Preparation of Solutions
and
Solution Phase Reactions

Solutions and Rxns in Solution

- Solutions = Homogenious Mixtures

- Solutions => 2 parts => Solvent + Solute
  - Solvent = Component in greatest amount
  - Solute = Component in least amount

Solutions and Rxns in Solution

- Characterization of Solutions
  - Organic Solutions – Solvent and solute are organic
  - Aqueous Solutions – Solvent is water
  - Ionic Solutions – Aqueous solutions containing ions
  - Nonionic Solutions – Aqueous solutions containing nonionic solutes
  - Concentration of Solute in Solution – Amount Solute in Solution

Solutions and Rxns in Solution

Concentration of Solute in Solution

$$\text{Concentration} = \frac{\text{Amount of Solute}}{\text{Amount of Solution}}$$

Concentration Terms

- Weight Percent (X% w/w)
- Volume Percent (X% v/v)
- Weight/Volume of Solution (wt solute / volume of solution)
    - Molarity (M) = Moles Solute / $(\text{Volume Solution})_{\text{Liters}}$ => Molar Solutions

Solutions and Rxns in Solution

- Preparation of Molar Solutions
  - Molar Solutions = Moles Solute / Volume Solution(L)
    - Preparation from Mfg Solid Stock
    - Preparation from Mfg Liquid Stock
    - Preparation via Dilution of Lab Stock Concentrate
  - General Preparation Method
    - To specific amount of solute, add solvent up to but not to exceed desired volume.

Solutions and Rxns in Solution

- **Preparation of Solutions from Mfgr Solid Stock**
  - Calculate Mass of Solute Needed(gms) = Molarity x Volume x Formula Wt. of Solute / Purity Factor
  - Dissolve into an amount of solvent less than final needed amount. (Use beaker as initial mixing flask)
  - Transfer pre-mix solution into calibrated Volumetric Flask
  - Add solvent up to but not to exceed needed solution volume

- Prepare 250 ml of 2.5 Molar Sodium Hydroxide Solution given manufactured stock that is 98% pure. Formula weight NaOH is 40.00 gms / mole.
  - Mass needed (gms) = [(2.5M)(0.250L)(40g./mole)]/0.98 = 2.55 gms NaOH
  - Measure 2.55 gms stock NaOH into a mixing flask/beaker and add quantity of solvent less than 250 ml and mix to dissolve solute.
  - Transfer preparation into a 250 ml. Volumetric Flask and add solvent up to but not to exceed calibration mark on flask.

Solutions and Rxns in Solution

- **Preparation of Solutions from Mfgr Liquid Stock**
  - Calculate Volume of Solute Needed(ml.) = (Molarity x Volume x Formula Wt. of Solute) / [(Purity Factor)(Specific Gravity)
  - Pipet Calculated amount of solute needed and dissolve into an amount of solvent less than final needed amount. (*In the case of strong acids, add acid into quantity of water before final dilution.*) Acid => Water => Then Dilute
  - Transfer pre-mix solution into calibrated Volumetric Flask
  - Add solvent up to but not to exceed needed solution volume

- Prepare 250 ml of 2.5 Molar Hydrochloric Acid aqueous solution given manufactured stock that is 37% pure, Specific Gravity* = 1.14 and formula weight HCl is 36.0 gms / mole.
  - Volume of HCl(37%) needed = [(2.5M)(0.250L)(36.0 g./mole)]/[(0.37)(1.14 g/ml)] = 53.3 ml stock HCl(37%)
  - Measure 53.3 ml. stock HCl (cautiously) into a quantity of solvent water at least 2x the volume of acid being diluted. (Example: To ~100 ml. solvent water add 53.3 ml of the HCl(37%), mix to homogeneous.)
  - Transfer preparation into a 250 ml. Volumetric Flask and add solvent up to but not to exceed calibration mark on flask.

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*If solvent is water, then Sp. Grv. = Solution Density (gms/ml.)

Solutions and Rxns in Solution

- **Preparation of Solutions from Lab Stock**
  - Lab Stock = Liquid concentrate for multiple solution preparations.
  - From liquid mfgr. Stock prepare 2000 ml. of 2.5M HCl(aq) Lab Stock. Quantities of this concentrate will be diluted to lower concentrations needed for experimental needs.
  - Solution preparation uses the **'Dilution Equation'** …
    - $(\text{Molarity x Volume})_{\text{Concentrate Lab Stock}} = (\text{Molarity x Volume})_{\text{Dilute Solution}}$
    - Solve for <u>Volume of Concentrate </u>that will be diluted to needed volume.
    - Extract calculated amount of Concentrate transfer and transfer to appropriate volumetric flask.
    - Dilute up to but not to exceed calibration mark on Volumetric Flask.

Solutions and Rxns in Solution

- Given lab stock of 2.5M HCl, prepare 100 ml of 0.50M HCl(aq) solution for use in experiment.

$M \cdot V_{conc'd} = M \cdot V_{diluted} \Rightarrow V_{conc'd} = (M \cdot V_{diluted})/(M_{conc'd})$

$M_{conc'd} = 2.5M \quad M_{diluted} = 0.50M$

$V_{conc'd} = ? \quad V_{diluted} = (100\ ml)^*$

$V_{conc'd} = [(0.50M)(100ml)]/[(2.50M)] = 20ml$

Transfer 20ml of stock HCl concentrate into mixing container and dilute with solvent water up to but not to exceed 100ml.

*For the Dilution Equation, volume values can remain in milliliters as both sides of the equation contain mls.

Solutions and Rxns in Solution

- What can one calculate from a balanced chemical equation?
  - Moles
  - Equation mass
  - Particle numbers
  - Gas volumes
  - Energy values

Solutions and Rxns in Solution

$$N_2(g) \quad + \quad 3H_2(g) \Rightarrow 2NH_3(g)$$

Moles	1 mole $N_2(g)$	3 moles $H_2(g)$	2 moles $NH_3(g)$
Equation Mass	1 mole (28 g/mole) = 28 gms $N_2(g)$	3 moles(2 g/mole) = 6 gms $H_2(g)$	2moles(17 g/mole) = 34 gms $NH_3(g)$
Particle Numbers ∝ Avogadro's Number (N_o) (N_o = 6.02 x 10^{23} particles/mole)	1 mole (N_o) = 6.02 x 10^{23} N_2 molecules	3 moles(N_o) =3(6.02 x 10^{23} H_2 molecules) =1.806 x 10^{24} H_2 molecules	2 moles(N_o) = 2(6.02 x 10^{23} H_2 molecules) = 1.204 x 10^{24} NH_3 molecules
Gas Volumes (@STP)	1 mole (22.4 L/mole) = 22.4 L $N_2(g)$	3 mole (22.4 L/mole) =3(22.4 L $H_2(g)$) = 67.2 L $H_2(g)$	2 mole (22.4 L/mole) = 2(22.4 L $NH_3(g)$) = 44.8 L $NH_3(g)$
Energy Values (Enthalpy = Heat of Reaction = ΔH°)	$N_2(g) + 3H_2(g) \Rightarrow 2NH_3(g)$; $\Delta H_{rxn}^o = -91.8$ Kj		

Solutions and Rxns in Solution

- Working Equation Related Problems
  - Convert given data to moles
  - Apply to balanced equation via ratio and proportion => answer in moles
  - Convert moles to dimension specified in problem

Solutions and Rxns in Solution

- Given grams => moles = (grams / f.wt. of substance)
- Given gas volumes (Liters) => moles = [(Vol given)$_{\text{Liters}}$ /22.4L/mole gas]$_{\text{STP}}$

- $2KClO_3$(s) => 2KCl(s) + $3O_2$(g)
- Given 20.0 gms $KClO_3$(s) … How much KCl(s) and O_2(g) will be produced. Express results in grams and Liters for O_2(g) assume 3 sig. fig. answer.
- (1) Convert given mass to moles:
  - Moles $KClO_3$(s) = (20 g / 122 g/mole) = 0.164 mole $KClO_3$(s)
- (2) Apply to Mole Ratios in equation by ratio and proportion …
  - 2 mole $KClO_3$(s) => 2 moles KCl(s)
  - 0.164 mole $KClO_3$(s) => ? moles KCl(s)
  - [2 mole $KClO_3$(s)/0.164 mole $KClO_3$(s)] = [2 moles KCl(s)/(x)]
    => x = 0.164 mole KCl(s)
- (3) Convert moles to grams
  - [0.164 mole KCl(s) x 74 g/mole KCl(s)] = 12.1 gms KCl(s)
- Same sequence for O_2(g) …
  - 2 mole $KClO_3$(s) => 3 moles O_2(g)
  - 0.164 mole $KClO_3$(s) => ? moles O_2(g)
  - [2 mole $KClO_3$(s)/0.164 mole $KClO_3$(s)] = [3 moles O_2(g)/(x)]
    => x = [3 moles O_2(g) x 0.164 mole $KClO_3$(g)] / 2 mole $KClO_3$(s) = 0.246 mole O_2(g)
- Convert to grams …
  - 0.246 mole O_2(g) x 32 g/mole = 7.87 gms O_2(g)

- For gas volumes, multiply moles x 22.4 L/mole at STP. Remember, the given balanced equation (whether specified or not) is assumed to be at STP conditions; i.e., 0^oC (=273K) & 1.00 Atm (=760 mmHg).
  - Volume O_2(g) = 0.164 mole O_2(g) x 22.4 Liters/mole = 3.67 Liters O_2(g)

Solutions and Rxns in Solution

- Solution Phase Reactions
  - Same procedure…
  - (1) Convert given data to moles
  - (2) Apply to equation via ratio and proportion
  - (3) Convert mole answer to dimensions specified in problem.

Solutions and Rxns in Solution

- Solution Data
  - Solution Data is specified in terms of concentration and volume of solution given.
  - Moles from solution data is calculated using:

    Moles Solute = Molarity x Volume(L)

  - Example:
    - Given 25ml of 0.250M NaOH(aq) solution.
    - Convert to moles.
    - Moles = M x V

      = (0.025L)(0.250M) = 0.00625 mole NaOH in solution

Solutions and Rxns in Solution

- Using Solution Data for Rxns in Solution
  - A solution of 30ml of 0.55M HCl(aq) is mixed with 25ml of 0.60M NaOH(aq). Which reagent will remain in excess after mixing?
  - HCl(aq) + NaOH(aq) => NaCl(aq) + H_2O(l)
    - Moles HCl(aq) = 0.030L(0.55M) HCl(aq) = 0.0165 mole HCl(aq)
    - Moles NaOH(aq) = 0.025L(0.60M) NaOH(aq) = 0.0150 mole NaOH(aq)

    $\Rightarrow$ 0.0165 mole HCl(aq) + 0.0150 Mole NaOH(aq)

    $\Rightarrow$ 0.0150 mole NaCl(aq) + (0.0165 – 0.0150) mole HCl(aq) in excess (i.e., unreacted) b/c rxn is a 1 to 1 rxn ration between HCl and NaOH.

    $\Rightarrow$ 0.0150 mole NaCl(aq) + 0.0015 mole HCl(aq)
  - Convert to Molarity(M) => Next Slide

Solutions and Rxns in Solution

- Converting Calculated Moles to Molarity
- A solution of 30ml of 0.55M HCl(aq) is mixed with 25ml of 0.60M NaOH(aq). Which reagent will remain in excess after mixing?
- After mixing =>
  - 0.0015 mole $HCl(aq)_{in\ excess}$ + 0.015 mole NaCl(aq) in 55ml of solution. What is the molarity of each reagent in solution?
  - Molarity(M) = Moles Solute / Volume of Soln in Liters
    - [HCl(aq)] = 0.0015mole/0.055L = 0.027M HCl(aq)
    - [NaCl(aq)] = 0.015mole/0.055L = 0.272M NaCl(aq)

Worksheets Chemical Equations:

http://misterguch.brinkster.net/pra_equationworksheets.html

Solutions and Rxns in Solution

- Problems – Solution Preparation
- Prepare 500 ml of 1.5M NaOH(aq) from manufactured stock that is 98% pure in NaOH. Determine the mass of reagent needed and describe the mixing procedure.

Solutions and Rxns in Solution

- Problems – Solution Preparation
- Prepare 1500 ml of 2.0M HCl(aq) aq solution from manufactured stock that is 37% active in HCl. Specific Gravity is 1.14. Determine the volume of reagent needed and describe the mixing procedure.

Solutions and Rxns in Solution

- Problems – Solution Preparation
- Prepare 100ml of 0.05M NaOH(aq) solution from a laboratory concentrate stock that is 2.0M.

Solutions and Rxns in Solution

- Problems – Solution Phase Reactions
- What volume of 0.250M HNO_3 (nitric acid) reacts with 44.8ml of 0.150M Na_2CO_3 (sodium carbonate)?

Solutions and Rxns in Solution

- Problems – Solution Phase Reactions
- A flask contains 49.8ml of 0.150M $Ca(OH)_2$ (calcium hydroxide). How many ml of 0.350M of Na_2CO_3 (sodium carbonate) are required to react completely with the calcium hydroxide?

Solutions and Rxns in Solution

- Problems – Solution Phase Reactions
- How many milliliters of 0.150M H_2SO_4 (sulfuric acid) are required to completely neutralize 8.20gms of sodium hydroxide (NaOH)?

Solutions and Rxns in Solution

- Problems – Solution Phase Reactions
- A solution of hydrogen peroxide (H_2O_2) is titrated with a solution of potassium permanganate ($KMnO_4$). The balanced reaction is:

$$5H_2O_2(aq) + 2KMnO_4(aq) + 3H_2O(aq) \Rightarrow 5O_2(aq) + 2MnSO_4(aq) + K_2SO_4(aq) + 8H_2O(l)$$

- It requires 51.7ml of 0.145M $KMnO_4$ to titrate 20.0 grams of the solution of hydrogen peroxide. What is the mass percentage of H_2O_2 in the solution?

Solutions and Rxns in Solution

- Problems – Solution Phase Reactions
- A 3.33 gram sample of iron ore is transformed to a solution of iron(II) sulfate ($FeSO_4$) and this solution is titrated with 0.150M $K_2Cr_2O_7$ (potassium dichromate). If it requires 43.7 ml of potassium dichromate solution to titrate the iron(II) sulfate solution, what is the percentage of iron in the ore sample? The balanced reaction is:
- $6FeSO_4(aq) + K_2Cr_2O_7(aq) + 7H_2SO_4(aq) \Rightarrow 3Fe_2(SO_4)_3(aq) + Cr_2(SO_4)_3(aq) + 7H_2O(l) + K_2SO_4(aq)$

Solutions and Rxns in Solution

- Problems – Solution Phase Reactions
- 35ml of 0.111M HNO_3(aq) (nitric acid) solution is mixed with 33ml of 0.086M NaOH(aq) (sodium hydroxide) solution. Is the final mixture acidic, basic or neutral?