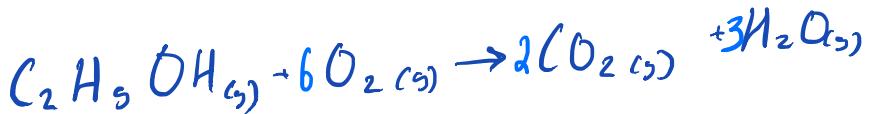


CHEMICAL EQUATIONS



* mass balance



* start with most complex

g (gas)
l (liquid)
s (solid)
aq (aqueous)

STOICHIOMETRY



What mass of oxygen will react with 91.6 g of propane?

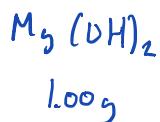
$$91.6 \text{ g } \cancel{\text{C}_3\text{H}_8} \times \frac{1 \text{ mol } \text{C}_3\text{H}_8}{44.1 \text{ g } \cancel{\text{C}_3\text{H}_8}} \times \frac{5 \text{ mol } \text{O}_2}{1 \text{ mol } \text{C}_3\text{H}_8} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 349 \text{ g O}_2$$

What mass of CO₂ is produced in this reaction?

$$96.1 \text{ g } \text{C}_3\text{H}_8 \times \frac{1 \text{ mol } \text{C}_3\text{H}_8}{44.1 \text{ g } \cancel{\text{C}_3\text{H}_8}} \times \frac{3 \text{ mol CO}_2}{1 \text{ mol } \text{C}_3\text{H}_8} \times \frac{44.0 \text{ g CO}_2}{1 \text{ mol CO}_2} = 288 \text{ g CO}_2$$

ex

MAALOX VS BAKING SODA



which can neutralize a greater amount
of HCl?

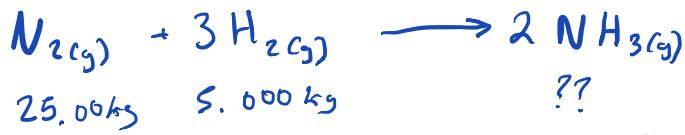


$$1.00\text{ g Mg(OH)}_2 \times \frac{1 \text{ mol Mg(OH)}_2}{58.32 \text{ g Mg(OH)}_2} \times \frac{2 \text{ mol HCl}}{1 \text{ mol Mg(OH)}_2} \\ \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} = 1.25 \text{ g HCl}$$

$$1.00\text{ g NaHCO}_3 \times \frac{1 \text{ mol NaHCO}_3}{84.01 \text{ g NaHCO}_3} \times \frac{1 \text{ mol HCl}}{1 \text{ mol NaHCO}_3} \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} \\ = 0.433 \text{ g HCl}$$

Maalox is more efficient

LIMITING REACTANT



$$25.00 \text{ kg } N_2 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } N_2}{28.0 \text{ g } N_2} = \frac{2 \text{ mol } NH_3}{1 \text{ mol } N_2} \times \frac{17.0 \text{ g } NH_3}{1 \text{ mol } NH_3}$$

\downarrow

$$8.93 \times 10^2 \text{ mol } N_2 = 30.357 \text{ g } NH_3$$

$$= 3.036 \times 10^{-4} \text{ g } NH_3$$

$$5.000 \text{ kg } H_2 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } H_2}{2.016 \text{ g } H_2} \times \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2} \times \frac{17.0 \text{ g } NH_3}{1 \text{ mol } NH_3}$$

\downarrow

$$2.48 \times 10^3 \text{ mol } H_2 = 2.81 \times 10^4 \text{ g } NH_3$$

LIMITING REACTANT

BALANCED EQ.	RATIO	AMOUNTS AVAILABLE
$\frac{H_2}{N_2} = \frac{3}{1} = 3$	$\frac{\uparrow H_2}{\uparrow N_2}$	$= \frac{2.48 \times 10^3 \text{ mol}}{8.93 \times 10^2 \text{ mol}} = 2.78 \uparrow$

THEORETICAL YIELD & ACTUAL YIELD

What could go wrong?

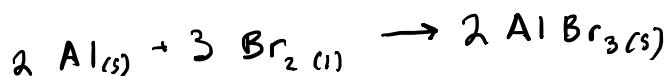
- impurities in system
- gradients in temperature (not homogeneous)
- new reactors with walls of container

Theoretical yield: maximum obtainable (calculated with limiting reactant)

Actual yield: amount produced under the real conditions

% yield: (actual yield/theoretical yield) × 100

- A good % yield varies from experiment to experiment.

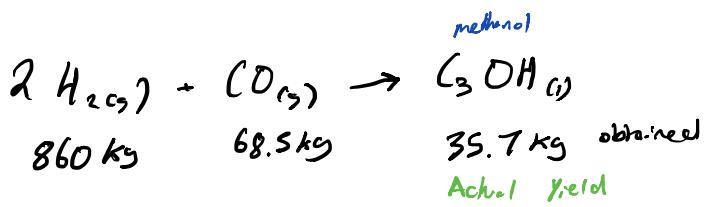


when 6.0 g of Al was reacted with an excess of bromine,
 so. 3 g of AlBr₃ was isolated. Calculate the theoretical and %
 yield of this rxn.

$$\begin{aligned} 6.0 \text{ g Al} &\times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{2 \text{ mol AlBr}_3}{2 \text{ mol Al}} \times \frac{266.68 \text{ g AlBr}_3}{1 \text{ mol AlBr}_3} \\ &= 59.3 \text{ g AlBr}_3 \end{aligned}$$

Theoretical yield

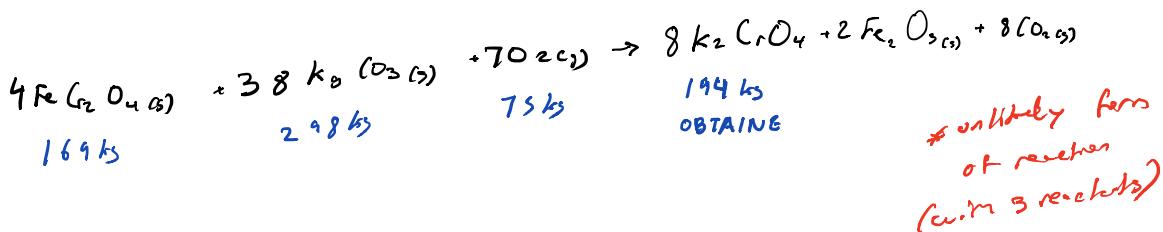
$$\% \text{ yield} = \frac{50.3 \text{ g}}{59.3 \text{ g}} = 84.8\%$$



$$\text{CO: } 68.5 \text{ kg CO} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol CO}}{28.01 \text{ g CO}} \times \frac{1 \text{ mol CH}_3\text{OH}}{1 \text{ mol CO}} \\ \times \frac{32.04 \text{ g CH}_3\text{OH}}{1 \text{ mol CH}_3\text{OH}} = 78.5 \text{ kg CH}_3\text{OH}$$

$$\text{H}_2: 8.6 \text{ kg H}_2 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol H}_2}{2.016 \text{ g H}_2} \times \frac{1 \text{ mol C}_2\text{OH}}{2 \text{ mol H}_2} \times \frac{32.04 \text{ g C}_2\text{OH}}{1 \text{ mol C}_2\text{OH}} \\ \text{Limiting Reactant} = \frac{68.4 \text{ kg}}{\text{Theoretical Yield}}$$

$$\% \text{ Yield} = \frac{35.7 \text{ g}}{68.4 \text{ g}} \times 100 = 52 \%$$



$$169 \text{ kg FeCr}_2\text{O}_4 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol FeCr}_2\text{O}_4}{223.8 \text{ g}} \times \frac{8 \text{ mol K}_2\text{CrO}_4}{4 \text{ mol FeCr}_2\text{O}_4} \\ = \frac{1.51 \times 10^3 \text{ mol K}_2\text{CrO}_4}{\text{Limiting Value}}$$

$$298 \text{ kg K}_2\text{CO}_3 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol K}_2\text{CO}_3}{138.215 \text{ g K}_2\text{CO}_3} \times \frac{8 \text{ mol K}_2\text{CrO}_4}{8 \text{ mol K}_2\text{CO}_3} \\ = 2.16 \times 10^3 \text{ mol K}_2\text{CrO}_4$$

$$75 \text{ kg O}_2 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol O}_2}{32.00 \text{ g}} \times \frac{8 \text{ mol K}_2\text{CrO}_4}{7 \text{ mol O}_2} = 2.67 \times 10^3 \text{ mol K}_2\text{CrO}_4$$

$$\text{Theoretical yield: } 1.51 \times 10^3 \text{ mol } \text{K}_2\text{CO}_4 \times \frac{194.19 \text{ g}}{1 \text{ mol}} = 2.93 \times 10^5 \text{ g}$$

or
293 kg

$$\% \text{ Yield} = \frac{194 \text{ kg}}{293 \text{ kg}} \times 100 = 66.2\%$$

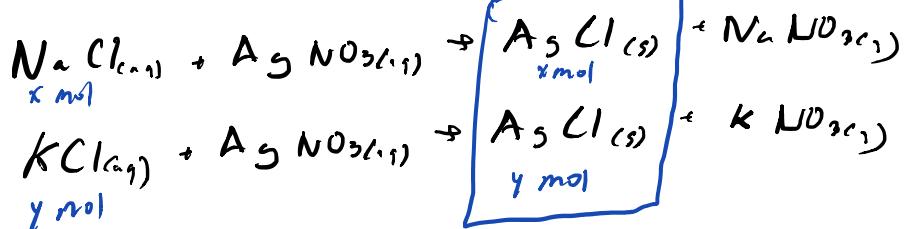
MIXTURE PROBLEM

* will not be on tests or quizzes (might be on assignments, but not on quiz)

A sample of a mixture containing only NaCl and KCl has a mass of 4.000 g. When it is dissolved in water and excess AgNO₃ is added, a white precipitate (AgCl) forms. The mass of dried precipitate is 8.5904 g. Calculate the mass % of each mixture component.

$$\begin{aligned} \text{moles of NaCl} &= x \\ \text{moles of KCl} &= y \end{aligned}$$

$$1) \underbrace{x \text{ mol NaCl} \times M_{\text{NaCl}}}_{g_{\text{NaCl}}} + \underbrace{y \text{ mol KCl} \times M_{\text{KCl}}}_{g_{\text{KCl}}} = 4.000$$



$$2) (x+y) \text{ mol AgCl} \times M_{\text{AgCl}} = 8.5904$$

Sub in Molar Masses

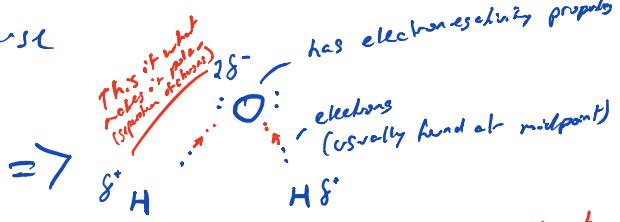
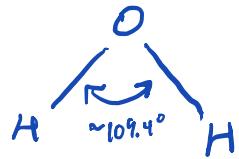
$$1) 58.43x + 74.55y = 4.00; x = \frac{4.00 - 74.55y}{58.43}$$

$$2) (x+y) \times 143.3 = 8.5904; \left(\frac{4.00 - 74.55y}{58.43} + y \right) \times 143.3 = 8.5904$$

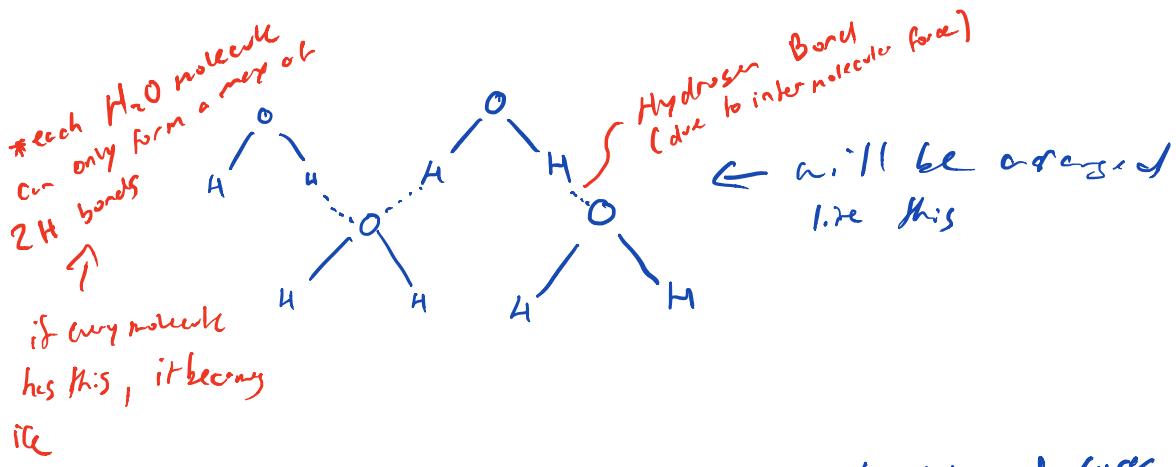
...
 $\% \text{ NaCl} = 42.47\% \quad \% \text{ KCl} = 57.53\%$

WATER AS A SOLVENT

polar separation of π and $-$ charge



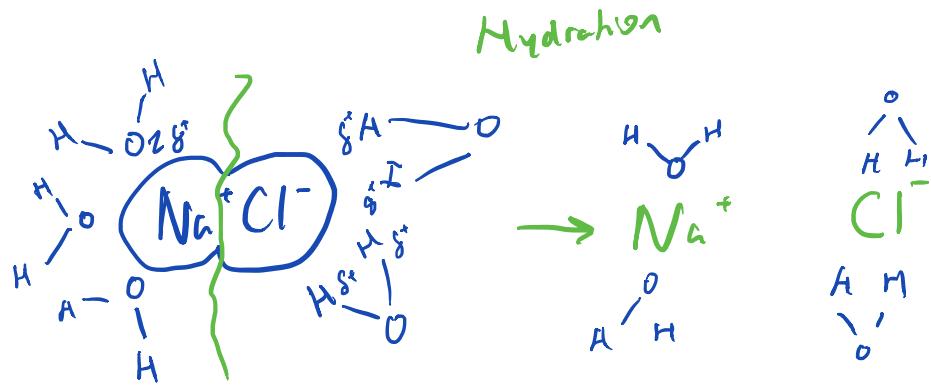
Instead of being found at midpoint
oxygen will pull the electrons to itself
(pull its electrons and hydrogens)
 \therefore It will acquire a very small negative charge



. With increase in temp to go to liquid \rightarrow breaking of 10% of H bonds

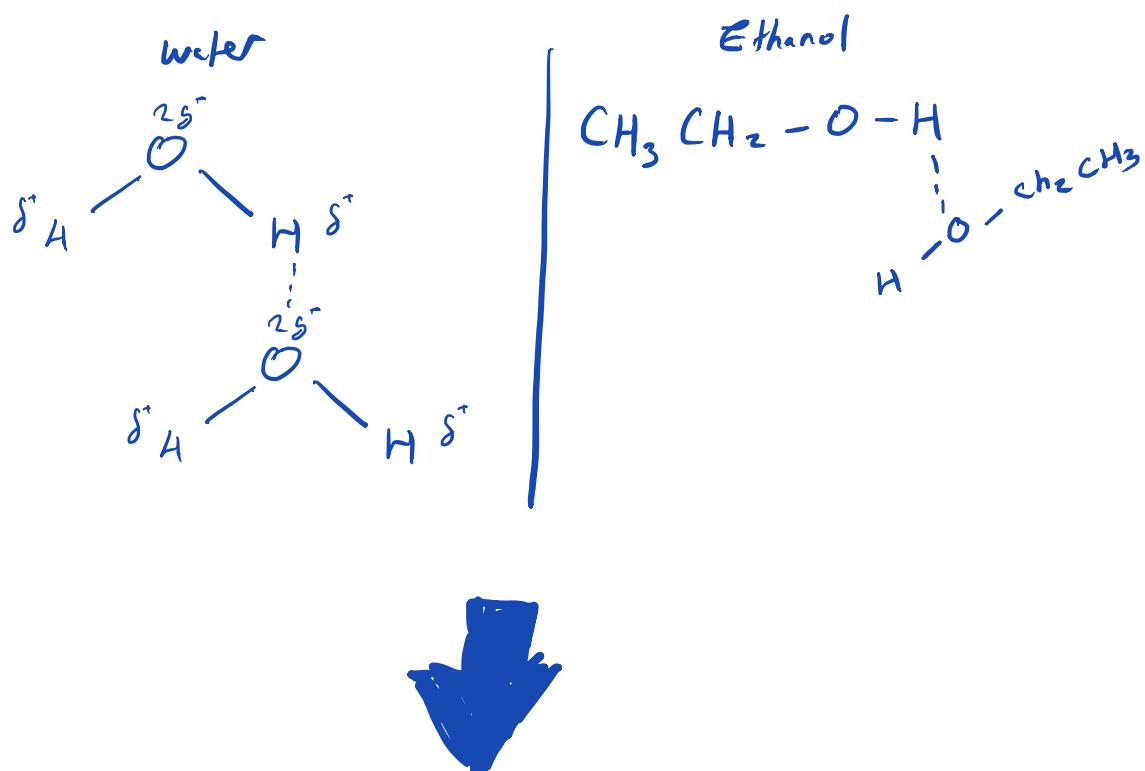
- All bonds broken at $100^\circ C$ (gaseous state) - no interaction between molecules
- Hydrogen bond strongest of intermolecular forces
- Not a real covalent bond, just attraction between 2 polar molecules

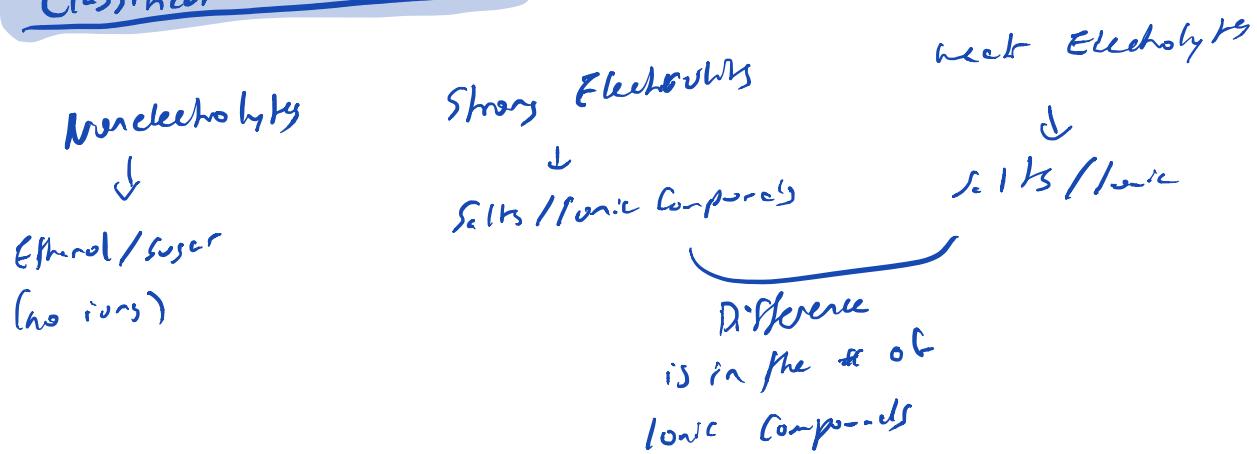
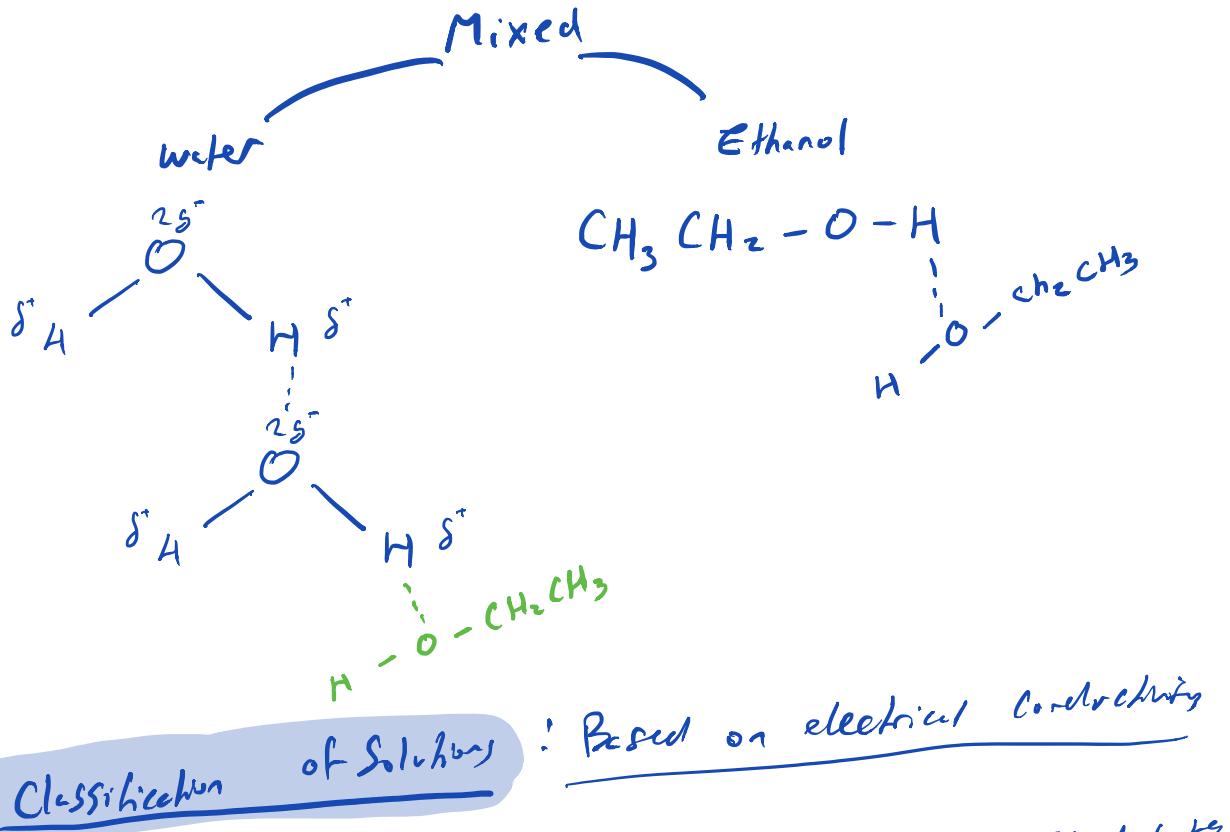
Dissolution of Ionic Compounds / Salts



Dissolution of Covalent Compounds

• a matter of compatibility





STRONG ELECTROLYTES

- Soluble Salts (Ionic Compounds) KCl , $NaCl$, ...
Assumed its a complete dissociation for all soluble salts
- Strong Acids : H_2SO_4 , HNO_3 , HCl , HBr , HI , $HClO_4$ (complete dissociation)
- Strong Bases: Soluble hydroxides : KOH , $NaOH$ (complete dissociation)

WEAK ELECTROLYTES

- weak acids : HF , CH_3COOH (partial dissociation)
- weak bases : NH_3 , ... (partial dissociation)

NON-ELECTROLYTES

- covalent compounds dissolved in water



Since they are covalent they won't conduct electricity

SOLUTION COMPOSITION

MOLARITY (M) : $\frac{\text{moles of solid}}{\text{litres of solution}} \left(\frac{\text{mol}}{\text{L}} \right)$

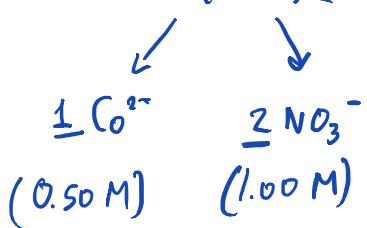
ex) Calculate the molarity of the sol'n prepared by dissolving 11.5g of NaOH in enough water to make 1.5 L of sol'n.

$$11.5\text{g NaOH} \times \frac{1 \text{ mol NaOH}}{40.0 \text{ g NaOH}} = 0.288 \text{ mol NaOH}$$

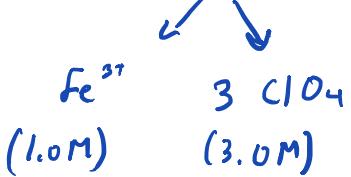
$$M = \frac{0.288 \text{ mol}}{1.5 \text{ L}} = 0.192 \text{ M}$$

ex) Give the concentrations of all of the ions in each of the following sol'n's :

a) 0.50 M $\text{Co}(\text{NO}_3)_2$



b) 1.0 M $\text{Fe}(\text{ClO}_4)_3$



ex) How many moles of Ag^+ ions are present in 25.0 mL of a 0.75M AsNO_3 ?

$$M = \frac{\text{mol}}{\text{L}}$$

$$\text{mol} = M \times L$$

$$\frac{0.75 \text{ mol AsNO}_3}{1.0 \cancel{\text{L}}} \times 25.0 \cancel{\text{mL}} \times \frac{1.0 \cancel{\text{L}}}{1000 \cancel{\text{mL}}} = 1.9 \times 10^{-2} \text{ mol Ag}^+$$

STANDARD SOL'N

= sol'n whose concentration is accurately known (3rd S_NS Russ)

e.g. 1.00 L of 0.200 M $K_2Cr_2O_7$

g $K_2Cr_2O_7$?

$$K_2Cr_2O_7 \text{ moles: } \frac{0.200 \text{ mol}}{1 \text{ L}} \times 1.00 \text{ L} = 0.200 \text{ mol } K_2Cr_2O_7$$

$$0.200 \text{ mol } K_2Cr_2O_7 \times \frac{294 \text{ g } K_2Cr_2O_7}{1 \text{ mol } K_2Cr_2O_7} = 58.8 \text{ g } K_2Cr_2O_7$$

STOCK SOL'N

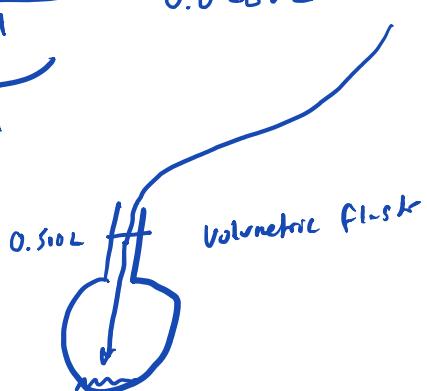
= standard sol'n of a very high concentration. (requires dilution)

DILUTION

Preparation of 0.500 L of 1.00M Acetic Acid from 17.5M stock sol'n.

$$\underbrace{0.500 \text{ L} \times \frac{1.00 \text{ mol}}{1 \text{ L}}} \times \frac{1.0 \text{ mol}}{17.5 \text{ mol}} = 0.0286 \text{ L} = 28.6 \text{ mL}$$

mol of acetic acid needed stock sol'n



ex/ what volume of 16.0 M H_2SO_4 must be used to prepare 1.50 L of 0.100 M H_2SO_4 ?

Can also use $C_1V_1 = C_2V_2$

$$C_1V_1 = C_2V_2$$

Final sol'n Stock sol'n

$$0.100 \text{ M} \times 1.50 \text{ L} = 16.0 \text{ M} \times V_2$$

$$V_2 = 9.4 \times 10^{-3} \text{ L or } 9.4 \text{ mL}$$

% BY MASS

$$= \frac{\text{Grams of Solute}}{\text{Grams of sol'n}} \times 100$$

ex/ 125 g of a sol'n when evaporated to dryness was found to contain 42.3 g of solute. What was the % by mass of the solute?

$$\% \text{ Mass} = \frac{42.3 \text{ g}}{125 \text{ g}} \times 100 = 33.8 \%$$

another method called molality

precipitation, acid - base, redox reac

September 7, 2016

Qsil will be next week

1st quiz on naming

5 formulas - find many

5 nerves - find formulas

Ex. An excess of Al-foil is allowed to react with 225 ml of an aqueous sol'n of HCl that has a density of 1.088g/mL and contains 18% HCl by mass. What mass of H₂ is produced?

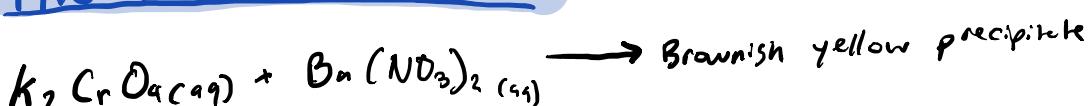


$$225 \text{ mL HCl sol'n} \times \frac{1.088 \text{ g soln}}{1 \text{ mL}} \times \frac{18.00 \text{ g HCl}}{100 \text{ g soln}} \times \frac{1 \text{ mol HCl}}{36.45 \text{ g HCl}}$$

$$x \frac{3/2 \text{ mol H}_2}{3 \text{ mol HCl}} \times \frac{2.016 \text{ g H}}{1 \text{ mol H}_2} = 1.22 \text{ g H}_2$$

Precipitation Reaction

= formation of precipitate when 2 ag salts are mixed

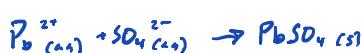
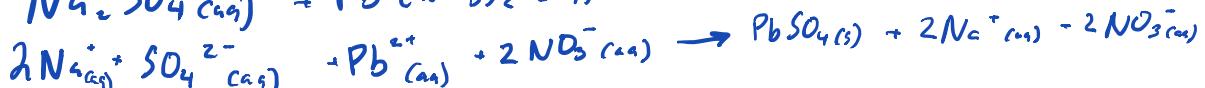
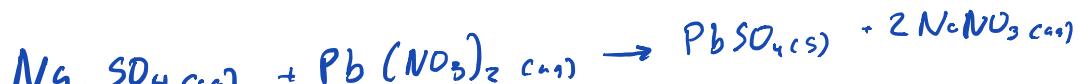
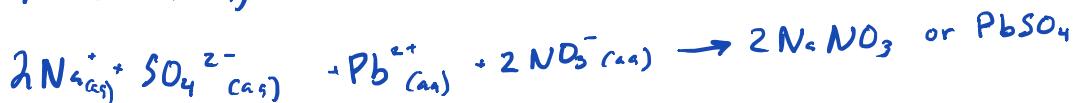
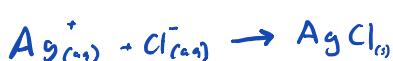
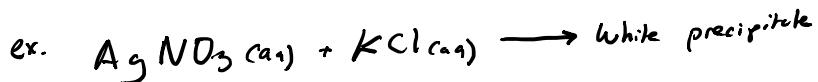


4 possible combinations, but K_2CrO_4 & $Ba(NO_3)_2$ cross out since we started with man & they w/o-⁻ charge



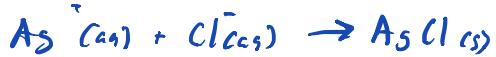
Cannot be the
precipitate due
to $K \in NO_3$
both can't
form precipitates





$$M = \frac{\text{mol}}{L} ; \text{ mol} = M \times L$$

Ex. Calculate the mass of solid NaCl that must be added to 1.50 L of a 0.100 M AgNO_3 sol'n to precipitate all of the Ag^+ ions in the form of AgCl .



$$1.50 \text{ L} \times \frac{0.100 \text{ mol}}{\text{L}} \text{ AgNO}_3 \times \frac{1 \text{ mol Ag}^+}{1 \text{ mol AgNO}_3} \times \frac{1 \text{ mol Cl}^-}{1 \text{ mol Ag}^+} \times \frac{1 \text{ mol NaCl}}{1 \text{ mol Cl}^-}$$

$$\times \frac{58.4 \text{ g NaCl}}{1 \text{ mol NaCl}} = 8.76 \text{ g NaCl}$$

Ex. Calculate the mass of PbSO_4 formed when 12.5 L of 0.050 M $\text{Pb}(\text{NO}_3)_2$ and 2.00 L of 0.0250 M Na_2SO_4 are mixed.



$$\text{Pb}^{2+} \cdot 1.25 \text{ L} \times \frac{0.050 \text{ mol Pb}(\text{NO}_3)_2}{\text{L}} \times \frac{1 \text{ mol Pb}^{2+}}{1 \text{ mol Pb}(\text{NO}_3)_2} \times \frac{1 \text{ mol PbSO}_4}{1 \text{ mol Pb}^{2+}}$$

$$= 0.0625 \text{ mol PbSO}_4$$

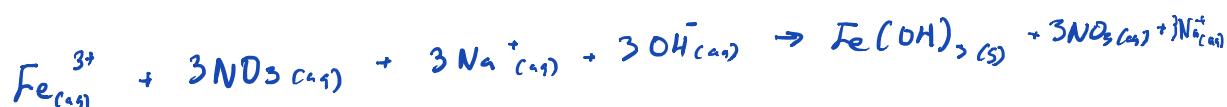
$$\text{SO}_4^{2-} \cdot 2.00 \text{ L} \times \frac{0.0250 \text{ mol Na}_2\text{SO}_4}{\text{L}} \times \frac{1 \text{ mol SO}_4^{2-}}{1 \text{ mol Na}_2\text{SO}_4} \times \frac{1 \text{ mol PbSO}_4}{1 \text{ mol SO}_4^{2-}}$$

$$= 0.0500 \text{ mol PbSO}_4$$

(SO₄²⁻ is limiting reagent)

$$0.0500 \text{ mol PbSO}_4 \times \frac{303.35}{1 \text{ mol PbSO}_4} = 15.2 \text{ g PbSO}_4$$

ex. what mass of Fe(OH)_3 would be produced by reacting 75.0 mL of 0.105 M $\text{Fe}(\text{NO}_3)_3$ with 125 mL of 0.150 M NaOH ? What are the concentrations of all the ions present in the sol'n per rxn is completed?



Initial Moles

$$\text{Fe}^{3+}: 0.075 \text{ L} \times \frac{0.105 \text{ mol Fe}(\text{NO}_3)_3}{\text{L}} \times \frac{1 \text{ mol Fe}^{3+}}{1 \text{ mol Fe}(\text{NO}_3)_3} = 7.875 \times 10^{-3} \text{ mol Fe}^{3+}$$

$$\text{NO}_3^-: 0.075 \text{ L} \times \frac{0.105 \text{ mol}}{\text{L}} \text{ Fe}(\text{NO}_3)_3 \times \frac{3 \text{ mol NO}_3^-}{1 \text{ mol Fe}(\text{NO}_3)_3} = 2.36 \times 10^{-2} \text{ mol NO}_3^-$$

$$\text{Na}^+: 0.125 \text{ L} \times \frac{0.150 \text{ mol}}{\text{L}} \text{ NaOH} \times \frac{1 \text{ mol Na}^+}{1 \text{ mol NaOH}} = 1.875 \times 10^{-2} \text{ mol Na}^+$$

$$\text{OH}^- = 1.875 \times 10^{-2} \text{ mol}$$

$$1.875 \times 10^{-2} \text{ mol OH}^- \times \frac{1 \text{ mol Fe(OH)}_3}{3 \text{ mol OH}^-} = \underbrace{6.25 \times 10^{-3} \text{ mol Fe(OH)}_3}_{\text{L. mols reacted}}$$

$$7.875 \times 10^{-3} \text{ mol Fe}^{3+} \times \frac{1 \text{ mol Fe(OH)}_3}{1 \text{ mol Fe}^{3+}} = 7.875 \times 10^{-3} \text{ mol}$$

$$6.25 \times 10^{-3} \text{ mol Fe(OH)}_3 \times \frac{106.875}{1 \text{ mol}} = 0.6685 \text{ mol Fe(OH)}_3$$

$$[\text{Na}^+] = \frac{1.875 \times 10^{-2} \text{ mol}}{(0.075 + 0.125) \text{ L}} = 0.0938 \text{ M}$$

$$[\text{NO}_3^-] = \frac{2.36 \times 10^{-2} \text{ mol}}{0.200 \text{ L}} = 0.118 \text{ M}$$

$$[\text{Fe}^{3+}] = \frac{\overbrace{7.875 \times 10^{-3} \text{ mol Fe}^{3+}}^{\text{initial}} - \overbrace{(1.875 \times 10^{-2} \text{ mol OH}^- \times \frac{1 \text{ mol Fe}^{3+}}{3 \text{ mol OH}^-})}^{\text{used up}}}{0.200 \text{ L}}$$

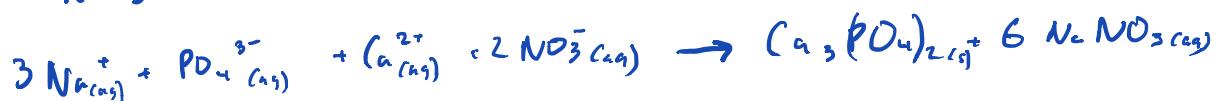
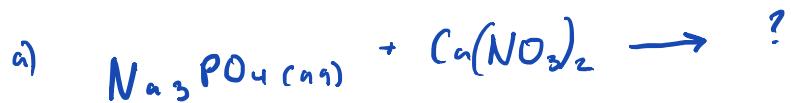
$$= 8.13 \times 10^{-3} \text{ M}$$

Ex. A mixture is prepared by adding 25.0 mL of 0.185 M Na_3PO_4 to 34.0 mL of 0.140 M $\text{Ca}(\text{NO}_3)_2$

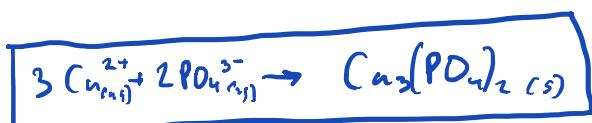
a) Write the net ionic eq for the rxn.

b) What mass (in grams) of will be formed?

c) Calculate the molar concentrations of all ions present in the sol'n after the rxn.



~~Na_3PO_4~~ or $\text{Ca}_3(\text{PO}_4)_2$ usually insoluble
but combined with
Ca which is always
soluble



b) Initial Concentrations

$$\text{Na}^+ : \frac{0.185 \text{ mol Na}_3\text{PO}_4}{L} \times \frac{3 \text{ mol Na}^+}{1 \text{ mol Na}_3\text{PO}_4} \times 0.025 \text{ L} = 1.388 \times 10^{-2} \text{ mol Na}^+$$

$\cancel{\text{mol Na}^+ / 3 = \text{mol PO}_4^{3-}}$

$$\text{PO}_4^{3-} : 1.388 \times 10^{-2} \text{ mol Na}^+ \times \frac{1 \text{ mol PO}_4^{3-}}{3 \text{ mol Na}^+} = 4.625 \times 10^{-3} \text{ mol PO}_4^{3-}$$

$$\text{Ca}^{2+} : \frac{0.140 \text{ mol Ca}(\text{NO}_3)_2}{L} \times \frac{1 \text{ mol Ca}^{2+}}{1 \text{ mol Ca}(\text{NO}_3)_2} \times 0.034 \text{ L} = 4.76 \times 10^{-3} \text{ mol Ca}^{2+}$$

$$\text{NO}_3^- : 4.76 \times 10^{-3} \text{ mol Ca}^{2+} \times \frac{2 \text{ mol NO}_3^-}{1 \text{ mol Ca}(\text{NO}_3)_2} = 9.52 \times 10^{-3} \text{ mol NO}_3^-$$

$$4.625 \times 10^{-3} \text{ mol PO}_4^{3-} \times \frac{1 \text{ mol Ca}_3(\text{PO}_4)_2}{2 \text{ mol PO}_4^{3-}} \times \frac{310.18 \text{ g}}{1 \text{ mol}} = 0.7175 \text{ g Ca}_3(\text{PO}_4)_2$$

$$4.76 \times 10^{-3} \text{ mol Ca}^{2+} \times \frac{1 \text{ mol Ca}_3(\text{PO}_4)_2}{3 \text{ mol Ca}^{2+}} \times \frac{310.18 \text{ g}}{1 \text{ mol}} = 0.492 \text{ g Ca}_3(\text{PO}_4)_2$$

Limiting reactant

c) $[\text{Ca}^{2+}] = 0$

Excess reagent

$$[\text{Na}^+] = \frac{1.388 \times 10^{-2} \text{ mol}}{0.034 \text{ L}} = 0.235 \text{ M}$$

$$[\text{NO}_3^-] = \frac{9.52 \times 10^{-3} \text{ mol}}{0.034 \text{ L}} = 0.161 \text{ M}$$

$$[\text{PO}_4^{3-}] = \frac{4.625 \times 10^{-3} \text{ mol PO}_4^{3-} - (4.76 \times 10^{-3} \text{ mol Ca}^{2+} \times \frac{2 \text{ mol PO}_4^{3-}}{3 \text{ mol Ca}^{2+}})}{0.034 \text{ L}} = 2.46 \times 10^{-2} \text{ M}$$

Free phosphate ions
In excess and reacting