Section 5

Elements From Stardust

Objectives

After this lesson, students will be able to

K.3.5.1 Explain how elements are created in stars.

K.3.5.2 Identify the results of fusion in large stars.

Target Reading Skill

Sequencing Explain that organizing information from beginning to end helps students understand a step-by-step process.

Answers

Sample flowchart:

Formation of Elements

Hydrogen nuclei fuse, forming helium.
Helium nuclei fuse, forming beryllium.
Fusion continues in smaller stars, forming elements up to oxygen.
Fusion in larger stars produces heavier elements up to iron.
The heaviest elements form during supernova explosions of the most massive stars.

All in One Teaching Resources

- Transparency K29

Preteach

Build Background Knowledge L2

Relating Stars to Particle Accelerators

Remind students how larger elements are made synthetically in particle accelerators. Ask: **How do particle accelerators work?** *(The nuclear particles of atoms are forced to crash into each other.)* Tell students that in this section they will learn how stars work like particle accelerators to form elements.

Section 5

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.

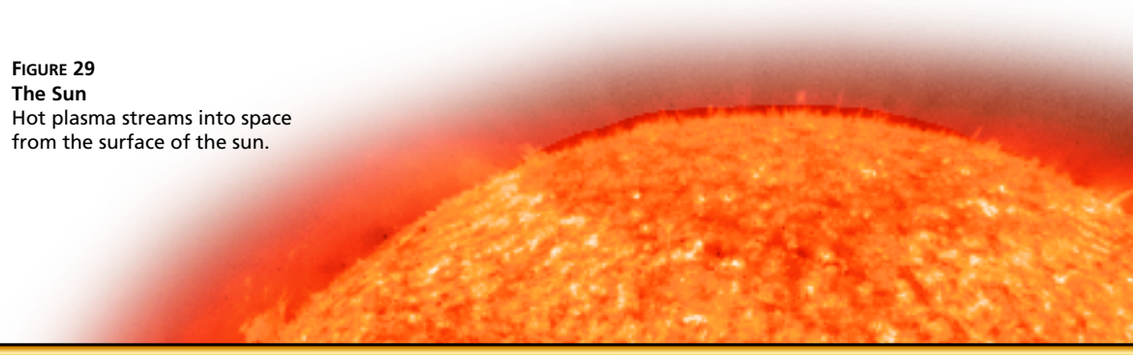


FIGURE 29
The Sun
Hot plasma streams into space from the surface of the sun.

Lab zone Discover Activity

Skills Focus Developing hypotheses L3

Materials none

Time 10 minutes

Tips Refer students to Figure 3 in *Introduction to Atoms* for a diagram showing the nuclei of isotopes. Remind them to draw only the nuclei of the atoms, not the electrons.

Think It Over Students might hypothesize that the atoms combine because the nuclei have lots of energy, are traveling at great speeds, or are under great pressure. Students' diagrams should show two hydrogen nuclei colliding with one another, forming a helium nucleus. The hydrogen nuclei must have neutrons because helium atoms have neutrons.

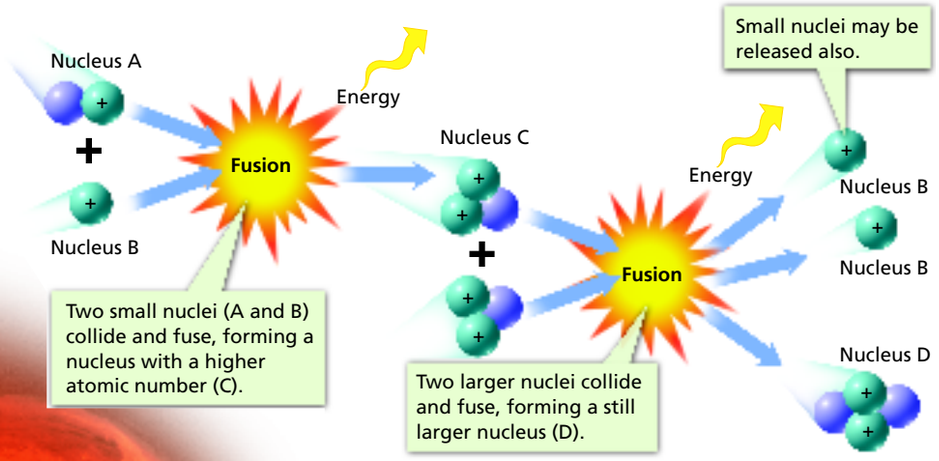
Plasma At the extreme temperatures found in the sun and other stars, matter does not exist as a solid, a liquid, or a gas. Instead, it exists in a state called plasma. The **plasma** state of matter consists of a gas-like mixture of free electrons and atoms stripped of electrons. Plasmas don't exist 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?*



Instruct

How Elements Form in Stars

Teach Key Concepts L2

Nuclear Fusion and New Elements

Focus Tell students that in stars the electrons have escaped from the nucleus.

Teach Ask: **What occurs during nuclear fusion?** *(Two atomic nuclei combine to form a larger nucleus, with the release of energy.)* **How does nuclear fusion create new elements?** *(Smaller nuclei combine to form larger nuclei, creating new, heavier elements.)*

Apply Ask: **Why does nuclear fusion occur in stars?** *(The pressure is so high that nuclei are squeezed together.)* **learning modality: verbal**

Use Visuals: Figure 31 L2

Steps in Nuclear Fusion

Focus Have students study Figure 31.

Teach Ask: **What particles make up nucleus A?** *(One proton and one neutron)* **What results from the fusion of nucleus A and nucleus B?** *(A larger nucleus and the release of energy)*

Apply Ask: **If this nuclear fusion reaction were occurring in the sun, what elements are A, B, C, and D?** *(A, isotope of hydrogen; B, isotope of hydrogen; C, isotope of helium; D, isotope of helium)* **learning modality: visual**

All in One Teaching Resources
- Transparency K30

Independent Practice L2

All in One Teaching Resources
- Guided Reading and Study Worksheet: *Elements From Stardust*

Student Edition on Audio CD

Differentiated Instruction

Gifted and Talented L3
Tracing the Path of Element Formation
Challenge students to diagram the pathway of element formation in nuclear fusion reactions by starting with hydrogen and ending with iron. Suggest that students develop a method of organizing information to help them see the progression. **learning modality: logical/mathematical**

Less Proficient Readers L1
Asking Questions Have students listen to *Elements From Stardust* on the **Student Edition on Audio CD**. Before they listen, have them draw 3 columns (*What I Know, What I Want to Know, What I Learned*) and fill in what they already know about the inside of stars. Next, have them list questions. As they listen, they can answer their questions. **learning modality: verbal**

Monitor Progress L2

Writing Have students explain why matter must be in the form of plasma and why the nuclei must be under high pressure for nuclear fusion to occur.

Answer
Figure 31 The number of protons in the resulting nucleus is different.

Discovery CHANNEL SCHOOL Video Field Trip

Elements and the Periodic Table

Show the Video Field Trip to let students understand the death of a star and how elements form. Discussion question: **How are elements formed when stars die?** *(As the layers of the star burn, the nuclei fuse into heavier elements.)*

Lab zone Build Inquiry L2

Modeling Element Formation

Materials 2 colors of modeling clay

Focus Remind students that electrons are not involved in fusion.

Teach Invite students to model the formation of helium, beryllium, carbon, and oxygen. Suggest that they use Figure 31 as a guide.

Apply Ask: **What factor determines which element an atom is?** *(The number of protons in the nucleus)* **learning modality: kinesthetic**

Go Online NSTA SCILINKS

For: Links on nuclear fusion
Visit: www.SciLinks.org
Web Code: scn-1135

Download a worksheet that will guide students' review of Internet resources on nuclear fusion.

Elements From Large Stars

Teach Key Concepts L2

Elements From Supernovas

Focus Tell students that stars larger than Earth's sun can produce heavier elements.

Teach Ask: **What is a supernova?** *(A huge explosion that breaks apart a massive star)* **How does a supernova create the heaviest elements?** *(Sample answer: It provides energy for the nuclear fusion reactions to occur.)*

Apply Ask: **Where did the matter in our sun and its planets come from?** *(From a gigantic supernova that occurred billions of years ago)* **learning modality: verbal**

Discovery CHANNEL SCHOOL

Elements and the Periodic Table

Video Preview
Video Field Trip
Video Assessment

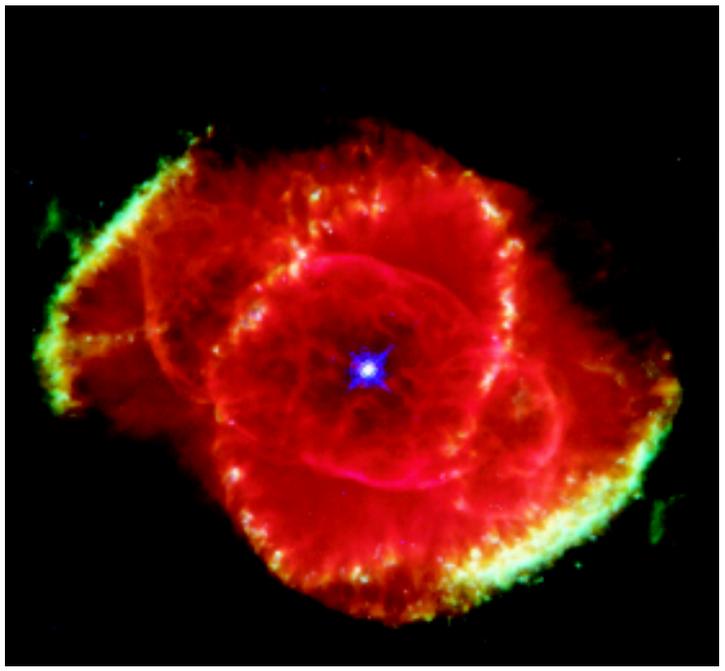


FIGURE 32
Planetary Nebula
The Cat's Eye Nebula is the remains of a star similar to the sun. Energy from the star causes the gases to glow.

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For: Links on nuclear fusion
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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?**

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?**

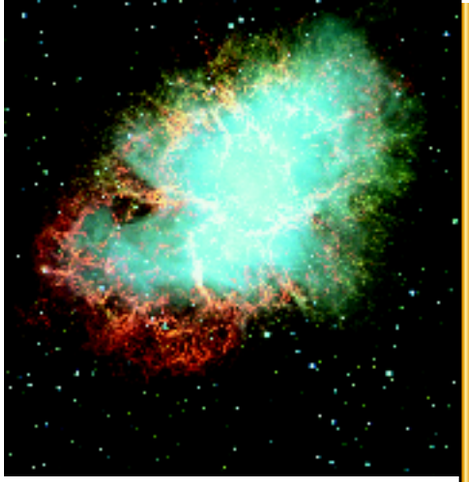

FIGURE 33
Supernova
The Crab Nebula is the supernova of a massive star first observed on Earth in the year 1054 by Chinese astronomers. **Making Generalizations** *What elements may have formed in this supernova that would not have formed in a smaller star?*

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.

Monitor Progress L2

Answers

Figure 33 All elements heavier than iron

Reading Checkpoint Oxygen and elements lighter than oxygen

Reading Checkpoint In a supernova

Assess

Reviewing Key Concepts

1. a. Nuclear fusion **b.** Beryllium, carbon, and oxygen are produced in stars when helium nuclei combine with other helium nuclei and with the nuclei of beryllium and carbon. **c.** The high pressures and temperatures that allow nuclear fusion to occur in the sun do not exist in Earth's atmosphere.

2. a. A huge explosion that breaks apart a massive star **b.** Temperatures up to one billion degrees Celsius and the energy created by the huge explosion **c.** Because Earth has elements heavier than iron, the matter that makes up Earth was probably formed in a gigantic supernova that occurred billions of years ago.

Reteach L1

Have students diagram how two helium nuclei can form beryllium.

Performance Assessment L2

Writing Invite students to write a paragraph explaining how stars function as element factories.

Writing Students can save their paragraphs in their portfolios.

All in One Teaching Resources

- Section Summary: *Elements From Stars*
- Review and Reinforce: *Elements From Stars*
- Enrich: *Elements From Stars*

Writing in Science

Writing Mode Exposition/How-to

Scoring Rubric

4 Exceeds criteria; includes complete and highly accurate instructions for differentiating among the three origins of the samples

3 Meets criteria

2 Includes adequate instructions for differentiating between at least two of the origins and/or contains minor errors

1 Includes adequate instructions for at least one of the origins and/or contains serious errors