Teaching ideas for Topic 6: *Atomic and nuclear physics*, Core

Questions

A number of worksheets are provided for this Topic:

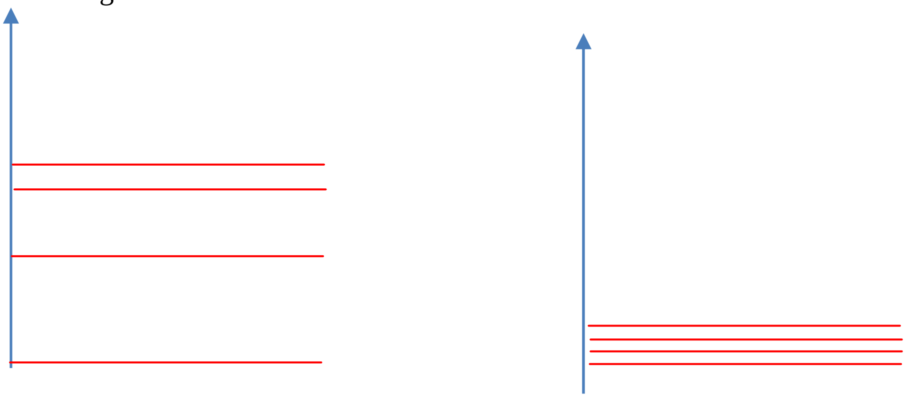
- support questions examine the very basic concepts of the syllabus
- extended questions delve deeper and are equivalent to exam level questions.

Teaching ideas

This is a topic with some abstract ideas, so it is worthwhile trying to make it as concrete as possible.

- The Hyperphysics site http://hyperphysics.phy-astr.gsu.edu/hbase/pertab/pertab.html#c1 will give all the necessary data for the elements that will be useful in this course and, of course, will provide so much more. Basic information includes atomic and nuclear masses, atomic radii, specific heat capacities, etc. as well as binding energies for each isotope, type of decay and energy released. It is crucial that students get a lot of experience doing calculations of mass defects, binding energies and energy produced in decays, fission and fusion. This site will give all the necessary data to get started easily.
- The most stable nuclide is ^{62}Ni, with a binding energy of 545.27 MeV and so a binding energy per nucleon of 8.79 MeV.
- It is important to concentrate on the meaning of the terms *random* and *spontaneous* when it comes to radioactive decay.
- Students must have an awareness of the fundamental forces of nature and the particles on which they act. The gravitational force is irrelevant here since the masses involved are so small. The electromagnetic force acts between particles with electric charge (so protons and electrons). It has an infinite range, meaning that a proton somewhere still acts on another proton (or electron) far away. The strong force acts between protons and neutrons. It has very short range, meaning that a proton will attract another proton or neutron only if the second nucleon is within the range which is about 10^{-15} m. The weak force acts between nucleons as well as electrons and neutrinos. Its range is even shorter than the strong nuclear force, with a range of around 10^{-18} m.
- The binding energy per nucleon is roughly constant for elements with mass number greater than about 20. This is evidence that the strong nuclear force has a short range. Very roughly, the argument goes: the binding energy per nucleon is a rough measure of the energy needed to extract one nucleon from the nucleus. For large nuclei, any one chosen nucleon is surrounded by the same number of *nearest* neighbours. If the force is short range, only these nearest neighbours will act on the chosen nucleon. Therefore the energy needed to extract it will be the same.
- The electron produced in beta decay did not exist within the nucleus from which it was somehow ejected. The electron was produced in the decay (along with the antineutrino).

- The diagram on the left below shows discrete energy levels in some atom. In atomic transitions, the energy carried away by a photon can only be a difference in energy between these levels and so the energy can be one of a small number of energies: the photons has discrete energies and so discrete wavelengths. What would happen if the energy were continuous rather than discrete? We can model continuous energies by discrete energies separated by very small differences (diagram on the right, below). Clearly then the emitted photons in this case would have any energy they wished, and the energies and so the wavelengths would not be discrete.



Practical activities/ICT

- A simulation of Rutherford scattering is found here: http://phet.colorado.edu/en/simulation/rutherford-scattering
- A very simple simulation of beta decay is http://phet.colorado.edu/en/simulation/beta-decay
- A simulation of nuclear fission is at http://phet.colorado.edu/en/simulation/nuclear-fission
- The aurora borealis (Northern lights) is one of nature's most spectacularly beautiful displays. The site http://www.psdeluxe.com/articles/inspiration/50-magnificent-aurora-borealis-pictures/ has an amazing collection of photographs which students will enjoy seeing (the ones at the end have been worked on with Photoshop!). The Northern lights can be tied to motion of charged particles in magnetic fields (it is good to do the example of helical motion) as well as atomic transitions and emission of photons.

Common problems

- Students often bring in electrons in discussions about nuclei. It is worthwhile to make simple calculations that show the relative sizes of nuclear diameters and atomic diameters. This should convince students that electrons are irrelevant when discussing phenomena taking place inside nuclei.

Theory of knowledge (TOK)

- This is the first topic in this course in which we delve deep into the atom. Different models have been used to understand the atom and this topic clearly shows how models are abandoned and others adopted (paradigm shifts) as new experimental evidence shows inconsistencies of the old models.