Elements From Stardust

Reading Preview

Key Concepts

- How are elements created in stars?
- What are the results of fusion in large stars?

Key Terms

- plasma
- nuclear fusion
- nebula
- supernova

Target Reading Skill

Sequencing As you read, make a flowchart like the one below that shows how elements are formed in stars. Write the steps in separate boxes in the flowchart in the order in which they occur.

Formation of Elements

Hydrogen nuclei fuse, forming helium.

↓

Helium nuclei fuse, forming beryllium.

↓

Lab zone Discover Activity

Can Helium Be Made From Hydrogen?

1. A hydrogen atom has a nucleus of 1 proton surrounded by an electron. Most hydrogen nuclei do not contain neutrons, but one isotope of hydrogen contains 1 neutron, and another isotope contains 2 neutrons. Draw models of each of the three isotopes of hydrogen.
2. All helium atoms have 2 protons and 2 electrons, and almost all have 2 neutrons. Draw a model of a typical helium atom.

Think It Over

Developing Hypotheses How might the hydrogen atoms you drew combine to form a helium atom? Draw a diagram to illustrate your hypothesis. Why would hydrogen nuclei with neutrons be important for this process?

Have you wondered where the elements come from, or why some elements are common here on Earth, while others are much more rare? To answer questions such as these, scientists have looked in a place that might surprise you: stars. They have looked not only at distant stars, but also at the nearest star, the sun. By studying the sun and other stars, scientists have formed some interesting models of how the stars shine and theories about the origins of matter here on Earth.

How Elements Form in Stars

Like many other stars, the sun is made mostly of one element—hydrogen. This hydrogen exists at tremendously high pressures and hot temperatures. How hot is it? The temperature in the sun's core is about 15 million degrees Celsius.

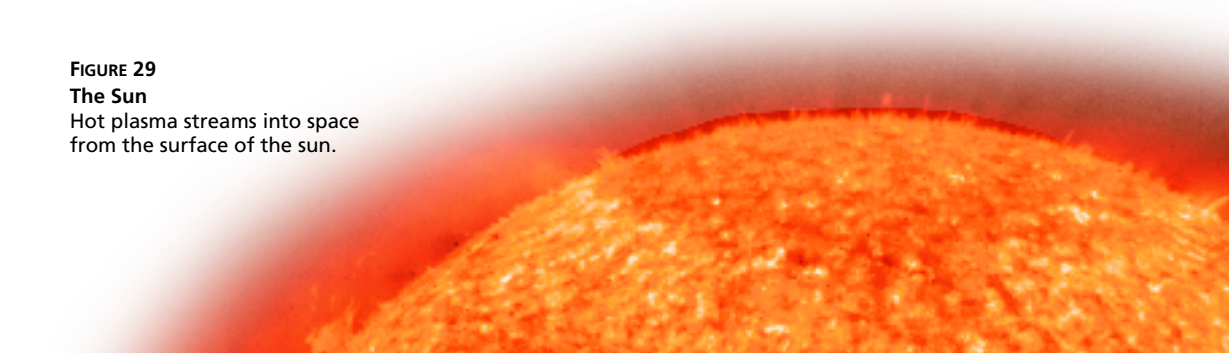


FIGURE 29
The Sun
Hot plasma streams into space from the surface of the sun.

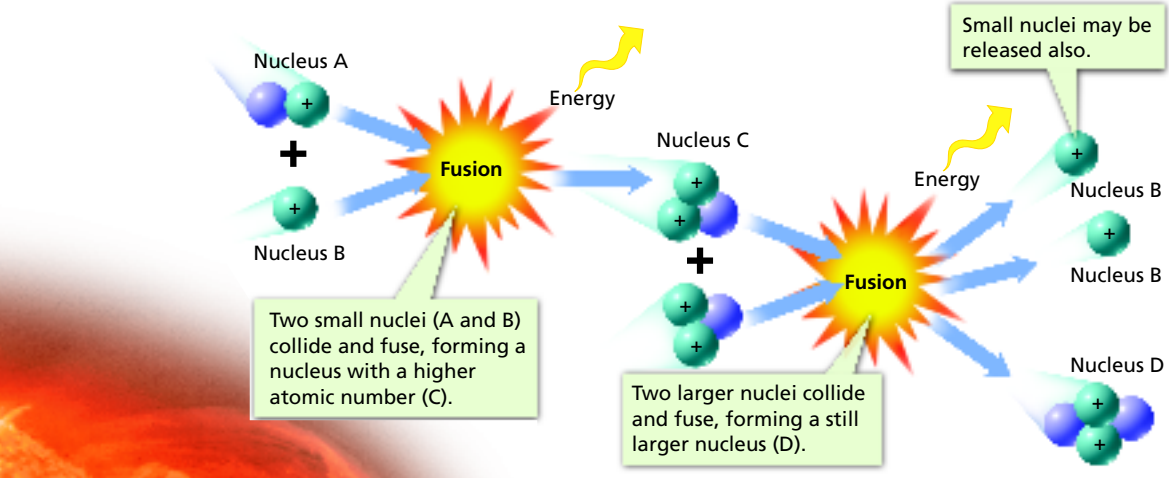
Plasma At the extreme temperatures found in the sun and other stars, matter does not exist as a solid, a liquid, or a gas. Instead, it exists in a state called plasma. The **plasma** state of matter consists of a gas-like mixture of free electrons and atoms stripped of electrons. Plasmas don't exist just in stars. A comet's tail is made partly of plasma. Plasmas also can be produced by high-voltage electricity or even an electric spark. A plasma forms inside a fluorescent light when it is switched on. Plasmas are also used to generate light inside flat-panel TV screens that you can hang on a wall. The difference between a plasma in a fluorescent light and plasma in the sun is that the sun's plasma is under extremely high pressure.

Figure 30
Plasma in Comets
The glowing tail of a comet consists partly of plasma that forms as the comet comes closer to the sun.

When Nuclei Combine Remember that atomic nuclei contain protons, which means that nuclei are positively charged. Usually, positively charged nuclei repel one another. But in stars, the pressure is so high that nuclei are squeezed close together and collide with one another.

As in particle accelerators, when colliding nuclei have enough energy, they can join together, as shown in Figure 31. **Nuclear fusion** is a process in which two atomic nuclei combine to form a larger nucleus, releasing huge amounts of energy in the process. **Nuclear fusion, which occurs in stars on a huge scale, combines smaller nuclei into larger nuclei, creating heavier elements.**

FIGURE 31
Nuclear Fusion
During nuclear fusion, two atomic nuclei collide and fuse. **Applying Concepts** *Why does nuclear fusion result in the production of a different element?*



Discovery CHANNEL SCHOOL

Elements and the Periodic Table

Video Preview
Video Field Trip
Video Assessment

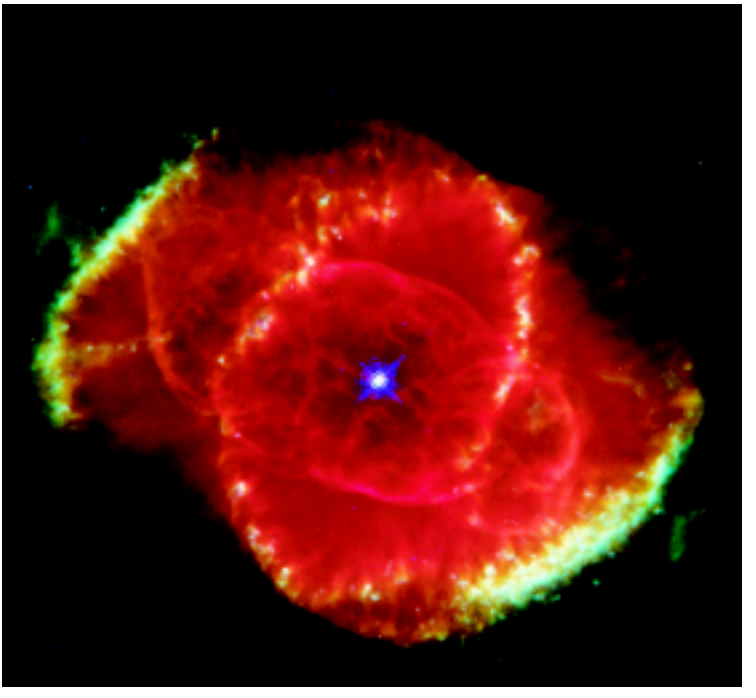


FIGURE 32
Planetary Nebula
The Cat's Eye Nebula is the remains of a star similar to the sun. Energy from the star causes the gases to glow.

New Elements From Fusion What are the steps of nuclear fusion in the sun and other stars? In the sun, different isotopes of hydrogen fuse, producing nuclei of helium. This reaction produces a huge amount of energy and is the most important source of the energy in the sun. In other words, hydrogen is the fuel that powers the sun. Scientists estimate that the sun has enough hydrogen to last another 5 billion years.

As more and more helium builds up in the core, the sun's temperature and volume change. New fusion reactions occur. Over time, two or more helium nuclei can fuse, forming nuclei of heavier elements. For example, two helium nuclei combine, forming a nucleus of beryllium. Another helium nucleus can fuse with the beryllium nucleus, resulting in a carbon nucleus. Yet another helium nucleus and a carbon nucleus can fuse, forming oxygen. But stars the size of the sun do not contain enough energy to produce elements heavier than oxygen. Eventually, a star like the sun shrinks and its elements blow away. It forms a **nebula** —or cloudlike region of gases—similar to the one shown in Figure 32.

Reading Checkpoint **What elements can be produced by stars the size of the sun?**

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Elements From Large Stars

As they age, larger stars become even hotter than the sun. These stars have enough energy to produce heavier elements, such as magnesium and silicon. In more massive stars, fusion continues until the core is almost all iron.

Find iron on the periodic table in Section 2. You can see that there are many other elements heavier than iron. How are elements heavier than iron produced? In the final hours of the most massive stars, scientists have observed an event called a supernova. A **supernova** is a huge explosion that breaks apart a massive star, producing temperatures up to 1 billion degrees Celsius. **A supernova provides enough energy for the nuclear fusion reactions that create the heaviest elements.** The elements are blown off into space as the star burns out.

Most astronomers agree that the matter in the sun and the planets around it, including Earth, originally came from a gigantic supernova that occurred billions of years ago. If so, this means that the matter all around you was created in a star, and all matter on Earth is a form of stardust.

Reading Checkpoint **Where are elements heavier than iron produced?**

FIGURE 33
Supernova
The Crab Nebula is the supernova of a massive star first observed on Earth in the year 1054 by Chinese astronomers.
Making Generalizations *What elements may have formed in this supernova that would not have formed in a smaller star?*

Section 5 Assessment

Target Reading Skill **Sequencing** Refer to your flowchart about the formation of elements in stars as you answer Question 1.

Reviewing Key Concepts

1. **a.** **Identifying** What is the process that produces elements in stars?
   b. **Explaining** How are the elements beryllium, carbon, and oxygen produced in stars like the sun?
   c. **Applying Concepts** Why can elements be produced in the sun but not in Earth's atmosphere?
2. **a.** **Defining** What is a supernova?
   b. **Describing** What conditions of a supernova cause elements that are heavier than iron to form?
   c. **Developing Hypotheses** Earth has abundant amounts of iron, but also has many elements heavier than iron. Form a hypothesis to explain the presence of these heavier elements.

Writing in Science

How-to Paragraph Suppose you are the science officer on a spaceship. Your mission is to collect and analyze samples of matter from various sites as the ship travels around the Milky Way Galaxy. You and your assistants are able to identify the elements present in a sample. You want to know whether the sample could have come from a star like the sun, a more massive star, or a supernova. Write a set of instructions telling your assistants how to decide on the origin of the samples.