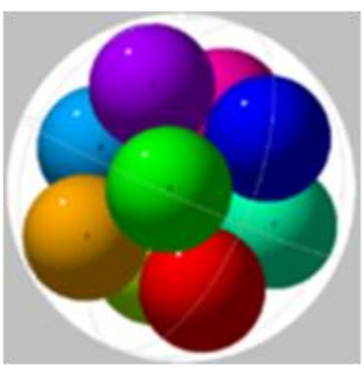
Teacher notes
Topic E

Why is binding energy per nucleon almost constant for large nuclei?

The first thing to note is that the binding energy per nucleon is a measure of the energy needed to remove one nucleon from a nucleus and so it is a measure of the stability of a nucleus. Experiments show that the radius of a nucleus of nucleon number A is given by $R = R_0 A^{\frac{1}{3}}$ where $R_0 = 1.2 \times 10^{-15}$ m. This implies close packing: the nucleons are packed in the nucleus with as little "wasted" space between them as possible. Imagine a nucleus of radius R with nucleon number A. It contains A nucleons, each of volume v. If the packing of the nucleons is very "close" i.e. as little wasted space as possible then approximately

$$Av \approx \frac{4\pi}{3}R^3 \qquad (1)$$

which immediately implies that $R \propto A^{\frac{1}{3}}$. This is a crude argument! Obviously there has to be some wasted space in between the nucleons so Equation 1 cannot be correct. However the argument shows that the A dependence of the radius is a sign of very close packing of the nucleons. The images (taken from Wikipedia) show close packing of 9 and then 12 unit radius spheres.



A = 9 A = 12

$A^{1/3}$ = 2.08 $A^{1/3}$ = 2.29

$R = 2.73 = 1.31 \times A^{1/3}$ $R = 2.90 = 1.27 \times A^{1/3}$

To a reasonable approximation the radius of the sphere scales as $A^{\frac{1}{3}}$.

Now, if the nucleus is *large enough*, any one nucleon is surrounded by the same number of **immediate** neighbours that fall within the range of the strong nuclear force. Precisely because the strong nuclear force has a short range, it is only these immediate neighbours that attract the given nucleon. And since the number of neighbours is the same, the energy required to remove the given nucleon from the nucleus is the same. I.e. the binding energy per nucleon is the same.