

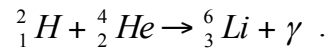
$$1 \text{ amu} = 931.50 \text{ MeV}/c^2$$

Particle rest masses:	Electron	$5.486 \times 10^{-4} \text{ u}$
	Proton	1.007276 u
	Neutron	1.008665 u

- Which of the following reactions is forbidden because it would involve the non-conservation of charge?
 - $p + p \rightarrow p + p + \pi^0$
 - $p + p \rightarrow p + p + \pi^+ + \pi^-$
 - $p + p \rightarrow p + p + \pi^+ + \pi^- + \pi^+$
- Which of the following reactions is forbidden because baryon number is not conserved?
 - $p + p \rightarrow \pi^+ + p + n$
 - $p + p \rightarrow \pi^+ + p + n + n$
 - $p + p \rightarrow p + p + \pi^0 + \pi^0$
- Why is the decay $\Lambda^0 \rightarrow p + \pi^- + \pi^0$ forbidden?
- The strong interaction conserves quark flavour. Analyse each of the following strong interactions in terms of their constituent quarks and confirm that quark flavour is conserved.
 - $\pi^- + p \rightarrow K^0 + \Lambda^0$
 - $\pi^+ + p \rightarrow K^+ + \Sigma^+$
- An electron-positron pair bound by their Coulomb attraction is called *positronium*. Show that when positronium decays from rest to two photons, the photons have equal energy. What is the wavelength of each photon?
[$2.42 \times 10^{-12} \text{ m}$]
 - Find:
 - An *approximate* expression for the mass of a nucleus of mass number A.
 - An expression for the volume of the nucleus in terms of A.
 - An estimate of the nuclear density (in kg m^{-3}).
[$3 \times 10^{17} \text{ kg m}^{-3}$]
- The compressed core of a star formed in the wake of a supernova explosion can consist of pure nuclear material (neutrons) and is called a pulsar or neutron star. Use the result from 6(c) to calculate the mass of a sugar lump sized piece of neutron star.
- ${}^{60}_{28}\text{Ni}$ has an atomic mass of 59.930789u.
 - What is its nuclear mass?
 - What is the binding energy per nucleon?
[59.9154u; 8.78MeV]

9. Which of the pair of nuclei, $^{41}_{20}\text{Ca}$ and $^{41}_{19}\text{K}$ is unstable with respect to the other (atomic masses 40.962278u and 40.961825u)? What decay mode/modes are possible and how much energy is released in each allowed mode?
10. (a) Show that ^8_4Be can decay into two α particles with an energy release of 0.1 MeV, but that $^{12}_6\text{C}$ cannot decay into three α particles.

(b) Find the energy released in the following reaction (including the energy of the photon):



Binding energies: $^8_4\text{Be} = 56.50\text{MeV}$; $^{12}_6\text{C} = 92.16\text{MeV}$; $^2_1\text{H} = 2.22\text{MeV}$; $^4_2\text{He} = 28.30\text{MeV}$ and $^6_3\text{Li} = 31.99\text{MeV}$.

[1.47MeV]

11. Two Th isotopes, $^{224}_{90}\text{Th}$ and $^{230}_{90}\text{Th}$, decay by emitting α particles with energies of 7.31 MeV and 4.77MeV respectively. For each isotope calculate the range r_c at which the α particle leaves the Coulomb potential barrier. Estimate the ratio of the half lives for these two isotopes.

(this last question is optional, but a good practice of what we saw in the lectures)