CHEM 100 **Name**________________________________

Exam 2 **Summer 2011**

Part I. Multiple choice. Circle the correct answer for each problem. 3 points each

1. In terms if energy, the statement "you cannot win, you can only break even" is another way of expressing

   A) Boyle's law.
   B) the third law of thermodynamics.
   C) the second law of thermodynamics.
   D) the first law of thermodynamics.

2. Water is a liquid at room temperature while methane is a gas. Which statement compares the intermolecular forces in these molecules correctly?

   A) Both water and methane have the same intermolecular forces.
   B) The intermolecular forces in water are stronger than those in methane.
   C) The intermolecular forces in methane are stronger than those in water.
   D) There is not enough information to compare these forces.

3. Solid lithium hydride (LiH) reacts with water to form aqueous lithium hydroxide and hydrogen gas. When this equation is written and balanced, the coefficient of lithium hydride is:

   A) 3
   B) 4
   C) 1
   D) 2

4. Which of the following is correct, according to Avogadro's hypothesis?

   A) At STP, equal volumes of gases contain equal masses.
   B) At STP, equal volumes of gases have the same density.
   C) At STP, 1 L of oxygen gas and 1 L of liquid water contain the same number of molecules.
   D) At STP, equal volumes of gases contain the same number of molecules

5. What volume of 0.100 M $MgCl_2$ is contains 0.050 moles of chloride ions?

   A) 1000 mL
   B) 500 mL
   C) 250 mL
   D) 150 mL

6. Which of the following is NOT a postulate of the kinetic-molecular theory?

   A) The molecules of a gas are weakly attracted to each other.
   B) Molecules of a gas move rapidly and in straight lines.
   C) If two molecules collide with each other, the total energy of the molecules before the collision is the same as their total energy after the collision.
   D) The molecules in a gas are large compared to the distance between them.

7. How many liters of a 0.2 M NaOH solution are needed in order to have 1.0 moles of NaOH?

   A) 8 L
   B) 0.8 L
   C) 0.2 L
   D) 5 L

8. Acetic acid ($C_2H_4O_2$) is the main ingredient in vinegar. How many moles of ethanol are represented by 25.0 kg of acetic acid?

A) 4.16 mol.

B) 416 mol.

C) 1.50 mol.

D) 150 mol.

9. The inevitable energy lost as heat in the generation of energy in the most efficient gasoline powered automobile engine

A) a poor understanding of energy conversion.

B) the first law of thermodynamics.

C) designed inefficiencies to increase costs to the consumer.

D) the second law of thermodynamics.

10. All of the following examples are classified as potential energy except

A) energy in chemical bonds.

B) energy of a moving object.

C) energy in nuclear particles.

D) energy stored by position.

Part II. Complete each of the following. Point values are noted by each question. Report numerical results to the correct number of significant figures and with the appropriate units.

11. Consider aspirin (acetylsalycilic acid, $C_9H_8O_4$).

a. How many molecules of aspirin are present in one 500 mg tablet? (5 points)

$$500\ \cancel{mg} \times \frac{10^{-3}\ g}{1\ \cancel{mg}} \times \frac{1\ \cancel{mol}}{180.16\ g} \times \frac{6.02\times10^{23}\ \text{molecules}}{1\ \cancel{mol}} = 1.67\times10^{21}\ \text{molecules}$$

b. What is the percent carbon in aspirin? (5 points)

$$\frac{9(12.011)\ g\ C}{180.16\ g\ C_9H_8O_4} \times 100\% = 60.0\ \%\ C$$

12. Balance the following reactions: (4 points each)

a. The reaction of calcium oxide with SO_2 in a smokestack to prevent the emission of acid rain-producing gases:

__2__ CaO + __2__ SO_2 + __1__ O_2 → __2__ $CaSO_4$

b. The combustion of hexane in air to form carbon dioxide and water:

__2__ C_6H_{14} + __19__ O_2 → __12__ CO_2 + __14__ H_2O

13. The first and second laws of thermodynamics tell us that nomatter what we do, we cannot convert a fuel to energy with 100% efficiency. Briefly explain why this is so. (8 points)

The first law states that the best we could hope to do is to completely convert the potential energy to kinetic energy (energy is neither created nor destroyed). Unfortunately, the second law states that every time we try to use energy to do work, some of that energy is lost to the surroundings. An example would be the conversion of fuel to motion in your car. During the conversion, a great deal of heat is produced, which radiates into the environment and is not used to make the car move.

14. What volume will 12.6 grams of oxygen gas occupy at 22.0°C and 0.950 atm? (8 points)

pV = nRT so: V = nRT/P. For 22.0°C, T = 295K

$$12.6\ \cancel{g\ O_2} \times \frac{1\ mol\ O_2}{32.0\ \cancel{g\ O_2}} = 0.3938\ mol\ O_2$$

$$V = \frac{nRT}{P} = \frac{(0.3938\ \cancel{mol}\ O_2)(0.0821\ L\ \cancel{atm}\ \cancel{mol^{-1}}\ \cancel{K^{-1}})(295\ \cancel{K})}{(0.850\ \cancel{atm})} = 10.04\ L$$

15. Describe the processes that must occur for sodium chloride to dissolve in water. (8 points)

You should talk about the following:

1. Interactions between Na^+ and Cl^- must be disrupted, which costs some energy. These are ionic interactions.
2. Interactions between Na^+ and water and Cl^- and water must be formed. These ion-dipole interactions occur because water is a polar molecule. The "negative" end of the water molecule can interact with Na^+ and the "positive" end of the molecule can interact with Cl^- The result of this interaction is a solvation of the ions and a release of some energy.
3. In order for the process to be favorable, the energy cost cannot exceed the energy return.

You may also have shown a diagram like figure 6.9 to illustrate your point.

Part III. Complete 3 of the following 4 problems. Clearly mark the problem you do not want graded. Each problem is worth ten (10) points. You must show you work on calculations to receive partial credit. Report numerical results to the correct number of significant figures and with the appropriate units.

16. For the following, consider the reaction between aluminum chloride and sulfuric acid to prepare aluminum sulfate and HCl:

$$2\,AlCl_3\,(s) + 3H_2SO_4\,(aq) \rightarrow Al_2(SO_4)_3\,(aq) + 6\,HCl\,(aq)$$

a. How many kg of aluminum sulfate can be prepared from 1.2 kg aluminum chloride and an excess of sulfuric acid? (6 points)

$$1.2\ \text{kg AlCl}_3 \times \frac{1000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{mol AlCl}_3}{133.34\ \text{g}} \times \frac{1\ \text{mol Al}_2(\text{SO}_4)_3}{2\ \text{mol AlCl}_3} \times \frac{342.15\ \text{g Al}_2(\text{SO}_4)_3}{1\ \text{mol Al}_2(\text{SO}_4)_3} \times \frac{1\ \text{kg}}{10^3\ \text{g}} = \mathbf{1.54\ kg\ Al_2(SO_4)_3}$$

b. How many moles of hydrogen chloride can be prepared by mixing 1.2 mol aluminum chloride and 1.5 moles sulfuric acid? (4 points)

We need to figure out which one runs out first (limiting reactant). This will determine the maximum product.

$$AlCl_3:\quad 1.2\ \text{mol AlCl}_3 \times \frac{6\ \text{mol HCl}}{2\ \text{mol AlCl}_3} = 3.6\ \text{mol HCl possible}$$

$$H_2SO_4:\quad 1.5\ \text{mol H}_2\text{SO}_4 \times \frac{6\ \text{mol HCl}}{3\ \text{mol H}_2\text{SO}_4} = 3.0\ \text{mol HCl possible}$$

Therefore, sulfuric acid is the limiting reactant and will run out after forming 3.0 mol HCl

17. In an explosion, the shock wave that results from a rapid increase in pressure can cause significant damage. Consider the detonation of TNT by the reaction below. If 100 g of TNT is detonated, what volume would the gas produced occupy at a pressure of 1 atm, assuming a temperature at detonation of 3000K? The molar mass of TNT is 227.13 g/mol.

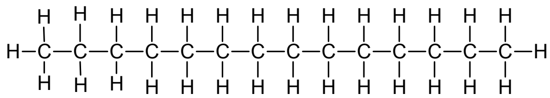
$$2\,C_7H_5N_3O_6\,(s) \rightarrow 3\,N_2\,(g) + 5\,H_2O\,(g) + 7\,CO\,(g) + 7\,C\,(s)$$

Looking at the reaction, every time 2 mol of TNT explodes (3+5+7) = 15 moles of gas are produced

$$100\ \text{g TNT} \times \frac{1\ \text{mol TNT}}{227.13\text{g}} \times \frac{15\ \text{mol gas}}{2\ \text{mol TNT}} = 3.302\ \text{mol gas}$$

$$V = \frac{nRT}{P} = \frac{(3.302\ \text{mol})(0.0821\ \text{L atm mol}^{-1}\ \text{K}^{-1})(3000\ \text{K})}{(1\ \text{atm})} = \mathbf{813\ L}$$

18. You've been asked back to your high school to explain the science behind the adage "*oil and water don't mix*". Outline your explanation below. Feel free to consider the "oil" as a long-chain hydrocarbon, like tetradecane, shown below.



tetradecane

Lets look at the two types of molecules:

1. "Oil" (tetradecane): since tetradecane is only carbon and hydrogen, and since C and H have similar electronegativities, bonds in a molecule of tetradecane are nonpolar, resulting in a nonpolar molecule. The predominant types of intermolecular force present in nonpolar, hydrocarbon-containing molecules are weak dispersion forces.
2. Water: Water is composed of H and O, resulting in very polar bonds and strong dipole-dipole interactions. Water is also able to undergo strong hydrogen bonding interactions as well as weak dispersion forces.

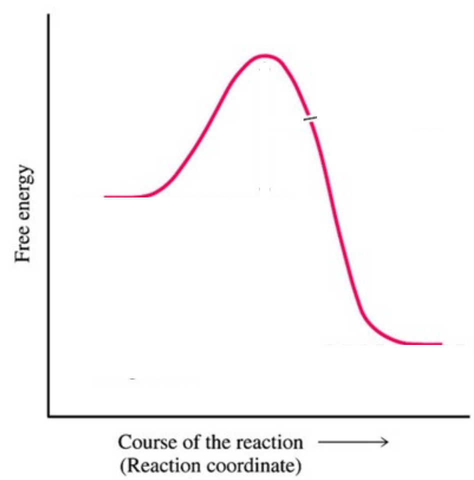
The great dissimilarity between the IM forces in tetradecane and water makes it difficult for them to interact (dissolve). It requires a fair amount of energy for a molecule to disrupt water's IM forces and dissolve. The energy cost in disrupting the interactions between water molecules and those between oil molecules is too great for the small energy return we might get when they mix.

19. We talked on a couple of occasions that the fact that a reaction is *favorable* does not mean the reaction will be *fast*. Explain why this is so. Use a reaction coordinate diagram to illustrate your discussion.

You should include the following:

1. *Favorable* means that the products of the reaction are more stable (lower energy) than the reactants. This is a thermodynamic description that describes the tendency of the reaction. In a reaction coordinated diagram, this corresponds to the vertical location of the reactants and products on the energy axis.

2. *Fast* refers to the rate at which reactants are converted to products and deals with the kinetics of the system. The rate of the reaction depends on the mechanism of the process and the energy barrier that must be overcome on going from reactants to products. The higher the barrier, generally the slower the reaction.



Possibly Useful Information

$PV = nRT$	$R = 0.0821$ L atm/(mol K)
$P_1V_1 = P_2V_2$	$V_1/T_1 = V_2/T_2$
$K = {}^{o}C + 273.15$	STP: P = 1 atm, T = 273 K
Don't eat the yellow snow.	$N_A = 6.02 \times 10^{23}$ mol^{-1}

PERIODIC CHART OF THE ELEMENTS

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	INERT GASES
1 H 1.00797																1 H 1.00797	2 He 4.0026
3 Li 6.939	4 Be 9.0122											5 B 10.811	6 C 12.0112	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.183
11 Na 22.9898	12 Mg 24.312											13 Al 26.9815	14 Si 28.086	15 P 30.9738	16 S 32.064	17 Cl 35.453	18 Ar 39.948
19 K 39.102	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.909	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.905	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (99)	44 Ru 101.07	45 Rh 102.905	46 Pd 106.4	47 Ag 107.870	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30
55 Cs 132.905	56 Ba 137.34	*57 La 138.91	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	†89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 ? (271)	111 ? (272)	112 ? (277)						

Numbers in parenthesis are mass numbers of most stable or most common isotope.

Atomic weights corrected to conform to the 1963 values of the Commission on Atomic Weights.

The group designations used here are the former Chemical Abstract Service numbers.

* Lanthanide Series

58 Ce 140.12	59 Pr 140.907	60 Nd 144.24	61 Pm (147)	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.924	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.97

† Actinide Series

90 Th 232.038	91 Pa (231)	92 U 238.03	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (249)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (256)	103 Lr (257)