Introduction to Nuclear Fusion (409.308A, 3 Credits)

Prof. Dr. Yong-Su Na

(32-206, Tel. 880-7204)

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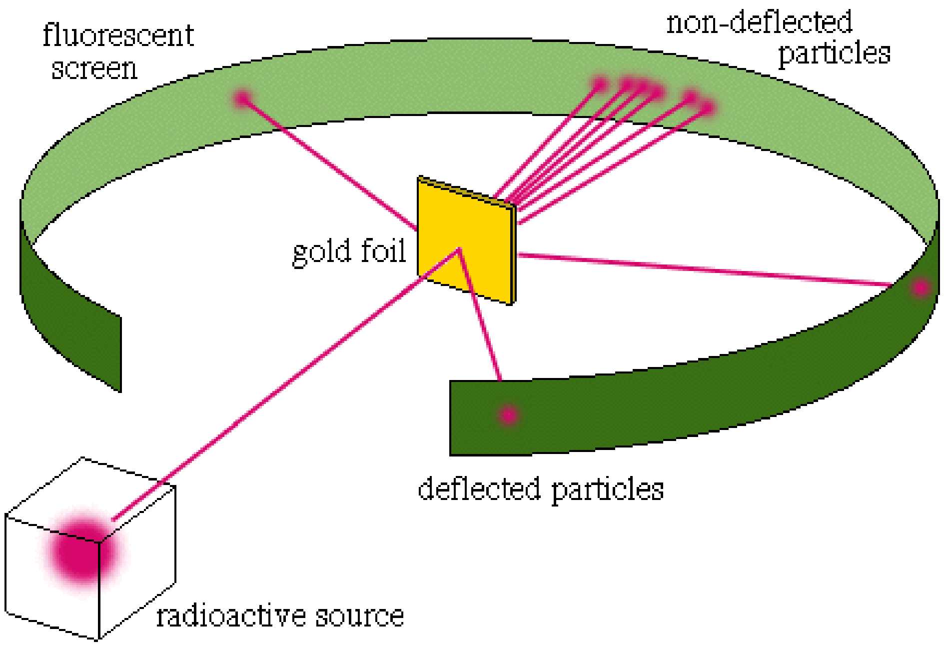
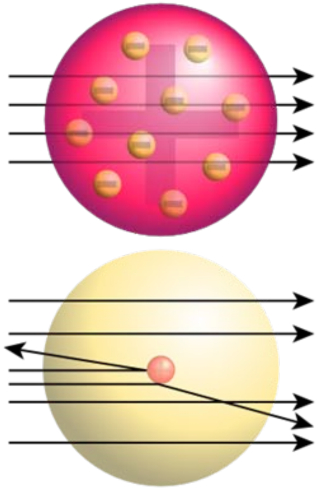
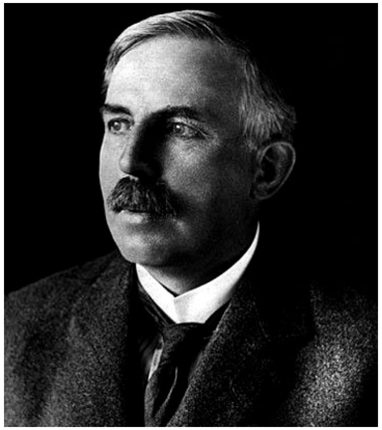
Rutherford Scattering



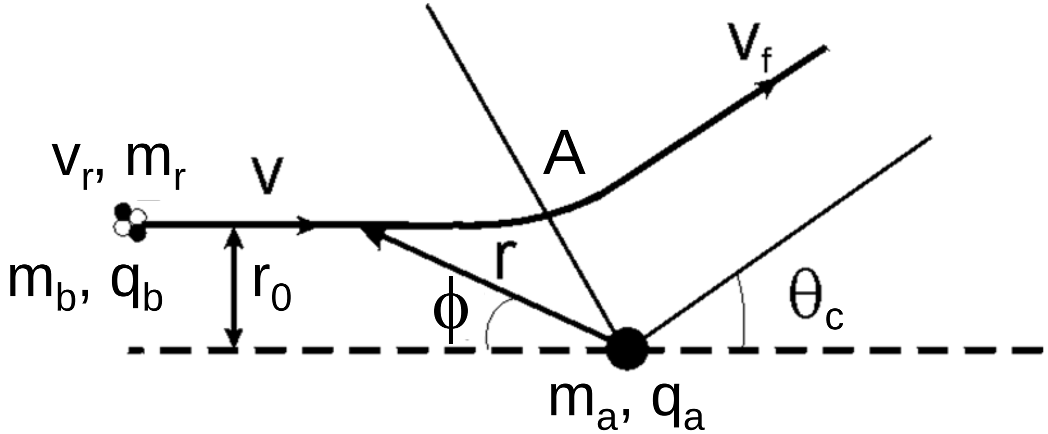


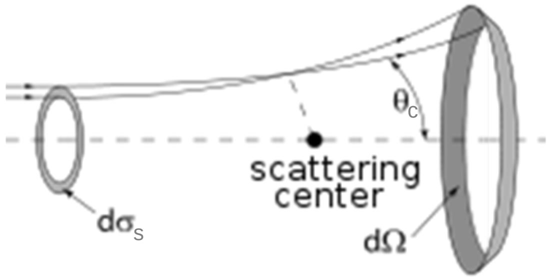


"It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you." by Rutherford

Ernest Rutherford
(1871-1937)
Nobel prize in Chemistry 1908

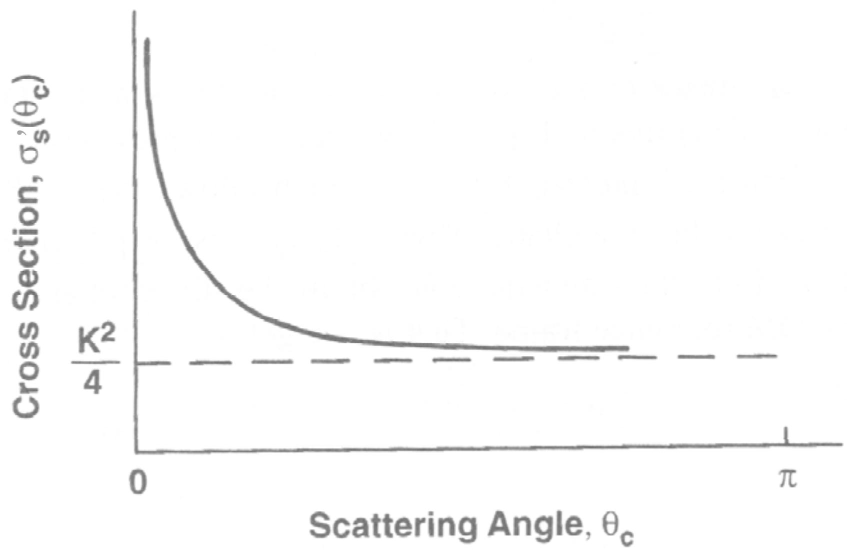
Coulomb Scattering Cross Section





$$\sigma_s'(\theta_c) \equiv \frac{d\sigma_s}{d\Omega} = \frac{K^2}{4\sin^4(\theta_c/2)}$$

$$K = \frac{q_a q_b}{4\pi\varepsilon_0 m_r v_r^2}$$

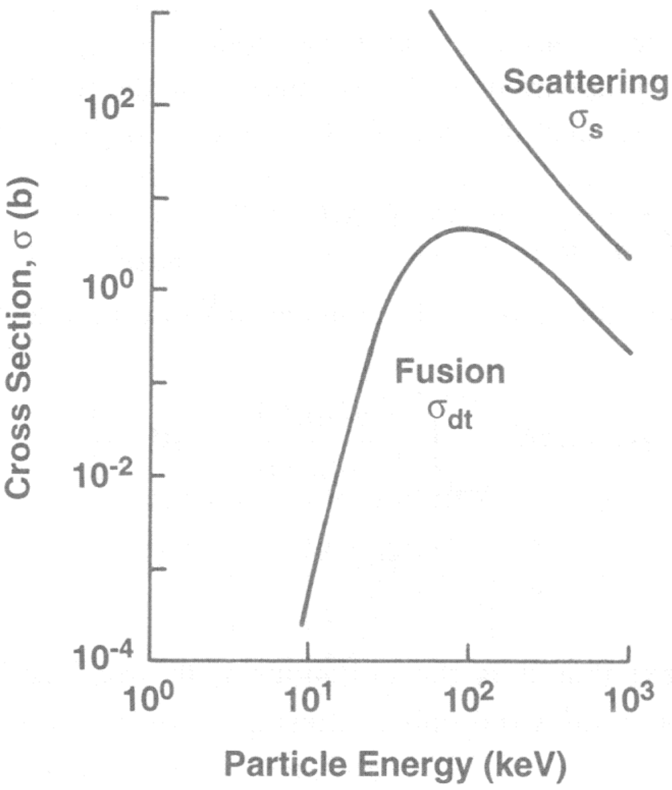


Coulomb Scattering Cross Section

$$\sigma_s = \int_0^\pi \sigma_s'(\theta_c)\,d\Omega = \pi K^2 \left\{ \left[\sin\left(\frac{\theta_{\min}}{2} \right) \right]^{-2} - 1 \right\}$$

$$\theta_{\min} = 2\tan^{-1}\left(\frac{K}{\lambda_D} \right)$$

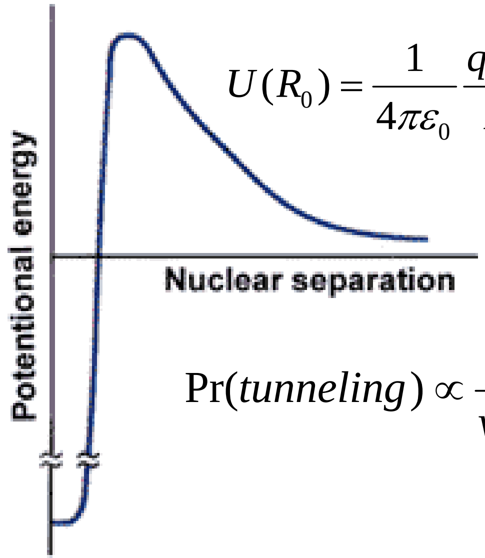
$$\lambda_D = \left(\frac{\varepsilon_0 k T_e}{N e^2} \right)^{1/2}$$



- loss energy >> fusion energy
  - ionisation, heating the target, bremsstrahlung radiation, etc
- Projectiles slowed down to energies far below the Coulomb barrier (370 keV in DT) rendering further fusion reactions most unlikely
- Fusion by beam-target collisions are not proper for practical energy-producing fusion reactors.

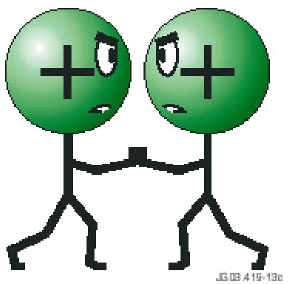
Confinement needed!

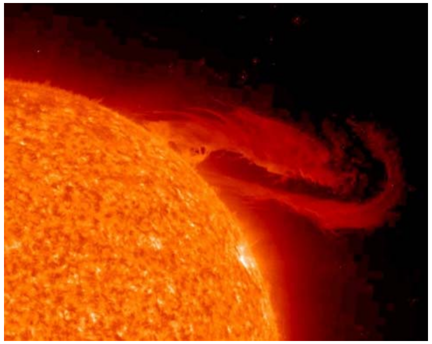
Necessity of Confinement



$$U(R_0) = \frac{1}{4\pi\varepsilon_0}\frac{q_a q_b}{R_0} \sim 0.4\,\text{MeV for } d, t, p$$

$$\Pr(tunneling) \propto \frac{1}{v_r}\exp[-\gamma\frac{q_a q_b}{v_r}]$$





- A high reactant temperature is required for fusion reactions to allow a sufficient number of ions to overcome the Coulomb barrier or to penetrate it by tunneling effect.
- Only high energy part of ion distribution function contributes to the desired fusion reactions.
- Reaction activation occurs due to random thermal motion of the nuclei
  → Thermal conditions with high temperature needed for the high fusion reaction rate

Thermonuclear Fusion:
Main approach to development of fusion power reactors