Stoichiometry

Z Ch 3, H Ch 1-4, 22-1

"Stoichiometry is the science of measuring the quantitative proportions or mass ratios in which chemical elements stand to one another." **Jeremias Benjamin Richter, 1792**

Richter introduced the word stoichiometry (Greek, *stoicheion*- element and *metron*- measure)

historical: H 85-90%, Q 70-75%, E ~ 65%

class GPA: 3-3 – 3.6

Q1 ave = 6.0

TA OFFICE HOURS

hours convenient?

Zoom or MSLC?

Balancing

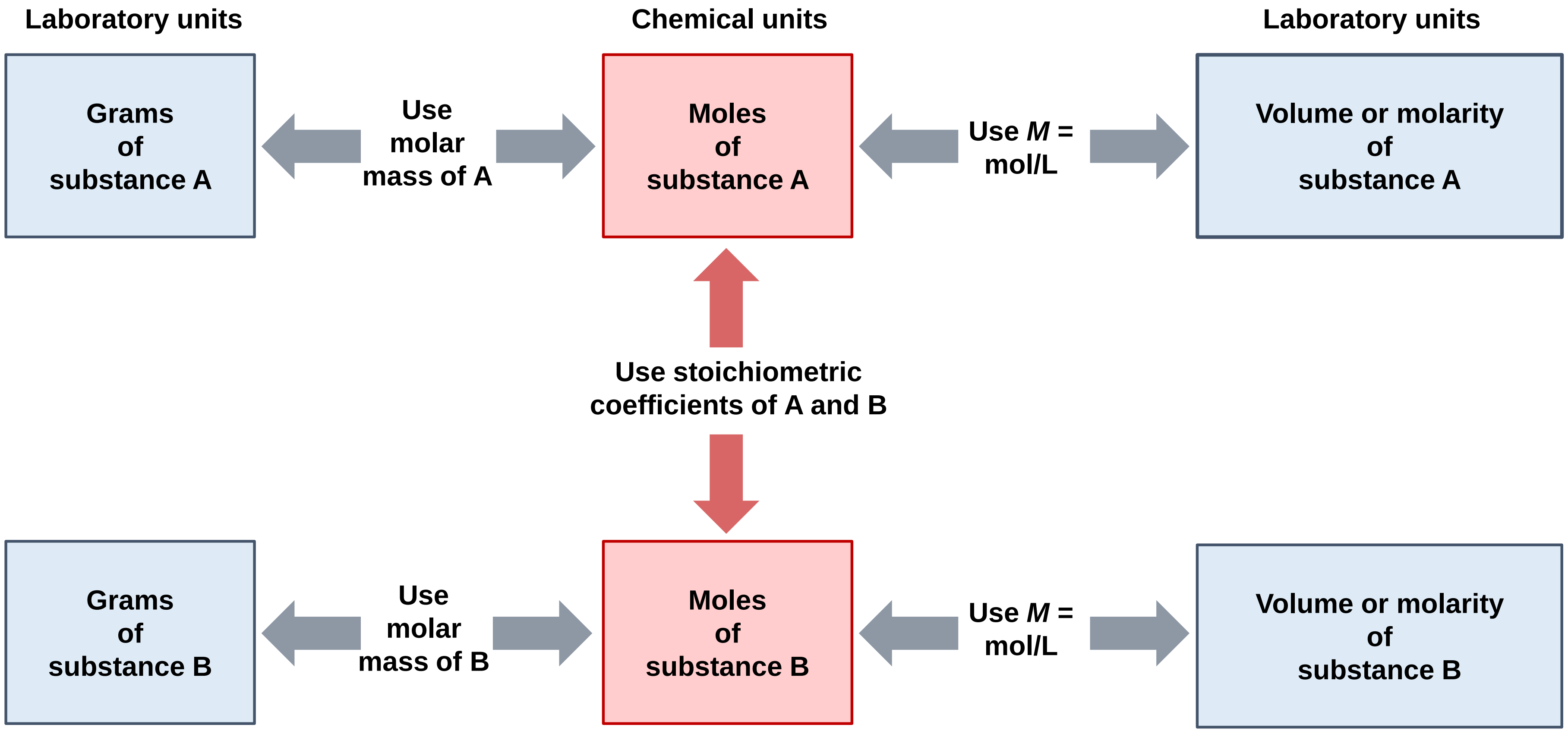
Stoichiometry Calculations

Yields

When writing in your lab notebook be sure to put the cardboard flap immediately under the original + carbon copy sheets

REVIEW FROM WEDNESDAY

Solving Stoichiometry Problems



worksheet – problem in tons

Yields

theoretical yield - yield (mass of product) predicted from stoichiometry assuming reaction goes to completion without loss or side reactions => maximum amount of product

actual yield - yield (mass of product) actually obtained experimentally

$$\textbf{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

Solving for % Yield

EX 15. Determine the % yield if 3.12 g of CH_4N_2O (*M*= 60.0556) is isolated when 5.11 g of NH_3 (*M* = 17.0307) and excess CO_2 react according to

$$2\ NH_3 + CO_2 \rightarrow CH_4N_2O + H_2O$$

g reactant **NH_3** -> mol reactant -> mol product -> g product **CH_4N_2O**

NH_3: (5.11 g NH_3 / 17.0307 g/mol) **mol NH_3**

× (1 mol CH_4N_2O / 2 mol NH_3) **mol CH_4N_2O**

× (60.0556 g CH_4N_2O / mol CH_4N_2O) **mass of CH_4N_2O**

= 9.009 g

% yield = 3.12 × 100 / 9.009 = **34.6%**

Chem Rxs, Stoich__________ Z Ch 2.9, 4; H Ch 1-2, 1-3, 7-1, 7-2, 16-4–16-6

"The world of chemical events is like a stage on which scene after scene is enacted in a continuous succession. The players on this stage are the elements. To each of them is assigned a characteristic role, either that of supernumerary or that of an actor playing a part."

Clemens Alexander Winkler, 1897

Almost all the chemical processes which occur in nature ... take place between substances in solution."

Friedrich Wilhelm Ostwald, 1890

(Nobel Prize for Chemistry in 1909 "in recognition of his work on catalysis and for his investigations into the fundamental principles governing chemical equilibria and rates of reaction".)

4.4 - Types of Chemical Reactions

dissolution reactions (solvent, solute) - two (or more) substances form homo-geneous mixture; dispersion on the level of individual molecules or ions

precipitation reactions - a substance exceeds its solubility in another, ppt

acid-base reactions - "classic" Arrhenius reaction in water of a strong acid and a strong base reacting to form a salt and water

oxidation-reduction reactions - chemical rx where electrons are transferred

Dissolution Reactions

$CH_3CH_2OH(\boldsymbol{l})$ -> $CH_3CH_2OH(\boldsymbol{aq})$

molecular compounds in water (*e.g.,* solid urea dissolving)

$$H_2NCONH_2(\boldsymbol{s}) \quad \rightarrow \quad H_2NCONH_2(\boldsymbol{aq})$$

ionic compounds in water **(dissociation, ionization)**

$$Na_2CO_3(\boldsymbol{s}) \quad \rightarrow \quad 2Na^+(\boldsymbol{aq}) + CO_3^-(\boldsymbol{aq})$$

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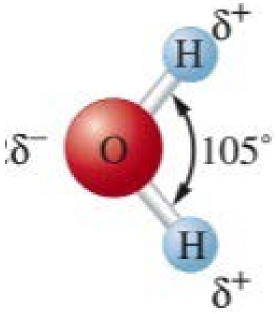
water is polar



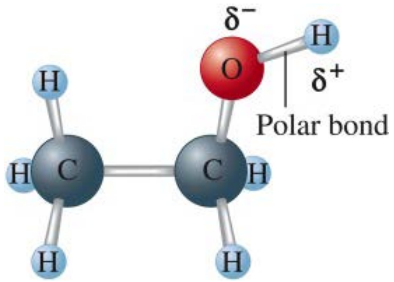
water is polar – unequal charge distribution

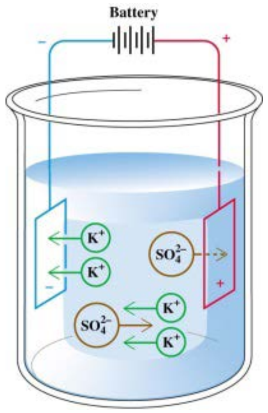
electrolytes (conduct electricity better than pure water)

strong: $Na_2CO_3(aq)$, $HCl(aq)$

weak (produce less **ions** => lower conductivity): ammonia, acetic acid

nonelectrolyte: ethanol, sugar





Dissolution Reactions

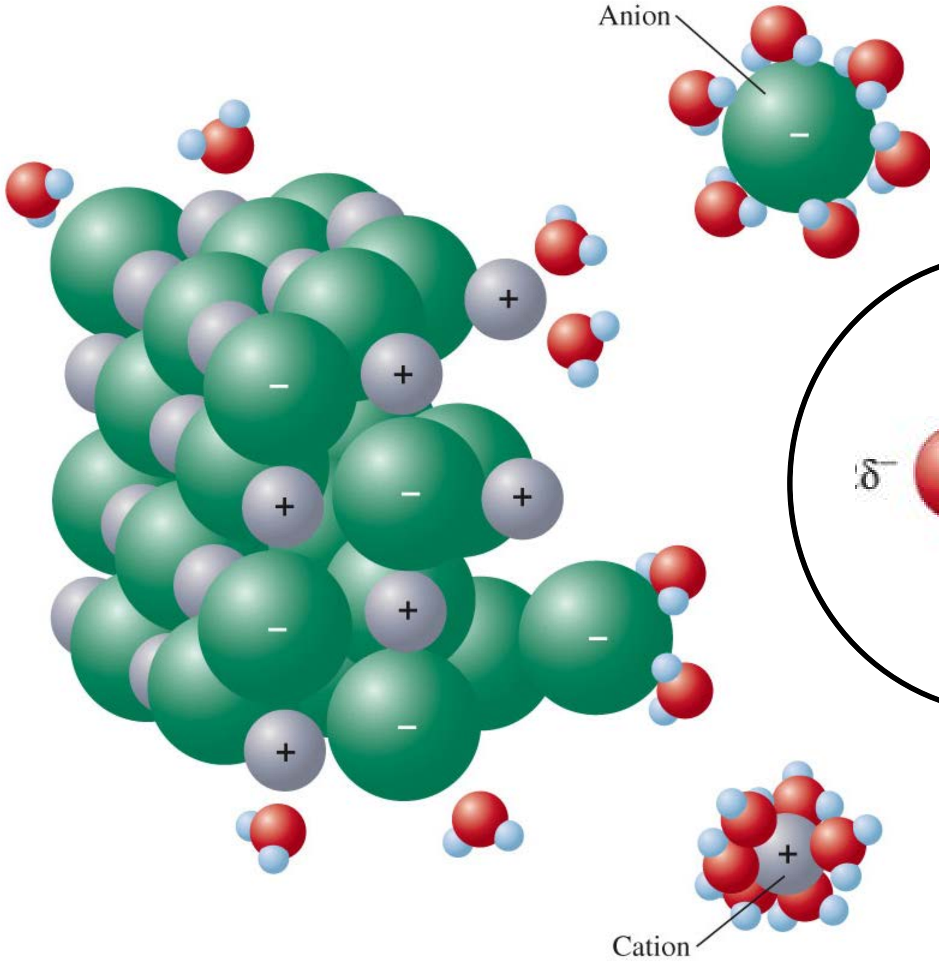
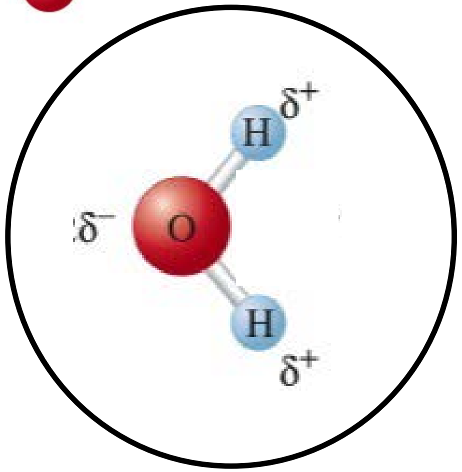


FIG II – Dissolution of NaCl in Water



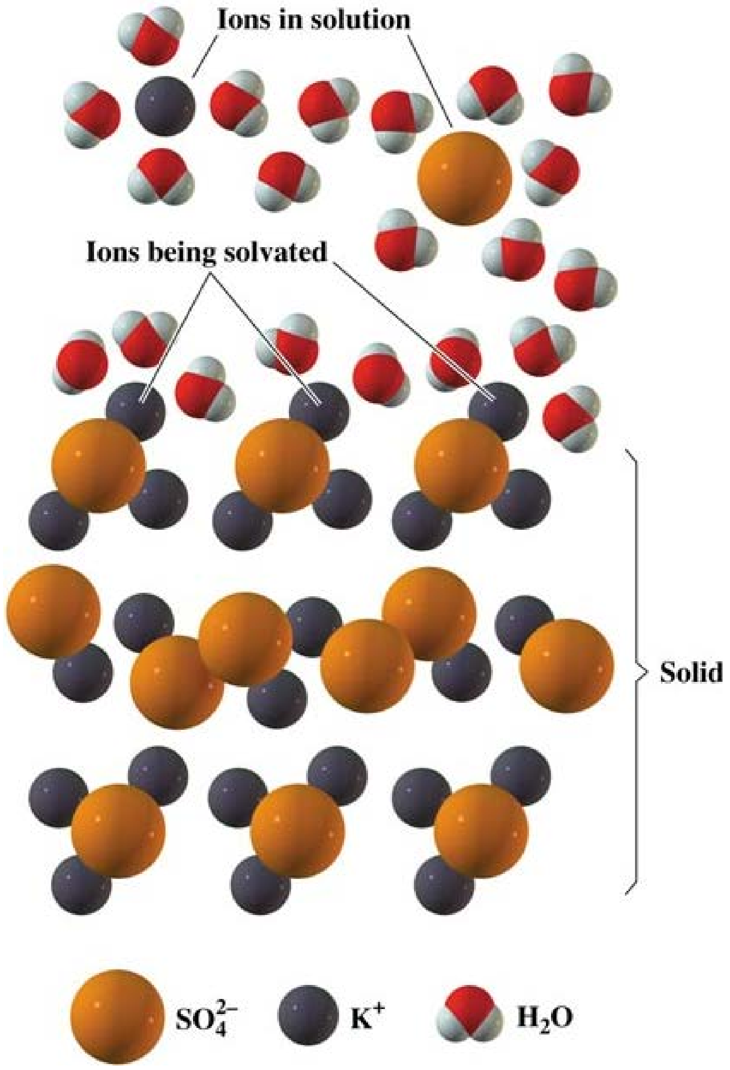


FIG I – Dissolution of K_2SO_4 in Water

Stoichiometry of Reactions in Solution

How to express composition: solute A + solvent = solution

mass percent = mass A / mass solution x 100

mole fraction, X_A = moles A / moles of solution

molarity, M_A = moles of A / 1 L of solution

molality, m_A = moles of A / 1 kg of solvent (later)

Molarity – Measuring Atoms in Solution

$$\mathbf{M = \mathit{n} / L}$$

Solutions

EX 2. What is the molarity of pure water? (M_{H2O} = 18.0152 g mol^{-1}, d = 1.00 g cm^{-3})

M = *n* / *L*   how many moles of water are in a L? d = 1.00 g cm^{-3} =>
1000 g/L => M = (1000 / 18.0152) / L
= **55.5 M**

EX 3. What mass of silver nitrate is needed to make 100. mL of a 0.100 M $AgNO_3$ solution? (M_{AgNO3} = 169.874 g mol^{-1})

M = *n* / *L* = (*m* / *M*) / L
0.100 = (*m* / 169.874) / 0.100
=> *m* = **1.70 g**

Diluting Solutions

When you **dilute or mix** solutions the total **number of moles of solute does not change** (1 is initial) $n_1 = M_1V_1 = n_2 = M_2V_2$ (2 is final)

EX 4. What is the molarity of the solution prepared by adding 29.0 mL of 17.4 M acetic acid to a 500-mL volumetric and filling with distilled water?

$$n_1 = M_1V_1 = n_2 = M_2V_2 \Rightarrow M_2 = M_1V_1 / V_2$$

$$= 29.0 \text{ **mL**} (17.4) / 500 \text{ **mL**}$$ **RATIO**

$$= 1.0092 \Rightarrow \mathbf{1.01\ M}$$

EX 5. How would you prepare 1.5 L of 0.10 M H_2SO_4 from a 16 M supply?

$$V_1 = M_2V_2 / M_1$$

$$= 0.10(1.5) / 16$$

$$= 0.0094 \text{ L} = \mathbf{9.4\ mL}$$

Mixing Solutions

When you **dilute or mix** solutions the total **number of moles of solute does not change**

$$n_{tot} = n_1 + n_2 = M_1V_1 + M_2V_2 = M(V_1 + V_2)$$

EX 6. What is the molarity of the sodium chloride solution obtained from mixing 53 mL of 0.52 M NaCl with 62 mL of 0.47 M NaCl?

$$M = [\ 53(0.52) + 62(0.47)\ ] / (53 + 62) = \mathbf{0.49\ M}$$

makes sense, between 0.47 and 0.62 M

Density in Molarity Calculations

EX 7. A solution which is 5.50% (by mass) sulfuric acid (M = 98. 0778) has a density of 1.0352 g cm^{-3}. What is the molarity of the solution?

the power of ratios!

assume 100 g of solution

$$(5.50 \text{ g } H_2SO_4 / 100 \text{ g sol'n}) (1 \text{ mol } H_2SO_4 / 98.0778 \text{ g } H_2SO_4)$$

$$\times \ (1.0352 \text{ g sol'n} / 1 \text{ cm}^3 \text{ sol'n}) (1000 \text{ cm of sol'n} / \text{L sol'n})$$

$$= \ \mathbf{0.581 \ M}$$

Precipitation Reactions

STRATEGY (do not memorize solubility tables)

- write down formulas of reactants
- identify nature of reactants in solution (if ionic, what ions are in solution)
- consult solubility table for combination of cations/anions that will precipitate
- write balanced equation
- write total ionic equation
- write net ionic equation - omits spectator ions - **CHEMISTRY**