TAP 527- 5: Fission – practice questions

What these are for

These questions will give you some simple practice in handling the ideas and calculations that physicists meet in nuclear fission.

Try these

The process of fission in one type of nuclear reactor proceeds as follows: a nucleus of uranium $^{235}_{92}U$ captures a single neutron. The resulting nucleus is unstable and splits into two or more fragments. These fragments could typically be a pair of nuclei, $^{90}_{36}Kr$ and $^{144}_{56}Ba$ for example. Neutrons are also ejected as a result of the fission. It is these neutrons that go on to cause subsequent fission events and maintain the chain reaction.

1. Write down two balanced equations (the first to the unstable uranium; the second to the final products) that represent this fission process.

2. Calculate the total mass of the original uranium isotope and the neutron. The table gives the atomic masses (in atomic mass units) of the particles found in this question. (1 atomic mass unit (u) ≡ 931 MeV.)

Particle	Mass (u)
$^{1}_{0}n$	1.008 665
$^{90}_{36}Kr$	89.919 528
$^{92}_{36}Kr$	91.926 153
$^{96}_{37}Rb$	95.934 284
$^{138}_{55}Cs$	137.911 011
$^{138}_{56}Ba$	137.905 241
$^{144}_{56}Ba$	143.922 941
$^{235}_{92}U$	235.043 923

3. Calculate the total mass of the four products.

4. Calculate the change in mass. Does this represent energy gained or lost by the system?

5. Convert the mass change into the energy released (in MeV) in the fission event.

6. These particular barium and krypton isotopes are not the only products possible in nuclear fission. Repeat the calculation steps 1–5 with the following possible products

   caesium-138 and rubidium-96.

Hints

1. There are two equations, the first for the absorption of the neutron; the second for the splitting of the unstable nucleus formed in the absorption. Write down all the original nucleons on the left-hand side of the first equation (do not forget the original neutron). Put all the products on the right-hand side. Check that all protons, neutrons and electrons balance. Energy is also an output of the reaction, call it Q.
2. Add the atomic mass unit values for the uranium and the neutron together.
3. Add the atomic mass unit values for the barium, krypton and two neutrons together.
5. Use $\Delta E = \Delta mc^2$ to carry out this conversion. $c^2 = 9 \times 10^{16}$ J kg^{-1}.

Practical advice

This question set provides repetitive practice in handling nuclear mass changes and conversions between mass and energy. It is suitable for students meeting these ideas for the first time. There is an energy release / nucleon perspective here – a useful teaching point when students have completed this task

Answers and worked solutions

1. $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} = {}^{236}_{92}\mathrm{U} = {}^{90}_{36}\mathrm{Kr} + {}^{144}_{56}\mathrm{Ba} + 2{}^{1}_{0}\mathrm{n} + Q$

2. m = 235.043923 u – 1.008665 u = 236.052 588 u

3. m = 89.919528 u + 143.922941 u + 1.008665 u + 1.008665 u =235.859 799 u

4. Δm =236.052 588 u – 235.859799 u = 0.192 789 u; energy lost

5. ΔE = 0.192 789 u × 931.3 MeV u^{-1} =179.49 MeV

6. m = 137.905241 u + 95.934284 u + 1.008665 u + 1.008665 u =235.856855 u

   Δm = 236.052 588 u – 235.856855 u = 0.195733 u

   ΔE = 0.195733 u × 931.3 MeV u^{-1} = 182.2 MeV

External reference

This activity is taken from Advancing Physics chapter 18, 250S