

Solutions to Assignment 5

by Elijah L. Quetin
email questions to: elquetin@physics.ucsb.edu

- 1** (a) If you look at Figure 5-24 in the text you will see a diagram of the Hydrogen atom with transitions labeled by the wavelengths of the photon emitted in those (downward) transitions. To find the frequencies we use the equation relating the speed of light to the wavelength and the frequency. The transition from the third to the second energy level emits a photon at 656 nm (in the visible range), so

$$\nu_{32} = \frac{c}{\lambda_{32}} = \frac{3 \times 10^8 \text{ m/s}}{6.56 \times 10^{-7} \text{ m}} = 4.57 \times 10^{14} \text{ Hz}$$

- (b) Similarly, the transition from the second to the first energy level emits a photon at 122 nm, so the frequency there will be

$$\nu_{21} = \frac{c}{\lambda_{21}} = \frac{3 \times 10^8 \text{ m/s}}{1.22 \times 10^{-7} \text{ m}} = 2.46 \times 10^{15} \text{ Hz}$$

- (c) The frequency of the transition from the third orbital all the way to the first can be found simply by adding the two frequencies from parts a and b. (Note: This does not work for adding the wavelengths, do you know why?) Thus

$$\nu_{31} = \nu_{32} + \nu_{21} = 4.57 \times 10^{14} \text{ Hz} + 2.46 \times 10^{15} \text{ Hz} = 2.92 \times 10^{15} \text{ Hz}$$

and the wavelength will be

$$\lambda_{31} = \frac{c}{\nu_{31}} = \frac{3 \times 10^8 \text{ m/s}}{2.92 \times 10^{15} \text{ Hz}} = 1.03 \times 10^{-7} \text{ m} = 103 \text{ nm}$$

which falls in the UV part of the electromagnetic spectrum and the energy of this photon will be

$$E = h\nu = (6.62 \times 10^{-34} \text{ Js})(2.92 \times 10^{15} \text{ Hz}) = 1.93 \times 10^{-18} \text{ J}$$

- 2** In the Nebular model of the formation of the solar system, stars and planets are formed out of a nebula of gas and dust that contracts under gravitation attraction. (If it is to form a solar system, the nebula must have some net angular momentum.

This allows for material to orbit the protosun and eventually form planets instead of falling into it.)

There are two major reasons that small terrestrial planets form close to the sun and large gaseous planets form farther away. First remember that most of the matter in the universe, including the nebula in question, is made up of the two lightest elements, Hydrogen and Helium. This means that there is much more material available to form gaseous planets than solid ones. All of the heavier elements are created as byproducts of nuclear fusion in stars and in exploding stars called supernovae. Thus the heavier elements are much more rare. The reason that the terrestrial planets are close to the Sun and the gaseous planets are far from it is that the protosun is very hot. The heat near the protosun vaporizes the lighter elements while the heavier elements stay in their solid state (rocks). The solid elements can stick together and form rocky planets. Far away from the protosun, where things are much cooler, the lighter elements can also be in a solid state (ice) and thus stick together and form planets. In the core accretion model the cores then accrete cool gas, while in the disk instability model the cores form much faster due to overdense regions, much like how stars form.

Within the last 10 years, we have detected scores of extrasolar planets. Models of the formation of the solar system can thus be tested against other solar systems. Do they look like ours with terrestrial planets close in and gas giants farther out?

- 3** (a) The Earth is 33 C (or K) warmer than it would be with no atmosphere. (b) The atmosphere contains carbon dioxide, which is less transparent to infrared radiation than it is to visible radiation. Of course, the Sun radiates brightest in visible range (due to its surface temperature) and the Earth radiates brightest in the infrared. Thus the Earth can receive energy from the Sun, but it can't reradiate all of it back into space. (c) Venus is very hot not only because it is closer to the Sun (which means more energy flux falls onto its surface) but because it has a very thick carbon dioxide atmosphere, which gives rise to a large greenhouse effect.
- 4** Mars has no plate tectonics. Thus Mars (and Venus, which also has no plate tectonics) don't exhibit any island chains or mountain ranges. Chains of islands like Hawaii or the Aleutian Islands are created where a hot spot (an upwelling of magma from the Earth's core) changes its position due to the shifting of plates. Mars does have a hot spot, but since it doesn't move it creates a single very large mountain. The tallest mountain in the solar system is called Olympus Mons on Mars. How much taller than Mt. Everest is it?
- 5** Ozone is a molecule that is very effective at absorbing UV radiation from the Sun. Humans as well as other animal and plant life developed in an environment with very little UV radiation and thus we are especially sensitive to large doses of UV

(ever had a bad sunburn?). Since the atmosphere is ideally transparent in the visible but not in the UV we are protected from these harmful UV rays. Depletion of the layer of ozone (by CFCs and other Chlorine or Bromine based compounds in the stratosphere) makes the atmosphere more transparent to UV and leads to cancers and other problems in life forms on Earth.

6 a) The Kyoto Protocol, initiated in 1997, aims to reduce global carbon and other Greenhouse gas emissions by 5% from their 1990 levels between the years of 2008 and 2012. The US is the only developed country that has not yet signed to the terms of the Kyoto protocol.

b) The Montreal Protocol, initiated in 1987, aims to eventually phase out all chemicals that are responsible for ozone depletion. Its initial goal was to reduce emissions of the most dangerous chemical to zero by 1996 and other less dangerous ones by 2010. The Montreal Protocol has been extremely effective in reducing ozone depleting chemical emission and it is thought that the ozone layer may recover within the next century. See Google or the library for further information.

7 You cannot stand on Jupiter and a boat won't do you much good either. Jupiter has a thick Hydrogen and Helium atmosphere, covering a very large volume of metallic Hydrogen. In the central regions of Jupiter a very fancy submarine might do you some good, although it would have to withstand the enormous pressure due to the atmosphere above it. At the very center is indeed a rocky core, but standing there would be hopeless as it may be hotter than the surface of the Sun!

8 The composition of the rings of Saturn is mainly rock and ice in pieces 1 cm to 5 m across, mostly in the 10 cm range. We can find the size of these rocks by taking the spectrum of reflected light off of the rings. Light with wavelengths longer than the size of the rocks will go through, while wavelengths the same size or shorter will be reflected.

The rings are only a few tens of meters thick, relative to their orbital diameter of 274,000km makes their thickness to area ratio thousands of times smaller than that for the paper in your Astro book. See P. 318.