ELLIS Chemistry 1061-003 **26 JAN 2015**

CHEMICAL CALCULATIONS INVOLVING LIMITING REACTANTS AND THE IDEAL GAS LAW; ALSO, TWO COMPLICATED SLIDES TO BE SHOWN IN LECTURE

{ WORK THROUGH THESE QUESTIONS BEFORE NEXT WEEK, WHEN I WILL DISCUSS SOME OF THEM, OR RELATED ONES, IN LECTURE! }

1. WRITE A BALANCED EQUATION FOR THE COMPLETE COMBUSTION OF METHANE (CH_4) IN AIR.

{ BE CAREFUL! IF YOUR EQUATION IS NOT BALANCED CORRECTLY YOUR CALCULATIONS WILL LIKELY BE WRONG! }

2. USE THIS EQUATION (QUESTION) TO CALCULATE THE MASS OF $CO_2(g)$, IN GRAMS, THAT WILL FORM WHEN 16.0g OF $CH_4(g)$ REACTS WITH 16.0g OF $O_2(g)$

{ CAREFUL! IS THERE A REACTANT PRESENT IN EXCESS OF THE REQUIRED AMOUNT BASED ON THE BALANCED EQUATION? IF SO, THE OTHER REACTANT (OR ANOTHER ONE, IF MORE THAN TWO REACTANTS ARE INVOLVED) IS THE "LIMITING REACTANT" OR "LIMITING REAGENT". OF CRITICAL IMPORTANCE IS THE FACT THAT THE AMOUNT OF THE LIMITING REACTANT MUST BE USED IN CALCULATING THE AMOUNT(S) OF PRODUCT(S) THAT CAN FORM IN THE REACTION. }

STEPS IN SOLUTION OF QUESTION 2

a. DETERMINE WHETHER A LIMITING REACTANT IS PRESENT. FOR EXAMPLE, CALCULATE HOW MUCH CH_4 WILL BE CONSUMED BY 16.0g O_2.

b. USE THE MASS OF THE LIMITING REACTANT TO DETERMINE THE MAXIMUM (i.e., THEORETICAL) MASS OF CO_2 THAT WILL FORM IN THE REACTION.

(CONTINUED ON NEXT SIDE)

RELATED QUESTIONS DESIGNED TO SHOW WHAT HAPPENS WHEN YOU CHOOSE THE REACTANT PRESENT IN EXCESS TO DO YOUR CALCULATIONS!

3. CALCULATE THE MASS OF CO_2 (IN GRAMS) THAT WOULD FORM, ASSUMING ALL OF THE 16.0 g OF METHANE (CH_4) WAS CONSUMED IN QUESTION 2

4. WHAT MASS OF OXYGEN GAS (O_2) WOULD BE REQUIRED TO COMPLETELY BURN THE METHANE IN QUESTION 3 ?

(RECALL THAT 16.0 g OF O_2 WAS ORIGINALLY PRESENT)

SOLUTIONS – ANSWERS (DON'T PEEK!)

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1. $CH_4(g) + 2\,O_2(g) \longrightarrow CO_2(g) + 2\,H_2O(l)$

2 a. $(16.0\,g\,O_2)\left(\frac{mol\,O_2}{32.0\,g\,O_2}\right)\left(\frac{mol\,CH_4}{2\,mol\,O_2}\right)\left(\frac{16.0\,g\,CH_4}{mol\,CH_4}\right) = 4.00\,g\,CH_4$

SINCE ONLY 4.00 g OF CH_4 IS CONSUMED, THIS REACTANT IS PRESENT IN EXCESS. THEREFORE O_2 IS THE LIMITING REACTANT IN THIS PROBLEM.

b. $(16.0\,g\,O_2)\left(\frac{mol\,O_2}{32.0\,g\,O_2}\right)\left(\frac{mol\,CO_2}{2\,mol\,O_2}\right)\left(\frac{44.0\,g\,CO_2}{mol\,CO_2}\right) = 11.0\,g\,CO_2$

• 3. $(16.0\,g\,CH_4)\left(\frac{mol\,CH_4}{16.0\,g\,CH_4}\right)\left(\frac{mol\,CO_2}{mol\,CH_4}\right)\left(\frac{44.0\,g\,CO_2}{mol\,CO_2}\right) = 44.0\,g\,CO_2$*

(* BUT TOTAL MASS OF REACTANTS = 32.0 g !)

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4. $(16.0\,g\,CH_4)\left(\frac{mol\,CH_4}{16.0\,g\,CH_4}\right)\left(\frac{2\,mol\,O_2}{mol\,CH_4}\right)\left(\frac{32.0\,g\,O_2}{mol\,O_2}\right) = 64.0\,g\,O_2$**

(** BUT ONLY 16.0 g OF O_2 WAS ORIGINALLY PRESENT!)

• THE ANSWER TO QUESTION 3 EMPHASIZES HOW IMPORTANT IT IS TO USE THE LIMITING REACTANT IN CALCULATIONS, WHEN ONE IS PRESENT!

PROBLEMS SHOWING USE OF THE IDEAL GAS LAW

$P_{gas}V_{gas} = n_{gas}RT_{gas}$ or $PV = nRT$

P = Pressure of gas in atmospheres (atm)

V = Volume of gas in liters (l)

n = amount of gas in moles (mol)

R = ideal gas constant = $0.0821 \frac{(l\text{-atm})}{mol\ K}$

T = temperature of gas in Kelvin units ; $°C + 273 = K$

$$PV = nRT$$

A useful variant of the ideal gas law is derived from the fact that $n = \frac{\text{mass of gas (in grams)}}{\text{molecular mass of gas in grams/mol}} = \frac{m}{\mathcal{M}}$

Since the density of a gas is $\frac{m}{V}$, we can determine the molecular mass of an unknown substance from the expression: $PV = \frac{m}{\mathcal{M}}(RT)$ or $\mathcal{M} = \left(\frac{m}{V}\right)\frac{RT}{P} = (\text{density})\frac{RT}{P}$

density of the gas is expressed in grams/liter.

1. Determine the mass of sodium azide, NaN_3, necessary to produce 22.2 L of nitrogen gas, N_2, at 20°C and 760 torr, by the following reaction: $Na^+N_3^-(s) \xrightarrow{spark} Na(s) + 3/2\, N_2(g)$

2. At 25°C, 8.80g of a certain nitrogen oxide, N_xO_y, occupies a volume of 5000 mL at 743 torr. Identify the nitrogen oxide!
   Hint: First determine the molecular mass of the gas by an appropriate modification of the ideal gas law equation.

3. Addition of 50.0 mL of 2.00 M hydrochloric acid to 3.00g of aluminum metal results in the evolution of hydrogen gas.
   a. Write a balanced equation for this reaction.
   b. Identify the limiting reactant, if any.
   c. Calculate the volume of dry hydrogen gas that will be produced at 760 torr and 25°C in this reaction.
   d. How much aluminum metal will be consumed, assuming the reaction is quantitative? (Give answer in grams)

4. The density of an unknown hydrocarbon (of general formula C_nH_{2n+2}) at 30°C and 750 torr is $1.745 gL^{-1}$. Determine the molecular formula of the hydrocarbon.

5. Treatment of 0.279 g of barium hydride, fm = 139.35, with 30.00 mL of 0.100 M sulfuric acid at 20°C and 750 torr gave a white precipitate and a colorless gas. (HINT: ionic hydrides react with acids to produce hydrogen gas and salts) (a) Write a balanced equation for this reaction (b) Determine the volume of dry gas that will be produced. (c) Determine the mass of solid formed in this reaction.

Answers (BE CAREFUL WITH SIGNIFICANT FIGURES!)

1. 49.8 g NaN_3 2. $M = 44.0\ g\,mol^{-1}$ N_2O

3 a) NET IONIC REXN: $Al(s) + 3H^+(aq) \longrightarrow Al^{3+}(aq) + \frac{3}{2}H_2(g)$
or "molecular eqn" $Al(s) + 3HCl(aq) \longrightarrow AlCl_3(aq) + \frac{3}{2}H_2(g)$

b) HCl, since Al (s) is present in excess

c) 1.22 L H_2

d) 0.90 g Al (i.e. 2.10 g of Al remains unreacted)

4. C_3H_8

5. a) $BaH_2(s) + 2H^+(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s) + 2H_2(g)$

* b) 0.0975 L or 97.5 mL of $H_2(g)$

c) 0.467 g $BaSO_4(s)$

* H_2SO_4 is present in excess, so BaH_2 is the limiting reagent or limiting reactant, since the amount of BaH_2 present determines the quantity of products that will form.

USE OF A LIGHT BULB APPARATUS TO QUALITATIVELY TEST FOR ELECTRICAL CONDUCTIVITY OF SOLIDS, LIQUIDS AND AQUEOUS SOLUTIONS

(ESSENTIALLY IDENTICAL TO THAT SHOWN IN FIG. 4.3 OF TEXT, ; ALSO YOU WILL *NOT* BE EXAMINED ON THE DETAILS OF HOW CURRENT (OR ELECTRICITY) FLOWS THROUGH AN ELECTRICALLY CONDUCTING SOLUTION; THAT IS, A WEAK OR STRONG ELECTROLYTE.)

INTENSITY OF LIGHT EMISSION IS ROUGHLY PROPORTIONAL TO THE TOTAL CONC. OF IONS PRESENT IN THE LIQUID, OR ITS ELECTRICAL CONDUCTIVITY

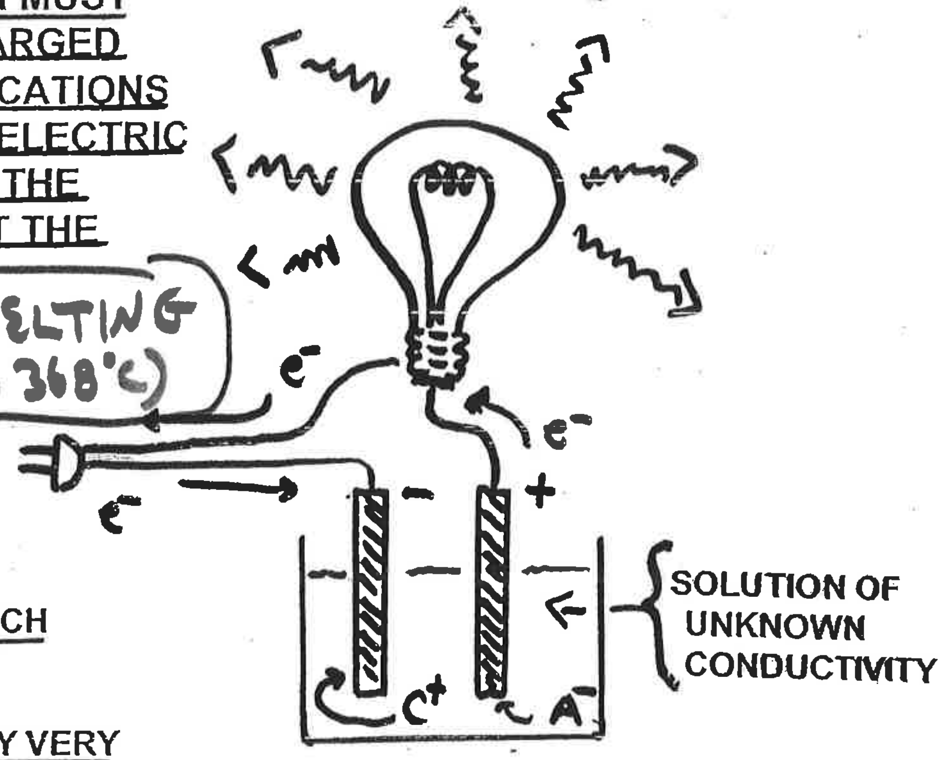
A SOLID, LIQUID OR SOLUTION MUST CONTAIN HIGHLY MOBILE CHARGED PARTICLES, i.e., ELECTRONS, CATIONS OR ANIONS, TO CONDUCT AN ELECTRIC CURRENT AND TO COMPLETE THE CIRCUIT AND THEREBY PERMIT THE FLOW OF ELECTRONS

CIRCUIT

DEMO – MELTING $KClO_3$ (mp 368°C)

PLUG IT IN THIS TIME!

ELECTRICITY SOURCE (120 V AC)



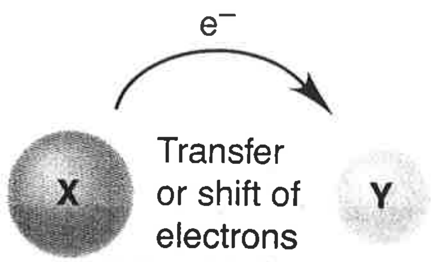
FOR LIQUIDS OR SOLUTIONS WHICH ARE NON, WEAK, OR STRONG ELECTROLYTES, "E's"

1. NON E's: NON-IONIZED OR ONLY VERY WEAKLY IONIZED (E.G., PURE WATER)
2. WEAK E's: WEAKLY IONIZED; LOW CONCENTRATIONS OF IONS
3. STRONG E's: HIGHLY IONIZED; HIGH CONCENTRATIONS OF IONS; CAN BE MOLTEN OR LIQUID SALTS

ELECTRODE PROCESSES
(will NOT be on 1061 exams)*
CATHODE: C(1+) + e(1-)--->C
ANODE: A(1-)---> A + e(1-)
(*SHOWN ONLY FOR CATIONS OR ANIONS WITH CHARGES OF +1 AND -1, BUT CHARGES ON CARRIERS CAN RANGE FROM +3 TO -3)

IN CHEM 1065 LAB YOU WILL USE AN ELECTRICAL CONDUCTIVITY METER TO QUANTITATIVELY MEASURE THE CONDUCTANCE OF A SOLUTION

SUMMARY OF IMPORTANT TERMS IN REDOX REACTIONS- YOU NEED TO KNOW THIS STUFF!!



REACTANTS -------> $X^+ Y^-$ **PRODUCTS**

X loses electron(s)	Y gains electron(s)
X is oxidized	Y is reduced
X is the reducing agent	Y is the oxidizing agent
X increases its oxidation number	Y decreases its oxidation number

Figure 4.17 **A summary of terminology for oxidation-reduction (redox) reactions.**

X^+

OXIDATION PRODUCT (THE REDUCING AGENT HAS BEEN OXIDIZED)

Y^-

REDUCTION PRODUCT (THE OXIDIZING AGENT HAS BEEN REDUCED)

SUMMARY:

- **THE REDUCING AGENT OR REDUCTANT ALWAYS LOSES ELECRONS AND IS THEREBY OXIDIZED (OR FORMS THE OXIDATION PRODUCT)**
- **THE OXIDIZING AGENT OR OXIDANT ALWAYS GAINS ELECTRONS AND IS THEREBY REDUCED (OR FORMS THE REDUCTION PRODUCT)**

NAMES OF REACTANTS AND PRODUCTS IN REDOX REXNS CAN BE CONFUSING, SO YOU NEED TO PRACTICE TO BECOME FAMILIAR WITH THEM!! POSSIBLY USEFUL MNEMONIC FOR NAMING PRODUCTS IN REDOX REXNS:

LEO the lion says GER

Loss of Electrons = Oxidation
(by reactant) (product)

Gain of Electrons = Reduction
(by reactant) (product)