Name _____ Class _____ Date _____

CHAPTER 19 The Solar System

SECTION 3

Formation of the Solar System

KEY IDEAS

As you read this section, keep these questions in mind:

- How did early astronomers understand and describe the solar system?
- How did our solar system form?
- How did Earth's moon form?

How Has Our Understanding of the Solar System Developed?

Many ancient peoples watched for changes in the sky. Some used myths to explain star movements that they did not understand. Eventually, people began to use mathematical tools to make more accurate models of objects in the sky that they observed. Early questions about how the universe worked and how it was organized helped develop science and the scientific method.

READING TOOLBOX

Summarize After you read this section, create a Chain-of-Events chart to describe how the solar system formed, according to the nebular hypothesis.

EARLY ASTRONOMY

A group of stones in Nabta, Egypt, may be the oldest record of human interest in astronomy. Scientists and historians think people arranged the stones 6,000 to 7,000 years ago to line up with the sun at the summer solstice. Scientists think a group of stones at Stonehenge in England may be one of the world's oldest observatories.

Stonehenge may be one of the world's oldest observatories.

Talk About It

Infer Learn more about Stonehenge, the stones in Nabta, or other ancient objects that may have been used to track the movements of objects in the sky. Share what you learn with a partner or a small group.

A LIMITED VIEW OF THE UNIVERSE

For much of history, people could study only the parts of the universe they could see with the naked eye. This included the sun, the moon, some stars, and a few planets. Early astronomers thought these objects made up the entire universe. Therefore, early models of the universe included only objects in our solar system. ☑

READING CHECK

1. Explain Why didn't early astronomers know that the universe is larger than our solar system?

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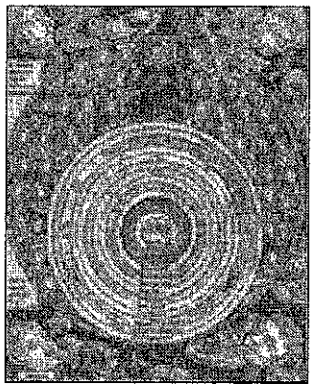
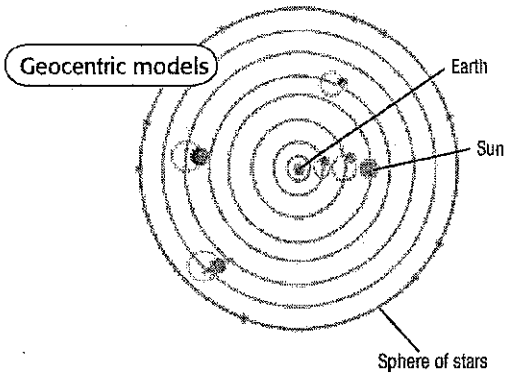
EARLY MODELS OF THE SOLAR SYSTEM

Like many people before them, the ancient Greeks observed the sky to keep track of time. However, they studied Earth's place in the universe in a new way. They used logic and mathematics, especially geometry. The Greek philosopher Aristotle made a model of the solar system in order to explain the phases of the moon and eclipses. His model was *geocentric*, or "earth-centered."

In 140 C.E., Ptolemy added to Aristotle's model. Ptolemy thought that the sun, moon, and planets orbited Earth in perfect circles. Although Ptolemy's model was incorrect, it helped astronomers predict many astronomical events and was used for more than a thousand years.





Before scientists were able to prove that Earth revolves around the sun, most people thought Earth was the center of the universe.

LOOKING CLOSER

2. Describe In the geocentric model of the solar system, where was Earth located?

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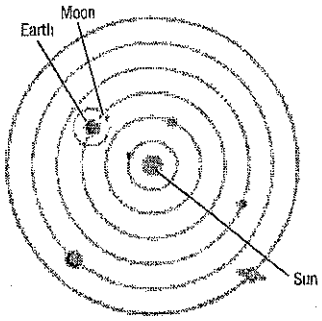
Ptolemy's model needed adjustments to make it work. Nicolaus Copernicus realized that these adjustments would not be needed if the sun was at the center of the solar system. In 1543, he proposed a *heliocentric*, or "sun-centered," model. In this model, Earth and the other planets orbit the sun in perfect circles.

In 1605, Johannes Kepler revised Copernicus's model. He proposed that the orbits of the planets are *ellipses*, or ovals, rather than circles. This model is similar to the one we use today.



Copernicus proposed that the planets orbit the sun in circular orbits.

ELLIPTICAL ORBITS EXPLAINED

Before 1687, scientists could describe the paths planets take around the sun, but they did not know why planets stayed in orbits. Sir Isaac Newton provided the answer. He explained that gravity keeps the planets in orbit around the sun and keeps satellites in orbit around planets. ☑

Newton's ideas did not apply only to planets in orbit. He stated that every object in the universe exerts a gravitational force on every other object. Newton proposed that everything in the universe follows the same rules and acts in predictable ways. His ideas form the basis for much of astronomy and physics.

How Did Our Solar System Form?

Scientists use the ages of meteorites to estimate the age of the solar system. They think the solar system formed about 4.6 billion years ago. How did it form? Like earlier scientists trying to explain the structure of the solar system, scientists studying its formation develop models. The currently accepted model is the **nebular hypothesis**. This model explains many features of the solar system.

THE NEBULAR HYPOTHESIS

A **nebula** is a large cloud of dust and gas in space. The nebular hypothesis states that planets formed when small particles in a nebula collided and stuck together. This process is called *accretion*. The nebular hypothesis also explains the following:

- why the terrestrial planets and gas giants differ in composition
- why the orbits of the planets are almost circular
- why the planets are almost in the same plane

LOOKING CLOSER

3. Identify Why is Copernicus's model of the solar system known as a heliocentric model?

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READING CHECK

4. Describe How did Sir Isaac Newton contribute to our understanding of astronomy?

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Critical Thinking

5. Explain What do you think is the reason that astronomers use models to learn about the formation of the solar system?

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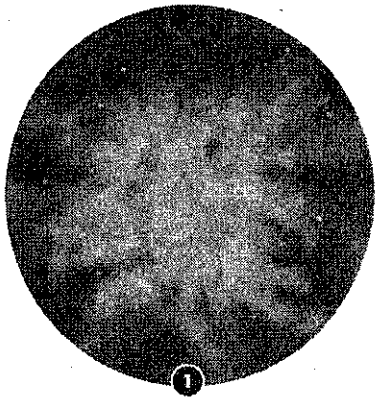
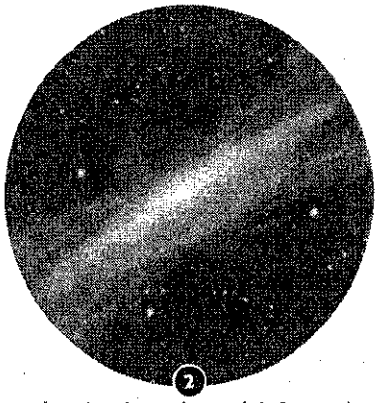
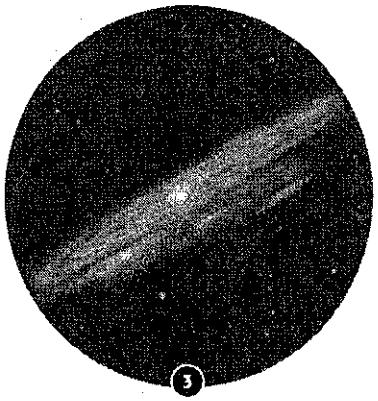
The Nebular Hypothesis



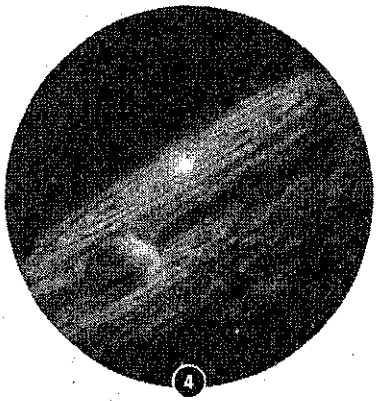
According to this model, the sun, like every star, formed from a cloud of dust and gas. Gravity caused the cloud to condense. For our solar system, this began about 4.6 billion years ago.



As the cloud condensed, it formed a disk. The material in the center of the disk became denser and hotter. This hot material started to form a star. As the nebula continued to collapse, it spun faster and faster.



Spinning caused the disk to flatten. Small particles began to collect in the disk. These particles collided to form larger objects that would become planets. These objects are called *planetesimals*.



As planetesimals grew, their gravitational pull grew. Their gravity pulled in even more gas and dust from the nebula.

LOOKING CLOSER

6. Identify About how long ago did our solar system begin to form?

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7. Define What were planetesimals?

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8. Describe How did the planets in the solar system form?

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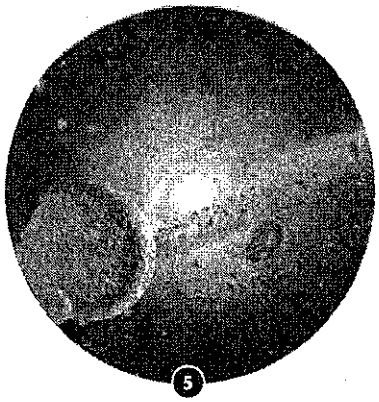
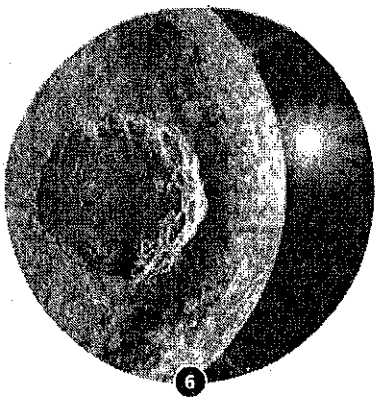


Small planetesimals collided with one another to form planets. The warmer inner planets were rocky. The colder outer planets collected gases in their atmospheres.



Because each planet had pulled in materials from around it, the orbits of the planets are separate from each other. Asteroids and other small objects are most likely left over from the formation of the solar system.

What Other Objects Are in Our Solar System?

There are many types of small objects, or bodies, in our solar system. These bodies include satellites, comets, asteroids, and meteoroids. *Satellites* are objects that orbit larger objects. **Comets** are small bodies made up of rock, ice, and dust that move around the sun in very elliptical orbits. *Asteroids* are small rocky objects found mainly between Mars and Jupiter. *Meteoroids* are smaller pieces of rock that move through space.

Critical Thinking

9. Compare How is a comet different from an asteroid?

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Why Do Scientists Study Comets?

Comets contain dust and ice made from methane, ammonia, carbon dioxide, and water. In 1994, pieces of the comet Shoemaker-Levy 9 hit Jupiter. The impacts showed that the comet also contained silicon, magnesium, and iron. By studying comets, scientists have learned more about the materials that make up the solar system. ☑

READING CHECK

10. Describe What can scientists learn by studying comets?

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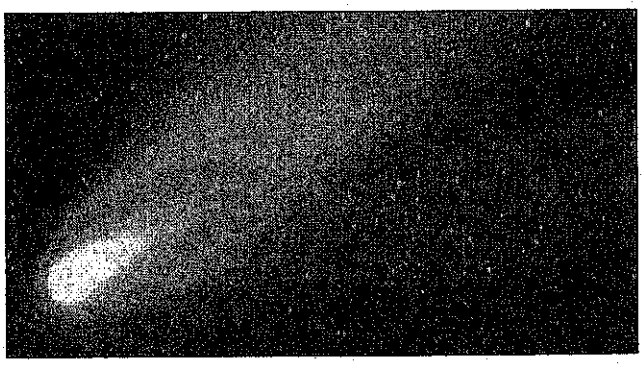
COMET TAILS

When a comet passes near the sun, the comet gives off gases that form a long tail. Some comets, such as the one below, have two tails. One is an ion tail made of charged particles. It always points away from the sun. The other is a dust tail that follows the comet's orbit.



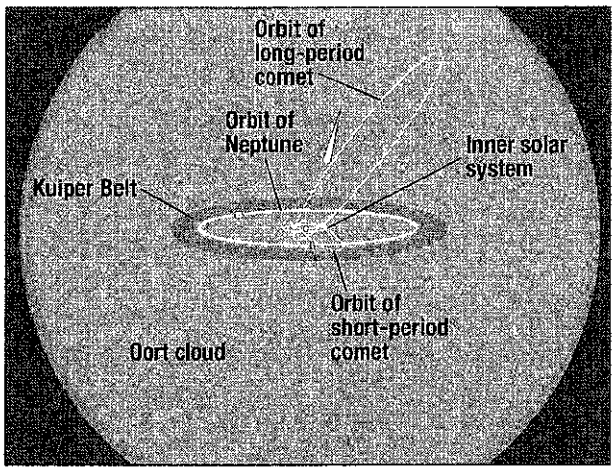
This photo shows the comet Hale-Bopp. The top streak is a dust tail. The bottom streak is an ion tail.

LOOKING CLOSER

11. Identify Label the ion tail and the dust tail on the photo.

Where Do Comets Come From?

As the solar system formed, some small planetisimals did not join with other planetisimals. Instead, they moved far away from the sun and developed very long orbital periods. These objects make up the Oort cloud of comets. The Oort cloud is shaped like a sphere and may be 100,000 AU wide.



The Oort cloud is a spherical region in the outer solar system beyond the Kuiper Belt.

LOOKING CLOSER

12. Identify Which is closer to the sun, the Kuiper Belt or the Oort cloud?

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Planetesimals that stayed in the nebula disk formed the Kuiper Belt. The Kuiper Belt is located beyond the orbit of the planet Neptune. Most of the small bodies in the Kuiper Belt are rocky and covered with ice. Most comets in our solar system come from this region. ☑

READING CHECK

13. Describe Where do most comets in our solar system come from?

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HALLEY'S COMET

Halley's comet is one of the most famous comets. Its orbit sometimes takes it out of the Kuiper Belt. The comet appears in Earth's sky once every 76 years. Compared to the orbits of other bodies in the solar system, Halley's comet orbits backward. Its orbit was probably affected by a planet's gravity.

What Are Meteorites?

Rocks and other objects in space frequently enter Earth's atmosphere. However, most of these objects burn up in Earth's atmosphere. Many of the large rocks from space that survive the trip through Earth's atmosphere come from asteroids. Rocks that reach Earth's surface are called *meteorites*.

READING CHECK

14. Identify What are the three main types of meteorites?

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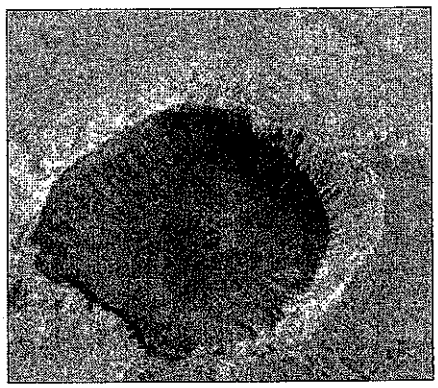
There are three major types of meteorites: stony, iron, and stony-iron. Stony meteorites contain rocky materials, carbon compounds, and water. Iron meteorites are made of iron and nickel. Stony-iron meteorites contain both rocky material and metallic material. Most known meteorites are stony. They have similar average compositions to Earth and the moon. ☑

EFFECTS OF METEORITE IMPACTS

Earth has close to 100 craters that are larger than 0.1 km in diameter. The crater in the figure below was made by a meteorite with a mass of about 200,000 metric tons (200,000,000 kg). The crater, called Barringer Crater, is more than 1 km wide and 175 m deep.



Barringer Crater in Arizona formed when a meteorite struck Earth's surface about 50,000 years ago.

LOOKING CLOSER

15. Identify What type of object formed Barringer Crater?

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Twenty-five metric tons (25,000 kg) of iron meteorite pieces, or fragments, have been found around Barringer Crater. Some of the meteorite vaporized at the impact. The rest was scattered, broken by weathering, or buried.

Many scientists think a large asteroid or comet hit Earth about 65 million yeas ago and caused the dinosaurs to become extinct. The impact may have released an amount of energy equal to that of 10 million hydrogen bombs. The impact would have thrown large amounts of dust into the atmosphere. The dust would have made the sky dark. Without enough light, plants, and the animals that ate them, could not survive. ☑

READING CHECK

16. Explain How could an asteroid or comet impact cause plants and animals far from the impact site to die out?

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How Did the Moon Form?

Before scientists knew what the moon was made of, they had several different theories to explain how it formed. Some thought that Earth's gravity trapped another object in the solar system. If this theory were correct, Earth and the moon would likely be made up of different materials. Other scientists thought the moon formed from the same material as Earth.

Scientists have found that Earth and the moon are made of similar, but not identical, materials. This has led scientists to a new theory for how the moon formed. According to this theory, the moon broke off from Earth when a large object hit Earth about 4.5 billion years ago.

THE EARLY EARTH

About 4.4 billion years ago, Earth was still forming. Much of Earth was *molten*, or melted. Dense materials, such as iron and nickel, sank to the center of the planet to form the core. Less-dense materials rose to the surface to form the mantle and crust.

Scientists think the moon formed from the materials in Earth's crust and mantle, along with iron from the object that hit Earth. This explains why Earth and the moon are made of similar, but not identical, materials.

Critical Thinking

17. Infer What materials make up Earth's core today?

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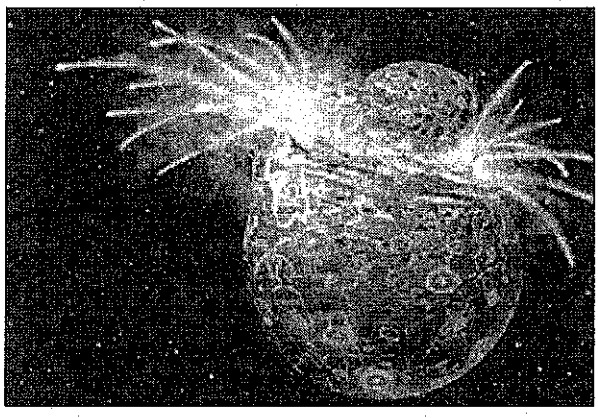
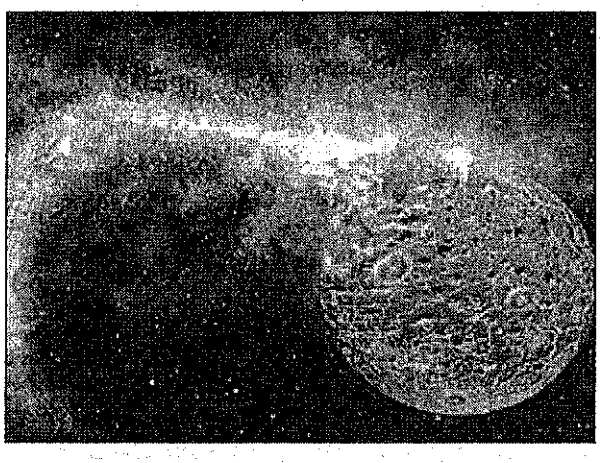


About 4.5 billion years ago, a Mars-sized object hit Earth. The impact threw a large part of Earth's mantle into space.



The pieces of the mantle that were thrown into space began to clump together. This debris consisted of iron core and mantle material from the object that hit Earth, and mantle material from Earth. The iron core became the core of the moon.

LOOKING CLOSER

18. Describe About how large was the object that struck Earth to form the moon?

_____

19. Identify Where did the iron in the moon's core probably come from?

_____

20. Infer What caused the material that was blown off of Earth to condense to form the moon?

_____

Earth's gravity pulled on the newly formed moon and caused it to revolve around Earth. After the moon cooled, asteroids and comets hit its surface, making large basins. The basins filled with lava and formed the maria. Smaller impacts on the moon's surface made craters.

What Is an Exoplanet?

Just as planets orbit our sun, other objects orbit other stars. Scientists call such objects exoplanets. An **exoplanet** is a planetlike object that orbits a star other than our sun. Scientists have found more than 200 exoplanets. ☑

READING CHECK

21. Define What is an exoplanet?

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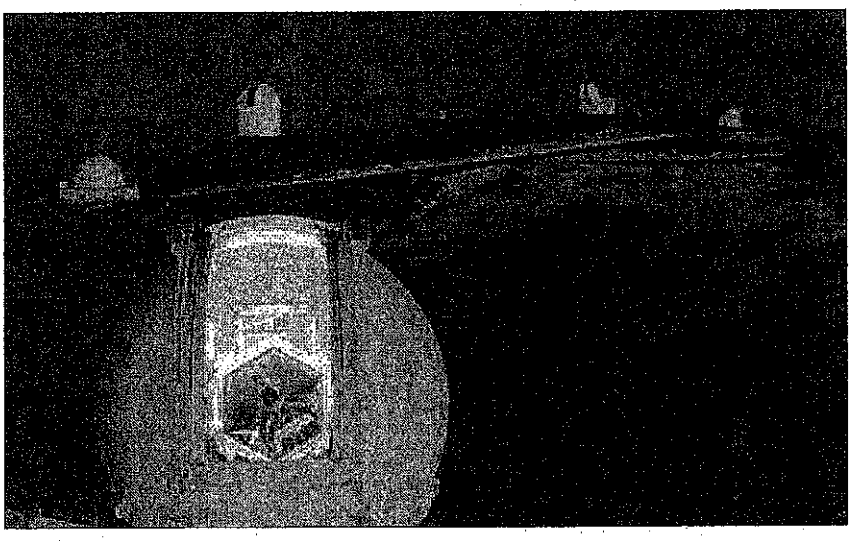
FINDING EXOPLANETS

Exoplanets are far too faint to see with optical telescopes. Thus, scientists must use other methods to find exoplanets.

Recall that every object in the universe exerts a gravitational force on every other object. As an exoplanet orbits its star, the exoplanet's gravitational forces pull on the star and cause it to wobble. Scientists find exoplanets by observing these wobble effects on stars.



The Keck telescopes and others like them help scientists find exoplanets.

Recall that objects with large masses exert more gravitational force than those with smaller masses. Thus, large exoplanets cause more star wobble than smaller exoplanets. Because of this, scientists have so far only been able to find large exoplanets. In fact, almost all of the newly discovered exoplanets have masses similar to those of Jupiter or Saturn. However, it is likely that small exoplanets do exist, and scientists are working on ways to find them.

Critical Thinking

22. Explain If exoplanets are too small to be seen with telescopes, how can telescopes help scientists identify exoplanets?

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Name _____ Class _____ Date _____

Section 3 Review

SECTION VOCABULARY

comet a small body of ice, rock, and cosmic dust that follows an elliptical orbit around the sun and that gives off gas and dust in the form of a tail as it passes close to the sun

exoplanet a planetlike body that orbits a star other than the sun

nebula a large cloud of dust and gas in interstellar space; a region in space where stars are born

nebular hypothesis a model for the formation of the solar system in which the sun and planets condense from a cloud (or nebula) of gas and dust

1. **Compare** Complete the table below to describe different models of the solar system that have been used throughout history.

Model proposed by	Geocentric or heliocentric?	Shape of orbits
Aristotle		not considered
Ptolemy		
Copernicus		perfect circles
Kepler		

2. **List** Identify four types of objects that are found in the solar system.

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3. **Identify** What is the approximate age of the solar system?

_____

4. **Summarize** State briefly how the objects in the solar system formed according the nebular hypothesis.

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5. **Explain** Why are scientists more likely to find large exoplanets than small exoplanets?

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