Chapter 3

- Atomic Masses(3.1)
- The Mole (3.2)
- Molar Mass (3.3)
- Percent Composition (3.4)
- Determining the Formula of a Compound (3.5)
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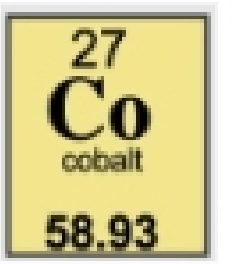
- Introducing Limiting Reagents (3.9)

This is the outline for the content we will cover in lecture. Please read the entire chapter.

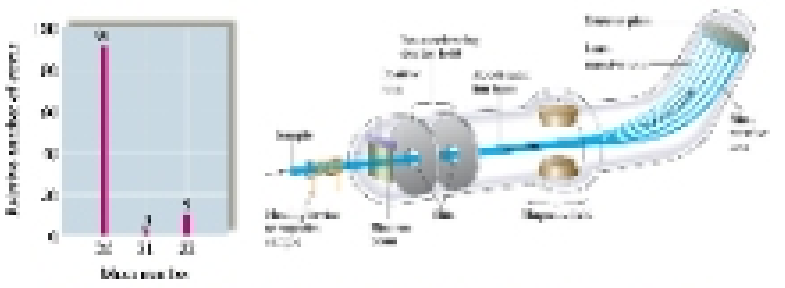
The Atomic Mass Unit (amu)

- Defined as 1/12 the mass of a carbon-12 atom
- The masses of all other atoms are given relative to this standard
- The atomic masses you find on the periodic table are a weighted average of the masses of each isotope of that element.

Example: Cobalt
More than 5 isotopes of cobalt exist. The most common isotope is cobalt-59, but several lighter isotopes lead to an atomic mass of 58.93.



Determining isotopic mass using a Mass Spectrometer



- Stream of vaporized atoms is bombarded with high-speed electrons, which knock electrons off the gaseous atoms, turning them into cations.
- Gaseous cations are accelerated through magnetic field, and their paths are bent according to their mass.

Some Isotope Comparisons

Element	Isotope	Mass of Isotope (amu)	Relative Abundance	Average Atomic Mass (amu)
Hydrogen	^{1}H	1.00782	99.9885%	1.0079
	^{2}H	2.01410	0.0115%	
Carbon	^{12}C	12 (exact)	98.892%	12.01115
	^{13}C	13.00335	1.108%	
Sulfur	^{32}S	31.972071	95.06%	32.064
	^{33}S	32.971458	0.76%	
	^{34}S	33.967867	4.18%	
	^{36}S	35.967080	0.0136%	
Lithium	^{6}Li	6.015123	7.5%	6.941
	^{7}Li	7.016005	92.5%	

Don't confuse "Atomic Mass" with the mass of one atom!!

- An atom can be only one isotope at a time.
  ^{12}C: A = 12, Isotopic mass = 12 amu (exactly)
  ^{13}C: A = 13, Isotopic mass = 13.003355 amu
- The Atomic Mass (aka **Atomic Weight** or **Average Atomic Mass**) is the ***average*** of the ***atomic masses of all of the element's isotopes***, weighted by isotopic abundance.
- Naturally occuring carbon has an **atomic mass** of 12.011 amu
- There is ***no carbon isotope*** that weighs 12.011 amu.

Calculating Atomic Mass

Let's say we have a sample of 1.000×10^4 carbon (C) atoms.
Based on isotopic abundance:

9889 weigh 12 amu (98.89%)
111 weigh 13.003355 amu (1.11%)

What is the average mass of a carbon atom in this sample?

(9889 ^{12}C)(12 amu/^{12}C) + (111 ^{13}C)(13.003355 amu/^{13}C) =

118668 amu + 1443.372405 amu =

120111.372405 amu

(120111.372405 amu)/(1.000×10^4 atoms) =

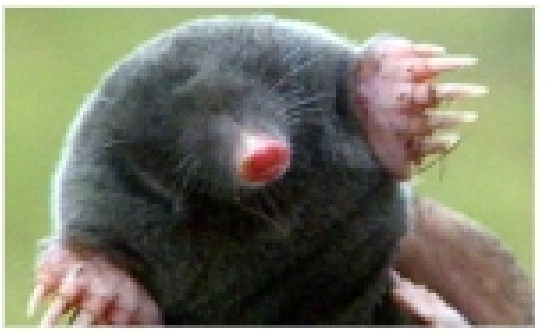
12.01 amu/atom

Counting by Weighing

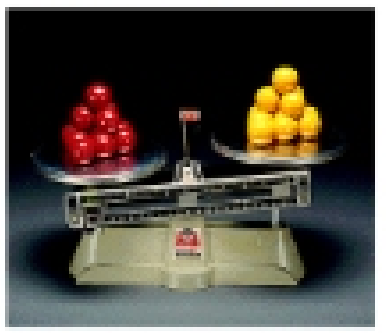
- Chemical reactions occur at the microscopic level, between individual molecules and/or atoms.
- In the lab, we measure substances in terms of grams or millliters… these are macroscopic measurements.
- The number of molecules in 1 g of water will be different than the number of molecules in 1 g of glucose, because these molecules have different masses.
- We need a way to convert between the microscopic and macroscopic descriptions.

The mole…

NOT this kind of mole



Dozen – mass



12 red marbles (7g each) = 84g
12 yellow marbles (4g each) = 48g

Mole – mass

6.022 x 10^{23} atoms Fe = 55.85g Fe
6.022 x 10^{23} atoms S = 32.07g S

How many ^{12}C atoms in 12 g?

Mass of one ^{12}C atom is 1.9926×10^{-23} g

of ^{12}C in 12.00 g = (12.00 g)/(1.9926×10^{-23} g/^{12}C) = 6.022×10^{23} ^{12}C atoms

One mole is the number equal to the number of carbon atoms in exactly 12 grams of pure ^{12}C

Interpreting the Mole

If we had 1 mol of bicycles…

- How many mol bike seats would we have?
- Tires?
- Spokes? (assuming 36 spokes/wheel)

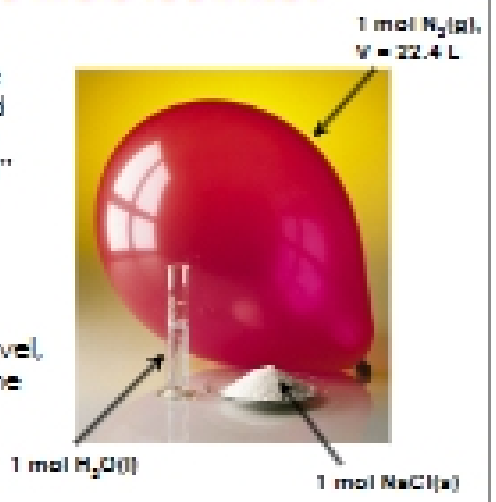
If we had 1 mol of isopropyl alcohol (C_3H_8O)…

- How many mol O atoms would we have?
- Carbon atoms?
- Hydrogen atoms?

What does one mole look like?

For condensed-phase substances (solids and liquids), **one mole** is a convenient "hand-full" sized quantity.

For gas-phase substances at room temperature at sea level, **one mole** has a volume of about 22.4 L.



Molar Mass as a Conversion Factor

Molar mass (the mass of one mole of a substance, equal to the atomic mass in grams per mole), allows us to convert between macroscopic and particulate points of view.

How many grams of oxygen corresponds to 0.50 moles?

$$? \text{ g } O_2 = 0.50 \text{ mol } O_2 \left(\frac{32 \text{ g } O_2}{1 \text{ mol } O_2} \right) = 16 \text{ g } O_2$$

How many moles of oxygen are there in 1.2 grams?

$$? \text{ mol } O_2 = 1.2 \text{ g } O_2 \left(\frac{1 \text{ mol } O_2}{32 \text{ g } O_2} \right) = 0.038 \text{ mol } O_2$$

Molar Mass

Find the molar mass of carbon dioxide, CO_2:

Molar mass of C: 12.01 g/mol
Molar mass of O: 16.00 g/mol

Molar mass of CO_2 = molar mass of C + 2(molar mass of O)

(12.01 g/mol) + 2(16.00 g/mol) = 44.01 g/mol

Calculating the Moles in a Given Mass of a Compound

Problem: Sodium phosphate is a component of some detergents. How many moles are in a 38.6 g sample?

Na_3PO_4
Molar mass = 3(22.99 g/mol) + (39.10 g/mol) + 4(16.00 g/mol) = 172.07 g/mol

# of moles = (38.6 g)(1 mol/172.07 g) = 0.224 mol

Aluminum (Al)

atomic weight = 26.98 amu.

molar mass = 26.98 g/mol

1 mol Al contains 6.022×10^{23} Al atoms

Lead (Pb)

atomic weight = 207.2 amu.

molar mass = 207.2 g/mol

1 mol Pb contains 6.022×10^{23} Pb atoms

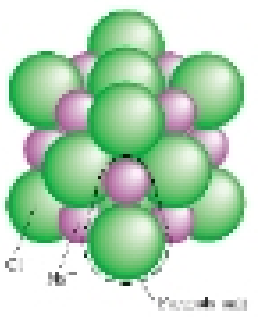


Table salt (NaCl)

formula mass = 58.44 amu
molar mass = 58.44 g/mol

1 mol of table salt contains 6.022×10^{23} NaCl formula units...this means:

6.022×10^{23} sodium ions (Na^+)

and...

6.022×10^{23} chloride ions (Cl^-)