OpenStax Astronomy, Ch.8: WS Solutions (Apr-2021)

Solutions

1. What are Earth's core and mantle made of? Explain how we know.

   The mantle is rock, which we know from chemical analysis of samples from upper mantle material that is ejected occasionally from volcanoes. The structure, density, and size of the core can be determined by analyzing the seismic waves traveling through Earth's interior. Based on our understanding of planetary formation, internal differentiation, the calculated density of the core, and the relative abundances of chemical elements in the solar system, scientists conclude that the core consists of heavy elements. The elements residing in the core are primarily, but not limited to, iron and nickel.

2. What is the source of Earth's magnetic field?

   The rotation and internal circulation of Earth's iron and nickel core creates what is, in effect, an electric current. As we know from the study of electromagnetism, it is electric charges in motion that generate a magnetic field.

3. Why is the shape of the magnetosphere not spherical like the shape of Earth?

   Charged particles from the Sun (known as the solar wind) moving at high velocities interact with the magnetic field, compressing it in the direction of the Sun and elongating the field away from the Sun.

4. Although he did not present a mechanism, what were the key points of Alfred Wegener's proposal for the concept of continental drift?

   Wegener observed on a global map that the shapes of the continental coastlines fit together. He noted the similarities of animal species currently living on widely separated continents, along with the similarities of fossils found only in South America and Africa.

5. List the possible interactions between Earth's crustal plates that can occur at their boundaries.

   Rift zones, where plates pull apart; subduction zones, where one plate slides over another; faults, where plates slide alongside each other; and last, plates can collide and crumple, creating mountains.

6. In which atmospheric layer are almost all water-based clouds formed?

   In the lowest layer, the troposphere.

7. What is, by far, the most abundant component of Earth's atmosphere?

   At 78%, it is molecular nitrogen, N_2.

8. Briefly describe the greenhouse effect.

   Sunlight penetrates to Earth's lower atmosphere and surface and is reradiated as infrared or heat radiation, which is then trapped by greenhouse gases in the atmosphere. The result is a higher surface temperature for the planet.

9. How do impacts by comets and asteroids influence Earth's geology, its atmosphere, and the evolution of life?

   Impacts by comets and asteroids can create large explosions and propel dust and debris into the atmosphere, potentially causing mass extinction events such as the

one that included the extinction of the dinosaurs. Early life on Earth had to survive the high temperatures and subsequent loss of sunlight that resulted from such impacts. And, as life evolved, species had to survive occasional local and global catastrophes.

10. Why are there so many impact craters on our neighbor world, the Moon, and so few on Earth?

The Moon experiences no geological changes, and so it retains all evidence of impacts. There is no atmosphere or surface water in liquid form on the Moon. In contrast, the ever-changing geography, weather, and erosion on Earth gradually erases the evidence of impacts.

11. Detail some of the anthropogenic changes to Earth's climate and their potential impact on life.

Although many of humankind's industrial activities affect the atmosphere, such as the release of sulfur dioxide, which can eventually result in acid rain, it is the pumping of massive amounts of CO2 into the air that causes the most concern. CO2 is a greenhouse gas that traps heat in our atmosphere, raising the temperatures of the surface and lower atmosphere. This increased average temperature is having and will have many effects, such as the melting of glaciers and polar ice. This will raise sea levels, inundating coastal cities and low-lying areas with seawater, eventually displacing millions of people. The increased heat also means increased energy available to drive severe weather events, such as hurricanes. The heating also raises the temperature of the oceans. It is known that corals prefer a fairly narrow range of temperatures, and many coral reefs worldwide are dying as a result. Also, CFCs have been destroying parts of our planet's ozone layer. Of course, there are other potential effects that have yet to be seen.

12. Why is a decrease in Earth's ozone harmful to life?

Ozone blocks solar ultraviolet radiation from reaching Earth's surface. If the ozone decreases, the level of ultraviolet radiation reaching the planet increases, with potentially serious negative effect on Earth's ecology (including our own health). Many plants cannot survive a significant increase in ultraviolet radiation, and animals (including humans) would be subject to increased cancer rates.

13. Do you think scientists should make plans to defend Earth from future asteroid impacts? Is it right to intervene in the same evolutionary process that made the development of mammals (including us) possible after the big impact 65 million years ago?

Most people think yes. Carl Sagan went so far as to write that the ability to deal with the impact hazard is the one requirement we know for a truly long-lived civilization (if other planetary systems are like our own). To survive, a civilization must eventually learn to protect itself from asteroid and comet impacts, and become space-faring, so that at least some part of the species' gene pool is not always located on the same world (sort of not putting all our eggs in one basket). Humans are interfering with evolution on Earth in many ways already, changing other species, causing the extinction of a variety of life-forms, and so on. Protecting the planet from outside hits may not seem so bad when you consider the alternative.

14. Europe and North America are moving apart by about 5 m per century. As the continents separate, new ocean floor is created along the mid-Atlantic Rift. If the rift is 5000 km long, what is the total area of new ocean floor created in the Atlantic each century? (Remember that 1 km = 1000 m.)

The new area added to the Atlantic is equal to the length of the rift times the rate of spreading. In one century, this is 5000 km, which equals 5,000,000 m × 5 m, or 25,000,000 m2. Since there are 1 million (1000 × 1000) m2 in a km2, this new area

amounts to about 20 km2/century, or 0.2 km2/y. This annual addition of area is about equivalent to 40 football fields.

15. Suppose a major impact that produces a mass extinction takes place on Earth once every 5 million years. Suppose further that if such an event occurred today, you and most other humans would be killed (this would be true even if the human species as a whole survived). Such impact events are random, and one could take place at any time. Calculate the probability that such an impact will occur within the next 50 years (within your lifetime).

The postulated average interval between major impacts is 5 million years. Say, just for the sake of easy math, that you have a life expectancy of at least 50 more years, so the chance of one of these random events taking place during your lifetime is about 50 in 5,000,000, or 1 in 100,000.

16. How do the risks of dying from the impact of an asteroid or comet compare with other risks we are concerned about, such as dying in a car accident or from heart disease or some other natural cause? (Hint: To find the annual risk, go to the library or internet and look up the annual number of deaths from a particular cause in a particular country, and then divide by the population of that country.)

In a given year, the chances of an individual dying from an impact are in 1 in 1,000,000. In the United States, about 40,000 people die each year from auto accidents, about 30,000 from gunshots, and only about 10 from lightning strikes. In these examples, the chance of dying for each individual in a year is the number of deaths divided by the U.S. population, or about one in 10,000 for autos and guns, or one in 20 million for lightning. To give another example, the chances of being killed as the result of a nuclear accident are much less than the chance of death from a major impact.

17. What fraction of Earth's volume is taken up by the core?

The radius of the core is about 3500 km and the radius of the whole Earth is 6378 km. The fraction taken up by the core is the ratio of the volume of the core divided by the volume of Earth, which is simply the ratio of the radii cubed:

$$\frac{v_{core}}{v_{Earth}} = \frac{(3500\ \text{km})^3}{(6378\ \text{km})^3} = \frac{4.28 \times 10^{10}}{2.59 \times 10^{11}} = 0.165$$

. Thus, the core makes up roughly 16.5% of Earth's total volume.