OpenStax Astronomy, Ch.12: WS Solutions (Apr-2021)

Solutions

1. What is the evidence for a liquid water ocean on Europa, and why is this interesting to scientists searching for extraterrestrial life?

   The surface of Europa features jagged blocks of ice that seem to have rotated and collided with one another, which would not likely happen on a solid moon. Long, straight cracks in the crust are also more likely to happen over a liquid subsurface layer than a solid one. Also, a weak magnetic field implies the presence of a liquid layer below the surface. This is interesting for searchers of extraterrestrial life because liquid water is essential for life as we know it, and life seems to exist in most places on Earth where liquid water is found. For example, life is found near vents on the deep ocean floor where chemical energy from hot springs can serve as a source of energy.

2. Explain the energy source that powers the volcanoes of Io.

   Io is close enough to Jupiter (and caught between Jupiter and the large moons on the other side of Io) to experience significant tidal heating, where the moon alternately stretches and relaxes in its elliptical orbit about the planet. This generates enough heat to produce molten silicate lava that erupts as volcanoes.

3. Compare the properties of Titan’s atmosphere with those of Earth’s atmosphere.

   Titan’s atmosphere is four times denser than Earth’s atmosphere at the surface, even though both atmospheres are mostly nitrogen. However, 20% of Earth’s atmosphere is oxygen; Titan’s atmosphere is 98% nitrogen, with no free oxygen in it. Methane makes up 1.5% of the atmosphere, and it also has small amounts of various other organic gases, including ethane, carbon monoxide, and hydrogen cyanide. Both atmospheres have a weather cycle of evaporation from surface liquid, formation of clouds, and precipitation back onto the surface, but Earth’s cycle is water-based and Titan’s cycle is hydrocarbon-based (methane and probably ethane).

4. How was Pluto discovered? Why did it take so long to find it?

   Pluto was discovered at Lowell Observatory by a young, relatively untrained Clyde Tombaugh, from comparisons of photographs taken several days apart that showed the relative motion of Pluto against a background of stars. Pluto was difficult to find because of its small size and great distance from Earth. Although Percival Lowell had suggested that Pluto could be found by its effects on the orbits of other outer planets such as Uranus and Neptune, in fact a planet with so little mass could not be pinpointed by its gravitational effects. It was just luck that Pluto was found where Tombaugh had been told to search.

5. How are Triton and Pluto similar?

   Both Triton and Pluto are very cold worlds in the outer reaches of the solar system. They are similar in size (between 2000 and 3000 km) and similar in density, and thus similar in the proportion of rock and ice that makes them up. Both have a thin atmosphere of nitrogen, which freezes and sublimates depending on the temperature. Both have irregular or unusual orbits, with Triton moving in a retrograde orbit (unique for a larger-size moon) and Pluto in a tilted, highly elliptical orbit. Astronomers think that Triton may be a captured moon from the realm of trans-neptunian dwarf planets like Pluto.

6. Describe and compare the rings of Saturn and Uranus, including their possible origins.

Saturn's rings form a wide and complex system, consisting mostly of particles and pieces of ice, and are highly visible. They may have formed from one or more moons that broke up due to a collision, or are left over from early debris that never coalesced into a moon. The rings of Uranus are thin and hard to see, consisting mostly of chunks of carbon and hydrocarbons with very little reflectivity. They may also have formed from the breakup of a small moon due to a collision. They may be kept thin by the presence of shepherd moons.

7. List at least three major differences between Pluto and the terrestrial planets.

Pluto is much smaller than all the terrestrial planets (and even smaller than many of the big moons of the giant planets). Its composition is ice and rock as opposed to the composition of rock and metal of the terrestrial planets. Pluto's orbit is highly elliptical and inclined to the plane of the ecliptic as opposed to the circular orbits near the plane of the ecliptic for the terrestrial planets. Pluto has a thin and variable atmosphere of nitrogen, while three of the terrestrial planets have much thicker and warmer permanent atmospheres. (Nitrogen dominates Earth's atmosphere, while carbon dioxide dominates the atmospheres of Venus and Mars. Mercury has only a very thin "temporary" atmosphere, borrowed from the solar wind.) Pluto is but one object of many (including some of the same size as Pluto) in the Kuiper Belt, whereas each of the terrestrial planets dominates the mass in their respective orbits.

8. The Hubble Space Telescope images of Pluto in 2002 showed a bright spot and some darker areas around it. Now that we have the close-up New Horizons images, what did the large bright region on Pluto turn out to be?

The bright spot turned out to be what has been nicknamed Sputnik Planum (the Sputnik Plains). It appears to be a bowl or sea of frozen and perhaps liquid nitrogen, much brighter and younger (no craters visible) than the darker highlands of Pluto.

9. Why do you think the outer planets have such extensive systems of rings and moons, while the inner planets do not?

The outer planets are larger (and more massive) than the inner planets and have wider spaces between them. Hence, they were able to accrete more material from the solar nebula, material that has presumably become the rings and moons that we see today. Since the temperatures are much cooler in the outer solar system than in the inner solar system, ices form in the outer solar system, and we see them composing (at least in part) the outer planets' moons and rings. This is the current theory, but no one is completely certain as to how these rings and moons formed.

10. Would you expect to find more impact craters on Io or Callisto? Why?

There are many more impact craters on Callisto because the impact craters on Io are removed relatively rapidly by surface deposits from volcanic activity. This is true even though craters form more frequently on Io than on Callisto, owing to the focusing effect of Jupiter's gravity on incoming projectiles. The rate of destruction is a far more important factor than the rate of formation of impact craters.

11. Why do you suppose the rings of Saturn are made of bright particles, whereas the particles in the rings of Uranus and Neptune are black?

Astronomers do not know the answer to this question! But one possibility is that the rings of Saturn were formed from the breakup of a parent body that was nearly pure water ice, while the rings of Uranus and Neptune are made of the dark organic material that is common in the outer solar system.

12. Suppose you miraculously removed all of Saturn’s moons. What would happen to its rings?

The rings would gradually expand (grow larger) in the plane they now occupy if the gravity of the inner moons were not present to confine their orbits.

13. Saturn's A, B, and C Rings extend 75,000 to 137,000 km from the center of the planet. Use Kepler's third law to calculate the difference between how long a particle at the inner edge and a particle at the outer edge of the three-ring system would take to revolve about the planet.

From Kepler's third law, as discussed in the chapter on Orbits and Gravity, and with P = period and a = semimajor axis (the average radius of an elliptical orbit), we have $\frac{P_{\text{outer}}}{P_{\text{inner}}} = \left(\frac{a_{\text{outer}}}{a_{\text{inner}}}\right)^{1.5} = \left(\frac{137{,}000\ \text{km}}{75{,}000\ \text{km}}\right)^{1.5} = 2.5$. Therefore, the outer ring particles take roughly 2.5 times longer to revolve about Saturn than the inner ring particles.