# FORMATION OF STABLE MOLECULES

- There are several stable molecules that may be formed in double replacement reactions, but the most common is WATER!

- Double replacement reactions that form water are also called "neutralizations"

$$\underset{\text{acid}}{HA} + \underset{\text{base}}{BOH} \longrightarrow H_2O + \underset{\text{salt}}{BA}$$

$$H^+ \; A^- \qquad B^+ \; OH^-$$

"HOH"

# ACIDS

- compounds that release hydrogen ion ($H^+$), when dissolved in water.

## Properties of acids:

- Corrosive: React with most metals to give off hydrogen gas
- Cause chemical burns on contact
- Taste sour (like citrus - citric acid!)
- Changes litmus indicator to RED

# BASES

- Substances that release hydroxide ion ($OH^-$) when dissolved in water

## Properties of bases:

- Caustic: Attack and dissolve organic matter (think lye, which is NaOH)
- Cause skin/eye damage on contact
- Taste bitter
- changes litmus indicator to BLUE

Examples of acid-base chemistry:

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow 2H_2O(l) + Na_2SO_4(aq)$$

$H^+$ $SO_4^{2-}$ $Na^+$ $OH^-$

$Na^+$ $SO_4^{2-}$

$Na^+$

Use the SOLUBILITY CHART on p170 of your textbook to predict whether these substances dissolve!

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$$HCl(aq) + NH_4OH(aq) \longrightarrow H_2O(l) + NH_4Cl(aq)$$

$H^+$ $Cl^-$ $NH_4^+$ $OH^-$

# DOUBLE REPLACEMENTS THAT FORM GASES

1. Formation of hydrogen sulfide: $H_2S$

   - need an ACID (source of hydrogen ion) and a SULFIDE

$$H_2SO_4(aq) + Na_2S(aq) \longrightarrow Na_2SO_4(aq) + H_2S(g)$$

$H^+$ $SO_4^{2-}$ $Na^+$ $S^{2-}$

$H^+$ $S^{2-}$
$H^+$

2. Formation of carbonic acid and carbon dioxide:

   - Carbonic acid DECOMPOSES when formed in double replacement reactions!

$$H_2CO_3(aq) \longrightarrow H_2O(l) + CO_2(g)$$

   - to form carbonic acid by double replacement, you need a source of hydrogen ion (ACID) and a source of carbonate (can be CARBONATE or BICARBONATE)

$CO_3^{2-}$ $HCO_3^-$

Example of a reactions that forms carbonic acid, then gas: The "baking soda volcano"!

VINEGAR

BAKING SODA

$$2HC_2H_3O_2(aq) + Na_2CO_3(aq) \rightarrow 2NaC_2H_3O_2(aq) + \boxed{H_2CO_3}$$

$H^+$ $C_2H_3O_2^-$ $Na^+$ $CO_3^{2-}$

$H^+$ $CO_3^{2-}$

$H^+$

$$\boxed{2HC_2H_3O_2(aq) + Na_2CO_3(aq) \rightarrow 2NaC_2H_3O_2(aq) + H_2O(l) + CO_2(g)}$$

This is the overall process. We show carbon dioxide and water as products, since we want to show the reaction as it's actually observed -with carbonic acid broken down to water and (gaseous) carbon dioxide.

# CHEMICAL CALCULATIONS - RELATING MASS AND ATOMS

$$Na_2CO_3 + 2HCl \longrightarrow H_2O + CO_2 + 2\,NaCl$$

Chemical equations are written and balanced in terms of ATOMS and MOLECULES

- While chemical equations are written in terms of ATOMS and MOLECULES, that's NOT how we often measure substances in lab!

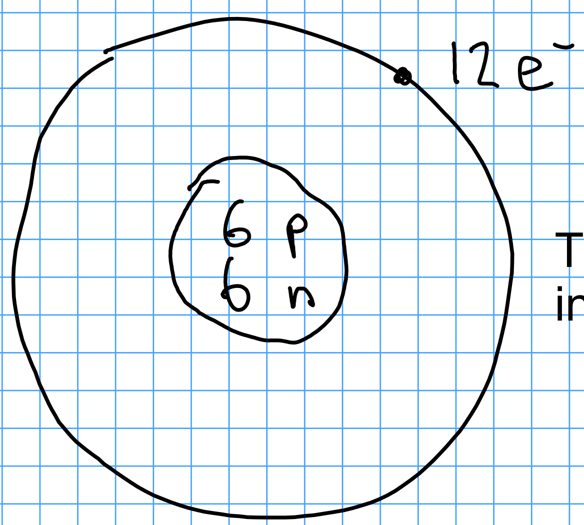
- measurements are usually MASS (and sometimes VOLUME), NOT number of atoms or molecules!

# THE MOLE CONCEPT

- A "mole" of atoms is $6.022 \times 10^{23}$ atoms

Why so big? Because atoms are so small!

- Why - in the metric dominated world of science - do we use such a strange number for quantity of atoms?




carbon-12

The mole is also defined as the number of carbon-12 atoms in exactly 12 g of carbon-12

# THE MOLE CONCEPT

- Why define the mole based on an experimentally-measured number?

- The atomic weight of an element (if you put the number in front of the unit GRAMS) is equal to the mass of ONE MOLE of atoms of that element!

Carbon (C): Atomic mass 12.01 ~~amu~~ → $\boxed{12.01\ g}$

the mass of ONE MOLE of naturally-occurring carbon atoms

Magnesium (Mg): 24.31 g = the mass of ONE MOLE OF MAGNESIUM ATOMS

- So, using the MOLE, we can directly relate a mass and a certain number of atoms!

# RELATING MASS AND MOLES

- Use DIMENSIONAL ANALYSIS (a.k.a "drag and drop")

- Need CONVERSION FACTORS - where do they come from?

- We use ATOMIC WEIGHT as a conversion factor.

Mg = 24.31 | 24.31 g Mg = 1 mol Mg

"mol" is the abbreviation for "mole"

Example: How many moles of atoms are there in 250. g of magnesium metal?

24.31 g Mg = 1 mol Mg

$$250.\,\cancel{g\ Mg} \times \frac{1\ mol\ Mg}{24.31\ \cancel{g\ Mg}} = \boxed{10.3\ mol\ Mg}$$

Example: You need 1.75 moles of iron. What mass of iron do you need to weigh out on the balance?

$55.85\,g\ Fe = 1\ mol\ Fe$

$$1.75\ \cancel{mol\ Fe} \times \frac{55.85\,g\ Fe}{1\ \cancel{mol\ Fe}} = \boxed{97.7\,g\ Fe}$$

# WHAT ABOUT COMPOUNDS? FORMULA WEIGHT

Example: 25.0 g of WATER contain how many MOLES of water molecules?

$H_2O$ H: 2 x 1.008 = 2.016

O: 1 x 16.00 = 16.00

18.016 ← formula weight of water!

Formula weight = mass of one mole of an element OR compound

18.016 g $H_2O$ = 1 mol $H_2O$

$$25.0\,g\,\cancel{H_2O} \times \frac{1\,mol\,H_2O}{18.016\,g\,\cancel{H_2O}} = \boxed{1.39\,mol\,H_2O}$$

Formula weight goes by several names:

- For atoms, it's the same thing as ATOMIC WEIGHT
- For molecules, it;s called MOLECULAR WEIGHT
- Also called "MOLAR MASS"

Example: How many grams of ammonium carbonate do we need to weigh out to get 3.65 moles of ammonium carbonate?

$NH_4^+$ $CO_3^{2-}$

$NH_4^+$

$(NH_4)_2CO_3$

N: 2 x 14.01
H: 8 x 1.008
C: 1 x 12.01
O: 3 x 16.00

96.094

$$96.094\,g\,(NH_4)_2CO_3 = 1\,mol\,(NH_4)_2CO_3$$

$$3.65\,\cancel{mol\,(NH_4)_2CO_3} \times \frac{96.094\,g\,(NH_4)_2CO_3}{1\,\cancel{mol\,(NH_4)_2CO_3}} =$$

$$\boxed{351\,g\,(NH_4)_2CO_3}$$