24.2 Nuclear Stability

Natural Radioactive Decay

1. Alpha Emission:
   $^{4}_{2}\alpha$ OR $^{4}_{2}He$ ... Old: $_{2}He^{4}$

2. Beta Emission:
   $^{0}_{-1}\beta$ OR $^{0}_{-1}e$ ... Old: $_{-1}e^{0}$

3. Positron Emission:
   $^{0}_{+1}\beta$ OR $^{0}_{+1}e$ ... Old: $_{+1}e^{0}$

4. Electron Capture:
   $^{0}_{-1}e$ ... Nucleus captures an electron.

Note:

1., 2., and 3: The emitted particle is a product.

4: The captured electron is a reactant.

24.2 Nuclear Stability

The Nucleus – Emitting Beta or Positron Particles

2. Nucleus emitting a $^{0}_{-1}\beta$ particle ... an electron ... where does this $^{0}_{-1}e$ come from?

$$^{1}_{0}n \rightarrow \; ^{1}_{1}H + \; ^{0}_{-1}e$$

Neutron → Proton + Electron (Beta particle) — emitted

Net result in nucleus → Neutron converted to a Proton.

3. Nucleus emitting a $^{0}_{+1}\beta$ particle ... a positron ... where does this $^{0}_{+1}e$ come from?

$$^{1}_{1}H \rightarrow \; ^{1}_{0}n + \; ^{0}_{+1}e$$

Proton → Neutron + Positron — emitted

Net result in nucleus → Proton converted to a Neutron.

24.2 **Nuclear Stability**

The Nucleus – Capturing an Electron

4. Nucleus capturing an electron ... why? ... what does the nucleus do with an $^{0}_{-1}e$?

$$^{1}_{1}H + ^{0}_{-1}e \rightarrow ^{1}_{0}n$$

Proton — Captured electron — Neutron

Net result in the nucleus → Proton converted to a Neutron.

24.2 Nuclear Stability

The Nucleus – Emitting an Alpha Particle

$^{234}_{92}U$ undergoes radioactive decay by emitting an alpha particle. As a result of this emission the #Neutron/#Proton ratio –

a) Increases ✓ b) Decreases c) Remains the same

$$^{234}_{92}U \rightarrow {}^{4}_{2}He + {}^{230}_{90}Th + \gamma \text{ rays}$$

$$^{234}_{92}U: \frac{142}{92} = 1.543 \qquad ^{230}_{90}Th: \frac{140}{90} = 1.556$$

The Nucleus – Emitting an Alpha Particle

BBC NEWS

Last Updated: Thursday, 30 November 2006, 21:26 GMT

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Radiation found at 12 locations

Mr Litvinenko died last week in a London hospital

Experts probing the death of former Russian spy Alexander Litvinenko have found traces of radioactivity at 12 locations, the home secretary has said.

Among them are two British Airways (BA) planes. A third one is awaiting checks.

Home Secretary John Reid told Parliament that two Russian aircraft, one of which is currently at Heathrow airport, were also of interest.

The Health Protection Agency said 24 people had been referred to a specialist clinic for tests.

BA is contacting 33,000 passengers from 221 flights. But Mr Reid stressed the public health risk was low.

Mr Litvinenko, an ex-KGB officer and a fierce critic of Russian President Vladimir Putin, died last week of radiation poisoning.

Traces of radioactive polonium-210 were discovered in his body, and more traces of the substance have been found at venues he visited in the capital on 1 November.

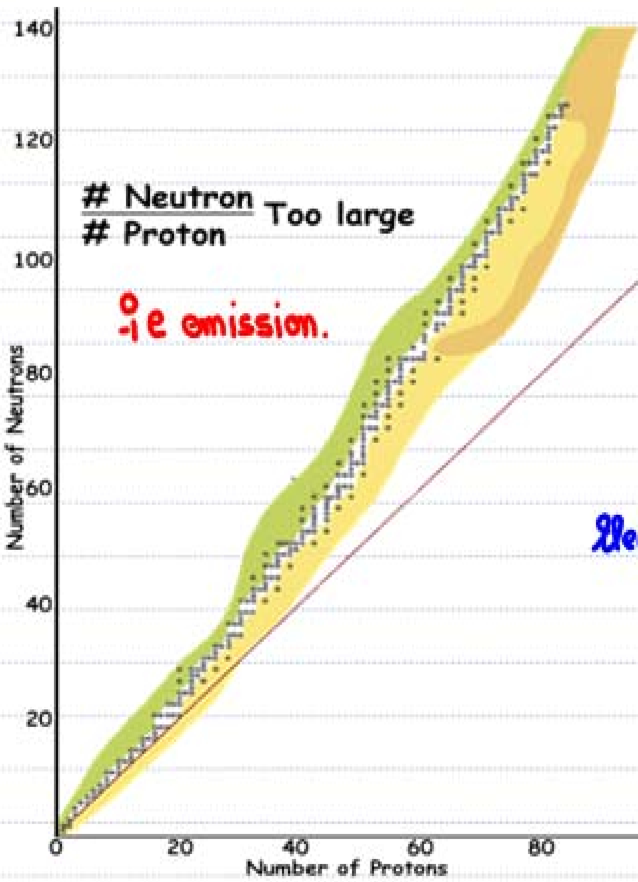
Earlier, an inquest into the death of Mr Litvinenko was

$$^{210}_{84}Po \rightarrow \, ^{4}_{2}He + \, ^{206}_{82}Pb$$

Do a web search for some 2015 articles.

24.2 Nuclear Stability

Predicting Decay Processes



$^{60}_{27}Co$ is one of many radioactive isotopes whose #Neutron/#Proton ratio is too large. Radioactive isotopes on this side of the stability have only one form of radioactive decay available to them –

a) Alpha emission

b) Positron emission

c) Electron capture

d) Beta emission. ✓

$^{4}_{2}He$: causes #N/#P to ↑. ✗

$^{0}_{+1}e$: Proton converted to Neutron. ✗

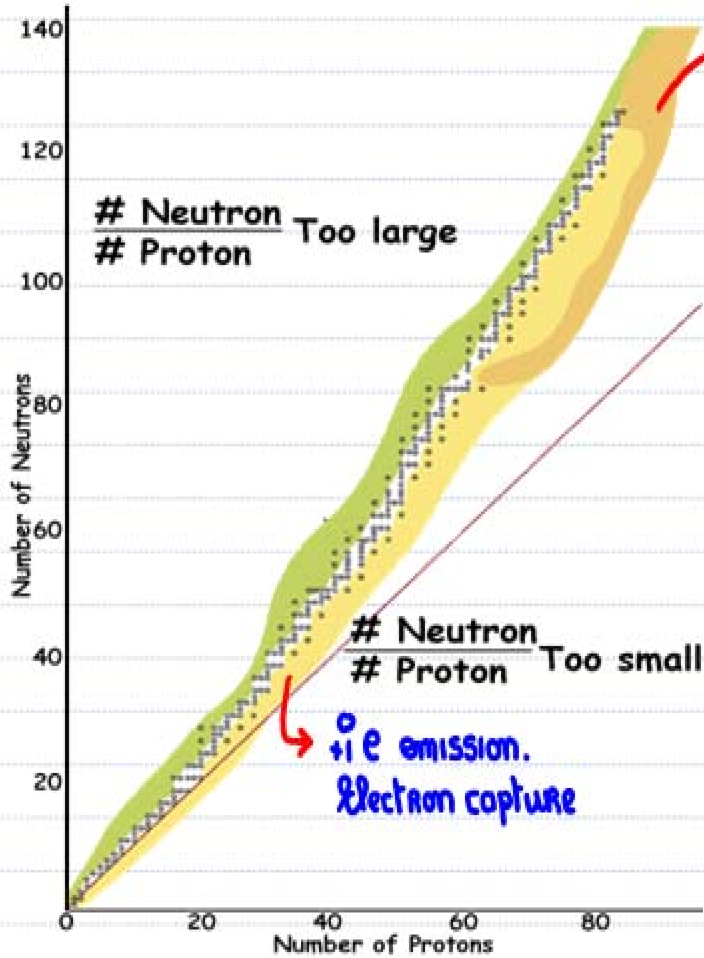
Electron capture : Proton converted to Neutron. ✗

$^{0}_{-1}e$: Neutron converted to Proton. ✓

$$^{60}_{27}Co \rightarrow \, ^{0}_{-1}e + \, ^{60}_{28}Ni + \gamma \text{ rays}$$

24.2 Nuclear Stability

Predicting Decay Processes



$^{4}_{2}He$ emission

Electron Capture:

$$^{41}_{20}Ca + ^{0}_{-1}e \rightarrow ^{41}_{19}K + \gamma \text{ rays}$$

↳ Reactant

Positron Emission:

$$^{18}_{9}F \rightarrow ^{0}_{+1}e + ^{18}_{8}O + \gamma \text{ rays}$$

↳ Used in PET

↳ Positron Emission Tomography*

*Will return to this later.

24.2 Nuclear Stability

Binding Energy

What is the binding energy in kJ/mol nucleons for nitrogen-15?

Masses (g/mol): $^{1}_{1}H = 1.00783$; $^{1}_{0}n = 1.00867$; $^{15}_{7}N = 15.00011$
Speed of Light = 2.998×10^{8} m.s^{-1}

$^{15}_{7}N$: $7(^{1}_{1}H) + 8(^{1}_{0}n)$

$7(1.00783) + 8(1.00867)$

↳ actually = $^{1}_{1}H + ^{0}_{-1}e$, ie takes into account of the mass of the electron.

$= 15.12417$ g.mol^{-1}

Mass defect = Δm

$\Delta m = 15.12417 - 15.00011$
$= 0.12406$ g.mol^{-1}
$= 1.2406 \times 10^{-4}$ kg.mol^{-1}

$\Delta E = \Delta m c^2$
$= 1.2406 \times 10^{-4} (2.998 \times 10^{8})^2$
$= 1.1151 \times 10^{13}$ J.mol^{-1}
$= 1.1151 \times 10^{10}$ kJ.mol^{-1}

Total nucleons : $7 + 8 = 15$

$$E_B = \frac{1.1151 \times 10^{10}}{15}$$
$= 7.4337 \times 10^{8}$ kJ.mol^{-1}. nucleon^{-1}