Warm-Up | Fission and Fusion

Lesson Question

Why do nuclear fission and nuclear fusion release large amounts of energy?

Lesson Goals

Compare and **contrast** nuclear fission and nuclear fusion.

Explain nuclear fission and nuclear fusion in terms of mass-energy equivalence.

Identify applications of nuclear fission and nuclear fusion.

Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

binding energy	the amount of energy required to break a nucleus into individual protons and neutrons
mass defect	the difference in mass between the whole nucleus and the nucleons
nuclear fission	the process in which the nucleus of an atom splits into two lighter atoms, releasing a large amount of energy
nuclear fusion	the process in which the nuclei of two atoms combine to form a heavier atom, releasing a large amount of energy

Warm-Up | Fission and Fusion

Parts of the Atom

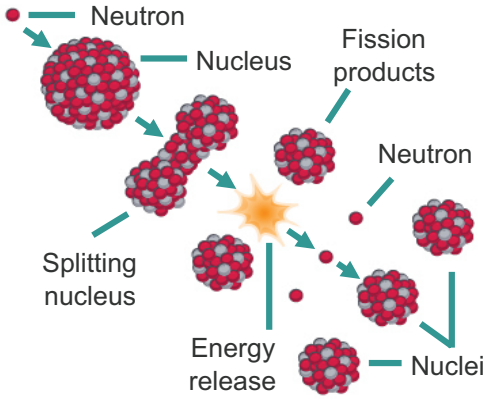
- The nucleus contains [protons] and neutrons, which are bound by the strong nuclear force.
    - Involved in nuclear reactions
- The [electron] cloud contains electrons.
    - Involved in chemical reactions

Instruction | Fission and Fusion

Slide 2

Nuclear Fission

- **Nuclear fission** is the process in which the nucleus of an atom splits into two lighter atoms, releasing a large amount of energy.
  - It begins when a neutron hits the [nucleus] of an atom.
  - The nucleus splits in two and releases [thermal] energy and more neutrons.
- The neutrons hit the nuclei of more atoms, splitting them and releasing more energy and [neutrons].



Fission Processes

EXAMPLE

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{94}_{38}\text{Sr} + {}^{140}_{54}\text{Xe} + 2{}^{1}_{0}\text{n}$$

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{140}_{55}\text{Cs} + {}^{94}_{37}\text{Rb} + \boxed{2}\,{}^{1}_{0}\text{n}$$

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{145}_{57}\text{La} + {}^{88}_{35}\text{Br} + 3{}^{1}_{0}\text{n}$$

Protons: $92 \Rightarrow 57 + 35 + 0 =$	[92]
Neutrons: $236 \Rightarrow 145 + 88 + 3 =$	[236]

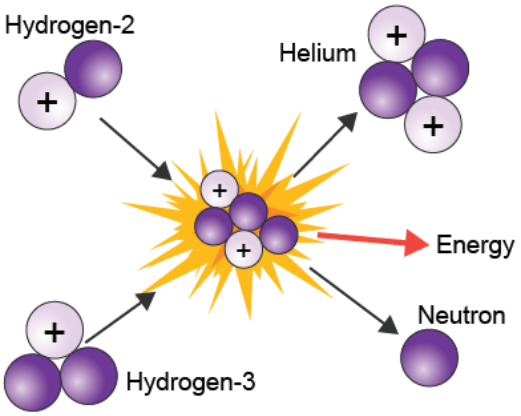
Instruction | Fission and Fusion

Slide 4

Nuclear Fusion

- **Nuclear fusion** is the process in which the [nuclei] of two atoms combine to form a heavier atom, releasing a large amount of energy.
- The products of fusion include:
  - a [heavier] atom.
  - thermal energy.

$${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \Rightarrow [{}^{4}_{2}\mathrm{H}] + {}^{1}_{0}\mathrm{n}$$



Slide 8

Mass-Energy Equivalence

- In 1905 Einstein published a paper titled “Does the Inertia of a Body Depend upon Its Energy-Content?” It stated that:
  - [mass] is a measure of the energy in an object.
  - the source of all energy in the universe is the conversion of mass into [energy].
- Mass-energy cannot be created or destroyed.

Instruction | Fission and Fusion

Slide 8

EXAMPLE

What is the energy equivalent of 1 kg of matter?

Given: $c = 3 \times 10^8\, m/s$

$E = mc^2$

$E = (1\,\text{kg})(3 \times 10^8\ \text{m/s})^2$

$E =$ [9×10^{16}] J

Slide 10

Binding Energy and Mass Defect

- The amount of energy required to [break] a nucleus into individual protons and neutrons is called **binding energy**.
- The mass of a stable nucleus is [less] than the total mass of the individual nucleons.
- The difference in mass is known as the **mass defect** (Δm).
  - $E_{binding} = (\Delta m)c^2$

Nuclear Reactions and Mass-Energy Equivalence

- In [fission], the nucleus of an atom splits into two lighter atoms.
  - For large nuclei, the mass of the original nucleus is [greater] than the mass of the products.
  - Some of the mass is converted into energy.
- In [fusion], two atoms combine to form a heavier atom.
  - For small nuclei, the binding energy of the lighter nuclei is greater than the binding energy of the [heavier] nucleus.
  - Energy is released as part of the reaction.

Instruction | Fission and Fusion

Slide 13

Nuclear Power

- There are over four hundred nuclear power reactors in operation worldwide.
- Nuclear power provides more than 5 percent of the world's energy and over 13 percent of the world's [electricity].
- Advantages
  - Relatively low [carbon dioxide] emission
  - Readily available
  - High [output]

Fission Nuclear Reactors

- A fission reactor:
  - uses [controlled] fission to generate electrical energy.
  - has rods containing [uranium].
  - is controlled by [neutron]-absorbing material and the depth of the rods in the material.

Fusion Nuclear Reactions

- Have been successful, but are expensive
- Require high [temperature] and pressure
- Do not produce a useable amount of energy

Summary | Fission and Fusion

Lesson Question

Why do nuclear fission and nuclear fusion release large amounts of energy?

Answer

(Sample answer) In nuclear fission, the total atomic mass of the decay products is less than the total mass of the fuel, because some of the mass is converted into energy. In fusion, the total binding energy for the lighter nuclei is greater than the binding energy for the resulting heavier nucleus. The extra energy is released during the fusion reaction.

Slide 2

Review: Key Concepts

- Nuclear fission is the process in which the nucleus of an atom splits into two lighter atoms.
  - Extra [mass] is converted into energy.
- Nuclear fusion is the process in which the nuclei of two atoms combine to form a heavier atom.
  - [Energy] is released as a part of the reaction.
- Nuclear power provides more than 5 percent of the world's energy and 13 percent of the world's electricity.
  - [Nuclear] fission is more practical than nuclear fusion.

Summary | Fission and Fusion

Use this space to write any questions or thoughts about this lesson.