# Atoms and Elements

## Structure of Atoms

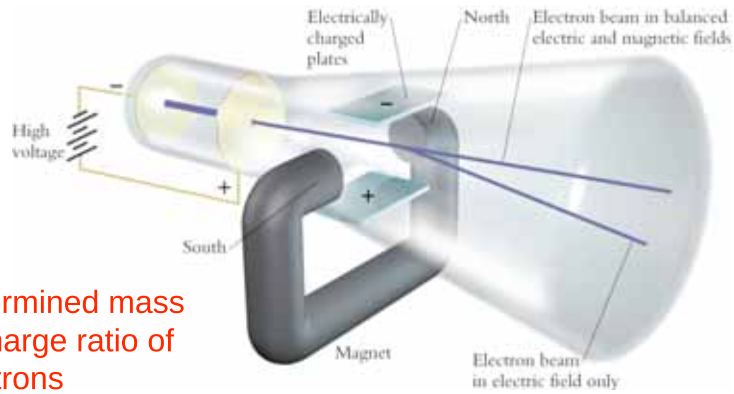
Through a series of experiments conducted by a number of different people (Thomson, Milliken, Rutherford, etc.), we know that atoms are composed of three different types of subatomic particles:

- electrons
- protons
- neutrons

## Structure of Atoms

Electrons:

Thomson's cathode ray tube

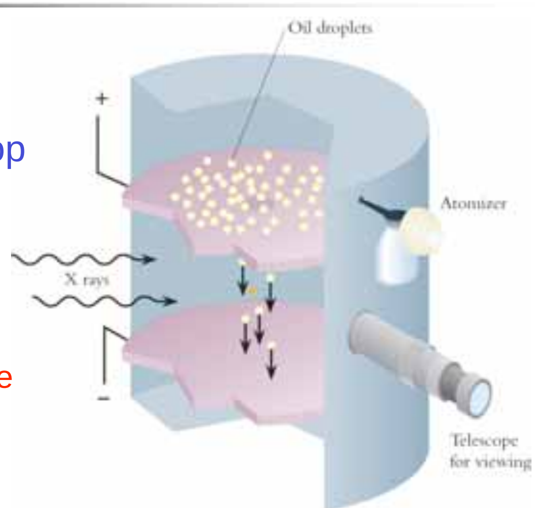



Determined mass to charge ratio of electrons

## Structure of Atoms

Electrons:

Millikan's oil drop experiment




Determined charge of an electron

## Structure of Atoms

Electrons:

- Electrons are negatively charged particles

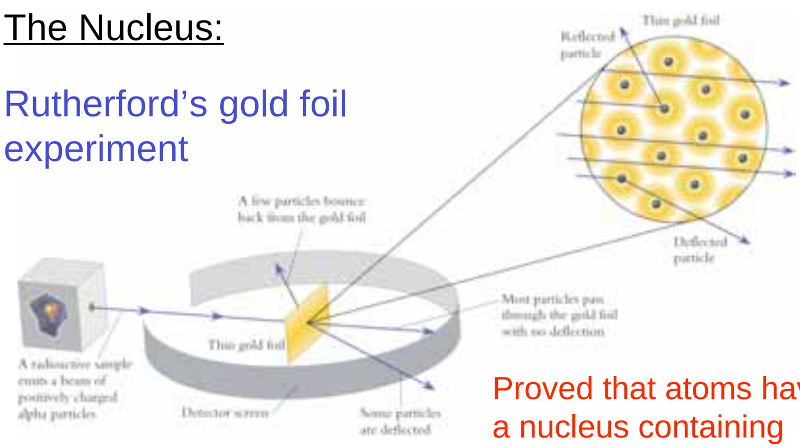
  charge = $-1.602 \times 10^{-19}$ C (C=coulomb)

  mass = $9.11 \times 10^{-31}$ kg

## Structure of Atoms

The Nucleus:

Rutherford's gold foil experiment




Proved that atoms have a nucleus containing most of atom's mass

## Structure of Atoms

Protons and neutrons combine to form the nucleus of the atom

## Structure of Atoms

Protons:

- Protons are positively charged particles with a charge that is equal in magnitude to an electron's, but opposite in sign

  charge = $+1.602 \times 10^{-19}$ C

  mass = $1.673 \times 10^{-27}$ kg
- The mass of a proton is ~1800 times that of an electron

## Structure of Atoms

Neutrons:

- Neutrons are uncharged particles that are slightly heavier than protons

  charge = 0.00 C

  mass = $1.675 \times 10^{-27}$ kg

## Atomic Number, Mass Number, and Atomic Mass

- Each element in the Periodic Table is identified by its **Atomic Number**
- Atomic number indicates the number of protons in the nucleus of an atom
- The **Mass Number** indicates the total number of particles in the nucleus
  - Mass number = protons + neutrons
  - Mass number is measured in atomic mass units (amu: 1 amu $\cong$ mass of p/n)

## Atomic Number, Mass Number, and Atomic Mass

- The atomic number and mass number can be expressed with the elemental symbol:
  - Atomic number (Z) is indicated by a left subscript
  - Mass number (A) is indicated by a left superscript

$${}^{A}_{Z}X$$

## Atomic Number, Mass Number, and Atomic Mass

Examples:

$${}^{12}_{6}C$$

C = carbon
Z = 6 protons
A = 12 ⇨ 6 neutrons

$${}^{1}_{1}H$$

H = hydrogen
Z = 1 proton
A = 1 ⇨ 0 neutrons

## Atomic Number, Mass Number, and Atomic Mass

Examples:

$^{235}_{92}U$

U = uranium
Z = 92 protons
A = 235 ⇨ 143 neutrons

$^{238}_{92}U$

U = uranium
Z = 92 protons
A = 238 ⇨ 146 neutrons

This an example of isotopes: isotopes have the same atomic number, but different mass numbers

## Atomic Number, Mass Number, and Atomic Mass

- **Atomic Mass** (or atomic weight) is the weighted average mass of the naturally occurring isotopes of an element

| isotope | mass | abundance |
|---|---|---|
| $^{1}_{1}H$ | 1.007825 | 99.9855% |
| $^{2}_{1}H$ | 2.014102 | 0.0145% |

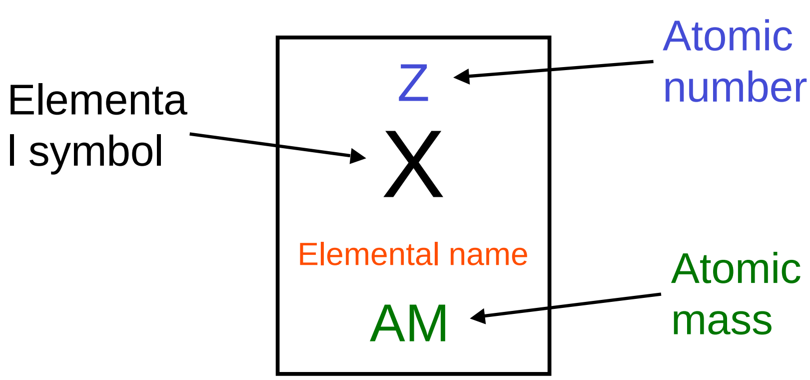
- The atomic mass of hydrogen is given as 1.00794

## Atomic Number, Mass Number, and Atomic Mass

- The units of atomic mass are grams per mole: g/mol
- 1 mole = $6.022 \times 10^{23}$ particles
  - A mole is just a convenient unit of measure for very large quantities (like a dozen [=12] or a score [=20])

## Atomic Number, Mass Number, and Atomic Mass

Relationship of these quantities to the Periodic Table:



## Atomic Number, Mass Number, and Atomic Mass

2
He
Helium
4.0026

Protons = 2

Neutrons = 2

## Atomic Number, Mass Number, and Atomic Mass

8
O
Oxygen
15.9994

Protons = 8

Neutrons = 8

## Atomic Number, Mass Number, and Atomic Mass

| |
|---|
| 17 |
| Cl |
| Chlorine |
| 35.453 |

Protons = 17

Neutrons = 18.45 ?

Chlorine has two isotopes:

$^{35}_{17}Cl$ = 75.53% (18 neutrons)

$^{37}_{17}Cl$ = 24.47% (20 neutrons)

The weighted average results in the listed atomic mass

## Example Problem #1

If a gold bar has a volume of 1027 mL, how many moles of gold are in the bar?

Step 1: Determine mass of the bar

$\rho_{Au}$ = 19.32 g/mL (Table 1.1)

$m_{Au} = (1027\ \cancel{mL})(19.32\ g/\cancel{mL}) = 19840\ g$

Step 2: Convert from grams to moles

$(19840\ \cancel{g})/(196.9666\ \cancel{g}/mol) = \boxed{100.7\ mol}$

## Example Problem #2

1 carat is equal to 200 mg. Diamond is a form of pure carbon with the C atoms arranged in a tetrahedral structure. How many moles of C are in a 2.31 carat diamond?

Step 1: Convert mass from carats to grams

$(2.31\ \cancel{\text{carat}})(200\ \cancel{\text{mg}}/\cancel{\text{carat}})(1\ \text{g}/1000\ \cancel{\text{mg}})$

$= 0.462\ \text{g}$

## Example Problem #2 (con't.)

1 carat is equal to 200 mg. Diamond is a form of pure carbon with the C atoms arranged in a tetrahedral structure. How many moles of C are in a 2.31 carat diamond?

Step 2: Convert from grams to moles

$(0.462\ \cancel{\text{g}})/(12.0107\ \cancel{\text{g}}/\text{mol}) = 0.0385\ \text{mol}$

## Example Problem #3

A piece of copper wire is 25 ft long and has a diameter of 2.0 mm.How many moles of copper and how many copper atoms are in the wire?

$\rho_{Cu}$ = 8.92 g/mL

Step 1: Calculate volume of wire

$V_{cylinder}$ = (cross sectional area)(height)

Area = $\pi r^2 = \pi(1.0\ mm)^2 = 3.1\ mm^2$

$(3.1\ \cancel{mm^2})(1\ cm/10\ \cancel{mm})^2 = 3.1 \times 10^{-2}\ cm^2$

## Example Problem #3 (con't.)

Step 1: Calculate volume of wire

$h = (25\ \cancel{ft})(12\ \cancel{in}/\cancel{ft})(2.54\ cm/\cancel{in})$

$= 760\ cm$

$V = (3.1 \times 10^{-2}\ cm^2)(760\ cm) = 24\ cm^3$

Step 2: Calculate mass of wire

m = (density)(volume)

$= (8.92\ g/\cancel{mL})(24\ \cancel{cm^3}) = 210\ g$

$1\ mL = 1\ cm^3$

## Example Problem #3 (con't.)

Step 3: Calculate moles

$(210\ \cancel{g})/(63.546\ \cancel{g}/mol) = 3.3\ mol$

Step 4: Determine number of atoms

$(3.3\ \cancel{mol})(6.022 \times 10^{23}\ atoms/\cancel{mol})$

$= \boxed{2.0 \times 10^{24}\ atoms}$

## Example Problem #4

What volume will 284.9 mol of water occupy at 20 $^oC$?

Step 1: Calculate molecular weight of water

The molecular weight of a molecule is determined by summing the atomic weights of all elements comprising the molecule.

## Example Problem #4 (con't.)

Step 1 (con't.): Calculate molecular weight of water

$H_2O$ has 2 hydrogens and 1 oxygen

MW = 2(1.0079 g/mol) + 15.9994 g/mol

= 18.0152 g/mol

Step 2: Calculate mass of $H_2O$

(284.9 ~~mol~~)(18.0152 g/~~mol~~) = 5133 g

## Example Problem #4 (con't.)

Step 3: Calculate volume of water

(5133 ~~g~~)/(0.99823 ~~g~~/mL) = 5142 mL

(5142 ~~mL~~)(1 L/1000 ~~mL~~) = 5.142 L