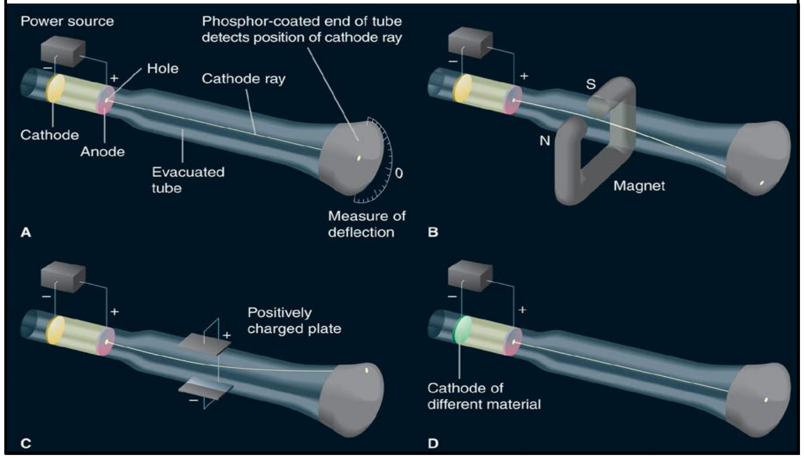
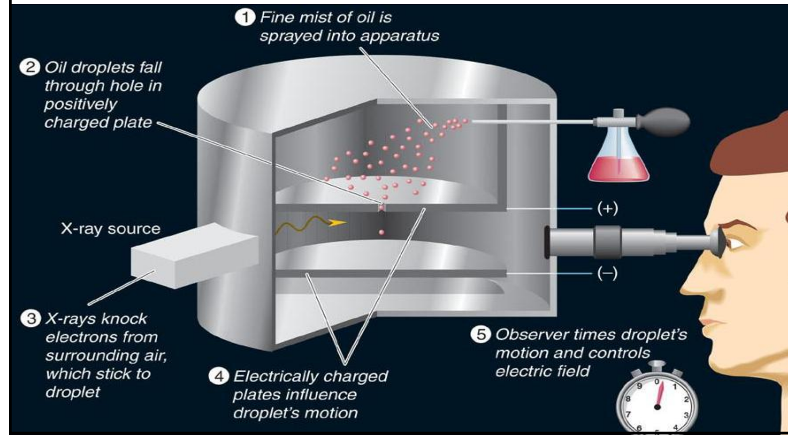
2.4 The Nuclear Model of the Atom

- **Discovery of the electron**
  - Cathode ray tubes (cathode rays → electrons)



- Mass-to-charge ratio of the electron (J.J. Thomson, 1897) → -5.686×10^{-12} kg/C
- Charge of the electron (R. Millikan, 1909) → -1.602×10^{-19} C

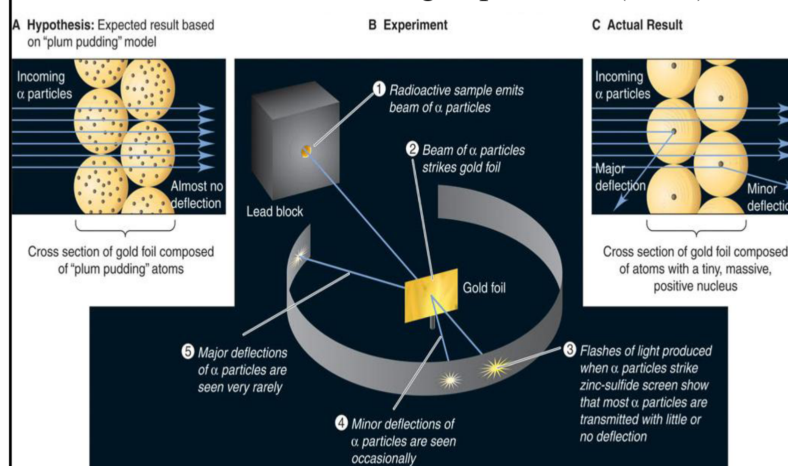


- Mass of the electron →

$(-1.602\times10^{-19}\ \text{C})\times(-5.686\times10^{-12}\ \text{kg/C})=9.109\times10^{-31}$ kg

- **Discovery of the nucleus**
  - Matter is electrically neutral → the negative electrons must be balanced by positive particles
  - J.J. Thomson's "plum pudding" model (electrons embedded in a diffuse sphere of positive charge)
  - Radioactivity (α, β, γ rays)
    - α-Particles – heavy and positive
    - β-Particles – light and negative
    - γ-Rays – electromagnetic radiation

- Rutherfords α-scattering experiment (1910)



- **Nucleus** – positive, heavy and compact

2.5 The Atomic Theory Today

- Subatomic particles (protons, neutrons and electrons)
  - Nucleus (protons & neutrons) and electron cloud

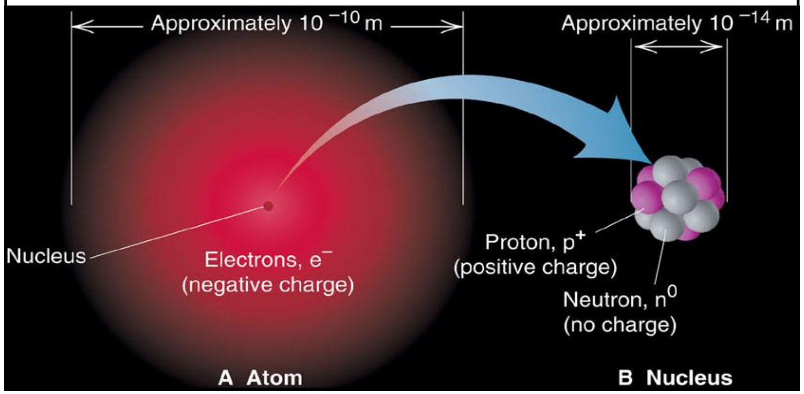


Table 2.2 Properties of the Three Key Subatomic Particles

	Charge		Mass	
Name (Symbol)	Relative	Absolute (C)*	Relative (amu)†	Absolute (g)
Proton (p^+)	1+	$+1.60218\times10^{-19}$	1.00727	1.67262×10^{-24}
Neutron (n^0)	0	0	1.00866	1.67493×10^{-24}
Electron (e^-)	1−	-1.60218×10^{-19}	0.00054858	9.10939×10^{-28}

*The coulomb (C) is the SI unit of charge.
†The atomic mass unit (amu) equals 1.66054×10^{-24} g; discussed later in this section.

- $\mathbf{p^+}$ – positive charge, ~2000 times heavier than the $\mathbf{e^-}$
- $\mathbf{n^0}$ – neutral, almost the same mass as the $\mathbf{p^+}$
- $\mathbf{e^-}$ – negative charge, same absolute charge as the $\mathbf{p^+}$
- Atoms are neutral $\Rightarrow$ $\#e^- = \#p^+$

- **Atomic number (Z)** – number of protons in the atomic nucleus
  - All atoms of a given element have the same **Z**

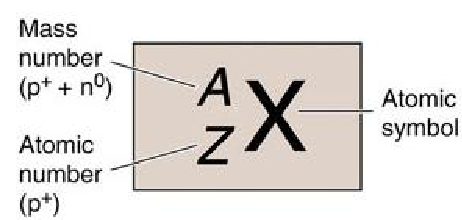
$$\mathbf{Z = \#p^+ = \#e^-}$$

- **Mass number (A)** – total number of protons and neutrons

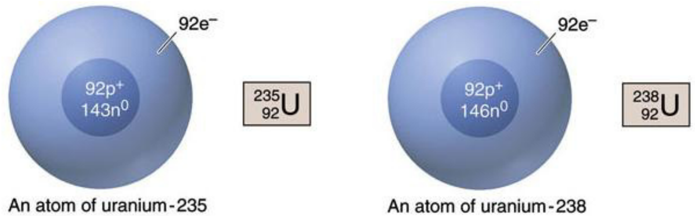
$$\mathbf{A = \#p^+ + \#n^0}$$

- Atomic symbols
  - H (hydrogen), C (carbon), O (oxygen), Ar (argon), Cl (chlorine)
  - Fe (iron, ferrum), Ag (silver, argentum), Sn (tin, stannum)

- **Isotopes and atomic masses**
  - The $\mathbf{\#p^+}$ in the nucleus of a given element is always the same, but the $\mathbf{\#n^0}$ can vary (**Z** is the same; **A** can vary)
- **Isotopes**
  - Atoms with the same **Z**, but different **A**
  - Belong to the same element, but have different atomic mass
- Isotopic symbols



- **Example:** Two of the isotopes of uranium (Z=92) have symbols ^{235}U and ^{238}U.



Problem:

- How many $\mathbf{p^+}$, $\mathbf{n^0}$, and $\mathbf{e^-}$ are present in an atom of Plutonium-239?

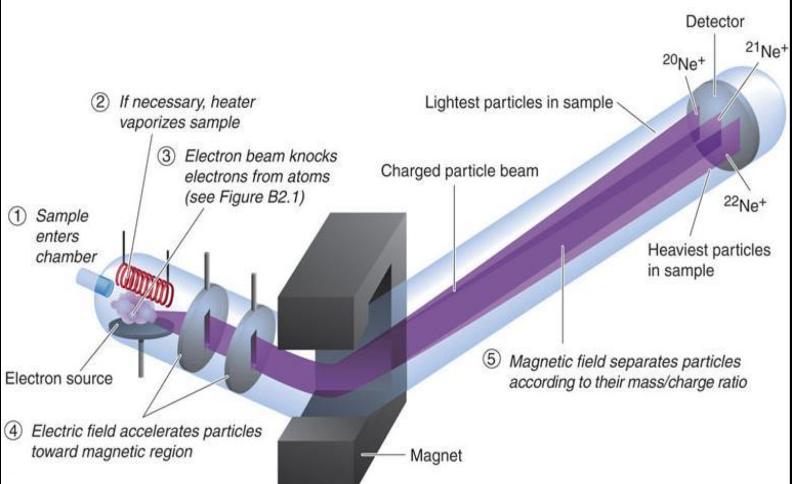
A = 239 Z = 94 (from list in textbook)

#n = A – Z = 239 – 94 = 145

#e = #p = Z = 94

- **Atomic mass unit** (**amu or D**) – **1/12** of the mass of a carbon-12 atom
  - Isotopic mass of $^{12}C \rightarrow$ 12 amu (exactly)
  - Isotopic mass of $^{1}H \rightarrow$ 1.008 amu
  - Isotopic mass of $^{29}Si \rightarrow$ 28.976 amu
- Elements occur in nature as mixtures of isotopes with certain abundances
- **Atomic mass** of an element – average of the masses of its naturally occurring isotopes (atomic masses are listed in the periodic table)

- **Mass spectrometer** – can measure the mass and abundance of isotopes



Problem:

Calculate the atomic mass of Cu, given that it naturally occurs as 69.17% ^{63}Cu (62.94 amu) and 30.83% ^{65}Cu (64.93 amu).

Use a weighted average:

Atomic mass of Cu =

$$= \mathbf{0.6917 \times 62.94}\ \boldsymbol{amu} + \mathbf{0.3083 \times 64.93}\ \boldsymbol{amu}$$

$$= \mathbf{63.55}\ \boldsymbol{amu}$$

- **Reassessment of Dalton's atomic theory:**
  1. Matter consist of atoms that are *divisible and composed of protons, neutrons and electrons*.
  2. All atoms of an element have the same *number of protons in their nucleus* which is different from the atoms of other elements.
  3. Compounds result from chemical combinations of different elements in specific atomic ratios
  4. Atoms don't change their identities in chemical reactions. *Nuclear reactions can convert atoms of one element to another*.