On nuclear stability

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1. Some 279 nuclei are stable, whilst others are not (about 2000 nuclides are known altogether). Discuss this statement and give some examples of unstable nuclides.

2. Assuming that protons may be modelled as small spherical balls of charge, use coulomb's law to calculate the force of electrostatic repulsion between two protons (both having charge $+1.6 \times 10^{-19}$ C) that are just touching each other. (diameter of proton $= 1.4 \times 10^{-15}$ m)

3. (a) Sketch an $N - Z$ chart for stable nuclei (up to ${}^{209}_{83}\mathrm{Bi}$).
   (b) Label the areas where proton-rich and neutron-rich nuclei are found, and what decay modes they are likely to follow.
   (c) On your chart draw arrows (in appropriate places) to show the directions that α, β^+, β^- and electron capture take a nucleus.

4. Discuss nuclear stability in terms of the four fundamental interactions in nature (strong, electromagnetic, weak, gravity). *Can you explain the shape of the valley of stability on the $N - Z$ chart?

5. ${}^{36}\mathrm{Cl}$ decays into ${}^{36}\mathrm{S}$ and ${}^{36}\mathrm{Ar}$. Write equations for these two decays, and describe each mode of decay in words.

6. Wolfgang Pauli proposed the neutrino (though it was Fermi who gave it that name) in 1930 (before Chadwick discovered the neutron in 1932!), and said of his proposal: "I have done a terrible thing. I have invented a particle which cannot be detected". What lead Pauli to make his prediction of a new particle, and what makes neutrinos so hard to detect? **How do we detect them[1]?

7. Draw an $N - Z$ decay chart for uranium-235 using the following data. Draw alpha decays with a red line and beta decays with a blue one.

   uranium-235, thorium-231, protactinium-231, actinium-227, thorium-227, radium-223, radon-219, polonium-215, lead-211, bismuth-211, thallium-207 , lead-207 (stable)

8. The isotope ${}^{232}\mathrm{Th}$ decays into another element, emitting an alpha particle. What is the element?

   This element decays, and the next, and so on until a stable element is reached. The complete list of particles emitted in this chain is:

   $$^{232}_{90}\mathrm{Th} \rightarrow [\alpha\beta\beta\alpha\alpha\alpha\beta\beta\alpha] \rightarrow \mathrm{X}.$$

   What is the stable element X? (You could write down each element in the series, but there is a quicker way.)

[1]The first detection was by Reines and Cowan (et al.) in 1956, and they got a Nobel prize in 1995 (forty years later)!