DETERMINING IONIC FORMULAS

sodium sulfate

Na^{+} SO_4^{2-}

Na^{+}

Na_2SO_4

strontium oxide

Sr^{2+} O^{2-}

SrO

tin(II) phosphate

Sn^{2+} PO_4^{3-}

Sn^{2+} PO_4^{3-}

Sn^{2+}

$Sn_3(PO_4)_2$

chromium(III) nitrate

Cr^{3+} NO_3^{-}

NO_3^{-}

NO_3^{-}

$Cr(NO_3)_3$

barium hydroxide

Ba^{2+} OH^{-}

OH^{-}

~~$BaOH_2$~~

$Ba(OH)_2$

titanium(IV) chloride

Ti^{4+} Cl^{-}

Cl^{-}

Cl^{-}

Cl^{-}

$TiCl_4$

Note: Be careful when adding subscripts to HYDROXIDE, CYANIDE, and HYPOCHLORITE ions. You need to add parenthesis to indicate more than one of any polyatomic ion, even if that ion doesn't end with its own subscript!

HYDRATES

- many ionic compounds are formed by crystallizing the compound from water. Sometimes, this causes water molecules to become part of the crystal structure.

- This water is present in a definite ratio to the ions in the compound. Can be removed by heating, but will NOT evaporate if the compound is left standing.

ex: $CuSO_4 \cdot 5H_2O$

\# water molecules per formula unit of compound

dot indicates that the water is weakly bound to the ionic compound

- many DESSICANTS are hydrates that have had their water molecules driven off. They will slowly reabsorb water from the air (and keep the environment in a dessicator at a low humidity)

- Hydrates are named using the name of the ionic compound, and a Greek prefix in front of the word "hydrate" to indicate how many water molecules are associated

Cu^{2+} SO_4^{2-}

Why "copper(II)"?

copper (II) sulfate pentahydrate

MOLECULAR COMPOUNDS

- There are several kinds of molecular compound. We will learn to name two simple but important classes

(1) BINARY MOLECULAR COMPOUNDS

- molecular compounds containing only two elements

(2) ACIDS

- molecular compounds that dissolve in water to release H^+ ions
- corrosive to metals (react with many to produce hydrogen gas)
- contact hazard: can cause chemical burns to eyes and skin
- sour taste
- turn litmus indicator RED
- two kinds of acids:

(1) BINARY ACIDS

- contain hydrogen and one other element (Usually from Group VIIA)

(2) OXYACIDS

- contain hydrogen, OXYGEN, and another element

BINARY MOLECULAR COMPOUNDS

- Named based on the elements they contain, plus prefixes to indicate the number of atoms of each element in each molecule

(1) FIRST ELEMENT

- Add a GREEK PREFIX to the name of the element.
- Omit the "MONO-" (1) prefix if there is only one atom of the first element

(2) SECOND ELEMENT

- Add a GREEK PREFIX to the STEM NAME of the element
- Add the suffix "-ide" (as if you were naming an anion)
- DO NOT omit the "mono-" prefix if there is only one atom of the second element

SEE COURSE WEB SITE FOR A LIST OF GREEK PREFIXES!
THESE ARE THE SAME PREFIXES USED FOR THE HYDRATES!

BINARY MOLECULAR COMPOUNDS

Examples:

BF_3	Cl_2O_7	CO	CO_2
boron trifluoride	dichlorine hept(a)oxide	carbon monoxide	carbon dioxide

*Note: metalloids like boron behave chemically like nonmetals do.

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carbon tetrachloride	dihydrogen monoxide	dinitrogen tetrafluoride
CCl_4	H_2O	N_2F_4

ACIDS

(1) BINARY ACIDS

- named after the element (other than hydrogen) they contain
- common binary acids include a Group VIIA element
- named: "Hydro-" + STEM NAME OF ELEMENT+ "-ic acid"

Four common binary acids

- HF: hydrofluoric acid * dissolves glass!
- HCl: hydrochloric acid * most common binary acid!
- HBr: hydrobromic acid
- HI: hydroiodic acid

ACIDS

(2) OXYACIDS

- Easy to think about as HYDROGEN IONS combined with POLYATOMIC IONS

- These acids are not true ionic compounds, but they interact with water to PRODUCE ions!

- named based on the polyatomic ion they contain, with an ending change:

(1) - ions ending in -ATE form acids ending in -IC

(2) - ions ending in -ITE form acids ending in -OUS

H_2SO_4 (sulfATE) — sulfuric acid

H_3PO_4 (phosphATE) — phosphoric acid

H_2SO_3 (sulfITE) — sulfurous acid

HNO_3 (nitrate) — nitric acid

OXYACID EXAMPLES

↙ based on acetATE

acetic acid

$H^+ \quad C_2H_3O_2^-$

$HC_2H_3O_2$

↙ based on nitrITE

nitrous acid

$H^+ \quad NO_2^-$

HNO_2

↙ based on carbonATE

carbonic acid

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

H^+

H_2CO_3

The number of hydrogen atoms at the beginning of the formula equals the charge of the anion the acid is based on!

SUMMING UP CHEMICAL NOMENCLATURE

- You need to be able to tell, by looking at a name OR a formula, what kind of compound you are working with!

DON'T GET THE NAMING SYSTEMS MIXED UP! EACH KIND OF COMPOUND IS NAMED WITH ITS OWN SYSTEM!

FROM A CHEMICAL NAME

- If the name has a Roman numeral, the name of a metal, or "ammonium", the compound is likely IONIC

- If the name has a Greek prefix AND the prefix is NOT in front of the word "hydrate", the compound is BINARY MOLECULAR

- If the name contains the word "acid":

... and starts with "hydro-", then the compound is a BINARY ACID

... and does not start with "hydro-", the compound is an OXYACID

FROM A CHEMICAL FORMULA

- if the formula contains a metal or the NH_4^+ ion, it is likely IONIC

H_2O H_2O_2

- If the formula starts with H and is not either water or hydrogen peroxide, the compound is likely an ACID. Which kind?

    - BINARY ACIDS contain only two elements

    - OXYACIDS contains oxygen

- If the formula contains only nonmetals (and is not an ammonium compound or an acid), the compound is likely MOLECULAR

Examples:

PCl_3: BINARY MOLECULAR
Name: phosphorus trichloride

NH_4Cl: IONIC (ammonium ion)
Name: ammonium chloride

H_3PO_4: OXYACID (hydrogen, phosphate)
Name: phosphoric acid

$Fe(OH)_2$: IONIC (starts with a metal)
Name: iron(II) hydroxide

CHEMICAL EQUATIONS

- are the "recipes" in chemistry
- show the substances going into a reaction, substances coming out of the reaction, and give other information about the process

"yields"

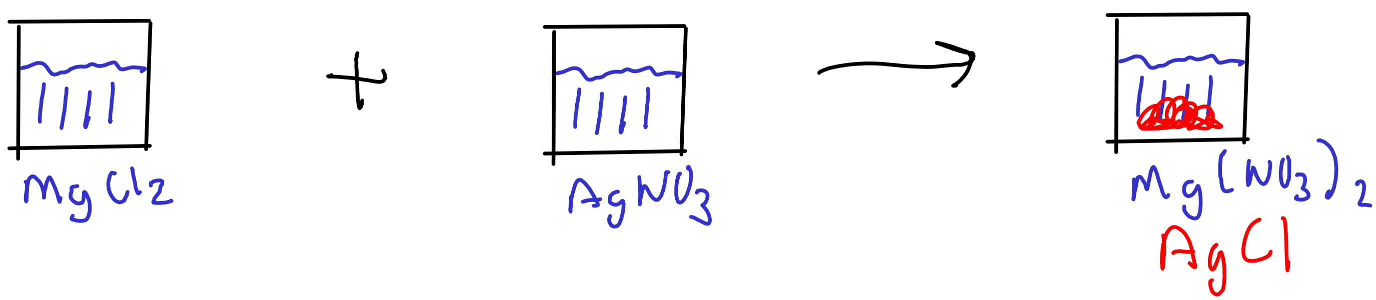
$$MgCl_2(aq) + 2AgNO_3(aq) \longrightarrow 2AgCl(s) + Mg(NO_3)_2(aq)$$

REACTANTS - materials that are needed fot a reaction

PRODUCTS - materials that are formed in a reaction

COEFFICIENTS - give the ratio of molecules/atoms of one substance to the others

PHASE LABELS - give the physical state of a substance:
(s) -solid
(l) - liquid
(g) - gas
(aq) - aqueous. In other words, dissolved in water



CHEMICAL EQUATIONS

$$2\,Mg_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2\,MgO_{(s)}$$

REACTION CONDITIONS - give conditions necessary for chemical reaction to occur. May be:

- Δ apply heat
- catalysts - substances that will help reaction proceed faster
- other conditions, such as required temperatures

- Reaction conditions are usually written above the arrow, but may also be written below if the reaction requires several steps or several different conditions

COEFFICIENTS

- Experimentally, we can usually determine the reactants and products of a reaction

- We can determine the proper ratios of reactants and products WITHOUT further experiments, using a process called BALANCING

  - BALANCING a chemical equation is making sure the same number of atoms of each element go into a reaction as come out of it.

- A properly balanced chemical equation has the smallest whole number ratio of reactants and products.

- There are several ways to do this, but we will use a modified trial-and-error procedure.

BALANCING

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

~~2~~ 10   6 + 4 = 10

1. Pick an element. Avoid (if possible) elements that appear in more than one substance on each side of the equation.

2. Change the coefficients on substances containing this element so that the same number of atoms of the element are present on each side. CHANGE AS LITTLE AS POSSIBLE!

3. Repeat 1-2 until all elements are done.

4. Go back and quickly VERIFY that you have the same number of atoms of each element on each side, If you used any fractional coefficients, multiply each coefficient by the DENOMIMATOR of your fraction.

Use SMALLEST WHOLE NUMBER RATIOS!

BALANCING

$$3MgCl_2 + 2Na_3PO_4 \rightarrow Mg_3(PO_4)_2 + 6NaCl$$ ✓

$$C_2H_2 + 2\tfrac{1}{2}O_2 \rightarrow 2CO_2 + H_2O$$

2 5 | 4 + 1 = 5

We used 2 1/2 as the coefficient for molecular oxygen (to give us 5 oxygen atoms going in), but we need WHOLE NUMBER coefficients. To get whole numbers, just multiply ALL the coefficients by the denominator of the fraction (2, here).

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$$ ✓

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

1 - Avoid H, balance S instead. (H shows up twice on left)
2 - Avoid O, balance Na. (O shows up in all four compounds!)
3 - Balance H (shows up less than O)
4 - Balance O.

CHEMICAL CALCULATIONS - RELATING MASS AND ATOMS

$$\_\,Na_2CO_3 + \underline{2}HCl \rightarrow \_\,H_2O + \_\,CO_2 + \underline{2}\,NaCl$$

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!

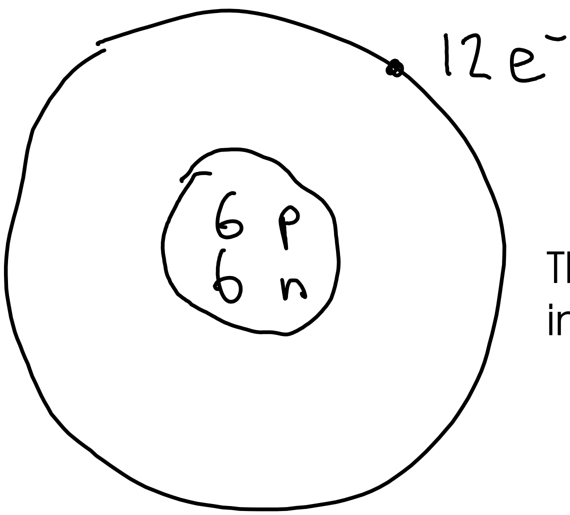
- measurements are usually MASS (and sometimes VOLUME), NOT number of atoms or molecules!

THE MOLE CONCEPT

- A "mole" of atoms is 6.022 x 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~~ → 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 = mol Mg

Atomic mass

"mol" is the abbreviation for "mole"

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

24.31 g Mg = mol Mg

$$250.\text{ g Mg} \times \frac{\text{mol Mg}}{24.31\text{ g Mg}} = 10.3\text{ mol Mg}$$

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 = mol Fe

$$1.75 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{\text{mol Fe}} = \boxed{97.7 \text{ g Fe}}$$

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 is the mass of one mole of either an element OR a compound.

18.016 g H_2O = mol H_2O

$$25.0 \text{ g } H_2O \times \frac{\text{mol } H_2O}{18.016 \text{ g } H_2O} = 1.39 \text{ mol } H_2O$$

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 barium chloride do we need to weigh out to get 3.65 moles of barium chloride?

First, find out the formula of barium chloride.

Ba^{2+} Cl^-

Cl^-

$BaCl_2$

Second, find the FORMULA WEIGHT

$BaCl_2$: Ba - 1 x 137.3

Cl - 2 x 35.45

208.2 g $BaCl_2$ = mol $BaCl_2$

FInally, calculate the mass needed ...

$$3.65 \text{ mol } BaCl_2 \times \frac{208.2 \text{ g } BaCl_2}{\text{mol } BaCl_2} = 760. \text{ g } BaCl_2$$

(or $76\bar{0}$ g $BaCl_2$)