ASTR323 HW2 Timothy Allen 66522411

1. (a) With mass fraction as w

$$\begin{aligned} w(H) &= \frac{1.007825}{1.007825 + 4.002603} \\ &= 0.201145490964 \\ w(H) &= 20\%(2sf) \\ w(He) &= \frac{4.002603}{1.007825 + 4.002603} \\ &= 0.798854509036 \\ w(He) &= 80\%(2sf) \end{aligned}$$

(b) With mean atomic weight as μ

$$\begin{aligned} \mu_{neutral} &= \frac{1.007825 + 4.002603}{2} \\ &= 2.505214 \\ \mu_{neutral} &= 2.5u(2sf) \end{aligned}$$

The change in mass due to binding energy is insignificant. Most change in mass comes from the mass of the electron and even this is relatively small. With u = 931493614.838934 eV:

$$\begin{aligned} m_{ion}(H) &= 1.007825 - \frac{511000}{931493614.838934} \\ &= 1.00727641868 \\ m_{ion}(He) &= 4.002603 - \frac{511000 * 2}{931493614.838934} \\ &= 4.00150583735 \\ \mu_{ion} &= \frac{1.00727641868 + 4.00150583735}{2} \\ &= 2.50439112801 \\ \mu_{ion} &= 2.5u(2sf) \end{aligned}$$

(c) Since there is 1kg of gas and 20% of it is hydrogen by weight there is 200g of hydrogen. With the neutral hydrogen weight of 1.007825amu per particle:

$$\begin{aligned}
particles(H) &= 201.145490964 * N_A * mass_{amu}(H) \\
&= 201.145490964 * 6.0 * 10^{23} * 1.007825 \\
&= 1.2163167266 * 10^{26} \\
&= 1.2 * 10^{26} particles(2sf) \\
E_{ion}(H) &= 13.6 * 1.2163167266 * 10^{26} \\
&= 1.6541907482 * 10^{27} \\
E_{ion}(H) &= 1.7 * 10^{27} eV(2sf) \\
&= 1.6541907482 * 10^{27} * 1.60 * 10^{-19} J \\
&= 264670519.712 J \\
E_{ion}(H) &= 2.6 * 10^{8} J(2sf)
\end{aligned}$$

At about 72kWh this is around what an average NZ household uses in 3-4 days (using 7261kWh per annum).

(d)

$$\begin{aligned}
particles(He) &= 798.854509036 * N_A * mass_{amu}(He) \\
&= 201.145490964 * 6.0 * 10^{23} * 4.002603 \\
&= 4.8306332734 * 10^{26} particles \\
E_{ion} &= (24.5 + 54.4) * 4.8306332734 * 10^{26} \\
&= 3.8113696527 * 10^{28} \\
E_{ion}(He) &= 3.8 * 10^{28} eV(2sf) \\
&= 3.8113696527 * 10^{28} * 1.60 * 10^{-19} J \\
&= 6.0981914443 * 10^{9} J \\
E_{ion}(He) &= 6.1 * 10^{9} J(2sf) \\
E_{ion}(tot) &= 6.0981914443 * 10^{9} + 264670519.712 \\
&= 6.0981914443 * 10^{9} + 264670519.712 \\
&= 6.362861964 * 10^{9} \\
E_{ion}(tot) &= 6.4 * 10^{9} J(2sf)
\end{aligned}$$

(e)

$$\begin{aligned}
E_{thermal} &= (4.8306332734 * 10^{26} + 1.2163167266 * 10^{26}) * \frac{3}{2} * 1.38 * 10^{-23} * 10^{6} \\
&= 1.25171865 * 10^{10} \\
E_{thermal} &= 1.3 * 10^{10} J(1sf)
\end{aligned}$$

Since the thermal energy is significantly higher than the ionization energy (double) it is probable that the mixture is fully ionzied at one million kelvin.