Term 2 Week 10

Nuclear Recap

Recall

The mass of the nucleus is* less *than the total mass of the individual particles that it contains!

This is true for all nuclei containing more than one nucleon.

The missing mass is known as the **mass difference** or the **mass defect**.

Values

As the masses involved are very small we usually measure them in atomic mass units u, where:

$$1\,\mathbf{u} = 1.6605 \times 10^{-27}\ \mathbf{kg}$$

Example 1

Using the data in the table opposite, calculate the mass difference for a helium nucleus in atomic mass units, and in kilograms.

	Mass (atomic mass units)
proton	1.00728 u
neutron	1.00867 u
helium nucleus	4.00151 u

$1\ \text{u} = 1.6605 \times 10^{-27}\ \text{kg}$

$$\text{Mass of } 2p + 2n = (2 \times 1.00728\ \text{u}) + (2 \times 1.00867\ \text{u})$$
$$= 4.03190\ \text{u}$$

But mass of helium nucleus = 4.00151 u

Example 1 continued

$\therefore$ Mass difference $= 4.03190 \text{ u} - 4.00151 \text{ u}$

$= 0.03039 \text{ u}$

$= 0.03039 \times 1.6605 \times 10^{-27} \text{ kg}$

$= 5.046 \times 10^{-29} \text{ kg}$

$$E = mc^2$$

E is the energy equivalent (in joules, J) of a mass m (in kilograms, kg).
c is the velocity of light (3.00×10^8 m s^{-1}).

Example 2
Calculate the energy equivalent of the mass difference for the helium nucleus calculated in Example 1.

$$E = mc^2 = 5.046 \times 10^{-29}\ \text{kg} \times (3.00 \times 10^8\ \text{m s}^{-1})^2$$

$$= 4.54 \times 10^{-12}\ \text{J} \quad (3\ \text{s.f.})$$

This is the energy that is needed to separate the helium nucleus into individual protons and neutrons.

$$ {}^{4}_{2}\mathrm{He} + \underbrace{4.54 \times 10^{-12}\,\mathrm{J}}_{\text{energy}} \Rightarrow 2p + 2n $$

Energy equivalent of 1 u

mass in kilograms and energy in joules

atomic mass units (u) and electron-volts (eV)

energy equivalent (in eV) of 1 u

$$\boldsymbol{E = m\,c^2} = 1.6605 \times 10^{-27}\,\mathrm{kg} \times (2.9979 \times 10^{8}\,\mathrm{m\,s^{-1}})^2$$

$$= 1.4924 \times 10^{-10}\,\mathrm{J}$$