

Additional Information on Nuclear Physics – PHYS102N SPRING 2022 – S. KUHN  
 (Photos taken from in-class white- and blackboard writing)

1.) How nuclear masses are defined, how they relate to energy, and units:

$m_e = 511,00 \frac{\text{eV}}{c^2}$   
 $m_p = 938,3 \frac{\text{MeV}}{c^2}$   
 $m_n = 939,5 \frac{\text{MeV}}{c^2}$   
 $m_e = 12 \cdot 931,5 \frac{\text{MeV}}{c^2}$

$\left. \begin{array}{c} n \\ p \end{array} \right\} \text{nucleons}$   
 $Z = \# \text{ p's}$   
 $N = \# \text{ n's}$   
 $A = Z + N$

$\text{few fm} = 10^{-15} \text{ m}$   
 $M_{\text{nucl}} \approx M_{\text{Atom}} < Z m_p + N m_n$   
 (up to  $\sim 9\%$  smaller)

$E = mc^2 \rightarrow m = \frac{E}{c^2}$   
 new unit for mass:  $\frac{\text{eV}}{c^2}$   
 $\Delta m = \Delta E / c^2$   
 $9 \cdot 10^{16} \frac{\text{m}^2}{\text{s}^2}$

2.) New concepts:

- a. Geiger-Müller counter (to measure ionizing radiation, e.g. from alpha/beta/gamma decays)
- b. Antiparticles: Every charged particle has an antiparticle with exactly the same properties but opposite charge. E.g.: Electrons (charge  $q = -e$ )  $\Rightarrow$  Anti-electrons = positrons (same mass, same properties, but charge  $q = +e$ )

3.) Different types of nuclear decay, with examples:

$E^* \rightarrow E_0$   
 $\gamma$ -decay  
 e.m. radiation  $\gamma = \text{photon}$   
 $Z, N, A$  same  
 Ex.:  ${}^3\text{H} \rightarrow {}^3\text{He} + \bar{e} (+ \text{D}_e)$

$e, \bar{e}$   
 $(Z, N) \rightarrow (Z \pm 1, N \mp 1)$   
 $\beta$ -decay (Beta $^\pm$ )  
 $A = \text{same}$

$\alpha$ -decay  
 Ex.:  ${}^{238}\text{U} \rightarrow {}^{234}\text{Th} + \alpha$   
 nucleus of  ${}^4\text{He}$   
 $(Z, N) \rightarrow (Z-2, N-2), A-4$

4.) Example for alpha-decay of uranium-238

$$m_{4\text{He}} + m_{234\text{Th}} < m_{238\text{U}}$$

$$m_{e^-} + m_p \text{ Th} < m_n \text{ U}$$

$$\Delta m = \frac{\Delta E}{c^2}$$

QM: decay is possible but improbable for a given time interval.

half life

5.) Half life, activity and radiometric dating – example carbon-14

Activity = decays/s [Bq]  $\propto \frac{\# \text{ of radioactive nuclei}}{\text{half life}}$

${}^{14}_6\text{C} \rightarrow {}^{14}_7\text{N} + e^- + \bar{\nu}_e$  | half life: 50% left

half life: 5700 yr	2			25% left
	3			$\frac{1}{8}$
${}^{238}\text{U}$ half life = 4.5 billion years	6			$\frac{1}{16}$