Grade 11 Chemistry

Chemical Quantities

Class 6

Big Ideas

- Relationships in chemical reactions can be described quantitatively

- The efficiency of chemical reactions can be determined and optimized by applying an understanding of quantitative relationships in such reactions.

Atomic Mass Unit (amu)

- A relative measure, defined by the mass of Carbon-12

- One atom of Carbon-12 is assigned a mass of 12 amu

- All other elements are compared to Carbon-12

C-12

12 "relative masses"
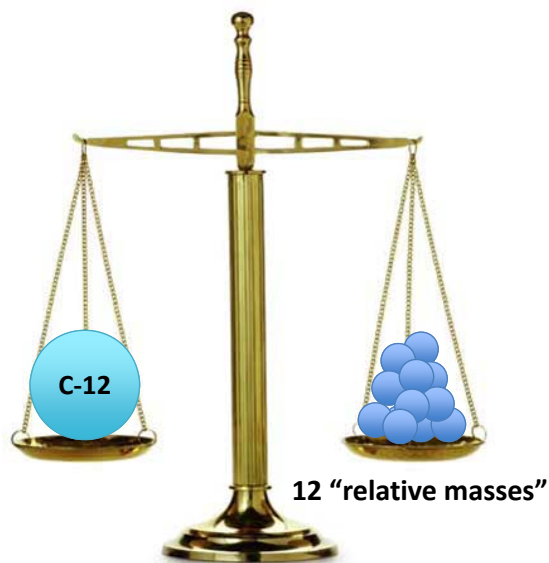
- Ex: Oxygen-16 is 1.333 times heavier than Carbon-12

Atomic Mass of O-16:

12 x 1.333 = 15.996 amu

- Ex: Hydrogen-1 has an atomic mass of 1.007825 amu. How does this compare to Carbon-12?

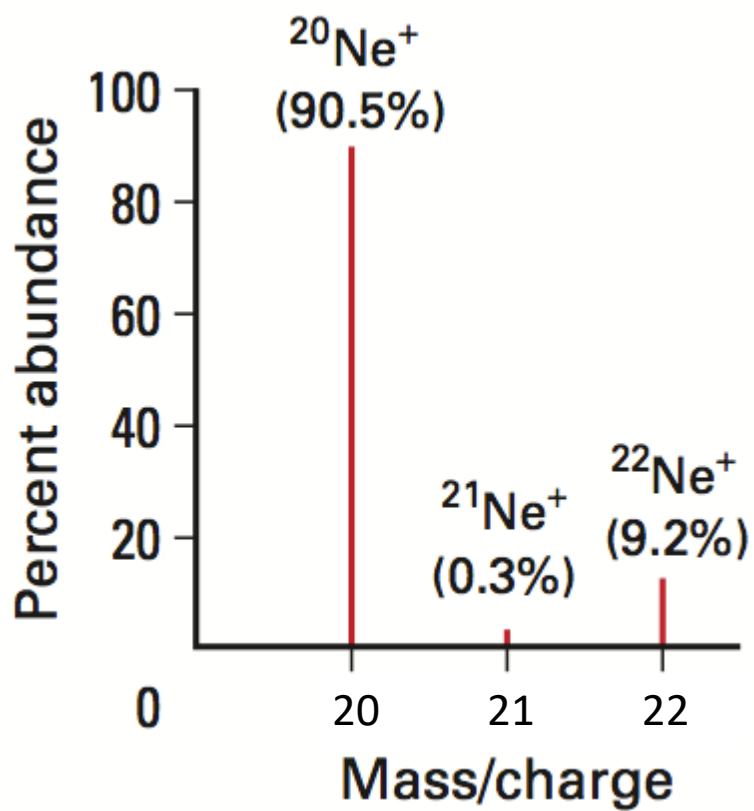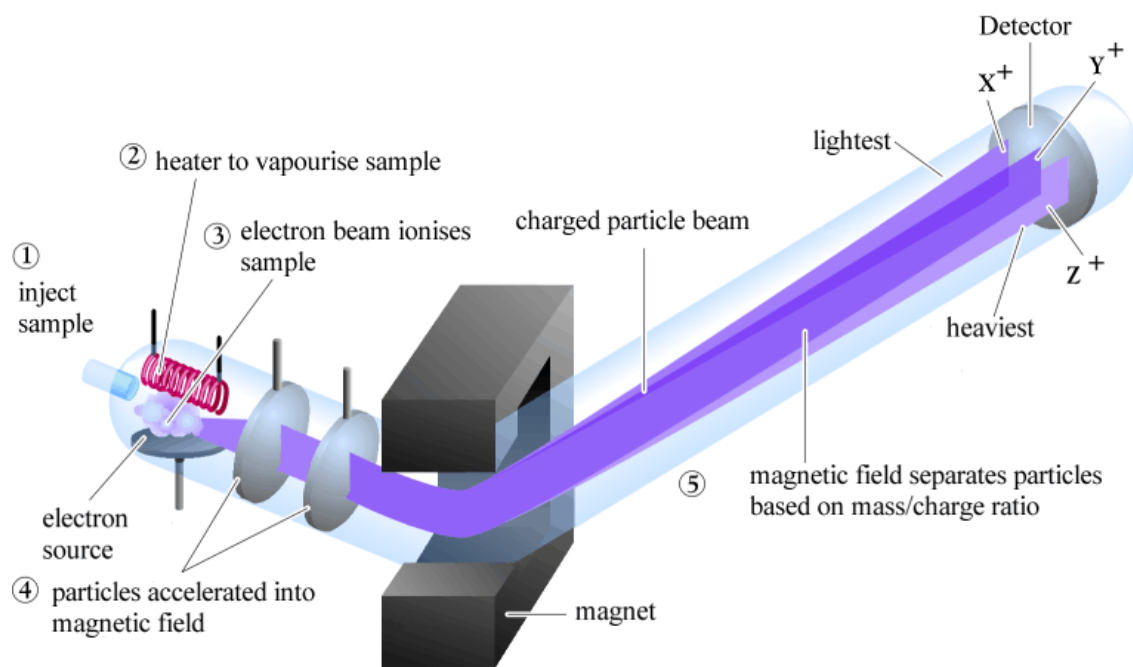Carbon-12 is (12 / 1.007825 = **11.9 times**) larger than Hydrogen-1

Isotopes

- Isotopes – elements that contain the same number of protons but a different number of neutrons

- Different isotopes have different mass and different functions
  – Ex: Carbon-12 stable isotope
  – Ex: Carbon-14 radioactive and used for carbon dating

Isotopic Abundance

- The relative amount in which each isotope is present in an element

  Ex: Magnesium has 3 naturally occurring isotopes:

  Mg-24 (79%)   Mg-25 (10%)   Mg-26 (11%)

  = Mg with an **average atomic mass** of 24.3 amu (shown on periodic table)

Mass Spectrometer

- How do chemists know an element's isotopic abundance?

- Mass Spectrometer – use a magnetic field to separate the isotopes of an element by charging the atom

  – Magnetic field deflects ions with the same charge but different masses on to separate paths

  – Isotopes with a smaller mass get deflected more than isotopes with a larger mass

  – A detector registers the current at each destination

  – Current is proportional to the number of ions that arrive at the destination (i.e. an isotope with a larger abundance generates a larger current)

- Used to deduce the proportion of each isotope in the element

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Detector

X⁺   Y⁺

lightest

heaviest

Z⁺

② heater to vapourise sample

③ electron beam ionises sample

① inject sample

charged particle beam

electron source

④ particles accelerated into magnetic field

⑤ magnetic field separates particles based on mass/charge ratio

magnet

Checkpoint

Calculating Average Atomic Mass:

Lithium exists as two isotopes: Lithium-7 and Lithium-6. Lithium-7 has a mass of 7.015u and makes up 92.58%. Lithium-6 has a mass of 6.015u and makes up the remaining 7.42%. What is the average atomic mass of lithium?

Checkpoint

Calculating Isotopic Abundance:

Hydrogen is found primarily as two isotopes in nature: $_{1}^{1}\mathrm{H}$ (1.0078u) and $_{1}^{2}\mathrm{H}$ (2.0140u). Calculate the percentage abundance of each isotope based on hydrogen's average atomic mass (1.0079 u).

The Mole (Avogadro's Constant)

- Mole (mol) is a number (N_A)

$$6.02 \times 10^{23}$$

- Defined as the amount of a substance that contains as many elementary entities (atoms, molecules, or formula units) as exactly 12 g of Carbon-12

- How many eggs are in 2 dozen?

Number of Eggs = 2 dozen x 12 eggs/dozen

Number of Eggs = 24 eggs

- How many molecules are in 2 moles?

Number of Molecules = 2 moles x 6.02×10^{23} molecules/mole

Number of Molecules = 1.204×10^{24} molecules

$$N = N_A \times n$$
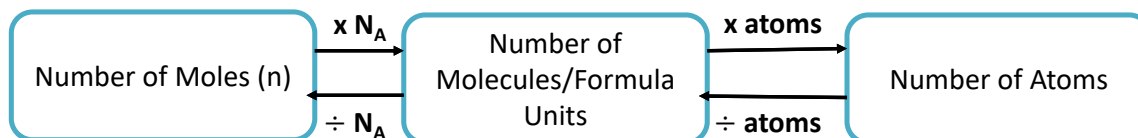
Number of particles   **Avogadro's Constant**   **Number of moles**

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Checkpoint

Number of Moles (n)	x N_A / ÷ N_A	Number of Molecules/Formula Units	x atoms / ÷ atoms	Number of Atoms

1. A sample contains 1.25 mol of NO_2

a) How many molecules are in the sample?

b) How many atoms are in the sample?

2. How many moles are present in a sample of CO_2 made up of 5.83×10^{24} molecules?

Molar Mass (M)

- The mass (g) of one mole of a substance
- Expressed in g/mol
- One mole of Carbon-12 atoms (6.02 x 10^{23} Carbon-12 atoms) has a mass of exactly 12g
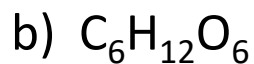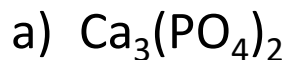
Element	Average Atomic Mass (amu)	Molar Mass (g/mol)
Hydrogen	1.0079	1.0079
Oxygen	15.999	15.999
Carbon	12.011	12.011

Checkpoint

Find the molar mass of:

a) $Ca_3(PO_4)_2$

b) $C_6H_{12}O_6$

c) $SrSO_4$

Moles (mol) → Mass (g)

$$n = \frac{m}{M}$$
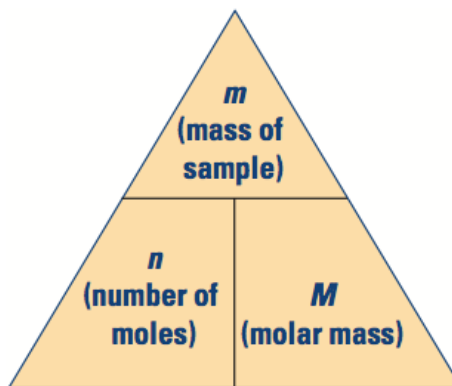
n = number of moles (mol)

m = mass (g)

M = Molar mass (g/mol)
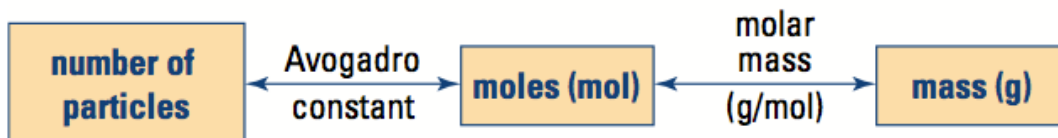
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Calculate the mass of each of the following:

a) 3.90 mol of carbon C

b) 2.50 mol of ozone O_3

c) 1.45 x 10^{-5} mol of $(NH_4)_2Cr_2O_7$

A flask contains 33.0g of CO_2. How many moles of CO_2 is in this sample?

Moles/Mass → Number of Particles

- Use both equations

$$n = \frac{m}{M} \qquad N = N_A \times n$$

STOP Checkpoint STOP

What is the mass of 5.67×10^{24} molecules of cobalt(II) chloride, $CoCl_2$?

What is the mass of lithium in 254 formula units of lithium chloride, LiCl?

How many oxygen atoms are in 3.50g of Fe_2O_3?

Percentage Composition By Mass

- Law of Definite Proportions – elements in a chemical compound are always present in the same proportions by mass
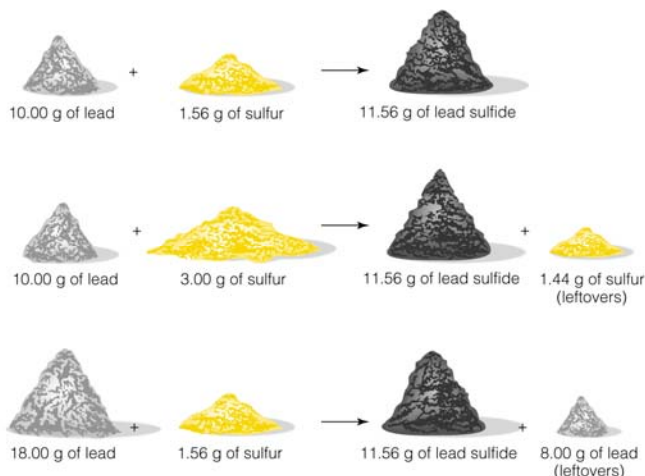
Percentage Composition By Mass

- The mass of an element in a compound expressed as a percent of the total mass of the compound (aka: mass percent)

- Percentage composition can be used to identify a compound

Compound	% Hydrogen	% Oxygen
H_2O	11.19%	88.81%
H_2O_2	5.926%	94.074%

Checkpoint

Percentage Composition from Mass Data

A compound with a mass of 48.72g is found to contain 32.69g of zinc and 16.03g of sulfur. What is the percentage composition of each element in the compound?

Checkpoint

Percentage Composition from a Chemical Formula

Cinnamaldehyde (C_9H_8O) is responsible for the odour of cinnamon. Determine the percentage composition of C_9H_8O by calculating the mass percents of carbon, hydrogen and oxygen.