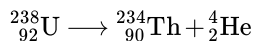
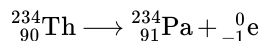


19.3: Radioactive Series

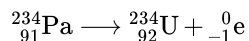
Naturally occurring uranium contains more than 99% $^{238}_{92}\text{U}$ that decays to $^{234}_{90}\text{Th}$ by α emission:



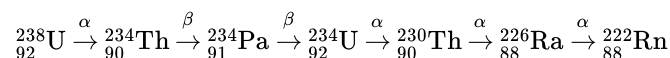
The product of this reaction is also radioactive, however, and undergoes β decay:



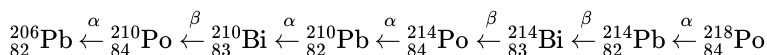
The $^{234}_{91}\text{Pa}$ produced in this second reaction also emits a β particle:



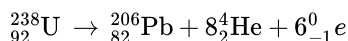
These three reactions are only the first of 14 steps. After emission of eight α particles and six β particles, the isotope $^{206}_{82}\text{Pb}$ is produced. It has a stable nucleus which does not disintegrate further. The complete process may be written as follows:



$\downarrow \alpha$ (2a)



While the net reaction is



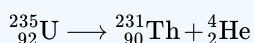
Such a series of successive nuclear reactions is called a **radioactive series**. Two other radioactive series similar to the one just described occur in nature. One of these starts with the isotope $^{232}_{90}\text{Th}$ and involves 10 successive stages, while the other starts with $^{235}_{92}\text{U}$ and involves 11 stages. Each of the three series produces a different stable isotope of lead.

✓ Example 19.3.1: Uranium-Actinium Series

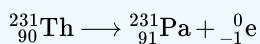
The first four stages in the uranium-actinium series involve the emission of an α particle from a $^{235}_{92}\text{U}$ nucleus, followed successively by the emission of a β particle, a second α particle, and then a second β particle. Write out equations to describe all four nuclear reactions.

Solution

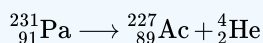
The emission of an α particle lowers the atomic number by 2 (from 92 to 90). Since element 90 is thorium, we have



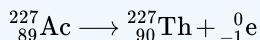
The emission of a β particle now increases the atomic number by 1 to give an isotope of element 91, protactinium:



The next two stages follow similarly:



and

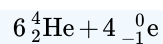


✓ Example 19.3.2: Thorium Series

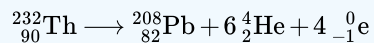
In _____ the _____ thorium _____ series, $^{232}_{90}\text{Th}$ loses a total of six α particles and four β particles in a 10-stage process. What isotope is finally produced in this series?

Solution

The loss of six α particles and four β particles:



involves the total loss of 24 nucleons and $6 \times 2 - 4 = 8$ positive charges from the ${}^{232}_{90}\text{Th}$ nucleus. The eventual result will be an isotope of mass number $232 - 24 = 208$ and a nuclear charge of $90 - 8 = 82$. Since element 82 is Pb, we can write



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