



DISTRIBUTION OF ELEMENTS IN EARTH'S CRUST

OVERVIEW

This lesson serves as an extension to the Howard Hughes Medical Institute short film *The Day the Mesozoic Died*. It provides an opportunity for students to learn about how planets in our solar system formed and why the element iridium is so rare in Earth's crust. This lesson requires students to read a passage and answer questions about the information presented, testing their non-fiction reading comprehension.

KEY CONCEPTS AND LEARNING OBJECTIVES

- After the big bang, the early universe contained only hydrogen and helium. Heavier elements were formed in the cores of stars found in the early universe and through their explosions as supernovae.
- One particular heavy element, iridium, is much more abundant in comets and asteroids than it is in Earth's crust, and thus is useful in determining if an object from space hit Earth.

Students will be able to:

- explain the origin of all elements in the universe.
- describe the basic conditions necessary for nuclear fusion.
- explain the conditions necessary for the formation of our solar system and Earth-like planets.
- describe the value of chemical analysis for identifying the origin of a substance or material.
- determine the central ideas and themes of a scientific text.
- cite specific textual evidence to support analysis of science and technical texts.
- identify and determine the meaning of key terms in the scientific domain based on context and by using reference resources.
- evaluate information within a scientific text and make reasonable inferences from it.

CURRICULUM CONNECTIONS

Curriculum	Standards
NGSS (April 2013)	HS-ESS1.A, HS-ESS1.B, HS - ESS1.C, HS-ESS2.A, HS-PS1.A
Common Core (2010)	CCSS.ELA-Literacy.RST.9-10.4, CCSS.ELA-Literacy.RST.11-12.4, CCSS.ELA-Literacy.RST.9-10.1, CCSS.ELA-Literacy.RST.11-12.1, CCSS.ELA-Literacy.WHST.9-12.1

KEY TERMS

asteroid, big bang, coalesce, differentiation, fusion, heavy elements, iridium, meteor, meteorite, nebula/nebulae, planets, planetesimals, solar wind, stars, supernova

TIME REQUIREMENT

This activity is designed to be assigned as homework, either before or after watching the short film. It can also be used as an in-class or group activity; it would require approximately 30 minutes in this format.

SUGGESTED AUDIENCE

This activity is designed for high school level classes in the disciplines of physics, chemistry, and earth science. It also provides a curriculum resource that addresses Common Core language arts requirements for the science content area at this level.



PRIOR KNOWLEDGE

Students should be familiar with the periodic table and be able to read science-domain text proficiently at an eighth-grade level.

MATERIALS

Students will need the student version of the activity sheet.

TEACHING TIPS

- The passage "Iridium: Calling Card from Outer Space" contextualizes information that is key to developing an in-depth understanding of the concepts presented in the short film *The Day the Mesozoic Died*. The passage can be used as a prefilm activity or an extension activity after watching the film.
- After reading the passage "Iridium: Calling Card from Outer Space" and answering the analysis questions, the students could be given the quiz included at the end of this handout. The quiz can also be used as a reading comprehension assessment that demonstrates compliance with Common Core requirements for reading within the science content area.
- When taking the quiz, students should be allowed to refer to their responses to the analysis questions (but not the original article). Those answers function as a set of notes and will provide information on how effectively students were able to interact with the text.
- If the vocabulary is complex for your students, consider reading the passage aloud and reviewing the vocabulary with students.

ANSWER KEY

ANALYSIS 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: an enormous cloud of gas and dust bound together by its mutual gravitational attraction

coalesce: to come together and merge into a single body

planetesimals: bodies of solid material held together by their mutual gravitation that form as an intermediate step in the creation of stars and planets from a nebula

solar nebula: the nebula from which our solar system and Earth formed

solar wind: a stream of charged particles ejected from a star and streaming outward in all directions

meteor: the scientific term for a shooting star, small grains of dust that are visible as bright light as they streak through Earth's atmosphere

meteorite: a body of debris in space that is sufficiently large not to burn up as it streaks through Earth's atmosphere and that strikes Earth's surface

differentiation: separation into different layers or parts

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

Fusion is a process that combines the nuclei of several atoms into a single nucleus of a larger atom. It occurs in the core of all stars under enormous pressures and temperatures.



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?

The modern universe is about 98% hydrogen and helium. All other elements in the universe comprise less than 2% of the total.

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

After the big bang, the early universe contained only hydrogen and helium. Heavier elements were formed in the cores of stars found in the early universe and through their explosions as supernovae. It took many billions of years of star formation and supernovae to produce a sufficient amount of heavy elements to begin to form solar systems that included rocky planets similar to Earth.

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

In this passage, “heavier elements” refer to any element heavier than iron on the periodic table. Such elements require the energy of a supernova to form, whereas lighter elements can form by fusion in stars. Examples from the passage include iridium, platinum, gold, and nickel.

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

A supernova is the explosion of a star. A supernova occurs when a star exhausts all of its nuclear fuel and collapses. The collapse drives pressures and temperatures to levels so high that fusion reignites, forming elements heavier than iron, and the star explodes violently. Our solar system, planet, and life on Earth all owe their existence to supernovae, since they all require large quantities of heavy elements.

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

Earth’s crust is depleted in iridium and other heavy metals because during the formation of the planet these materials sank into Earth’s core due to their higher density.

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?

The word “pristine” means something that is pure and unchanged since its creation or beginning. The phrase “pristine remnants of material that made up the original solar nebula” refers to the fact that comets and asteroids preserve unchanged materials that scientists can use to understand exactly what the solar nebula was composed of. Specifically, comets and asteroids have much higher concentrations of iridium and other heavy metals than Earth’s crust has.

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

Iridium is useful in determining that an asteroid struck Earth because iridium is much more abundant in comets and asteroids than it is in Earth’s crust. The impact of an asteroid spreads large amounts of iridium over Earth’s surface, creating a chemical signal. Where scientists find high levels of iridium in a rock layer, it is a clue that an asteroid of significant size impacted the planet.



QUIZ QUESTIONS

1. Which of the following is/are formed as gravity pulls increasing amounts of dust and debris in a nebula together?

b. planetesimals

2. Heavy elements make up: **c. less than 2% of the universe.**

3. Earth's crust contains very little iridium because: **b. iridium is very dense like iron and sank into the core.**

4. The formation of a solar system with planets like Earth requires: **a. a nebula rich in heavy elements.**

5. The term "pristine" is best defined as: **d. original, pure, and unchanged since the beginning.**

6. Which of the following statements is true?

a. Asteroids and comets have much more iridium in them than Earth's crust has.

7. The fusion of hydrogen into helium requires extremely high **pressure** and **temperature** in the core of a star.

8. Earth has four major layers in its interior: crust, mantle, outer core, and inner core. The process that leads to the formation of these layers is called: **differentiation.**

9. Write the vocabulary term that best describes the process of a nebula collapsing and coming together to form planets and a star. **coalesce**

10. Why did Carl Sagan describe us all as being made out of "star stuff" in the quote at the beginning of the passage?

The heavy elements that Earth and all living things on it formed from were produced in the cores of stars and through their explosions as supernovae. In this sense, every atom in our bodies came from the core of a star long ago.

11. Briefly explain why iridium is helpful as evidence that an asteroid or comet struck Earth at some point in the past.

Iridium is much more abundant in asteroids and comets than it is in Earth's crust. When ancient rocks contain high levels of iridium, it is a clue that one of these extraterrestrial bodies struck Earth and spread its iridium widely over the surrounding area.

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IRIDIUM: CALLING CARD FROM OUTER SPACE

READING COMPREHENSION QUIZ

MULTIPLE CHOICE

Write the letter corresponding to the best answer on the line provided.

1. ____ Which of the following is/are formed as gravity pulls increasing amounts of dust and debris in a nebula together?
a. the solar wind b. planetesimals
c. meteors d. meteorites

2. ____ Heavy elements make up:
a. 98% of the universe. b. the solar wind.
c. less than 2% of the universe. d. the bulk of nebulae.

3. ____ Earth's crust contains very little iridium because:
a. the solar nebula had almost no iridium when Earth formed in it.
b. iridium is very dense like iron and sank into the core.
c. the solar wind blew most of the iridium away from the sun.
d. iridium underwent radioactive decay and melted Earth's crust.

4. ____ The formation of a solar system with planets like Earth requires:
a. a nebula rich in heavy elements.
b. sufficient quantities of iridium to form the planets.
c. a constant supply of meteors.
d. a pristine solar nebula.

5. ____ The term "pristine" is best defined as:
a. rare and almost unheard-of.
b. changed and differentiated over time.
c. depleted in heavy elements.
d. original, pure, and unchanged since the beginning.

6. ____ Which of the following statements is true?
a. asteroids and comets have much more iridium in them than Earth's crust has.
b. asteroids and comets have similar amounts of iridium compared to Earth's crust.
c. asteroids and comets have much less iridium in them than Earth's crust has.
d. iridium is almost unknown in asteroids, comets, and Earth's crust.



FILL IN THE BLANKS

Fill in the blanks using the vocabulary term from the passage that best completes the sentence.

7. The fusion of hydrogen into helium requires extremely high _____ and _____ in the core of a star.

8. Earth has four major layers in its interior: crust, mantle, outer core, and inner core. The process that leads to the formation of these layers is called: _____

9. Write the vocabulary term that best describes the process of a nebula collapsing and coming together to form planets and a star. _____

SHORT ANSWERS

Briefly respond to each question in complete sentences.

10. Why did Carl Sagan describe us all as being made out of "star stuff" in the quote at the beginning of the passage?

11. Briefly explain why iridium is helpful as evidence that an asteroid or comet struck Earth at some point in the past.
