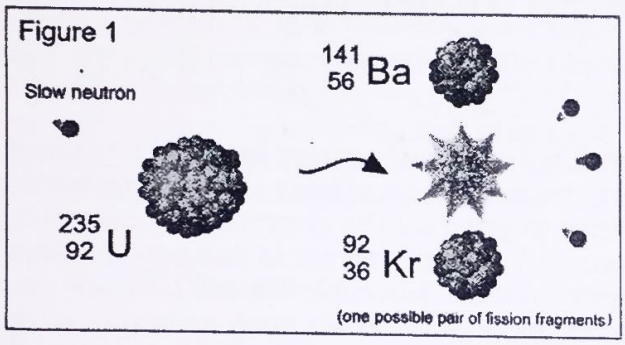
Nuclear Fission and Fusion

Key

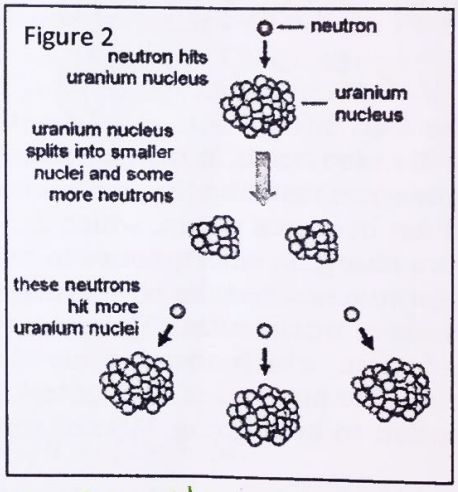
Background: Ever wonder why the sun constantly radiates or how energy is created in a nuclear power plant? How about how atomic bombs generate such massive explosions? Fission and fusion are two processes that alter the nucleus of an atom. Both fission and fusion reactions generate large amounts of energy.

NUCLEAR FISSION

The process of **fission** occurs when a ***larger, more massive nucleus splits into smaller pieces.*** To accomplish fission, a nucleus is bombarded with a neutron, which results in a highly unstable nucleus that then splits into two more stable nuclei. In this process, mass is converted into a large amount of energy. Nuclear fission provides the energy in modern day nuclear power plants and the use of fission in power plants can help conserve or one day possibly eliminate the need for fossil fuels.



http://www.arpansa.gov.au/images/basics/fission.jpg



1. What is nuclear fission?

   Splitting a larger nucleus into smaller nuclei

2. a. What is a nucleus bombarded with to initiate a fission reaction?

   neutron

   b. Using this knowledge, would nuclear fission be classified as a spontaneous or nonspontaneous reaction?

   nonspontaneous

3. Evaluate the equations below and look for similarities:

   The following equations represent fission reactions, where n = neutron.

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

   $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{131}_{50}Sn + {}^{103}_{42}Mo + 2\,{}^{1}_{0}n$

   $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{52}Te + {}^{97}_{40}Zr + 2\,{}^{1}_{0}n$

   $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{138}_{54}Xe + {}^{95}_{38}Sr + 3\,{}^{1}_{0}n$

   $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{152}_{60}Nd + {}^{81}_{32}Ge + 3\,{}^{1}_{0}n$

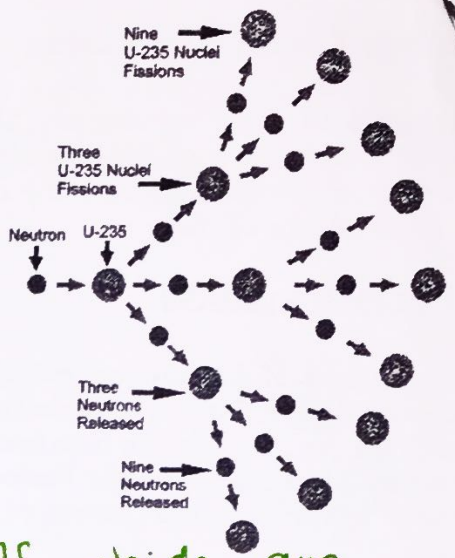
   a. How would you identify a fission reaction when given an equation?

   larger nucleus + neutron → smaller nuclei

   b. Based on the nuclear equations, would fission be classified as a natural or artificial transmutation?

   artificial

Nuclear Weapons vs. Nuclear Energy

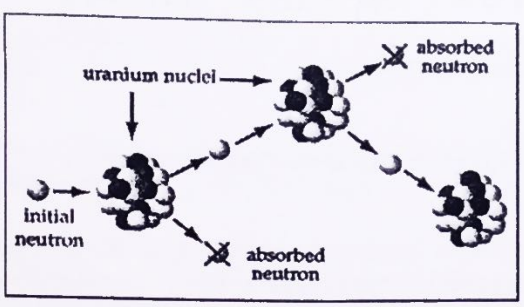


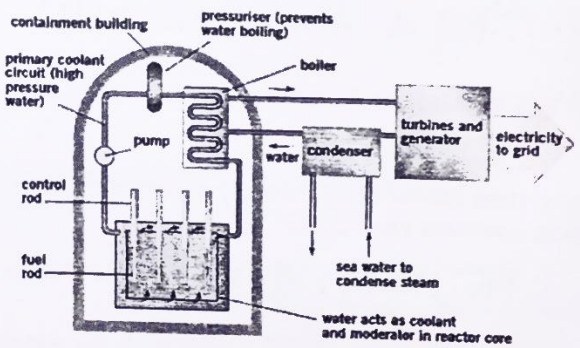
Read This: *Atomic Bombs*
Nuclear fission produces the atomic bomb, a weapon of mass destruction that uses power released by the splitting of atomic nuclei. When a single free neutron strikes the nucleus of an atom of radioactive material like uranium or plutonium, it knocks two or three more neutrons free. Energy is released when those neutrons split off from the nucleus, and the newly released neutrons strike other uranium or plutonium nuclei, splitting them in the same way, releasing more energy and more neutrons. This chain reaction spreads almost instantaneously. Atomic bombs were exploded in war in Hiroshima and Nagasaki at the end of World War II.

4. Why are fission reactions considered to be **chain reactions**?

Each fission event generates neutrons, which are then used to trigger more fission events, which generate more neutrons, etc.

Read This: *Nuclear Energy*
Fission reactions also occur in nuclear reactors to produce electrical energy. Inside the nuclear reactor, the energy emitted by the fission reaction occurs in the form of heat. In a boiling water reactor, this heat becomes steam, which drives turbines to generate the electricity that is used for everything from charging smartphones to heating homes. A nuclear reactor is designed to allow a *controlled* chain reaction to take place, rather than an explosion. Moveable control rods are placed between the rods of nuclear fuel. These control rods are made of materials such as boron, silver, indium, or cadmium, which absorb some of the neutrons so that fewer are available to split uranium nuclei. The position of the control rods is adjusted so there are just enough neutrons for the chain reaction to keep going, but not enough neutrons released to create an explosion.





5. How is the fission chain reaction in a nuclear reactor different than that in an atomic bomb?

In the nuclear reactor, the fission chain reaction is controlled, so not as many neutrons are available to trigger successive fission rxns.

6. Describe the function of the control rods and how they contribute to maintaining the controlled fission.

Control rods absorb some of the neutrons so that limited neutrons are available for successive fissions. It prevents an explosion from occuring

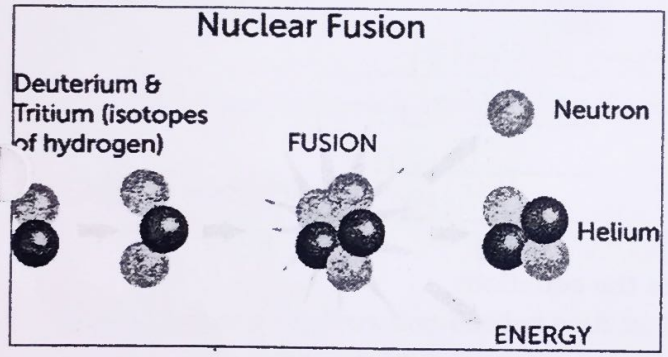
NUCLEAR FISSION BIG IDEA: Complete the paragraph below by circling the correct word from each pair in parentheses. Use the information obtained from the diagram above to make your choices.

In a nuclear fission reaction, a (light/heavy) nucleus is bombarded with a (neutron/electron). This creates a/an (stable/unstable) nucleus, which then (splits/combines) into two (smaller/larger) nuclei. The daughter nuclei are (more/less) stable that the parent nuclide. The conversion of (energy/mass) into (energy/mass) results in the liberation of lots of energy in a fission reaction.

Stop here pd. 5

NUCLEAR FUSION

Fusion occurs when ***two lighter nuclei join together to form a larger, more massive nucleus.*** Similar to fission reactions, in fusion reactions there is a conversion of mass to energy. Fusion is the source of the sun's energy and without the energy produced by fusion of hydrogen in the sun the Earth would quickly change into a cold planet that could not support life as we know it. Like other stars, the sun is a big ball of gases – mostly hydrogen and helium atoms. The hydrogen atoms in the sun's core combine to form helium while generating energy in the process. The sun's extremely high pressure and temperature is needed to allow the atoms to overcome their repulsive forces and fuse together.



The following are some examples of nuclear equations illustrating fusion:

$$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{1}p$$
$$^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$$
$$^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + 2({}^{1}_{1}H)$$

7. What is nuclear fusion?

the combination of lighter nuclei to form a single more massive nucleus.

8. Evaluate the nuclear equations representing fusion equations and answer the following questions:
   a. How would you identify a fusion reaction when given an equation?

2 lighter nuclei form a heavier nucleus + emission.

   b. Based on the nuclear equations, would fission be classified as a natural or artificial transmutation?

fusion

artificial

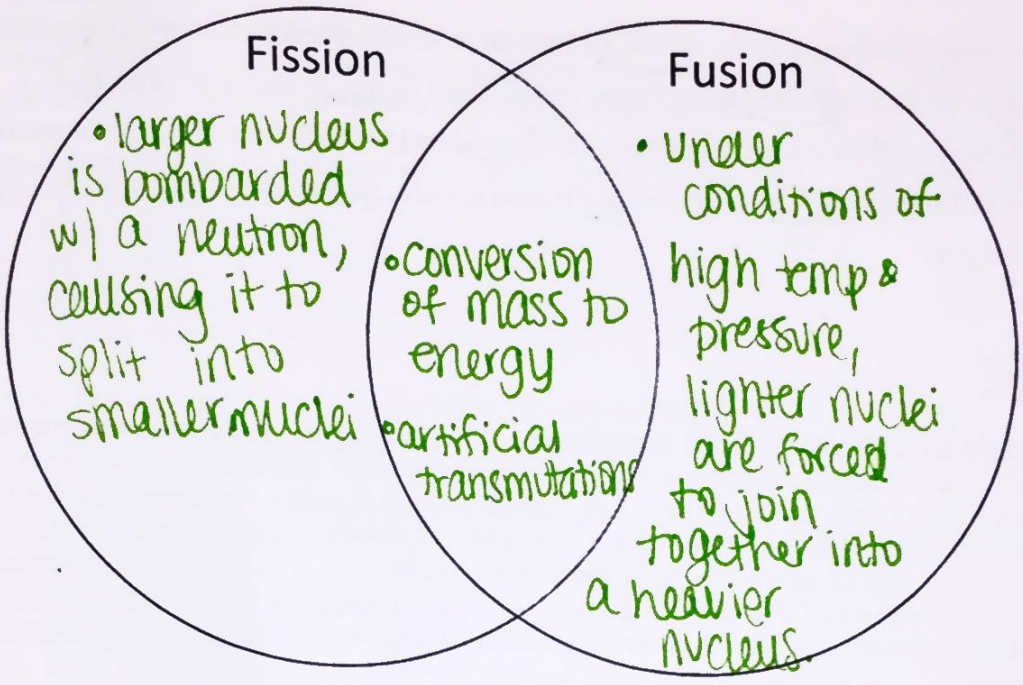
9. Why are the conditions of high temperature and pressure needed for fusion?

+ nuclei of

so the repulsive forces of the atoms can be overcome, allowing them to fuse together.

Summary and Practice:

10. Compare and contrast nuclear fission and nuclear fusion using the Venn Diagram below.



11. Identify the following equations as fission or fusion.

$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{1}p$ — fusion

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

$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{138}_{54}Xe + {}^{95}_{38}Sr + 3({}^{1}_{0}n)$ — fission

$^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + 2({}^{1}_{1}H)$ — fusion

12. Describe *how* to find the identity of the species X in the equation:

$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{152}_{60}Nd + X + 3({}^{1}_{0}n)$

13. During a fission reaction, which type of particle is captured by a nucleus?

a. deuteron b. electron **c. neutron** d. proton

14. Compared to an ordinary chemical reaction, a fission reaction will

a. Release smaller amounts of energy
b. Release larger amounts of energy
c. absorb smaller amounts of energy
d. absorb larger amounts of energy

15. What is the primary result of a fission reaction?

a. Conversion of mass to energy
b. Conversion of energy to mass
c. binding together two heavy nuclei
d. binding together two light nuclei

16. When a uranium nucleus breaks up into fragments, which type of reaction occurs?

a. Fusion **b. fission** c. single replacement d. redox

17. Which statement explains why fusion reactions are difficult to initiate?

a. Positive nuclei attract each other
b. Positive nuclei repel each other
c. Neutrons prevent nuclei from getting close enough to fuse
d. Electrons prevent nuclei from getting close enough to fuse