Final Exam Worksheet – Chemistry 102

Chapter 9 – Chemical Bonding I: The Covalent Bond

1. For the compounds and elements listed, designate the type of bonding present: ionic (I), covalent (C), both ionic and covalent (IC), or neither (N).
    a. Na_2O
    b. $MgCO_3$
    c. N_2O
    d. $NaNO_2$
    e. NO_2
    f. Al
    g. K_2SO_4
    h. K_2S
    i. Al_2O_3
    j. SO_3
    k. Pd
    l. PCl_5
    m. Cl_2
    n. Ne
    o. $NaClO_4$
    p. ICl_3
    q. $FeCl_3$

2. Give the reaction corresponding to the lattice energy for each ionic compound listed and describe (in general) what is needed to determine the lattice energy in a Born-Haber cycle.
    a. LiCl
    b. $MgCl_2$
    c. KF
    d. CaF_2

3. Give the Born-Haber cycle for magnesium chloride. The molar enthalpy of sublimation of magnesium is 147.70 $kJ \cdot mol^{-1}$. What is the lattice energy for magnesium chloride?

4. Give the Lewis dot structure, the shape (at the central atom, unless otherwise stated), the hybridization, and the polarity of the following molecules.
    a. SO_2
    b. COH_2
    c. CH_3OH (give shape, etc. for carbon and oxygen)
    d. HCN
    e. N_2O
    f. $SOCl_2$

g. CF_2Cl_2
h. HCCH
i. H_2CCH_2
j. N_2O_4
k. $H_2C_2O_4$ (this is oxalic acid – the hydrogen atoms are bonded to oxygen)
l. Cl_2CCH_2
m. H_2CO_3

5. Give resonance structures for any applicable molecules in number 4, using formal charges – comment on the validity of the structures.

6. Determine the number and type of bonds broken versus formed for the reactions. Assign which are exothermic and which are endothermic.
   a. Combustion of 1 mol of methanol (CH_3OH)
   b. Combustion of 1 mol of acetylene (C_2H_2)
   c. Formation of 2 mol of ammonia
   d. Combustion of 1 mol of CO
   e. Formation of 2 mol of hydrogen fluoride
   f. Formation of 2 mol of hydrogen chloride
   g. Dimerization of NO_2 to N_2O_4 (making 1 mol of N_2O_4)

7. Using bond enthalpies, assign whether the reactions in number 6 will be exothermic or endothermic.

8. Calculate the reaction enthalpies for the reactions in number 6 using standard molar enthalpies of formation.

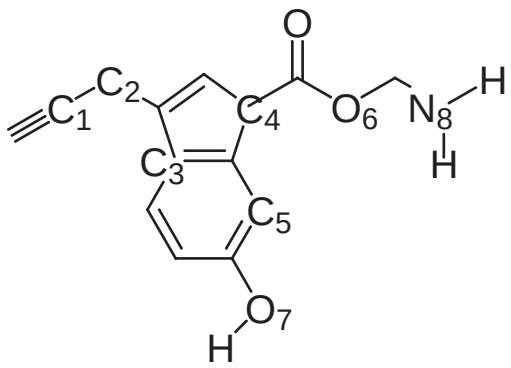
9. Comment on any differences between the values in number 7 to number 8.

10. Plot the reactions in number 7 in an enthalpy diagram showing the "intermediate" where all bonds are broken.

11. Do you think any "intermediate" you designated in number 10 is a true intermediate for these reactions?

Chapter 10 – Chemical Bonding II: Molecular Geometry and Hybridization of Atomic Orbitals

1. For the molecule shown give the shape, number of σ and π bonds, and hybridization of each marked atom. Give the total number of valence electrons for the molecule and the total number of σ and π bonds.



2. Give the hybridization on all carbons and oxygens in the following molecules.
    a. CH_3OH
    b. HCCH
    c. H_2CCH_2
    d. H_2CO_3
    e. $H_2C_2O_4$

3. Show σ versus π overlap for 2p orbitals.

4. Show π overlap for 2d orbitals – can d orbitals orientate for σ overlap?

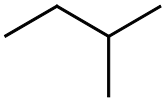
5. Show bonding and antibonding orbitals for both sigma and pi molecular orbitals.

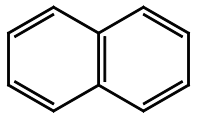
6. Give the molecular orbital diagram for Li_2, Li_2^- and Li_2^+. What is the bond order for each molecule or ion and which would be predicted to be the most stable?

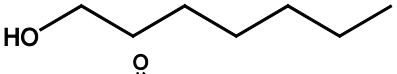
7. What is the molecular orbital diagram for N_2, N_2^-, and N_2^{2-}? What is the bond order for each molecule or ion and which be predicted to have the longest or shortest bond length?

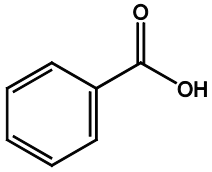
Chapter 11 – Organic Chemistry

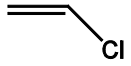
1. What is the molecular and empirical formula for the organic molecules listed?
    a. An alkene with 6 carbons (with 1 double bond only). What is the hybridization on one of the carbons in the double bond?
    b. An alkane with 18 carbons. Do all of the carbon atoms have the same hybridization?
    c. An alkyne with 2 carbons. What is the shape at one carbon atom? What is the hybridization of this carbon?
    d. An alkene with 2 carbons. What is the shape at one carbon atom? What is the hybridization of this carbon?
    e. An alkane alcohol with 4 carbons. How many sigma and pi bonds are in this molecule?
    f. An alkane carboxylic acid with 4 carbons. Is the hybridization on both oxygen atoms the same?

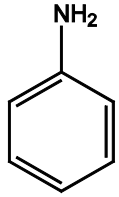
2. What is the formula, the number of sigma and the number of pi bonds in the organic molecules shown?
    a. 

b. 

c. 

d. 

e. 

f. 

Chapter 12 – Intermolecular Forces and Liquids and Solids

1. Give the intermolecular forces of the following pairs of substances
    a. CO_2 and O_2
    b. CH_3CN and CH_3OH
    c. CH_3CH_2OH and NH_3
    d. CH_3OCH_3 and CH_3CH_2OH
    e. Cl_2 and Br_2
    f. HCl and HF
    g. N_2 and CO
    h. $CH_3(CH_2)_8OH$ and H_2O

2. For the preceding substances, select which substance would have a higher boiling point (based on intermolecular forces).

3. For the substances in number 1, once mixed together, give the forces between the substances and comment on the degree of solubility.

4. What type(s) of intermolecular forces are present in a mixture of potassium nitrate with the solvents? In which substance is potassium nitrate most soluble?
    a. Carbon tetrachloride
    b. Benzene
    c. Acetonitrile, CH_3CN
    d. Ethanol
    e. Hexane

5. Show hydrogen bonding between molecules of formic acid (HCOOH) and also with formic acid and water.

6. Show the interaction of a soluble ionic salt (like KCl) and water. Is it correct to simply show 1 water molecule interacting for every 1 ion in solution? What happens (macroscopically) when the number of ions exceeds the capacity of water to solvate? What is this called?

7. Describe cohesion and adhesion and how these work together for water in a glass capillary tube. Why does water form a meniscus with a concave shape?

8. What is viscosity and which substance is more viscous?
    a. Water or carbon tetrachloride
    b. Diethyl ether or ethanol
    c. Ethylene glycol ($HOCH_2CH_2OH$) or glycerol

9. Determine the volume of the unit cells with the given interatomic distances in Å.
    a. Palladium, (FCC), 2.751
    b. Gold, (FCC), 2.884
    c. Barium, (BCC), 4.347
    d. Cesium, (BCC), 5.32

10. Determine the atomic radius of the atoms, given the packing efficiency and volume.
    a. Nickel (FCC), 74.0 %, 0.04377 nm^3
    b. Potassium (BCC), 68.0 %, 0.1508 nm^3
    c. Polonium (PC), 52.4 %, 0.03743 nm^3

11. Determine the type of unit (cubic) cell given the atomic radius, volume of the unit cell, and packing efficiency (determine the number of atoms per unit cell).
    a. Copper, 1.278 Å, 0.04723 nm^3, 74%
    b. Thallium, 1.681 Å, 0.05851 nm^3, 68.0%

12. Metallic sodium (BCC) has a density of 0.97 $g \cdot cm^{-3}$. Determine the length of an edge of the unit cell. What is the atomic radius of sodium?

13. Gold (FCC) has a unit cell length of 407.86 pm and a density of 19.31 $g \cdot cm^{-3}$. Determine Avogadro's number using this information.

14. Silver has an atomic radius of 144 pm. Determine the density of silver if it crystallized in PC, BCC, or FCC. The density of silver is 10.6 $g \cdot cm^{-3}$, which cubic lattice does silver have?

15. Why is the melting point for ionic or covalent solids so high? How are these solids similar and how are they different?

16. You have a solid which has a melting point of 800°C, is soluble in water and does not conduct electricity in the solid state. What type of solid is this?

17. You have a solid which has a melting point of 1650°C, is insoluble in water or hexane and does not conduct electricity in the solid state. What type of solid is this?

18. You have a solid which has a melting point of 175°C, does not conduct electricity in the solid state and is soluble in hexane. What type of solid is this?

19. What is the correlation between vapor pressure and intermolecular forces?

20. What is the correlation between enthalpy of vaporization and intermolecular forces?

21. Determine the normal boiling point of the substances given the vapor pressure at 25ºC and the ΔH_{vap}:
    a. CCl_4 (P = 98.28 mm Hg; ΔH_{vap} = 30.0 kJ·mol^{-1})
    b. C_6H_6 (P = 72.53 mm Hg; ΔH_{vap} = 30.8 kJ·mol^{-1})
    c. I_2 (P = 6.264 mm Hg at 40ºC; ΔH_{vap} = 41.80 kJ·mol^{-1})
    d. Hg (P = 0.001646 mm Hg; ΔH_{vap} = 59.30 kJ·mol^{-1})

22. Determine the vapor pressure of the following substances at room temperature (25ºC) given the normal boiling point and ΔH_{vap}:
    a. Br_2 (T_b = 332.4 K; ΔH_{vap} = 29.45 kJ·mol^{-1})
    b. H_2O (T_b = 373 K; ΔH_{vap} = 40.656 kJ·mol^{-1})
    c. CS_2 (T_b = 319.4 K; ΔH_{vap} = 26.74 kJ·mol^{-1})

23. Explain the correlation of pressure to boiling point and explain how to find this on a phase diagram.