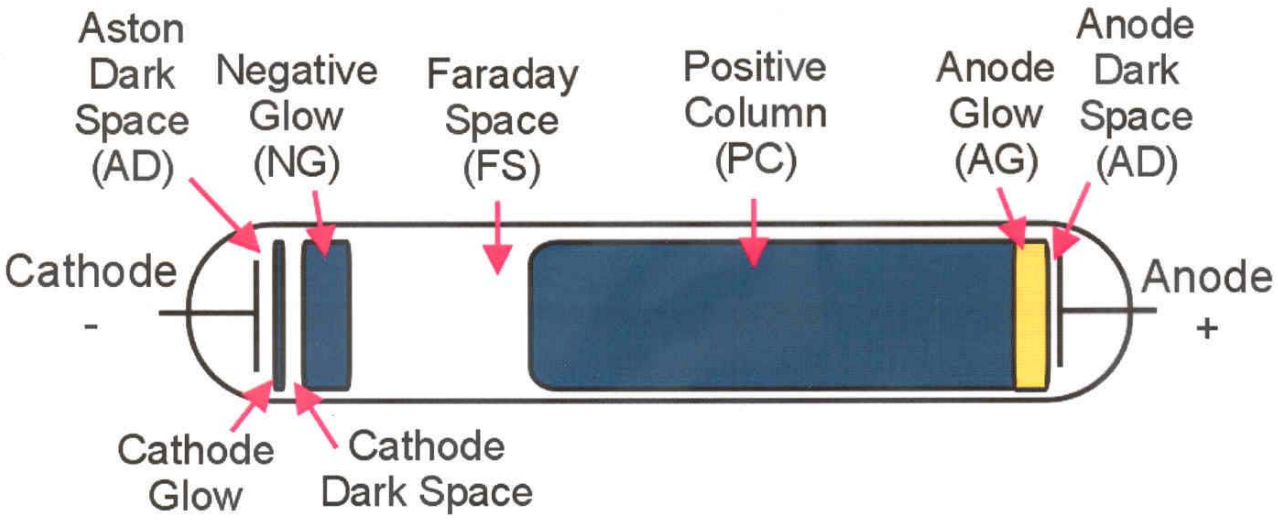
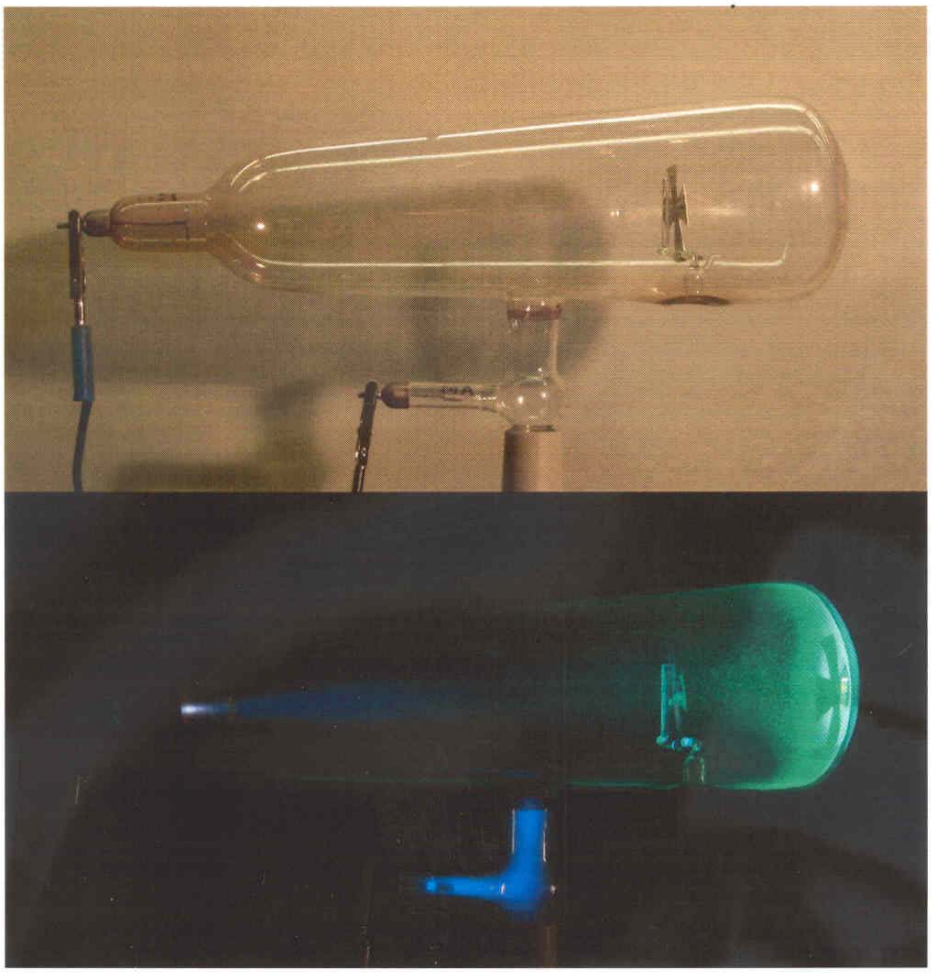
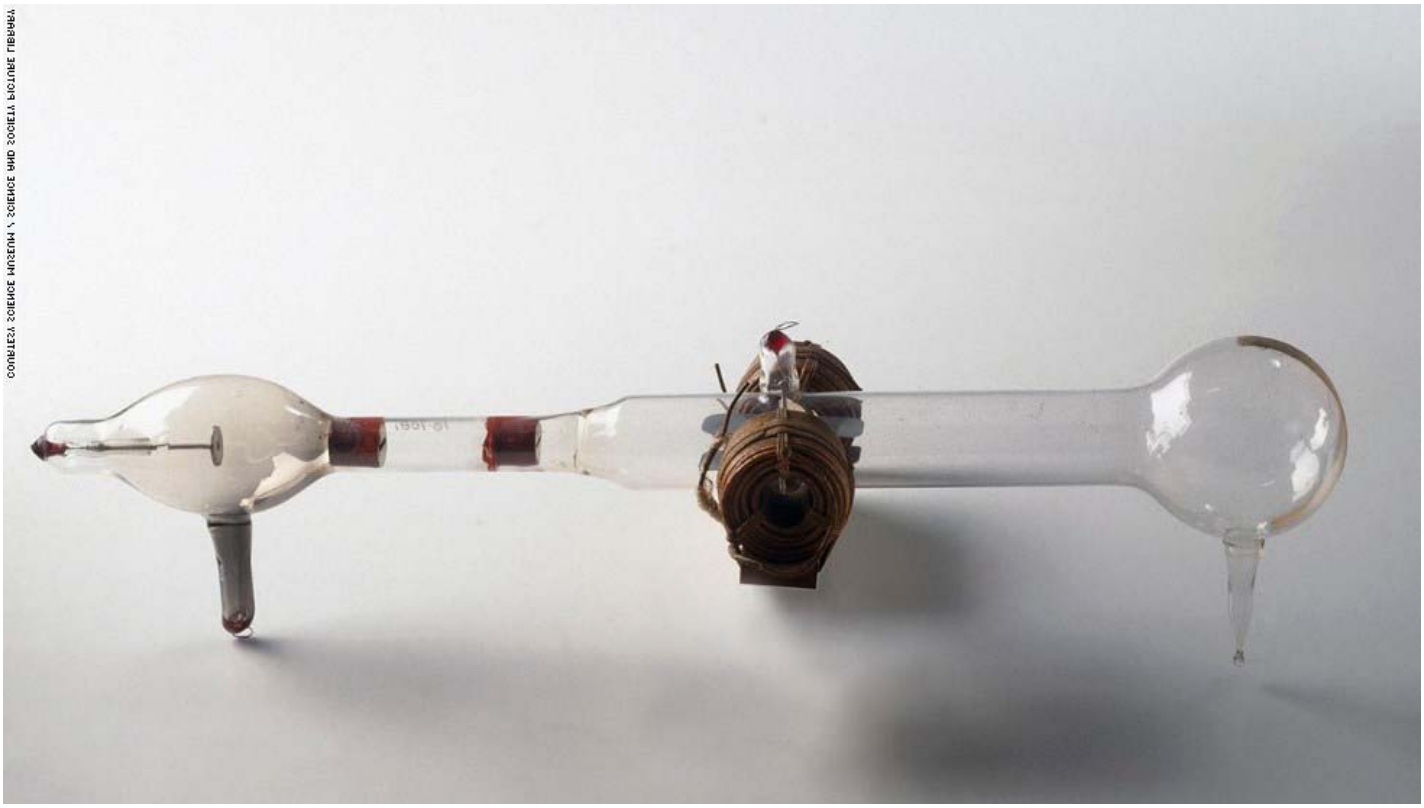
Topic 1A - Investigating Atoms

Crookes Tube:





Cathode-Ray Tube of the type used by J.J. Thomson:



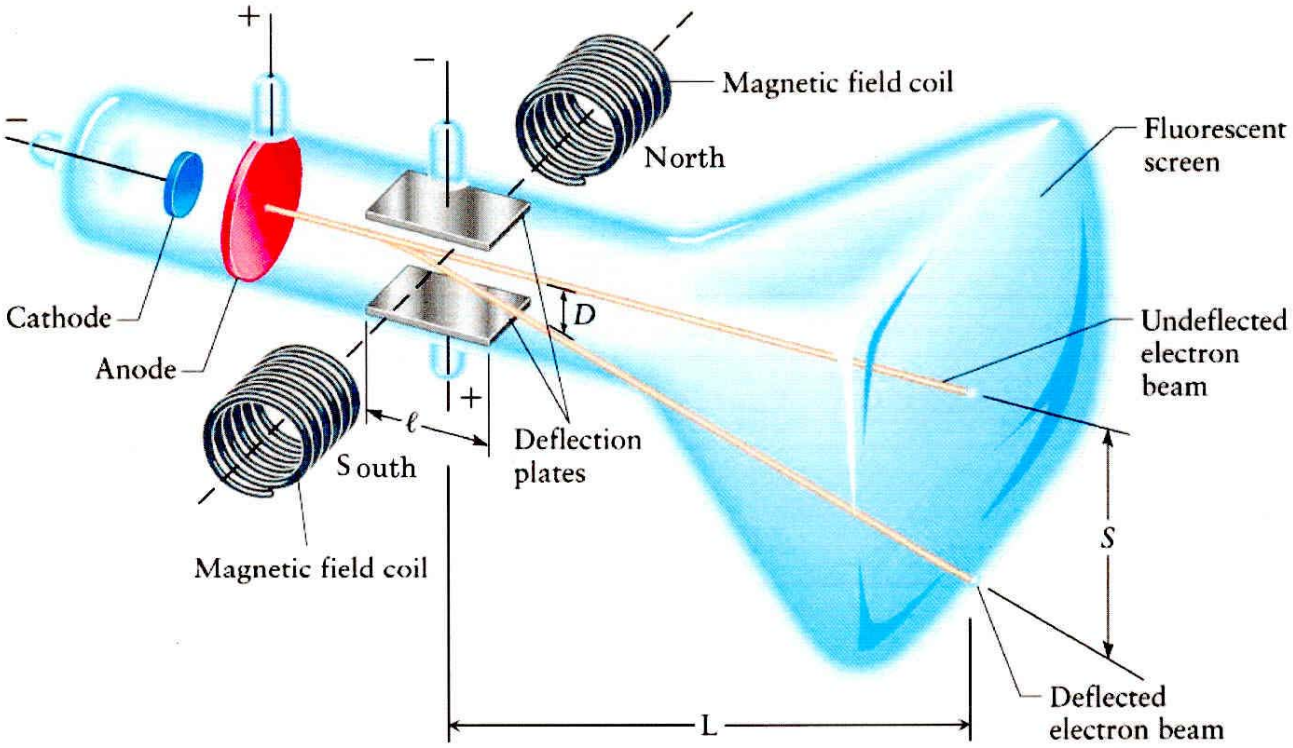


FIGURE 1.8 Thomson's apparatus to measure the electron charge-to-mass ratio, e/m_e. Electrons (cathode rays) stream across the tube from left to right. The electric field alone deflects the beam down, and the magnetic field alone deflects it up. By adjusting the two field strengths, Thomson could achieve a condition of zero net deflection. (ℓ indicates the length of the deflection plates.)

(1897)

$$S = 2\frac{L}{\ell}D = \left(\frac{e}{m_e}\right)\left(\frac{\ell}{v}\right)^2\left(\frac{L}{\ell}\right)E$$

$$= \left(\frac{e}{m_e}\right)\left(\frac{\ell H}{E}\right)^2\left(\frac{L}{\ell}\right)E$$

$$\left(\frac{e}{m_e}\right) = \frac{SE}{\ell L H^2} = 1.76 \times 10^{11}\,\frac{coul}{kg}$$

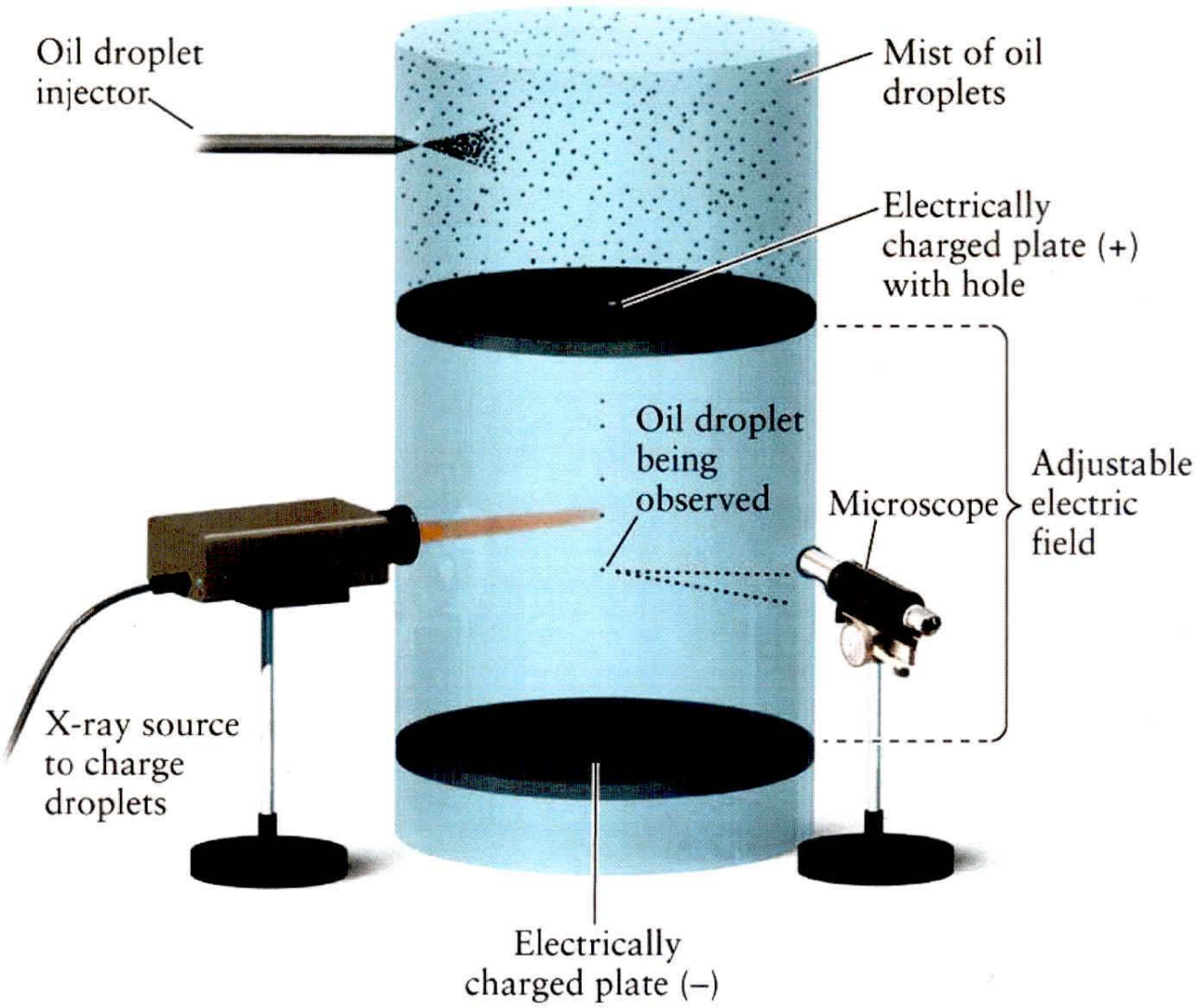


FIGURE 1.9 Millikan's apparatus to measure the charge on an electron, *e*. By adjusting the electric field strength between the charged plates, Millikan could halt the fall of negatively charged oil drops and determine their net charge. (1906)

Millikan determined that the charge on an electron, e^-, is 1.60×10^{-19} C. Combined with Thomson's result for the e/m_e ratio of 1.76×10^{11} C/kg, the mass of an electron, m_e, is thus 9.11×10^{-31} kg

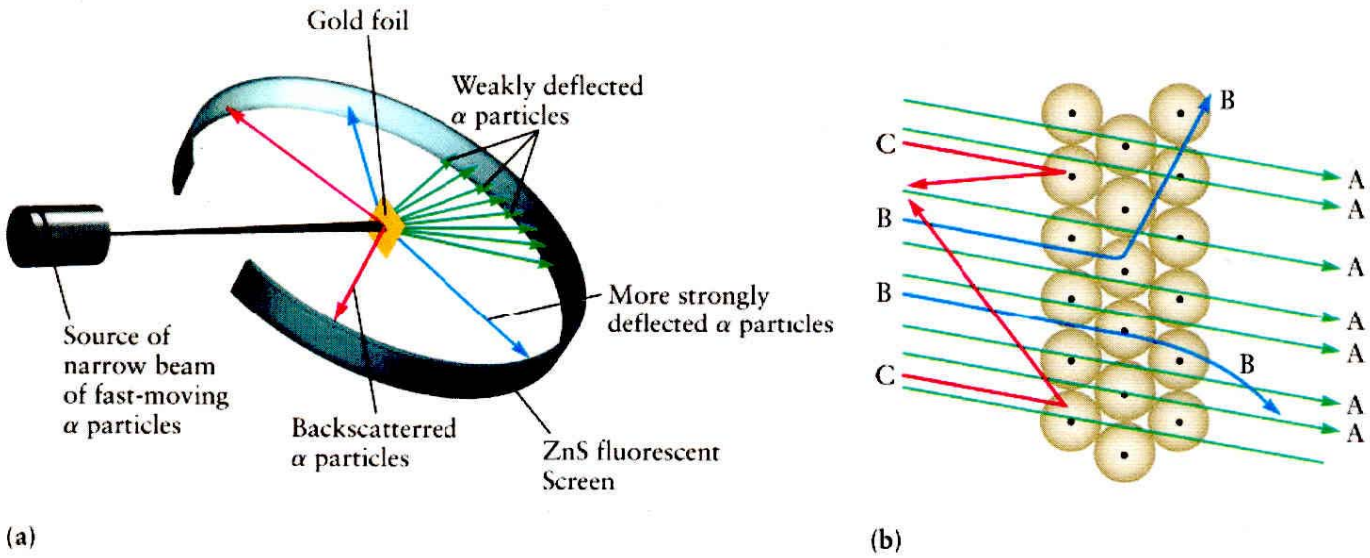
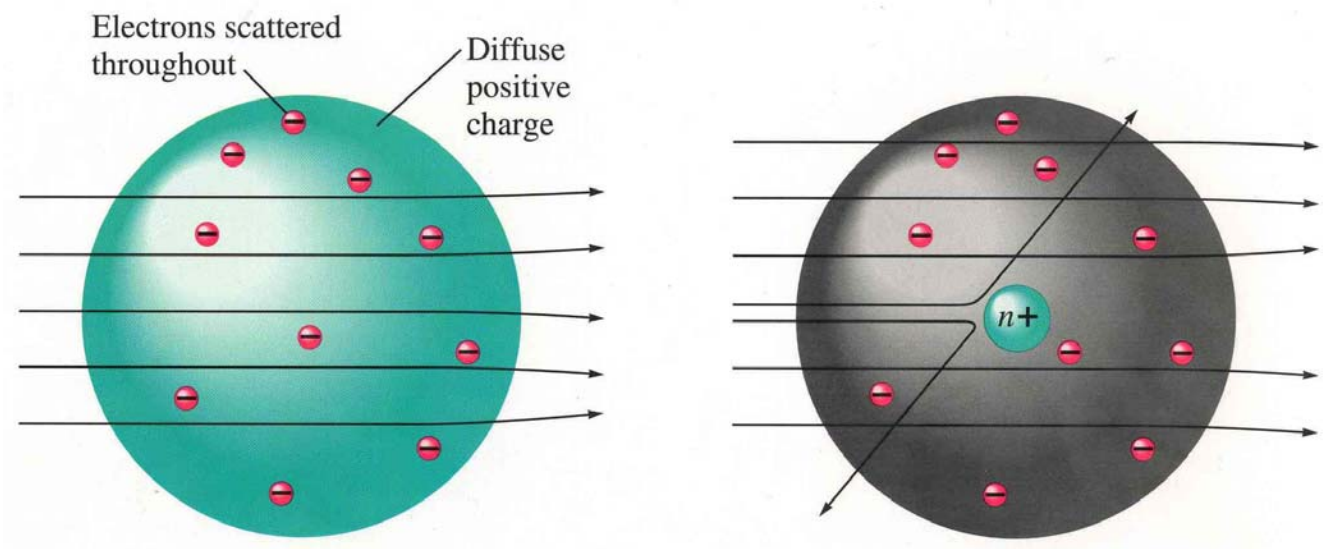
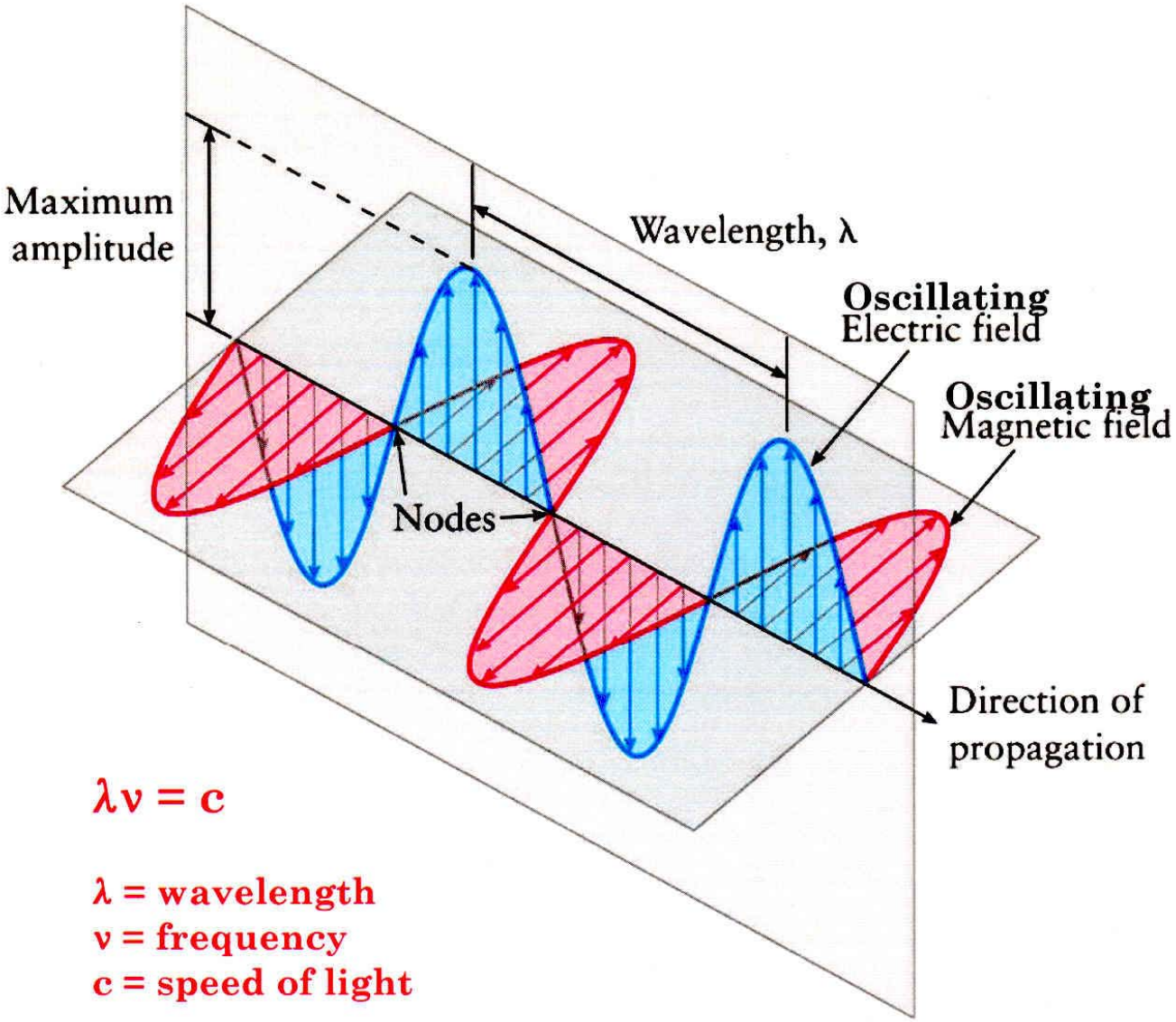


FIGURE 1.10 (a) Flashes of light mark the arrival of alpha particles at the detector screen. In the Rutherford experiment, the rate of hits on the screen varied from about 20 per minute at high angles to nearly 132,000 per minute at low angles. (b) Interpretation of the Rutherford experiment. Most of the alpha particles pass through the space between nuclei and undergo only small deflections (A). A few pass close to a nucleus and are more strongly deflected (B). Some are even scattered backward (C). The nucleus is far smaller proportionately than the dots suggest. (1911)

Rutherford's Experiment:



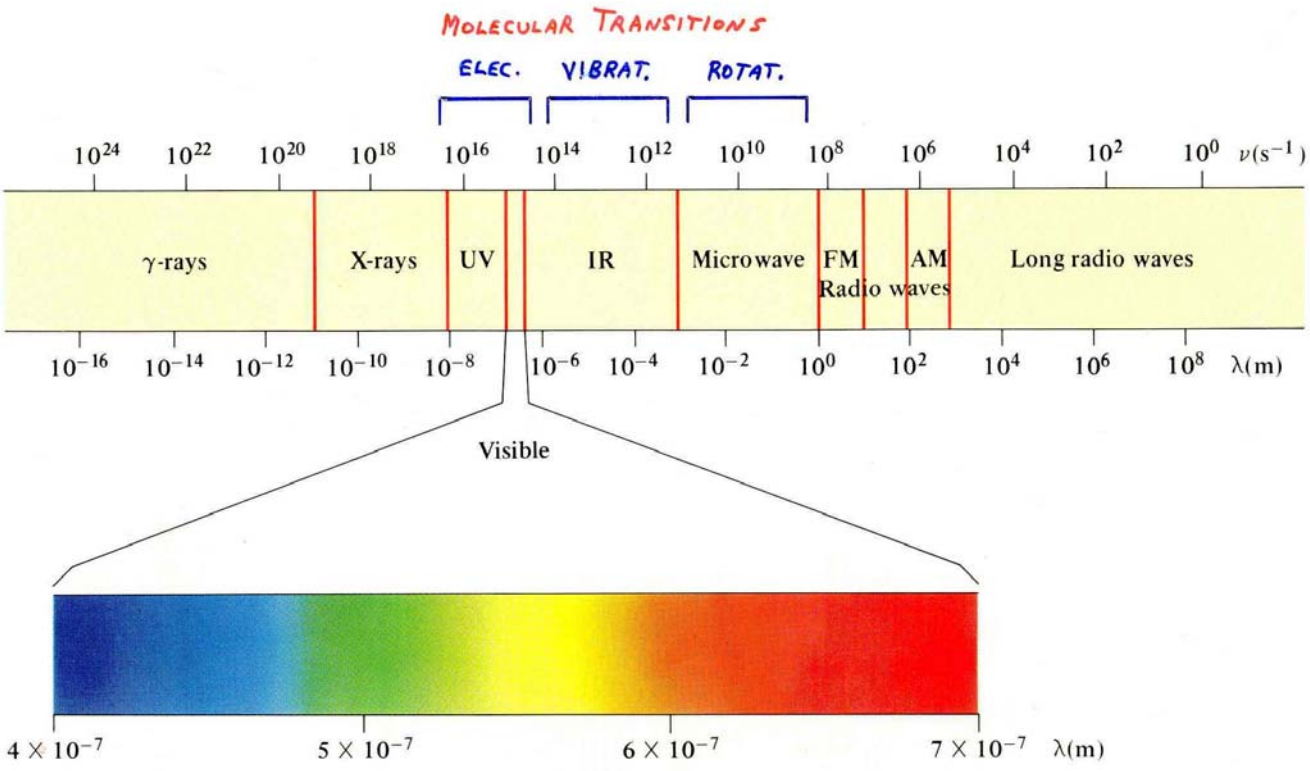
Expected Results **Observed Results**



$\lambda\nu = c$

λ = wavelength
ν = frequency
c = speed of light

FIGURE 4.2 Light consists of waves of oscillating electric and magnetic fields that are perpendicular to each other and to the direction of propagation of the light.


MOLECULAR TRANSITIONS
ELEC.
VIBRAT.
ROTAT.
10^{24} 10^{22} 10^{20} 10^{18} 10^{16} 10^{14} 10^{12} 10^{10} 10^{8} 10^{6} 10^{4} 10^{2} 10^{0} $\nu(s^{-1})$
γ-rays
X-rays
UV
IR
Microwave
FM
AM
Radio waves
Long radio waves
10^{-16} 10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 10^{0} 10^{2} 10^{4} 10^{6} 10^{8} λ(m)
Visible
4×10^{-7} 5×10^{-7} 6×10^{-7} 7×10^{-7} λ(m)

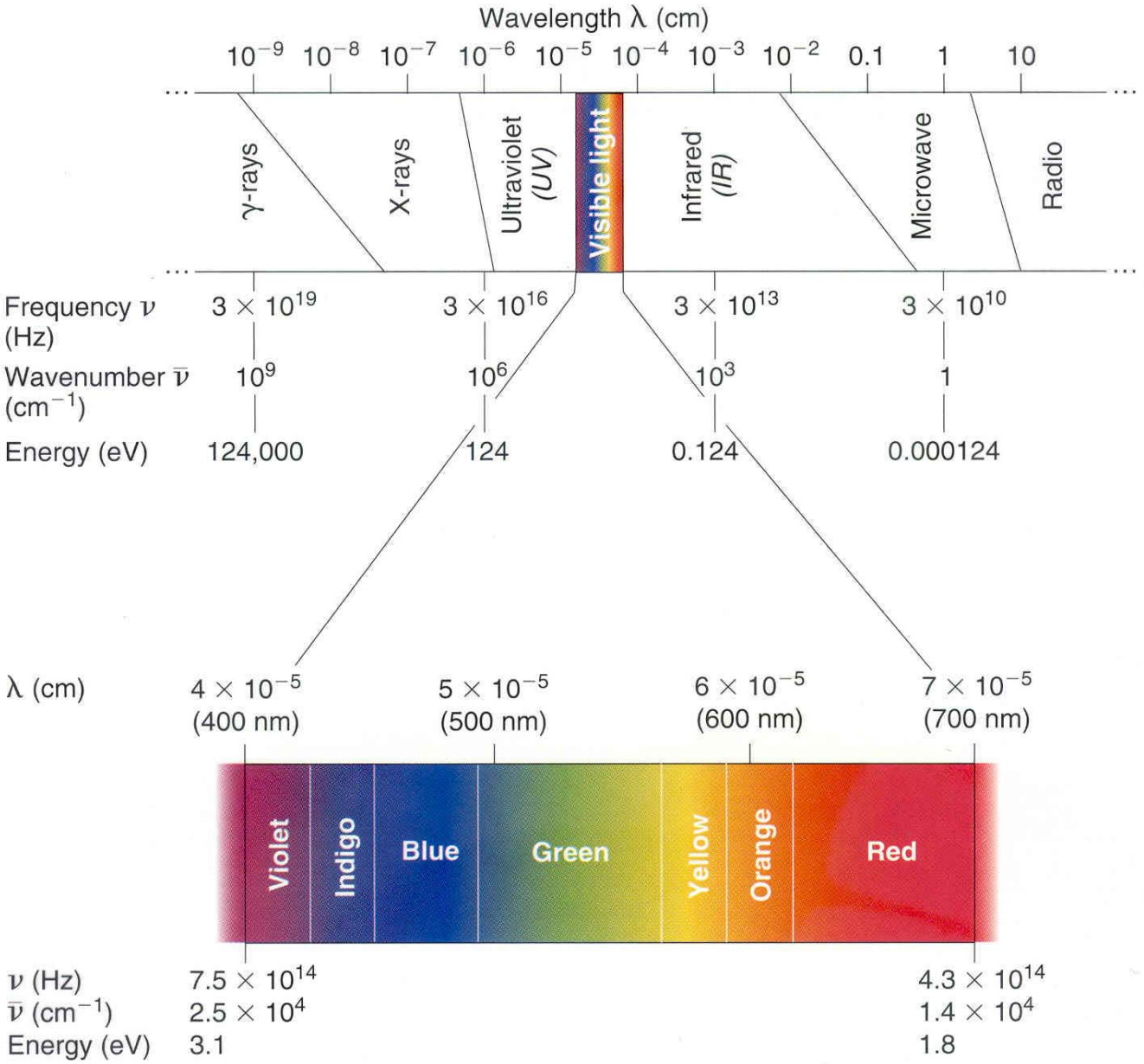
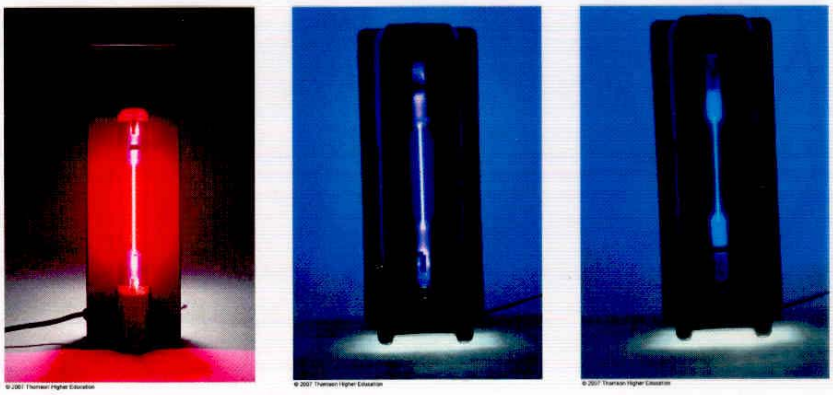
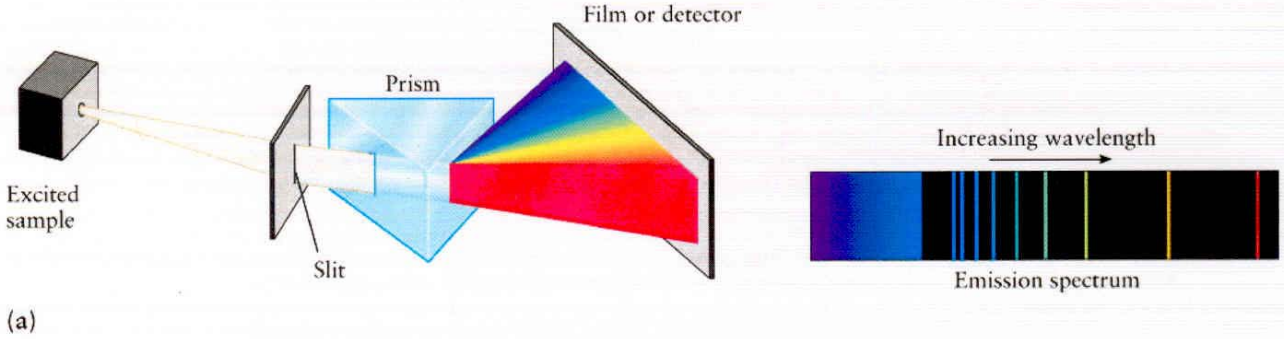
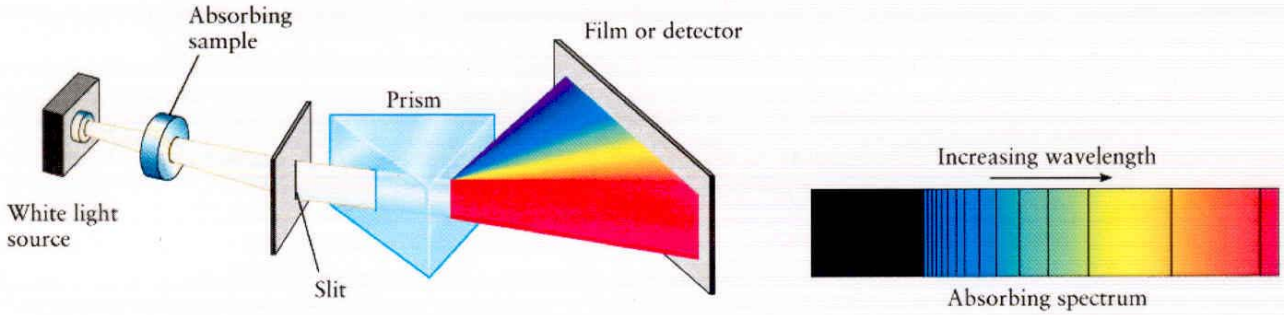

Wavelength λ (cm)
10^−9 10^−8 10^−7 10^−6 10^−5 10^−4 10^−3 10^−2 0.1 1 10
γ-rays
X-rays
Ultraviolet (UV)
Visible light
Infrared (IR)
Microwave
Radio
Frequency ν (Hz)
3 × 10^19
3 × 10^16
3 × 10^13
3 × 10^10
Wavenumber ν̄ (cm^−1)
10^9
10^6
10^3
1
Energy (eV)
124,000
124
0.124
0.000124
λ (cm)
4 × 10^−5 (400 nm)
5 × 10^−5 (500 nm)
6 × 10^−5 (600 nm)
7 × 10^−5 (700 nm)
Violet
Indigo
Blue
Green
Yellow
Orange
Red
ν (Hz)
7.5 × 10^14
4.3 × 10^14
ν̄ (cm^−1)
2.5 × 10^4
1.4 × 10^4
Energy (eV)
3.1
1.8

FIGURE 4.8 When a gas is excited in an electrical discharge, it glows as it emits light. The colors of the light emitted by three gases are shown: (a) neon, (b) argon, and (c) mercury. Each emission consists of several wavelengths of light, and the perceived color depends on which wavelength predominates.





(a)



(b)

FIGURE 4.9 (a) The emission spectrum of atoms or molecules is measured by passing the light emitted from an excited sample through a prism to separate it according to wavelength, then recording the image on photographic film or with another detector. (b) In absorption spectroscopy, white light from a source passes through the unexcited sample, which absorbs certain discrete wavelengths of light. Dark lines appear on a bright background.

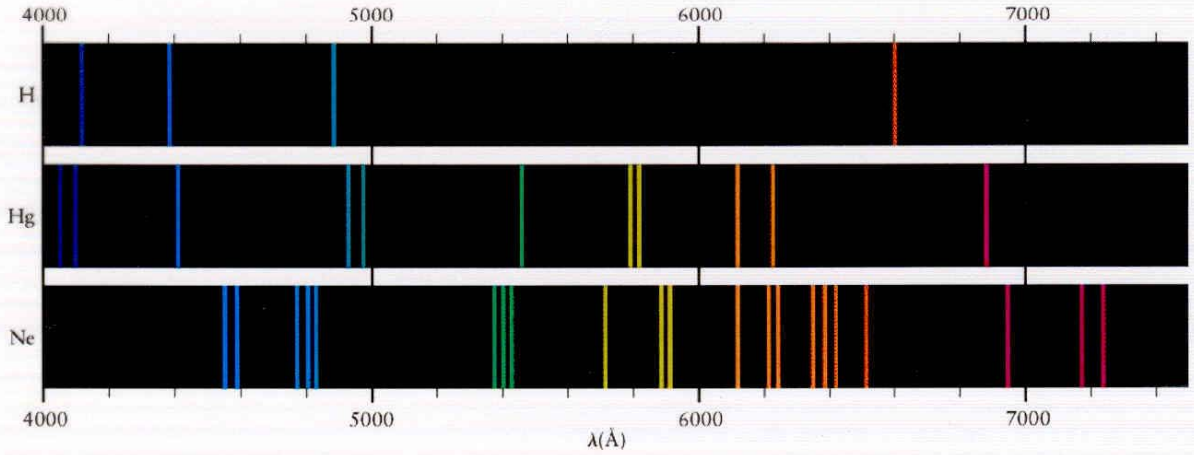


FIGURE 4.10 Atoms of hydrogen, mercury, and neon emit light at discrete wavelengths. The pattern seen is characteristic of the element under study. 1 Å = 10^{-10} m.

Spectrum of Atomic Hydrogen

Rydberg Eq.: $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$