



## DISTRIBUTION OF ELEMENTS IN EARTH'S CRUST

### INTRODUCTION

The Howard Hughes Medical Institute short film *The Day the Mesozoic Died* examines the evidence that allowed scientists to determine that a gigantic asteroid struck Earth and resulted in a mass extinction that also ended the age of the dinosaurs. The passage included in this document provides background information that will help you understand the themes and ideas presented in this film.

### PROCEDURE

1. Read the passage on the next page, "Iridium: Calling Card from Outer Space."
2. Answer the questions following the reading passage, either in class or as a homework assignment, as directed by your teacher. Be sure to copy each question or restate it as part of your response.



## READING PASSAGE

### IRIDIUM: CALLING CARD FROM OUTER SPACE

*"Some part of our being knows this is where we came from. We long to return. And we can. Because the cosmos is also within us. We are made of star stuff. We are a way for the cosmos to know itself."*

—Carl Sagan

The universe began about 13.8 billion years ago with the big bang, an event in which enormous quantities of energy and matter—consisting primarily of the elements hydrogen and helium—started expanding into what today we think of as space. Over time, hydrogen and helium particles **coalesced** into dense clouds, or **nebulae**, of contracting gas, which eventually formed the first stars. As the atoms in these stars were crushed under the enormous pressure generated by their mutual gravitation, their cores reached temperatures of many millions of degrees. At such temperatures and pressures, the simultaneous collisions of four hydrogen nuclei can cause them to fuse into a single helium nucleus. In this process, known as fusion, a small amount of the mass of the hydrogen atoms is converted directly into energy. This is how stars produce the energy that sets them ablaze and fills our universe with myriad points of light.

As the star matures, the helium can be fused into carbon, and carbon into neon, and neon into oxygen. Eventually, this chain of fusion reactions results in the production of iron in a star's core. When this stage is reached, the star's core no longer produces the energy necessary to support the enormous mass of the matter surrounding it. As a result, the star collapses onto its core, driving pressure and temperature to extremes that lead to an explosion known as a **supernova**. These conditions allow for the fusion of iron into heavier elements. As the star blows apart, matter composed of all the elements in the periodic table is hurled into space in an expanding cloud of particles and dust to become new nebulae.

The first stars to form after the big bang were made entirely of hydrogen and helium. Their explosions seeded the universe with the first atoms of heavier elements, which included everything from aluminum to xenon. Countless generations of stars that were formed afterward added to this stock of **heavy elements** in the universe; however, even today, billions of years later, 98% of our universe is composed of hydrogen and helium and just 2% is everything else!

After billions of years, the universe became sufficiently rich in heavy elements that nebulae of coalescing hydrogen, helium, and other matter could begin to form bodies that were not destined to become stars. Small grains of simple compounds and heavier elements that were part of such nebulae began to clump together by static forces. As the clumps grew in size, they formed **planetesimals**: aggregations of matter massive enough to attract and hold material by their gravitational force. Over time, the largest planetesimals began to sweep up all of the matter in their regions of the solar system, becoming planets. This is how the Earth and the planets formed from the expansion of the solar nebula.

The formation of Earth and our solar system was affected by a number of additional physical processes. The newly formed sun sent out a constant stream of particles called **solar wind**, which tended to sweep lighter elements out toward the farther reaches of the solar system. There they formed planets that were mostly made out of gases, which became the gas giants. Heavier elements were not as easily swept away by the solar wind and formed smaller but denser rocky planets, such as Earth and Mars, in orbits much closer to the sun.

Deep inside the newly formed Earth, the radioactive decay of elements released so much heat that the entire planet melted, allowing the densest elements—metals like iron and nickel—to gradually sink into the growing core of the planet. During this process of **differentiation**, most other dense metals such as iridium, platinum, and gold also migrated into the core. As a result, these metals are rare in Earth's crust.

But elements like iridium are not rare in **asteroids** that circle our sun between the orbits of Mars and Jupiter, or **comets** that sweep in from the farthest reaches of the solar system. These **pristine** remnants of material that made up the original solar nebula are the source of **meteors**: dust of comet tails and shattered asteroids that burn up in Earth's **atmosphere**. This dust constantly rains down to Earth, bringing a mixture of elements, including iridium. When



**meteorites**—chunks ranging from the size of a pebble to the size of a mountain—strike the planet, enormous quantities of iridium-rich debris can be scattered over Earth’s surface. Because these pure and **undifferentiated** samples from space are relatively rich in iridium—in sharp contrast to Earth’s crust—scientists use the presence of it and a few other metals as markers of ancient extraterrestrial impacts. For scientists, iridium-rich debris is a calling card from outer space.

#### **ASTEROID, COMET, METEOR, OR METEORITE?**

According to NASA, a large, rocky body in orbit around the sun is referred to as an asteroid. Most asteroids lie in the asteroid belt between the orbits of Mars and Jupiter. Comets are also objects in space; their icy nuclei can vaporize when they pass near the sun, releasing streams of dust particles and gas. They originate from the Kuiper belt or Oort cloud, at a greater distance from the sun than Pluto—the very edge of the solar system. A meteoroid is a small solid particle that travels through space; some meteoroids are as large as asteroids, but most are the size of sand grains. When a meteoroid enters Earth’s atmosphere and vaporizes, it becomes a meteor, or shooting star. If a small asteroid or large meteoroid survives the passage through Earth’s atmosphere and strikes Earth’s surface, it is called a meteorite. Very large asteroids or comets that strike Earth explode, releasing so much energy that they vaporize and leave no fragments.



**QUESTIONS**

1. Find each of the following terms in the text. Use a dictionary to write a definition for each term; the definition should fit the context of the passage.

nebula/nebulae \_\_\_\_\_

coalesce \_\_\_\_\_

planetesimals \_\_\_\_\_

solar nebula \_\_\_\_\_

solar wind \_\_\_\_\_

meteor \_\_\_\_\_

meteorite \_\_\_\_\_

differentiation \_\_\_\_\_

2. What is fusion? What conditions are necessary for it to occur?

\_\_\_\_\_  
\_\_\_\_\_

3. Hydrogen and helium are the two lightest elements in the periodic table. What fraction of the mass in the known universe is made up of hydrogen and helium?

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

4. Why did it take billions of years after the big bang for planets like Earth to form?

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

5. What is meant by the term "heavy elements?" List three examples of heavy elements that are mentioned in the passage.

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\_\_\_\_\_  
\_\_\_\_\_



6. What is a supernova? How are supernovae connected to Earth’s formation and our own existence?

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7. Why are heavy metals like iridium so rare in Earth’s crust?

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8. The passage states that comets and asteroids are “pristine remnants of material that made up the original solar nebula.” What does this phrase mean and how does the composition of these bodies differ from that of Earth’s crust?

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9. Why is iridium so useful for determining that an asteroid struck Earth more than 65 million years ago?

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