Activity: Fission vs. Fusion Reading

FOR THE TEACHER

Summary
In this activity, students will annotate an informational text about fission and fusion using the “text-in-the-middle” reading strategy. They will then compare and contrast the two types of nuclear reactions.

Grade Level
High School

NGSS Alignment
This activity will help prepare your students to meet the performance expectations in the following standards:

- **HS-PS1-8**: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- **Scientific and Engineering Practices**:
  - Developing and Using Models
  - Obtaining, Evaluating, and Communicating Information

Objectives
By the end of this activity, students should be able to:

- Annotate an informational text using the “text-in-the-middle” reading strategy.
- Compare and contrast the processes of fission and fusion.

Chemistry Topics
This activity supports students’ understanding of:

- Nuclear chemistry
- Radioactive decay
- Fission
- Fusion

Time
**Teacher Preparation**: 10 minutes
**Lesson**: 40–60 minutes (longer, if teacher introduces/models the “text-in-the-middle” reading strategy)

Materials
- Student Handout
- Optional: “Practice” text selection for teacher to model this reading strategy
- Optional: Computer with projector and sound to view video on nuclear fission and fusion

Safety
- No specific safety precautions need to be observed for this activity.

Teacher Notes
- This activity can be used as an introductory activity for nuclear chemistry, as well as a way to incorporate reading informational texts in your classroom. I struggle to get my students to read more, and providing them with a short text is more manageable/less intimidating for many students compared to a textbook.

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I picked up the “text-in-the-middle” reading strategy at a Reading in the Content Area workshop several years ago. The two blank columns on either side of the text are used to help students organize their thoughts as they read and look at the information presented from more than one perspective for a deeper analysis of the text. There are a variety of ways to structure the two columns. One option, if the text compares two topics or positions, is to have one column for notes on one topic/position and the other column for notes on the other topic/position, as this activity does. Another way to do it is to have one column for identifying/summarizing the most important ideas in each section of text and the other column for identifying their questions, connections to other concepts/ideas beyond the text, or problems/flaws in the author’s position.

Since the article for this activity contrasts two things (nuclear fission vs. fusion), you might encourage students to use two different colored highlighters on their first read-through of the text, before they even start taking notes in either side column, with one color associated with fission-related information and the other color for fusion. (This type of activity encourages deep, close reading and should require more than one read-through of the text.) Then, when they do a second read-through, they could fill in the columns with the information they highlighted.

If you have never done a “text-in-the-middle” text annotation with your students before, you may want to model this reading strategy for them with a different text before assigning this activity for students to work on independently. It might be helpful to use another text that compares two things – perhaps something they may have learned about before, such as mitosis vs. meiosis from biology class, or chemical vs. physical changes if you covered that earlier in the year. You could find an article on a topic of interest, or use a section of their textbook.

Engaging in deep reading like this can be mentally taxing, especially for students who aren’t used to it. Be sure to use a fairly short text to model or introduce this kind of reading and annotating, or to break the text up into smaller chunks with breaks in between reading sessions. It might help students to annotate in chunks of a paragraph or two at a time and discuss what they read and any difficulties they had with a partner before moving on.

For more information on this and other reading strategies, see the following resources:
  o These slides on SlideShare, particularly slides 34-35
  o This article on how one teacher uses this template.

The reading and images are adapted from ACS’s first-year high school chemistry textbook, Chemistry in the Community, 6th edition, Unit 6, Section D: “Nuclear Energy: Benefits and Burdens.”

After students read and complete the organizer, a follow-up option is to view a video, such as this one, on fission and fusion and add on to their organizer. The video provides audio/visual learners a way to pick up on some information they may have missed.

Another resource that would expand on the discovery of fission is AACT’s video on Lise Meitner from the Founders of Chemistry series.

As an extension activity, I have had students create small posters comparing and contrasting fission and fusion. The posters include a model of each, types of atoms involved, where it occurs, and relative amounts of energy produced.

Another possible extension activity would be to have students research the pros and cons of nuclear energy in more detail and take a position on the issue in a written statement or class debate. There are several AACT resources that you could use to further this discussion:
  o Town Meeting
  o Nuclear Energy Debate
  o Nuclear Energy Power Plants
# Fission vs. Fusion Reading

## Instructions
Read the text below about nuclear fission and fusion. Highlight it as you read, and take notes in the left and right columns on fission and fusion, respectively – definitions, similarities and differences, questions you have as you read, etc.

<table>
<thead>
<tr>
<th>Fission</th>
<th>Text adapted from *Chemistry in the Community, 6th edition, Unit 6, Section D “Nuclear Energy: Benefits and Burdens”</th>
<th>Fusion</th>
</tr>
</thead>
</table>
| What is it? | **Nuclear Fission and E=mc²**  
In the late 1930’s, scientists first discovered the process of nuclear fission – splitting an atom into two smaller atoms.  
The nuclear fission of heavy atoms such as uranium releases a huge quantity of energy. Gram for gram, the released energy is at least a million times more than the energy of any chemical reaction, such as burning petroleum products like gasoline and natural gas. This is what makes nuclear explosions so devastating and nuclear energy so powerful.  
Nuclear reactions, like chemical reactions, are based on conserving energy and mass. However, during nuclear fission, very small quantities of mass are converted into measurable quantities of energy.  
When a large nucleus, like that of a uranium atom, splits into two smaller nuclei, a small loss of mass results and is converted into large quantities of released energy, as depicted in Figure 1. | What is it? |
| Types of atoms involved? | | Types of atoms involved? |
### Advantages

**Figure 1** Nuclear Fission – a large atom, struck with a neutron, breaks into two smaller atoms, releasing 3 neutrons and lots of energy. Adapted from *Chemistry in the Community*, 6th Edition.

How much mass and energy are involved? The mass loss is very small, often less than 0.1% of the total mass of the fissioning atom. Even so, the conversion of these small quantities of mass into energy accounts for the vast power of nuclear reactions.

Albert Einstein’s famous equation relates mass and energy: \( E = mc^2 \). This equation indicates that the energy released (\( E \)) equals the mass lost (\( m \)) multiplied by the speed of light (a very large number) squared (\( c^2 \)). If one kilogram of U-235 fissions, a mass of about one gram is converted into energy. That one gram converted to energy would produce the same amount of energy generated by burning 700,000 gallons of high-octane gasoline!

#### Nuclear Weapons, Nuclear Energy

Shortly after the first fission reactions were explained in 1939, scientists recognized that they could employ large-scale nuclear reactions in military weapons. Germany and the United States soon initiated projects to build atomic bombs during World War II. In 1945, U.S. planes dropped two such bombs on Hiroshima and Nagasaki in Japan, which led quickly to the end of the war.

### Disadvantages
More recently, nuclear engineers have used the energy produced by nuclear fission chain reactions to generate electricity. They carefully monitor and control the rate of fission for such uses. Nuclear power plants harness the enormous energy produced by nuclear fission reactions, while also minimizing the risks of an uncontrolled chain reaction.

The first nuclear reactors were designed and built during World War II. Since then, commercial companies have built many nuclear reactors to generate electricity. In 2010, slightly more than 100 commercial nuclear reactors were generating electricity in the United States. Globally, an estimated 438 nuclear reactors in 29 nations produce about 14% of the world’s electricity.

Most conventional power plants generate electricity by burning fossil fuels to boil water and produce steam. A nuclear power plant operates in much the same way. However, instead of using fossil-fuel combustion to boil water, **nuclear power plants** use the thermal energy released from nuclear-fission reactions to heat water and produce steam. The steam spins turbines of giant generators, producing electricity.

**Nuclear Fusion**

In addition to releasing energy by splitting massive nuclei (fission), large quantities of nuclear energy can be generated by fusing, or combining, small nuclei. **Nuclear fusion** involves forcing two relatively small nuclei to combine into a new, more massive nucleus. As with fission, the energy released by nuclear fusion can be enormous, again due to the conversion of mass into energy. Gram for gram, nuclear fusion liberates even more energy than nuclear fission—that is, between 3 and 10 times more energy.
Nuclear fusion powers the Sun and other stars. Scientists believe that the Sun formed when a huge quantity of interstellar gas, mostly hydrogen, condensed under the force of gravity. As the volume of gas decreased, its temperature increased to about 15 million °C, and hydrogen atoms began fusing into helium. The nuclei that fused together were all positively charged and tended to repel one another. The high temperature gave each nucleus considerable kinetic energy, which helped overcome the repulsions.

Once fusion was started, the Sun began to shine, converting nuclear energy into radiant energy. Scientists estimate that the Sun, believed to be about 4.5 billion years old, is about halfway through its life.

The nuclear-fusion reactions occurring in the Sun are rather complicated, but the result is the conversion of hydrogen nuclei into helium nuclei, as depicted in Figure 2.

![Figure 2 Nuclear Fusion - two smaller atoms combine to form a larger atom (top right), releasing a neutron and lots of energy. Adapted from Chemistry in the Community, 6th Edition.](image)

How much energy does such a nuclear fusion reaction produce? The nuclear energy released from the fusion of one gram of hydrogen-1 equals the thermal energy released by burning nearly 5,000 gallons of gasoline or 20 tons of coal.
Powerful military weapons incorporate nuclear fusion. The hydrogen bomb, also known as a thermonuclear device, is based on a fusion reaction that uses the thermal energy from the explosion of a small atomic (fission) bomb to initiate fusion.

Can the energy of nuclear fusion be harnessed for beneficial purposes, such as producing electricity? This remains to be seen. Scientists have spent more than five decades pursuing this possibility. They have tried many schemes, but have not yet succeeded. The major difficulties have been maintaining the high temperatures needed for fusion while also containing the reactants and fused nuclei. So far, in the experiments that have achieved temperatures sufficient to initiate fusion, the total energy consumed by the process is more than the total energy released.

If scientists finally succeed in controlling nuclear fusion in the laboratory, there is still no guarantee that fusion reactions will become a practical source of energy. Low-mass isotopes needed to fuel such reactors are plentiful and inexpensive, but confinement of the reaction could be very costly. Further, although the fusion reaction itself produces less radioactive waste than nuclear fission, capturing the high-energy byproducts and shielding the heat of the reaction could generate nearly as much radioactive waste as that produced now by fission-based power plants.

In splitting and fusing atoms, the nuclear energy that fuels the universe has been unleashed. Much good has arisen from it, but so have scientific, social, and ethical questions. Along with great benefits come great risks. How much risk is worth any potential benefits?
Conclusion
In your own words, write a paragraph or two comparing and contrasting nuclear fission and nuclear fusion using the information you learned from the article.