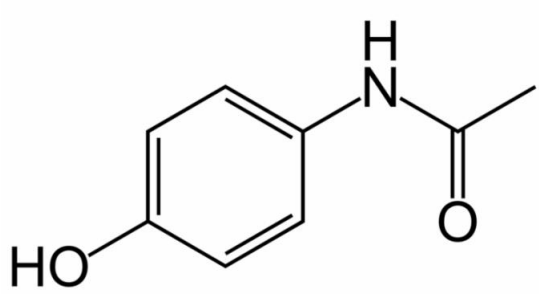
172. What is the shape of the molecule AX_4E_2?
A) Octahedral
B) Tetrahedral
C) Seesaw
D) Square planar
E) Square pyramidal
Ans: D

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173. The molecules OF_2 and O_3 both have bent shapes. What is the hybridization of the central atom in OF_2 and O_3, respectively?
A) sp^3 and sp^2
B) both sp^3
C) both sp^2
D) sp^3 and sp
E) both sp
Ans: A

174. Dinitrogen monoxide has a dipole moment. Draw the arrangement of atoms and indicate the shape of dinitrogen monoxide.
Ans: N-N-O; linear

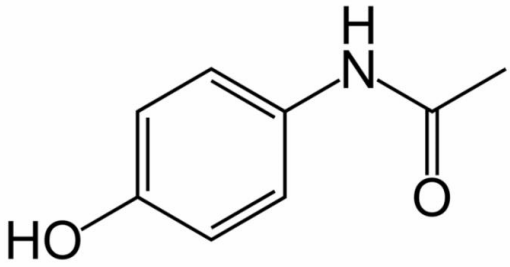
175. The structure of Tylenol is given below:



Estimate the C-N-H bond angle.
A) ~ 109°
B) ~ 120°
C) > 109°
D) > 120°
E) ~ 90°
Ans: A

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176. The structure of Tylenol is given below:



What hybrid orbitals are used on the N atom and the carbonyl carbon, respectively?
A) sp^3 and sp^2
B) sp^2 and sp^2
C) sp^3 and sp^3
D) sp^2 and sp
E) sp^3 and sp
Ans: A

177. All of the following are polar except
A) NO_2^-. B) SO_3^{2-}. C) NO_2Cl. D) NO_3^-. E) N_2O (N is the central atom).
Ans: D

178. In NO, the unpaired electron occupies what type of molecular orbital?
A) 3σ
B) $4\sigma^*$
C) $2\pi^*$
D) 1π
E) The oxygen 2p orbital.
Ans: C

179. Both C_2 and C_2^{2-} are diamagnetic. True or false?
Ans: True

180. What are the electron arrangements and the shape around the central atom of $SeCl_4$?
A) Octahedral and square pyramidal
B) Both tetrahedral
C) Trigonal bipyramidal and seesaw
D) Both square pyramidal
E) Seesaw
Ans: C

181. Why does the best Lewis structure for sulfuric acid (H_2SO_4) have the sulfur atom formally possessing five bonds?
A) This configuration gives all atoms in the molecule a formal charge of 0.

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B) It is the best expanded octet structure for the molecule.
C) It doesn't; it should possess four bonds.
D) It doesn't; it should possess six bonds.

Ans.: D

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