

CHAPTER 1--COVALENT BONDING AND SHAPES OF MOLECULES

Student: _____

1. How many electrons can the shell with a principal quantum number of 1 hold?

- A. 1
- B. 2
- C. 4
- D. 8

2. How many electrons can the shell with a principal quantum number of 2 hold?

- A. 1
- B. 2
- C. 4
- D. 8

3. What is the ground-state electronic configuration of a nitrogen atom (nitrogen: atomic number 7)?

- A. $1s^2 2s^1 2p^4$
- B. $1s^2 2s^2 2p^3$
- C. $1s^1 2s^1 2p^5$
- D. $1s^2 2s^2 2p^2$

4. What is the ground-state electronic configuration of a fluorine atom (fluorine: atomic number 9)?

- A. $1s^1 2s^1 2p^7$
- B. $1s^2 2s^2 2p^5$
- C. $1s^2 2s^2 2p^6$
- D. $1s^0 2s^2 2p^7$

5. What is the ground-state electronic configuration of a fluoride anion (fluorine: atomic number 9)?

- A. $1s^2 2s^2 2p^2$
- B. $1s^2 2s^2 2p^5$
- C. $1s^2 2s^2 2p^6$
- D. $1s^2 2s^2 2p^7$

6. What is the ground-state electronic configuration of a sodium cation (sodium: atomic number 11)?

- A. $1s^2 2s^2 2p^6 3s^1$
- B. $1s^2 2s^2 2p^5 3s^1$
- C. $1s^2 2s^2 2p^6$
- D. $1s^2 2s^2 2p^6 3s^2$

7. Which of the following species has an atom that has an unfilled valence shell of electrons?

- A. molecular hydrogen, H_2
- B. hydroxide anion, HO^-
- C. boron trifluoride, BF_3
- D. water, H_2O

8. Which of the following species has an atom that has an unfilled valence shell of electrons?

- A. molecular bromine, Br_2
- B. fluoride anion, F^-
- C. ammonia, NH_3
- D. aluminum trichloride, $AlCl_3$

9. Which of the following species possesses a formal charge?

- A. BH_3
- B. BH_4
- C. CCl_4
- D. H_2S

10. Which of the following species possesses a formal charge?

- A. CCl_4
- B. $SiCl_4$
- C. $AlCl_4$
- D. PCl_3

11. Which of the following compounds is an aldehyde?

- A. $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{CHO}$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D. $\text{CH}_3\text{CH}_2\text{COCH}_3$

12. Which of the following compounds is an alcohol?

- A. $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{OCH}_3$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D. $\text{CH}_3\text{CH}_2\text{CHO}$

13. Which of the following compounds is a carboxylic acid?

- A. $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{OCH}_3$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D. $\text{CH}_3\text{CH}_2\text{CHO}$

14. Which of the following compounds is a ketone?

- A. $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{CHO}$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D. CH_3COCH_3

15. Which of the following compounds is a ketone?

- A. $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{CHO}$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D. CH_3COCH_3

16. Which of the following compounds is a carboxylic ester?

- A. $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{OCH}_3$
- C. $\text{CH}_3\text{CH}_2\text{COOCH}_3$
- D. $\text{CH}_3\text{CH}_2\text{COCH}_3$

17. Which of the following is a tertiary alcohol?

- A. $\text{CH}_3\text{CH}_2\text{OCH}_3$
- B. $(\text{CH}_3)_3\text{COH}$
- C. $(\text{CH}_3)_2\text{CHOH}$
- D. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$

18. Which of the following is a tertiary amine?

- A. $\text{CH}_3\text{CH}_2\text{N}(\text{CH}_3)_2$
- B. $(\text{CH}_3)_3\text{CNH}_2$
- C. $\text{CH}_3\text{CH}_2\text{NHCH}_3$
- D. $\text{CH}_3\text{CH}_2\text{NHCH}(\text{CH}_3)_2$

19. Which of the following is a primary amine?

- A. $\text{CH}_3\text{CH}_2\text{NHCH}_3$
- B. $\text{CH}_3\text{CH}_2\text{NHCH}(\text{CH}_3)_2$
- C. $\text{CH}_3\text{CH}_2\text{N}(\text{CH}_3)_2$
- D. $(\text{CH}_3)_3\text{CNH}_2$

20. Which of the following is trigonal planar?

- A. boron trifluoride, BF_3
- B. methyl anion, CH_3^-
- C. methane, CH_4
- D. ammonia, NH_3

21. Which of the following molecules is not linear?

- A. H_2O
- B. CO_2
- C. $\text{HC}\equiv\text{CH}$
- D. Cl_2

22. What is the approximate value of the H-C-H bond angles in methane, CH_4 ?

- A. 90°
- B. 109°
- C. 120°
- D. 180°

23. What is the approximate C-C-C bond angle in propene, $\text{CH}_3\text{CH}=\text{CH}_2$?

- A. 90°
- B. 109°
- C. 120°
- D. 180°

24. What is the approximate C-C-C bond angle in propyne, $\text{HC}\equiv\text{CCH}_3$?

- A. 90°
- B. 109°
- C. 120°
- D. 180°

25. What is the approximate H-C-O bond angle in formaldehyde, $\text{H}_2\text{C}=\text{O}$?

- A. 90°
- B. 109°
- C. 120°
- D. 180°

26. Which of the following elements has the highest electronegativity?

- A. N
- B. C
- C. O
- D. S

27. Which of the following elements has the highest electronegativity?

- A. C
- B. P
- C. Si
- D. Cl

28. Which of the following bonds is the most polar?

- A. F-F
- B. H-F
- C. C-H
- D. C-Si

29. Which of the following bonds is the most polar?

- A. O-H
- B. C-H
- C. C-C
- D. H-H

30. Which of the following is a polar covalent bond?

- A. Na-F
- B. C-H
- C. C-O
- D. Cl-Cl

31. Which of the following is a polar covalent bond?

- A. Na-Cl
- B. C-Cl
- C. C-H
- D. Cl-Cl

32. Which of the following is an ionic bond?

- A. Br-Br
- B. C-Cl
- C. C-S
- D. Na-O

33. Which of the following is an ionic bond?

- A. F-F
- B. C-H
- C. Li-O
- D. C-N

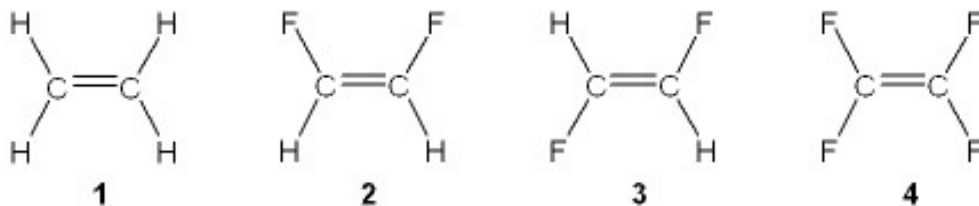
34. Which of the following bonds has the smallest dipole moment?

- A. C-N
- B. C-O
- C. C-F
- D. O-H

35. Which of the following bonds has the smallest dipole moment?

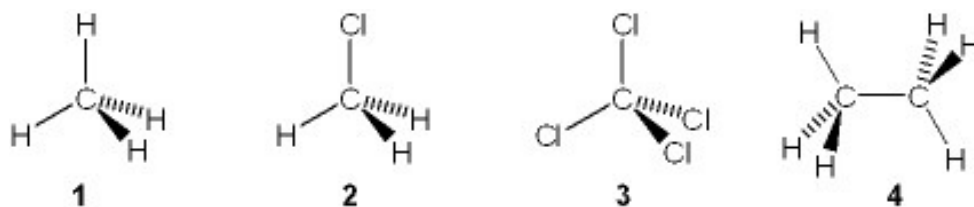
- A. Li-Cl
- B. C-H
- C. O-H
- D. H-Cl

36. Which of the following molecules has a molecular dipole?



- A. 1
- B. 2
- C. 3
- D. 4

37. Which of the following molecules has a molecular dipole?



- A. 1
- B. 2
- C. 3
- D. 4

38. Which of the following molecules has a molecular dipole?

- A. CO_2
- B. BF_3
- C. NH_3
- D. CH_4

39. Which of the following molecules has a molecular dipole?

- A. H_2O
- B. CO_2
- C. HC°CH
- D. Cl_2

40. Which of the following best represents the shape of the $2s$ atomic orbital of carbon?



1 2 3 4

- A. **1**
- B. **2**
- C. **3**
- D. **4**

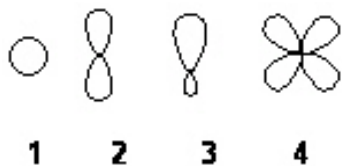
41. Which of the following best represents the shape of a $2p$ atomic orbital of carbon?



1 2 3 4

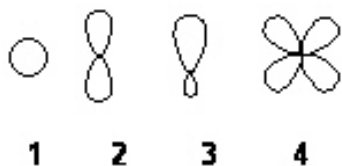
- A. **1**
- B. **2**
- C. **3**
- D. **4**

42. Which of the following best represents an sp^2 hybridized atomic orbital of carbon which overlaps with the $1s$ atomic orbital of hydrogen to form a C-H σ bonding molecular orbital in ethene, $H_2C=CH_2$



- A. 1
- B. 2
- C. 3
- D. 4

43. Which of the following best represents an sp^3 hybridized atomic orbital containing the lone pair of electrons of ammonia, NH_3 ?



- A. 1
- B. 2
- C. 3
- D. 4

44. Which atomic orbitals overlap to form the C=O bond of acetone, $(CH_3)_2C=O$?

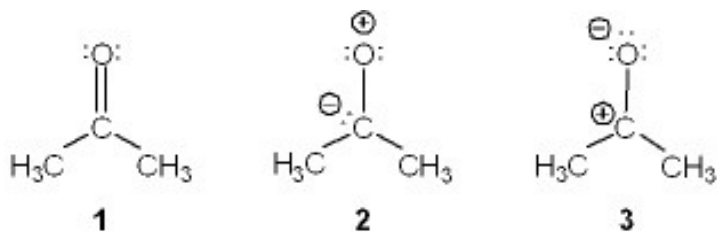
- A. C $2sp^3$ + O $2sp^2$
- B. C $2sp^2$ + O $2p$
- C. C $2sp^2$ + O $2sp^2$
- D. C $2sp^3$ + O $2sp$

45. Which atomic orbitals overlap to form the C-O bond of dimethyl ether, $(CH_3)_2O$?

- A. C $2sp^3$ + O $2sp^2$
- B. C $2sp^2$ + O $2p$
- C. C $2sp^2$ + O $2sp^2$
- D. C $2sp^3$ + O $2sp^3$

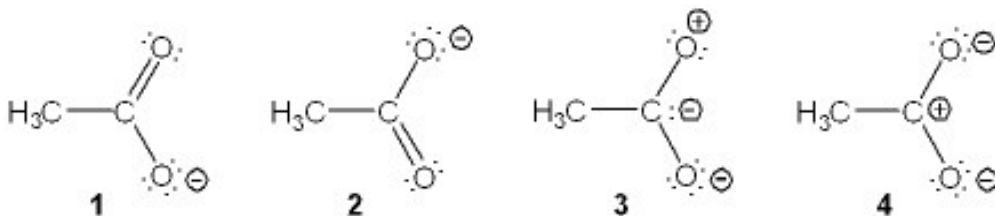
46. What is the approximate value of the length of the C=C bond in ethane, $\text{CH}_2=\text{CH}_2$?
- A. 121 pm
 - B. 134 pm
 - C. 142 pm
 - D. 154 pm
47. What is the approximate value of the length of the $\text{C}\equiv\text{C}$ bond in ethyne, $\text{HC}\equiv\text{CH}$?
- A. 121 pm
 - B. 134 pm
 - C. 142 pm
 - D. 154 pm
48. Which of the following statements is *not* true regarding resonance structures?
- A. All resonance structures must have the same number of electrons
 - B. Each atom in all of the resonance structures must have a complete shell of valence electrons
 - C. All resonance structures must have the same arrangement of atoms
 - D. All resonance structures must be valid Lewis structures
49. Which of the following statements is *not* true regarding resonance structures?
- A. Each resonance structure is in rapid equilibrium with all of the other structures
 - B. The resonance structures may have different energies
 - C. All resonance structures must have the same arrangement of atoms
 - D. All resonance structures must have the same number of electrons
50. Which of the following statements is *not* true about the carbonate anion, CO_3^{2-} ?
- A. All of the oxygen atoms bear the same amount of charge
 - B. All of the carbon-oxygen bonds are the same length
 - C. The carbon atom bears the negative charge
 - D. It is basic
51. Which of the following statements is *not* true about the acetate anion, CH_3CO_2^- ?
- A. The oxygen atoms bear the same amount of charge
 - B. The two carbon-oxygen bonds are the same length
 - C. The carbon atom bears the negative charge
 - D. It is basic

52. Rank the following in order of decreasing importance as a contributing resonance structure to the molecular structure of acetone, CH_3COCH_3 (more important > less important)



- A. $1 > 2 > 3$
- B. $1 > 3 > 2$
- C. $2 > 1 > 3$
- D. $3 > 1 > 2$

53. Which of the following resonance structures is the least important contributor to the resonance hybrid of the acetate anion, CH_3COO^- ?



- A. 1
- B. 2
- C. 3
- D. 4

54. How many electrons are there in the valence shell of the carbon atom of a methyl cation, CH_3^+ ?

- A. 4
- B. 5
- C. 6
- D. 7

55. How many electrons are there in the valence shell of the carbon atom of the methyl anion, CH_3^- ?

- A. 2
- B. 4
- C. 6
- D. 8

56. How many electrons are there in the valence shell of the oxygen atom of water?

- A. 2
- B. 4
- C. 6
- D. 8

57. How many electrons are there in the valence shell of the nitrogen atom of ammonia?

- A. 4
- B. 5
- C. 6
- D. 8

58. What is the approximate value of the H-C-H bond angles in a methyl cation, CH_3^+ ?

- A. 90°
- B. 109°
- C. 120°
- D. 180°

59. What is the approximate value of the H-C-H bond angles in a methyl anion, CH_3^- ?

- A. 90°
- B. 109°
- C. 120°
- D. 180°

60. Which atomic orbitals overlap to form the carbon-hydrogen s bonding molecular orbitals of ethane, CH_3CH_3 ?

- A. $\text{C}2p + \text{H}1s$
- B. $\text{C}2sp + \text{H}1s$
- C. $\text{C}2sp^2 + \text{H}1s$
- D. $\text{C}2sp^3 + \text{H}1s$

61. Which atomic orbitals overlap to form the carbon-hydrogen s bonding molecular orbitals of ethene, $\text{H}_2\text{C}=\text{CH}_2$?

- A. $\text{C}2p + \text{H}1s$
- B. $\text{C}2sp + \text{H}1s$
- C. $\text{C}2sp^2 + \text{H}1s$
- D. $\text{C}2sp^3 + \text{H}1s$

62. Which atomic orbitals overlap to form the carbon-carbon s and p bonding molecular orbitals of ethene, $\text{H}_2\text{C}=\text{CH}_2$?

- A. $\text{C}2sp^3 + \text{C}2sp^3$, and $\text{C}2p + \text{C}2p$
- B. $\text{C}2sp^2 + \text{C}2sp^2$, and $\text{C}2sp^2 + \text{C}2sp^2$
- C. $\text{C}2sp^2 + \text{C}2sp^2$, and $\text{C}2p + \text{C}2p$
- D. $\text{C}2sp^3 + \text{C}2sp^3$, and $\text{C}2sp^2 + \text{C}2sp^2$

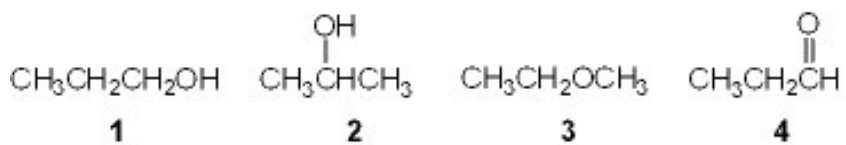
63. Which atomic orbitals overlap to form the carbon-hydrogen s bonding molecular orbitals of ethyne, $\text{HC}\equiv\text{CH}$?

- A. $\text{C}2p + \text{H}1s$
- B. $\text{C}2sp + \text{H}1s$
- C. $\text{C}2sp^2 + \text{H}1s$
- D. $\text{C}2sp^3 + \text{H}1s$

64. Which atomic orbitals overlap to form the carbon-carbon s molecular bonding orbital of ethyne, $\text{HC}\equiv\text{CH}$?

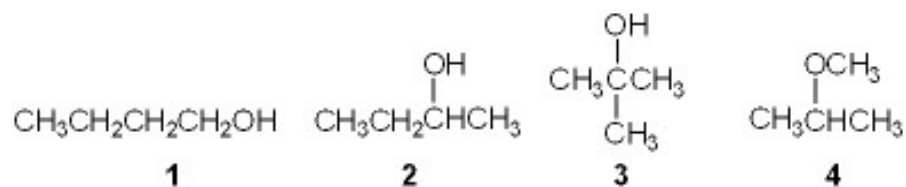
- A. $\text{C}2p + \text{C}2p$
- B. $\text{C}2sp + \text{C}2sp$
- C. $\text{C}2sp^2 + \text{C}2sp^2$
- D. $\text{C}2sp^3 + \text{C}2sp^3$

65. Which of the following is a primary (1°) alcohol?



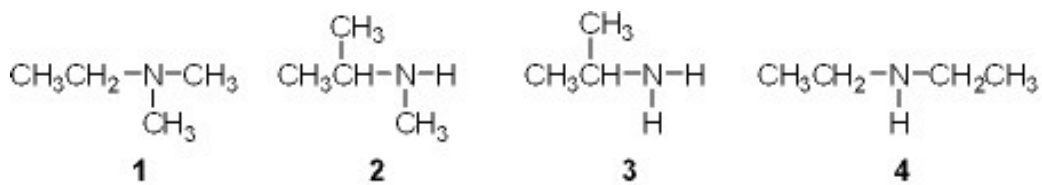
- A. 1
- B. 2
- C. 3
- D. 4

66. Which of the following is a tertiary (3°) alcohol?



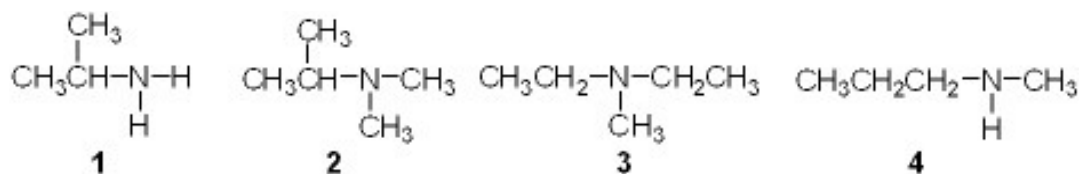
- A. 1
- B. 2
- C. 3
- D. 4

67. Which of the following is a primary (1°) amine?



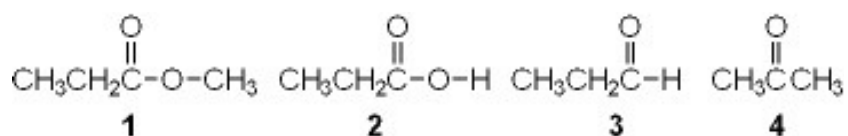
- A. 1
- B. 2
- C. 3
- D. 4

68. Which of the following is a secondary (2°) amine?



- A. **1**
- B. **2**
- C. **3**
- D. **4**

69. Which of the following is an ester?

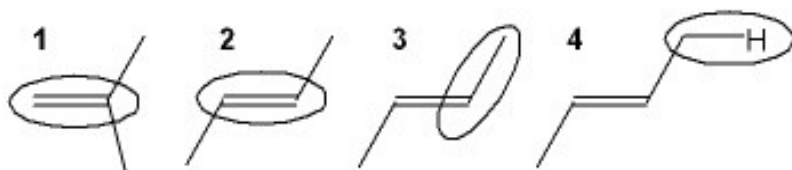


- A. **1**
- B. **2**
- C. **3**
- D. **4**

70. What is the approximate strength of the C-C bond of ethane?

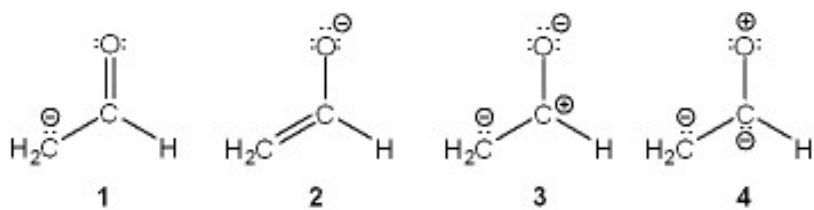
- A. 376 kJ/mol (90 kcal./mol)
- B. 422 kJ/mol (101 kcal./mol)
- C. 556 kJ/mol (133 kcal./mol)
- D. 727 kJ/mol (174 kcal./mol)

71. Which of the circled bonds is the strongest?



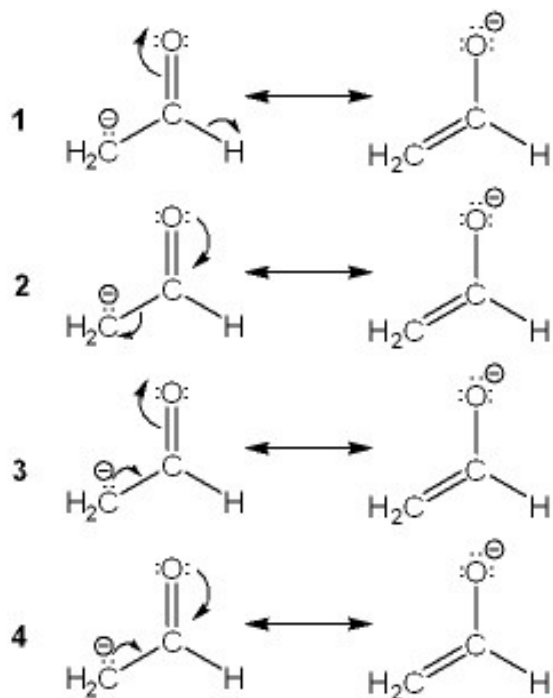
- A. 1
- B. 2
- C. 3
- D. 4

72. Which of the following resonance structures makes the largest contribution to the structure of $[\text{H}_2\text{CCHO}]^-$?



- A. 1
- B. 2
- C. 3
- D. 4

73. Which of the following shows curved arrows that correctly accounts for the differences between the two structures?



- A. 1
- B. 2
- C. 3
- D. 4

74. Which of the following statements is not true?

- A. The sp^3 C-H bond of an alkane is weaker than the sp C-H bond of an alkyne.
- B. The carbon-carbon triple bond of an alkyne is shorter than the carbon-carbon bond of alkenes.
- C. The carbon-carbon triple bond of an alkene is exactly three times as strong as a carbon-carbon single bond of an alkane.
- D. The sp^3 C-H bond of an alkane is longer than the sp C-H bond of an alkyne.

75. Which of the following is/are tetrahedral?

- 1. methane, CH_4
- 2. methyl carbocation, CH_3^+
- 3. methyl carbanion, CH_3^-
- 4. methyl radical, $CH_3^\cdot$

- A. only 1 and 2
- B. only 1 and 3
- C. only 1 and 4
- D. only 2 and 3

76. Provide a neatly drawn figure to show the atomic orbitals that overlap to form each of the bonds in water (H_2O) and which contain the lone pair of electrons. Label each orbital with its hybridization.

77. Provide a neatly drawn figure to show the atomic orbitals that overlap to form each of the bonds in ammonia (NH_3) and which contain the lone pair of electrons. Label each orbital with its hybridization.

78. Provide a neatly drawn figure to show the atomic orbitals that overlap to form each of the bonds in ethene (ethylene, $\text{H}_2\text{C}=\text{CH}_2$). Label each bond (e.g., C–H σ bond) and indicate which atomic orbitals contribute to this bond (e.g., C $2sp^3$ + H $1s$).

79. Provide a neatly drawn figure to show the atomic orbitals that overlap to form each of the bonds in ethyne (acetylene, $\text{HC}\equiv\text{CH}$). Label each bond (e.g., C–H σ bond) and indicate which atomic orbitals contribute to this bond (e.g., C $2sp^3 + \text{H } 1s$).

80. Draw bond-line structures of all of the alkanes that have the formula C_5H_{12} .

81. Draw bond-line structures of all of the alcohols that have the formula $\text{C}_4\text{H}_{10}\text{O}$.

82. Draw bond-line structures of all of the aldehydes that have the formula $\text{C}_5\text{H}_{10}\text{O}$.

83. Draw bond-line structures of all of the ketones that have the formula $C_5H_{10}O$.

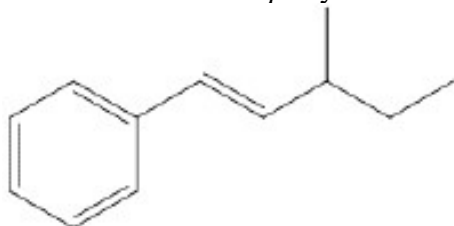
84. Draw bond-line structures of all of the primary (1°) alcohols that have the formula $C_5H_{12}O$.

85. Draw bond-line structures of all of the tertiary (3°) alcohols that have the formula $C_6H_{14}O$.

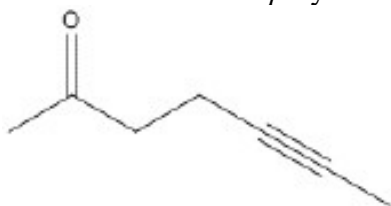
86. Draw bond-line structures of all of the secondary (2°) amines that have the formula C_4H_9N .

87. Draw bond-line structures of all of the tertiary (3°) amines that have the formula $\text{C}_5\text{H}_{11}\text{N}$.

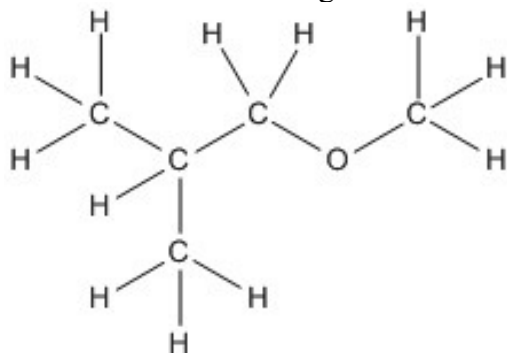
88. Circle all of the sp^2 hybridized atoms in the following molecular structure.



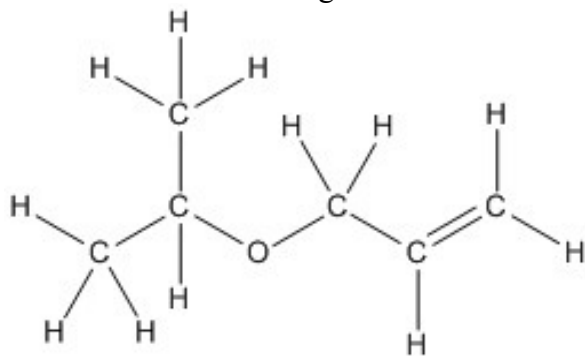
89. Circle all of the sp hybridized atoms in the following molecular structure.



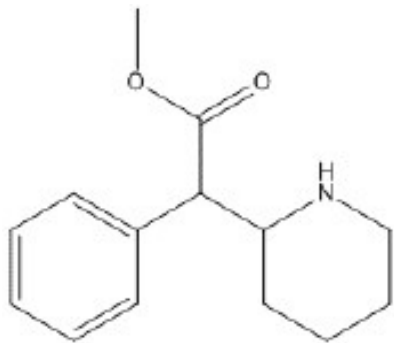
90. Convert the following structure into a bond-line drawing.



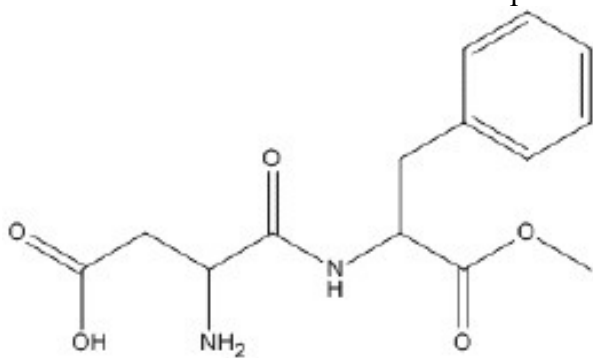
91. Convert the following structure into a bond-line drawing.



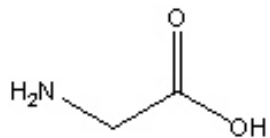
92. What is the molecular formula of Ritalin, shown below?



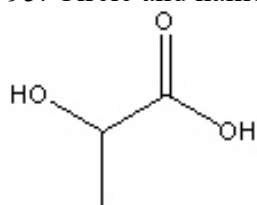
93. What is the molecular formula of aspartame, shown below?



94. Circle and name the functional groups in the following molecule.



95. Circle and name the functional groups in the following molecule.



CHAPTER 1--COVALENT BONDING AND SHAPES OF MOLECULES **Key**

1. How many electrons can the shell with a principal quantum number of 1 hold?

- A. 1
- B. 2**
- C. 4
- D. 8

2. How many electrons can the shell with a principal quantum number of 2 hold?

- A. 1
- B. 2
- C. 4
- D. 8**

3. What is the ground-state electronic configuration of a nitrogen atom (nitrogen: atomic number 7)?

- A. $1s^2 2s^1 2p^4$
- B. $1s^2 2s^2 2p^3$**
- C. $1s^1 2s^1 2p^5$
- D. $1s^2 2s^2 2p^2$

4. What is the ground-state electronic configuration of a fluorine atom (fluorine: atomic number 9)?

- A. $1s^1 2s^1 2p^7$
- B. $1s^2 2s^2 2p^5$**
- C. $1s^2 2s^2 2p^6$
- D. $1s^0 2s^2 2p^7$

5. What is the ground-state electronic configuration of a fluoride anion (fluorine: atomic number 9)?

- A. $1s^2 2s^2 2p^2$
- B. $1s^2 2s^2 2p^5$
- C. $1s^2 2s^2 2p^6$**
- D. $1s^2 2s^2 2p^7$

6. What is the ground-state electronic configuration of a sodium cation (sodium: atomic number 11)?

- A. $1s^2 2s^2 2p^6 3s^1$
- B. $1s^2 2s^2 2p^5 3s^1$
- C. $1s^2 2s^2 2p^6$**
- D. $1s^2 2s^2 2p^6 3s^2$

7. Which of the following species has an atom that has an unfilled valence shell of electrons?

- A. molecular hydrogen, H_2
- B. hydroxide anion, HO^-
- C. boron trifluoride, BF_3**
- D. water, H_2O

8. Which of the following species has an atom that has an unfilled valence shell of electrons?

- A. molecular bromine, Br_2
- B. fluoride anion, F^-
- C. ammonia, NH_3
- D. aluminum trichloride, $AlCl_3$**

9. Which of the following species possesses a formal charge?

- A. BH_3
- B. BH_4**
- C. CCl_4
- D. H_2S

10. Which of the following species possesses a formal charge?

- A. CCl_4
- B. $SiCl_4$
- C. $AlCl_4$**
- D. PCl_3

11. Which of the following compounds is an aldehyde?

- A. $CH_3CH_2CH_2COOH$
- B. CH_3CH_2CHO**
- C. $CH_3CH_2CH_2OH$
- D. $CH_3CH_2COCH_3$

12. Which of the following compounds is an alcohol?

- A. $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{OCH}_3$
- C.** $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D. $\text{CH}_3\text{CH}_2\text{CHO}$

13. Which of the following compounds is a carboxylic acid?

- A.** $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{OCH}_3$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D. $\text{CH}_3\text{CH}_2\text{CHO}$

14. Which of the following compounds is a ketone?

- A. $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{CHO}$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D.** CH_3COCH_3

15. Which of the following compounds is a ketone?

- A. $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{CHO}$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D.** CH_3COCH_3

16. Which of the following compounds is a carboxylic ester?

- A. $\text{CH}_3\text{CH}_2\text{COOH}$
- B. $\text{CH}_3\text{CH}_2\text{OCH}_3$
- C.** $\text{CH}_3\text{CH}_2\text{COOCH}_3$
- D. $\text{CH}_3\text{CH}_2\text{COCH}_3$

17. Which of the following is a tertiary alcohol?

- A. $\text{CH}_3\text{CH}_2\text{OCH}_3$
- B.** $(\text{CH}_3)_3\text{COH}$
- C. $(\text{CH}_3)_2\text{CHOH}$
- D. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$

18. Which of the following is a tertiary amine?

- A.** $\text{CH}_3\text{CH}_2\text{N}(\text{CH}_3)_2$
- B. $(\text{CH}_3)_3\text{CNH}_2$
- C. $\text{CH}_3\text{CH}_2\text{NHCH}_3$
- D. $\text{CH}_3\text{CH}_2\text{NHCH}(\text{CH}_3)_2$

19. Which of the following is a primary amine?

- A. $\text{CH}_3\text{CH}_2\text{NHCH}_3$
- B. $\text{CH}_3\text{CH}_2\text{NHCH}(\text{CH}_3)_2$
- C. $\text{CH}_3\text{CH}_2\text{N}(\text{CH}_3)_2$
- D.** $(\text{CH}_3)_3\text{CNH}_2$

20. Which of the following is trigonal planar?

- A.** boron trifluoride, BF_3
- B. methyl anion, CH_3^-
- C. methane, CH_4
- D. ammonia, NH_3

21. Which of the following molecules is not linear?

- A.** H_2O
- B. CO_2
- C. $\text{HC}\equiv\text{CH}$
- D. Cl_2

22. What is the approximate value of the H-C-H bond angles in methane, CH_4 ?

- A. 90°
- B.** 109°
- C. 120°
- D. 180°

23. What is the approximate C-C-C bond angle in propene, $\text{CH}_3\text{CH}=\text{CH}_2$?

- A. 90°
- B. 109°
- C.** 120°
- D. 180°

24. What is the approximate C-C-C bond angle in propyne, $\text{HC}\equiv\text{CCH}_3$?

- A. 90°
- B. 109°
- C. 120°
- D.** 180°

25. What is the approximate H-C-O bond angle in formaldehyde, $\text{H}_2\text{C}=\text{O}$?

- A. 90°
- B. 109°
- C.** 120°
- D. 180°

26. Which of the following elements has the highest electronegativity?

- A. N
- B. C
- C.** O
- D. S

27. Which of the following elements has the highest electronegativity?

- A. C
- B. P
- C. Si
- D.** Cl

28. Which of the following bonds is the most polar?

- A. F-F
- B.** H-F
- C. C-H
- D. C-Si

29. Which of the following bonds is the most polar?

- A.** O-H
- B. C-H
- C. C-C
- D. H-H

30. Which of the following is a polar covalent bond?

- A. Na-F
- B. C-H
- C.** C-O
- D. Cl-Cl

31. Which of the following is a polar covalent bond?

- A. Na-Cl
- B.** C-Cl
- C. C-H
- D. Cl-Cl

32. Which of the following is an ionic bond?

- A. Br-Br
- B. C-Cl
- C. C-S
- D.** Na-O

33. Which of the following is an ionic bond?

- A. F-F
- B. C-H
- C.** Li-O
- D. C-N

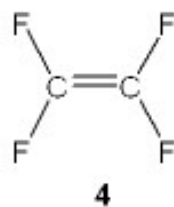
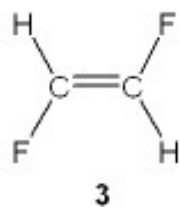
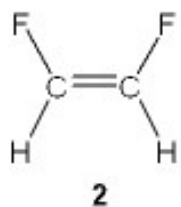
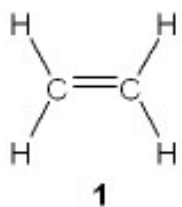
34. Which of the following bonds has the smallest dipole moment?

- A.** C-N
- B. C-O
- C. C-F
- D. O-H

35. Which of the following bonds has the smallest dipole moment?

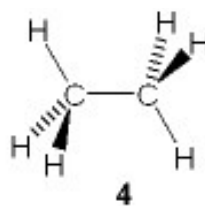
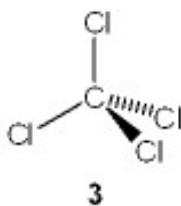
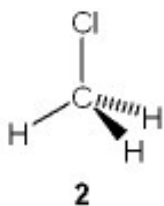
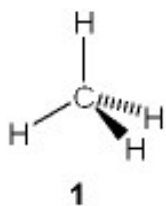
- A. Li-Cl
- B.** C-H
- C. O-H
- D. H-Cl

36. Which of the following molecules has a molecular dipole?



- A. 1
B. 2
C. 3
D. 4

37. Which of the following molecules has a molecular dipole?



- A. 1
B. 2
C. 3
D. 4

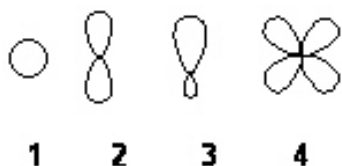
38. Which of the following molecules has a molecular dipole?

- A. CO_2
B. BF_3
C. NH_3
D. CH_4

39. Which of the following molecules has a molecular dipole?

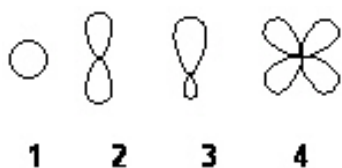
- A. H_2O**
B. CO_2
C. HC°CH
D. Cl_2

40. Which of the following best represents the shape of the $2s$ atomic orbital of carbon?



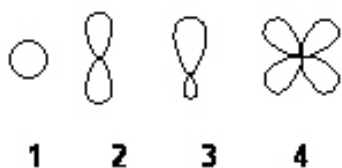
- A. 1
B. 2
C. 3
D. 4

41. Which of the following best represents the shape of a $2p$ atomic orbital of carbon?



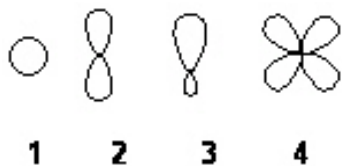
- A. 1
B. 2
C. 3
D. 4

42. Which of the following best represents an sp^2 hybridized atomic orbital of carbon which overlaps with the $1s$ atomic orbital of hydrogen to form a C-H σ bonding molecular orbital in ethene, $H_2C=CH_2$



- A. 1
B. 2
C. 3
D. 4

43. Which of the following best represents an sp^3 hybridized atomic orbital containing the lone pair of electrons of ammonia, NH_3 ?



- A. 1
- B. 2
- C. 3**
- D. 4

44. Which atomic orbitals overlap to form the $\text{C}=\text{O}$ bond of acetone, $(\text{CH}_3)_2\text{C}=\text{O}$?

- A. $\text{C } 2sp^3 + \text{O } 2sp^2$
- B. $\text{C } 2sp^2 + \text{O } 2p$
- C. $\text{C } 2sp^2 + \text{O } 2sp^2$**
- D. $\text{C } 2sp^3 + \text{O } 2sp$

45. Which atomic orbitals overlap to form the $\text{C}-\text{O}$ bond of dimethyl ether, $(\text{CH}_3)_2\text{O}$?

- A. $\text{C } 2sp^3 + \text{O } 2sp^2$
- B. $\text{C } 2sp^2 + \text{O } 2p$
- C. $\text{C } 2sp^2 + \text{O } 2sp^2$
- D. $\text{C } 2sp^3 + \text{O } 2sp^3$**

46. What is the approximate value of the length of the $\text{C}=\text{C}$ bond in ethane, $\text{CH}_2=\text{CH}_2$?

- A. 121 pm
- B. 134 pm**
- C. 142 pm
- D. 154 pm

47. What is the approximate value of the length of the $\text{C}\equiv\text{C}$ bond in ethyne, $\text{HC}\equiv\text{CH}$?

- A. 121 pm**
- B. 134 pm
- C. 142 pm
- D. 154 pm

48. Which of the following statements is *not* true regarding resonance structures?

- A. All resonance structures must have the same number of electrons
- B. Each atom in all of the resonance structures must have a complete shell of valence electrons**
- C. All resonance structures must have the same arrangement of atoms
- D. All resonance structures must be valid Lewis structures

49. Which of the following statements is *not* true regarding resonance structures?

- A. Each resonance structure is in rapid equilibrium with all of the other structures**
- B. The resonance structures may have different energies
- C. All resonance structures must have the same arrangement of atoms
- D. All resonance structures must have the same number of electrons

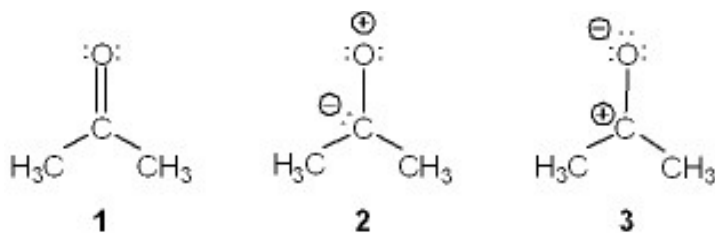
50. Which of the following statements is *not* true about the carbonate anion, CO_3^{2-} ?

- A. All of the oxygen atoms bear the same amount of charge
- B. All of the carbon-oxygen bonds are the same length
- C. The carbon atom bears the negative charge**
- D. It is basic

51. Which of the following statements is *not* true about the acetate anion, CH_3CO_2^- ?

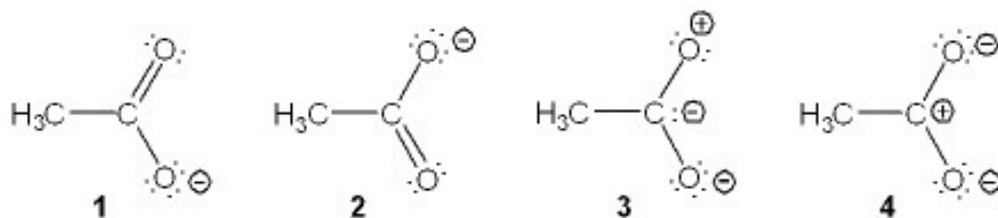
- A. The oxygen atoms bear the same amount of charge
- B. The two carbon-oxygen bonds are the same length
- C. The carbon atom bears the negative charge**
- D. It is basic

52. Rank the following in order of decreasing importance as a contributing resonance structure to the molecular structure of acetone, CH_3COCH_3 (more important > less important)



- A. **1 > 2 > 3**
- B. 1 > 3 > 2**
- C. 2 > 1 > 3
- D. 3 > 1 > 2

53. Which of the following resonance structures is the least important contributor to the resonance hybrid of the acetate anion, CH_3COO^- ?



- A. 1
- B. 2
- C. 3**
- D. 4

54. How many electrons are there in the valence shell of the carbon atom of a methyl cation, CH_3^+ ?

- A. 4
- B. 5
- C. 6**
- D. 7

55. How many electrons are there in the valence shell of the carbon atom of the methyl anion, CH_3^- ?

- A. 2
- B. 4
- C. 6
- D. 8**

56. How many electrons are there in the valence shell of the oxygen atom of water?

- A. 2
- B. 4
- C. 6
- D. 8**

57. How many electrons are there in the valence shell of the nitrogen atom of ammonia?

- A. 4
- B. 5
- C. 6
- D. 8**

58. What is the approximate value of the H-C-H bond angles in a methyl cation, CH_3^+ ?

- A. 90°
- B. 109°
- C.** 120°
- D. 180°

59. What is the approximate value of the H-C-H bond angles in a methyl anion, CH_3^- ?

- A. 90°
- B.** 109°
- C. 120°
- D. 180°

60. Which atomic orbitals overlap to form the carbon-hydrogen σ bonding molecular orbitals of ethane, CH_3CH_3 ?

- A. $\text{C}2p + \text{H}1s$
- B. $\text{C}2sp + \text{H}1s$
- C. $\text{C}2sp^2 + \text{H}1s$
- D.** $\text{C}2sp^3 + \text{H}1s$

61. Which atomic orbitals overlap to form the carbon-hydrogen σ bonding molecular orbitals of ethene, $\text{H}_2\text{C}=\text{CH}_2$?

- A. $\text{C}2p + \text{H}1s$
- B. $\text{C}2sp + \text{H}1s$
- C.** $\text{C}2sp^2 + \text{H}1s$
- D. $\text{C}2sp^3 + \text{H}1s$

62. Which atomic orbitals overlap to form the carbon-carbon σ and π bonding molecular orbitals of ethene, $\text{H}_2\text{C}=\text{CH}_2$?

- A. $\text{C}2sp^3 + \text{C}2sp^3$, and $\text{C}2p + \text{C}2p$
- B. $\text{C}2sp^2 + \text{C}2sp^2$, and $\text{C}2sp^2 + \text{C}2sp^2$
- C.** $\text{C}2sp^2 + \text{C}2sp^2$, and $\text{C}2p + \text{C}2p$
- D. $\text{C}2sp^3 + \text{C}2sp^3$, and $\text{C}2sp^2 + \text{C}2sp^2$

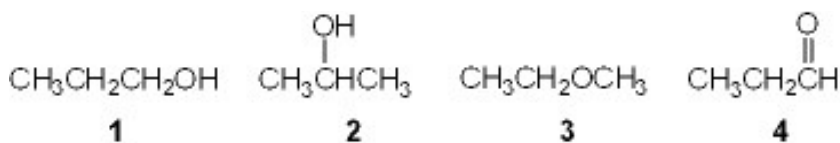
63. Which atomic orbitals overlap to form the carbon-hydrogen σ bonding molecular orbitals of ethyne, $\text{HC}\equiv\text{CH}$?

- A. $\text{C}2p + \text{H}1s$
- B. $\text{C}2sp + \text{H}1s$**
- C. $\text{C}2sp^2 + \text{H}1s$
- D. $\text{C}2sp^3 + \text{H}1s$

64. Which atomic orbitals overlap to form the carbon-carbon σ molecular bonding orbital of ethyne, $\text{HC}\equiv\text{CH}$?

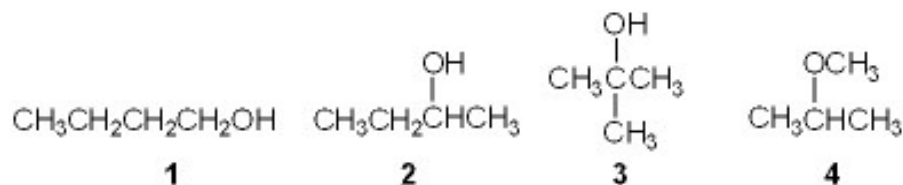
- A. $\text{C}2p + \text{C}2p$
- B. $\text{C}2sp + \text{C}2sp$**
- C. $\text{C}2sp^2 + \text{C}2sp^2$
- D. $\text{C}2sp^3 + \text{C}2sp^3$

65. Which of the following is a primary (1°) alcohol?



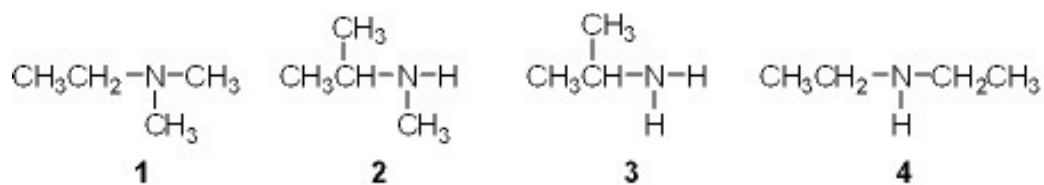
- A. 1**
- B. 2
- C. 3
- D. 4

66. Which of the following is a tertiary (3°) alcohol?



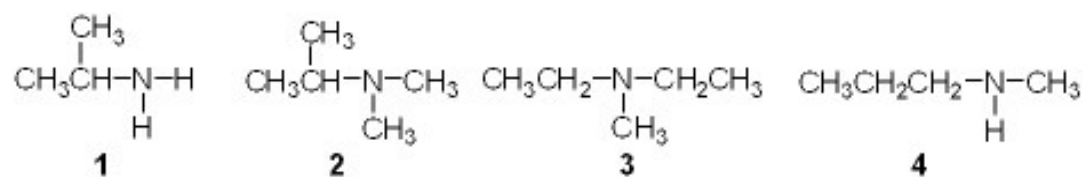
- A. 1
- B. 2
- C. 3**
- D. 4

67. Which of the following is a primary (1°) amine?



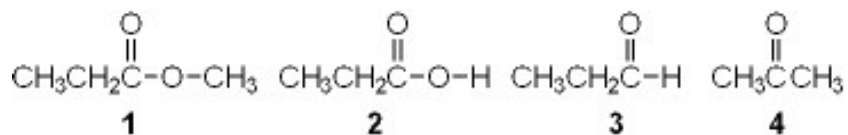
- A. 1
B. 2
C. 3
D. 4

68. Which of the following is a secondary (2°) amine?



- A. 1
B. 2
C. 3
D. 4

69. Which of the following is an ester?

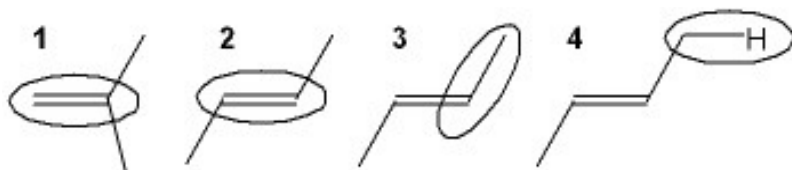


- A. 1
B. 2
C. 3
D. 4

70. What is the approximate strength of the C-C bond of ethane?

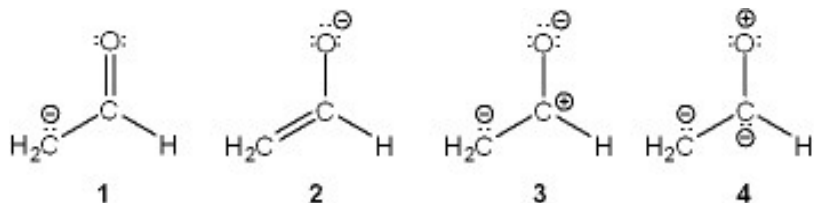
- A.** 376 kJ/mol (90 kcal./mol)
- B. 422 kJ/mol (101 kcal./mol)
- C. 556 kJ/mol (133 kcal./mol)
- D. 727 kJ/mol (174 kcal./mol)

71. Which of the circled bonds is the strongest?



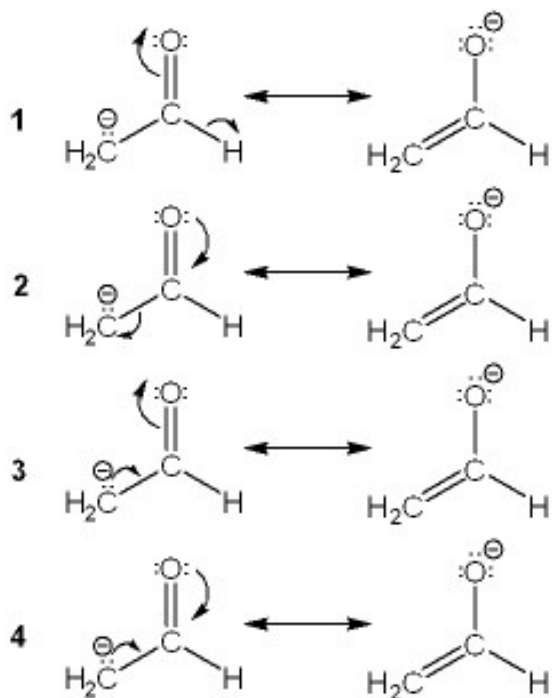
- A.** 1
- B. 2
- C. 3
- D. 4

72. Which of the following resonance structures makes the largest contribution to the structure of $[\text{H}_2\text{CCHO}]^-$?



- A. 1
- B.** 2
- C. 3
- D. 4

73. Which of the following shows curved arrows that correctly accounts for the differences between the two structures?



- A. 1
B. 2
C. 3
D. 4

74. Which of the following statements is not true?

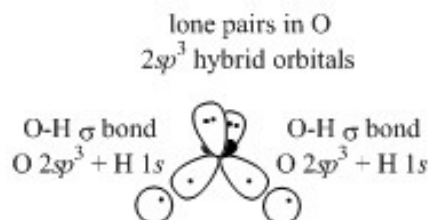
- A. The $sp^3\text{C}-\text{H}$ bond of an alkane is weaker than the $sp\text{C}-\text{H}$ bond of an alkyne.
B. The carbon-carbon triple bond of an alkyne is shorter than the carbon-carbon bond of alkenes.
C. The carbon-carbon triple bond of an alkene is exactly three times as strong as a carbon-carbon single bond of an alkane.
D. The $sp^3\text{C}-\text{H}$ bond of an alkane is longer than the $sp\text{C}-\text{H}$ bond of an alkyne.

75. Which of the following is/are tetrahedral?

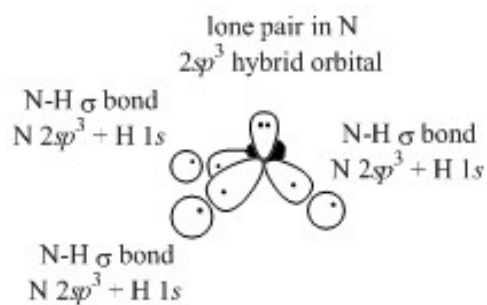
1. methane, CH_4
2. methyl carbocation, CH_3^+
3. methyl carbanion, CH_3^-
4. methyl radical, $\text{CH}_3^\cdot$

- A. only 1 and 2
- B. only 1 and 3**
- C. only 1 and 4
- D. only 2 and 3

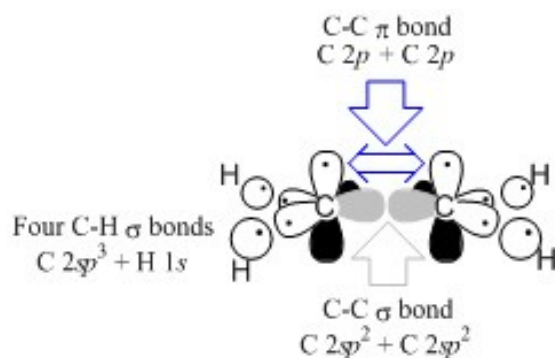
76. Provide a neatly drawn figure to show the atomic orbitals that overlap to form each of the bonds in water (H_2O) and which contain the lone pair of electrons. Label each orbital with its hybridization.



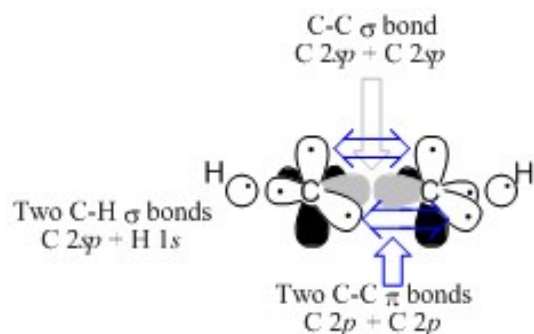
77. Provide a neatly drawn figure to show the atomic orbitals that overlap to form each of the bonds in ammonia (NH_3) and which contain the lone pair of electrons. Label each orbital with its hybridization.



78. Provide a neatly drawn figure to show the atomic orbitals that overlap to form each of the bonds in ethene (ethylene, $\text{H}_2\text{C}=\text{CH}_2$). Label each bond (e.g., C–H σ bond) and indicate which atomic orbitals contribute to this bond (e.g., C $2sp^3 + \text{H } 1s$).



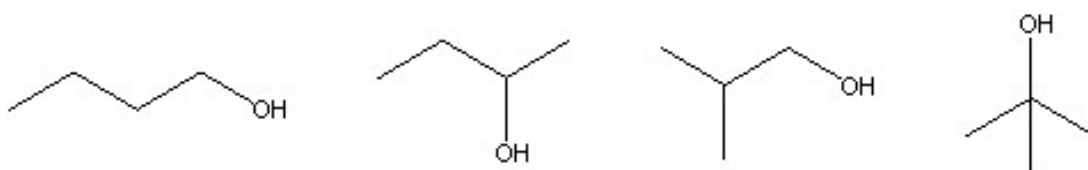
79. Provide a neatly drawn figure to show the atomic orbitals that overlap to form each of the bonds in ethyne (acetylene, $\text{HC}\equiv\text{CH}$). Label each bond (e.g., C–H σ bond) and indicate which atomic orbitals contribute to this bond (e.g., C $2sp^3 + \text{H } 1s$).



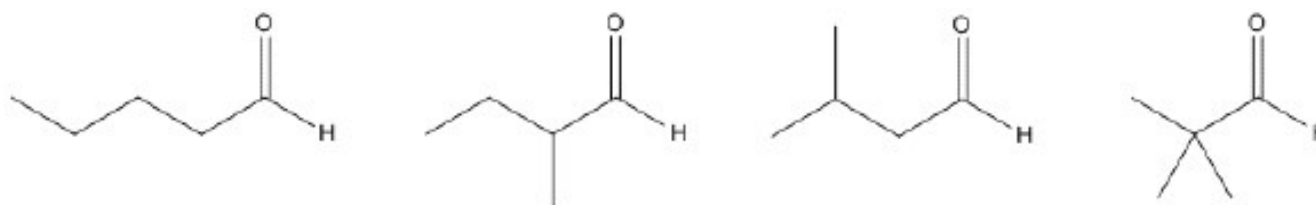
80. Draw bond-line structures of all of the alkanes that have the formula C_5H_{12} .



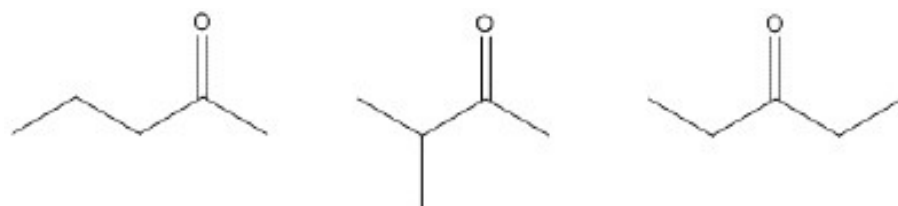
81. Draw bond-line structures of all of the alcohols that have the formula $C_4H_{10}O$.



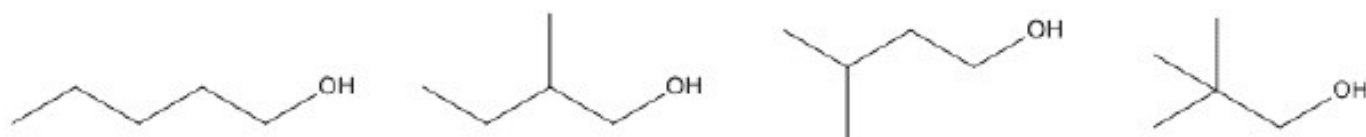
82. Draw bond-line structures of all of the aldehydes that have the formula $C_5H_{10}O$.



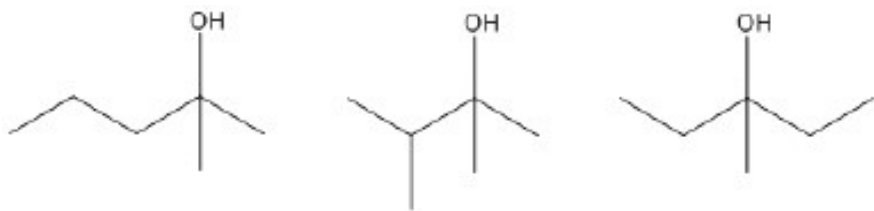
83. Draw bond-line structures of all of the ketones that have the formula $C_5H_{10}O$.



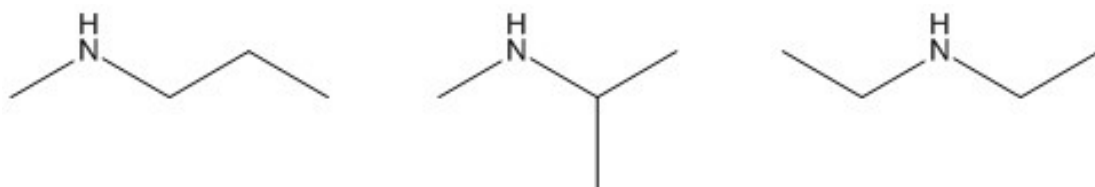
84. Draw bond-line structures of all of the primary (1°) alcohols that have the formula $C_5H_{12}O$.



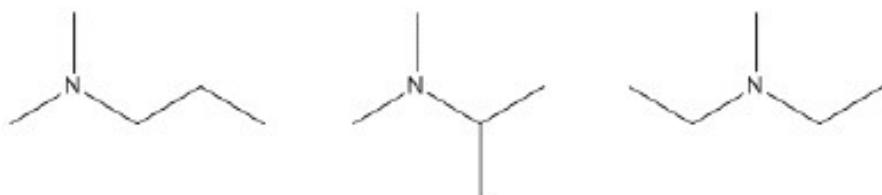
85. Draw bond-line structures of all of the tertiary (3°) alcohols that have the formula $C_6H_{14}O$.



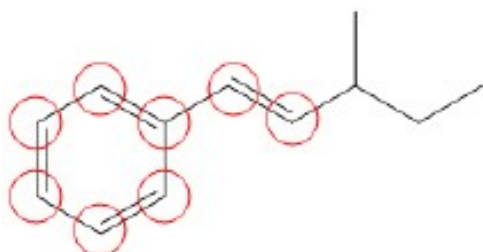
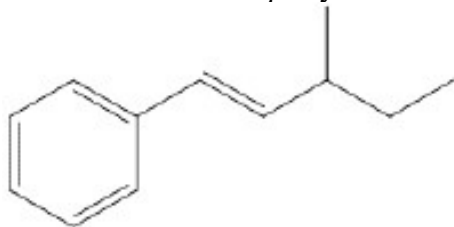
86. Draw bond-line structures of all of the secondary (2°) amines that have the formula C_4H_9N .



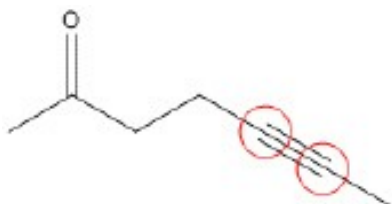
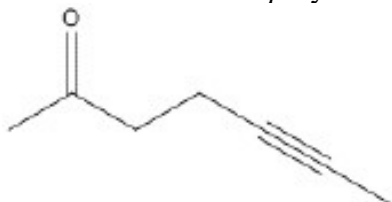
87. Draw bond-line structures of all of the tertiary (3°) amines that have the formula $C_5H_{11}N$.



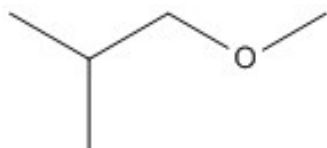
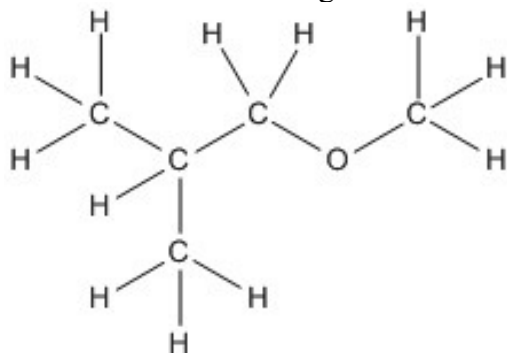
88. Circle all of the sp^2 hybridized atoms in the following molecular structure.



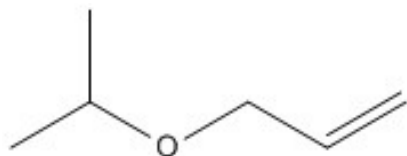
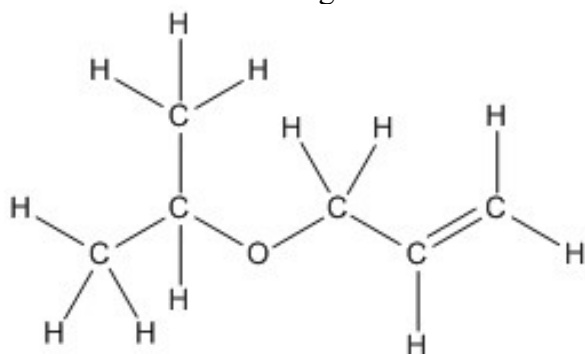
89. Circle all of the sp hybridized atoms in the following molecular structure.



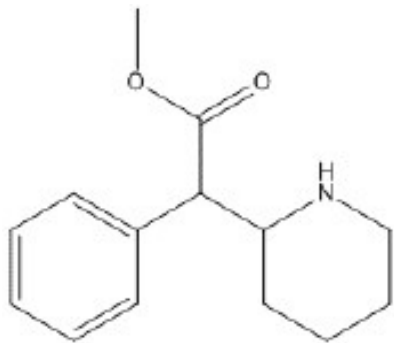
90. Convert the following structure into a bond-line drawing.



91. Convert the following structure into a bond-line drawing.

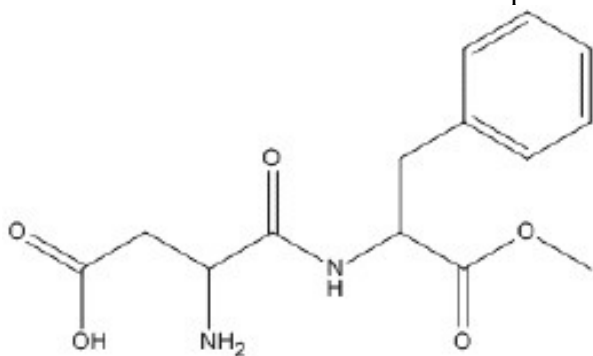


92. What is the molecular formula of Ritalin, shown below?



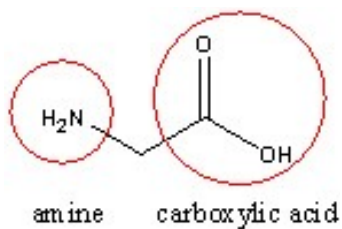
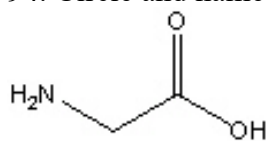
$C_{14}H_{19}NO_2$

93. What is the molecular formula of aspartame, shown below?



$C_{14}H_{18}N_2O_5$

94. Circle and name the functional groups in the following molecule.



95. Circle and name the functional groups in the following molecule.

