CHEM 100 **Name**_____
Exam 2 **Summer 2010**

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

1. 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.

2. Which of the following is the weakest?

   A) dipole forces
   C) ionic bonds
   B) hydrogen bonds
   D) dispersion forces

3. Which of the following does not contain Avogadro's number of particles?

   A) 6.02×10^{23} atoms of silicon
   C) 23 g of sodium
   B) 12 g of water
   D) 1.0 mole of carbon

4. A balloon is inflated outdoors on a cold day in North Dakota at a temperature of -40°C to a volume of 2.00 L. The pressure remains constant. What is the volume of the balloon indoors at a temperature of 25°C?

   A) -3.2 L
   C) 2.0 L
   B) 1.6 L
   D) 2.6 L

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

   A) The molecules of a gas are strongly 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 tiny compared to the distance between them.

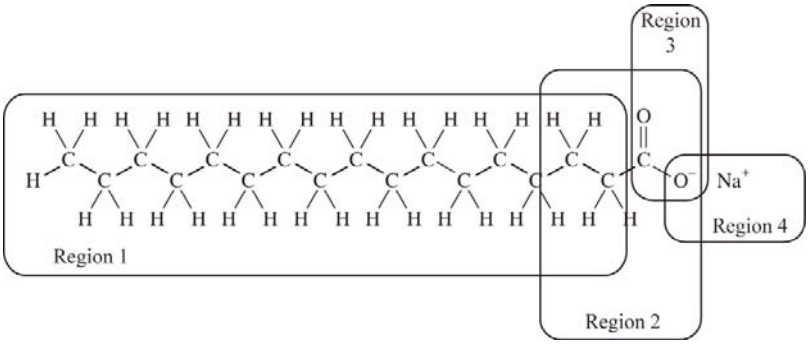
6. Ethanol (C_2H_6O) is a common intoxicant and fuel produced from the fermentation of various grains. How many moles of ethanol are represented by 50.0 kg of ethanol?

   A) 1085 mol.
   C) 46.1 mol.
   B) 9.0 mol.
   D) 1.09 mol.

7. In terms if energy, the statement "you cannot break even" is another way of expressing

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

8. Which region of the soap molecule shown dissolves most easily in nonpolar materials such as grease?



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

9. The phenomenon that is primarily responsible for the unusual physical properties of water (such as its high boiling point) is:
A) ion-ion interactions
C) ion-dipole interactions
B) hydrogen bonding
D) dispersion forces

10. Which of the following covalent bonds would you expect to be the most polar?
A) C-C
C) C-O
B) C-F
D) C-H

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. Define th efollowiing terms. (8 points total, 4 each)
a. enthalpy: Energy transferred as heat

b. stoichiometry: Molecule per molecule, or mole per mole relationships in reactions that allow us to relate one component of a reaction with another.

12. How many ammonia molecules are present in 4.48 L of ammonia gas at 0°C and 0.500 atm? (6 points)

pV = nRT so: n = PV/RT. For 0°C, T = 273K

$$n = \frac{PV}{RT} = \frac{(0.500\ \cancel{atm})(4.48\ \cancel{L})}{(0.0821\ \cancel{L}\ \cancel{atm}\ mol^{-1}\ \cancel{K}^{-1})(273\ \cancel{K})} = 0.0999\ mol$$

$$0.0999\ mol \times \frac{6.02 \times 10^{23}\ molecules}{1\ mol} = \mathbf{6.01 \times 10^{22}\ molecules}$$

13. For the reaction below, how many grams of silver chloride can be prepared by reacting 1000.0 g silver nitrate with 4.45 g of magnesium chloride? (10 points)

$2\ AgNO_3\ (aq) + \quad MgCl_2\ (aq) \rightarrow \quad 2\ AgCl\ (s) + \quad Mg(NO_3)_2\ (aq)$ (not balanced)

If $AgNO_3$ is limiting reagent

$$1000\ \text{g } AgNO_3 \times \frac{1\ \text{mol } AgNO_3}{169.87\ \text{g}} \times \frac{1\ \text{mol } AgCl}{1\ \text{mol } AgNO_3} \times \frac{143.32\ \text{g } AgCl}{1\ \text{mol } AgCl} = \mathbf{843.7\ g\ AgCl}$$

If $MgCl_2$ is limiting reagent

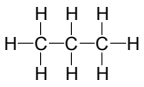
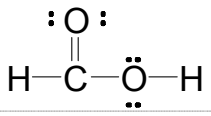
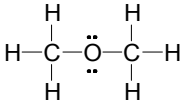
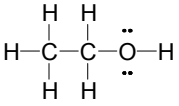
$$4.45\ \text{g } MgCl_2 \times \frac{1\ \text{mol } MgCl_2}{95.21\ \text{g}} \times \frac{2\ \text{mol } AgCl}{1\ \text{mol } MgCl_2} \times \frac{143.32\ \text{g } AgCl}{1\ \text{mol } AgCl} = \mathbf{13.4\ g\ AgCl}$$

So, $MgCl_2$ must be the limiting reagent, producing 13.4 grams of silver chloride.

14. A student was asked to prepare exactly 250 mL of a 0.500 M aqueous potassium hydroxide solution. What mass of potassium hydroxide must the student dissolve in the 250 mL of solution? (8 points)

$$\frac{0.500\ \text{mol KOH}}{1\ \text{L}} \times 0.250\ \text{L} \times \frac{56.110\ \text{g KOH}}{1\ \text{mol KOH}} = \mathbf{7.01\ g\ KOH}$$

15. Rank the compounds below in order of boiling point, from lowest to highest. Clearly explain your reasoning. (Hint: higher boiling points mean greater difficulty in breaking up intermolecular interactions) (8 points)

Compound	Propane	Formic Acid	Methyl Ether	Ethanol
Formula	$CH_3CH_2CH_3$	CHCOOH	CH_3OCH_3	CH_3CH_2OH
Molar Mass	44.1 g/mole	46.0 g/mole	46.1 g/mole	46.1 g/mole
Lewis Structure				
Rank	Lowest	Highest	Second lowest	Second highest
IM Forces Present	Dispersion	Dispersion Dipole-Dipole Hydrogen Bonding	Dispersion Dipole-Dipole	Dispersion Dipole-Dipole Hydrogen Bonding

The key here is that an increase in the strength of the intermolecular forces present in a material will lead to an increase in boiling point. Since propane only experiences dispersion forces, it has the lowest boiling point. Methyl ether can undergo stronger dipole-dipole interactions and has a higher boiling point. Both formic acid and ethanol undergo hydrogen bonding as well, but the acid has more polar bonds and greater opportunity for hydrogen bonding (they have a hydrogen bound to an oxygen that has a lone pair of electrons), and therefore the highest boiling point.

IMPORTANT: COVALENT BONDS ARE NOT BROKEN WHEN SOMETHING BOILS

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 potassium carbonate and ammonium nitrate to prepare potassium nitrate:

$$K_2CO_3\,(s) + 2NH_4NO_3\,(s) \rightarrow 2KNO_3\,(s) + CO_2\,(g) + H_2O\,(g) + 2NH_3\,(g)$$

a. How many kg of potassium nitrate can be prepared from 1.2 kg potassium carbonate and an excess of ammonium nitrate? (6 points)

$$1.2\ \text{kg } K_2CO_3 \times \frac{1000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{mol } K_2CO_3}{138.28\ \text{g}} \times \frac{2\ \text{mol } KNO_3}{1\ \text{mol } K_2CO_3} \times \frac{101.11\ \text{g } KNO_3}{1\ \text{mol } KNO_3} \times \frac{1\ \text{kg}}{1000\ \text{g}} = \mathbf{1.76\ kg\ KNO_3}$$

b. How many moles of carbon dioxide can be prepared by mixing 1.2 mol potassium carbonate and 1.0 moles ammonium nitrate? (4 points)

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

$$K_2CO_3\text{:}\quad 1.2\ \text{mol } K_2CO_3 \times \frac{1\ \text{mol } CO_2}{1\ \text{mol } K_2CO_3} = 1.2\ \text{mol } CO_2 \text{ possible}$$

$$NH_4NO_3\text{:}\quad 1.0\ \text{mol } NH_4NO_3 \times \frac{1\ \text{mol } CO_2}{2\ \text{mol } NH_4NO_3} = 0.5\ \text{mol } CO_2 \text{ possible}$$

Therefore, ammonium nitrate is the limiting reactant and will run out after forming 0.5 mol CO_2

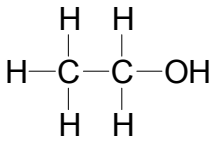
17. Copper (II) sulfide can be converted to copper metal by reaction with oxygen in the reaction below. What volume of SO_2 (at STP) would be made from the complete conversion of 1,100 g of CuS ore?

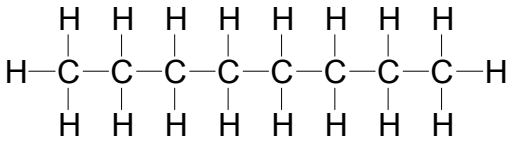
$$CuS + O_2 \rightarrow Cu + SO_2$$

$$1100\ \text{g CuS} \times \frac{1\ \text{mol CuS}}{95.60\ \text{g}} \times \frac{1\ \text{mol } SO_2}{1\ \text{mol CuS}} = 11.505\ \text{mol } SO_2$$

$$V = \frac{nRT}{P} = \frac{(11.505\ \text{mol})(0.0821\ \text{L atm mol}^{-1}\ \text{K}^{-1})(273\ \text{K})}{(1\ \text{atm})} = 257.9\ \text{L} = \mathbf{260\ L}$$

18. Consider the solubility of ethanol and octane in water. Explain why ethanol is much more soluble in water than octane.





Lets look at the three types of molecules:

1. Octane: since octane is only carbon and hydrogen, and since C and H have similar electronegativities, bonds in a molecule of octane are nonpolar, resulting in a nonpolar molecule. The predominant types of intermolecular force present in nonpolar, hydrocarbon-containing molecules are weak dispersion forces.
2. Ethanol: Ethanol is composed of C, H and O, resulting in both polar and nonpolar bonds. The addition of polar bonds introduces dipole-dipole interactions. Ethanol is also able to undergo hydrogen bonding interactions because of the alcohol functional group as well as weak dispersion forces.
3. 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 octane 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. Since ethanol and water share the same types of IM forces, they can more readily interact with one another and dissolve.

19. A student, Kimmy Nurd, conducted the malachite to copper conversion experiment that we did in lab. She started with 1.135 grams of malachite and performed the roasting and reduction steps in the same way we did in lab. After cooling and cleaning her beads, the final mass of copper was determined to be 0.598 grams. What was her percent yield for the overall process?

Roasting: $Cu_2CO_3(OH)_2(s) \rightarrow 2\ CuO(s) + CO_2(g) + 2H_2O(g)$

Reduction: $2\ CuO(s) + C(s) \rightarrow 2\ Cu(s) + CO_2(g)$

To calculate a percent yield, we first need a theoretical yield:

$$\frac{1.135\ g\ Cu_2CO_3(OH)_2}{} \times \frac{1\ mol}{221.1g\ Cu_2CO_3(OH)_2} \times \frac{2\ mol\ CuO}{1\ mol\ Cu_2CO_3(OH)_2} = 0.01027\ mol\ CuO$$

$$0.01027\ mol\ CuO \times \frac{2\ mol\ Cu}{1\ mol\ CuO} \times \frac{63.54\ g\ Cu}{1\ mol\ Cu} = 0.652g\ Cu\ possible = theoretical\ yield$$

Now we can determine the % yield:

$$\%\ yield = \frac{actual}{theoretical} \times 100\% = \frac{0.598\ g}{0.652\ g} \times 100\% = \mathbf{91.7\ \%\ yield}$$

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 walk between parked cars…or moving ones!	$N_A = 6.02 \times 10^{23}$ 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)