Chem 1515.001 - 009
Problem Set #1
Spring 2003

Name____________________________________

TA's Name ________________________________

Sec _____

RPS.1. Write the chemical formula(s) of the product(s) and balance the following reactions. Identify all product phases as either (g)as, (l)iquid, (s)olid or (aq)ueous. Soluble ionic compounds should be written in the form of their component ions.

a) ammonium carbonate(aq) + lead nitrate(aq) ---> **$2NH_4^+(aq) + 2NO_3^-(aq) + PbCO_3(s)$**

b) **2**hexane(g) + **19**oxygen(g) --heat--> **$12CO_2(g) + 14H_2O(l)$**

c) nitric acid(aq) + potassium hdroxide(aq) ---> **$K^+(aq) + NO_3^-(aq) + H_2O(l)$**

d) iron(s) + lead nitrate(aq) ---> **$Pb(s) + Fe(NO_3)_2(aq)$**

e) sodium carbonate(aq) + **2**nitric acid(aq) ---> **$2Na^+(aq) + 2NO_3^-(aq) + CO_2(aq) + H_2O(l)$**

f) potassium hydroxide(aq) + hydrofluoric acid(aq) ---> **$K^+(aq) + F^-(aq) + H_2O(l)$**

g) **2**ethyl alcohol(l) + **14**oxygen(g) --heat--> **$4CO_2(g) + 6H_2O(l)$**

RPS.2. Write ionic and net ionic equations for 1a, 1c, and 1f).

1a) ionic equation

$2NH_4^+(aq) + CO_3^{2-}(aq) + 2NO_3^-(aq) + Pb^{2+}(aq) \rightarrow 2NH_4^+(aq) + 2NO_3^-(aq) + PbCO_3(s)$

1a) net ionic equation

$Pb^{2+}(aq) + CO_3^{2-}(aq) \rightarrow PbCO_3(s)$

1c) ionic equation

$H^+(aq) + NO_3^-(aq) + K^+(aq) + OH^-(aq) \rightarrow K^+(aq) + NO_3^-(aq) + H_2O(l)$

1c) net ionic equation

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

1f) ionic equation

$HF(aq) + K^+(aq) + OH^-(aq) \rightarrow F^-(aq) + H_2O(l)$

1f) net ionic equation

$HF(aq) + OH^-(aq) \rightarrow F^-(aq) + H_2O(l)$

RPS.3. Methane, CH_4, is a hydrocarbon that is commonly used as a fuel for cooking and heating.
a) Write a balanced chemical equation for the complete combustion of methane.

$$CH_4(g) + 2O_2(g) \text{ --heat--> } CO_2(g) + 2H_2O(l)$$

b) Calculate the volume of air at 28 ˚C and 1.1 atmosphere that is needed to burn completely 13.81 grams of methane. Assume that air is 21.0 percent O_2 by volume.

$$13.81\ \text{g}\ CH_4 \left(\frac{1\ \text{mol}\ CH_4}{16\ \text{g}\ CH_4}\right)\left(\frac{2\ \text{mol}\ O_2}{1\ \text{mol}\ CH_4}\right)\left(\frac{0.0821\left(\frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)\cdot 301\ \text{K}}{1.1\ \text{atm}}\right)\left(\frac{100\ \text{L air}}{21\ \text{L}\ O_2}\right) = 184\ \text{L}$$

c) The heat of combustion of methane is -889 kJ mol^{-1}. Calculate the heat of formation, H˚$_f$, of methane given that the H˚$_f$ of $H_2O(l)$ is -285.3 kJ mol^{-1} and H˚$_f$ of $CO_2(g)$ is -393.5 kJ mol^{-1}. (Note: I expect you to calculate the H˚$_f$ of methane from the data in this problem.)

$$\Delta H^\circ_{rxn} = \Sigma\Delta H^\circ_f(\text{Products}) - \Sigma\Delta H^\circ_f(\text{Reactants})$$

$$-889\ \text{kJ mol}^{-1} = \Delta H^\circ_f(CO_2(g)) + 2\Delta H^\circ_f(H_2O(l)) - (\Delta H^\circ_f(CH_4(g)) + 2\Delta H^\circ_f(O_2(l)))$$

$$-889\ \text{kJ mol}^{-1} = -393.5\ \text{kJ mol}^{-1} + (2\cdot -285.3\ \text{kJ mol}^{-1}) - \Delta H^\circ_f(CH_4(g)) + 2\cdot 0)$$

$$\Delta H^\circ_f(CH_4(g)) = -75.1\ \text{kJ mol}^{-1}$$

d) Assuming that all of the heat evolved in burning 13.81 grams of methane is transferred to 6.01 kilograms of water (specific heat = 4.184 J g-1 deg C-1) initially at 24.7 degrees Celsius, calculate the increase in temperature of the water.

$$13.81\ \text{g}\ CH_4 \left(\frac{1\ \text{mol}\ CH_4}{16\ \text{g}\ CH_4}\right)\left(\frac{-889\ \text{kJ}}{1\ \text{mol}\ CH_4}\right)\left(\frac{1000\ \text{J}}{1\ \text{kJ}}\right)\left(\frac{1}{4.184\left(\frac{\text{J}}{\text{g}\ ^\circ\text{C}}\right)\cdot 6010\ \text{g}}\right) = 15.3\ ^\circ\text{C}$$

RPS4. 124.7 g of NO are added to an amount of O_2. After the reaction occurs 1.21 moles of N_2O_3 are produced according to the equation,

$$4NO(g) + O_2(g) \text{ ---> } 2N_2O_3(l)$$

Is it possible to determine

a) the moles of N_2O_3 produced?

1.21 mole N_2O_3

b) the moles of O_2 reacting?

1.21 mole N_2O_3 $\left(\frac{1 \text{ mol } O_2}{2 \text{ mol } N_2O_3}\right)$ = 0.61 mol O_2

c) the moles of NO reacting?

1.21 mole N_2O_3 $\left(\frac{4 \text{ mol NO}}{2 \text{ mol } N_2O_3}\right)$ = 2.42 mol NO

d) the moles of NO remaining?

124.7 g NO $\left(\frac{1 \text{ mol NO}}{30 \text{ g NO}}\right)$ = 4.16 mol NO – 2.42 mol NO = 1.74 mol NO

e) the moles of O_2 remaining?

Unable to determine. We know how much reacted, but we do not know how much we started with.

RPS5. Use effective nuclear charge and shielding to explain why:

a) the atomic radius of S is smaller than the atomic radius of Mg;

Sulfur and magnesium have the same number of inner core electrons (10) partially shielding the the nuclear charge from the valence electrons. Since sulfur has 16 protons and magnesium has only 12, the valence electrons in sulfur 'feel' a greater effective nuclear charge (+6 for sulfur and +2 for magnesium) and are more attracted to the nucleus. So the atomic radius of sulfur is less than the atomic radius of magnesium.

b) it takes considerably more energy to remove the 3rd electron in Mg compared to the energy required to remove the 3rd electron in Al;

The electron configuration for Mg is $1s^22s^22p^63s^2$ and for Al $1s^22s^22p^63s^23p^1$. Removing 3 electron from Al takes a certain amount of energy. All three electrons in Al are located in the outer most level For magnesium the first two electrons are in the outer most level, but the third electron must be removed from the 2^{nd} level (an inner core). The effective nuclear charge experienced by the inner core electrons in the 2^{nd} level is +10, significantly greater

than the effective nuclear charge experienced by the valence electrons (+2). So it takes much more energy to remove the 3rd electron in Mg compared to Al.

c) the ionic radius of O^{2-} is greater than the ionic radius of F^-.

Both F^- and O^{2-} have the same electron configuration, $1s^22s^22p^6$. So both atoms have the same number of valence electrons and the same number of inner core electrons shielding the valence electrons from the nuclear charge. Since oxygen has fewer protons than fluorine the valence electrons on oxygen feel less attraction to the nucleus. Therefore, the ionic radius of O^{2-} is greater than the ionic radius of F^-.

RPS6. A sample of dolomite limestone containing only $CaCO_3$ and $MgCO_3$ was analyzed.

a) When a 0.2564 gram sample of this limestone was decomposed by heating, 0.0725 L of CO_2 at 751 mmHg and 34 degrees Celsius were evolved. How many grams of CO_2 were produced?

$$n = \left(\frac{PV}{RT}\right) = \left(\frac{(751\ \text{mmHg})\left(\frac{1\ \text{atm}}{760\ \text{mmHg}}\right)(0.0725\ \text{L})}{\left(0.0821\ \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)(307\ \text{K})}\right) = 2.84 \times 10^{-3}\ \text{mol}\left(\frac{44.0\ \text{g}\ CO_2}{1\ \text{mol}}\right) = 0.125\ \text{g}$$

b) write chemical equations for the decomposition of both carbonates described above.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$
$$MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$$

c) It was also determined that the initial sample contained 0.04272 grams of calcium. What percent of the limestone by mass is $CaCO_3$?

$$0.04272\ \text{grams Ca}\left(\frac{100\ \text{grams}\ CaCO_3}{40.0\ \text{g Ca}}\right) = 0.1068\ \text{grams}\ CaCO_3$$

$$\left(\frac{0.1068\ \text{gram}\ CaCO_3}{0.2564\ \text{gram of limestone}}\right) \times 100 = 41.7\%$$

d) How many grams of magnesium containing product were present in the sample in part a) after it had been heated?

0.2564 gram – 0.1068 gram $CaCO_3$ = 0.1496 grams $MgCO_3$

$$0.1496\ \text{grams}\ MgCO_3\left(\frac{1\ \text{mol}\ MgCO_3}{84.0\ \text{gram}\ MgCO_3}\right)\left(\frac{1\ \text{mol MgO}}{1\ \text{mol}\ MgCO_3}\right)\left(\frac{40.3\ \text{grams}}{1\ \text{mol MgO}}\right) = 0.0718\ \text{gram}$$

RPS7. Complete the following table

Compound	Lewis Structure	# of bonding groups (CA)	# of lone-pairs (CA)	Molecular geometry	Bond angle(s)	Polarity
ClO_3^-		**3**	**1**	**Trigonal pyraqmidal**	**<109.5°**	
XeF_5^+		**5**	**1**	**Square pyramidal**	**90°, 180°**	
BF_3		**3**	**0**	**Trogonal planar**	**120°**	**Nonpolar**
IF_3		**3**	**2**	**'T'-shaped**	**90°, 180°**	**Polar**
$SbCl_5$		**5**	**0**	**Trigonal bipyramidal**	**90°, 120°, 180°**	**nonpolar**

RPS8a. Write the complete electron configuration for each of the following:

i) P **$1s^22s^22p^63s^23p^3$**

ii) Na **$1s^22s^22p^63s^1$**

iii) I **$1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p^5$**

iv) Zn **$1s^22s^22p^63s^23p^64s^23d^{10}$**

v) O **$1s^22s^22p^4$**

vi) Al^{3+} **$1s^22s^22p^6$**

b) Which elements listed in RPS8a. are metals and which are nonmetals?

☐ **P, I and O are nonmetals and Na, Zn and Al are metals**

c) As it relates to electron gain or loss, explain the difference between metals and nonmetals. use electron configuration of a neutral atom and its ion to support your explanation.

- **Metals tend to lose electrons and nonmetals gain electrons. Metals lose electrons so their electron configuration is most like the nearest noble gas. Nonmetals gain electrons to have an electron configuration like the nearest noble gas.**

d) By combining a metal and a nonmetal, or a nonmetal and a nonmetal, from the neutral elements listed in RPS8a, write the formula and name of at least eight compounds. The compounds should include 5 ionic and 3 covalent examples.

Na_3P sodium phosphide **P_2O_5 diphosphorus pentoxide**
ZnI_2 zinc(II) iodide
AlI_3 aluminum iodide
ZnO zinc(II) oxide
Al_2O_3 aluminum oxide

RPS9.Solve

a) $\log(7.45 \times 10^{7})$ = **7.87**

b) $\log(7.45 \times 10^{-7})$ = **–6.13**

c) $-\log(7.45 \times 10^{-5})$ = **4.13**

d) antilog(-5.481) = **3.30×10^{-6}**

e) antilog(5.96) = **9.12×10^{5}**

f) ln (206) = **5.33**

g) ln (0.596) = **–0.518**

h) $e^{-2.72}$ = **6.59×10^{-2}**

i) $e^{4.21}$ = **67.4**

j) $\ln\left(\frac{378}{293}\right)$ = **0.255**

k) $\ln\left(\frac{864}{x}\right) = 0.251$ Solve for x

$$e^{\ln\left(\frac{864}{x}\right)} = e^{0.251}$$

□ $\left(\frac{864}{x}\right) = 1.29$

x = 672

l) $\left(\frac{1}{0.204}\right) - \left(\frac{1}{x}\right) = 5.61$ Solve x

$\left(\frac{1}{x}\right)$ **= 4.90 – 5.61 = –0.708**

□ **x = –1.41**

m) $x^2 + 7x - 19 = 0$

RPS10. Consider five unlabeled bottles, each containing 5.0 g of one of the following pure salts.

$AgCl$, $BaCl_2$, $CoCl_2$, $NaCl$, NH_4Cl

(a) Identify the salt that can be distinguished by its appearance alone. Describe the observation that supports your identification.

$CoCl_2$ is blue or red depending on whether water is present.□

(b) Identify the salt that can be distinguished by adding 10 mL of H2O to a small sample of each of the remaining unidentified salts. Describe the observation that supports your identification.

□ **Of the remaining compounds AgCl is insoluble in water,**

(c) Identify a chemical reagent that could be added to the salt identified in part (b) to confirm the salt's identity. Describe the observation that supports your identification.

□ **Adding aqueous ammonia (NH_3) to the AgCl will dissolve the AgCl. The reaction is,**

$$AgCl(s) + 2NH_3(aq) \rightarrow Ag(NH_3)_2^+(aq) + Cl^-(aq)$$

(d) Identify the salt that can be distinguished by adding 1.0 M Na_2SO_4 to a small sample of each of the remaining unidentified salts. Describe the observation that supports your identification.

□ **When $BaCl_2$ is added to 1.0 M Na_2SO_4 a white precipitate of $BaSO_4$ is formed.**

$$BaCl_2(aq) + Na_2SO_4(aq)\ BaSO_4(s) + 2NaCl(aq)$$

(e) Identify the salt that can be distinguished by adding 1.0 M NaOH to a small sample of each of the remaining unidentified salts. Describe the observation that supports your identification.

NH_4Cl reacts with NaOH to release NH_3 which has a distinct odor.