Physics 203
Exam 4
Fall 1998

1. Calculate the binding energy per nucleon for \(^{209}\)Hg.

\[
\text{BE} = 1.70696 \times 931.5 = 1590.90 \text{ MeV/nucleon}
\]

2. Identify the missing particle and the type of nuclear reaction:

(a) \(^{20}\)Na \rightarrow \(^{20}\)Ne + \(^{4}\)He. \(\alpha\) decay (other possibilities)

(b) \(^{41}\)Ca \rightarrow \(^{40}\)Ar + \(^{2}\)He. \(\beta^{-}\) decay

(c) \(^{21}\)Po \rightarrow \(^{20}\)Ar + \(^{1}\)He + \(\gamma\). \(\beta^{-}\) decay

(d) \(^{22}\)Ne + \(^{3}\)He \rightarrow \(^{18}\)O + \(^{4}\)He. electron capture

(e) \(^{12}\)C + \(^{4}\)He \rightarrow \(^{16}\)O. fusion

3. Find the speed of the positron released in the \(\beta^{+}\) decay of \(^{22}\)Na.

\[
\gamma \text{Na} \rightarrow \gamma \text{Ne} + e^+ + \gamma
\]

\[
\text{max} = 21.994124 - 21.993563 = 0.000561 \text{ MeV} = 0.000761 \text{ eV}
\]

\[
\frac{0.000761}{21.993563} = 0.035 \text{ MeV/c}
\]

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4. Find the speed of the alpha particle released in the decay of \(^{22}\)Na.

\[
\gamma \text{Na} \rightarrow \gamma \text{Ne} + \alpha + \gamma
\]

\[
\text{max} = 2.22 \times 10^{-14} \text{ MeV} = 2.22 \times 10^{-14} \text{ eV}
\]

\[
\frac{2.22 \times 10^{-14}}{2.22 \times 10^{-14} \text{ eV/c}} = 0.1 \text{ MeV/c}
\]

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\]
5. Calculate the energy released for the "carbon burning" reaction for 1 kg. of carbon fused in the reaction

\[ ^{12}\text{C} + ^{4}\text{He} \rightarrow ^{16}\text{O} + \text{gamma} \]

\[ 12.000000 \]
\[ 4.0676202 \]
\[ 15.999915 \]
\[ 0.002687 \]
\[ 2.5 \text{ MeV/reaction} \]

\[ \frac{12}{15.999915} = \frac{12}{15.999915} \approx 0.76 \text{ MeV/kg} \]

6. If a sample of ancient organic matter is found to have only 9% of the fraction of carbon as \(^{12}\text{C}\) as a modern sample, what is the age of the sample?

\[ \frac{N}{N_0} = 0.09 = e^{-\lambda t} \]
\[ \lambda = 0.693 = 0.00121 \text{ year}^{-1} \]
\[ t = \frac{\ln(0.09)}{-0.00121} = 19,900 \text{ years} \]

7. Determine if the following reactions can occur. If they can not, name a conservation law which forbids the reaction.

- \( p' \rightarrow \pi^0 + \pi^- \)
- \( p' + p' \rightarrow p' + \pi^- \)
- \( \pi^- \rightarrow \mu^- + \nu_\mu \)
- \( n' \rightarrow p' + \bar{e}^- + \bar{\nu}_e \)
- \( \pi^- \rightarrow \mu^- + \nu_\mu \)