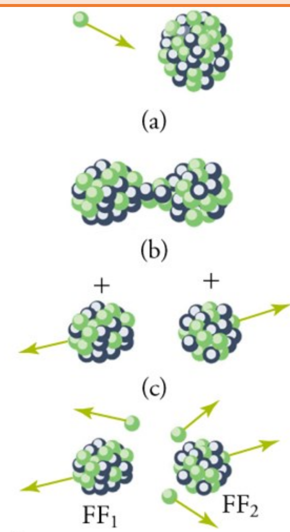
Physics 13-03 Nuclear Fission **Name: ______________**

Fission



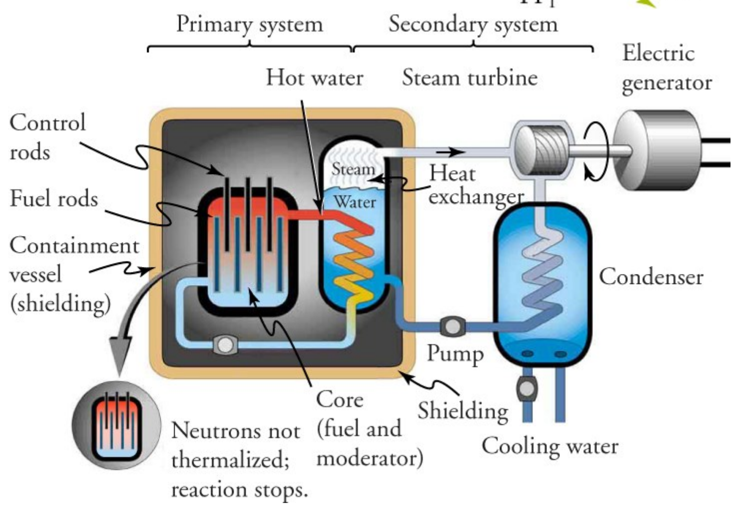
- ____________of a nucleus
- Releases a lot of ____________
- An unstable nucleus can naturally decay with α or β radiation, but can take a long time
- ____________done by hitting a large nucleus with a ____________(β radiation)

Chain reaction

- When the nucleus splits it releases free ____________
- Those can ____________other nuclei and ____________them
- Critical mass – Minimum amount of ____________material necessary to sustain fission ____________reaction
- Number of fission reactions increases ____________

Nuclear Reactor

- To keep a nuclear fission reaction from becoming a __________, slow down the neutrons with _________
- Fuel rods contain ____________
- Control rods ____________neutrons
  - Insert control rods to ____________reaction
- Fission reaction ____________water
- Steam turns turbines to make ____________
- ____________water goes back to be heated



Energy from Fission

- The mass of the products of fission is ____________ than parent nucleus
- That mass is converted to ____________by $E = mc^2$
- Average fission reaction produces about ____________MeV of energy

Find the energy released in the fission of uranium-235 given in the equation

$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\ {}^{1}_{0}n $$

Neutron: 1.008665 u, ^{235}U: 235.0439299 u, ^{141}Ba: 140.9144035 u, ^{92}Kr: 91.926173094 u

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Calculate the amount of energy produced by the fission of 1.00 kg of 239Pu, given the average fission reaction of ^{239}Pu produces 211.5 MeV. The atomic mass of ^{239}Pu is 239.05 u.

Practice Work

1. How can a nuclear reactor contain many critical masses and not go supercritical? What methods are used to control the fission in the reactor? (OpenStax C32.23)
2. If a nucleus elongates due to a neutron strike, which of the following forces will decrease? (HSP 22.20)
(a) Nuclear force between neutrons only
(b) Coulomb force between protons only
(c) Strong nuclear force between all nucleons and Coulomb force between protons, but the strong force will decrease more
(d) Strong nuclear force between neutrons and Coulomb force between protons, but Coulomb force will decrease more
3. (a) Calculate the energy released in the neutron-induced fission (similar to the spontaneous fission in Example 32.3) $n + {}^{238}U \rightarrow {}^{96}Sr + {}^{140}Xe + 3n$, given $m({}^{238}U) = 238.050783\ u$, $m({}^{96}Sr) = 95.921750\ u$ and $m({}^{140}Xe) = 139.92164\ u$. (b) This result is about 6 MeV greater than the result for spontaneous fission. Why? (c) Confirm that the total number of nucleons and total charge are conserved in this reaction. (OpenStax 32.43) **177.0 MeV; 239 nucleons, 92 + charges**
4. (a) Calculate the energy released in the neutron-induced fission reaction $n + {}^{235}U \rightarrow {}^{92}Kr + {}^{142}Ba + 2n$, given $m({}^{235}U) = 235.043923\ u$, $m({}^{92}Kr) = 91.926269\ u$ and $m({}^{142}Ba) = 141.916361\ u$. (b) Confirm that the total number of nucleons and total charge are conserved in this reaction. (OpenStax 32.44) **179.4 MeV; 236 nucleons, 92 + charges**
5. (a) Calculate the energy released in the neutron-induced fission reaction $n + {}^{239}Pu \rightarrow {}^{96}Sr + {}^{140}Ba + 4n$, given $m({}^{239}Pu) = 239.0521634\ u$, $m({}^{96}Sr) = 95.921750\ u$ and $m({}^{140}Ba) = 139.910581\ u$. (b) Confirm that the total number of nucleons and total charge are conserved in this reaction. (OpenStax 32.45) **180.6 MeV; 240 nucleons, 94 + charges**
6. The naturally occurring radioactive isotope ${}^{232}Th$ does not make good fission fuel, because it has an even number of neutrons; however, it can be bred into a suitable fuel (much as is bred into ${}^{239}U$). (a) What are Z and N for ${}^{232}Th$? (b) Write the reaction equation for neutron captured by ${}^{232}Th$ and identify the nuclide ${}^{A}X$ produced in $n + {}^{232}Th \rightarrow {}^{A}X + \gamma$. (c) The product nucleus β^- decays, as does its daughter. Write the decay equations for each, and identify the final nucleus. (d) Confirm that the final nucleus has an odd number of neutrons, making it a better fission fuel. (e) Look up the half-life of the final nucleus to see if it lives long enough to be a useful fuel. (OpenStax 23.48) ***Z* = 90, *N* = 142; Thorium; Daughters are ^{233}Pa and ^{233}U; 141 neutrons; 160000 yrs**
7. The electrical power output of a large nuclear reactor facility is 900 MW. It has a 35.0% efficiency in converting nuclear power to electrical. (a) What is the thermal nuclear power output in megawatts? (b) How many ${}^{235}U$ nuclei fission each second, assuming the average fission produces 200 MeV? (c) What mass of ${}^{235}U$ is fissioned in one year of full-power operation? (OpenStax 32.49) **2570 MW; $\mathbf{8.04 \times 10^{19}}$ fissions/s; 990 kg**