Workshop Tutorials for Introductory Physics

QI4: **The Nucleus**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
nucleons, neutrons, Gravity, protons, protons, N, mass, energy, binding, atomic, neutral, nucleus, stable, bigger, defect

The nucleus

The nucleus is made up of _____ and _____, which are collectively called _____. A nucleus can be described by three numbers: N, Z and A. _____ is the number of neutrons in the nucleus, and Z is the number of _____, also called the _____ number. A is the _____ number and is the total number of nucleons which is equal to N + Z.

The neutrons are _____, and the protons are positively charged. So if the only significant force in the nucleus was the Coulomb force, the nuclei would blow apart. _____ is very weak compared to the Coulomb force, so it doesn't hold them together. The force that holds them together is very strong, and acts over short distances between nucleons. Hence it is called the "strong nuclear force".

Because there is a strong force which pulls nucleons together, they have lower potential _____ when they are bound together in a nucleus than if they were free. In the same way, an electron has lower potential energy when it is bound by the Coulomb force to a _____ to form an atom. In the same way that you need to give an electron energy to allow it to escape from an atom, you need to give a nucleon energy to pull it apart from the nucleus. For an electron this is called the ionisation energy, for a nucleon it is called the _____ energy.

The binding energy tells us how _____ a nucleus is, how hard it is to break it apart. This is usually shown in charts as a binding energy per nucleon, which is the amount of energy you need to pull a nucleus completely apart into protons and neutrons, divided by the number of protons and neutrons (A). The _____ this energy, the more stable the nucleus. The binding energy can also be expressed as a mass. The mass of a nucleus is a bit less than the sum of the masses of its protons and neutrons. The difference is called the mass _____ which, using $E=mc^2$, is equivalent to the binding energy.

Discussion questions

What is the Coulomb force? What force holds the earth in its orbit around the sun?
What force holds your nose onto your face and electrons into atoms?
What force holds nucleons into nuclei?

B. Activity Questions:

1. Binding energies

Examine the chart of binding energies.

a. What does the diagram represent?

Fission and fusion are opposite processes, when fission occurs a nucleus breaks apart and when fusion occurs two nuclei fuse to form a larger one.

b. How can both these processes release energy?

c. Which nuclei are more likely to undergo fusion? Which will undergo fission? Explain your answer.

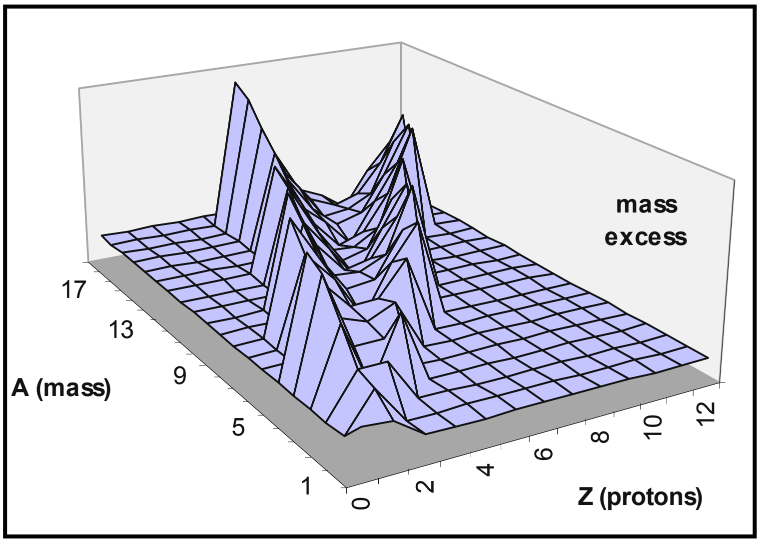
2. Coolite Balls

Charge the coolite balls so that they have opposite charges. What happens?
Now charge them so they have like charges and observe what happens. What would happen to nuclei if there wasn't a strong nuclear force to hold them together?

C. Qualitative Questions:

1. Captain Picard and Data have just completed a successful mission on the planet Zog and are beaming back aboard the starship Enterprise (mark III) when there is an error in the transporter circuits!
The transporter de-materialises all their atoms on the planet surface and converts them into information in the circuits of the ship's transporter, and then reconstructs the atoms and puts them back in the right places. However the computer mixes up its N's and Z's so the codes for protons and neutrons are mixed up. When the transporter in the ship reconstructs them all their protons have been exchanged for neutrons and vice versa.
a. What is the effect of this on the carbon, oxygen, nitrogen and hydrogen which make up Captain Picard?
b. What will be the likely effect of this on Captain Picard?
c. What is the likely effect on Data, who is mostly metal (such as copper and iron) beneath his plastic simulated skin?
Hint : you may want to look at a periodic table.

2. The figure below shows the mass excess as a function of A and Z for the first 12 elements.



a. In which region are the nuclei stable?
There are two regions of unstable nuclei, one to the left of the valley, and one to the right.
b. Why are the nuclei to the left unstable?
c. Why are the nuclei to the right unstable?
(Hint: Look at the A and Z numbers.)
The nuclei from each of these regions become stable by different processes.
d. Describe these processes.
e. What happens to N and Z during these processes?

D. Quantitative Question:

A deuteron (a proton and a neutron) has a binding energy of 2.22 MeV = 3.55×10^{-13}J.
a. What is the binding energy *per nucleon* for a deuteron?
b. By how much is a deuteron lighter than a proton plus a neutron?
c. How much energy is released when two hydrogen nuclei and two neutrons fuse to form a helium nucleus in the sun?
d. How much energy is released when uranium232 decays into a thorium228 nucleus and a helium nucleus?
e. Comment on your answers to **c** and **d**.

Particle	proton	neutron	H	He	^{232}U	^{228}Th
Mass (amu)	1.007276	1.008665	1.0107276	4.002603	232.0371	228.0287

1amu = 1.66054×10^{-27} kg.= 931.3 MeV/c^2.