

MODERN PHYSICS

QUESTIONS AND PROBLEMS SPECTROSCOPY

Use the energy level diagram to the right to answer the following four questions:

- What are the highest and lowest energy photons that could be produced by this atom?

lowest $\Delta E = .9 \text{ eV}$

highest $\Delta E = 9.6 \text{ eV}$

- If an electron were in the highest energy level, how many different types of photons could be produced? Illustrate by drawing arrows, on the diagram, indicating all of these possible transitions.

10

- The range of wavelengths for light is roughly:

$< 4 \times 10^{-7} \text{ m} \Rightarrow \text{ultraviolet}$

$4 \times 10^{-7} \text{ m} - 5 \times 10^{-7} \text{ m} \Rightarrow \text{blue}$

$5 \times 10^{-7} \text{ m} - 6 \times 10^{-7} \text{ m} \Rightarrow \text{green}$

$6 \times 10^{-7} \text{ m} - 7 \times 10^{-7} \text{ m} \Rightarrow \text{red}$

$> 7 \times 10^{-7} \text{ m} \Rightarrow \text{infrared}$

Energy ranges
 $E_f > 3.1 \text{ eV}$

$2.48 < E_f < 3.1$

$2.067 < E_f < 2.48$

$1.77 < E_f < 2.067$

$E_f < 1.77$

Using this information, determine which of the possible transitions leads to photons that are infrared, visible, or ultraviolet. If they are visible, list their color.

UV
5-2 4-2 3-1
5-1 4-1 2-1

Blue
3-2 5-3

Green

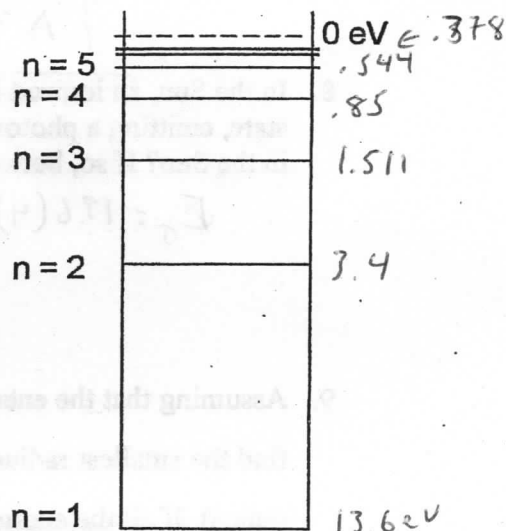
Red

IR

5-4
4-3

To the right is the energy-level diagram for Hydrogen. Lots of scientists have studied the hydrogen spectrum because hydrogen is the most abundant element in the universe. All stars mostly consist of Hydrogen atoms. The hydrogen spectrum is divided into different series, named after the men who studied them.

- Lyman Series: All frequencies where the electron drops to $n = 1$ state.
- Balmer Series: All frequencies where the electron drops to $n = 2$ state.
- Paschen Series: All frequencies where the electron drops to $n = 3$ state.



- Find the color of the 4 visible spectral lines that constitute the Balmer Series.

3-2: $E_f = 1.89$ red

4-2: $E_f = 2.55$ blue/green

5-2: $E_f = 2.856$ blue

6-2: $E_f = 3.02$ blue

6. Below is a set of data from an unknown atom. The wavelengths of spectral lines are given in nm. The rows are based on starting energy states and the columns are the ending energy states. Use these wavelengths to identify the element.

Ending E-States

	1	2	3	4	5	6	7	8	9
Starting E-states									
1									
2	3.38								
3	2.85	18.25							
4	2.70	13.52	52.14						
5	2.64	12.07	35.64	112.64					
6	2.61	11.40	30.41	72.99	207.36				
7	2.59	11.04	27.94	60.21	129.36	343.89			
8	2.57	10.81	26.54	54.07	103.97	208.54	529.85		
9	2.57	10.66	25.66	50.53	91.64	164.23	314.34	772.83	
10	2.56	10.56	25.07	48.27	84.48	142.56	243.50	450.55	1080.44

A: $\lambda = 60.21 \text{ nm}$
 $n_i = 7$
 $n_f = 4$

$$\frac{1240 \text{ eV nm}}{\lambda} = 13.6 \text{ eV } Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$Z^2 = \frac{1240}{13.6 (60.21)} \Rightarrow Z = 5.998$$

B: $\lambda = 164.23$
 $n_f = 6$
 $n_i = 9$
 $Z = 5.998$

C: $\lambda = 25.07$
 $n_f = 3$
 $n_i = 10$
 $Z = 5.998$
Carbon

7. Elements in space can absorb radiation to excite their electrons to higher energy states. This is called the absorption spectrum. If an electron is in the 2nd energy state of Beryllium (4 protons) what are the 3 longest wavelength of light that the gas can absorb?

$$\frac{1240}{\lambda} = 13.6 (4^2) \left(\frac{1}{2^2} - \frac{1}{n^2} \right)$$

$\lambda = 41.03 \text{ nm}, 30.4 \text{ nm}, 27.14 \text{ nm}$

8. In the Sun, an ionized helium (He^+) atom makes a transition from the 6th to the 2nd state, emitting a photon. Can the photon be absorbed by hydrogen atoms present in the Sun? If so, between what energy states will the hydrogen atom jump?

$$E_g = 13.6 (4) \left(\frac{1}{2^2} - \frac{1}{6^2} \right) = 12.09 \text{ eV}$$

Same as ΔE from 3-1 of H.

9. Assuming that the energy of the electron is all electric potential energy $U_{\text{elec}} = \frac{kq_1q_2}{r}$ find the smallest radius for an electron in a hydrogen atom (known as the Bohr radius). If all the energy were gravitational energy $U_{\text{grav}} = \frac{6.67E-11 m_1 m_2}{r}$ what would be the Bohr radius now? Hint: $m_e = 9.11 \times 10^{-31} \text{ kg}$ $m_p = 1.6726 \times 10^{-27} \text{ kg}$

$$E = -13.6 \text{ eV} = -2.18 \cdot 10^{-18} \text{ J} = \frac{k e^2}{r}$$

$-2.18 \cdot 10^{-18} \text{ J} = \frac{(6.67 \cdot 10^{-11})(9.11 \cdot 10^{-31})(1.67 \cdot 10^{-27})}{r}$

$r_e = 1.06 \cdot 10^{-10} \text{ m}$

$r_g = 2.98 \cdot 10^{-50} \text{ m}$