Charles University Prague **FP 2B 2022**
Mathematics and Physics Faculty

Electron collisions

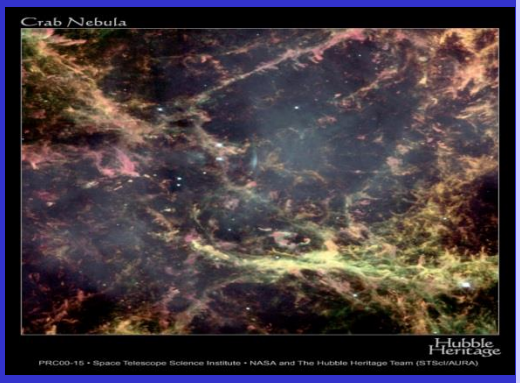
Collision Cross section

Collision rate coefficient

Reaction Cross section

Reaction rate coefficient

Temperatures and kinetic energies



$E/k \leftrightarrow T$

1eV ~ 11 400 K

1K ~ 9×10^{-5}eV

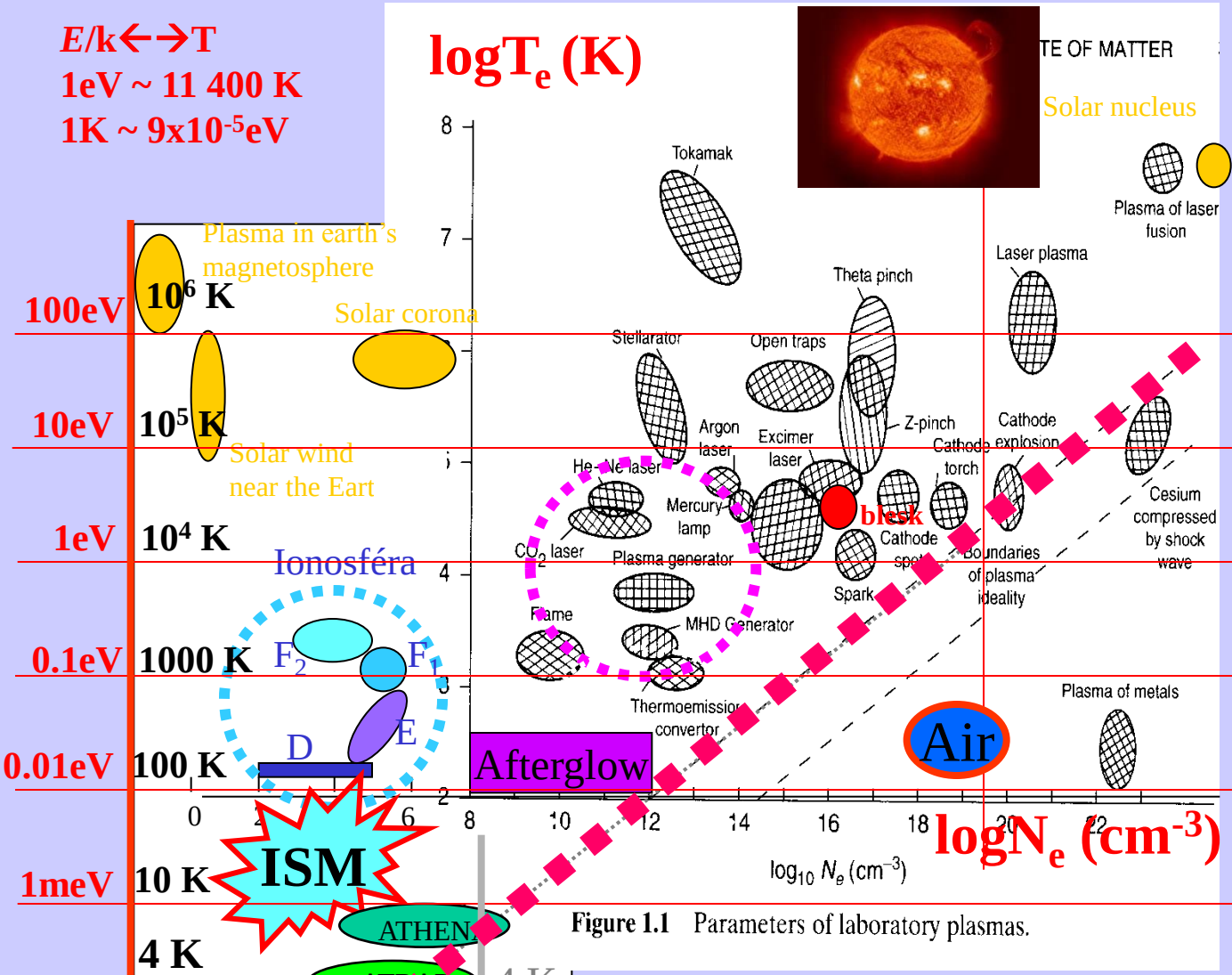


Figure 1.1 Parameters of laboratory plasmas.

De Broglie wave length

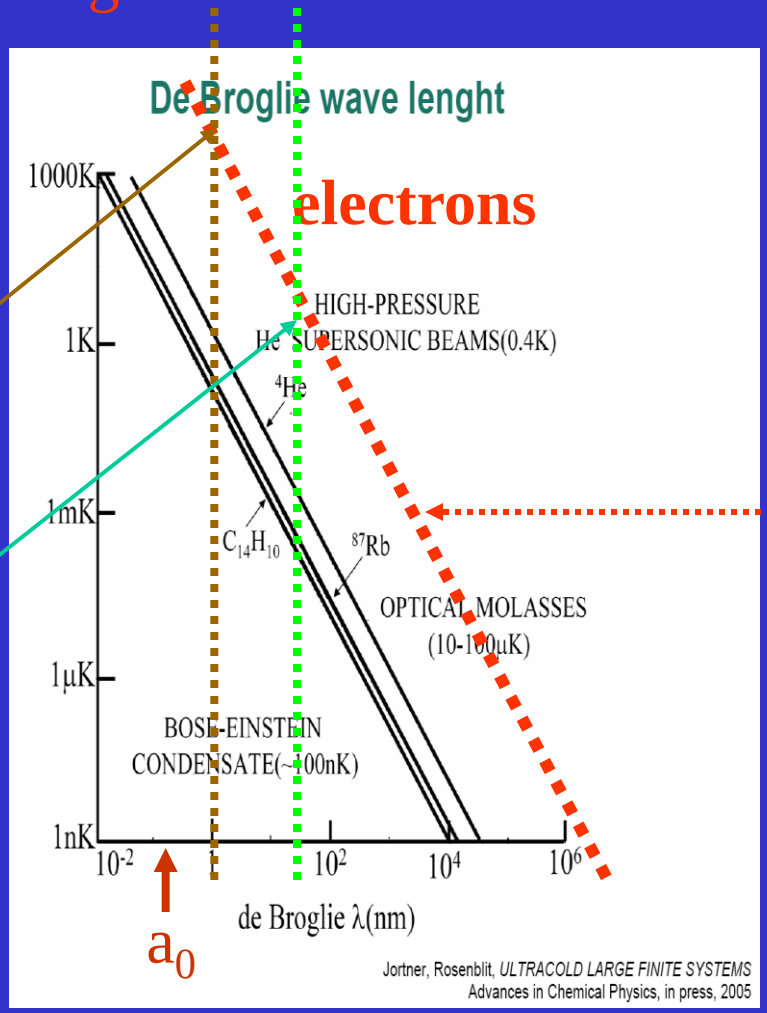
$$\lambda_{DB} = \frac{h}{p} = \frac{h}{Mv} \sim \frac{h}{\sqrt{MT}}$$

1eV

$$\lambda_{eDB}(1eV) \sim 11.6\,A \sim 1.16x10^{-9}\,m$$

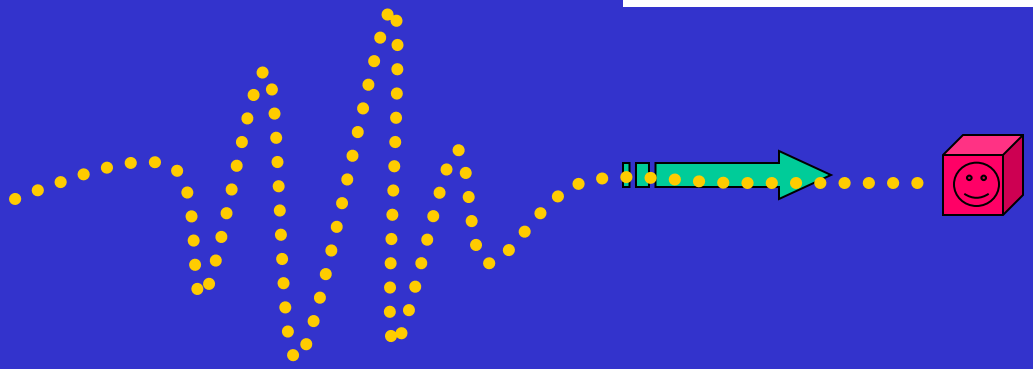
4K

$$\lambda_{eDB}(4K) \sim 540\,A \sim 54x10^{-9}\,m$$



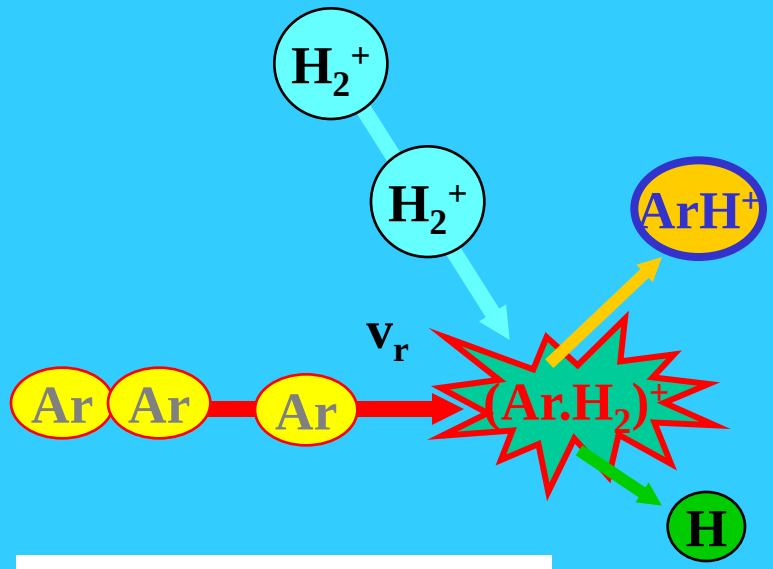
$$\lambda_{DB} = \frac{h}{m_e v_e} \sim \frac{h}{\sqrt{m_e T}}$$

$$T \sim= \frac{1}{\lambda_{DB}^{\,2}}$$

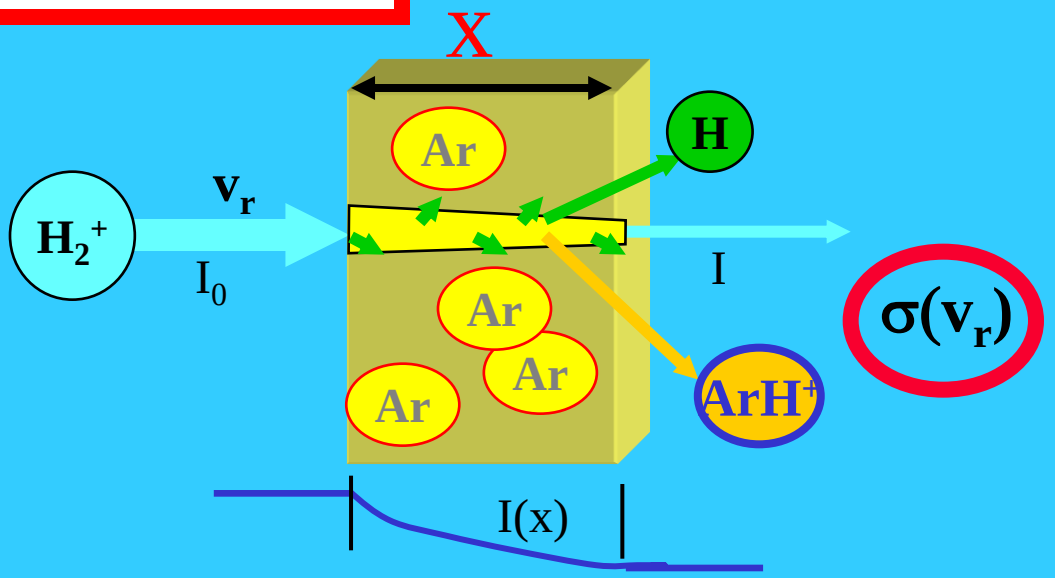


Single collision

$$H_2^+ + Ar \Rightarrow ArH^+ + H$$



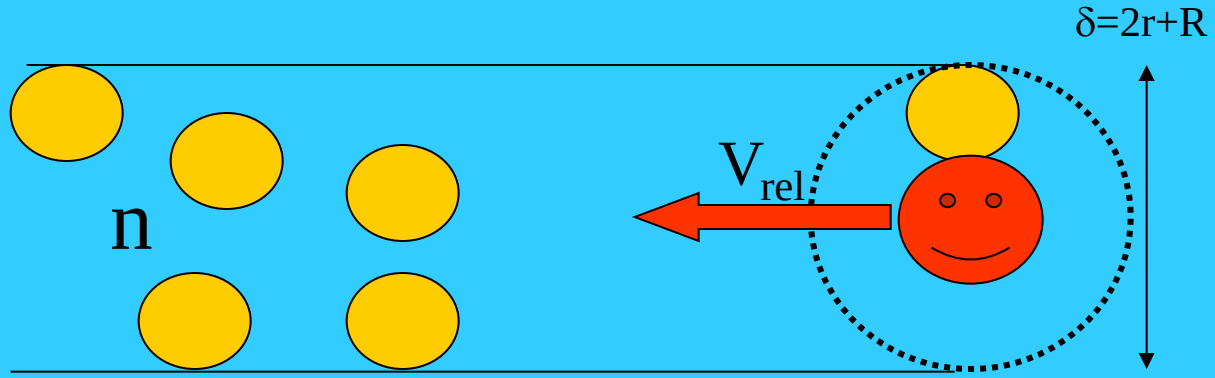
reaction cross section



$I=I_0\exp(-\sigma n_{Ar} x)$

$$\nu_{coll} = +nV_{rel} = +n\nu S = +n\nu\pi\delta^2 = +n\nu\sigma$$

$$\frac{dI}{dt} = -\frac{I}{\tau_{coll}} = -I\nu_{coll}$$

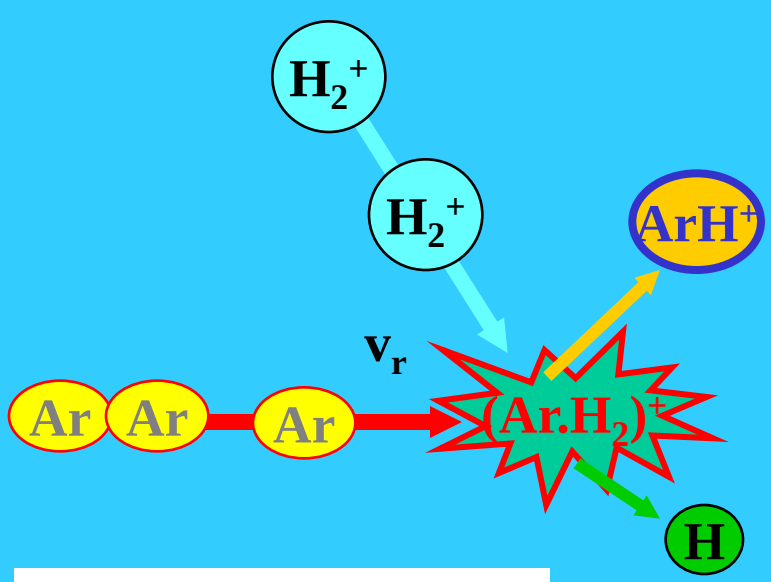


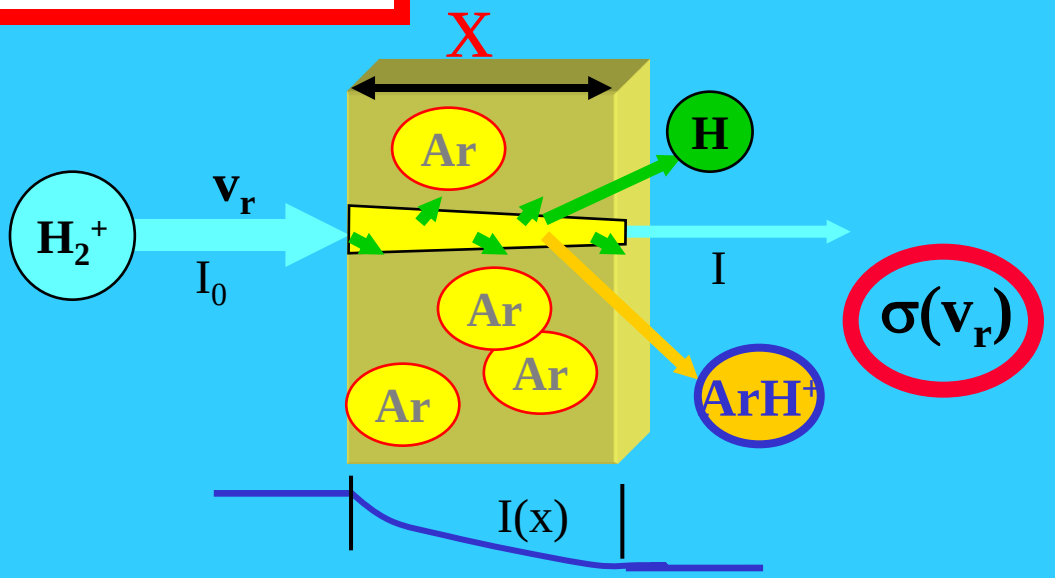
$$I(t) = I_0 \exp(-\nu_{coll} t) = I_0 \exp(-\sigma n \nu_{rel} t)$$

$I=I_0\exp(-\sigma n_{Ar} x)$

Single collision

$$H_2^+ + Ar \Rightarrow ArH^+ + H$$





reaction cross section

$$I = I_0 \exp(-\sigma n_{Ar} x)$$

$$\frac{dI}{dx} \sim -INx \qquad \frac{dI}{dx} = -\sigma INx$$

Proportionality factor

$$\frac{dI}{Idx} = \frac{d\ln(I)}{dx} = -\sigma Nx$$

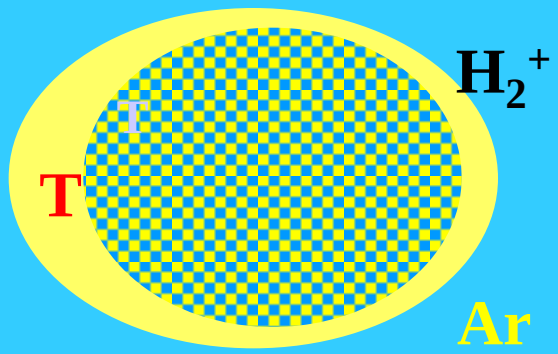
$$I(x) = I_0 \exp(-\sigma Nx)$$

Kinetics of elementary process

$$H_2^+ + Ar \Rightarrow ArH^+ + H$$

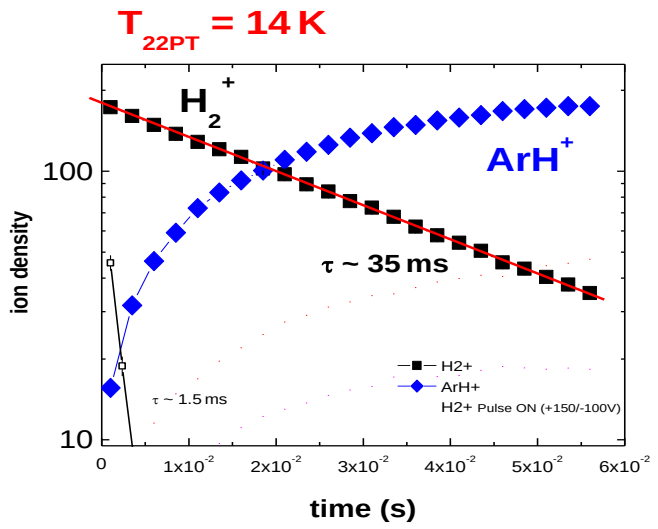
Multiple collision

@ T



reaction rate coefficient

$$d(n_{H2^+})/dt = -k\, n_{H2^+}.\, n_{Ar}$$

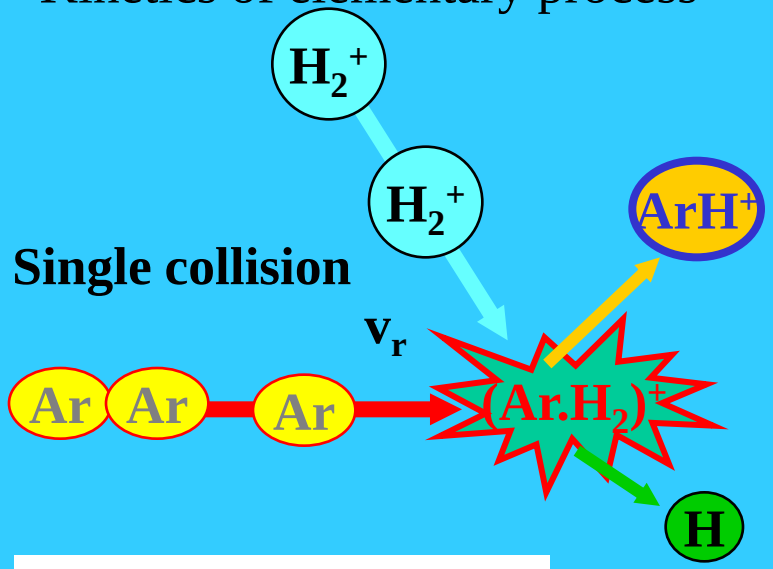


$$n_{H2^+}. = (n_{H2^+}).{}_0 \exp(-k n_{Ar} t)$$

k(T)

Kinetics of elementary process

$$H_2^+ + Ar \Rightarrow ArH^+ + H$$



reaction cross section

$$I = I_0 \exp(-\sigma n_{Ar} x)$$

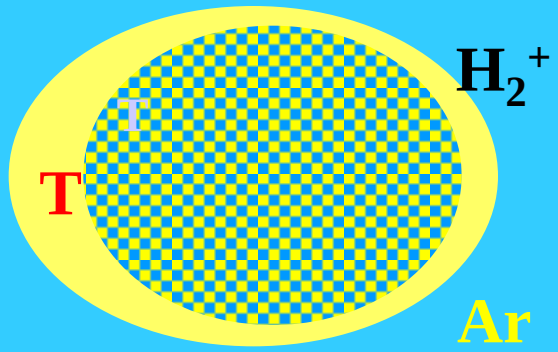
$\sigma(v_r)$

$k(T) = \langle v\sigma \rangle$

$k(T)$

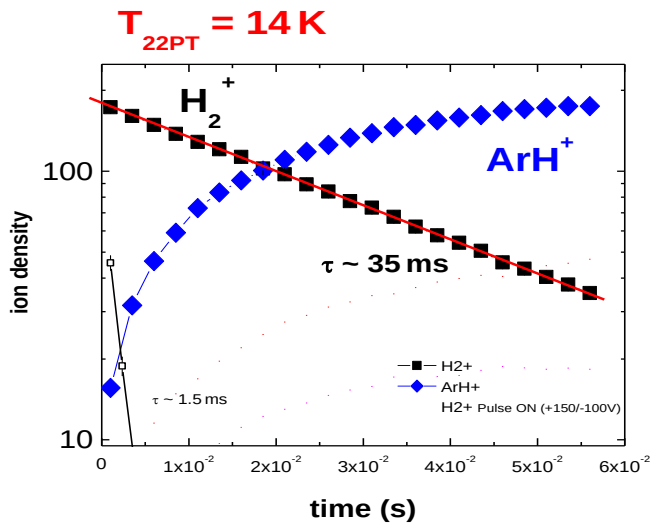
Multiple collision

@ T



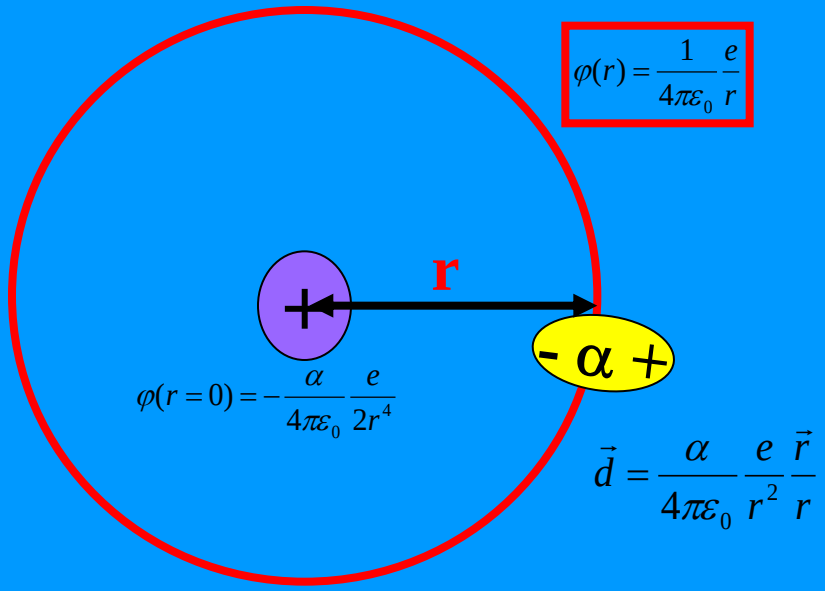
reaction rate coefficient

$$d(n_{H2^+})/dt = -k\, n_{H2^+}.\, n_{Ar}$$



$$n_{H2^+}. = (n_{H2^+}).{}_0 \exp(-k n_{Ar} t)$$

Collision cross section of IMR

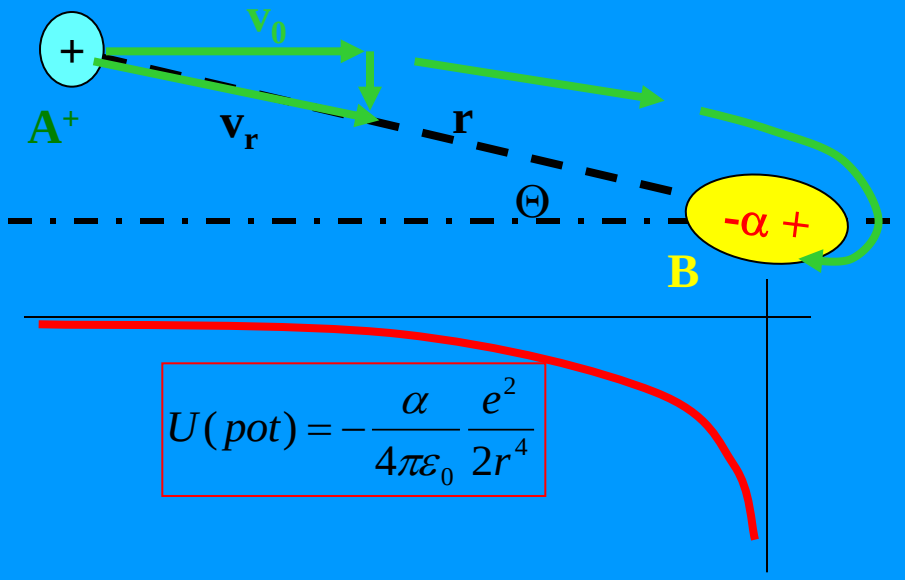


$$\varphi(r) = \frac{1}{4\pi\varepsilon_0}\frac{e}{r}$$

$$\varphi(r=0) = -\frac{\alpha}{4\pi\varepsilon_0}\frac{e}{2r^4}$$

$$\vec{d} = \frac{\alpha}{4\pi\varepsilon_0}\frac{e}{r^2}\frac{\vec{r}}{r}$$

α - polarizability

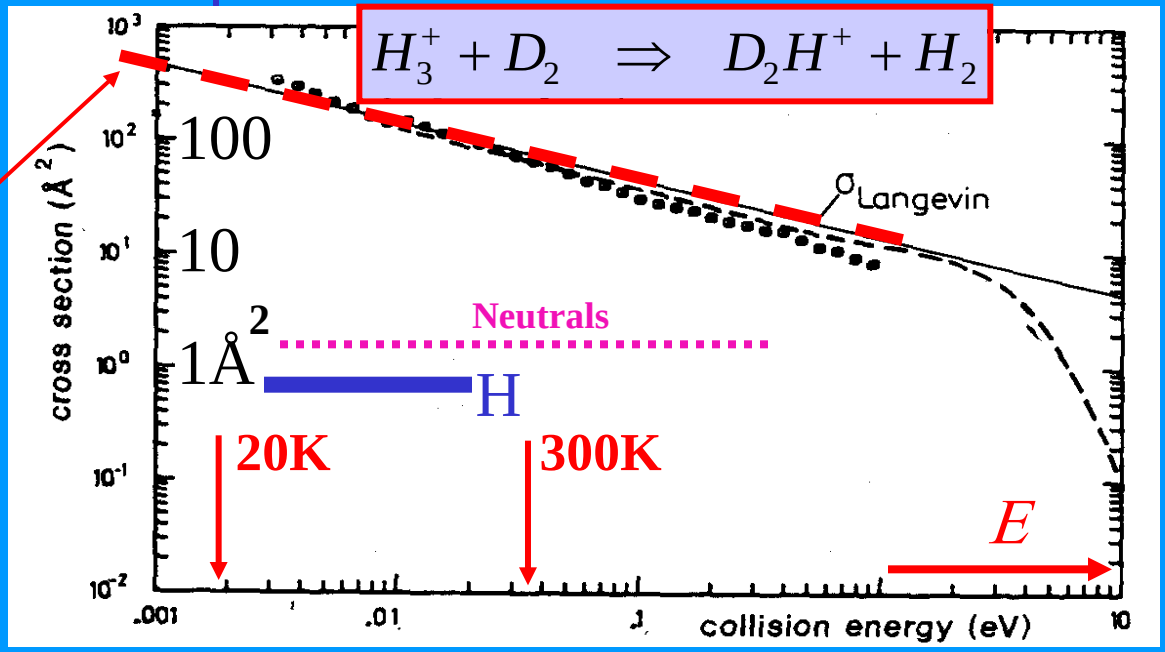


$$U(pot) = -\frac{\alpha}{4\pi\varepsilon_0}\frac{e^2}{2r^4}$$

$$\frac{\mu v_0^2}{2} = \frac{\alpha}{4\pi\varepsilon_0}\frac{e^2}{2r^4}$$

$$\sigma = \pi\rho_0^2 = \frac{2\pi e}{v_0(4\pi\varepsilon_0)}\sqrt{\frac{\alpha}{\mu}}$$

$$\sigma = \pi\rho_0^2 \sim \frac{1}{v_0}\sqrt{\frac{\alpha}{\mu}} \sim \frac{1}{\sqrt{E}}$$

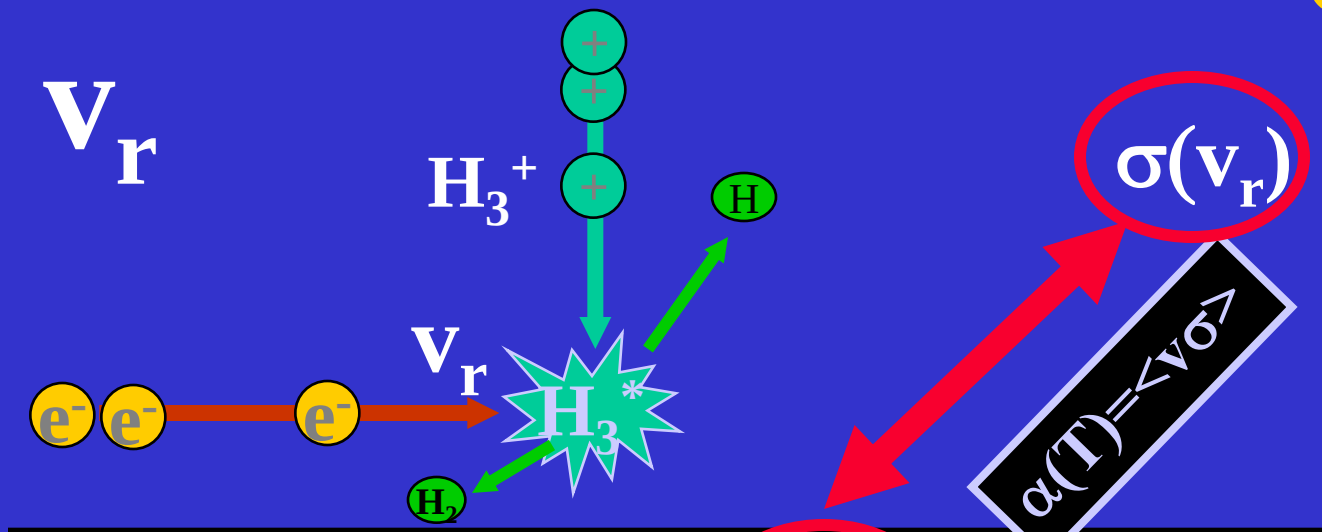


N3+

Recombination

$H_3^+ + e^- \rightarrow H + H_2; 3H$

Cross section

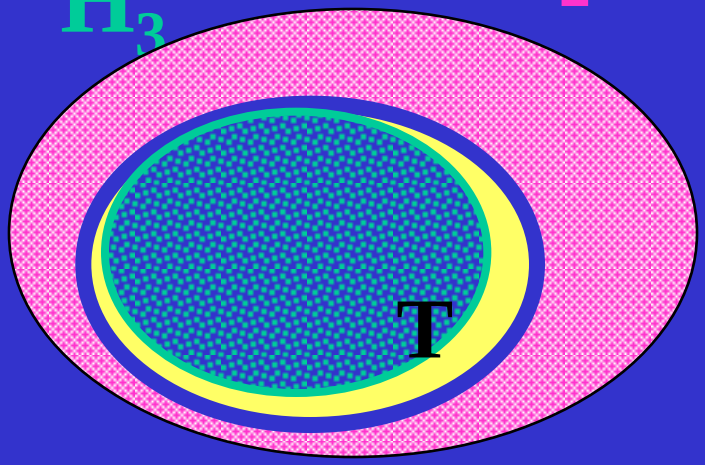


$\alpha(T)$ Rate coefficient

T

Multiple collisions

H_3^+ He, H,H_2 hν…



$dn_e/dt=-\alpha n_i n_e=-\alpha n_e^2$