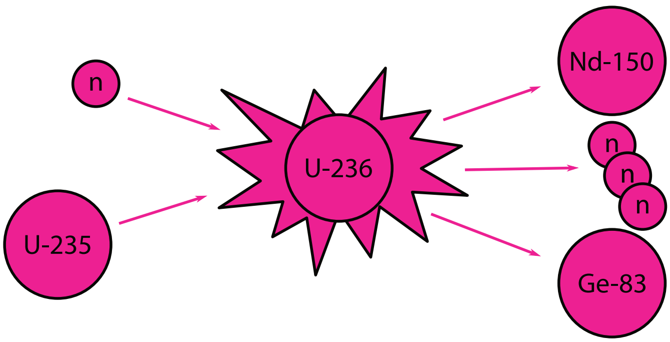
54 Fission – The Process

Nuclear fission is the process by which one atomic nucleus splits to form two atomic nuclei. If the nucleus that splits has an atomic number above 26 (the atomic number of iron, Fe), the nuclear reaction releases energy.



Heavy nuclei can often be made even less stable by absorbing an additional neutron. Uranium−235, for example, has 143 neutrons in the nucleus. If a uranium-235 nucleus absorbs a neutron, it quickly fissions (splits) into two daughter nuclei and a few free neutrons. The two daughter nuclei tend to have a mass ratio close to 2:3; however, this is random, and two or three free neutrons are also released. The free neutrons can hit other uranium nuclei, and could cause them to split. If these neutrons cause uranium nuclei to fission, releasing further neutrons which cause other uranium nuclei to fission, we call this a chain reaction.

The total number of neutrons before a fission is equal to the total number of neutrons after a fission.

Similarly, the total number of protons before a fission is equal to the total number of protons after a fission.[1]

The fission products are usually highly radioactive.

[1] For an interactive periodic table where you can check isotopes, masses, half lives etc, see www.ptable.com.

Example - Balanced nuclear fission reactions:

$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{150}_{60}\text{Nd} + ^{83}_{32}\text{Ge} + 3\ ^{1}_{0}\text{n}$

Check mass (top) numbers balance: $235 + 1 = 150 + 83 + (3 \times 1)$

Check atomic (bottom) numbers balance: $92 + 0 = 60 + 32 + (3 \times 0)$

$^{239}_{94}\text{Pu} + ^{1}_{0}\text{n} \longrightarrow ^{149}_{58}\text{Ce} + ^{88}_{36}\text{Kr} + 3\ ^{1}_{0}\text{n}$

54.1 Fill in the missing numbers in the following fission reactions:

(a) $^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{196}_{77}\text{Ir} + ^{[\,]}_{[\,]}\text{P} + 2\ ^{1}_{0}\text{n}$

(b) $^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{167}_{66}\text{Dy} + ^{[\,]}_{[\,]}\text{Fe} + 3\ ^{1}_{0}\text{n}$

(c) $^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{167}_{65}\text{Tb} + ^{65}_{[\,]}\text{Co} + [\,]^{1}_{0}\text{n}$

(d) $^{239}_{[\,]}\text{Pu} + ^{1}_{0}\text{n} \longrightarrow ^{155}_{62}\text{Sm} + ^{83}_{32}\text{Ge} + [\,]^{1}_{0}\text{n}$

(e) $^{233}_{[\,]}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{154}_{[\,]}\text{Pm} + ^{[\,]}_{[\,]}\text{Ga} + 4\ ^{1}_{0}\text{n}$

54.2 When a nucleus of uranium−235 captures a neutron, fission takes place. One possible fission is:

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{90}_{36}\text{Kr} + ^{144}_{56}\text{Ba} + [\,]^{1}_{0}\text{n}$$

Calculate how many neutrons are released.

54.3 When a nucleus of uranium−235 captures a neutron, fission takes place. One possible fission is:

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{95}_{36}\text{Kr} + ^{x}_{y}\text{Ba} + 3\ ^{1}_{0}\text{n}$$

Calculate x and y.

54.4 When a nucleus of plutonium−239 captures a neutron, fission takes place. One possible fission is:

$$^{239}_{94}\text{Pu} + ^{1}_{0}\text{n} \longrightarrow ^{137}_{52}\text{Te} + ^{x}_{y}\text{Z} + 3\ ^{1}_{0}\text{n}$$

Calculate x and y and identify the element Z.

54.5 State the two most viable fuels for nuclear fission reactions.

54.6 Explain why there is so much variety in the daughter isotopes produced in fission reactions and why this adds to the challenge of managing nuclear waste.

54.7 For a sustainable chain reaction, one neutron released in the reaction must go on to cause one further fission reaction. Describe what happens to the other free neutrons.

54.8 In the reaction equations in this section, an intermediate step has been missed off (for example, in Q54.1a, $^{235}_{92}U$ plus one neutron becomes $^{236}_{92}U$ before the fission reaction takes place). How can we justify ignoring this middle step?

54.9 In the following examples of nuclear disintegrations, identify the missing numbers, elements or particles.

(a) $^{238}_{92}U \longrightarrow ^{[\,]}_{[\,]}Th + ^{4}_{2}He$

(b) $^{234}_{90}Th \longrightarrow ^{[\,]}_{[\,]}Pa + ^{0}_{-1}e$

(c) $^{234}_{91}Pa \longrightarrow ^{[\,]}_{[\,]}[\,] + ^{0}_{-1}e$

(d) $^{222}_{86}Rn \longrightarrow ^{[\,]}_{[\,]}Po + ^{4}_{2}He$

(e) $^{[\,]}_{82}Pb \longrightarrow ^{210}_{[\,]}Hg + ^{[\,]}_{2}He$

(f) $^{14}_{6}C \longrightarrow ^{[\,]}_{[\,]}N + ^{0}_{-1}e$

(g) $^{[\,]}_{82}Pb \longrightarrow ^{214}_{[\,]}Bi + ^{[\,]}_{-1}e$

54.10 Fill in the missing numbers and symbols in the following nuclear processes.

(a) $^{[\,]}_{[\,]}Si \longrightarrow ^{28}_{14}Si + ^{1}_{0}n$

(b) $^{[\,]}_{[\,]}K \longrightarrow ^{40}_{18}Ar + ^{1}_{1}H$

(c) $^{52}_{24}Cr \longrightarrow ^{48}_{22}Ti + ^{[\,]}_{[\,]}[\,]$

(d) $^{[\,]}_{[\,]}Cr \longrightarrow ^{55}_{25}Mn + ^{0}_{-1}\beta$

(e) $^{124}_{57}La + ^{1}_{0}n \longrightarrow ^{40}_{20}Ca + ^{[\,]}_{[\,]}Rb$

(f) $^{142}_{62}Sm + ^{1}_{1}H \longrightarrow ^{55}_{25}Mn + ^{[\,]}_{[\,]}Sr$

(g) $^{113}_{49}In + ^{[\,]}_{[\,]}[\,] \longrightarrow ^{9}_{4}Be + ^{108}_{47}Ag$

(h) $^{73}_{32}Ge + ^{19}_{9}F \longrightarrow ^{92}_{42}Mo + ^{[\,]}_{[\,]}[\,]$