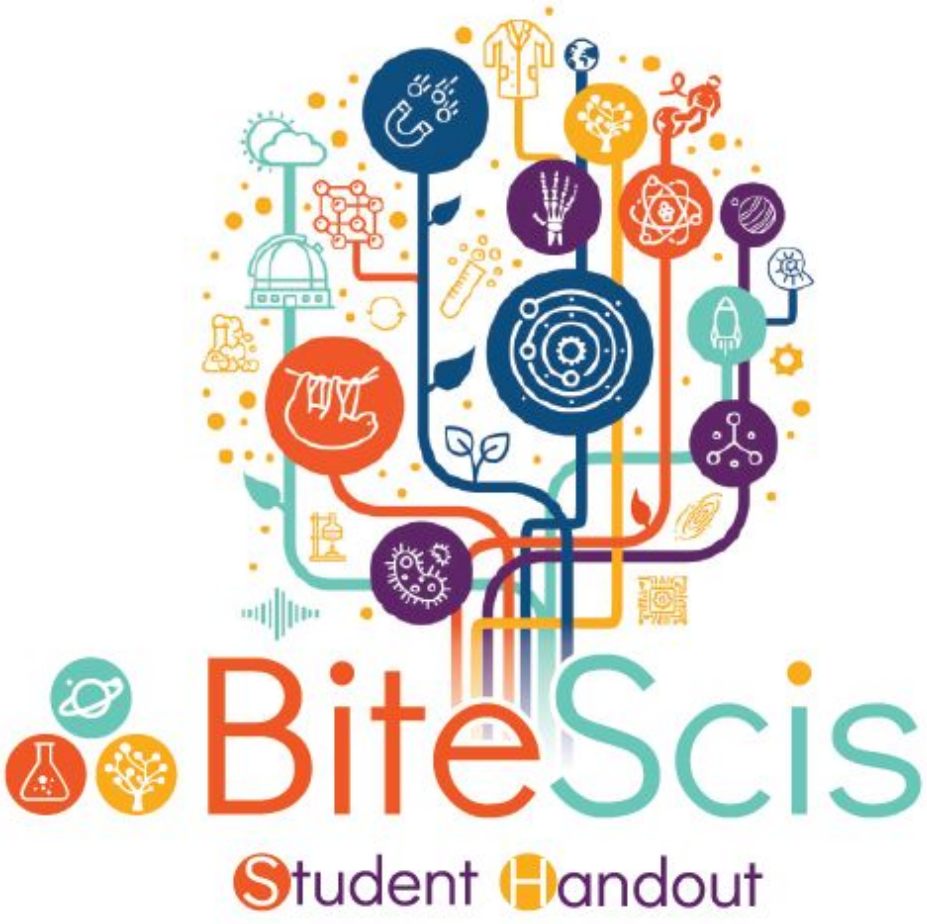

Molecular Energy and Earth's Atmosphere

What happens when a planet forms near a back hole?

BiteScis

Student Handout

Molecular Energy and Earth's Atmosphere

Introduction

One of the biggest questions in science is, "Why did life evolve on a planet like Earth and not on any other planets that we know of?" To some extent, the answer is simple—Earth has a rocky surface, thin atmosphere, and temperatures that can sustain liquid water. No other planet in our solar system has that combination of traits. Earth isn't just an oddball in our solar system, though. It's an oddball in the universe! Ninety-eight percent of matter in the universe is locked up in the two lightest elements, hydrogen and helium, in the form of gas or plasma. But 90% of Earth's mass is made up of relatively heavy elements such as iron, oxygen, silicon, and magnesium. And stranger still (as far as planets go), most of Earth's mass is in solid and liquid form, not gases. Sure, Earth's atmosphere is gaseous, which is important because we live our entire lives in this layer of air, but it is incredibly thin. Earth's atmosphere is less than 0.0001% of the planet's total mass! That's about the same percentage of your body's mass accounted for by the tip of your pinky fingernail! By comparison, our planetary neighbor Venus, which has about the same total mass as Earth, has an atmosphere about 100 times as massive.

What factors can contribute to making a rocky planet's atmosphere like Earth's, so thin? In this activity, you'll explore one factor very important in some regions of our galaxy: black holes.

What To Do

Answer the analysis questions below, reading the Bite when instructed.

Analysis Questions

1. While elements as diverse as neon, titanium, and even familiar elements like oxygen and iron have fantastic uses in biology and technology, most of these are exceedingly rare outside of Earth's surface. What elements comprise most of the universe's mass?

2. The introduction includes an analogy for the fraction of Earth's mass accounted for by its atmosphere.

   a. Explain the analogy.

   b. What do you think the purpose of the analogy is? Why does the author use it?

STOP & read Science Bite:
The Mystery of the Missing Atmosphere

3. Summarize and explain **Figure 1** in the Science Bite in your own words.

4. A student describes the process of photoevaporation by saying, “When a molecule in the atmosphere is struck by UV radiation, energy is created, causing the molecule to move much faster.”

a. What is wrong with this description?

b. What is a more accurate way to describe the process by which molecules’ kinetic energy increases during the photoevaporation process?

5. “Evaporation” usually means liquid molecules changing to gas molecules. How is the typical definition different from how the term evaporation is used in the Science Bite?

6. What are two possible sources of the energy required to cause photoevaporation of molecules in the atmosphere of rocky planets?

7. A common misunderstanding is that heat from the sun warms Earth by conducting heat directly from the sun to Earth. Using what you learned in the Science Bite, explain how the sun actually transfers energy to the Earth.

8. What is “escape velocity” and why is it important?

9. The escape velocity of Earth is about 11,000 m/s. A hydrogen molecule has a mass of approximately 1.7×10^{-27} kg. Calculate the minimum kinetic energy a hydrogen molecule needs to photoevaporate. Show your work and include units in your answer.

10. Earth is located near the edge of the Milky Way, far from the supermassive black hole at the center of the galaxy. Based on this information and the information from the Science Bite, do you think photoevaporation due to heating from the matter around a supermassive black hole is a significant cause of Earth's thin atmosphere? Support your answer with at least two pieces of evidence.

11. Is the amount of kinetic energy required for an oxygen molecule, which is about 16 times heavier than a hydrogen molecule, to photoevaporate greater than, less than, or equal to the amount needed for a hydrogen molecule to photoevaporate? Justify your choice.

12. **Connect to the Big Question.** Would hydrogen or oxygen be more likely to photoevaporate from Earth? Explain how you know. Why is this significant for human life?