Nuclear Fission Equation With Example

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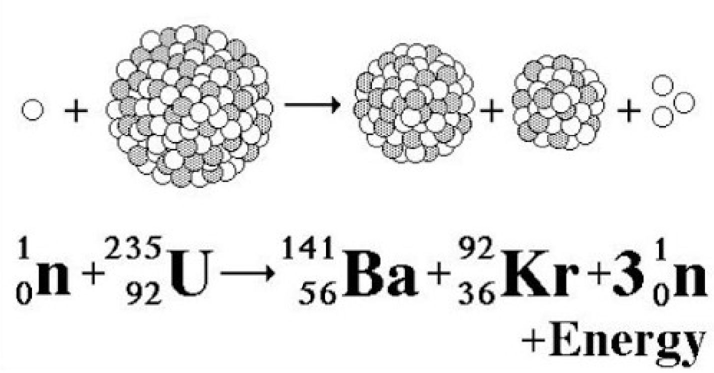

Nuclear Fission Equation – Nuclear fission is a reaction in which a nucleus is split. Controlled fission is a fact whereas controlled fusion is a dream that may be reached in the future. Hundreds of nuclear fission power plants worldwide attest that controlled fission is possible and economical. Global warming has caused nuclear power as a viable and attractive energy alternative to fossil fuels.

Linquip's website provides all of the information about nuclear equipment and devices you could possibly need. Linquip's team of experts is ready to answer any questions you may have about nuclear fission. The best place to start learning about nuclear equipment is Linquip's article, "**What Is Nuclear Power?**".

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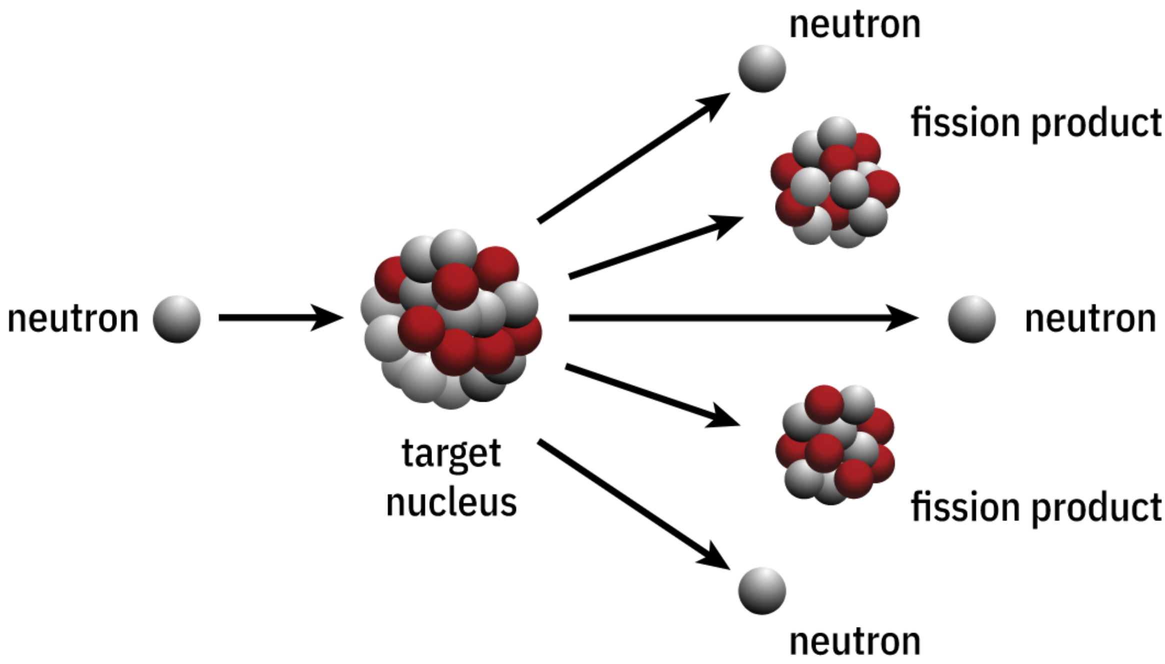
About 440 nuclear power reactors generate around 10% of the world's electricity. According to the World Nuclear Association, about 50 more reactors are under development, equivalent to around 15% of current capacity. In 2019 nuclear plants provided 2657 TWh of electricity, up from 2563 TWh in 2018. France produces over 75% of its electricity with nuclear power, while the US has 104 running reactors giving 20% of its electricity.

Nuclear Fission Basics

As mentioned before, fission is the splitting of a nucleus that delivers free neutrons and lighter nuclei. The fission of heavy particles is extremely exothermic than burning coal, releasing about 200 million eV. The quantity of energy discharged during nuclear fission is millions of times more effective per mass than that of coal, assuming that only 0.1 percent of the original nuclei is transformed to energy.

In the 1930s, scientists determined that some nuclear reactions can be launched and regulated. Scientists ordinarily performed this task by blasting a large isotope with a second, smaller one — usually a neutron. The collision made the larger isotope break apart into two or more components called nuclear fission. The following equation is the nuclear fission of uranium-235:

_{92}^{235}\textrm{U}+_{0}^{1}\textrm{n}\rightarrow_{56}^{142}\textrm{Ba}+_{36}^{91}\textrm{Kr}+3_{0}^{1}\textrm{n}
92235U+01n→56142Ba+3691Kr+301n



Nuclear fission basics (Reference: **atomicarchive.com**)

The mentioned equation is not unique. Let us clarify this problem. Statistical probability governs the number of neutrons and the specific fission products from any fission event. In that, the exact break-up of a single nucleus cannot be foretold.

Nevertheless, conservation laws need the total number of nucleons and the total energy to be conserved. The fission reaction in U-235 creates fission products such as Ba, Kr, Sr, Cs, I, and Xe, as shown in the above equation, with atomic masses distributed around 95 and 135. Here some other examples of typical reaction products along with the released energy:

U-235+n\rightarrow \rightarrow Ba-144+Kr-90+2n+about~200~MeV U−235+n→→Ba−144+Kr−90+2n+about 200 MeV

U-235+n\rightarrow \rightarrow Ba-141+Kr-92+3n+about~170~MeV U−235+n→→Ba−141+Kr−92+3n+about 170 MeV

U-235+n\rightarrow \rightarrow Zr-94+Te-139+3n+about~197~MeV U−235+n→→Zr−94+Te−139+3n+about 197 MeV

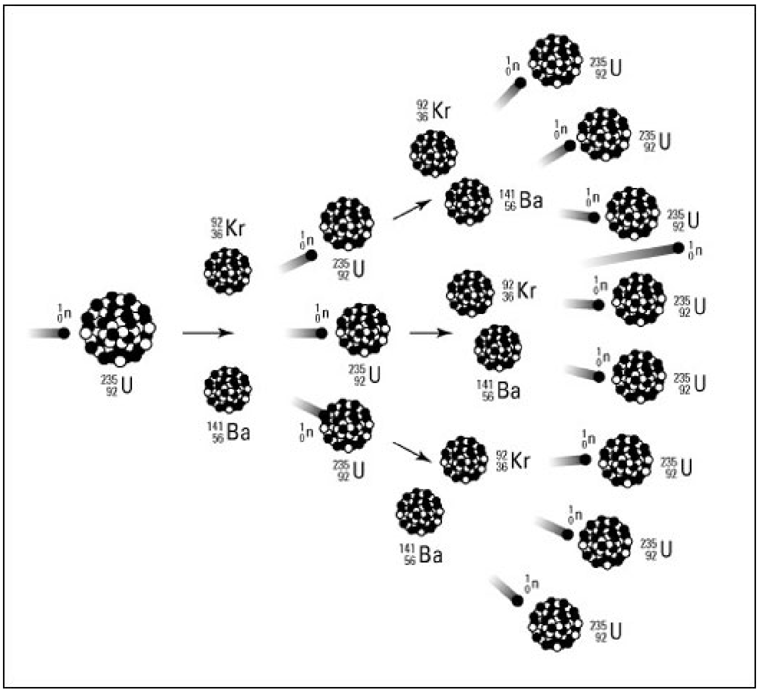
In the mentioned equations, the number of nucleons (protons + neutrons) is conserved, as shown in the following relations for the above equations:

$235 + 1 = 144 + 90 + 2$,

$235 + 1 = 141 + 92 + 3$,

$235 + 1 = 94 + 139 + 3$.

However, a slight loss in atomic mass may be determined, which is equivalent to the energy discharged. The barium and krypton isotopes consequently decay and form more stable neodymium and yttrium isotopes, with numerous electrons' emissions from the nucleus (beta decays). The beta decays, with remarkably associated gamma rays, make the fission products extremely radioactive. This radioactivity diminishes with time. The following figure depicts an illustration of the chain reaction:



An illustration of chain reaction (Reference: **dummies.com**)

To determine the energy discharged during the mass loss in nuclear fission, we apply Einstein's equation that relates energy and mass:

$$E=mC^{2}$$

Critical Mass

The blast of a bomb only happens if the chain reaction passes its critical mass. The critical mass is the limit at which a chain reaction converts self-sustaining. If the neutrons are dropped faster than they are produced by fission, the reaction is not self-sustaining. The spontaneous nuclear fission rate is the incident per second that produces atom fission spontaneously, without any external interference.

In nuclear power plants, nuclear fission is managed by a medium such as water in the nuclear reactor. The water serves as a heat transfer environment to cool down the reactor and slow down neutron particles. By this procedure, the neutron emission and usage are controlled. If the nuclear reaction is not controlled because of a lack of cooling water, then a meltdown occurs.

Examples of Nuclear Fission Equations

In this section, we are going to solve two examples of the Nuclear Fission Equation to clarify this topic more.

Example One

Calculate the amount of energy released for the fission reaction of the ^{235}U when ^{144}Cs and ^{90}Rb are two neutrons.

So, let's first write the balance equation:

$${}_{92}^{235}\textrm{U}+{}_{0}^{1}\textrm{n}\rightarrow {}_{55}^{144}\textrm{Cs}+{}_{37}^{90}\textrm{Rb}+2\,{}_{0}^{1}\textrm{n}$$

The strategy of solving such problems is summarized below:

- First, calculate the change in the mass in the reaction, then convert this mass to the energy change per atom.
- Then the change in mass per mol of U-235 should be calculated. Then the energy shift can be calculated.

Let's take a look to the solution of this problem.

The change in mass follows the reaction can be calculated using the following relations:

$$\Delta m=\mathrm{mass_{products}}-\mathrm{mass_{reactants}}=\textrm{mass}(_{55}^{144}\textrm{Cs}+\,_{37}^{90}\textrm{Rb}+\,_0^1\textrm n)-\textrm{mass }\,_{92}^{235}\textrm U$$
Δm=massproducts−massreactants=mass(55144Cs+3790Rb+01n)−mass 92235U

$$=(143.932077\textrm{ amu}+89.914802\textrm{ amu}+1.008665\textrm{ amu})-\textrm{235.043930 amu}$$
=(143.932077 amu+89.914802 amu+1.008665 amu)−235.043930 amu

$$=-0.188386\textrm{ amu}$$
=−0.188386 amu

So, the energy variation in electronvolts per atom is:

$$\Delta E=(-0.188386\textrm{ amu})(931\textrm{ MeV/amu})=-175\textrm{ MeV}$$
ΔE=(−0.188386 amu)(931 MeV/amu)=−175 MeV

The difference in mass per mole of $_{92}^{235}\textrm{U}$ 92235U is $-0.188386~g = -0.188386\times 10^{-4}$ kg −0.188386 g=−0.188386×10−4kg, so the shift in energy in kilojoules per mole is:

$$\Delta E=(\Delta m)c^2=(-1.88386\times10^{-4}\textrm{ kg})(2.998\times10^8\textrm{ m/s})^2$$
ΔE=(Δm)c2=(−1.88386×10−4 kg)(2.998×108 m/s)2

$$=-1.693\times10^{13}\textrm{ J/mol}=-1.693\times10^{10}\textrm{ kJ/mol}$$
=−1.693×1013 J/mol=−1.693×1010 kJ/mol

Example Two

Suppose we are going to determine the energy discharged in the following fission reaction:

$$_{}^{238}\textrm{U}\rightarrow _{}^{95}\textrm{Sr}+_{}^{140}\textrm{Xe}+3_{}^{}\textrm{n}$$
238U→95Sr+140Xe+3n

Like the previous example, the energy discharged is equivalent to the mass consumed times c^2, so we need to find the mass variation within the parent ^{238}U and the fission products. The total mass of products is:

$$m_{products}=94.919388~u + 139.921610~u + 3(1.008665)~u=237.866993~u$$
mproducts =94.919388 u+139.921610 u+3(1.008665) u=237.866993 u

So, the mass lost is:

$$\Delta m=238.050784 ~u-237.8669933 ~u=0.183791~u$$
Δm=238.050784 u−237.8669933 u=0.183791 u

Finally, the energy released can be calculated using the following equation:

$$E=(\Delta m)C^{2}$$
E=(Δm)C2

$$= (0.183791~u)\frac{931.5~MeV/C^{2}}{u}C^{2}=171.2~MeV$$
=(0.183791 u)u931.5 MeV/C2C2=171.2 MeV

What Is the Purpose of Nuclear Fission?

Fission generates energy for nuclear power and supplies nuclear weapons. Several substances called nuclear fuels can be used for both purposes because, when hit by fission neutrons, they undergo fission and emit neutrons when they break apart.

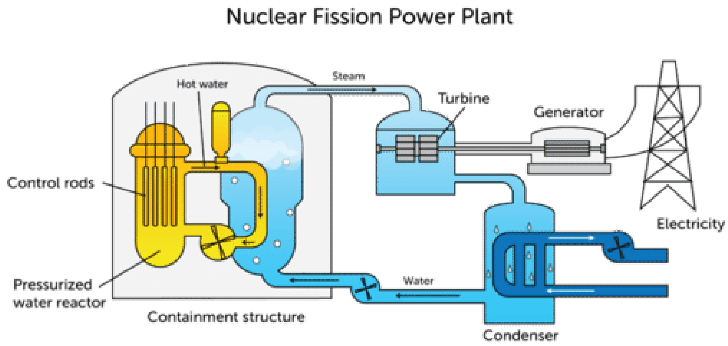


Diagram of a nuclear fission power plant (Reference: **flexbooks.ck12.org**)