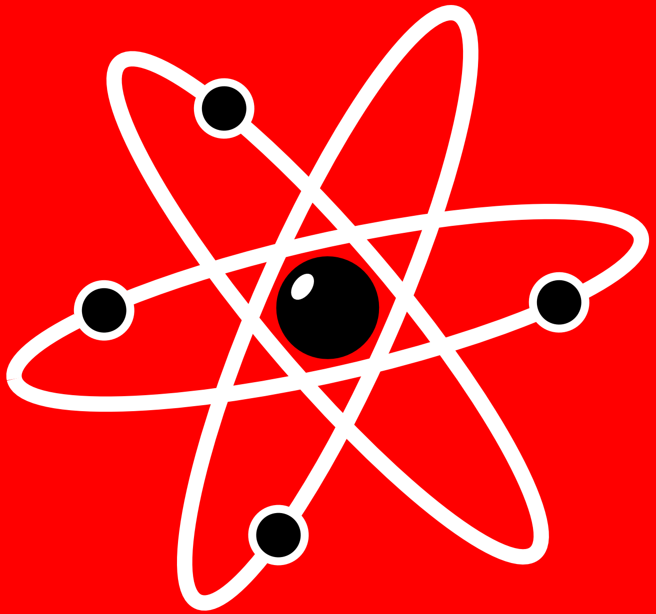
Bohr's atomic model
Franck-Hertz experiment
Moseley's law



Presented by:
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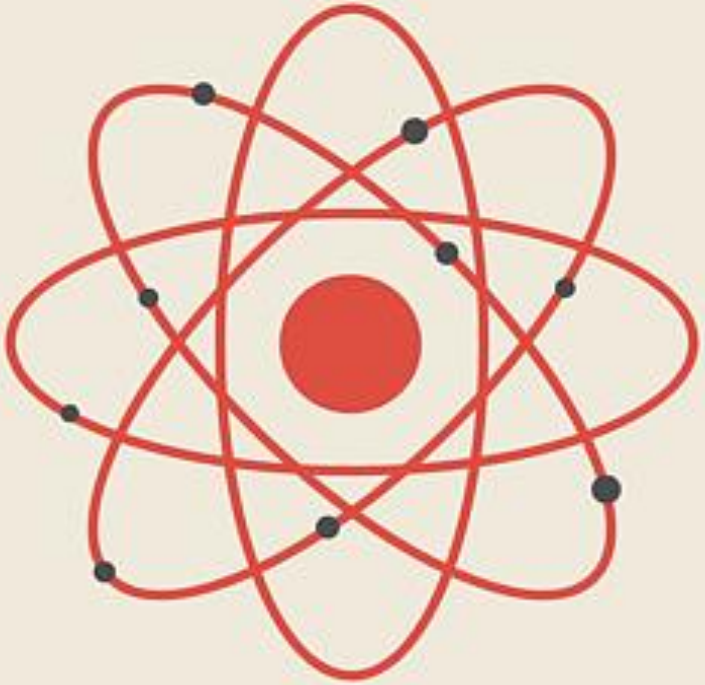
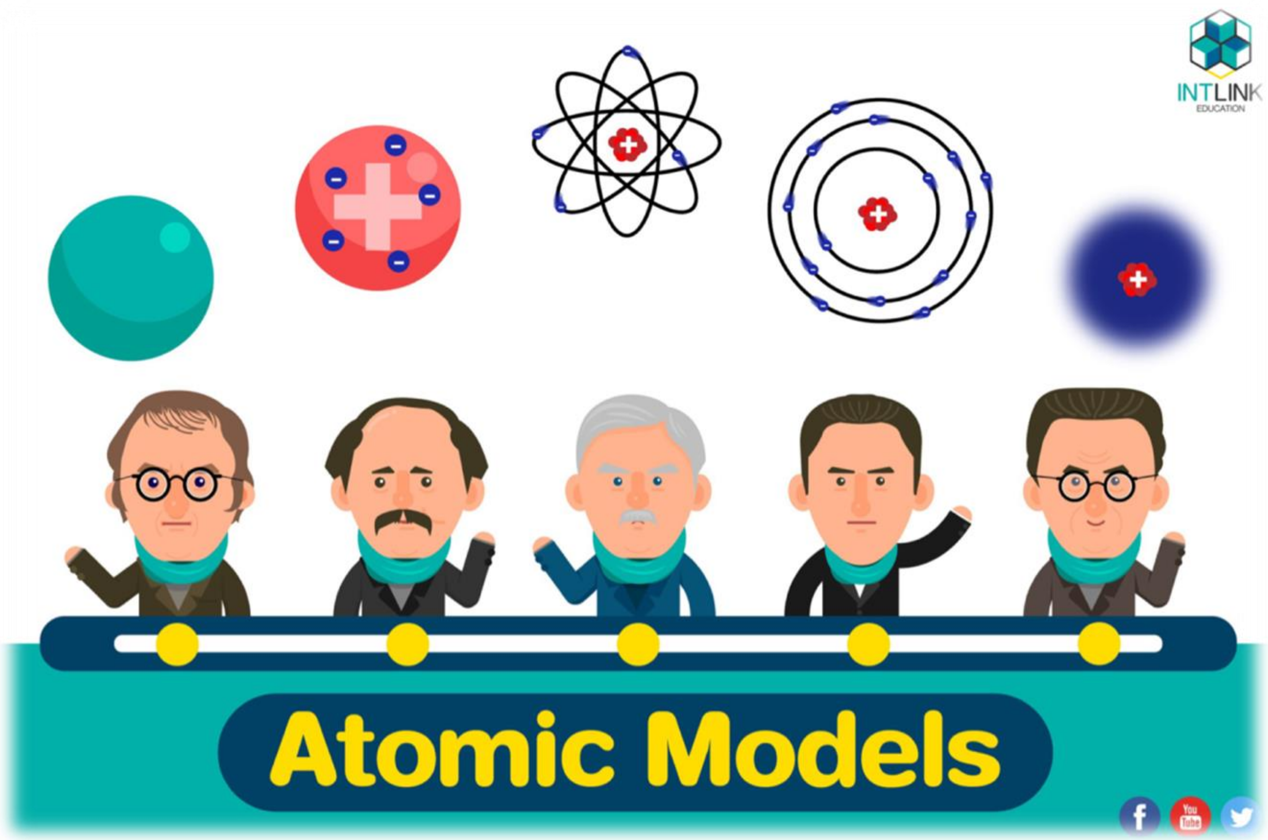
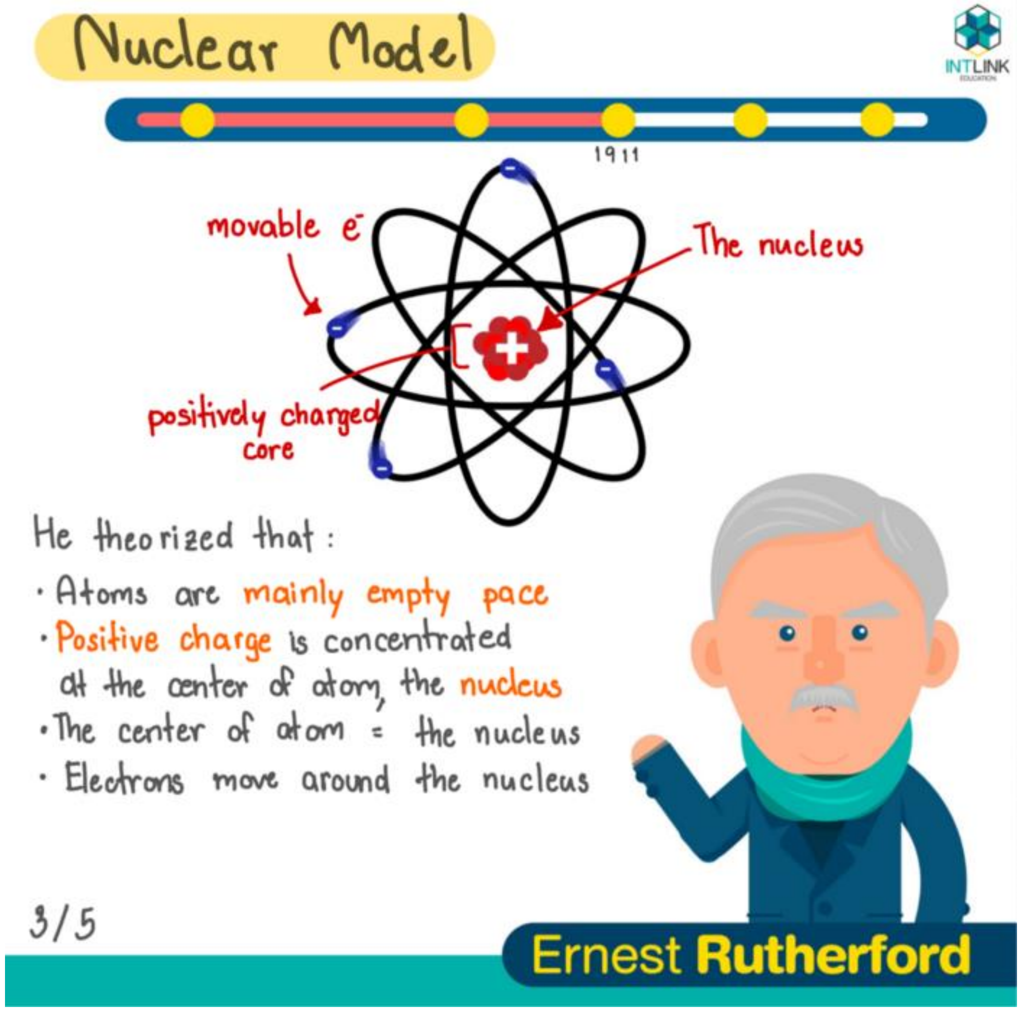


INTRODUCTION

Timeline of atomic models



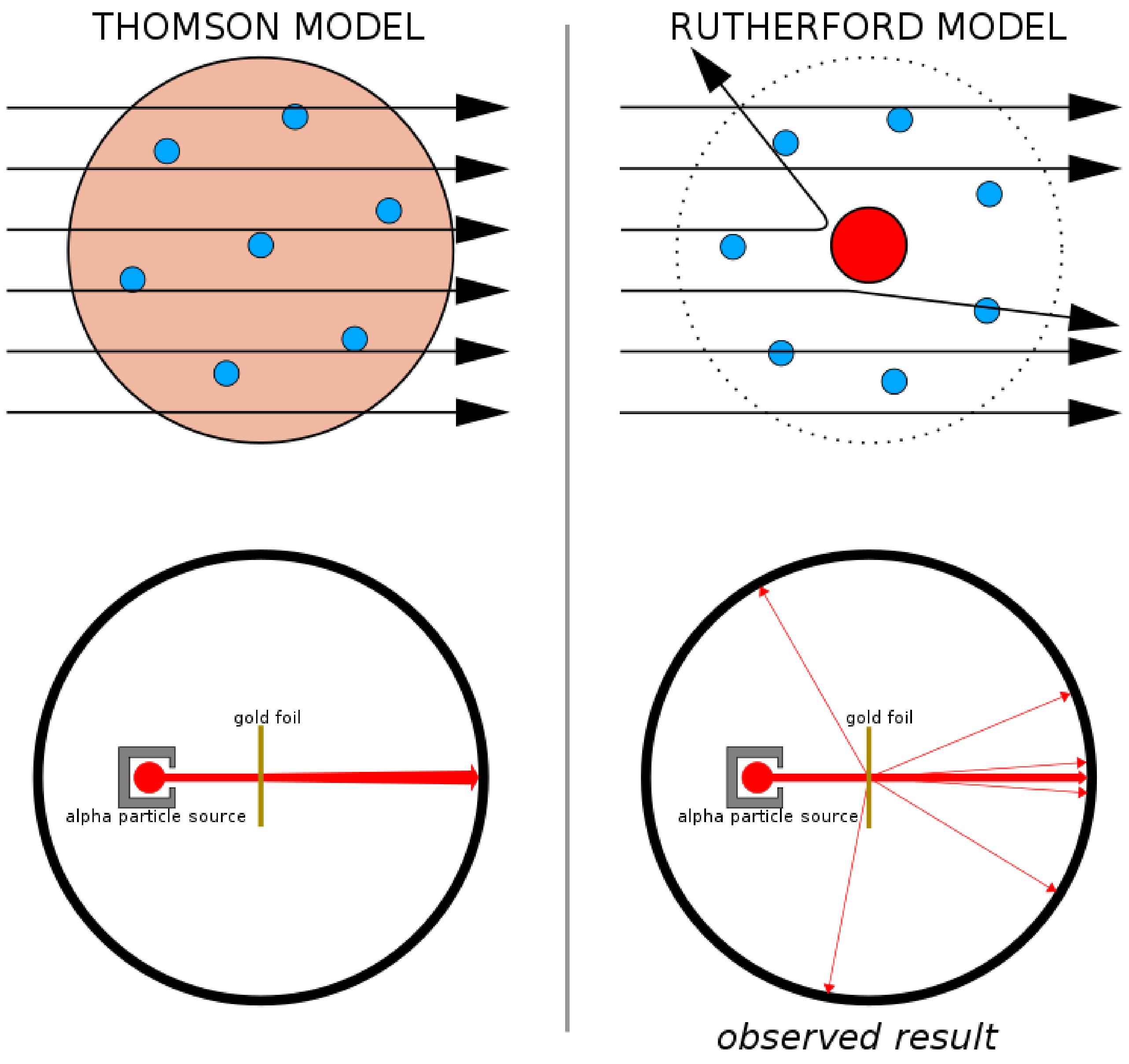


Rutherford's model

and discussion about it

Gieger-Marsden-Rutherford experiments

Rutherford designed an experiment to use the alpha particles emitted by a radioactive element as probes to the unseen world of atomic structure. If Thomson was correct, the beam would go straight through the gold foil. Most of the beams went through the foil, but a few were deflected.

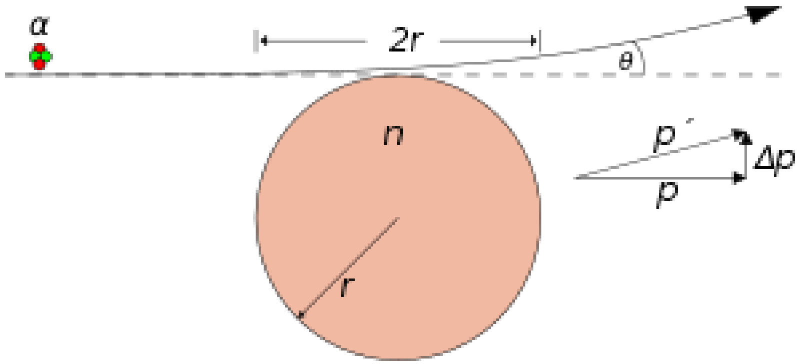


Mathematical model of the scattering pattern

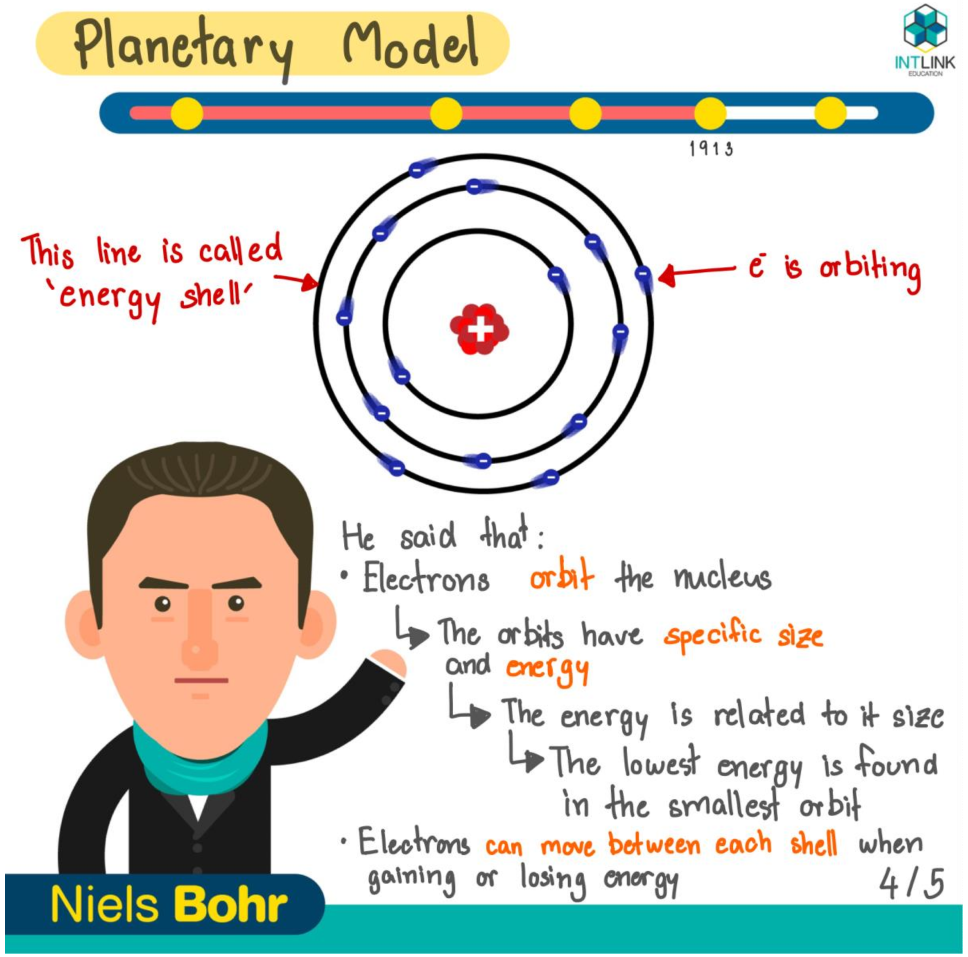
$$\Delta p = F\Delta t = k \cdot \frac{Q_\alpha Q_n}{r^2} \cdot \frac{2r}{v_\alpha}$$

$$\theta \approx \frac{\Delta p}{p} < k \cdot \frac{2Q_\alpha Q_n}{m_\alpha r v_\alpha^2} = 8.998 \cdot 10^9 \times \frac{2 \times 3.204 \cdot 10^{-19} \times 1.266 \cdot 10^{-17}}{6.645 \cdot 10^{-27} \times 1.44 \cdot 10^{-10} \times (1.53 \cdot 10^7)^2}$$

$$\theta < 0.000326 \text{ rad (or } 0.0186°)$$



Bohr vs Rutherford



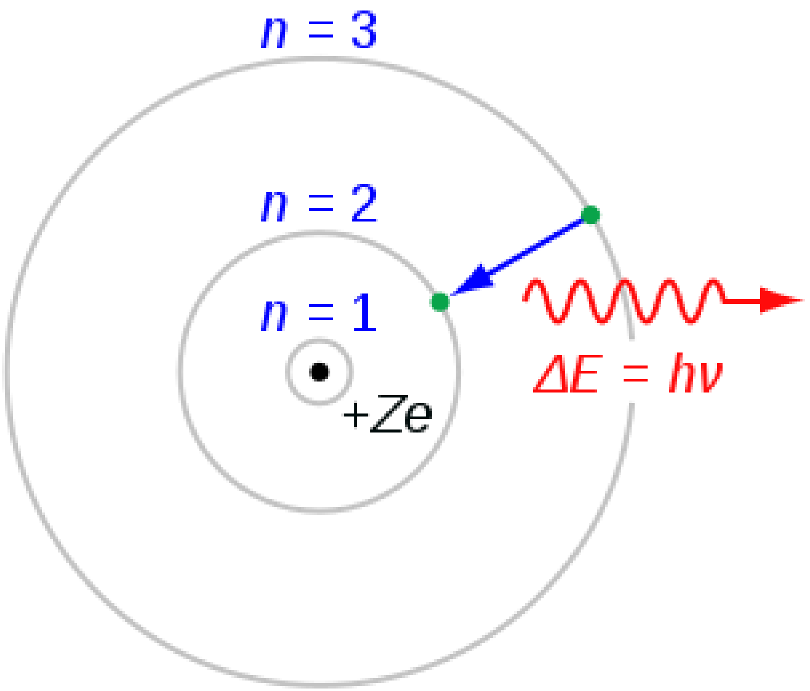
Bohr’s model

Experiments by Ernest Rutherford established that atoms consisted of a diffuse cloud of negatively charged electrons surrounding a small, dense, positively charged nucleus. Given this experimental data, Rutherford naturally considered a planetary model of the atom, the Rutherford model of 1911. This had electrons orbiting a solar nucleus, but involved a technical difficulty: the laws of classical mechanics predict that the electron will release electromagnetic radiation while orbiting a nucleus. Because the electron would lose energy, it would rapidly spiral inwards, collapsing into the nucleus on a timescale of around 16 picoseconds. This atom model is disastrous because it predicts that all atoms are unstable. Also, as the electron spirals inward, the emission would rapidly increase in frequency due to the orbital period becoming shorter, resulting in electromagnetic radiation with a continuous spectrum. However, late 19th-century experiments with electric discharges had shown that atoms will only emit light (that is, electromagnetic radiation) at certain discrete frequencies.

Rydberg vs Bohr

Rydberg had been working on a formula for spectral lines and had earlier found the Balmer formula for hydrogen and rewritten it in 1888.

$$\frac{1}{\lambda_{\mathrm{vac}}} = R_{\mathrm{H}} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right),$$



Bohr's postulates

1. The electron is able to revolve in certain stable orbits around the nucleus without radiating any energy, contrary to what classical electromagnetism suggests. These stable orbits are called stationary orbits and are attained at certain discrete distances from the nucleus. The electron cannot have any other orbit in between the discrete ones.

2. The stationary orbits are attained at distances for which the angular momentum of the revolving electron is an integer multiple of the reduced Planck constant: $m_e v r = n\hbar$, where n = 1, 2, 3, ... is called the principal quantum number, and $\hbar = h/2\pi$. The lowest value of n is 1; this gives the smallest possible orbital radius of 0.0529 nm known as the Bohr radius.

Bohr's postulates

3.Electrons can only gain and lose energy by jumping from one allowed orbit to another, absorbing or emitting electromagnetic radiation with a frequency *v* determined by the energy difference of the levels according to the Planck relation, where *h* is Planck's constant.

$$\Delta E = E_2 - E_1 = h\nu$$

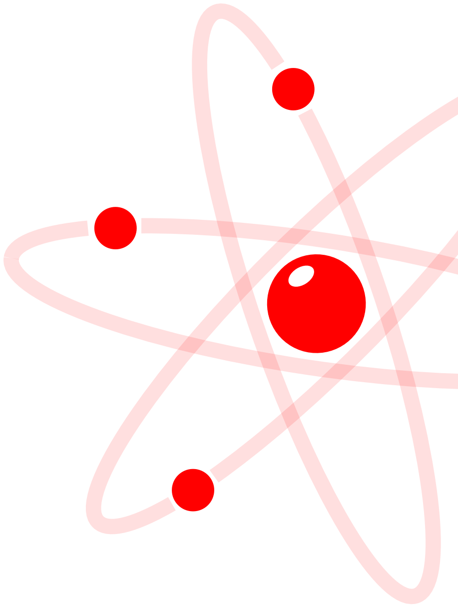
de Broglie's: $$\frac{nh}{2\pi} = mvr$$

Bohr's: $$m_e v r = n\hbar$$

$\hbar = h/2\pi$

Electron energy levels

The Bohr model gives almost exact results only for a system where two charged points orbit each other at speeds much less than that of light. This not only involves one-electron systems such as the hydrogen atom, singly ionized helium, and doubly ionized lithium, but it includes positronium and Rydberg states of any atom where one electron is far away from everything else. It can be used for K-line X-ray transition calculations if other assumptions are added (see Moseley's law below). In high energy physics, it can be used to calculate the masses of heavy quark mesons.



Electron energy levels

Classical mechanics:

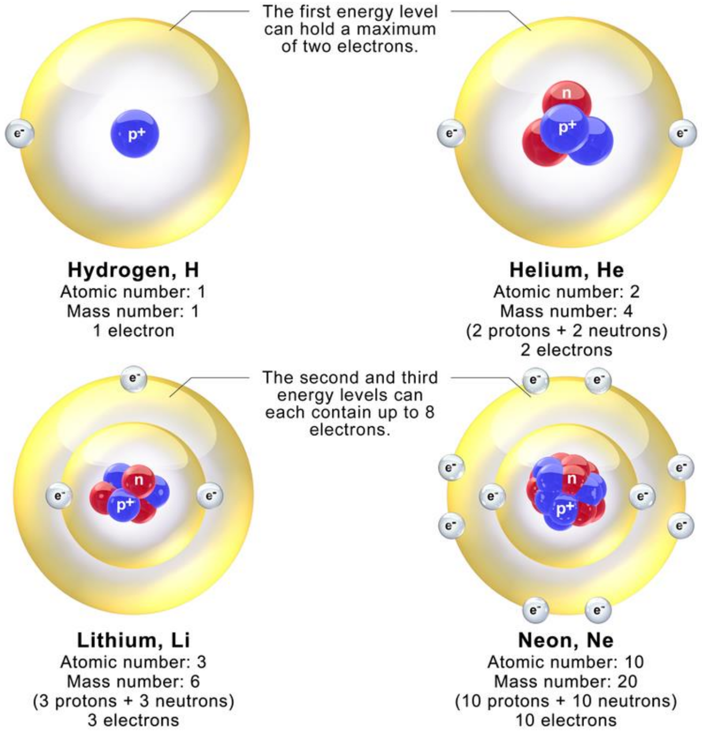
$$\frac{m_e v^2}{r} = \frac{Z k_e e^2}{r^2}$$

$$v = \sqrt{\frac{Z k_e e^2}{m_e r}}.$$

$$E = -\frac{1}{2} m_e v^2$$

A quantum rule:

$$m_e v r = n\hbar$$



Derivation

$$\Delta E \propto \frac{1}{r^{\frac{3}{2}}} \propto E^{\frac{3}{2}}.$$

$$E \propto \frac{1}{r} \propto \frac{1}{L^2}$$

$$\Delta E \propto \frac{1}{(L+\hbar)^2} - \frac{1}{L^2} \approx -\frac{2\hbar}{L^3} \propto -E^{\frac{3}{2}}.$$

$$\Delta E = E_2 - E_1 = h\nu$$

$$L = \frac{nh}{2\pi} = n\hbar.$$

Modeling the Hydrogen atom:

Rydberg formula for H^1_1:

$$E = E_i - E_f = R_E \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

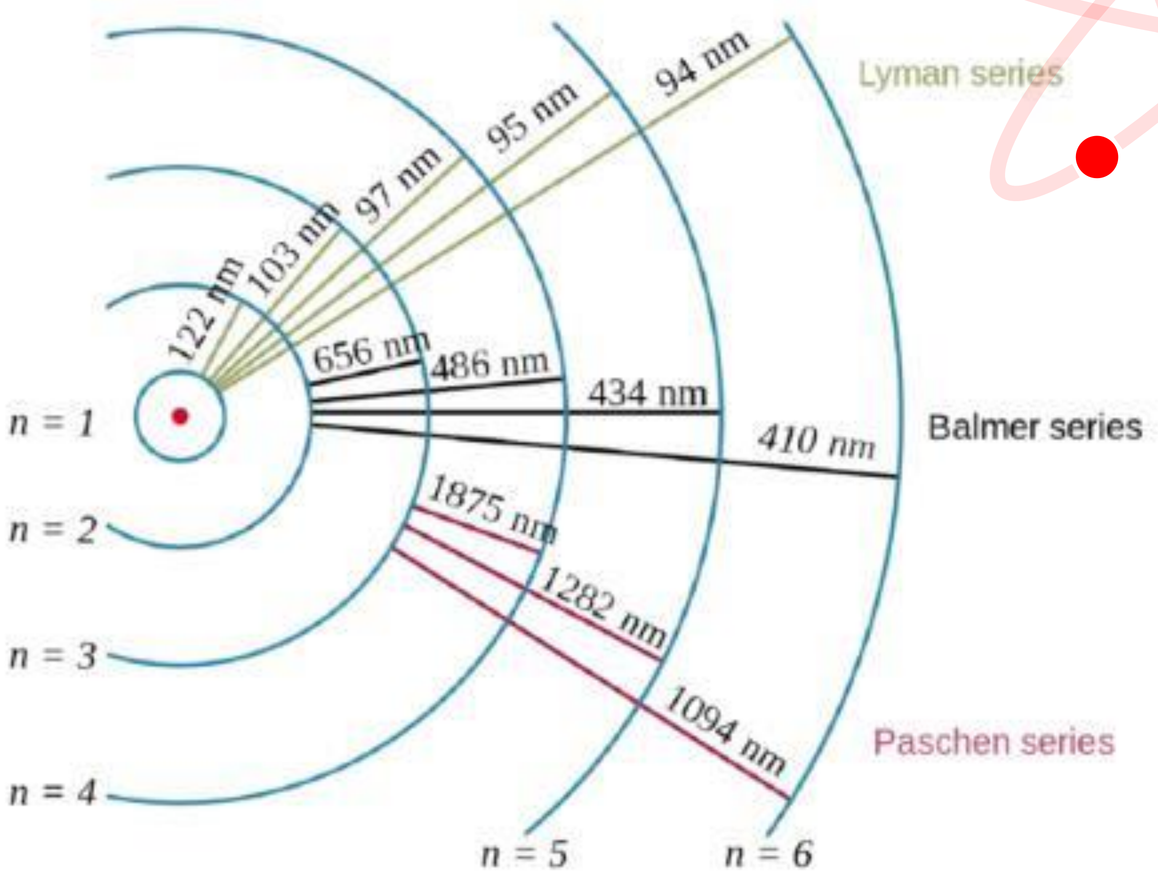
Quantized electron energy:

$$m_e \sqrt{\frac{k_e Z e^2}{m_e r}}\, r = n\hbar$$

$$r_n = \frac{n^2 \hbar^2}{Z k_e e^2 m_e} \qquad * \; R_E = \frac{(k_e e^2)^2 m_e}{2\hbar^2}$$

$$r_1 = \frac{\hbar^2}{k_e e^2 m_e} \approx 5.29 \times 10^{-11} \mathrm{m}$$

$$E = -\frac{Z k_e e^2}{2 r_n} = -\frac{Z^2 (k_e e^2)^2 m_e}{2\hbar^2 n^2} \approx \frac{-13.6 Z^2}{n^2} \mathrm{eV}$$



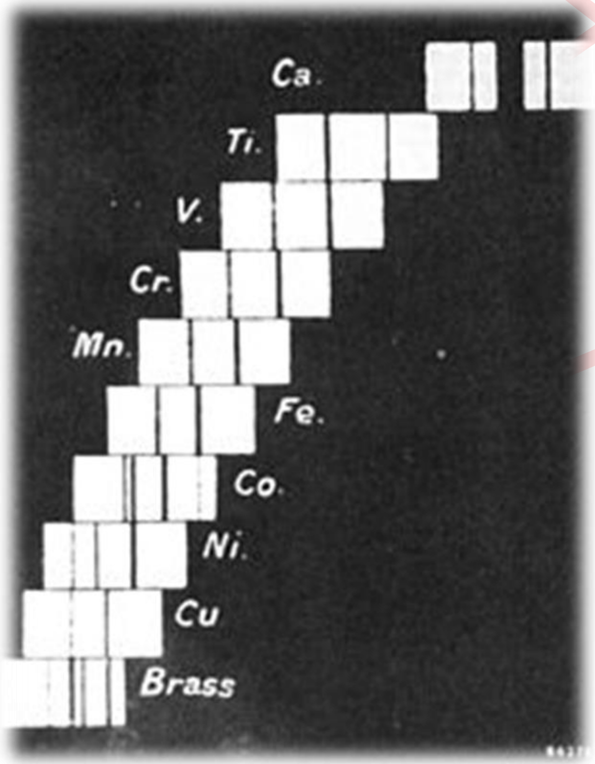
Moseley's law:

Niels Bohr said in 1962, "You see actually the Rutherford work was not taken seriously. We cannot understand today, but it was not taken seriously at all. There was no mention of it any place. The great change came from Moseley."

$$E = h\nu = E_i - E_f = \frac{m_e q_e^2 q_Z^2}{8h^2 \varepsilon_0^2} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$E = h\nu = E_i - E_f = \frac{m_e q_e^4}{8h^2 \varepsilon_0^2} \left(\frac{1}{1^2} - \frac{1}{2^2} \right) (Z-1)^2 = \left(\frac{3}{4} \right) (Z-1)^2 \times 13.6\ \mathrm{eV}$$

$$\nu = \frac{E}{h} = \frac{m_e q_e^4}{8h^3 \varepsilon_0^2} \left(\frac{3}{4} \right) (Z-1)^2 = (2.47 \cdot 10^{15}\ \mathrm{Hz})(Z-1)^2$$



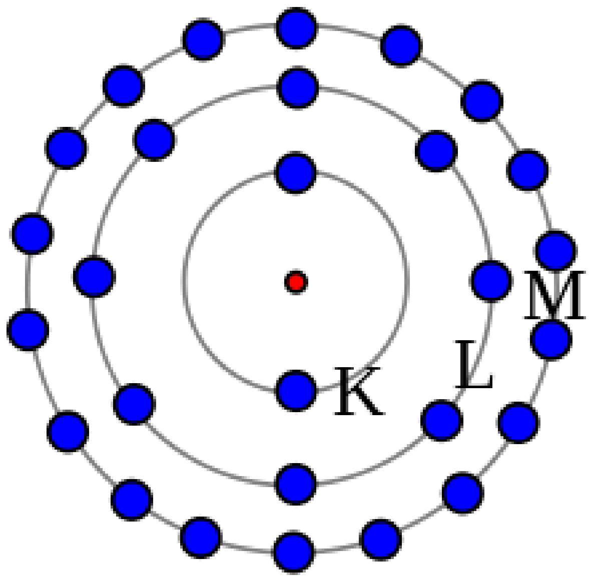
Moseley’s law:

The K-alpha line of Moseley's time is now known to be a pair of close lines, written as (**Kα_1** and **Kα_2**) in Siegbahn notation.

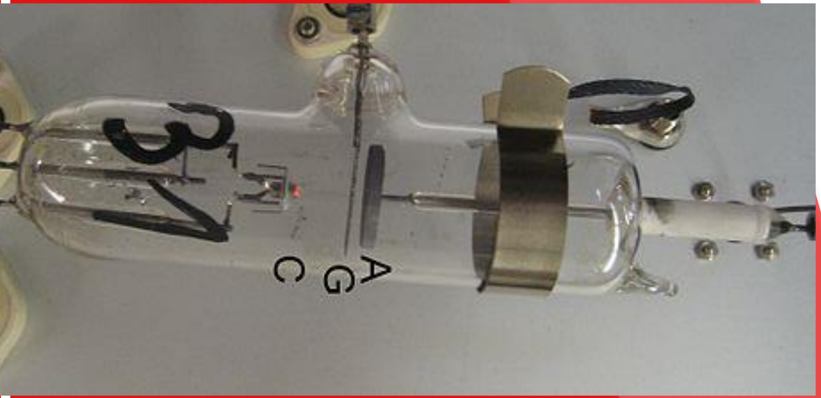
$$\nu = A \cdot (Z - b)^2$$

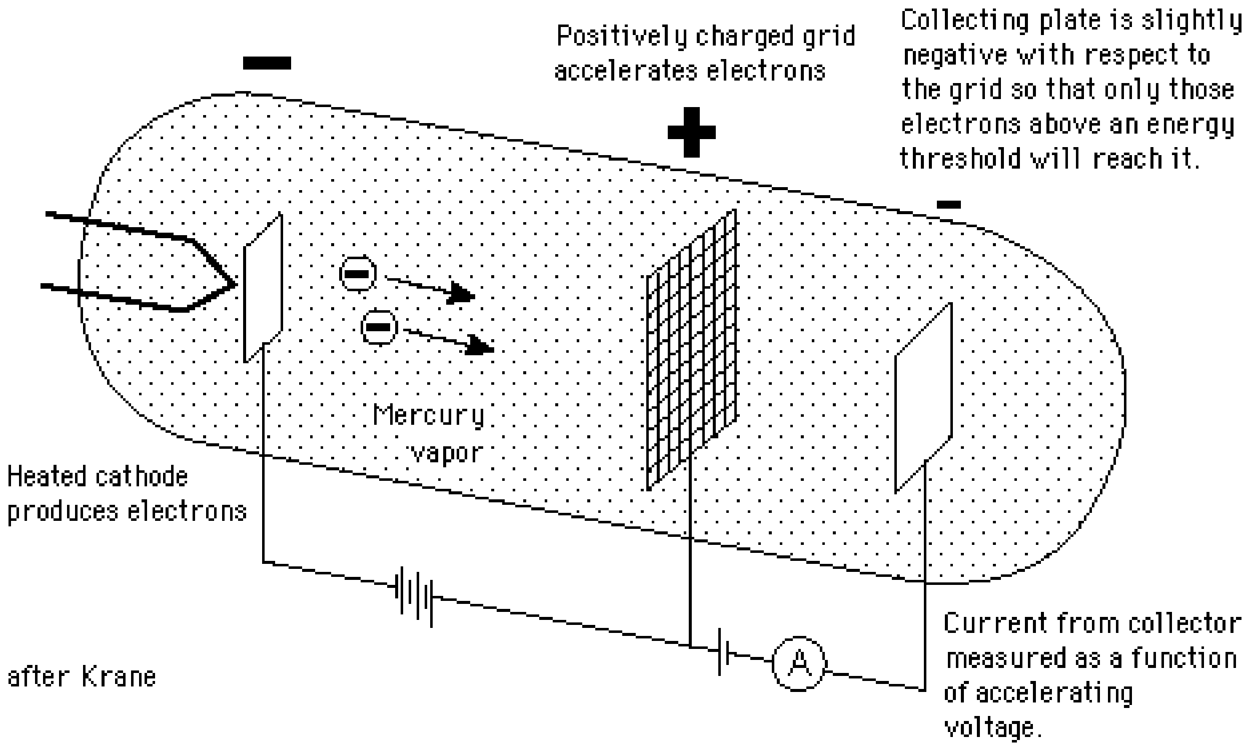
$$A = \left(\frac{1}{1^2} - \frac{1}{2^2}\right) \cdot$$

$$A = \left(\frac{1}{2^2} - \frac{1}{3^2}\right) \cdot$$

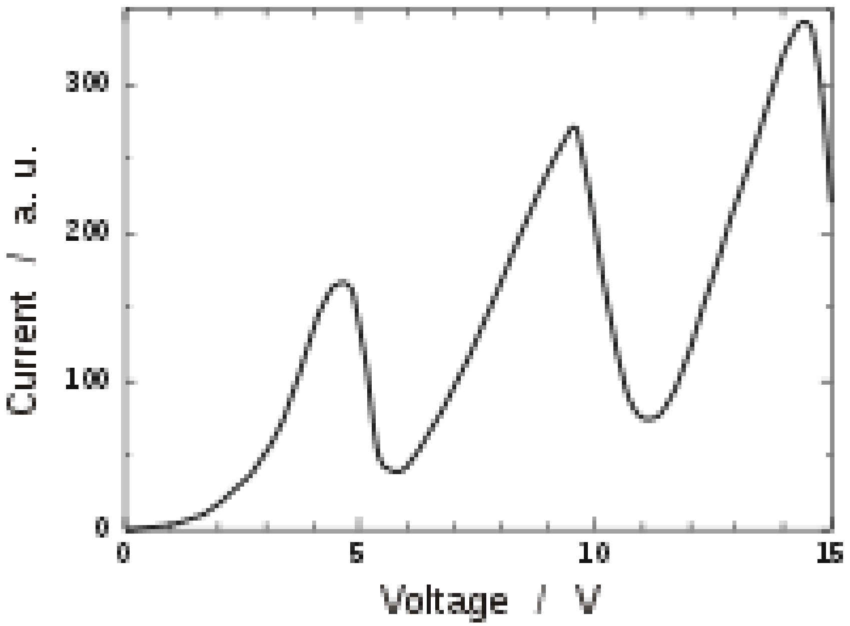


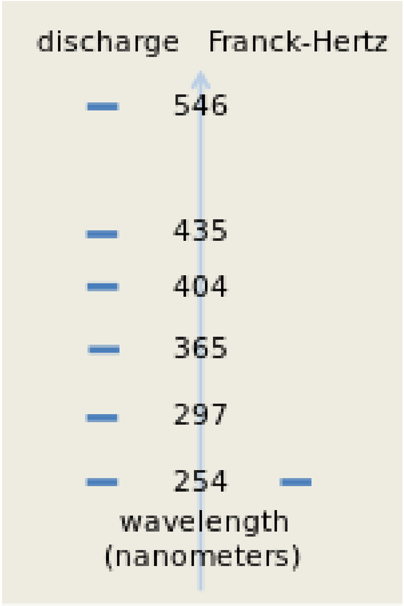
Franck-Hertz experiment

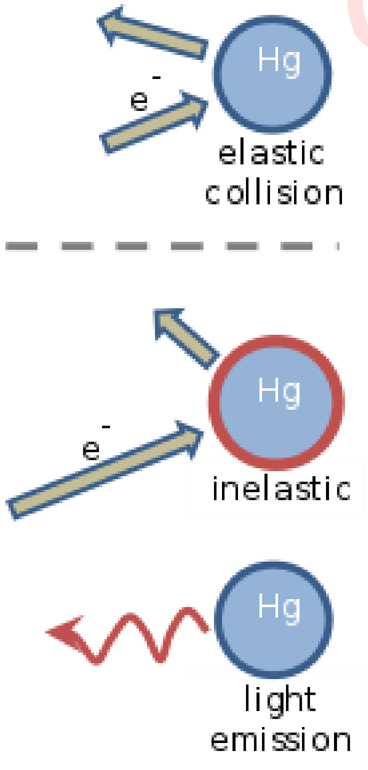




Franck-Hertz experiment





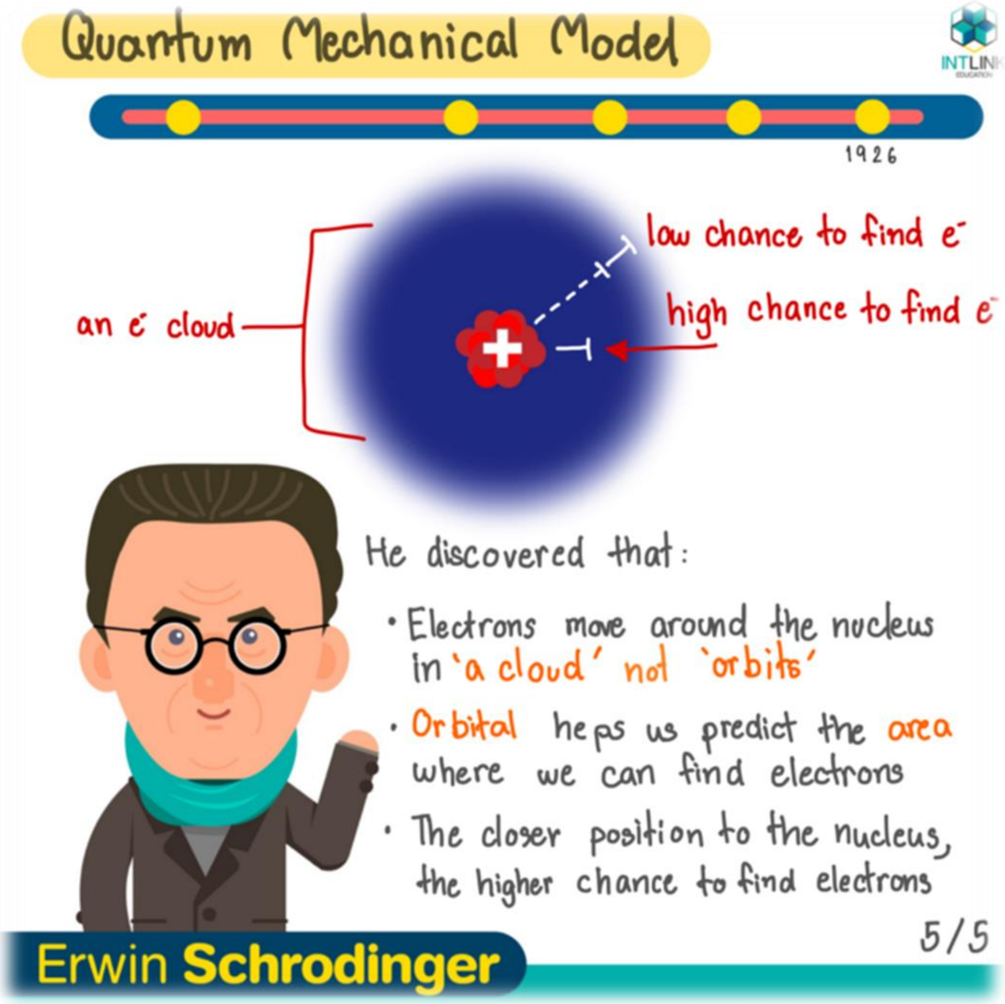


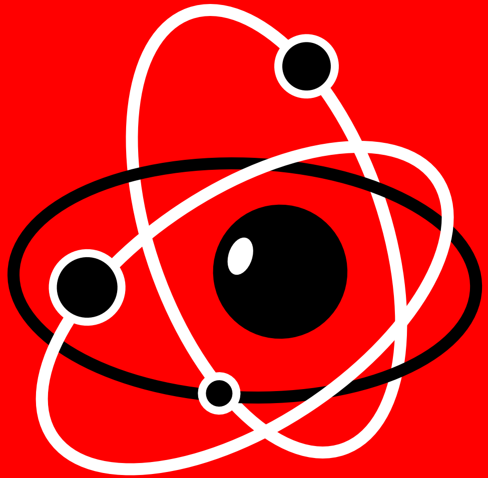
Failures of Bohr's model

The most important failure of Bohr theory:

This theory was very successful in predicting and accounting the energies of line spectra of hydrogen i.e. one electron system. It could not explain the line spectra of atoms containing more than one electron.

Impress on modern theories





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Grazie!