Grade 11 Chemistry

Chemical Quantities

Class 7

Empirical Formula vs. Molecular Formula

- Empirical Formula - shows the lowest whole number ratio of the elements in the compound; simplest formula
- Molecular Formula – shows the actual number of atoms of each element that makes up the molecule
- Ex: Benzene = C_6H_6 (molecular)

  CH (empirical) ratio: 1:1

Name of compound	Molecular (actual) formula	Empirical (simplest) formula	Lowest ratio of elements
hydrogen peroxide	H_2O_2	HO	1:1
glucose	$C_6H_{12}O_6$	CH_2O	1:2:1
benzene	C_6H_6	CH	1:1
acetylene (ethyne)	C_2H_2	CH	1:1
aniline	C_6H_7N	C_6H_7N	6:7:1
water	H_2O	H_2O	2:1

Checkpoint

Finding a Compound's Empirical Formula
(reverse of finding percent composition)

Calculate the empirical formula of a compound that is 85.6% carbon and 14.4% hydrogen by mass.

Calculate the empirical formula of a compound that is 15.9% boron and 84.1% fluorine by mass.

Rounding in Empirical Formulas

- General Guidelines:
  - 0.95-0.99 can be rounded up to the nearest whole number; ex: 9.96 → 10
  - 0.01-0.05 can be rounded down to the nearest whole number; ex: 3.02 → 3
  - 0.5 double until all subscripts are whole numbers; ex: $C_{1.5}H_3O_1$ → $C_3H_6O_2$
  - 0.45-0.55 round to 0.5 and then double;

    ex: 6.47 → 6.50 times two → 13

When you see this decimal...	Try multiplying all subscripts by...
$x.80\ (\frac{4}{5})$	5
$x.75\ (\frac{3}{4})$	4
$x.67\ (\frac{2}{3})$	3
$x.60\ (\frac{3}{5})$	5
$x.40\ (\frac{2}{5})$	5
$x.50\ (\frac{1}{2})$	2
$x.33\ (\frac{1}{3})$	3
$x.25\ (\frac{1}{4})$	4
$x.20\ (\frac{1}{5})$	5
$x.17\ (\frac{1}{6})$	6

x stands for any whole number

Strategy: Treat the decimal as a fraction and then multiply the number by its denominator

Checkpoint

The percentage composition of fuel is 81.7% carbon and 18.3% hydrogen by mass. Find the empirical formula of the fuel.

Molecular Formula

- Molecular formula can be found using the empirical formula and the molar mass

$$M_{\text{Molecular Formula}} = n \times M_{\text{Empirical Formula}}$$

Where n = 1, 2, 3,… is a whole number

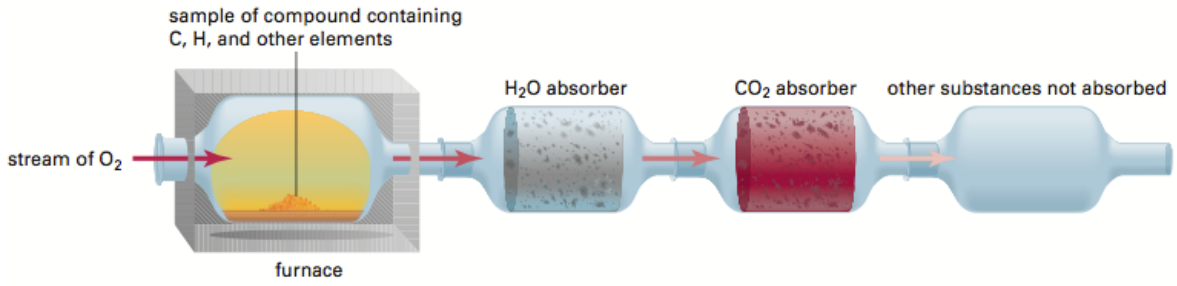
(not moles)

Checkpoint

The percentage composition of ribose is 40.00% carbon, 6.67% hydrogen and 53.33% oxygen by mass. Using mass spectrometer, you find that the molar mass of ribose was 150g/mol. What is the molecular formula?

Finding Empirical and Molecular Formulas by Experiment

- Carbon-Hydrogen Combustion Analyzer
  - Instrument that determines the percentage composition of compounds that are made up of carbon, hydrogen and oxygen
  - Used in forensic science, food chemistry, pharmaceuticals, etc.



- Sample only made of carbon and hydrogen is placed in the furnace
- A stream of O_2 is added to allow for complete combustion yielding water vapour and CO_2
- Water vapour is collected by passing through a tube that contains $Mg(ClO_4)_2$, which absorbs all of the water
  - Measure the mass of the tube before and after the reaction. The difference tells you the water produced in the reaction. Find the mass of hydrogen using the percentage composition of hydrogen in water
- CO_2 is collected in a second tube that contains NaOH

Checkpoint

A 1.000g sample of pure compound, containing only carbon and hydrogen was combusted in a carbon-hydrogen combustion analyzer. The combustion produced 0.6919g of water and 3.338g of carbon dioxide.

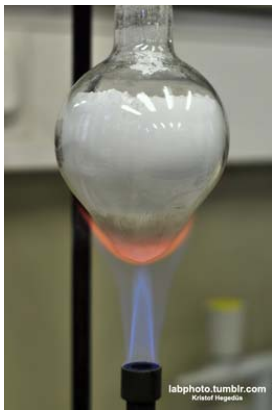
- Calculate the masses of the carbon and hydrogen in the sample
- Find the empirical formula of the compound.

Hydrated Compounds

- Hydrate – A compound that has a specific number of water molecules bonded to each formula unit
- Many ionic compounds crystallize from a water solution with water molecules incorporated into their crystal structure
- Ex: $MgSO_4 \bullet 7H_2O$ (Epsom salts)
- Note: The dot represents a weak bond between the ionic compound and the water molecules; NOT multiplication

Anhydrous Molecules

- Anhydrous – compounds with no water molecules incorporated in them
- Ex: $CaSO_4$ – anhydrous calcium sulphate



Checkpoint

A hydrate of $Ba(OH)_2 \bullet xH_2O$ is used to make barium salts. Since it reacts with CO_2 from air to yield $BaCO_3$, it must be stored in a tightly stoppered bottled.

a) A 50.0g sample of the hydrate contains 27.2g of $Ba(OH)_2$. Calculate the mass percent of water in $Ba(OH)_2 \bullet xH_2O$

b) Find the value of *x* in $Ba(OH)_2 \bullet xH_2O$