CHAPTER 4
STOICHIOMETRY & CHEMICAL EQUATIONS

4

CHAPTER 6
INTRO TO CHEMICAL REACTIONS

Writing and Balancing Chemical Equations [4.1]

¿WHY BALANCE CHEMICAL EQUATIONS?

$$2H_2 + O_2 \rightarrow 2H_2O$$

HOW TO BALANCE CHEMICAL EQUATIONS: THE TWIN ELEMENTS METHOD

(see “DrStephensonChemistry” youtube videos)

1. ID “lone” elements
   (pure elements that are all “alone”)

2. ID “twin” elements
   (element whose symbol appears once-and-only-once on each side of the equation. One of the twins lives on the reactant-side, the other on the product-side)

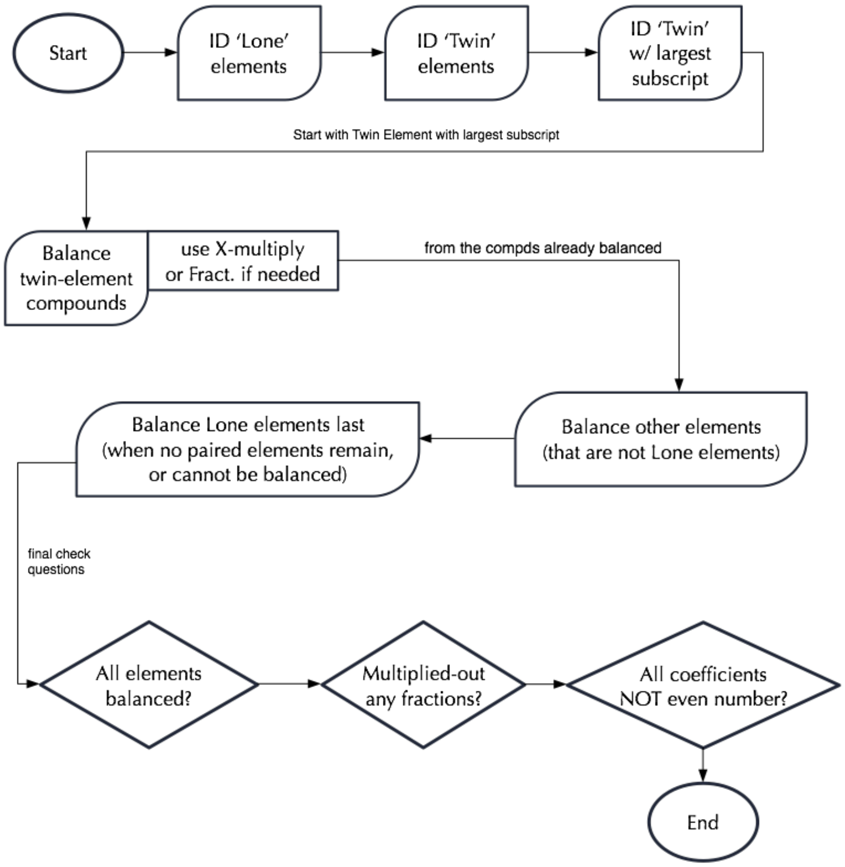
3a. START with the Twin Element with the largest subscript.

3b. END by determining the coefficient of a Lone Element, if present.

4. Exploit opportunities to employ two tricks of the trade:
   (i) cross-multiplication
   (ii) fractionations

$$CH_4 + O_2 \longrightarrow H_2O$$

FIRST-ORDER BCE FLOW DIAGRAM



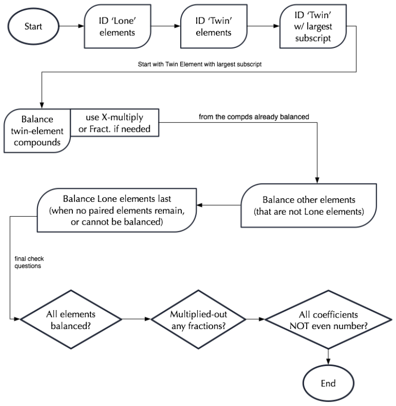
FRACTIONATION

$$\frac{2}{1}\left(\overset{2}{\cancel{1}}\, C_2H_6 + \overset{7}{\frac{7}{\cancel{2}}}\, O_2 \rightarrow \overset{4}{\cancel{2}}\, CO_2 + \overset{6}{\cancel{3}}\, H_2O \right)$$

$$2\,\boxed{} = 4 \qquad 3$$

$$\frac{2}{1}\,\boxed{\frac{7}{2}} = \frac{7}{1}$$

FIRST-ORDER BCE FLOW DIAGRAM



Start

ID 'Lone' elements

ID 'Twin' elements

ID 'Twin' w/ largest subscript

Start with Twin Element with largest subscript

Balance twin-element compounds

use X-multiply or Fract. if needed

from the compds already balanced

Balance other elements (that are not Lone elements)

Balance Lone elements last (when no paired elements remain, or cannot be balanced)

final check questions

All elements balanced?

Multiplied-out any fractions?

All coefficients NOT even number?

End

CROSS MULTIPLY

$$2\,Sb + 3\,Cl_2 \rightarrow 2\,SbCl_3$$

$$\frac{2}{1}\left(1\,Sb + \frac{3}{2}\,Cl_2 \rightarrow 1\,SbCl_3 \right)$$

‘ONE-SHORT’ situation (2 or 3 known; 3 of 4 known; etc)

$$\underbrace{1\,Al_20_3 + \boxed{3}\,CO}_{6} \;\longrightarrow\; \underbrace{2\,Al + \boxed{3}\,CO_2}_{6}$$

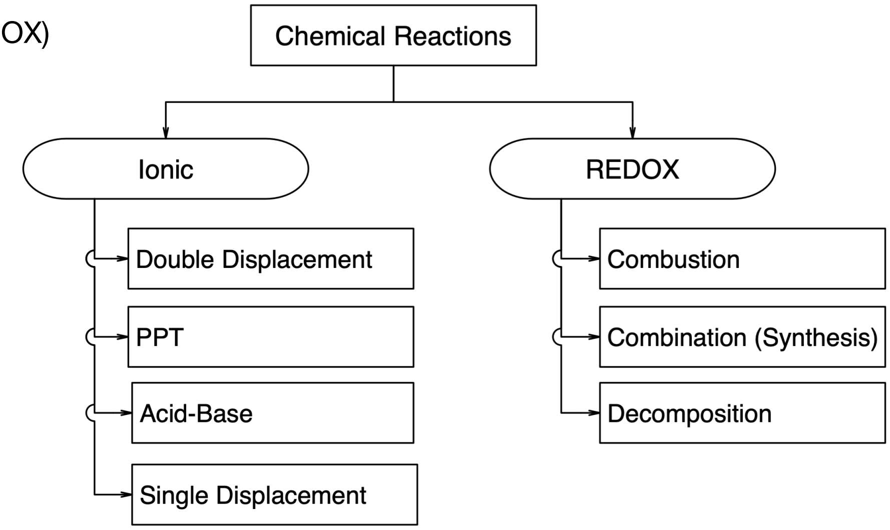
$\boxed{ox}$

$$3 + x = 2y$$
$$x = y$$
$$\downarrow$$
$$3 + x = 2x$$
$$3 = 2x - x$$
$$3 = x$$

Classifying Chemical Reactions [4.2]

Two General Classifications

① Ionic
② Oxidation-Reduction (REDOX)



Chemical Reactions

- Ionic
  - Double Displacement
  - PPT
  - Acid-Base
  - Single Displacement
- REDOX
  - Combustion
  - Combination (Synthesis)
  - Decomposition

IONIC reactions occur between ionic compounds
↳ recall, ionic compound is usually a Metal + Nonmetal
↳ or another way of putting it: a Type I or Type II compound
REDOX reactions are reactions between covalent compounds
↳ reactions between Type III compounds

Double Displacement (Metathesis): The ‘Partner Swap’ Reaction

Double Displacement Reactions

- Also known as a METATHESIS reaction
- Common vernacular is the PARTNER SWAP reaction
- Essentially, cations exchange their associated anions with each other
- Falls under the class of IONIC reactions
  - ↳ Ionic Compound = a Metal + a Nometal
  - ↳ Ionic Compound = Type I or Type II compound

$$\overset{+}{A}\overset{-}{X} + \overset{+}{B}\overset{-}{Y} \longrightarrow AY + BX$$

$$\overset{2+}{Pb}(\overset{-}{N0_3})_2 + \overset{+}{H_2}\overset{2-}{SO_4} \rightarrow 2\ \overset{+}{H}\overset{-}{N0_3} + \overset{2+}{Pb}\overset{2-}{SO_4}$$

Predicting ionic reaction products

$$AX + BY \rightarrow ?? + ??$$

$\underline{\overset{2+}{A}\overset{-}{Y}}_2 + \underline{BX}$

Given 2 Ionic Reactants: Procedure for Predicting Correct Molecular Equation

(1) Pair (elements)
(2) CHG neutral (compounds on Product-side)
(3) BCE (entire chemical equation)

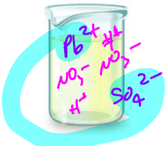
3

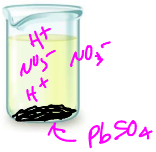
Three Versions of Ionic Equations (each of which serves a different purpose)

① MOLECULAR (or Formula Unit) equation
② TOTAL IONIC equation
③ NET IONIC equation

Pb^{2+} NO_3^-
H^+
NO_3^- H^+ SO_4^{2-}

MOLECULAR > $\overset{2+}{Pb}\overset{-}{(N0_3)_2} + \overset{+}{H_2}\overset{2-}{SO_4} \rightarrow ?? + ??$ $\overset{2+}{Pb}\overset{2-}{SO_4}{}_{(s)} + 2\overset{+}{H}\overset{-}{NO_3}$





spectator ions

TOTAL IONIC > $Pb^{2+} + \cancel{2NO_3^-} + \cancel{2H^+} + SO_4^- \longrightarrow PbSO_{4(s)} + \cancel{2H^+} + \cancel{2NO_3^-}$

solubility table

NET IONIC > $Pb^{2+} + SO_4^- \longrightarrow PbSO_{4(s)}$

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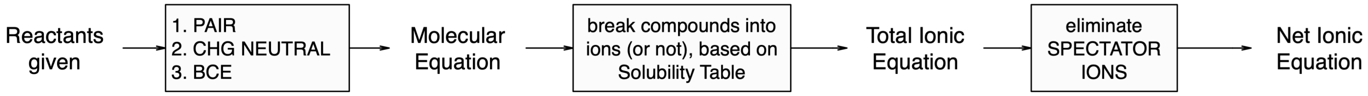

Reactants given
1. PAIR
2. CHG NEUTRAL
3. BCE
Molecular Equation
break compounds into ions (or not), based on Solubility Table
Total Ionic Equation
eliminate SPECTATOR IONS
Net Ionic Equation

Equations for Ionic Reactions

Reactants given → 1. PAIR 2. CHG NEUTRAL 3. BCE → Molecular Equation → break compounds into ions (or not), based on Solubility Table → Total Ionic Equation → eliminate SPECTATOR IONS → Net Ionic Equation

RECALL: ionic compounds are typically
- those composed of metals and non-metals (Type I & II)
- Acids or Bases

Molecular: $Pb(NO_3)_2 + H_2SO_4 \rightarrow 2\,HNO_3 + PbSO_4$

Total Ionic: $Pb^{2+} + 2NO_3^- + 2H^+ + SO_4^{2-} \rightarrow 2H^+ + 2NO_3^- + PbSO_4(s)$

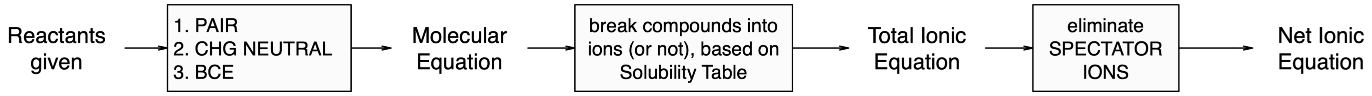
Net Ionic: $Pb^{2+} + SO_4^{2-} \rightarrow PbSO_4(s)$

Does NOT disassociate

SPECTATOR IONS
- cancel-out in Net Ionic
- are neither physically nor chemically changed by the rxn

Additional Information in Chemical Equations

Phase Changes: (s) $\underbrace{(l)\ \ (g)\ \ (aq)}_{\text{vs.}}$



Reactants given → 1. PAIR 2. CHG NEUTRAL 3. BCE → Molecular Equation → break compounds into ions (or not), based on Solubility Table → Total Ionic Equation → eliminate SPECTATOR IONS → Net Ionic Equation

(EX) Determination of Net Ionic Reaction
¿What is the net ionic equation for the following unbalanced equation?

$HCl + Ca(OH)_2 \rightarrow CaCl_2 + H_2O$

$2\,HCl + Ca(OH)_2 \longrightarrow CaCl_2 + 2H_2O$ Molecular

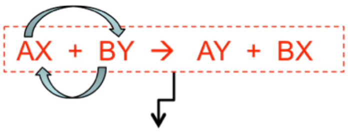
↓

$2H^+ + \cancel{2Cl^-} + \cancel{Ca^{2+}} + 2HO^- \longrightarrow \cancel{Ca^{2+}} + \cancel{2Cl^-} + 2H_2O(l)$ Total Ionic

↓

$2H^+ + 2HO^- \longrightarrow 2H_2O(l)$ Net Ionic

Precipitation Reactions



$AX + BY \rightarrow AY + BX$

Molecular: $Pb(NO_3)_2 + H_2SO_4 \rightarrow 2\,HNO_3 + PbSO_4$

Total Ionic: $Pb^{2+} + 2NO_3^- + 2H^+ + SO_4^{2-} \rightarrow 2H^+ + 2NO_3^- + PbSO_4(s)$

Net Ionic: $Pb^{2+} + SO_4^{2-} \rightarrow \boxed{PbSO_4(s)}$

precipitate

SOLUBLE
- Group 1 cations (LI^+ – CS^+)
- ammonium NH_4^+
- halides Cl^-, Br^-, I^- —> **EXCEPT halides of Ag^+, Hg_2^{2+}, Pb^{2+}**
- acetate $C_2H_3O_2^-$
- bicarbonate HCO_3^-
- nitrate NO_3^-
- chlorate ClO_3^-
- sulfate SO_4^{2-} —> **EXCEPT sulfates of Ag^+, Hg_2^{2+}, Pb^{2+} Ba^{2+}, Ca^{2+}, Sr^2**

IN-SOLUBLE —> **EXCEPT in presence of Group 1 cations and Ammonia**
- carbonate CO_3^{2-}
- chromate CrO_4^{2-}
- phosphate PO_4^{3-}
- sulfide S^{2-}
- hydroxide OH^- —> **EXCEPT hydroxides of Group 1 cations and Ba^{2+}**

Precipitation Reactions and Solubility Rules

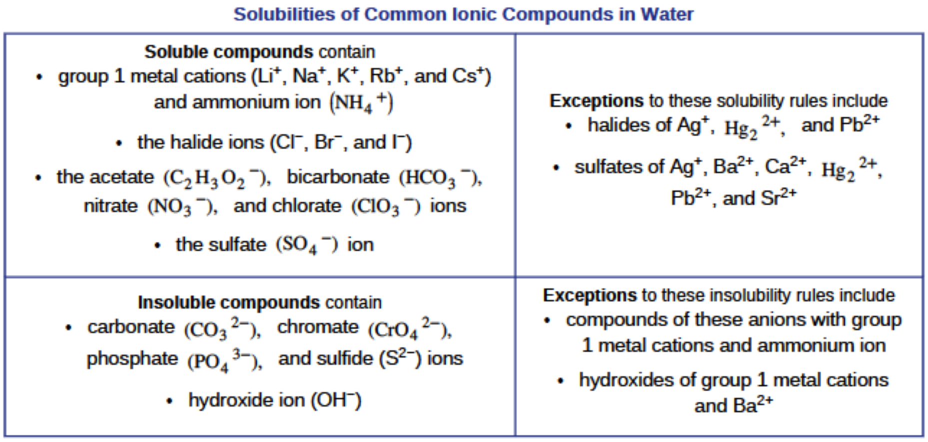
- PRECIPITATION RXN — substance reacts to form solid product

- Examples:
  - KIDNEY STONES (several varieties)

$$Ca^{2+} + C_2O_4^{2-} \rightarrow \underset{\text{calcium oxilate}}{CaC_2O_4} \quad K_{sp} = [Ca^{2+}][C_2O_4^{2-}]$$

  - CORAL REEF: CaCO3 + sea salt + algae for color

- SOLUBILITY / INSOLUBILITY
  - are condition dependent (solube under circumstances, not others)… but…
  - often, cast solubility as simply “Yes/No” or “is soluble / is insoluble”



Solubilities of Common Ionic Compounds in Water

Soluble compounds contain - group 1 metal cations (Li^+, Na^+, K^+, Rb^+, and Cs^+) and ammonium ion $(NH_4{}^+)$ - the halide ions (Cl^-, Br^-, and I^-) - the acetate $(C_2H_3O_2{}^-)$, bicarbonate $(HCO_3{}^-)$, nitrate $(NO_3{}^-)$, and chlorate $(ClO_3{}^-)$ ions - the sulfate $(SO_4{}^-)$ ion	**Exceptions** to these solubility rules include - halides of Ag^+, $Hg_2{}^{2+}$, and Pb^{2+} - sulfates of Ag^+, Ba^{2+}, Ca^{2+}, $Hg_2{}^{2+}$, Pb^{2+}, and Sr^{2+}
Insoluble compounds contain - carbonate $(CO_3{}^{2-})$, chromate $(CrO_4{}^{2-})$, phosphate $(PO_4{}^{3-})$, and sulfide (S^{2-}) ions - hydroxide ion (OH^-)	**Exceptions** to these insolubility rules include - compounds of these anions with group 1 metal cations and ammonium ion - hydroxides of group 1 metal cations and Ba^{2+}

Table 4.1

	Ion	Ion Formula	Soluble	Insoluble	Exceptions
1	sodium ion	Na^+	✓		
2	potassium ion	K^+	✓		
3	ammonium	NH_4^+	✓		
4	nitrate	NO_3^-	✓		
5	acetate	AcO^-	✓		
6	halogen ion	Cl^-, Br^-, I^-	✓		salts with... Ag^+, Hg_2^{2+}, Pb^{2+}
7	sulfate	SO_4^{2-}	✓		salts with… Ba^{2+},Ca^{2+}, Pb^{2+}, Hg^{2+}
8	sulfide	S^{2-}		✓	salts with… Na^+, K^+, NH_4^+, Mg_2^+,Ca_2^+
9	carbonate	CO_3^{2-}		✓	salts with… Na^+, K^+, NH_4^+
10	phosphate	PO_4^{3-}		✓	salts with… Na^+, K^+, NH_4^+
11	arsenate	AsO_4^{3-}		✓	salts with… Na^+, K^+, NH_4^+
12	oxide	O^{2-}		✓	salts with… Group 1 & 2 metals
13	hydroxide	HO^-		✓	strong bases

(EX) Predict PPT Reactions

¿(a) Which solution could be used to precipitate the barium ion, Ba2+ , in a water sample: sodium chloride, sodium hydroxide, or sodium sulfate? (b) What is the formula for the expected precipitate?

(i) $Ba^{2+} + NaCl \rightarrow BaCl_2$ ← soluble

(ii) $Ba^{2+} + NaOH \rightarrow Ba(OH)_2$ ← soluble

(iii) $Ba^{2+} + NaSO_4 \rightarrow \boxed{BaSO_4}$ ← precipitates

Acid-Base Reactions

H^+
H_3O^+
HO^-

- ACID-BASE REACTION
  - ↳ hydrogen ion (aka proton), H^+, is transferred, or
  - ↳ hydronium ion, H_3O^+, is transferred
- ARRHENIUS ACID – donates H^+ in water
- ARRHENIUS BASE – donates hydroxide ion, OH^- (aka HO^-), in water

$HA \rightarrow A^- + \boxed{H^+}$
$BOH \rightarrow B^+ + \boxed{HO^-}$

$H^{+} | OH^{-}$

Strong vs. Weak Acids

↳ STRONG ACID – dissociates 100%
↳ WEAK ACID – dissociates <100%

Strong

	HA	→	H^+	+	A^-
I:	100		0		0
E:	0		100		100

Weak

	HA	→	H^+	+	A^-
I:	100		0		0
E:	95		5		5

8 STRONG BASES

Hydroxides of …

① Li
② Na
③ K
④ Rb
⑤ Cs
⑥ Ba
⑦ Sr
⑧ Ca

7 STRONG ACIDS

① HNO_3
② H_2SO_4
③ $HClO_4$
④ $HClO_3$
⑤ HCl
⑥ HI
⑦ HBr

$CH_3CO_2H \rightarrow CH_3CO_2^- + H^+$

100 95 5

$HCl \Rightarrow H^+ + Cl^-$

HCl	H^+	Cl^-
100	0	0
0	100	100

Generic Acid-Base Reaction

general reaction

$\overset{+}{H}\overset{-}{A} + \overset{+}{B}\overset{-}{OH} \rightarrow BA + H_2O$

acid + base → salt + water

SALT = cation other than H^+ + anion other than HO^-

$NaCl$ = table salt

$MgSO_4$ = epsom salt

NOMENCLATURE = Type I and Type II

eg: $HCl + NaOH \rightarrow NaCl + H_2O$

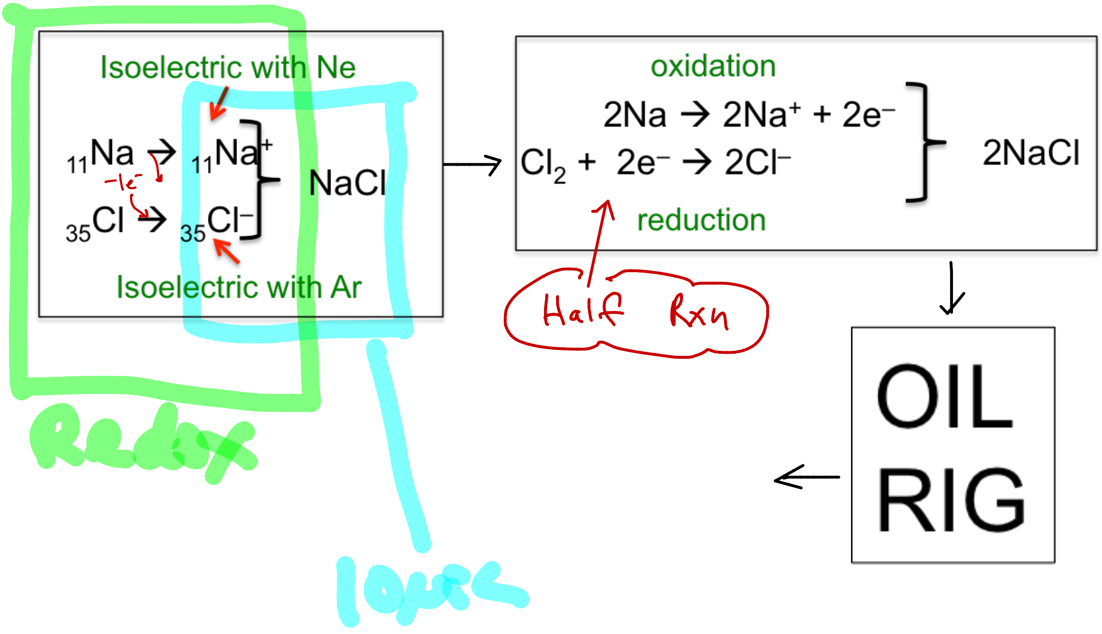
Acid-Base Reaction is a type of Double Displacement

Molecular: $Ba(OH)_2 + 2HNO_3 \rightarrow 2H_2O_{(l)} + Ba(NO_3)_2$

Total Ionic: $\cancel{Ba^{2+}} + 2HO^- + 2H^+ + 2\cancel{NO_3^-} \rightarrow 2H_2O_{(l)} + \cancel{Ba^{2+}} + 2\cancel{NO_3^-}$

Net Ionic: $2HO^- + 2H^+ \rightarrow 2H_2O$

Oxidation-Reduction Reactions (buckle up… here's where it starts to get hairy)



Isoelectric with Ne

$_{11}Na \rightarrow {}_{11}Na^+$

$_{35}Cl \rightarrow {}_{35}Cl^-$

NaCl

Isoelectric with Ar

oxidation

$2Na \rightarrow 2Na^+ + 2e^-$

$Cl_2 + 2e^- \rightarrow 2Cl^-$

reduction

2NaCl

OIL RIG

Definition: REDOX

- OXIDATION = ⬆ O.N.
- REDUCTION = ⬇ O.N.

OIL } electron flow (−) is opposite the
RIG } direction of O.N (+)

“AGENTS” (facilitates an action): What it is, not what it does

- Oxidizing agent (OXIDANT) = species that causes something else to become oxidized ... it is, itself, reduced.

- Reducing agent (REDUCTANT) = species that causes something else to become reduced... it is, itself, oxidized.

Oxidation Numbers

oxidation number (oxidation state) — charge atom would bear if it were part of an ionic compound.

Rules for Assigning ON’s

1. The oxidation number of an atom in an elemental substance is zero.
2. The oxidation number of a monatomic ion is equal to the ion’s charge.
3. Oxidation numbers for common nonmetals are usually assigned as follows:
    - Hydrogen: +1 when combined with nonmetals, –1 when combined with metals
    - Oxygen: –2 in most compounds, sometimes –1 (so-called peroxides, O 2 2–), very rarely – 1 (so-2 called superoxides, O 2 –), positive values when combined with F (values vary)
    - Halogens: –1 for F always, –1 for other halogens except when combined with oxygen or other halogens (positive oxidation numbers in these cases, varying values)
4. The sum of oxidation numbers for all atoms in a molecule or polyatomic ion equals the charge on the molecule or ion.
5. GROUP 1 = +1
6. GROUP 2 = +2
7. GROUP 3 = usually +3
8. Transition metals - Type I / Type II rules as guidance
9. Polyatomic Ions considered as SINGLE GROUP.

(EX) Assign ON’s. [4.5b]
¿Assign oxidation states to the elements whose atoms are underlined in each of the following compounds or ions:

ⓐ

+1	+5	−6	= 0
K^{+}_{1}	$N^{\square}_{1}$	O^{2-}_{3}	

$1 \times \boxed{5} = 5$

ⓑ

+3	−3	= 0
Al^{3+}_{1}	$H^{\square}_{3}$	

← total CHG
← ON
← sub

$3 \times \boxed{-1} = -3$

ⓒ

−3	+4	= +1
N_{1}	H^{+}_{4}	+

$1 \times \boxed{-3} = -3$

ⓓ

+2	+5	−8	= −1
H^{+}_{2}	$P^{\square}_{1}$	O^{2-}_{4}	−

$1 \times \boxed{+5} = 5$

COMBUSTION REACTION (Redox subclass)

- Reaction of fuel
- ex: hydrocarbon (HC) + oxidant (esp. O_2)

4 Types of “REDOX questions. (easier to harder)

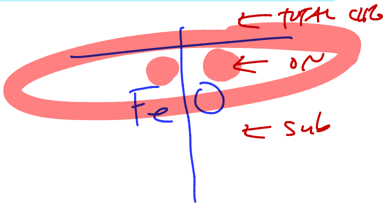
(1) Is this reaction a redox?
(2) What is oxidized? (or, What is reduced?)
(3) What is oxidizing agent? (or, What is reducing agent?)
(4) How many electrons are transferred

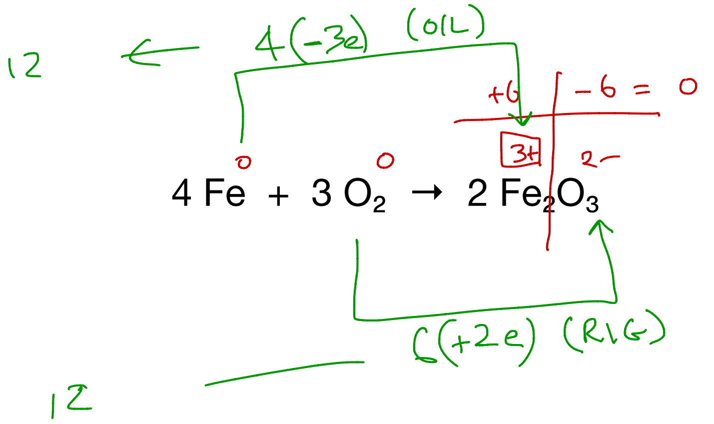
<see example problem next page>

Thur, Oct 3

(EX) I.D. Redox Combustion Rxn Components

¿Consider the formation of a rust from a pure iron, according to the following equation. What is... (a) the material that is reduced?; (b) the material that is oxidized?; (c) how many electrons were transferred?; (d) the oxidizing agent?; (e) the reducing agent?



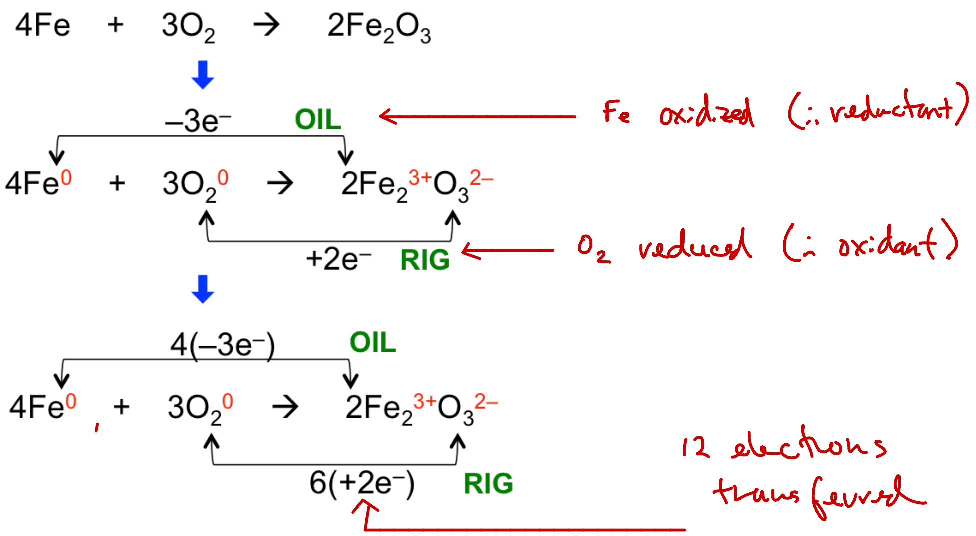


$$4\,Fe + 3\,O_2 \rightarrow 2\,Fe_2O_3$$

⬇ <see answer next page>

(EX) I.D. Redox Combustion Rxn Components

¿Consider the formation of a rust from a pure iron, according to the following equation. What is... (a) the material that is reduced?; (b) the material that is oxidized?; (c) how many electrons were transferred?; (d) the oxidizing agent?; (e) the reducing agent?



$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

$$4Fe^0 + 3O_2^0 \rightarrow 2Fe_2^{3+}O_3^{2-}$$

Fe oxidized (∴ reductant)

O_2 reduced (∴ oxidant)

$$4Fe^0 + 3O_2^0 \rightarrow 2Fe_2^{3+}O_3^{2-}$$

12 electrons transferred

TIP: any reaction which forms a compound from an element (or vice versa) is necessarily a REDOX reaction

Single-Displacement (Replacement) Reaction: another REDOX subclass:

↳ only 1 moitey displaced
↳ especially common reactions with METALS

$$Zn + 2\,HCl \rightarrow ZnCl_2 + H_2\uparrow$$

$$Cu + 2\,AgNO_3 \rightarrow Cu(NO_3)_2 + 2\,Ag$$

Balancing Redox Reactions via the Half-Reaction Method

(page 189/196)

<‘BALANCING REDOX EQUATIONS’ NOT COVERED ON THIS EXAM>

Notes - Part "a" //

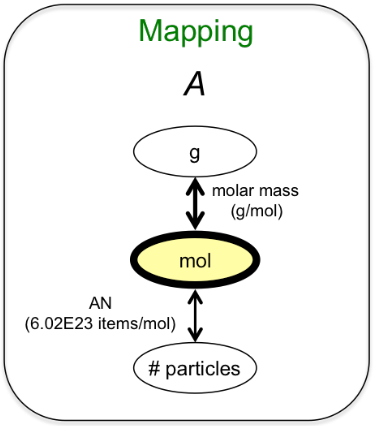
Reaction Stoichiometry [4.3]

Review from Last Chapter

☐ g   128 g   ☐ g

~~atoms~~ moles → $2 H_2 + O_2 \rightarrow 2 H_2O$

② Scale Up   ① Count-by-Weighting

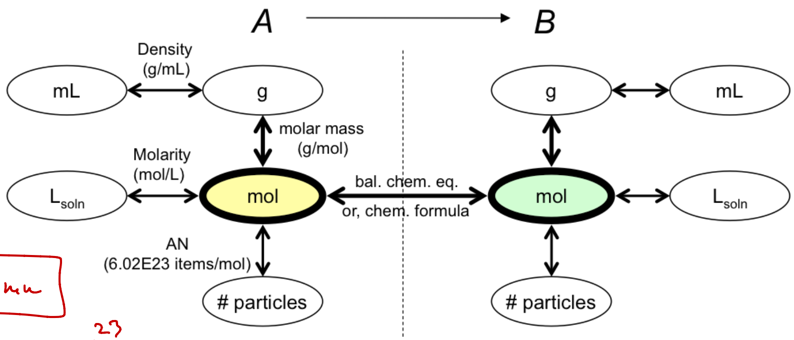


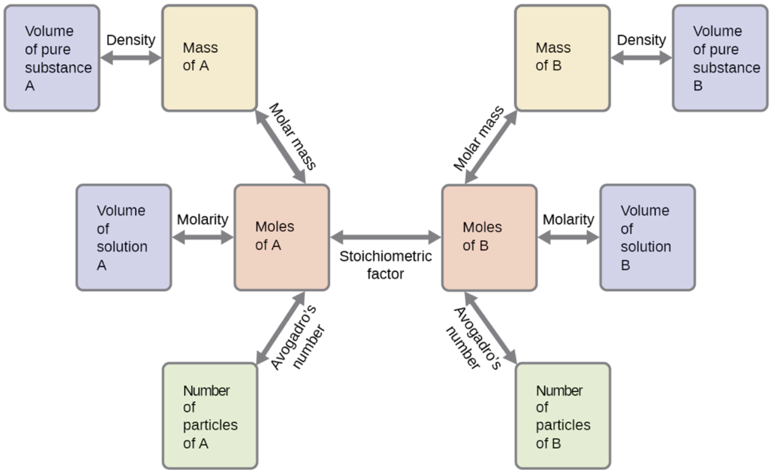
1 atoms — 12 amu

×6.02×10^23 (AN)

1 mol — 12g

pt





Volume of pure substance A

Density

Mass of A

Molar mass

Volume of solution A

Molarity

Moles of A

Stoichiometric factor

Moles of B

Molarity

Volume of solution B

Molar mass

Mass of B

Density

Volume of pure substance B

Avogadro's number

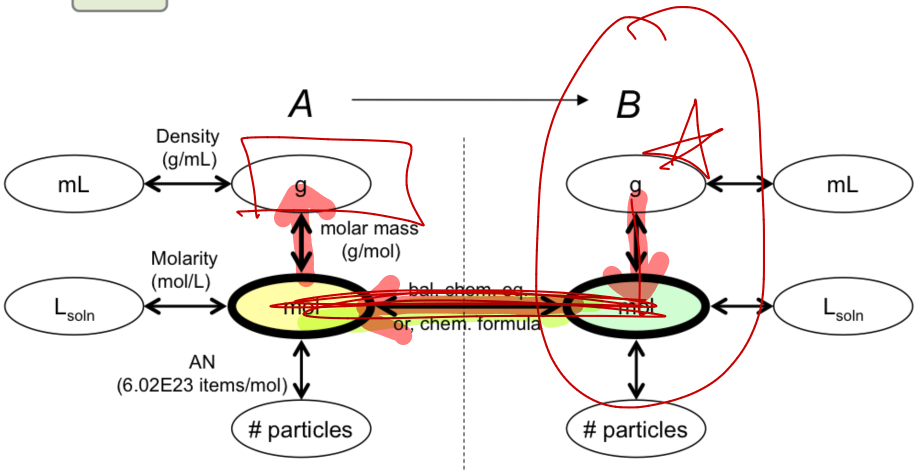
Number of particles of A

Avogadro's number

Number of particles of B

Figure 4.10. (OpenStax)

Possibly, the most important diagram in the textbook



A → B

Density (g/mL)

mL ↔ g

molar mass (g/mol)

Molarity (mol/L)

L_{soln} ↔ mol

bal. chem. eq. or, chem. formula

AN (6.02E23 items/mol)

particles

g ↔ mL

L_{soln} ↔ mol

particles

(EX) ‘gram-to-gram’ Stoichiometry Problem

¿For the synthesis of water from hydrogen and oxygen, how many grams of hydrogen are required to react with 128 g of oxygen, ?

when what

PC, MM

16 ☐ g   128 g ★   ☐ g

$$2H_2 + O_2 \longrightarrow 2H_2O$$

$$\frac{\square\ g, H_2}{1} = \frac{128\ g, O_2}{1} \bigg| \frac{1\ mol\ O_2}{32\ g, O_2} \bigg| \frac{2\ mol\ H_2}{1\ mol\ O_2} \bigg| \frac{2.0\ g\ H_2}{1\ mol\ H_2} = 16$$

H_2O

$2(1) + 1(16)$

$= 18$

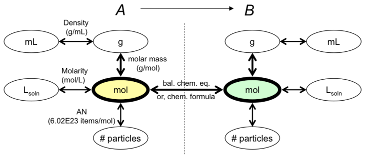
$$?\ gH_2 = 128gO_2 \cdot \frac{1molO_2}{32gO_2} \cdot \frac{2molH_2}{1molO_2} \cdot \frac{2gH_2}{1molH_2} = 16gH_2$$

$$?\ gH_2O = 128\ gO_2 \cdot \frac{1\ molO_2}{32\ gO_2} \cdot \frac{2\ molH_2O}{1\ molO_2} \cdot \frac{18\ gH_2O}{1\ molH_2O} = 144\ gH_2O$$

$$\frac{\square}{1} = \frac{★}{1} \bigg| \quad \bigg| \quad \bigg| \quad \bigg| \quad$$

(EX) g(a) —> g(b) [4.11b]

¿What mass of CO is required to react with 25.13 g Fe2O3 according to the equation:



□, ☆

$\frac{\square}{1} = \frac{\star ++|}{1}$

25.13g ☐ g

$$Fe_2O_3 + 3\,CO \rightarrow 2\,Fe + 3\,CO_2$$

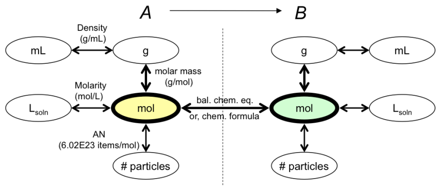
$$\square g_{CO} = \frac{25.13\,g_A}{} \left|\frac{mol_A}{159.7\,g_A}\right| \frac{3\,mol\,CO}{1\,mol_A} \left|\frac{28.01g\,CO}{1\,mol\,CO}\right. = \boxed{13.22g}$$

(EX) g(a) —> g(b) [4.11b]

¿What mass of SO2 contains the same mass of oxygen as is contained in 33.7 g of As2O5?

$$As_20_5 \rightarrow O \rightarrow SO_2$$

☐ g



$$?\ \underline{g\cdot SO_2} = \frac{33.7\ g\cdot As_2O_5}{1} \bullet \frac{1\ mol\cdot As_2O_5}{229.8\ g\cdot As_2O_5} \bullet \frac{5\ mol\cdot O}{1\ mol\cdot As_2O_5} \bullet \frac{1\ mol\cdot SO_2}{2\ mol\cdot O} \bullet \frac{64.1\ g\cdot SO_2}{1\ mol\cdot SO_2} = 23.5\ g\cdot 'S'$$

Reaction Yields [4.4]

Limiting Reactant

2 bread	+	1 meat	→	1 sandwich
14		4		??? 7
				4

CLAIM: with 14 slices of bread and 4 slices of meat, I can make 7 sandwiches

ARGUMENT:

$$??sand = \frac{14\ bread}{} \cdot \frac{1\ sandwich}{2\ bread} = 7\ sandwiches$$

COUNTER ARGUMENT:

$$??sand = \frac{4\ meat}{} \cdot \frac{1\ sandwich}{1\ meat} = 4\ sandwiches$$

ANSWER: cannot make more product than the material in least supply (*Limiting Reagent*) will allow.

$$\frac{\square \text{ sand}}{1} = \frac{4 \text{ meat}}{} \bigg| \frac{1 \text{ sand}}{1 \text{ meat}} = \boxed{4 \text{ sand}}$$

$$\frac{\square \text{ sand}}{1} = \frac{14 \text{ bred}}{} \bigg| \frac{1 \text{ sand}}{2 \text{ bred}} = 7 \text{ sand}$$

(EX) ID Limiting Reagent

$$\overset{38.0\text{ g}}{2H_2} + \overset{225\text{ g}}{O_2} \longrightarrow \overset{\square\text{ g}}{2H_2O}$$

$$2H_2 + O_2 \rightarrow 2H_2O$$

$$??gW = \frac{38.0gH_2}{} \cdot \frac{1molH_2}{2.02gH_2} \cdot \frac{2molH_2O}{2molH_2} \cdot \frac{18.0gH_2O}{1molH_2O} = 339gH_2O$$

$$??gW = \frac{225gO_2}{} \cdot \frac{1molO_2}{32.00gO_2} \cdot \frac{2molH_2O}{1molO_2} \cdot \frac{18.0gH_2O}{1molH_2O} = 253gH_2O$$

LIMITING

(EX) Calculate Excess of Excess Reagent
¿EXCESS: back-calculate to find the am. of Excess Reagent needed to make the lesser amt of product, then subtract from the amt. of Excess Reagent available at the start?

Back-c

start → 38.0 g ~~225 g~~ 253. ☐ g
used → $\boxed{28}$.4g

$2H_2$ + O_2 —> $2H_2O$

$$??\,gH_2 = \frac{253gH_2O}{} \cdot \frac{1molH_2O}{18.0gH_2O} \cdot \frac{2molH_2}{2molH_2O} \cdot \frac{2.02gH_2}{1molH_2} = 28.4gH_2$$

$$??\,gH_2(excess) = 38.0 - 28.4 = 9.6gH_2$$

Percent Yield

lab

$$\%Yield = \frac{actual\ \ (measured)}{theoretical\ (calculated)} \cdot 100$$

stoichiometric calc

(EX) Calculate % Yield from grams of reactant
¿What is the % yield of a rxn that produces 12.5 g of the gas Freon from 32.9 g of CCl4 in excess HF?

<see answer next page> ⬇

LECTURE STOP

⬆

(EX) Calculate % Yield from grams of reactant
¿What is the % yield of a rxn that produces 12.5 g of the gas Freon from 32.9 g of CCl4 in excess HF?

25.9g (theo)

32.9 g excess 12.5 g (measured)

$CCl_4 + 2HF \rightarrow CF_2Cl_2 + 2HCL$

start with answer, &
work backwards;
only unknown

(1) $\%Yield = \frac{12.5g}{???\ theoretical} \cdot 100$

(2) $??gCF_2Cl_2 = \frac{32.9gCCl_4}{} \cdot \frac{1\,molCCl_4}{153.82gCCl_4} \cdot \frac{1\,molCF_2Cl_2}{1\,molCCl_4} \cdot \frac{120.91gCF_2Cl_2}{1\,molCF_2Cl_2} = 25.9gCF_2Cl_2$

(3) $\%Yield = \frac{12.5g}{25.9g} \cdot 100 = 48.3\%$

Tue, Oct 8

(EX) Calculate % Yield from given amount of product
¿If you ran this reaction with 128 g of oxygen, but you only recovered 105 g of water, how well did you do?

$$2H_2 + \overset{128\text{ g}}{O_2} \longrightarrow \overset{\text{ther}}{\boxed{}}\; 2H_2O \qquad ??\text{ g}$$

$$\boxed{\%Y} = \frac{\overset{105\text{ g}}{\text{exp}}}{\cancel{16.0\text{ g}}\ \text{ther}} \times 100$$

$$\overset{16.0\text{ g}}{2H_2} + \overset{128\text{ g}}{O_2} \rightarrow \overset{\overset{105\text{ g}}{144\text{ g}}}{2H_2O}$$

$$\%\ Yield = \frac{part}{whole}\cdot 100 = \frac{105}{144}\cdot 100 = 0.6935\cdot 100 = 69.3\ \%$$

Quantitative Chemical Analysis [4.5]

QUANTITATIVE ANALYSIS — det'n of amt of material present.

(1) Titration,
(2) Gravimetric, &
(3) Combustion

mL_B

M_B

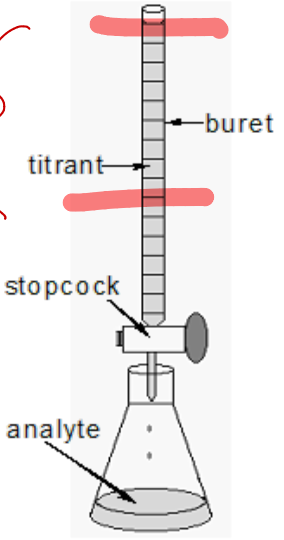


Figure 1: Titration Setup

Titration

DESCRIPTION: a known amount of Titrant (known conc) is added to a known amount of Analyte (unknown conc) until the Equivalence Point (point at which the amount of Titrant and Analyte are equal, per Indicator at the End Point).

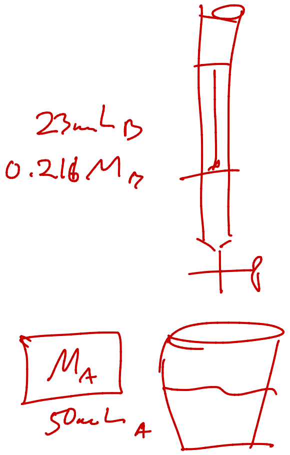
$\boxed{M_A}$

mL_A

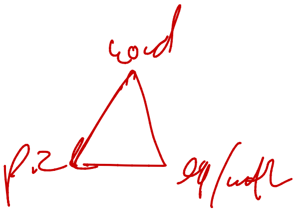
$$M_A V_A = M_B V_B$$

(EX) Calculate Molarity and g(Titrant used)
¿50.0 mL of HCl is titrated to the equivalence point with 23.4 mL of 0.216 M NaOH. What is the molarity of the HCl solution?

HCl + NaOH → NaCl + H_2O

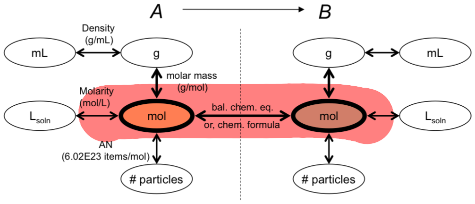


M•V = M’•V’
50.0•X = 23.4•0.216
X = 0.101 M



(b) ¿How many grams of HCl were in the titrated sample?

- HINT: For “calc g” problems, use DA/mapping



50.0 mL

23.4 mL
0.216 mol/L

$HCl + NaOH \rightarrow NaCl + H_20$

$$??g_a = \frac{23.4mL_b}{1000mL_b} \cdot \frac{0.216\ mol_b}{1000mL_b} \cdot \frac{1\ mol_a}{1\ mol_b} \cdot \frac{36.46g_a}{1\ mol_a} = 0.184g_a$$

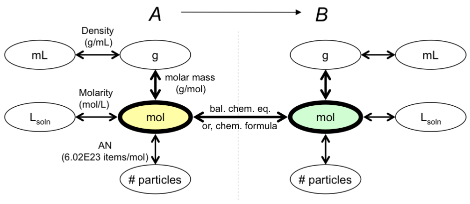
Gravimetric Analysis

↳ based on CHANGE IN MASS (which affects the pull of Gravity)
↳ ex: dehydration
WATER LOSS = mass(before) – mass(after)

(EX) Gravimetric Analysis: Calc Amount of Reactant Based on Product Precipitate [4.15b]

¿What is the % of chloride ion in a sample if 1.1324 g of the sample precipitates 1.0881 g of AgCl when treated with excess Ag+?

$$\overbrace{\mathrm{Ag^+}(aq) + \mathrm{Cl^-}(aq)}^{1.1324\ \mathrm{g}} \rightarrow \overset{1.0881\ \mathrm{g}}{\mathrm{AgCl}(s)}$$



ⓐ

$$?\ \frac{g_{Cl^-}}{1} = \frac{1.0881\ g_{AgCl}}{1} \bullet \frac{1\ mol_{AgCl}}{143.32\ g_{AgCl}} \bullet \frac{1\ mol_{Cl^-}}{1\ mol_{AgCl}} \bullet \frac{35.45\ g_{Cl^-}}{1\ mol_{Cl^-}} = 0.2691\ g_{Cl^-}$$

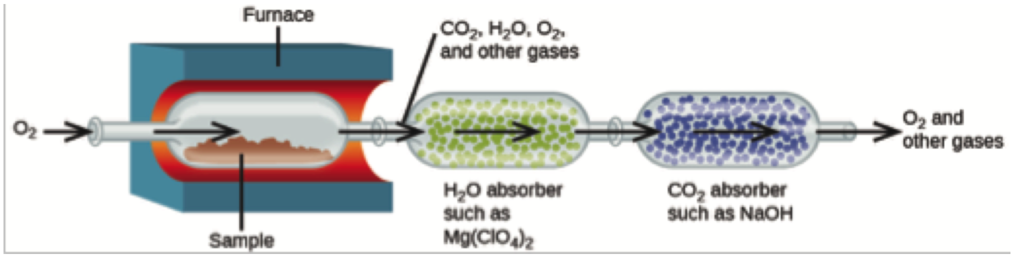
ⓑ

$$\%\ Cl = \frac{0.2691g}{1.1324} \cdot 100 = 23.76\ \%$$

Combustion Analysis

- Oxidizes hydrocarbon (reacts with O2) to blast material into pieces, then in captures those H2O and CO2 pieces.
  - ↳ H2O gives measure of H
  - ↳ CO2 given measure of C

$$2\,C_2H_6 + 7\,O_2 \rightarrow 4\,CO_2 + 6\,H_2O$$



weight (before - after)

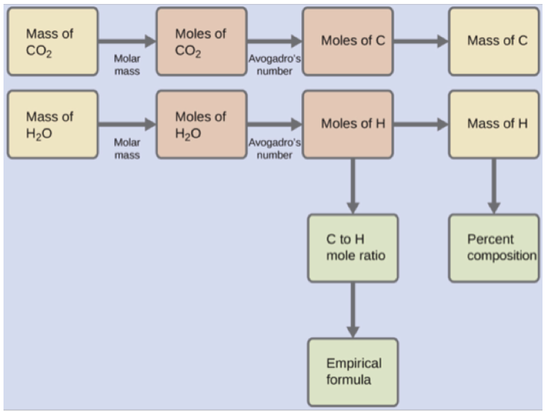
Δ - H_2O

weigh (before - after)

$\Delta = CO_2$

(EX) Calculate Emp. Formula from Combustion Data [4.16b]
¿A 0.00215-g sample of polystyrene, a polymer composed of carbon and hydrogen, produced 0.00726 g of CO_2 and 0.00148 g of H_2O in a combustion analysis. What is the empirical formula for polystyrene?

C_xH_y ← TARGET



(i) $$\square \text{ mole C} = \begin{array}{c|c|c} 0.00726\text{ g } CO_2 & 1\text{ mol } CO_2 & 1\text{ mol C} \\ \hline & 44.01\text{ g} & 1\text{ mol } CO_2 \end{array} = 1.65E{-4}\text{ mol C}$$

(ii) $$\square \text{ mol H} = \begin{array}{c|c|c} 0.00148\text{ g W} & 1\text{ mol W} & 2\text{ mol H} \\ \hline & 18.02\text{ g W} & 1\text{ mol W} \end{array} = 1.64E{-4}\text{ mol H}$$

(iii) $$C_xH_y \Rightarrow C_{\frac{1.65E-4}{1.64E-4}}H_{\frac{1.64E-4}{1.64E-4}} \Rightarrow C_1H_1 \Rightarrow \boxed{CH}$$