Section 2: Nuclear Fission and Fusion

Preview

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Key Ideas

- What holds the nuclei of atoms together?
- What is released when the nucleus of a heavy atom is split?
- What happens when the nuclei of small atoms are joined?

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Bellringer

In your study of chemical reactions, you learned that one convenient way to classify reactions was as synthesis or decomposition. In synthesis reactions, the products are larger and more complex than the reactants. In decomposition reactions, the opposite is true.

In some situations, nuclear reactions can occur. These reactions can also be categorized by how the product nuclei compare to the reactant nuclei. Study the models of the nuclei shown on the next slide, and answer the following questions.

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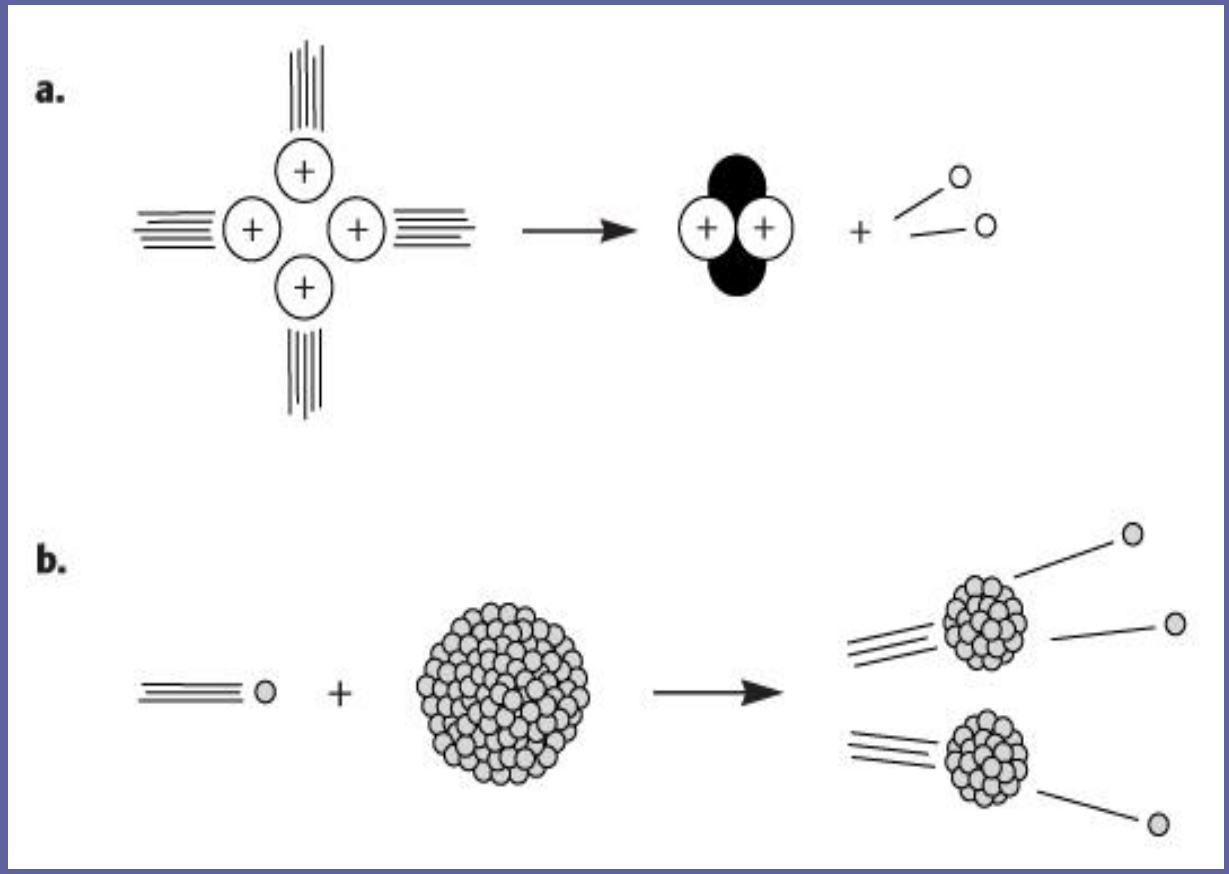
Bellringer, continued



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Bellringer, *continued*

1. In which of the diagrams did a complex nucleus form simpler nuclei?

2. In which of the diagrams did simple nuclei combine to form a complex nucleus?

3. Each year, scientists around the world attempt to "discover" new elements using nuclear reactions. Which of the reactions shown in the diagrams above most likely would be useful for this type of research? Explain your answer.

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Nuclear Forces

〉 What holds the nuclei of atoms together?

〉 The stability of a nucleus depends on the nuclear forces that hold the nucleus together. These forces act between the protons and the neutrons.

- Nuclei are held together by a special force.

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Nuclear Forces, *continued*

- Protons and neutrons are tightly packed in the tiny nucleus of an atom.
- *strong nuclear force*: causes protons and neutrons in the nucleus to attract each other
  - This attraction is much stronger than the electric repulsion between protons.
- Neutrons contribute to nuclear stability.
- Too many neutrons or protons can cause a nucleus to become unstable and decay.
  - Nuclei with more than 83 protons are always unstable.

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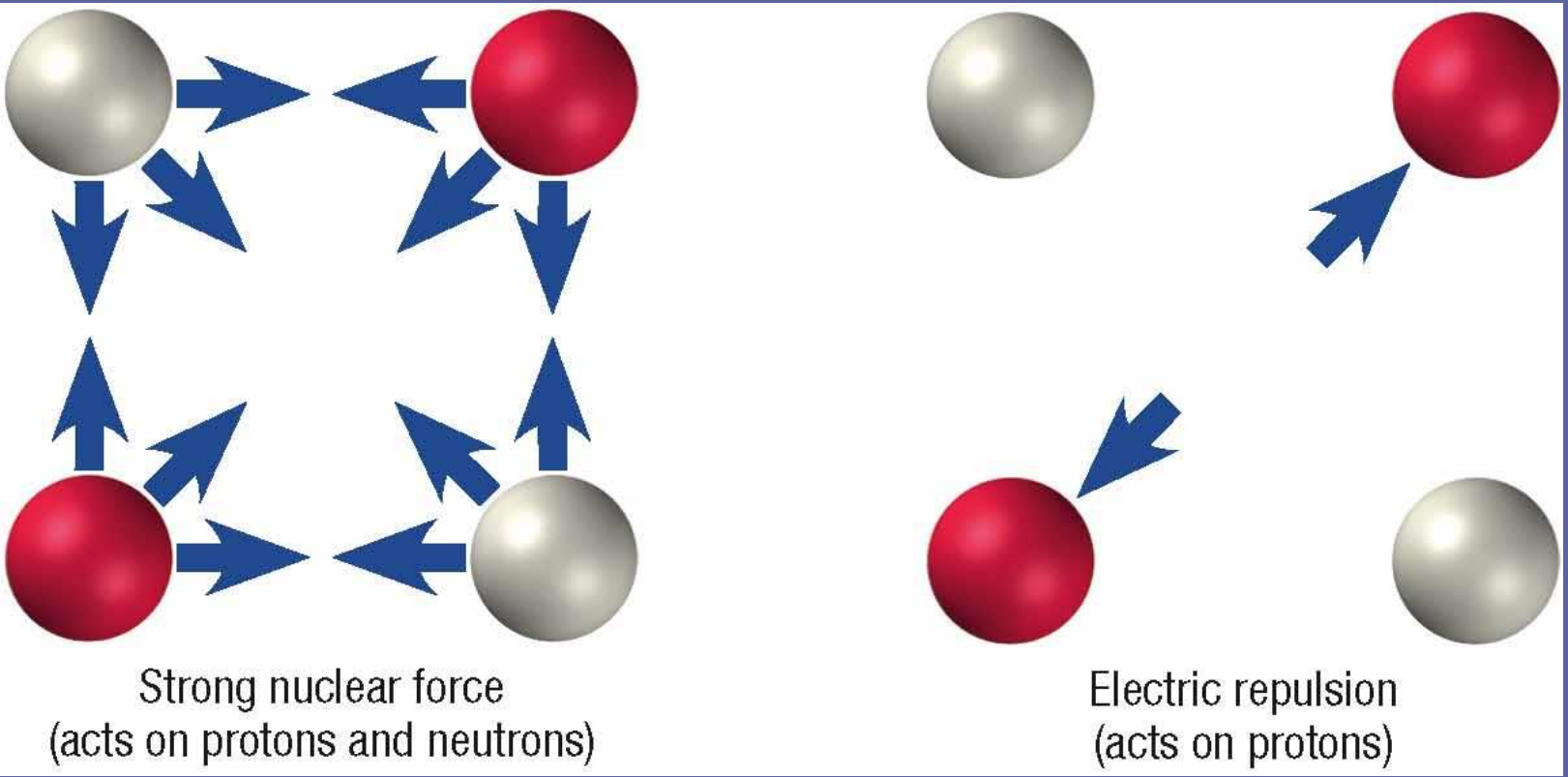
Nuclear Forces, *continued*



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Nuclear Fission

〉 What is released when the nucleus of a heavy atom is split?

〉 In the fission process, when the nucleus splits, both neutrons and energy are released.

- **fission:** the process by which a nucleus splits into two or more fragments and releases neutrons and energy

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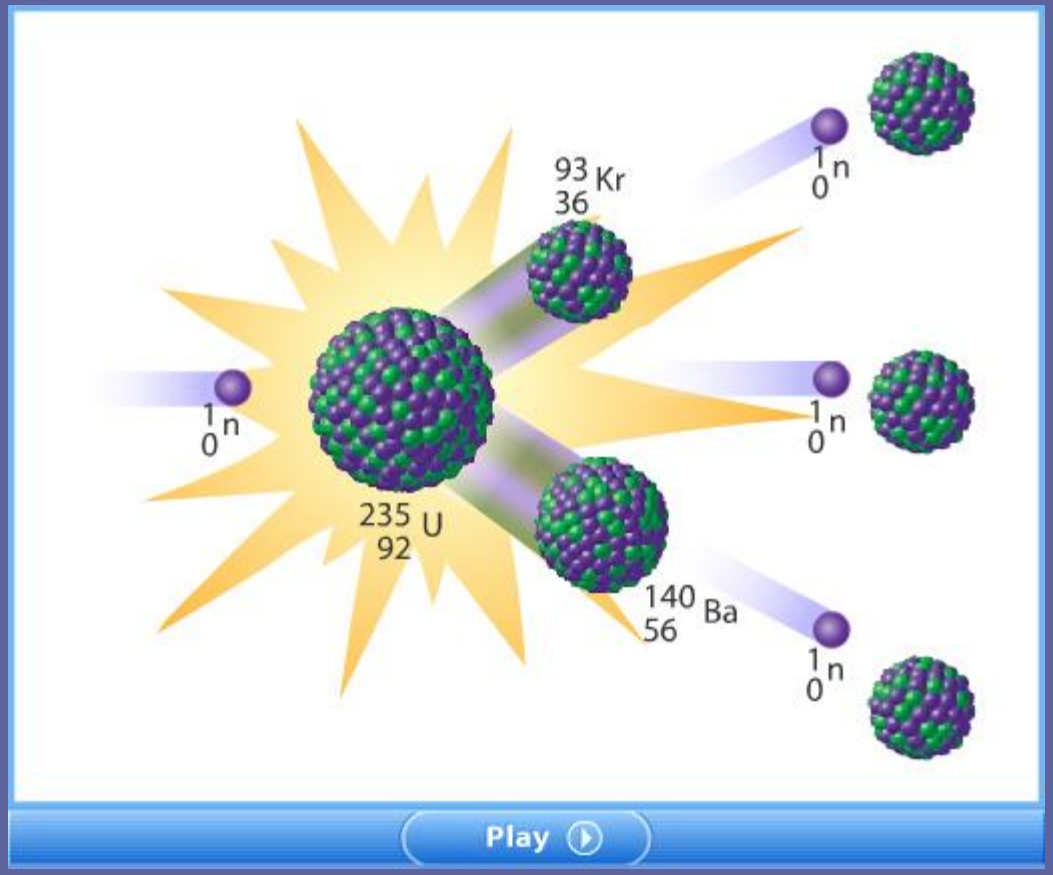
Visual Concept: Nuclear Fission



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Nuclear Fission, *continued*

- Uranium-235 can also undergo fission by producing different pairs of lighter nuclei.

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{140}_{56}\mathrm{Ba} + {}^{93}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} + \text{energy}$$

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Nuclear Fission, *continued*

- Energy is released during nuclear fission.
  - The equivalence of mass and energy observed in nature is explained by the special theory of relativity.
- Mass-Energy Equation

$$Energy = mass \times (speed\ of\ light)^2$$

$$E = mc^2$$

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Nuclear Fission, *continued*

- Energy is released when nuclei form.
  - *mass defect:* the difference in the total measured mass of a nucleus and the sum of the individual masses of the neutrons and protons that make up the nucleus
  - This small amount of mass changes into energy.

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Nuclear Fission, *continued*

- Neutrons released by fission can start a chain reaction.
  - **nuclear chain reaction:** a continuous series of nuclear fission reactions
- Chain reactions can be controlled.
  - If the amount of fissionable substance is less than the critical mass, a chain reaction will not continue.
  - **critical mass:** the minimum mass of a fissionable isotope that provides the number of neutrons needed to sustain a chain reaction

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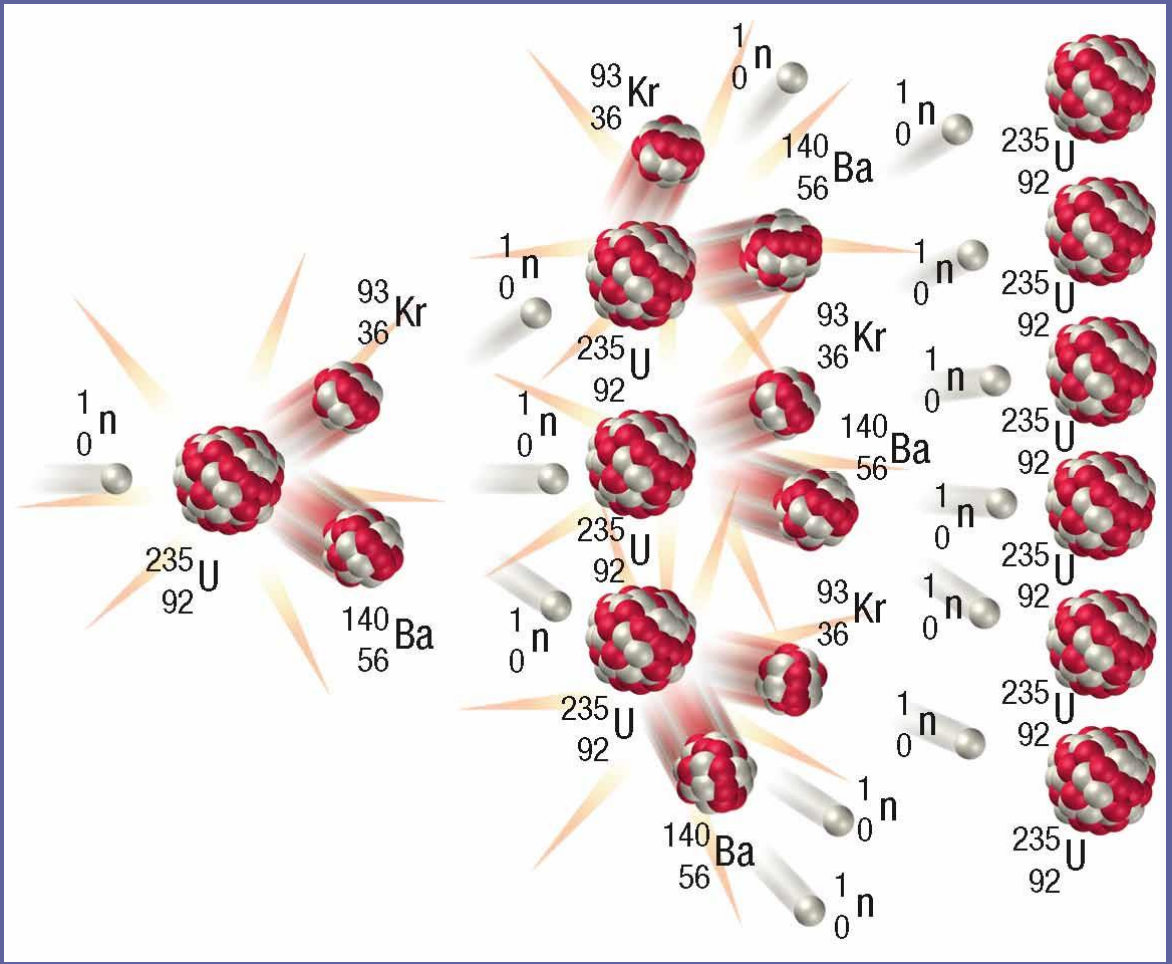
Chain Reaction



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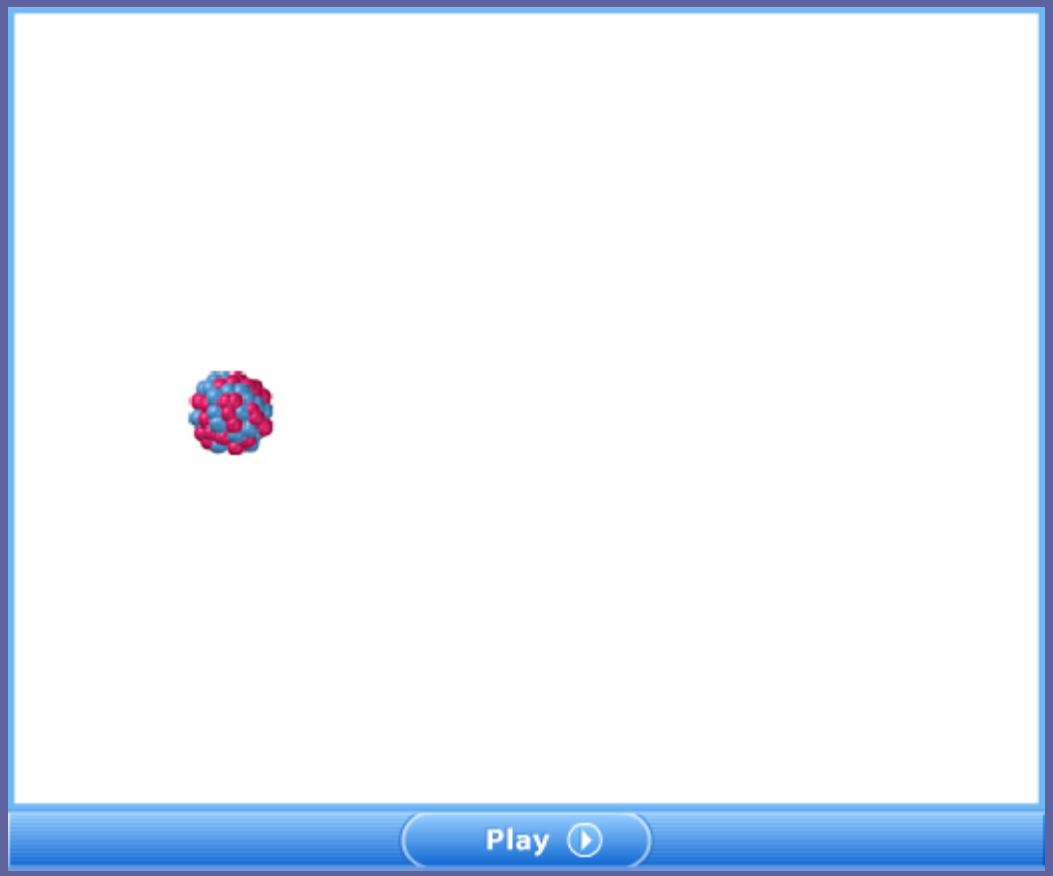
Visual Concept: Nuclear Chain Reaction



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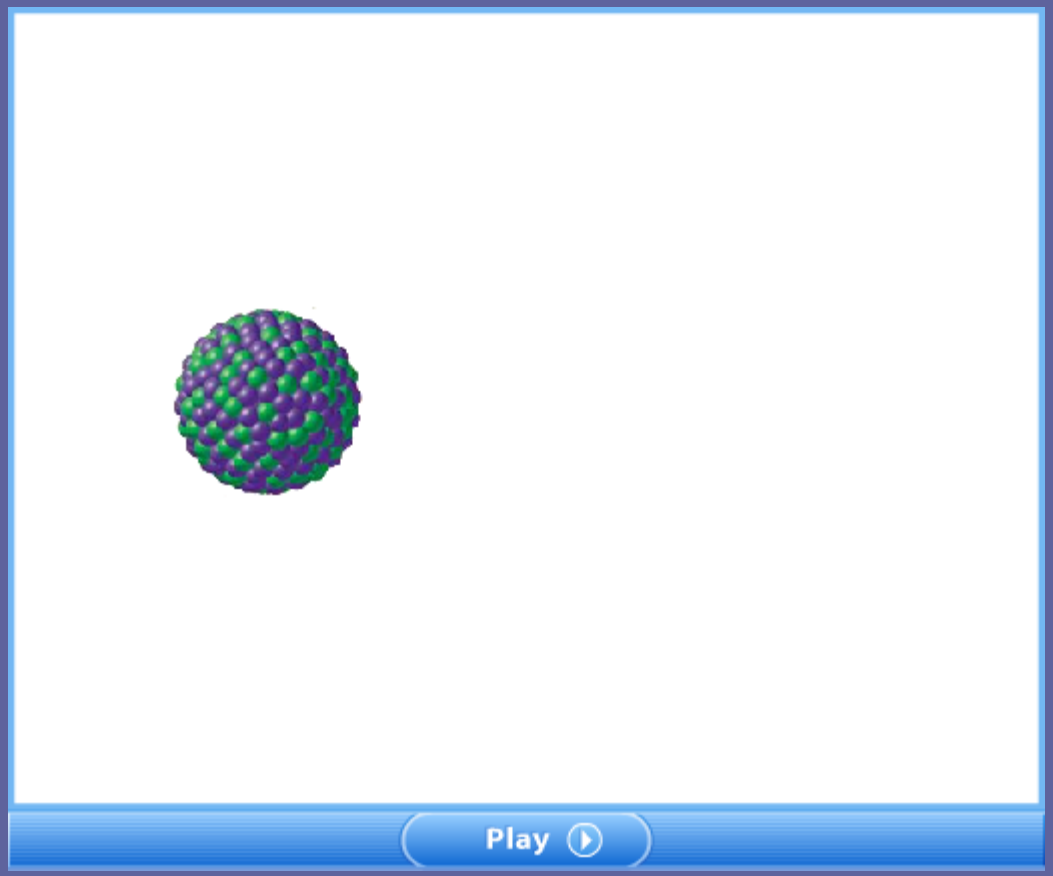
Visual Concept: Critical Mass



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Nuclear Fusion

〉 What happens when the nuclei of small atoms are joined?

〉 Energy can be obtained when very light nuclei are combined to form heavier nuclei.

- **fusion:** the process in which light nuclei combine at extremely high temperatures, forming heavier nuclei and releasing energy

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Nuclear Fusion, *continued*

- In stars, energy is produced when hydrogen nuclei combine.
  - A large amount of energy is needed to start a fusion reaction.
  - Four hydrogen atoms combine to make a helium atom and high-energy gamma rays in a three-step process.

$$ {}_{1}^{1}\mathrm{H} + {}_{1}^{1}\mathrm{H} \rightarrow {}_{1}^{2}\mathrm{H} + \text{other particles} $$

$$ {}_{1}^{2}\mathrm{H} + {}_{1}^{1}\mathrm{H} \rightarrow {}_{2}^{3}\mathrm{He} + {}_{0}^{0}\gamma $$

$$ {}_{2}^{3}\mathrm{He} + {}_{2}^{3}\mathrm{He} \rightarrow {}_{2}^{4}\mathrm{He} + {}_{1}^{1}\mathrm{H} + {}_{1}^{1}\mathrm{H} $$

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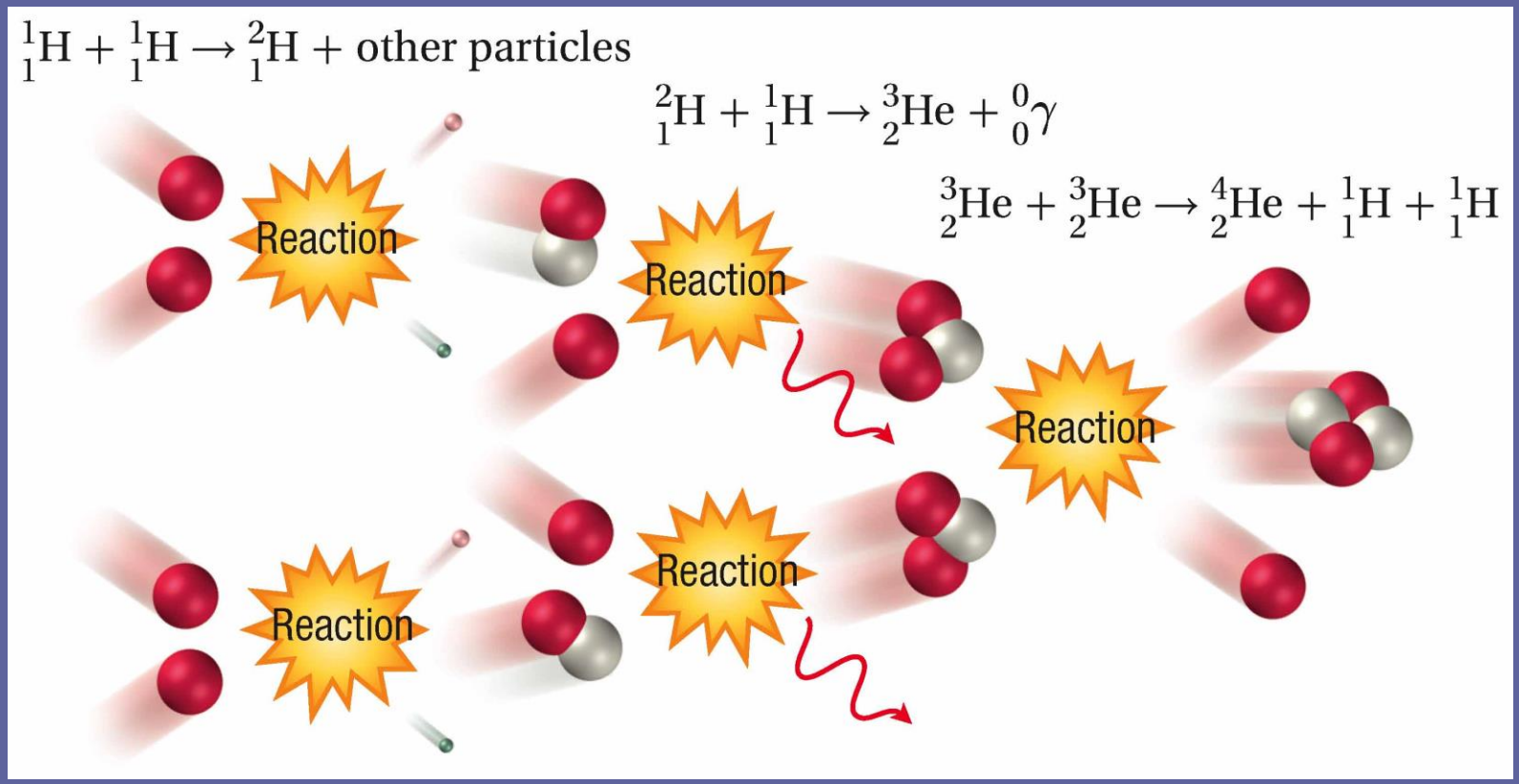
Nuclear Fusion, *continued*



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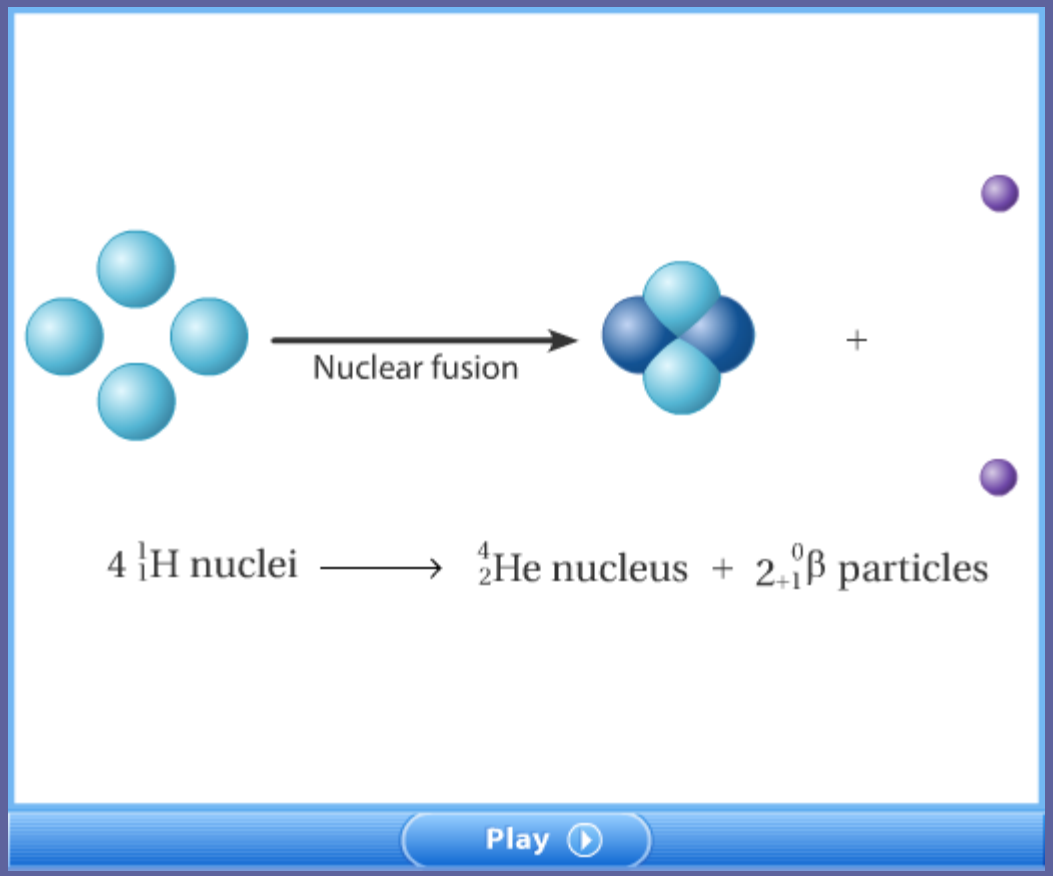
Visual Concept: Nuclear Fusion



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