ChemQuest 10

Bohr's Atomic Model

Name: ______________________________

Date: ________________

Hour: _____

Information: Bohr's Solar System Model of the Atom

All the planets are attracted to the sun by gravity. The reason that the Earth doesn't just float out into space is because it is constantly attracted to the sun. Similarly, the moon is attracted to the Earth by Earth's gravitational pull. So all of the planets are attracted to the sun but they never collide with the sun.

Negative charges are attracted to positive ones. Therefore the negative electrons in an atom are attracted to the positive protons in the nucleus. In the early 1900's scientists were looking for an explanation to a curious problem with their model of the atom. Why don't atoms collapse? The negative electrons should collapse into the nucleus due to the attraction between protons and electrons. Why doesn't this happen? Scientists were at a loss to explain this until Neils Bohr proposed his "solar system" model of the atom.

Critical Thinking Questions: Bohr's reasoning

1. Consider swinging a rock on the end of a string in large circles. Even though you are constantly pulling on the string, the rock never collides with your hand. Why is this?
   The rock must move so quickly that the pull from your hand is not enough to pull the rock into your hand. If you were to let go, it would fly away from you in a straight line. The pull from your hand keeps the rock near you, but because of its initial velocity it doesn't get closer to you.

2. Even though the Earth is attracted to the sun by a very strong gravitational pull, what keeps the Earth from striking the sun?
   The fact that the earth is moving keeps it from striking the sun. The earth would move away from the sun, but the gravity of the sun attracts it, causing a circular orbit for the earth.

3. Why doesn't the moon strike the Earth?
   The reasoning is the same as that for questions 1 and 2.

4. How could it be possible for electrons to not "collapse" into the nucleus?
   The electrons must be moving in orbits so fast that the pull from the nucleus is not enough to attract them toward the nucleus—this is Bohr's "solar system model" of the atom.

Information: Light

Recall that light is a wave. White light is composed of all the colors of light in the rainbow. All light travels at the same speed (c), 3.00×10^8 m/s. (The speed of all light in a vacuum is always equal to 3.0×10^8 m/s.) Different colors of light have different frequencies (f) and wavelengths (λ). The speed (c), frequency (f) and wavelength (λ) of light can be related by the following equation:

$$c = f \quad \lambda$$

It is important that the wavelength is always in meters (m), the speed is in m/s and the frequency is in hertz (Hz). Note: 1 Hz is the inverse of a second so that 1 Hz = 1/s.

Critical Thinking Questions

5. As the frequency of light increases, what happens to the wavelength of the light?
   As the frequency increases, the wavelength must be smaller. This is because the frequency times the wavelength must always equal 3.00×10^8 m/s.

6. What is the frequency of light that has a wavelength of 4.25×10^{-8} m?

$$c = f \quad \lambda \rightarrow f = \frac{c}{\lambda} = \frac{3.00x10^8\, m/s}{4.25x10^{-8}\, m} = 7.06x10^{15}\, Hz$$

7. What is the wavelength of light that has a frequency of 3.85×10^{14} Hz?

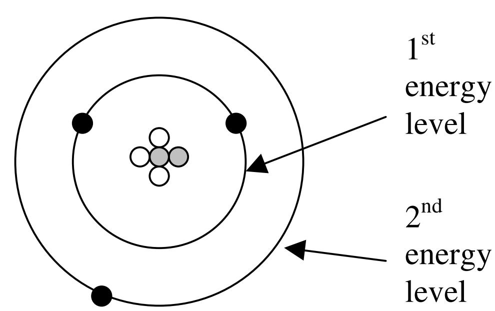
$$c = f \quad \lambda \rightarrow \lambda = \frac{c}{f} = \frac{3.00x10^8\, m/s}{3.85x10^{14}\, Hz} = 7.79x10^{-7}\, m$$

Information: Energy levels

After Bohr proposed the Solar System Model (that electrons orbit a nucleus just like planets orbit the sun), he called the orbits "energy levels".

Consider the following Bohr model of a Boron atom:

○ = proton (positive charge)
● = electron (negative charge)
◐ = neutron (no charge)



Higher energy levels are further from the nucleus. For an electron to go into a higher energy level it must gain more energy. Sometimes the electrons can absorb light energy. (Recall that different colors of light have different frequencies and wavelengths.) If the right color (and therefore, frequency) of light is absorbed, then the electron gets enough energy to go to a higher energy level. The amount of energy (E) and the frequency (f) of light required are related by the following equation:

$$E = h \quad f$$

E is the energy measured in Joules (J), f is the frequency measured in Hz, and h is Planck's constant in units of J/Hz which is the same as J-second. Planck's constant, h, always has a value of 6.63×10^{-34} J-s.

An electron that absorbs energy and goes to a higher energy level is said to be "excited." If an excited electron loses energy, it will give off light energy. The frequency and color of light depends on how much energy is released. Again, the frequency and energy are related by the above equation. When an excited electron loses energy, we say that it returns to its "ground state". Since not all electrons start out in the first energy level, the first energy level isn't always an electron's ground state.

Critical Thinking Questions

8. Does an electron need to absorb energy or give off energy to go from the 2nd to the 1st energy level?
   It needs to give off energy to go to a lower energy level.
9. How is it possible for an electron go from the 3rd to the 4th energy level?
   The electron must absorb energy to go to a higher energy level.

10. Red light of frequency 4.37 x 10^{14} Hz is required to excite a certain electron. What energy did the electron gain from the light?

$$E = h\ f = (6.63x10^{-34})(4.37x10^{14}) = 2.90x10^{-19}\,J$$

11. The energy difference between the 1st and 2nd energy levels in a certain atom is 5.01 x 10^{-19} J. What frequency of light is necessary to excite an electron in the 1st energy level?

$$E = h\ f \rightarrow f = \frac{E}{h} = \frac{5.01x10^{-19}}{6.63x10^{-34}} = 7.56x10^{14}\,Hz$$

12. a) What is the frequency of light given off by an electron that loses 4.05 x 10^{-19} J of energy as it moves from the 2nd to the 1st energy level?

$$E = h\ f \rightarrow f = \frac{E}{h} = \frac{4.05x10^{-19}}{6.63x10^{-34}} = 6.11x10^{14}\,Hz$$

    b) What wavelength of light does this correspond to (hint: use c = f λ)?

$$c = f\ \lambda \rightarrow \lambda = \frac{c}{f} = \frac{3.00x10^{8}\,m/s}{6.11x10^{14}\,Hz} = 4.91x10^{-7}\,m$$

13. Do atoms of different elements have different numbers of electrons?
    Yes, atoms of different elements have different numbers of electrons, just as they have different numbers of protons.

14. If all of the electrons in atom "A" get excited and then lose their energy and return to the ground state the electrons will let off a combination of frequencies and colors of light. Each frequency and color corresponds to a specific electron making a transition from an excited state to the ground state. Consider an atom from element "B". Would you expect the excited electrons to let off the exact same color of light as atom "A"? Why or why not?
    A different color would be let off because atom B and atom A have different numbers of electrons. Therefore, we would expect at least a slight difference in colors that are let off.