24.2 Nuclear Stability

Binding Energy

What is the binding energy in kJ/mol nucleons for copper-63?

Masses (g/mol): $^{1}_{1}H = 1.00783$; $^{1}_{0}n = 1.00867$; $^{63}_{29}Cu = 62.92980$

Speed of Light = 2.998×10^{8} m.s^{-1}

$E_b = X.XXXX \times 10^{?}$? = 8

a) 5
b) 6
c) 7
d) 8 ✓
e) 9

Determine the Mass of the Isotope built from its Particles

$$^{63}_{29}Cu = 29(^{1}_{1}H) + 29(^{0}_{-1}e) + 34(^{1}_{0}n)$$
$$= 29(1.00783) + 34(1.00867)$$
$$= 63.52185 \text{ g.mol}^{-1}$$

Determine the Mass Defect (in Kg.mol^{-1})

$$\Delta m = 63.52185 - 62.92980$$
$$= 0.59205 \text{ g.mol}^{-1}$$
$$= 5.9205 \times 10^{-4} \text{ kg.mol}^{-1}$$

Convert the Mass Defect to Energy (in kJ.mol^{-1})

$$\Delta E = \Delta m c^2$$
$$= 5.9205 \times 10^{-4} (2.998 \times 10^{8})^2$$
$$= 5.3213 \times 10^{13} \text{ J.mol}^{-1}$$
$$= 5.3213 \times 10^{10} \text{ kJ.mol}^{-1}$$

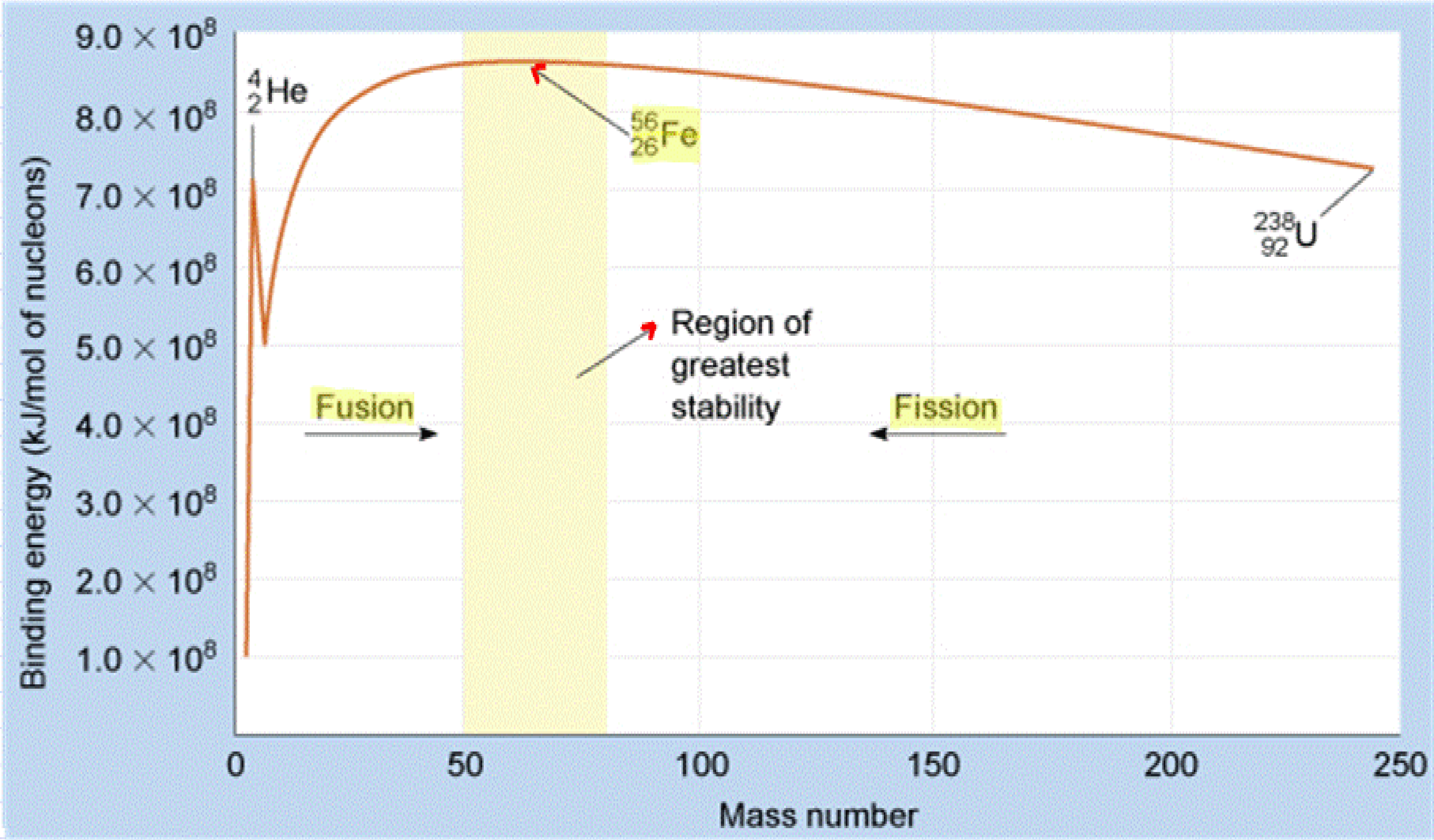
Divide this Energy by the number of Nucleons

$$^{63}_{29}Cu = 29 + 34 = 63 \text{ Nucleons}$$

$$E_B = \frac{5.3213 \times 10^{10}}{63} = 8.4466 \times 10^{8} \text{ kJ.mol}^{-1}.\text{nucleon}^{-1}$$

24.2 Nuclear Stability

Relative Binding Energy



24.3 Kinetics of Radioactive Decay

Rate of Decay

Radioactive Decay follows first order kinetics

First Order Kinetics Recall:

A → Products

Integrated Rate Law:

$$\ln \frac{[A]_t}{[A]_0} = -kt$$

Half Life:

$$t_{1/2} = \frac{\ln 2}{k}$$

Radioactive Decay:

Substitute N (the number of nuclei) for A

Integrated Rate Law:

$$\ln \frac{[N]_t}{[N]_0} = -kt$$

Half Life:

$$t_{1/2} = \frac{\ln 2}{k}$$

24.3 Kinetics of Radioactive Decay

Rate of Decay

Radioactive radon-222, found in many homes, is a potential health hazard. The half-life of radon-222 is 3.82 days. How much time is required for the activity of a sample of radon-222 to fall to 19.5 percent of its original value?

? Days =

a) 5
b) 6
c) 7
d) 8
e) 9 ✓

a) Use $t_{1/2}$ to find k:

$$t_{1/2} = \frac{\ln 2}{k}$$

OR

$$k = \frac{\ln 2}{t_{1/2}}$$

$$= \frac{0.693}{3.82}$$

$$= 0.1815$$

How do I deal with this 19.5% of its original value? Simply convert to a decimal.

$[N]_t = 0.195 \qquad [N]_0 = 1$

$$\ln \frac{[N]_t}{[N]_0} = -kt$$

$$\ln 0.195 = -0.1815t$$

$$-1.6348 = -0.1815t$$

$$t = \frac{-1.6348}{-0.1815}$$

$$= 9 \text{ days}$$

24.3 Kinetics of Radioactive Decay

Radioactive Dating

An artifact classified as seeds, found in a site at Newlands Cross, Ireland, is found to have a ^{14}C radioactivity of 9.71×10^{-2} **counts per second** per gram of carbon. If living carbon-containing objects have an activity of **0.255 counts per second** per gram of carbon, estimate the age of the artifact?

The half-life of ^{14}C is **5730 years**

a) Use $t_{1/2}$ to calculate k (see previous slide)

$$k = \frac{0.6931}{5730}$$

$$= 1.21 \times 10^{-4}$$

i) While the seeds were alive their activity remained constant at $0.255 = [N]_0$

ii) Now today the count is at $0.0971 = [N]_t$

$$\ln \frac{0.0971}{0.255} = -1.21 \times 10^{-4}\ t$$

$$\ln 0.381 = -1.21 \times 10^{-4}\ t$$

$$-0.965 = -1.21 \times 10^{-4}\ t$$

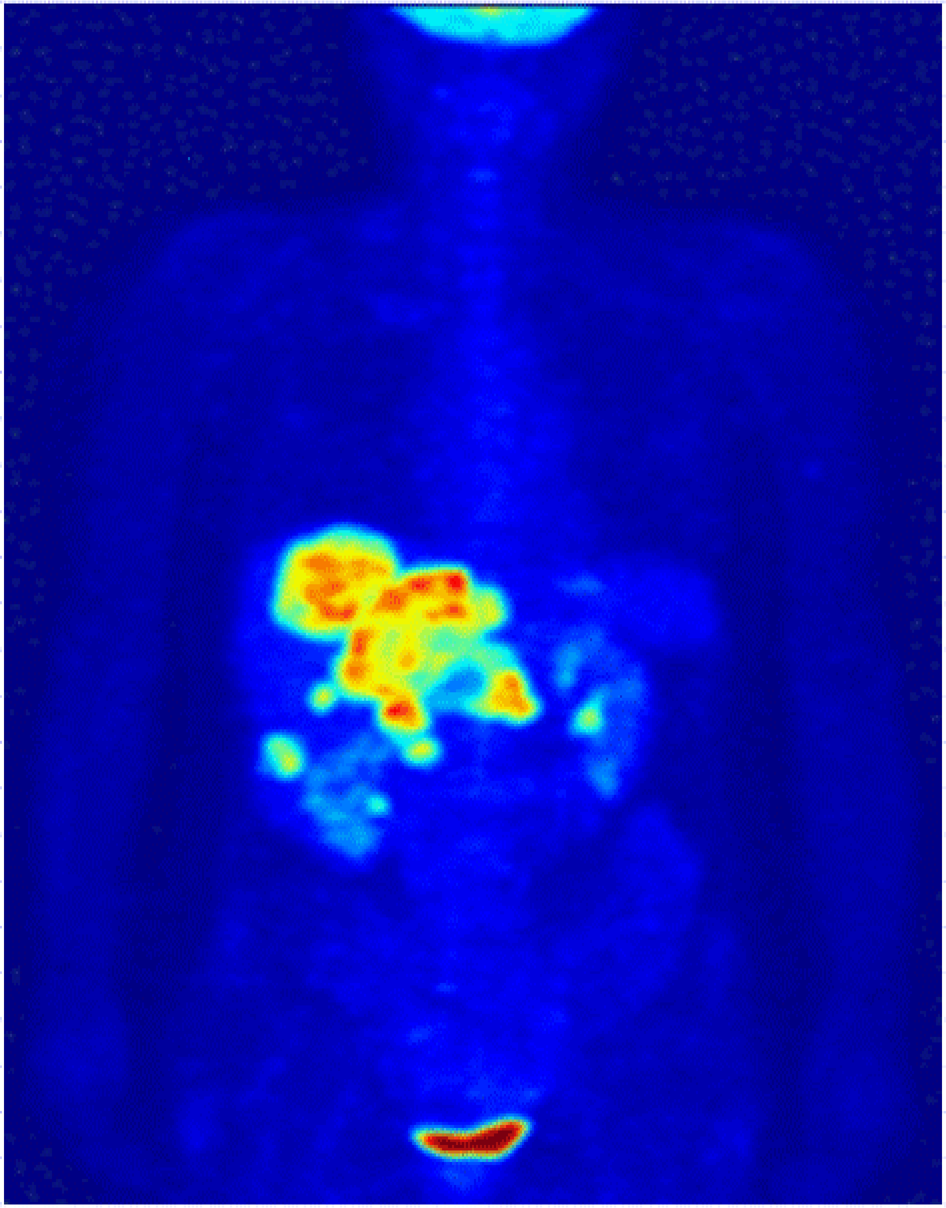
$$t = \frac{-0.965}{-1.21 \times 10^{-4}} = 7980 \text{ years}$$

Hypothetical:- Redo this calculation with the argument that ~8,000 years ago the living count was 0.245 counts per second

See how this flawed logic could be used to assert false claims, and we only changed the living count by 0.01

24.5 Applications and Uses of Nuclear Chemistry

Nuclear Medicine – Positron Emission Tomography



Because I had to seriously condense this it lost a huge amount of its clarity.

Isotopes used in PET ... short $t_{1/2}$

$^{11}_{6}C$: ~ 20 mins

$^{13}_{7}N$: ~ 10 mins

$^{15}_{8}O$: ~ 2 mins

$^{18}_{9}F$: ~ 110 mins

$^{18}_{9}F$ the most common, the others while used would have to have the source in the hospital. $^{18}_{9}F$ does not.

24.5 Applications and Uses of Nuclear Chemistry

Nuclear Medicine – Positron Emission Tomography

24.5 Applications and Uses of Nuclear Chemistry

Radioactivity in the Home

Naturally found in Earths crust (→ Uranium)

Radon → Why so dangerous ∴ $^{222}_{66}Rn$ is a gas.

$^{222}_{66}Rn(g) = {}^{4}_{2}He + {}^{218}_{84}Po + \gamma$ rays

(Po → See LITVINENKO)

↳ Adheres to lung tissue

$^{218}_{84}Po = {}^{4}_{2}He + {}^{214}_{82}Pb + \gamma$ rays

↳ Now inside the body an it is the highest energy particle.

Cheap and easy fix:

a) Use a fan in basement to get rid of what has built up.

b) Apply a sealant.