Nuclear Reactions

Shorthand notation:

$^1H + {}^1H \rightarrow {}^2H + e^+ + \nu_e$ also $\underbrace{^1H\,(^1H}_{\text{reactants}},\ \underbrace{e^+\nu_e)\,^2H}_{\text{products}}$.

$^2H + {}^1H \rightarrow {}^3He + \gamma$ $\qquad$ $^2H(^1H, \gamma)\,^3He$

$^3He + {}^3He \rightarrow {}^4He + {}^1H + {}^1H$ $\qquad$ $^3He(^3He, {}^1H\,{}^1H)\,^4He$

or $^3He(^3He, 2\,{}^1H)\,^4He$

Sense of the Energy Scale

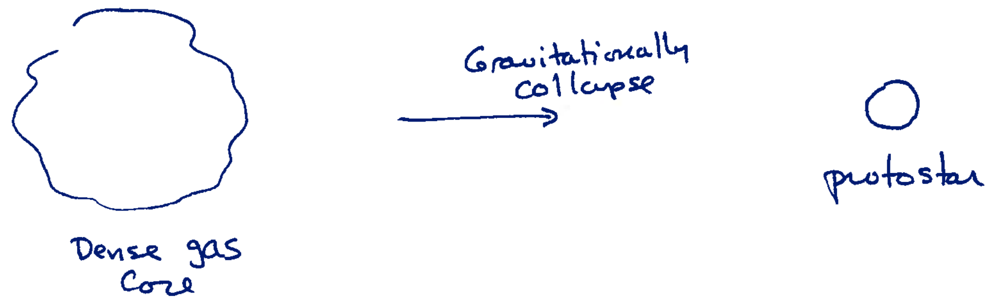
Remember

$1\ eV = 1.602 \times 10^{-12}$ erg

E

- 938 MeV — rest mass of p^+ $\quad E = m_{p^+} c^2$
- 26.7 MeV — Conversion of $4\,{}^1H \rightarrow {}^4He$ $\quad$ p-p chain
- 511 keV — rest mass energy of e^- $\quad E = m_{e^-} c^2$
- 13.6 eV — energy to ionize ^1H
- 2.2 eV — Yellow light

Virial Theorem Derivation of Jeans Mass



$$K + \mathcal{U} = E_{TOT}$$

$$\langle K \rangle = -\frac{1}{2}\langle \mathcal{U} \rangle \quad \text{so}$$

$$-\frac{1}{2}\mathcal{U} + \mathcal{U} = E_{TOT} = \frac{1}{2}\mathcal{U}$$

$$\Rightarrow \quad K + \mathcal{U} = \frac{1}{2}\mathcal{U}$$

in equilibrium: $2K + \mathcal{U} = 0$ or $2K = -\mathcal{U}$

For collapse of gas cloud, we need $-\mathcal{U} > 2K$

$$K = N \cdot \frac{3}{2} k T \qquad \mathcal{U} = -\frac{3}{5}\frac{GM^2}{R}$$

so $\cancel{3} N k T < \frac{\cancel{3}}{5}\frac{GM^2}{R}$ $\qquad N = \frac{M}{\bar{m}}$ ← mean mass per particles

$$\frac{\cancel{M}}{\bar{m}} k T < \frac{GM^{\cancel{2}}}{5R} \qquad R = \left(\frac{3M}{4\pi\rho}\right)^{1/3}$$

Solving for M:

$$M > \frac{5kTR}{\bar{m}G} > \frac{5kT}{\bar{m}G}\cdot\left(\frac{3M}{4\pi\rho}\right)^{1/3}$$

$$M^{2/3} > \frac{5kT}{\bar{m}G}\cdot\left(\frac{3}{4\pi\rho}\right)^{1/3}$$

Jean's Mass $\rightarrow$ $$M > \left(\frac{5kT}{\bar{m}G}\right)^{3/2}\left(\frac{3}{4\pi\rho}\right)^{1/2}$$

If $M_{cloud} > M_J$
$\Rightarrow$ Collapse!