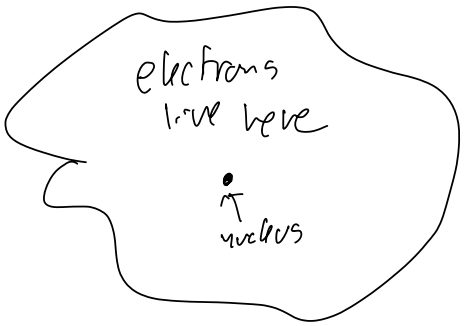
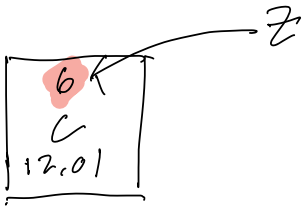
Atoms + Molecules

atoms - nucleus that contains protons (heavy, +1) and neutrons (heavy, 0 charge)
- space outside of nucleus where electrons live (light, -1)



Atomic # = # protons (Z). Atomic number defines what kind of atom something is



Mass # (A) = # protons + # neutrons

$^{12}_{6}C$ (A = 12, Z = 6) — carbon-12 (mass #)

atom with 6 protons and 7 neutrons

$^{13}_{6}C$ is carbon-13

carbon-12 and carbon-13 are isotopes of carbon
(same Z, different A)

Atomic mass - relative scale such that
1 atom of $^{12}_{6}C$ has a mass of
exactly 12 atomic mass units (amu)

$^{16}_{8}O$ is 15.9948 amu

$1\ amu = 1.661 \times 10^{-24}\ g$

Isotopes must have same Z

$^{12}_{6}C$ $^{13}_{6}C$ $^{14}_{6}C$ - all isotopes of carbon

$^{14}_{7}N$ - not an isotope of carbon

$^{14}_{7}N$ $^{16}_{7}N$ - isotopes of N

In nature

$^{12}_{6}C$ 98.9% $^{13}_{6}C$ 1.0999% $^{14}_{6}C$ 0.000001%

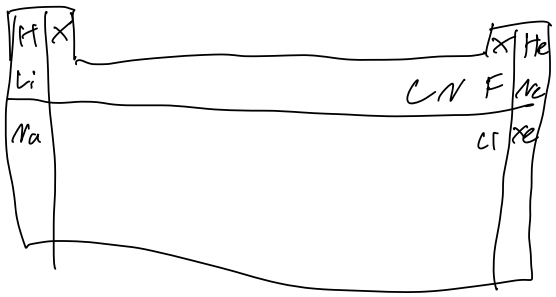
$^{35}_{17}Cl$ 75.8% $^{37}_{17}Cl$ 24.2%

$^{35}_{17}Cl$ → 34.969 amu

$^{37}_{17}Cl$ → 36.966 amu

$(0.758)(34.969\ amu) + (0.242)(36.966\ amu) = 35.45\ amu$

17
Cl
35.45 ← atomic weight



Z increases L → R

top → bottom → a column is an important grouping

things in same group (column) have similar properties

How to represent groups of atoms (ie molecules)

Molecular formula - how many of each kind of atom

C_5H_{12}

condensed formula - shows connectivity of groups of atoms

$CH_3CH_2CH_2CH_2CH_3$

structural formula - picture showing how all atoms are connected

In reality molecule is 3-D

Ion / Ionic compounds

Molecular compounds - made of molecules (sugar)

Ionic compounds - made of ions

ion: atom or group of atoms w/ a charge

anion - neg charged ion - somehow got electrons
cation - pos charge - somehow lost electrons

NaCl - not 1 Na atom and 1 Cl atom
- is 1 Na^+ ion and 1 Cl^- ion
↗ ↑
Na atom that lost 1 electron — Cl atom that gained 1 electron

H, Li, Na, K etc → +1 ions
Be, Mg, Ca etc → +2 ions
F, Cl, Br etc → -1 ions
O, S, Se etc → -2 ions

An ionic compound with Mg and Cl

Mg^{2+} Cl^-

* Ionic compound must have net zero charge

so $MgCl_2$

polyatomic ions - groups of atoms w/ charge

NH_4^+ - ammonium CO_3^{2-} MnO_4^- $C_2O_4^{-2}$ OH^-
NO_3^- - nitrate PO_4^{3-} CH_3COO^- ClO_4^{-1} SO_4^{2-}

Ionic compound w/ Mg^{2+} and NO_3^-

$Mg(NO_3)_2$ ~~MgN_2O_6~~

* Properties of ionic compounds depend on charge of ions

How to keep track of all atoms + molecules

Use a counting unit called the "mole"

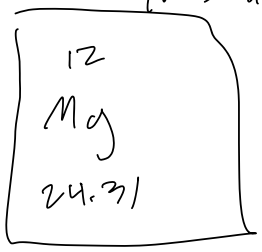
1 mole is the number of atoms of $^{12}_{6}C$ in exactly 12 grams of $^{12}_{6}C$

1 mole = 6.02×10^{23}

1 mole of Mt Ms is 6.02×10^{23} Mt Ms ~ size of small moon

1 mole of H_2O molecules is 6.02×10^{23} H_2O molecules ~ 1 sip of water

*** The mass in grams of 1 mole of an element equals atomic weight from periodic table



1 atom Mg weighs 24.31 amu

1 mole of Mg atoms = 6.02×10^{23} Mg atoms and weighs 24.31 g

Put a chunk of Mg on scale → 11.2 g

$$11.2 \text{ g Mg} \times \frac{1 \text{ moles Mg}}{24.31 \text{ g Mg}} \times \frac{6.02 \times 10^{23} \text{ atoms Mg}}{1 \text{ moles Mg}} = 2.77 \times 10^{23} \text{ atoms of Mg}$$

How much does 4.97×10^{24} atoms of Mg weigh?

$$4.97 \times 10^{24} \text{ atoms Mg} \times \frac{1 \text{ moles Mg}}{6.02 \times 10^{23} \text{ atoms Mg}} \times \frac{24.31 \text{ g Mg}}{1 \text{ moles Mg}} = 200.7 \text{ g Mg}$$

H_2O → 1 mole of water containing 1 mol of O atoms
2 mol of H atoms

1 molecule H_2O has 2 H atoms, 1 O atoms

50 molecules H_2O has 100 H atoms, 50 O atoms

1 mole H_2O has 2 moles H atoms, 1 mole of O atoms

$2 \text{ moles H} \times \frac{1.01 \text{ g H}}{1 \text{ mol}} = 2.02 \text{ g}$ $\quad 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{\text{mole}} = 16.00 \text{ g}$

1 mole H_2O weighs 18.02 g

"molar mass" of water is 18.02 g

$$35.6 \text{ g } H_2O \times \frac{1 \text{ mole } H_2O}{18.02 \text{ g } H_2O} \times \frac{6.02 \times 10^{23} \text{ molecules } H_2O}{1 \text{ mole } H_2O} = 1.19 \times 10^{24} \text{ } H_2O \text{ molecules}$$

1.19×10^{24} O atoms

2.38×10^{24} H atoms

Mass % (% composition)

$CH_4 \rightarrow$ molar mass $= 12.01 \text{ g} + 4 \times (1.01 \text{ g}) = 16.06 \text{ g/mol}$

(12.01 g from C; 4 × 1.01 g from H)

$$\text{mass \% C} = \frac{12.01 \text{ g}}{16.06 \text{ g}} \times 100 = 75\%$$

$$\text{Mass \% H} \quad \frac{4.04 \text{ g}}{16.06 \text{ g}} \times 100 = 25\%$$

Formula from mass %

Unknown 85.6% C by mass
14.4% H by mass

If we had 100 g $\rightarrow$ $85.6 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g}} = 7.12 \text{ mol C}$

$$14.4 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g}} = 14.28 \text{ mol H}$$

This gives us mole ratio C:H 7.12:14.28

or

C:H 1:2.006 ~ 1:2

empirical formula CH_2 - has correct ratio of all element

C_2H_4
C_3H_6
C_4H_8
} all have empirical formula of CH_2

Need more information to find actual molecular formula - need molar mass

If molar mass is 28 g/mol → formula must be C_2H_4