Limiting Reagent

What is limiting reagent?

- Two reagents react, you need to find out how much of each reacted
- There will be less of one reagent available to react, this will be your limiting reagent
- Use dimensional analysis to:
  - Determine how much of each reagent reacts
    - Determine limiting reagent
  - Use limiting reagent to determine how much product is formed

Consider the following reaction: $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$. If 3.25 g NH_3 are allowed to react with 3.50 g O_2, how many grams of NO are formed?

$$3.25\ g\ NH_3 \cdot \frac{1\ mol\ NH_3}{17.03\ g\ NH_3} \cdot \frac{4\ mol\ NO}{4\ mol\ NH_3} = 0.191\ mol\ NO$$

$$3.50\ g\ O_2 \cdot \frac{1\ mol\ O_2}{32\ g\ O_2} \cdot \frac{4\ mol\ NO}{5\ mol\ O_2} = 0.0875\ mol\ NO$$

↑ LR ↑ max amount possible

$$0.0875\ mol\ NO \cdot \frac{30\ g}{1\ mol\ NO} = 2.625\ g\ NO$$

Consider the following reaction: $N_2 + 3H_2 \rightarrow 2NH_3$. If you use 30g of N_2 and 10 g of H_2, what is the mass of the excess reagent?

$$30\ g\ N_2 \cdot \frac{1\ mol\ N_2}{28\ g\ N_2} \cdot \frac{3\ mol\ H_2}{1\ mol\ N_2} \cdot \frac{2.016\ g\ H_2}{1\ mol\ H_2} = 6.48\ g\ H_2$$

$$10\ g\ H_2 - 6.48\ g\ H_2 = 3.52\ g\ excess\ H_2$$

$$10\ g\ H_2 \cdot \frac{1\ mol\ H_2}{2.016\ g\ H_2} \cdot \frac{1\ mol\ N_2}{3\ mol\ H_2} \cdot \frac{28\ g\ N_2}{1\ mol\ N_2} = 46.3\ g\ N_2\ needed$$

*we only have 30 g N_2, we can't react w/ 46.3 g N_2 *

- N_2 will not be the excess reagent, do dimensional analysis using N_2

Redox Reactions

Finding Oxidation Numbers

- Oxidation number
  - The hypothetical charge of an atom if all of its bonds to different atoms were fully ionic
- Group 1 metals: always +1
- Group 2 metals: always +2
- Oxygen: usually -2
- Hydrogen: usually +1
- Halogens: usually -1
- Elements by themselves= 0!

oxidation numbers in a molecule MUST add up to 0 unless you have an ion (need to add up to charge of the ion

What is the oxidation number of each atom in Fe_2O_3?

(↑ overall charge = 0)

- O is usually -2

$2(Fe) + 3(-2) = 0$

$2(Fe) - 6 = 0$; +6 +6

$\frac{2(Fe)}{2} = \frac{6}{2} \rightarrow Fe = +3,\ O = -2$

What is the oxidation number of each atom in H_2CO_3?

(↑ overall charge of 0)

$2(H) + 1(C) + 3(O) = 0$

$2(+1) + 1(C) + 3(-2) = 0$

$2 + 1(C) - 6 = 0$

$1(C) - 4 = 0$; +4 +4

$\frac{1(C)}{1} = \frac{4}{1} \rightarrow C = 4,\ H = +1,\ O = -2$

How Oxidation Numbers Relate to Redox

- Loss of electrons: oxidation
  - Charge gets more positive
- Gain of electrons: reduction
  - Charge gets more negative
- Remember: LEO the lion goes GER!
  - (Loss of Electrons=Oxidation, Gain of Electrons=Reduction)

In the reaction, $2HCl + Zn \rightarrow H_2 + ZnCl_2$, which reactant is oxidized and which reactant is reduced?

(+1, -1, 0, 0, +2, $2(-1) = -2$)

LEO GER

- H: $+1 \rightarrow 0$ REDUCED (oxidizing agent)
- Cl: $-1 \rightarrow -1$ NO CHANGE
- Zn: $0 \rightarrow +2$ OXIDIZED (reducing agent)

In the reaction, $Au + 4H^+ + NO_3^- + 4Cl^- \rightarrow AuCl_4 + 2H_2O + NO$, which reactant is the oxidizing agent?

$Au + 4H^+ + NO_3^- + 4Cl^- \rightarrow AuCl_4 + 2H_2O + NO$

(Au: 0; H: +1; $1(N) + 3(-2) = -1$, $1(N) - 6 = -1$, +6 +6, $\frac{1(N)}{1} = \frac{+5}{1}$, $N = +5, O = -2$; Cl: -1; Au: +4, Cl: -1; H: +1, O: -2; N: +2, O: -2)

- Au: $0 \rightarrow +4$ Oxidized (red. ag.)
- Cl: $-1 \rightarrow -1$ NO CHANGE
- H: $+1 \rightarrow +1$ NO CHANGE
- N: $+5 \rightarrow +2$ reduced (ox. ag.)
- O: $-2 \rightarrow -2$ NO CHANGE

LEO GER

Balancing Redox Reactions

- Half reaction method
  - Balance each species individually
  - Electrons are included
  - Ensure that electrons lost= electrons gained
  - Combine half reactions

Balance $MnO_4^- + SO_3^{2-} \rightarrow MnO_2 + SO_4^{2-}$ using the half reaction method

$MnO_4^- \longrightarrow MnO_2$

$1(Mn) + 4(-2) = -1$; $Mn = +7$, $O = -2$

$1(Mn) + 2(-2) = 0$; $Mn = +4$, $O = -2$

$MnO_4 + \underline{3}\ e^-s \rightarrow MnO_2$ (+7, -3 = +4)

$SO_3^{2-} \longrightarrow SO_4^{2-}$

$1(S) + 3(-2) = -2$; $S = +4$, $O = -2$

$1(S) + 4(-2) = -2$; $S = +6$, $O = -2$

$SO_3^{2-} \longrightarrow SO_4^{2-} + \underline{2}\ e^-s$ (+4 = +6, -2)

make sure our electrons are equal

$2(MnO_4 + 3e^-s \rightarrow MnO_2)$ | $3(SO_3^{2-} \rightarrow SO_4^{2-} + 2e^-s)$

$2MnO_4 + 6e^-s \rightarrow 2MnO_2$ | $3SO_3^{2-} \rightarrow 3SO_4^{2-} + 6e^-s$

$2MnO_4 + 6e^-s + 3SO_3^{2-} \rightarrow 2MnO_2 + 3SO_4^{2-} + 6e^-s$

$2MnO_4 + 3SO_3^{2-} \rightarrow 2MnO_2 + 3SO_4^{2-}$ ← end of e^-s part, need to make sure atoms are equal

Mn = 2; +2H⁺ → O = 8 + 9 = 17 ← one more O; S = 3

Mn = 2; O = 4 + 12 = 16 + H_2O; S = 3

$$2H^+ + 2MnO_4 + 3SO_3^{2-} \rightarrow 2MnO_2 + 3SO_4^{2-} + H_2O$$

Titration

Titration

- You will have an acidic/basic solution
- You want it to become neutral, so you add base (acidic solution) or acid (basic solution)
- Titration stops when the solution is neutral

$H^+ = OH^-$

$83 mL \cdot \frac{1 L}{1000 mL} = 8.3 \times 10^{-2} L$ $\quad 235 mL \cdot \frac{1 L}{1000 mL} = 0.235 L$

It takes 83 mL of a 0.45 M NaOH solution to neutralize 235 mL of an HCl solution. What was the initial concentration of the HCl solution?

$\frac{0.45 mol}{1 L} \cdot 8.3 \times 10^{-2} L = 3.74 \times 10^{-2} mol\ NaOH \cdot \frac{1 mol\ OH^-}{1 mol\ NaOH} = 3.74 \times 10^{-2} mol\ OH^-$

definition of neutrality

$3.74 \times 10^{-2} mol\ H^+$

neutrality: $H^+ = OH^-$

$3.74 \times 10^{-2} mol\ H^+ \cdot \frac{1 mol\ HCl}{1 mol\ H^+} = \frac{3.74 \times 10^{-2} mol\ HCl}{0.235 L} = 0.16\ M\ HCl$

$0.038 L$ $\quad$ 1:1

It takes 38 mL of 0.75 M NaOH solution to completely neutralize a 0.092 M solution of sulfuric acid (H_2SO_4). What was the initial volume of the sulfuric acid solution, in mL?

diprotic

$\frac{0.75 mol\ OH^-}{1 \cancel{L}} \cdot 0.038 \cancel{L}\ OH^- = 0.0285 mol\ OH^- = 0.0285 mol\ H^+$

definition of neutrality

$0.0285 mol\ H^+ \cdot \frac{1 mol\ H_2SO_4}{2 mol\ H^+} = \frac{0.01425 mol\ H_2SO_4}{? L} = \frac{0.092 mol}{1 L}$

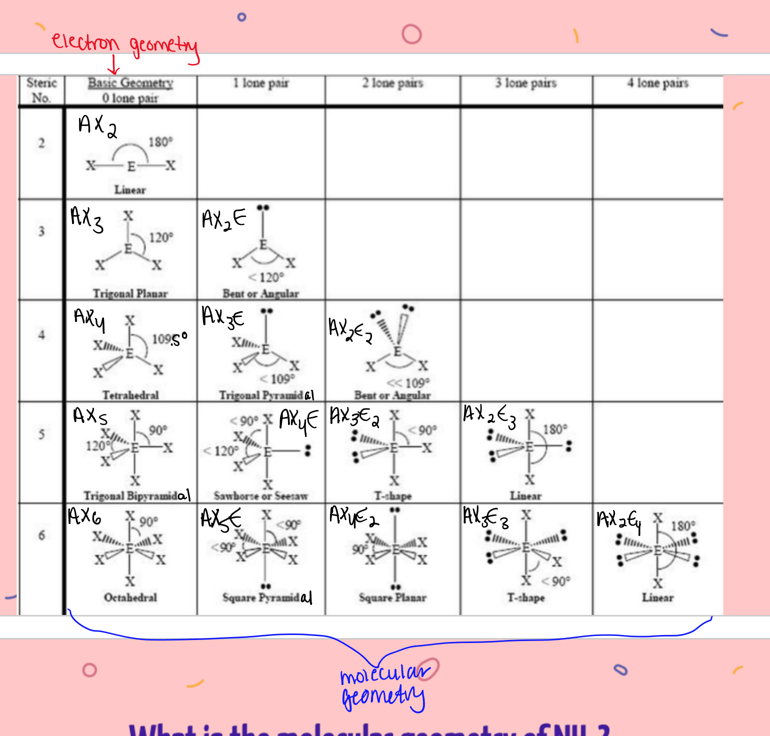
$(0.01425)(1) = (0.092)(x)$

$0.155 L$ or $155 mL$

$0.01425 \cancel{mol\ H_2SO_4} \cdot \frac{1 L\ H_2SO_4}{0.092 \cancel{mol\ H_2SO_4}} = 0.155$ or $155 mL$

Molecular Geometry

electron geometry



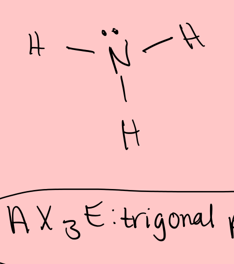
molecular geometry

What is the molecular geometry of NH_3?

N: 5 e⁻s

H: 1 e × 3 = 3 e⁻s

total: 8 valence e⁻s



8 e⁻s − 6 = 2e⁻

AX_3E: trigonal pyramidal

What is the molecular geometry of SF_6?

S = 6 e⁻s

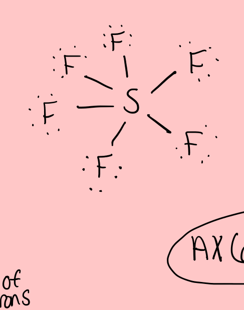
F = 7 e⁻s × 6 = 42

42 + 6 = 48 valence e⁻s

In bonds: 48 − (6·2) = 36

Each F gets 6 e⁻s × 6 Fs = 36

will use the rest of the electrons



AX_6: octahedral

Naming

Ionic Compounds

- Cation, then anion
- Normal ending for cation, -ide ending for anion
- Remember: polyatomic anion names may not adhere to this, use THEIR name
  - Ex. sulfate ion
- Transitions metals' charge indicated in name
  - Determine using deductive reasoning with anion
  - Ex. $FeCl_2$ is iron (II) chloride

+2 $\quad$ −1×2 = −2 $\quad$ 2+

Covalent Compounds

- Name non-metal furthest to the left by its elemental name
- Name the other non-metal by its elemental name and -ide ending
- Use prefixes to indicate the number of that element in the molecule
  - 1-mono, 2-di, 3-tri, 4-tetra, 5-penta, 6-hexa, 7-hepta, 8-octa, 9-nona, 10-deca-
- If mono is the first prefix, you do not need to include it
- Example: N_2O_4 is dinitrogen monoxide

What is the molecular formula of iron (III) oxide?

$Fe^{3+}\ O^{2-} \rightarrow Fe_2O_3$

What is the molecular formula of carbon tetrachloride?

4

CCl_4

Empirical vs. Molecular Formula

Empirical vs. Molecular Formula

- Empirical formula Fe_2O_3
  - The simplest formula that shows the combination of atoms
  - No associated molar mass
- Molecular formula
  - Variant of empirical formula
  - Must be given molar mass in order to determine

molar mass: 319.38

− we know molar mass of Fe_2O_3 = 159.69 g/mol

$\frac{319.38}{159.69} = 2$ ← Need to multiply every number in empirical formula by 2 → molecular formula = Fe_4O_6

A compound is 40.3% carbon, 6.7% hydrogen, and 53% oxygen by mass, and has a molar mass of 60.05 g/mol. What is it's molecular formula?

pretend you have 100g of substance, now all percents are masses

$40.3 g\ C \cdot \frac{1 mol\ C}{12.01 g\ C} = 3.36 mol\ C \div 3.31 = 1.02$

$6.7 g\ H \cdot \frac{1 mol\ H}{1.008 g\ H} = 6.65 mol\ H \div 3.31 = 2.00$

$53 g\ O \cdot \frac{1 mol\ O}{16 g\ O} = 3.31 mol\ O \div 3.31 = 1$

CH_2O ← empirical formula

divide all by smallest number so one of the atoms has a coefficient of 1

molar mass: 60.05 g/mol

Empirical formula: CH_2O = 30.03 g/mol ← half substance's molar mass

Need to multiply everything by 2 to get molecular formula

$2(CH_2O) \rightarrow C_2H_4O_2$ ← molecular formula

Specific Heat

Specific Heat (c)

- Characteristic of a substance
  - Not dependent on total mass!
- Amount of heat per unit mass required to raise the temperature by 1ºC
- Equation: q=mcΔt ← change in temperature
  - Question types
    - Can be asked about q, m, or Δt, and you will be given c and 2 variables
    - Can be asked to find c, given 2 variables (one of them being q)

heat (energy) $\quad$ mass $\quad$ specific heat

Given that the specific heat of water is 4.184 J/g*C, if a water sample increases 3ºC when given 50 J of heat, how much water was in the sample, in grams?

$q = mc\Delta t$

$\frac{q}{c\Delta t} = m$

$\frac{(50 J)}{(4.184 \frac{J}{g \cdot C^\circ})(3^\circ C)} = 3.98\ g\ H_2O$

q = 50 J

m = ?

$c = 4.184 \frac{J}{g \cdot C^\circ}$

Δt = 3°C

units do check out

$\frac{1}{\frac{1}{g}} = 1 \times \frac{g}{1} = g$