

- III

## "Stellar evolution"

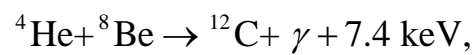
( )

(Gravitational pressure)

( )

(Thermal)

(Gravitational)



.(Exothermic)

(Degeneracy pressure)

:

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:

$$dU_g = -G \frac{\left(\frac{4}{3}\pi r^3 \rho\right)(4\pi r^2 \rho dr)}{r}$$

$$= -G \frac{(4\pi\rho)^2 (r^4 dr)}{3}$$

:

$$U_g = -G \frac{(4\pi\rho)^2}{3} \int_0^R r^4 dr = -G \frac{(4\pi\rho)^2 R^5}{15}$$

:  $\rho$ 

$$\left(\frac{4}{3}\pi R^3 \rho\right) = M = Nm_n$$

.( )

 $m_n$ 

$$: R = \left(\frac{3V}{4\pi}\right)^{1/3} \quad \rho = \frac{Nm_n}{V}$$

V

$$U_g = -\frac{3}{5}G(Nm_n)^2 \left(\frac{4\pi}{3V}\right)^{1/3}$$

: ( )

$$P_g = -\frac{\partial U_g}{\partial V} = \frac{1}{5}G(Nm_n)^2 \left(\frac{4\pi}{3}\right)^{1/3} V^{-4/3}$$

: ( )

(Degeneracy pressure)

$$P_{deg} = \frac{\hbar^2 \pi^3}{15m_e} \left(\frac{3n}{\pi}\right)^{5/3} = \frac{\hbar^2 \pi^3}{15m_e} \left(\frac{3N_e}{\pi}\right)^{5/3} V^{-5/3} *$$

$$: \quad P_g = P_{deg} \quad N_e \sim \frac{N}{2}$$

$$V^{1/3} = \frac{3\pi\hbar^2}{4Gm_e m_n^2 (2N)^{1/3}}$$

:

$$R^* = \left(\frac{3V}{4\pi}\right)^{1/3} = \frac{3(3\pi^2)^{1/3} \hbar^2}{8Gm_e m_n^2 N^{1/3}}^{**}$$

:

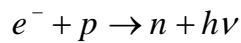
$$M_\odot = 2 \times 10^3 \text{ kg}$$

$$.R^* = 7 \times 10^3 \text{ km}$$

Ans:  $\frac{\langle E \rangle_e}{m_e c^2} = 0.23, \quad \frac{\langle E \rangle_n}{m_n c^2} = 1.7 \times 10^{-7}$

(Neutron stars)

"M<sub>n</sub>"



$$N_e = N$$

R\*

$$N_e \sim \frac{N}{2} \quad P_g$$

$$R_n^* = \left( \frac{3V}{4\pi} \right)^{1/3} = \frac{(81\pi^2)^{1/3}}{16} \frac{\hbar^2}{Gm_n^3 N^{1/3}}$$

$R_n^* = 6.5 \text{ km!!}$        $M_n / M_\odot = 7$       :

(White dwarf)

( )

$\cdot 10^7 \text{ K}$

"Sirius (B)"

."Ganis major"

$$P_{deg} = \frac{2}{5} \left( \frac{N}{V} \right) \mathcal{E}_F$$

$$T \ll T_F$$

Mass " $M = 2.09 \times 10^{30} \text{ kg}$ "

Radius " $R = 5.57 \times 10^6 \text{ m}$ "

Volume " $V = 7.23 \times 10^{20} \text{ m}^3$ "

-1

-2

-3

$$1.26 \times 10^{57} = \frac{2.09 \times 10^{30}}{1.66 \times 10^{-27}} =$$

$$: \quad .N = 0.63 \times 10^{57} :$$

$$\varepsilon_F = \frac{\hbar^2}{2m_e} \left( \frac{3N}{8\pi V} \right)^{2/3} = 5.33 \times 10^{-14} \text{ J} = 0.33 \text{ MeV.}$$

$$: \quad T_F = \frac{\varepsilon_F}{k_B} = 3.9 \times 10^9 \text{ K}$$

$$10^7 \text{ K}$$

$$: \quad ( \quad )$$

$$P_{deg} = \frac{2}{5} \left( \frac{N}{V} \right) \varepsilon_F = \frac{2}{5} \left( \frac{0.63 \times 10^{57}}{7.23 \times 10^{20}} \right) (5.33 \times 10^{-14}) = 1.8 \times 10^{22} \text{ Pa}$$

$$= 1.8 \times 10^{17} \text{ atm!!!}$$

$$: \quad :$$

$$R_{wd}^* = \left( \frac{3V}{4\pi} \right)^{1/3} = \frac{(81\pi^2)^{1/3}}{16} \frac{\hbar^2}{Gm_e^3 N^{1/3}}$$

$$.R_{wd}^* \approx 7 \times 10^6 \text{ m} :$$

:(3)

$T_F$ (K)		
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0.3		<sup>3</sup> He
10 <sup>4</sup>		
10 <sup>9</sup>		
10 <sup>11</sup>		
10 <sup>12</sup>		

(Black hole)

$$f = f_o \left[ 1 - G \frac{M}{rc^2} \right]$$

 $f$ 

$$f = f_o \left[ 1 - G \frac{M}{R^* c^2} \right] = 0 \Rightarrow R^* = \frac{GM}{c^2}$$

$$v_{\text{escape}} = \sqrt{\frac{2GM}{r}}$$

$$\{v_{\text{escape}} \rightarrow c\}$$

$$R^* = \frac{2GM}{c^2}$$

(Neutron star)

(White dwarf)

