

**“Goldilocks and the Three Planets”
Teacher Answer Key**

1. Explain what the Goldilocks problem is.

The Goldilocks problem asks the question: Why is Venus too hot, Mars too cold, and the Earth just right for liquid water?

2. Define the greenhouse effect and explain its impact on the Goldilocks problem.

Light from the Sun passes through the Earth's atmosphere and warms the surface of the Earth. The Earth then re-radiates the energy as infrared radiation. Certain gases in the atmosphere (particularly carbon dioxide and water vapor) absorb and re-radiate (are opaque to) infrared radiation. Thus, the infrared radiation (heat radiation) is trapped in the Earth's atmosphere, making the surface of the Earth and the lower atmosphere much warmer than it would be without the greenhouse effect.

Venus has too much greenhouse gas in its atmosphere, making it too hot. Mars has too little greenhouse gas in its atmosphere, making it too cold. The Earth has the right amount of greenhouse gas to maintain moderate temperatures.

3. Describe the carbon cycle and explain its impact on the Goldilocks problem.

In the carbon cycle, rainwater removes carbon dioxide from the atmosphere and deposits it in the Earth's crust. Volcanic action then releases carbon dioxide from the crust, putting it back into the atmosphere. A fully active carbon cycle acts like a thermostat, regulating a planet's climate and temperature.

The carbon cycle is incomplete on Venus because there is no liquid water; therefore, carbon dioxide emitted by volcanoes cannot be removed from the atmosphere and remains in the atmosphere, trapping heat and raising the temperature. The carbon cycle is broken on Mars because Mars has no active volcanoes to replenish the carbon dioxide in its atmosphere, and there is not enough carbon dioxide in its thin atmosphere to keep its surface warm. Due to the Earth's fully functioning carbon cycle, temperatures remain moderate. If it gets too hot, there will be more evaporation from the oceans, and, therefore, more precipitation will remove carbon dioxide from the atmosphere, and the Earth will cool down. If it gets too cold, less water will evaporate from the oceans, and, therefore, the amount of precipitation will decrease with less carbon dioxide removed from the atmosphere, and the Earth will heat up.

4. Explain why Venus is too hot, Mars too cold, and the Earth just right to support life.

Venus is too close to the Sun to retain water, which breaks its carbon cycle, leading to an overabundance of greenhouse gases in its atmosphere and a hot surface. Mars is too small to have a hot interior, therefore, there are no active volcanoes to pump greenhouse gases into

its atmosphere□ with no greenhouse insulation, it remains cold. Earth has water, volcanoes, and a fully functioning carbon cycle, thus temperatures remains moderate.