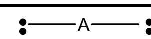
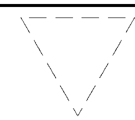
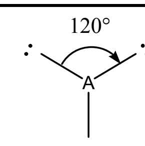
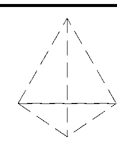
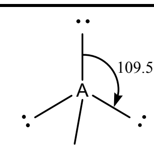
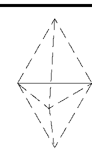
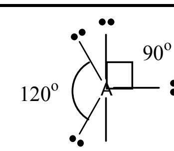
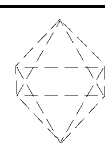
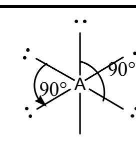
Test Review № 5

Bond Type and Polarity. When the electronegativity difference is greater than or equal to 1.7, the atom with the greater electronegativity gains the electron, and an **ionic bond** is formed. Electronegativity differences below 1.7 result in covalent bonds or sharing. If the electronegativity difference is close to zero (<0.4), the atoms share equally and a **nonpolar bond** forms. Higher electronegativity differences (still below 1.7) result in unequal sharing or **polar bonds**.

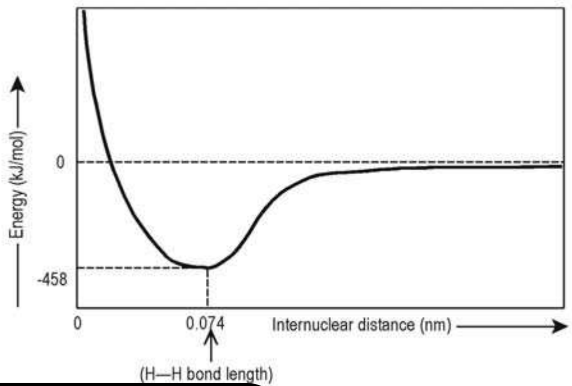
Lewis Structures. Lewis structures show how valence electrons are arranged among atoms in a compound using dots to represent the valence electrons that are not shared in a covalent bond. To draw Lewis structures showing covalent bonds for elements in periods 1 and 2, do the following: [1] sum the valence electrons; [2] use a pair of electrons to form a bond (bonding electrons); and [3] arrange the remaining electrons to satisfy the duet rule for hydrogen and the octet rule for other elements (lone pairs). Lewis structures show how valence electrons are arranged among atoms in a compound using dots to represent the valence electrons that are not shared in a covalent bond. To draw Lewis structures showing covalent bonds for elements in periods 1 and 2, do the following: [1] sum the valence electrons; [2] use a pair of electrons to form a bond (bonding electrons); and [3] arrange the remaining electrons to satisfy the duet rule for hydrogen and the octet rule for other elements (lone pairs).There may several valid equivalent Lewis structures for some molecules. This is called resonance. When there are several nonequivalent Lewis structures for a molecule, it is possible to choose among them using formal charge. Formal charge is the difference between the number of valence electrons on the free atom and the number of valence electrons assigned to the atom in the molecule. Lone pairs belong entirely to the atom in question. Shared electrons are divided equally among the sharing atoms. Atoms in molecules should have formal charges as close to zero as possible. Negative formal charges reside with the most electronegative element.

VSEPR. One approach to predicting molecular shape is the valence shell electron repulsion model (VSEPR). According to VSEPR theory, repulsion between sets of valence shell electrons causes them to be as far apart as possible. Taking this repulsion into account, the shape of a molecule depends upon how many pairs of valence electrons surround the central atom, the number of lone pairs of electrons, and the presence of multiple bonds (double bonds or tripe bonds).

Number of Electron Pairs	Shape	Arrangement of Electron Pairs	
2	Linear	— — — — —	
3	Trigonal planar		
4	Tetrahedral		
5	Trigonal bipyramidal		
6	Octahedral		

Ammonia (NH_3) and water (H_2O) have a tetrahedral arrangement of valence electrons, but the shape of the molecule includes only the bonded atoms and not the lone pair electrons. As a result, ammonia is pyramidal with a bond angle of 107°, and water is bent with a bond angle of 105°. The bond angle is smaller in water than in ammonia because it has two lone pairs of electrons instead of one.

Bond Length. The bond length is the distance at which the system has minimum energy. (the best compromise between attraction and repulsion). The bond energy is the average energy required to break all the similar bonds in a gas. Bonds are sensitive to their molecular environment. The energy associated with breaking a bond may differ under different circumstances. As the number of bonds between atoms increases, so does the bond energy. As bond strength increases, bond length decreases. In general, as bond energy increases, bond length decreases. There is no mathematical equation to describe this relationship. Bond breaking requires energy (endothermic). Bond making releases energy (exothermic). If you know the amount of energy needed to break a bond, and the amount of energy released when a new bond forms, it is possible to approximate the energy change of a reaction. The energy change of the reaction is the sum of the energies required for breaking the bonds minus the sum of the energies released making the bonds.



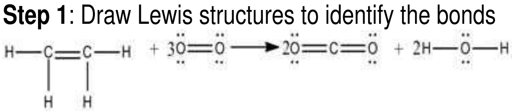
$$\Delta H = \sum \Delta H_{(\text{bond breaking})} - \sum \Delta H_{(\text{bond making})}$$

Sample Problem

What is the energy change associated with the reaction:

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

Step 1: Draw Lewis structures to identify the bonds



Step 2: Sum the energies of the bonds broken.

Bond	Bond Energy	Number	Total
C=C	614	1	614
C–H	413	4	1652
O=O	495	3	1485
		TOTAL	3751

Step 3: Sum the energies of the bonds formed.

Bond	Bond Energy	Number	Total
C=O	799	4	3196
O–H	467	4	1868
		TOTAL	5064

Step 4: Find the difference

$3751\ ^{kj}/_{mol} - 5064\ ^{kj}/_{mol} = -1313\ ^{kj}/_{mol}$

Average Bond Energies (kj/mol)

Single Bonds						Multiple Bonds	
H—H	432	N—H	391	I—I	149	C=C	614
H—F	565	N—N	160	I—Cl	208	C≡C	839
H—Cl	427	N—F	272	I—Br	175	O=O	495
H—Br	363	N—Cl	200			C=O*	745
H—I	295	N—Br	243	S—H	347	C≡O	1072
		N—O	201	S—F	327	N=O	607
C—H	413	O—H	467	S—Cl	253	N=N	418
C—C	347	O—O	146	S—Br	218	N≡N	941
C—N	305	O—F	190	S—S	266	C≡N	891
C—O	358	O—Cl	203			C=N	615
C—F	485	O—I	234	Si—Si	340		
C—Cl	339			Si—H	393		
C—Br	276	F—F	154	Si—C	360		
C—I	240	F—Cl	253	Si—O	452		
C—S	259	F—Br	237				
		Cl—Cl	239				
		Cl—Br	218				
		Br—Br	193				

*C=O (CO_2) =799

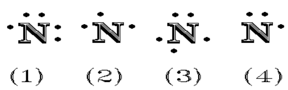
Hybrid Orbitals. The native orbitals found in an atom in the free state cannot always account for the geometry of the compounds formed from the atom. Atomic orbitals that provide for minimum energy in the free state, are often different from those in a molecule. Mixing of native atomic orbitals to allow bonding to occur is known as **hybridization**. Methane (CH_4) illustrates how hybridization explains observed molecular structure. Methane has four equivalent bonds with a tetrahedral arrangement. The valence structure of carbon ($2s^22p^2$) does not fit this structure because *s* orbitals are nondirectional, *p* orbitals are at right angles, and *s* and *p* orbitals don't form equivalent bonds. When methane forms, one *s* orbital combines with three *p* orbitals to form four equivalent sp^3 hybrid orbitals. sp^3 hybrid orbitals are tetrahedral. Other molecular shapes can be explained by other types of hybrid orbitals:

Number of Effective Pairs of Electrons	Hybridization	Shape
2	sp	linear
3	sp^2	trigonal planar
4	sp^3	tetrahedral
5	dsp^3	trigonal bipyramidal
6	d^2sp^3	octahedral

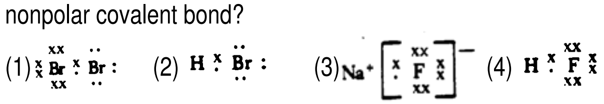
Polar Molecules. Electronegativity differences between 0.4 and 1.7 are found in molecules with polar bonds. These molecules can be polar depending on their shapes. Molecules with polar bonds distributed symmetrically are nonpolar. Asymmetrical molecules with polar bonds are polar. Water is polar. An imaginary line can be drawn through a water molecule separating the positive pole from the negative pole. This is because the charges are distributed asymmetrically. Carbon dioxide is nonpolar because the electronegative oxygens are distributed symmetrically around the carbon. (O=C=O)

Answer the questions below by circling the number of the correct response

1. Which of the following is the correct electron dot diagram for nitrogen?



2. Which compound contains both covalent and ionic bonds? (1)HCl (2) NH_4Cl (3) $MgCl_2$ (4) CCl_4
3. In potassium hydrogen carbonate, $KHCO_3$, the bonds are (1) ionic, only, (2) covalent, only, (3) both ionic and covalent, (4) both covalent and metallic.
4. In water, the bond between hydrogen and oxygen is (1) ionic, (2) polar covalent, (3) nonpolar covalent, (4) nonpolar noncovalent.
5. Which of the following occurs during covalent bonding? (1) Electrons are lost. (2) Electrons are gained. (3) Valence electrons fall from the excited state to the ground state. (4) Unpaired electrons form pairs.
6. Which of the following is an example of a substance with a nonpolar covalent bond? (1) HCl (2) Cl_2 (3) $HClO_2$ (4) NaCl
7. The electronegativity of sulfur is (1) 16, (2) 239, (3) 2.6, (4) 32.
8. Which of the following elements has the highest electronegativity? (1) fluorine (2) chlorine (3) barium (4) hydrogen
9. Which compound contains a bond with the *least,* ionic character? (1) CO (2) K_2O (3) CaO (4) Li_2O
10. Which type of bond is contained in a water molecule? (1) nonpolar covalent (2) ionic (3) polar covalent (4) electrovalent
11. The bonding in NH_3 most similar to the bonding in (1) H_2O (2) MgO (3) NaCl (4) KF
12. Which is the formula of an ionic compound? (1) SO_2 (2) CH_3OH (3) CO_2 (4) KCl
13. Which electron dot formula represents a molecule that contains a nonpolar covalent bond?



14. When a reaction occurs between atoms with ground state electron configurations 2–1 and 2–7, the predominant type of bond formed is (1) polar covalent, (2) ionic, (3) nonpolar covalent, (4) metallic.
15. The P—Cl bond in a molecule of PCl_3 is (1) nonpolar covalent, (2) coordinate covalent, (3) polar covalent, (4) electrovalent.
16. A Ca^{2+} ion differs from a Ca atom in that the Ca^{2+} ion has (1) more protons, (2) more electrons, (3) fewer protons, (4) fewer electrons.
17. In which compound does the bond between the atoms have the least ionic character? (1) HF (2) HCl (3) HBr (4) HI
18. Which substance contains a polar covalent bond? (1) Na_2O (2) Mg_3N_2 (3) CO_2 (4) N_2
19. In which pair do the members have identical electron configurations? (1) S^{2-} and Cl^- (2) S^0 and Ar^0 (3) K^0 and Na^+ (4) Cl^- and K^0
20. When a chlorine atom reacts with a sodium atom to form an ion, the chlorine atom will (1) lose one electron, (2) gain one electron, (3) lose two electrons, (4) gain two electrons.
21. When a calcium atom loses its valence electrons, the ion formed has an electron configuration that is the same as the configuration of an atom of (1) Cl (2) Ar (3) K (4) Sc
22. Which of the following compounds has the most ionic character? (1) KI (2) NO (3) HCl (4) MgS
23. Which atom has the strongest attraction for electrons? (1) Cl (2) F (3) Br (4) I
24. Which compound is ionic? (1) HCl (2) $CaCl_2$ (3) SO_2 (4) H_2O
25. Two atoms of element A unite to form a molecule with the formula A_2. The bond between the atoms in the molecule is (1) electrovalent, (2) nonpolar covalent, (3) ionic, (4) polar covalent.
26. When an ionic bond is formed, the atom that transfers its valence electron is the atom that has the (1) higher electronegativity value, (2) lower atomic number. (3) higher atomic mass, (4) lower ionization energy.
27. When an ionic bond is formed, the atom that transfers its valence electron becomes an ion with (1) positive charge and more protons, (2) positive charge and no change in the number of protons, (3) negative charge and more protons, (4) negative charge and no change in the number of protons.
28. Which compound best illustrates ionic bonding? (1) CCl_4 (2) $MgCl_2$ (3) H_2O (4) CO_2
29. An atom that loses or gains one or more electrons becomes (1) an ion, (2) an isotope, (3) a molecule, (4) an electrolyte

30. Which kind of bond is formed when two atoms share electrons to form a molecule? (1) ionic (2) metallic (3) electrovalent (4) covalent

31. Which type of bonding is usually exhibited when the electronegativity difference between two atoms is 1.2? (1) ionic (2) metallic (3) network (4) covalent

32. Which element will form an ion with a larger radius than its atom? (1) Na (2) Ba (3) Ca (4) Cl

33. Which element will form an ion whose radius is larger than its atomic radius? (1) F (2) Fr (3) Ca (4) Cs

34. When chlorine reacts with a Group 1 metal, it becomes an ion with a charge of (1) 1-, (2) 2-, (3) 1+, (4) 2+.

35. Which compound contains both covalent and ionic bonds? (1)HCl (2) NH_4Cl (3) $MgCl_2$ (4) CCl_4

36. When a chlorine atom reacts with a sodium atom to form an ion, the chlorine atom will (1) lose one electron, (2) gain one electron, (3) lose two electrons, (4) gain two electrons.

37. When a reaction occurs between atoms with ground state electron configurations $1s^22s^1$ and $1s^22s^22p^5$ the predominant type of bond formed is (1) polar covalent, (2) ionic, (3) nonpolar covalent, (4) metallic.

38. What is the total number of electrons in a Mg^{2+} ion? (1) 10 (2) 2 (3) 12 (4) 24

39. Which compound is ionic? (1) HCl (2) $CaCl_2$ (3) SO_2 (4) N_2O_5

40. What is the electron configuration for Be^{2+} ions? (1) $1s^1$ (2) $1s^2$ (3) $1s^22s^1$ (4) $1s^22s^2$

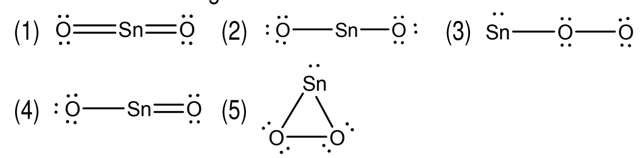
41. As a chemical bond forms between hydrogen and chlorine atoms, the potential energy of the atoms (1) decreases, (2) increases, (3) remains the same.

42. In potassium hydrogen carbonate, $KHCO_3$, the bonds are (1) ionic, only, (2) covalent, only, (3) both ionic and covalent, (4) both covalent and metallic.

43. When potassium and chlorine form a chemical compound, energy is (1) released and ionic bonds are formed, (2) released and covalent bonds are formed, (3) absorbed and ionic bonds are formed, (4) absorbed and covalent bonds are formed.

44. Which compound contains both covalent and ionic bonds? (1)HCl (2) NH_4Cl (3) $MgCl_2$ (4) CCl_4

45. Which of the following is the correct Lewis structure for tin IV oxide?



46. Which of the following molecules has a nonlinear structure? (1) PbO_2 (2) $BeCl_2$ (3) O_3 (4) CO_2 (5) N_2O (central atom is N)

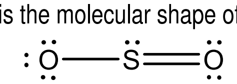
47. Which formula represents a tetrahedral molecule? (1) $CaCl_2$ (2) Br_2 (3) CH_4 (4) HBr

48. Which formula represents a bent molecule? (1) Br_2 (2) HBr (3) $CaCl_2$ (4) SO_2

49. The four single bonds of a carbon atom are spatially directed toward the comers of a regular (1) rectangle (2) tetrahedron (3) triangle (4) square

50. What is the molecular geometry of the NH_3? (1) octahedral (2) pyramidal (3) linear (4) bent (5) tetrahedral

51. What is the molecular shape of the following molecule?



(1) bent (2) linear (3) octahedral (4) tetrahedral (5) pyramidal

52. What is the molecular shape of water? (1) bent (2) octahedral (3) pyramidal (4) linear (5) tetrahedral

53. What would be the shape of a molecule where the central atom has two lone pairs and two bonds? (1) pyramidal (2) octahedral (3) tetrahedral (4) linear (5) bent

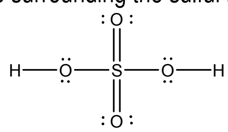
54. Which of the following molecules is linear? (1) CO_2 (2) SO_2 (3) O_3 (4) H_2O (5) all of the above

55. Which of the following molecules has two pairs of nonbonding electrons on the central atom? (1) BH_3 (2) CO_2 (3) H_2O (4) H_2S (5) choices 3 and 4

56. Which of the following molecules should have the same molecular shape and approximate bond angles as ammonia, NH_3? (1) SO_3 (2) CH_4 (3) PH_3 (4) BH_3 (5) NO_2

57. Germanium chloride, $GeCl_2$, has only two atoms surrounding the central germanium atom. Why then is the germanium chloride molecule bent? (1) It is bent only periodically as it swings between both bent and linear shapes. (2) A lone pair of electrons on germanium pushes it to this orientation. (3) There is a covalent bond between the two chlorine atoms. (4) Lone pairs of electrons on the chlorine atoms push it to this orientation.

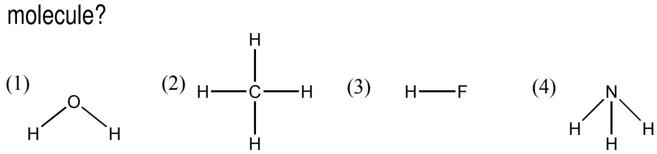
58. In two dimensions sulfuric acid, H_2SO_4, is often written as shown below. What three-dimensional shape does this molecule most likely have surrounding the sulfur?



(1) trigonal planar (2) octahedral (3) trigonal bipyramid (4) tetrahedal

59. Which molecule is nonpolar and contains a nonpolar covalent bond? (1) CCl_4 (2) F_2 (3) HF (4) HCl

60. Which structural formula represents a nonpolar symmetrical molecule?



61. Which type of bonding is usually exhibited when the electronegativity difference between two atoms is 1.2? (1) ionic (2) metallic (3) network (4) covalent

62. Why is NH_3 classified as a polar molecule? (1) It is a gas at STP. (2) H—H bonds are nonpolar. (3) Nitrogen and hydrogen are both nonmetals. (4) NH_3 molecules have asymmetrical charge distributions.

63. Which statement best explains why carbon tetrachloride (CCl_4) is nonpolar? (1) Each carbon-chloride bond is polar. (2) Carbon and chlorine are both nonmetals. (3) Carbon tetrachloride is an organic compound. (4) The carbon tetrachloride molecule is symmetrical.

64. Regarding statement B which is meant to explain statement A below:
    - A. Some covalent bonds are polar in nature

      BECAUSE
    - B. atoms of different electronegativities are unequal in the degree to which they attract electrons;

    which of the following statements is correct? (1) Both A and B are true, but B does NOT explain A. (2) Both A and B are true, and B does explain A. (3) Both A and B are false. (4) A is true and B is false. (5) A is false and B is true.

65. Regarding statement B which is meant to explain statement A below:
    - A. Most atoms are less stable in the bonded state than in the unbonded state

      BECAUSE
    - B. both ionic and covalent bonds fail to provide the participating atoms with a stable electron configuration;

    which of the following statements is correct? (1) Both A and B are true, but B does NOT explain A. (2) Both A and B are true, and B does explain A. (3) Both A and B are false. (4) A is true and B is false. (5) A is false and B is true.

66. How many single bonds are in a molecule of carbon dioxide, CO_2 ? (1) None (2) One (3) Two (4) Three (5) Four

67. The geometry of a molecule of SO_2 is (1) linear, (2) bent, (3) trigonal planar, (4) trigonal pyramidal, (5) tetrahedral.

68. What is the approximate *ΔH* for the reaction
    $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ given the following bond energies:
    - C–H bond = 410 kj/mol
    - C–Cl bond = 330 kj/mol
    - Cl–Cl bond = 240 kj/mol
    - H–Cl bond = 430 kj/mol

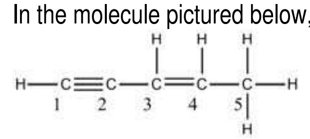
    (1) +270 kj (2) +110 kj (3) +70 kj (4) –70 kj (5) –110 kj

69. Which substance has a polar covalent bond between its atoms? (1) K_3N (2) Ca_3N_2 (3) NaCl (4) F_2 (5) NH_3

70. Which molecule is a polar molecule? (1) N_2 (2) H_2O (3) CH_4 (4) CO_2 (5) KCl

71. Which molecule has both nonpolar intramolecular and nonpolar intermolecular bonds? (1) CCl_4 (2) CO (3) HF (4) HCl (5)F_2

72. In the molecule pictured below,



pi bonds are found between (1) carbons 1 and 2 only, (2) carbons 2 and 3 only, (3) carbons 3 and 4 only, (4) carbons 4 and 5 only, (5) carbons 1 and 2 and carbons 3 and 4, (6) carbons 2 and 3 and carbons 4 and 5.

Answer questions 77-80 by indicating if the hybridization is (1) *sp* (2) sp^2 (3) sp^3 (4) dsp^3 or (5) d^2sp^3

73. Type of hybridization found in BF_3.

74. Type of hybridization found in CS_2.

75. Type of hybridization found in phosphorus pentachloride

76. Type of hybridization found in hydrogen sulfide.

Answers

1. 3	14. 2	27. 2	40. 2	53. 5	66. 1
2. 2	15. 3	28. 2	41. 1	54. 1	67. 2
3. 3	16. 4	29. 1	42. 3	55. 5	68. 5
4. 2	17. 4	30. 4	43. 1	56. 3	69. 5
5. 4	18. 3	31. 4	44. 2	57. 2	70. 2
6. 2	19. 1	32. 4	45. 1	58. 4	71. 5
7. 3	20. 2	33. 1	46. 3	59. 2	72. 5
8. 1	21. 2	34. 1	47. 3	60. 2	73. 2
9. 1	22. 1	35. 2	48. 4	61. 4	74. 1
10. 3	23. 2	36. 2	49. 2	62. 4	75. 4
11. 1	24. 2	37. 2	50. 2	63. 4	76. 3
12. 4	25. 2	38. 1	51. 1	64. 2	
13. 1	26. 4	39. 2	52. 1	65. 3	