



Atoms and Elements



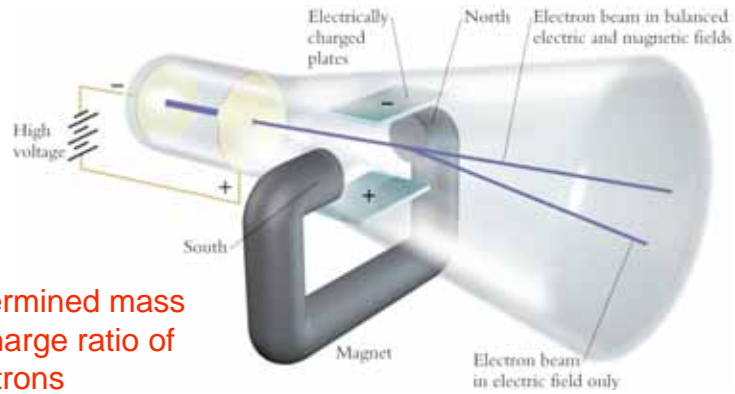
Structure of Atoms

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

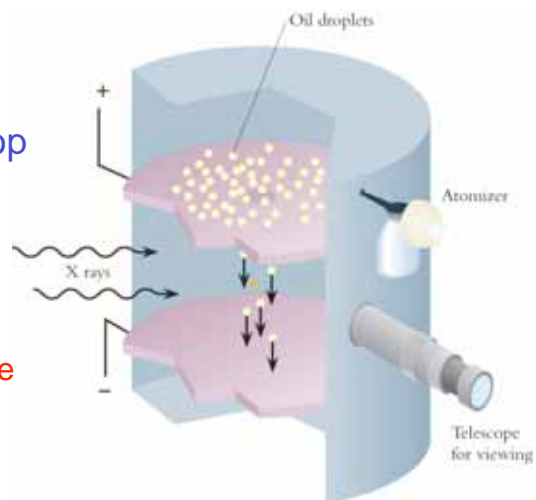
Electrons: Thomson's cathode ray tube



Determined mass to charge ratio of electrons

Structure of Atoms

Electrons: Millikan's oil drop experiment



Determined charge of an electron

Structure of Atoms

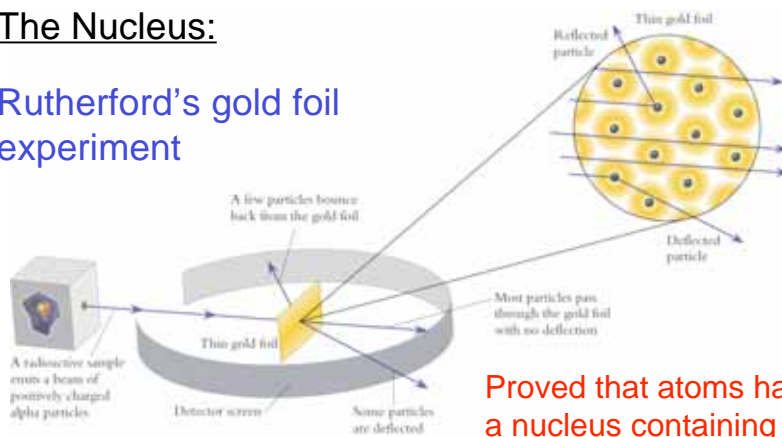
Electrons:

- Electrons are negatively charged particles
charge = -1.602×10^{-19} C (C=coulomb)
mass = 9.11×10^{-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 = 1.673×10^{-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 = 1.675×10^{-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: $1 \text{ amu} \cong \text{mass of p/n}$)

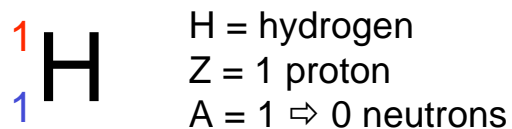
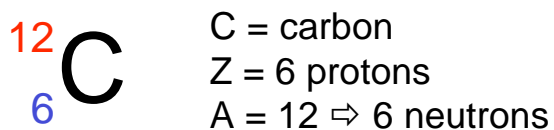
Atomic Number, Mass Number, and Atomic Mass

- 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



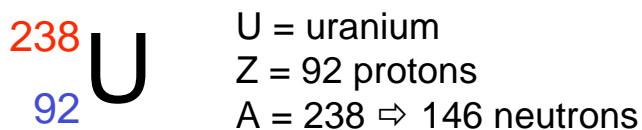
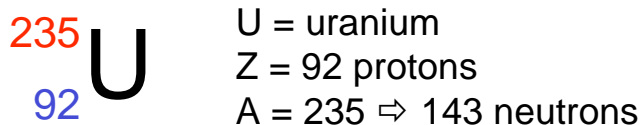
Atomic Number, Mass Number, and Atomic Mass

Examples:



Atomic Number, Mass Number, and Atomic Mass

Examples:



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

| <u>isotope</u> | <u>mass</u> | <u>abundance</u> |
|----------------|-------------|------------------|
| ^1_1H | 1.007825 | 99.9855% |
| ^2_1H | 2.014102 | 0.0145% |

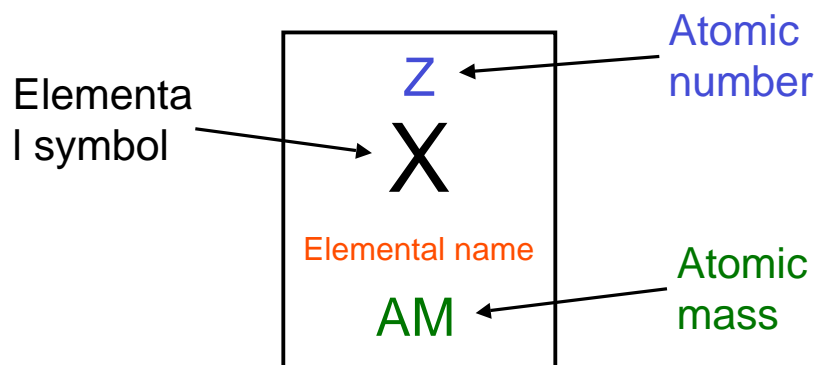
- The atomic mass of hydrogen is given as 1.00794

Atomic Number, Mass Number, and Atomic Mass

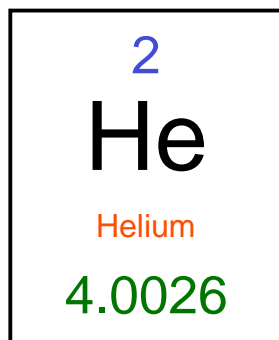
- The units of atomic mass are grams per mole: g/mol
- 1 mole = 6.022×10^{23} particles
 - A mole is just a convenient unit of measure for very large quantities (like a dozen [=12] or a score [=20])

Atomic Number, Mass Number, and Atomic Mass

Relationship of these quantities to the Periodic Table:



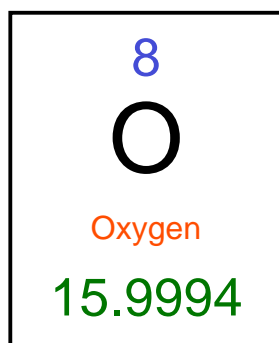
Atomic Number, Mass Number, and Atomic Mass



Protons = 2

Neutrons = 2

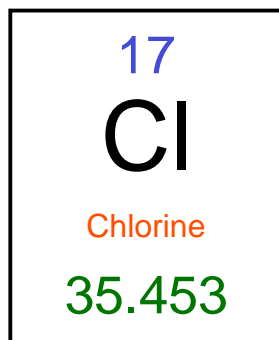
Atomic Number, Mass Number, and Atomic Mass



Protons = 8

Neutrons = 8

Atomic Number, Mass Number, and Atomic Mass



Protons = 17

Neutrons = 18.45 ?

Chlorine has two isotopes:

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

$^{37}_{17}\text{Cl}$ = 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

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

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

Step 2: Convert from grams to moles

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



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

$$(2.31 \text{ carat})(200 \text{ mg/carat})(1 \text{ g}/1000 \text{ mg}) \\ = 0.462 \text{ g}$$



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

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



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?

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

Step 1: Calculate volume of wire

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

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

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



Example Problem #3 (con't.)

Step 1: Calculate volume of wire

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

$$= 760 \text{ cm}$$

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

Step 2: Calculate mass of wire

$$m = (\text{density})(\text{volume})$$

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

$$1 \text{ mL} = 1 \text{ cm}^3$$



Example Problem #3 (con't.)

Step 3: Calculate moles

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

Step 4: Determine number of atoms

$$(3.3 \text{ mol}) (6.022 \times 10^{23} \text{ atoms/mol}) \\ = 2.0 \times 10^{24} \text{ atoms}$$



Example Problem #4

What volume will 284.9 mol of water occupy at 20 °C?

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

H₂O has 2 hydrogens and 1 oxygen

$$\begin{aligned} \text{MW} &= 2(1.0079 \text{ g/mol}) + 15.9994 \text{ g/mol} \\ &= 18.0152 \text{ g/mol} \end{aligned}$$

Step 2: Calculate mass of H₂O

$$(284.9 \text{ mol})(18.0152 \text{ g/mol}) = 5133 \text{ g}$$



Example Problem #4 (con't.)

Step 3: Calculate volume of water

$$(5133 \text{ g}) / (0.99823 \text{ g/mL}) = 5142 \text{ mL}$$

$$(5142 \text{ mL})(1 \text{ L} / 1000 \text{ mL}) = 5.142 \text{ L}$$