1 Nuclear Energy

The fission of one atom of uranium-235 gives off energy of approximately 3 x 10^{-11} J. This energy goes into heating the reactor core of a nuclear power plant. A typical nuclear power plant burns uranium-235 at a rate of 4 kg per day. The atomic weight of uranium-235 is part of its name, i.e. 235 g/mol. The heat from fission is converted to electrical energy with an efficiency fraction of 0.3 (i.e. 0.3 J of electrical energy per 1 J of heat energy). At what rate is electrical energy produced? Give your answer in Joules per second (i.e. Watts).

2 Practice Nuclear Physics

1. Rutherford scattering

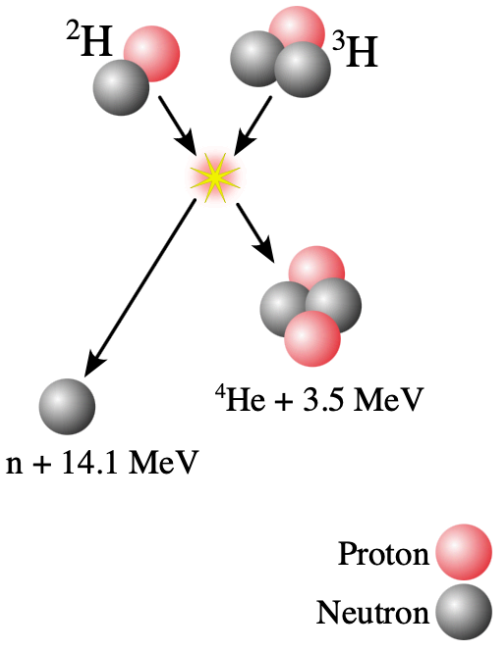
Based on Q13M.2 from Unit Q 3rd Edition

Estimate the minimum kinetic energy that an alpha particle must have to get stuck to a gold nucleus? Give your answer in both joules and electron volts.

(Note: The atomic number of gold is $Z = 79$, the mass number of gold is $A = 197$. An alpha particle consists of 2 protons and 2 neutrons. This question can be solved using knowledge of the Coulomb potential for a system of two point charges).

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2. Fusion



(a) The figure shows the fusion reaction between tritium and deuterium. Estimate the electrostatic potential energy of a deuterium-tritium pair at separation distance where the strong nuclear force becomes significant (i.e. the nuclei "touch" and the strong force can stick them together). Give a numerical answer in joules.

(b) Fusion is happening in a hot ionized gas of deuterium and tritium (also known as a D-T plasma). The average kinetic energy of the individual deuterium and tritium ions is about 10 times smaller than your answer to part a. (Fusion can be sustained by a small fraction of nuclei that have higher-than-average kinetic energy). Estimate the temperature of the plasma using the relationship:

$$\text{Average kinetic energy of gas atom} = (3/2)k_B T,$$

where $k_B = 1.38 \times 10^{-23}$ J/K is called the Boltzmann constant. Give a numerical answer in kelvin.

(c) Compare the mass of ^{3}He (a nucleus with two protons and one neutron) to the combined mass of two isolated protons and one isolated neutron. You are welcome to reference emperical data, but the main task of this question is to estimate the mass difference using the coarse-grained model we discussed in class. In this coarse-grained model, the biggest contributions to binding energy are the electrostatic interaction and the strong interaction.
- Estimate the mass difference and give your answer in units of kilograms.
- Is the mass of the composite particle larger or smaller than the mass of the individual parts?

3 Three ideas for the term project

Read the description of the term project on the class website at "Introduction to term project". Identify three (3) subjects that you find interesting/intriguing (for example, solar energy, exoplanets, ...). Within each subject, pose a question that might have an interesting quantitative answer: "Since it requires energy to make a solar panel, how long does it take to recoup that energy?", "How far away could we see an Earth-like planet orbiting a Sun-like star?" ... You should turn in 3 different subjects and 3 different quantitative questions (quantitative means "quantities that can be calculated and/or measured")

Let your mind wander as broadly as possible. Subjects and questions are not restricted to the topics taught in PH315. During this exploratory stage, be bold and daring; you are not committing yourself to solve all 3 questions. To spark your imagination, there is a list of ideas on the class website. The instructor will read your ideas and give you feedback. Whenever possible, the feedback will point you towards a coarse-grained model that is helpful for answering your question. Use the feedback to help decide which question you will develop further (or whether you need to go back to the drawing board).