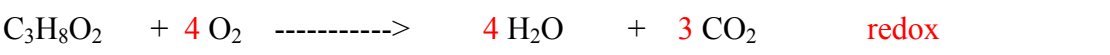
CHM 1010 GAGE

FINAL REVIEW QUESTIONS FOR CHM 101

Wow! It=s almost the end of the semester and you have a head full of chemical concepts. To get ready for the final exam and review those concepts work on the following material. Keep in mind that this is only a sample and does not cover every point we discussed.

1. Complete (if necessary), write in symbols (if necessary) and balance each of the following chemical equations. Indicate what type of reaction each one represents.

single replacement



redox

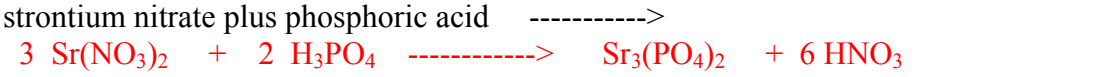
combination

combination

decomposition

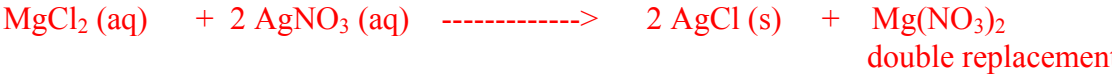
double replacement

strontium nitrate plus phosphoric acid ---------->



double replacement

magnesium chloride in water reacts with silver nitrate to form solid silver chloride and soluble magnesium nitrate



double replacement

2. a. List every characteristic or piece of information you can about the element sulfur. Be sure to include all properties you can determine from the periodic table. Remember atomic structure.

16 p+, 16 e-, 16 or more n
non-metal
Group VIA
Forms ionic or covalent bonds
Forms S^{2-} ions
Chemical properties similar to O or Se
3rd period element
atomic mass = 32.1 amu
1 mole = 32.1 g
$1s^2 2s^2 2p^6 3s^2 3p^4$; 1st shell = 2 e-, 2nd shell = 8 e-, third shell = 6 e-; 2 unpaired e-
can determine relative: electronegativity, atomic and ionic radii, electron affinity

b. Sulfur can form ionic and covalent bonds. Explain why and how. Provide examples for each type of bond.

In the presence of a metal, sulfur will gain 2e- to complete its octet, form S^{2-} and be attracted to the subsequent metal ion forming an ionic bond. In the presence of a non-metal, S will share e- to complete its octet and thereby form a covalent bond.

3. A gas has a volume of 380 mL at STP.

a. What is its volume at 25°C and 1.8 atm?

$P_1 = 1.00$ atm $V_1 = 380$ mL $T_1 = 0°C = 273$ K

$P_2 = 1.8$ atm $V_2 = ?$ mL $T_2 = 250°C = 298$ K

$$\frac{P_1V_1T_2}{P_2T_1} = \frac{(1.00\text{ atm})(380\text{ mL})(298\text{ K})}{(273\text{ K})(1.8\text{ atm})} = 230\text{ mL} = 2.3 \times 10^2\text{ mL}$$

b. How many moles does the sample contain?

$$PV = nRT \quad \frac{PV}{RT} = n = \frac{(1.00\text{ atm})(0.380\text{ L})}{(0.0821\text{ L atm/mol K})(273\text{ K})} = 0.0170\text{ mol}$$

c. What pressure is needed to change the volume to 300 mL at standard temperature?

$P_1 = 1.00$ atm $V_1 = 380$ mL $T_1 = 0°C = 273$ K

$P_2 = ?$ atm $V_2 = ?$ mL $T_2 = 0°C = 273$ K

$$\frac{P_1V_1}{V_2} = \frac{(1.00\text{ atm})(380\text{ mL})}{(300\text{ mL})} = 1.27\text{ atm}$$

d. How can you tell if the gas is really an ideal gas at all conditions?

Predict the volume (from the ideal gas law) for given sets of conditions and then measure the volume at those conditions. If the gas is ideal, the predicted volume will match the measured volume.

4. Give an example of each of the following:

a. chemical change
b. physical property
c. gas variable
d. empirical and molecular formula
e. element chemically similar to phosphorus
i. endothermic physical process
j. halogen
k. homogeneous mixture
l. diatomic element
m. ionic compound

f. property unique to metals
g. compound that shows hydrogen bonding
h. exothermic chemical reaction
n. hypothesis
o. theory

5. Consider the compounds HNO_3, CH_3COOH, NaOH, NH_3, $CaCO_3$, and BF_3 in aqueous solution.

a. Which are Arrhenius acids? Arrhenius bases?

AA = HNO_3, CH_3COOH AB = NaOH

b. Which are considered strong and which weak?

Strong = HNO_3, NaOH Weak = CH_3COOH, NH_3, $CaCO_3$, BF_3

c. Which are Lewis acids and Lewis bases?

LA = HNO_3, CH_3COOH, BF_3 LB = NaOH, NH_3, $CaCO_3$

d. Which would react with active metals? Which would taste bitter?

Metals = HNO_3, CH_3COOH bitter = NaOH, NH_3, $CaCO_3$

e. Assume you had solutions of the same molarity of HNO_3, CH_3COOH, NaOH, and NH_3. Put them in order from highest to lowest pH and explain (using chemical equations) why they are in that order.

NaOH > NH_3 . CH_3COOH . HNO_3

6. Consider the following reaction for the production of phosphoric acid from phosphorus pentoxide for use in fertilizer or explosive manufacture:

P_2O_5 + 3 H_2O ----------> 2 H_3PO_4

a. How many grams of phosphoric acid can be made from 0.54 moles of water?

$$0.54 \text{ mol } H_2O \times \frac{2 \text{ mol } H_3PO_4}{3 \text{ mol } H_2O} \times \frac{98.0 \text{ g } H_3PO_4}{1 \text{ mol } H_3PO_4} = 35 \text{ g } H_3PO_4$$

b. How many atoms of hydrogen are needed to form 38 molecules of phosphoric acid?

$$38 \text{ molecules } H_3PO_4 \times \frac{3 \text{ atoms H}}{1 \text{ molecule } H_3PO_4} = 114 \text{ atoms H}$$

c. If you have 3.2×10^{22} molecules of water, how many grams of P_2O_5 will be needed to react with it?

$$3.2 \times 10^{22} \text{ molecules } H_2O \times \frac{1 \text{ mol } H_2O}{6.02 \times 10^{23} \text{ molecules } H_2O} \times \frac{1 \text{ mol } P_2O_5}{3 \text{ mol } H_2O} \times \frac{142.0 \text{ g } P_2O_5}{1 \text{ mol } P_2O_5} = 2.5 \text{ g } P_2O_5$$

d. How many grams of phosphoric acid can be produced from 90. g of phosphorus pentoxide and 50.0 grams of water. How much of which reactant will remain?

$$\overline{90} \text{ g } P_2O_5 \times \frac{1 \text{ mol } P_2O_5}{142.0 \text{ g } P_2O_5} \times \frac{2 \text{ mol } H_3PO_4}{1 \text{ mol } P_2O_5} \times \frac{98.0 \text{ g } H_3PO_4}{1 \text{ mol } H_3PO_4} = 1.2 \times 10^2 \text{ g } H_3PO_4$$

$$50.0 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.0 \text{ g } H_2O} \times \frac{2 \text{ mol } H_3PO_4}{3 \text{ mol H2O}} \times \frac{98.0 \text{ g } H_3PO_4}{1 \text{ mol } H_3PO_4} = 181 \text{ g } H_3PO_4$$

Since 120 g is the lesser amount, that is the quantity that will be made.

7. Epsom salts is the common name for magnesium sulfate.

a. If you have 35.0 grams of magnesium sulfate in 650 mL of solution, what is the g/v% and molarity of the solution?

$$\frac{35.0\text{ g}}{650\text{ mL}} \times 100 = 5.38\%$$

$$35.0\text{ g } MgSO_4 \times \frac{1\text{ mol } MgSO_4}{120.4\text{ g } MgSO_4} = 0.291\text{ mol } MgSO_4$$

$$M = \frac{\text{mol}}{L} = \frac{0.291\text{ mol}}{0.650\text{ L}} = 0.447\text{ M } MgSO_4$$

b. How many grams of magnesium sulfate would you need to make 750 mL of a 0.26M solution?

$$M = \frac{\text{mol}}{L} \quad M \times L = \text{mol} \quad \frac{0.26\text{ mol}}{L} \times 0.750\text{ L} = 0.195\text{ mol}$$

$$0.195\text{ mol} \times \frac{120.4\text{ g } MgSO_4}{1\text{ mol } MgSO_4} = 23\text{ g } MgSO_4 \text{ (2 sig fig)}$$

c. What happens on a particle level when the magnesium sulfate dissolves in water? Would it be the same process when CH_3CH_2OH dissolves in water? Explain.

As the magnesium sulfate which is ionically bonded comes in contact with the polar water molecules, ion-dipole forces form between the positive magnesium ions and the slightly negative oxygen ends of water and between the slightly positive hydrogen areas of water and the negative sulfate ion. The ions are separated from each other and dispersed in the solution. The ions are surrounded by water molecules in solution.

The process would be similar for CH_3CH_2OH except that this compound is polar-covalently bonded and so will not separate into ions in water. Dipole-dipole forces, specifically hydrogen bonding, will cause the interactions between the molecules and the dispersion of CH_3CH_2OH in the water.

8. Explain how you could accomplish the following in the lab (or possibly at home):

a. raise the boiling point of water without adding material

Increase the pressure over the water by sealing the container (such as in a pressure cooker or autoclave). Since the atmospheric pressure over the water is higher, more energy will be needed to overcome the pressure and allow the vapor to escape and the boiling point will increase.

b. lower the freezing point of water

Add a solute to the water and this will reduce the freezing point by requiring the system to go to a lower energy state to achieve order among the solvent particles and exclude the solute particles from the solid lattice.

c. determine the molar mass of a mystery gas

Obtain a given mass of the gas. Measure the pressure, temperature and volume of the gas. Use the ideal gas law to determine the molar mass of the gas.

d. determine the identity of an element without using a chemical reaction

Determine several physical properties such as density, boiling point and/or melting point. Along with physical characteristics such as state and color, you should be able to use a reference book to determine the identity of the element.

e. determine if a substance is a compound or element

Attempt to separate the substance by chemical means. If the separation is unsuccessful, the substance is an element. If it can be separated it is a compound.

9. Complete the following table:

Substance	electron geometry	molecular geometry	polar or non-polar bonds?	Polar or non-polar molecule?	Type of Hybridization
nitrite ion	trigonal planar	angular	polar (just barely)	NA	sp^2
arsenic pentachloride	trigonal bipyramidal	trigonal bipyramidal	polar	non-polar	sp^3d
calcium oxide	NA ionic	NA	NA	NA	NA
ammonia	tetrahedral	trigonal pyramidal	polar	polar	sp^3
silicon dioxide	linear	linear	polar	non-polar	sp
boron trichloride	trigonal planar	trigonal planar	polar	non-polar	sp^2

10. A 1.60 gram sample of a compound contains 0.276 grams of hydrogen and 1.32 grams of carbon. The sample occupies a volume of 655 mL at 100°C and 980.0 mmHg. What are the empirical and molecular formulas for the compound?

$0.276\text{ g H} \times \frac{1\text{ mol H}}{1.0\text{ g H}} = 0.276\text{ mol H}$ $1.32\text{ g C} \times \frac{1\text{ mol C}}{12.0\text{ g C}} = 0.11\text{ mol C}$

$\frac{0.276}{0.11} \approx 2.5$ $\frac{0.11}{0.11} \approx 1$ Multiply by 2 to achieve whole numbers

Empirical formula = C_2H_5

Use the Ideal Gas Law to determine the molar mass for this compound.

$$MM = \frac{gRT}{PV} = \frac{(1.60\text{ g})(0.0821\text{ L atm/mol K})(373\text{ K})}{(1.29\text{ atm})(0.655\text{ L})} = 58.0\text{ g/mol}$$

$$\frac{\text{Molar mass}}{\text{Empirical mass}} = \frac{58.0\text{ g/mol}}{29.0\text{ g/mol}} = 2$$

Therefore the molecular formula is twice as large as the empirical formula.

Molecular formula = C_4H_{10}

11. Ponder and answer the following questions or statements with a scientific explanation.

a. Why does hot air rise?

As the temperature of a gas increases the molecules move faster. Since the air is not contained, the pressure will not increase but the volume the gas occupies will. The mass remains the same and the volume increases so the density decreases. Less dense materials rise so the hot air will rise above the denser, cooler air.

b. Water is very efficient at cooling our bodies as we sweat. Explain why.

Water molecules interact through strong dipole-dipole forces (hydrogen bonding). To overcome these forces and separate these molecules takes a significant amount of energy. As a result, when the molecules do leave the body they carry a lot of energy with them. This makes the sweating/evaporating process very efficient at cooling the human body.

c. Why will a 0.1 M solution of table salt boil at a higher temperature than 0.1 M table sugar (sucrose)?

When NaCl dissolves in water each unit of the substance dissociates into 2 particles while the sucrose molecules, which are covalently bonded, do not dissociate. Therefore, there are twice as many particles in the NaCl solution as there are in the sucrose solution and the boiling point elevation depends on the number of solute particles in solution.

d. Boron trifluoride and nitrogen trifluoride both have three bonds from the central atom. Do they have the same geometries? Why or why not?

They have different geometries. BF_3 has only three pairs of electrons around the central atom and therefore has a trigonal planar geometry. NF_3 has four pairs of electrons around the central atom so the electron geometry is tetrahedral and the resulting molecular geometry is trigonal pyramidal.

e. What happens on a particle level when water vapor at 120 degrees Celsius is cooled to minus 10 degrees Celsius?

The high energy gas particles lose energy and move more slowly until they reach 100^oC. At this temperature there is a transition from the vapor to liquid. The temperature remains constant until all the molecules have liquified. The liquid molecules continue to cool (slow down their translational motion) until they reach 0^oC. At this point the transition from liquid to solid occurs while the molecules arrange themselves in a crystal lattice. Once the molecules have all entered the lattice the temperature will fall from 0^oC to -10 as the solid loses additional energy.

f. Silicon dioxide melts above 1500^oC while sulfur dioxide melts well below 0^oC. Explain why.

SO_2 has a higher molar mass than SiO_2 and has polar covalent bonding and therefore chances for stronger interactions than the non-polar silicon dioxide. However, silicon dioxide forms a covalent or network crystal while sulfur dioxide forms a molecular crystal. It is much easier to break apart the dipole-dipole forces in SO_2 than it is to break the covalent bonds in the SiO_2 crystal. Therefore it will take less energy to melt the sulfur dioxide.

g. All reactions require the input of some energy. Correct?

Yes. Any reaction system must absorb enough energy to make it past any barriers. This is the activation energy. Once the barrier is past some or more than the energy absorbed will be released.

h. Chemical equations have to be balanced. Why?

Because there is a fundamental law of nature that says that matter cannot be created or destroyed, we must account for all matter that is involved in a chemical change. This is why equations must be balanced.

i. Why did Bohr suspect that electrons moved about the nucleus in set orbits? Why did Rutherford think that the atom had a dense, positively charged nucleus?

When Bohr looked at the atomic spectra for elements he noticed that the patterns of light released were always the same. Since each wavelength of light has a specific energy, Bohr knew that whatever was occurring took specific amounts of energy. He concluded that electrons must occupy specific energy levels and were making transitions from one set level to another.

Rutherford's gold foil experiment involved directing positively charged alpha particles at gold foil. Most of the alpha particles made it through the foil unhindered. A small percentage of the particles were slightly deflected from a straight line path or were deflected back toward the source. Based on these results he concluded that atoms must be mostly empty space but do contain a small, positively charged center (because + particles were deflected). Since the mass of the atom must be contained in this tiny region, it would be very dense.

12. A 3.50×10^2 g sample of a material is heated from -10^0C to gas at 80°C. How much energy is involved in the process?

mp = -5°C
bp = 80.0°C
$sp.ht._{sol}$ = 1.5J/g °C
$sp.ht._{liq}$ = 2.4 J/g °C
$sp.ht._{vap}$ = 1.2 J/g °C

ΔH_{vap} = 566 J/g
ΔH_{fus} = 245 J/g

$1.5 \frac{J}{g\ °C}$ x 5°C x 350 g = 2625 J

$245 \frac{J}{g}$ x 350 g = 85750 J

$2.4 \frac{J}{g\ °C}$ x 85°C x 350 g = 71400 J

$566 \frac{J}{g}$ x 350 g = 198100 J

Total = 357875 J = 3.58×10^5 J

The molar mass of this compound is about 46 g/mol. Are the intermolecular forces

between molecules of this compound stronger or weaker than water? Explain.
All of the specific heats and enthalpies for this compound are lower than water despite the fact the compound is heavier than water. Therefore, the forces in this compound are probably weaker than in water since less energy is required for each transition.

13. What are the intermolecular forces between molecules or units of each of the following compounds? Justify your answer by drawing and labeling chemical structures.

Compound	Structure and IMFs
CH_3F	dipole-dipole forces; polar molecule
PH_3	dipole-dipole forces; although the bonds between H and P are non-polar, there is a lone pair of electrons on P and that makes the P end of the molecule slightly negative
$CH_3CH_2CH_3$	dispersion; non-polar molecule
$CaCl_2$	electrostatic forces; ionic compound
PCl_5	dispersion forces; polar bonds but symmetrical, non-polar molecule
CO_2	dispersion forces; polar bonds but symmetrical, non-polar molecule

14. Arrange the species in each set below from highest to lowest boiling point and explain why they should be ordered that way:

Set	Compounds	Boiling Point Order and explanation
1	CH_4 H_2O NH_3	$H_2O > NH_3 > CH_4$ Both water and ammonia have hydrogen bonding while non-polar methane interacts through weaker dispersion forces. Because O is more electronegative than N and there are more possible interaction possibilities in water, water has stronger interactions than ammonia
2	SiH_4 GeH_4 CH_4	$GeH_4 > SiH_4 > CH_4$ All three of these molecule are non-polar so the order of boiling point depends on the molar mass since the heavier a molecule is the more energy it will require to become a gaseous particle.
3	RbBr AsH_2Br Br_2	$RbBr > AsH_2Br > Br_2$ Intermolecular forces dominate here- stronger forces, more energy. RbBr is ionic so the forces are electrostatic; AsH_2Br is polar so forces are dipole-dipole; Br_2 is non-polar so the forces are dispersion

15. Consider a 10 L container of carbon dioxide gas at 10°C. In the table below, indicate whether the frequency of collision of the gas particles with the walls of the container and the average kinetic energy of the particles will increase, remain the same or decrease with each change indicated and why:

Change	Average KE	Collisions
volume changed to 25 L	same	reduced; more space so fewer interactions
number of moles doubled	same	increased; more particles so more possible collisions
pressure decreased	same	decreased; less forces without a temp change means fewer collisions
temperature changed to 30°C	increased	increased; more energetic particles will generate more collisions in same volume