NPRE 321 HW 1

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1. a) i.
$$D + T \to n + {}^4\text{He}$$

ii. By searching online, $E_{^4He} = 28.3$ MeV, $E_D = 2.2$ MeV, $E_T = 8.482$ MeV. Then

$$28.3 - (2.2 + 8.482) = 17.618\text{MeV}$$

iii. It will be around 17.6 MeV

b)
$$D + T \to n + {}^4\text{He}$$

$$\begin{aligned}
m_b = m_D + m_T &= (2.014 + 3.016) \times 1.66 \times 10^{-27} \\
&= 8.35 \times 10^{-27} \text{ kg} \\
E_b &= m_b \times c^2 \\
&= 8.35 \times 10^{-27} \times \left(2.998 \times 10^8\right)^2 \\
&= 7.505 \times 10^{-10} \text{ J} \\
m_a = m_{^4\text{He}} + m_n &= (4.0026 + 1.0087) \times 1.66 \times 10^{-27} \\
&= 8.3187 \times 10^{-27} \text{ kg} \\
E_a &= m_a \times c^2 \\
&= 7.47685 \times 10^{-10} \text{ J} \\
\Delta E = E_a - E_b &= (7.47685 - 7.505) \times 10^{-10} \\
&= -2.8142 \times 10^{-12} \text{ J} \\
&= -2.8142 \times 10^{-12} \times 6.242 \times 10^{12} \\
&= 17.5683 \text{ MeV}
\end{aligned}$$

c)

$$\begin{aligned}
E &= K\frac{Q_1 Q_2}{r} \\
&= 9 \times 10^9 \times \frac{\left(1.602 \times 10^{-19}\right)^2}{(1.80 + 2.13) \times 0.5 \times 10^{-15}} \\
&= 1.17545 \times 10^{-13} \text{ J} \\
&= 6.242 \times 10^{18} \times 1.17545 \times 10^{-13} \\
&= 733715.89 \text{ eV} \\
&= 733715.89 \times 11604 \\
&= 8.514 \times 10^9 \text{ K}
\end{aligned}$$

I belive this temperature do make some sense, as we do need high temperature for fussion and it is not so hot making it impossible to reach.

d)

$$D + D \rightarrow {}^3\text{He} + n$$

$$D + D \rightarrow T + p$$

$$\begin{aligned}
m_b &= (2.014 \times 2) \\
&= 4.0282 \text{ u} \\
m_{a1} &= (3.016 + 1.00866) \\
&= 4.024 \text{ u} \\
m_{a2} &= (3.016 + 1.0072) \\
&= 4.0222 \text{ u} \\
\Delta m &= 4.02397 - 4.0282 \\
&= -0.004231 \\
\Delta E &= \Delta m c^2 \\
&= 0.004231 \times 1.66 \times 10^{-27} \times (2.998 \times 10^8)^2 \\
&= 6.31269 \times 10^{-13} \text{ J} \\
&= 3.94038 \text{ MeV}
\end{aligned}$$

2. a)

$$
\begin{aligned}
\sigma_i &= \pi \times (r_{Ar,i} + r_{Ar})^2 \\
&= \pi((285 + 97) \times 10^{-12})^2 \\
&= 4.58434 \times 10^{-19}\text{m}^2 \\
n &= \frac{p}{k_b T} \\
&= \frac{133.322 \times 5 \times 10^{-3}}{1.38 \times 10^{-23} \times (25 + 273)} \\
&= 1.62098 \times 10^{20}\text{m}^{-3} \\
\lambda_{0e} &= \frac{1}{\sigma_e n} \\
&= \frac{1}{5 \times 10^{-19} \times 1.62098 \times 10^{20}} \\
&= 0.012338 \text{ m} \\
\lambda_{0i} &= \frac{1}{\sigma n} \\
&= \frac{1}{4.58434 \times 10^{-19} \times 1.62098 \times 10^{20}} \\
&= 0.013457 \text{ m}
\end{aligned}
$$

Does seems like, there will be average less than 4 collisions in the container which is not so sufficient for a plasma to form.

b)

$$
\begin{aligned}
\omega_c &= \frac{qB}{m} \\
&= \frac{1.602 \times 10^{-19} \times 50 \times 10^{-3}}{2\pi \times 9.11 \times 10^{-31}} \\
&= 1.39928 \times 10^9 \text{ Hz} \\
v_\perp &= \sqrt{\frac{2E}{m}} \\
&= \sqrt{\frac{2k_b T}{m}} \\
&= 1.027 \times 10^6\text{m/s} \\
r_L &= \frac{v_\perp}{\omega_c} \\
&= \frac{1.027 \times 10^6}{1.39928 \times 10^9} \\
&= 7.339 \times 10^{-4} \text{ m}
\end{aligned}
$$

Yes, there will be average over 60 collisions per electron in the chamber.

c)

$$\begin{aligned}
E &= qdV \\
&= 1.602 \times 10^{-19} \times 0.005 \times 500 \\
&= 4.005 \times 10^{-19}\ \mathrm{J} \\
&= 4.005 \times 10^{-19} \times 6.242 \times 10^{18} \\
&= 2.49992\ \mathrm{eV}
\end{aligned}$$