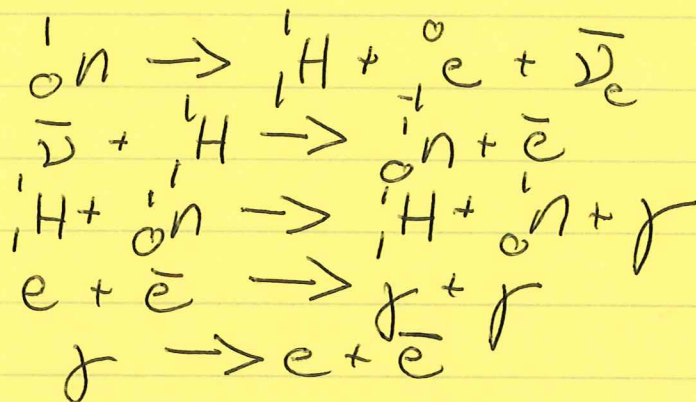


11

## Genesis of the Elements

I. In the first ten minutes, the following processes would take place:

"Big Bang"



equilibration  
at high  
temperature

where  ${}^1_1H = p$  = proton of charge +1, mass = 1.007 amu  
 $\gamma$  = gamma ray (high energy photon) with zero rest mass

${}^0_{-1}e = e^-$  = electron of charge -1, mass  $\frac{1}{1823}$  amu  
 also known as  $\alpha$  or  $\beta$  particle

${}^0_{+1}e = e^+ = \bar{e}$  = positron, charge +1, mass  $\frac{1}{1823}$  amu

$\nu_e$  = neutrino with no charge & very small mass

$\bar{\nu}_e$  = antineutrino, no charge & very small mass

${}^1_0n$  = neutron with no charge, mass = 1.009 amu

amu  $\equiv 1.660 \times 10^{-27}$  kg (or dalton)

convention:  $\begin{matrix} \text{mass \#} \\ \text{atomic \#} \end{matrix} \text{Symbol} \quad \begin{matrix} Z+N=A \\ Z \end{matrix} \text{Symbol}$

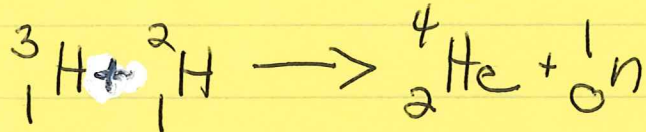
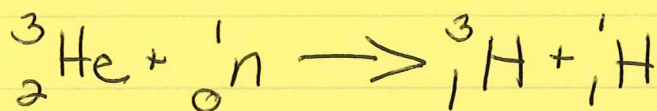
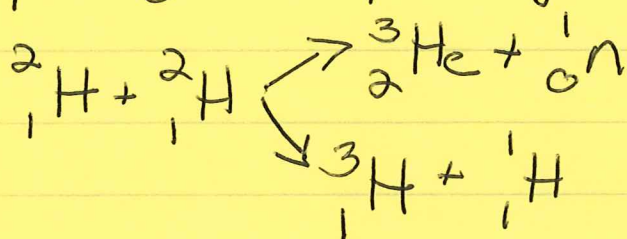
mass # = #protons + #neutrons  
 atomic # = nuclear charge = #protons

(2)

II. In the high-density equilibrium distribution that existed for a short time before the system blew itself apart,  $T$  dropped to  $\sim 10^9$  K as universe expanded, and He would be formed:

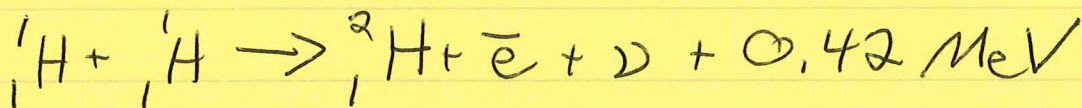


He formed to about 10%



90% essentially  ${}^1_1\text{H}$  mostly from  $\beta$ -decay of  ${}^1_0\text{n}$  that formed themselves in free space after big bang

III.  ${}^1_1\text{H}$ -burn



two  ${}^1_1\text{H}$  fuse ( $1 \text{ eV} = 1.602 \times 10^{-22} \text{ kJ}$ )

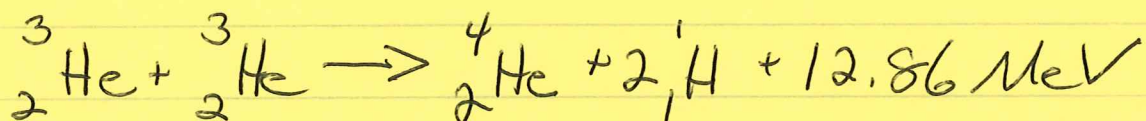
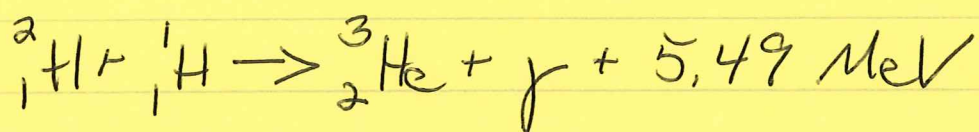
$$\text{Now: } \frac{1 \text{ eV}}{\text{mol}} = \frac{96.48 \text{ kJ}}{\text{mol}} = \frac{23.06 \text{ kcal}}{\text{mol}}$$

$$\frac{\text{MeV}}{\text{mol}} \approx \frac{9.7 \times 10^7 \text{ kJ}}{\text{mol}} \approx \frac{2.3 \times 10^7 \text{ kcal}}{\text{mol}}$$

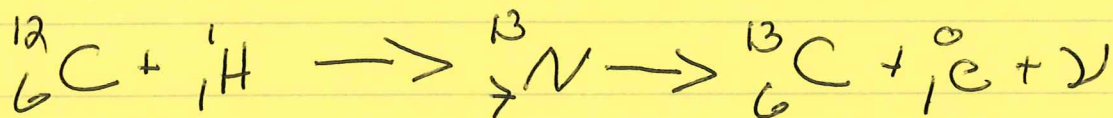
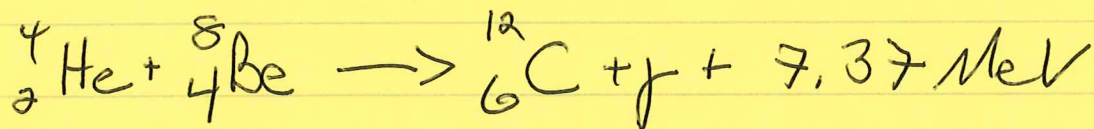
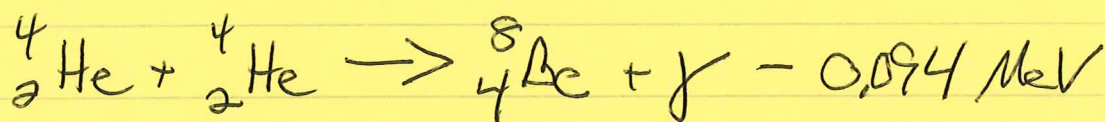


(3)

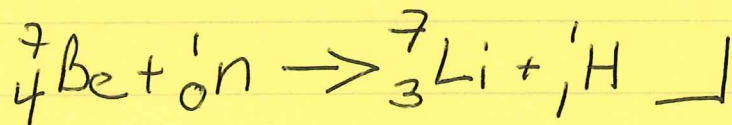
IV. He is formed in a star cycle of rxns called the proton-proton cycle, consisting of the proceeding rxns followed by  ${}^1_1\text{H}$  /  ${}^3_2\text{He}$  - burn



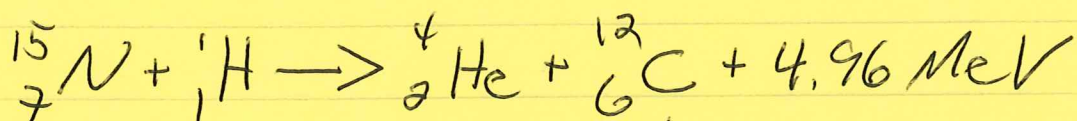
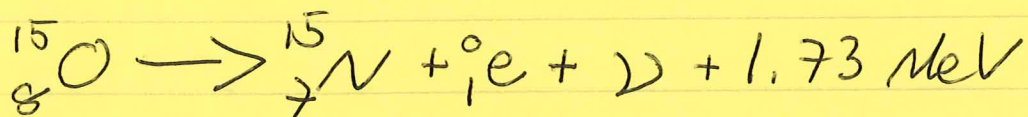
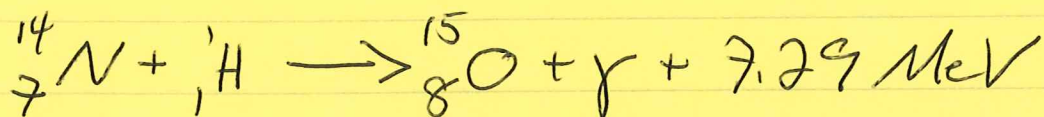
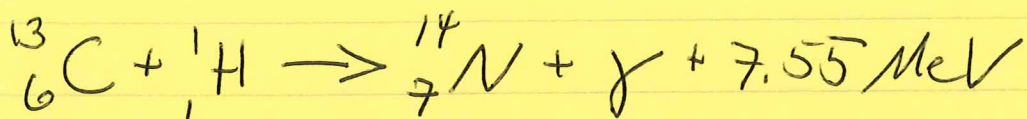
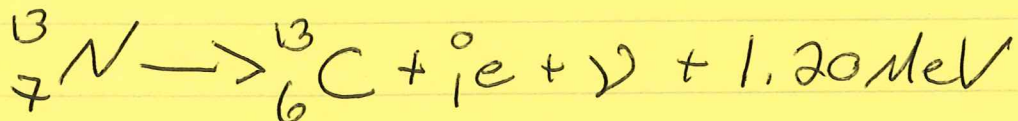
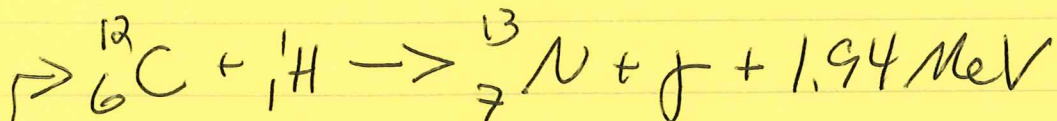
V He-burn ( $\sim 10^8 \text{ K}$ )



Other rxns include:

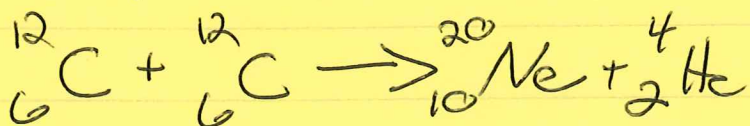


## VI Carbon cycle (C/N-burn)

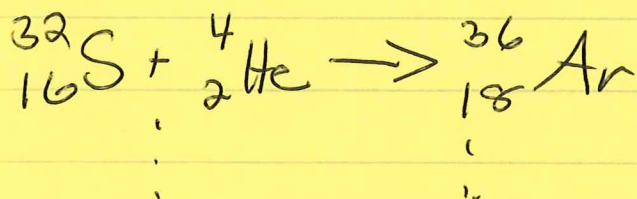
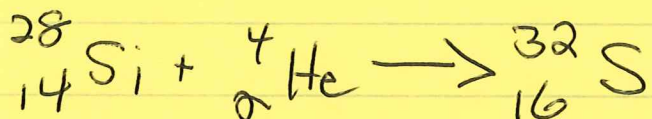
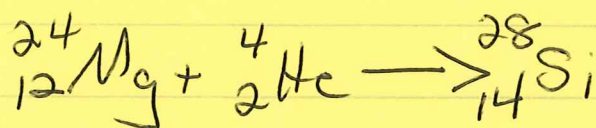
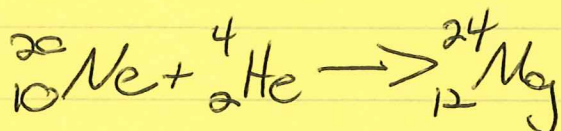
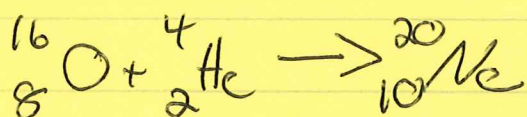
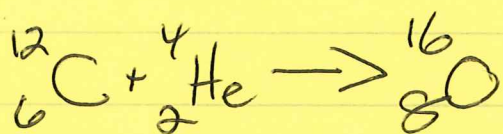


${}_6^{12}\text{C}$  is a "catalyst"

## VII Heavier elements: successive captures of ${}_2^4\text{He}$ by ${}_6^{12}\text{C}$ :

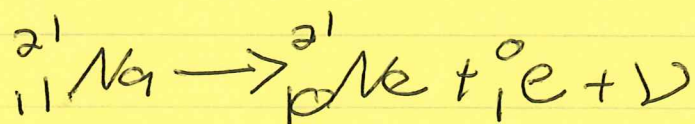
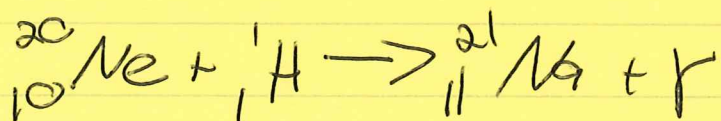


5



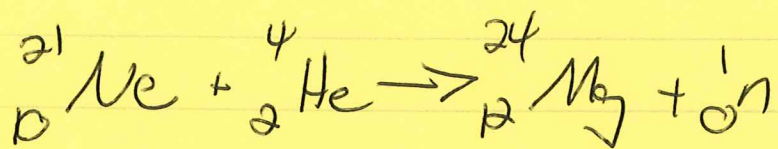
through  ${}^{56}_{26}\text{Fe}$

Nuclei of odd A values can be formed; if even-A nuclei are forced by turbulence out of the stellar core into the surrounding cooler zone where  ${}^1_1\text{H}/{}^1_1\text{H}$  cycle is occurring



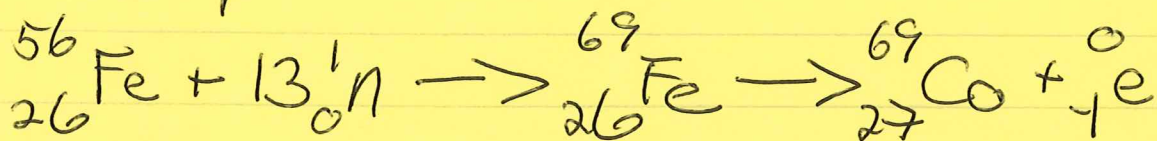


6



process stops at  $A \approx 60$ , which is  ${}_{26}^{56}\text{Fe}$ , the most stable nucleus

to go past Fe requires extreme conditions



14-body collision  
not common