PHYSICS 3204
WORKSHEET #4: BOHR

Around 1913, Niels Bohr introduced a new model of the hydrogen atom in which electrons could only be located at certain orbital levels. Bohr mathematically calculated the radius and electron energy for the orbital levels of hydrogen. In doing so he found that energy at the electron level is quantized and its value depends on the difference in energy between orbital levels.

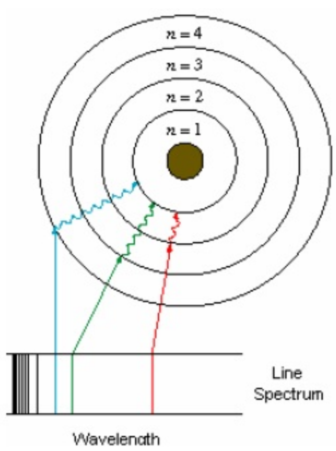
When light is spread out into its separate colours, this is called a spectrum. The light from a tungsten filament lamp produces a continuous spectrum. When a high voltage is applied across a gas discharge tube, radiation from the excited gases produce a line spectrum (ie. only at certain wavelengths).

Emission spectra - the spectrum lines which are created from an excited gas.

Absorption spectra - the dark lines which are observed when a continuous spectrum passes through a gas. These lines have the same wavelength as the emission lines from that gas.

For a given gas (say neon) the lines are always of the same wavelength, like an atomic fingerprint!

Bohr was able to use his new model to explain these spectral lines. His model, with various electron orbital levels, suggests that an electron emits energy (a photon) when it drops from a higher energy level to a lower energy level.



- Thus, each emission line corresponds to a wavelength (frequency) which is determined by the given energy difference between orbital levels in that gas atom.

- Each dark absorption line corresponds to the wavelength (freq) which relates to the energy taken to raise an electron to a higher orbital level in that gas atom.

Note: Bohr's model explains that energy at the atomic level is quantized since the energy differences between orbital levels are discrete (of fixed values).

To prove this Bohr mathematically calculated the possible orbital radii and electron energies for the simplest Bohr atom, the hydrogen atom. His calculations perfectly matched the experimental data for spectral lines of hydrogen.

This gave further support for the quantum theory, and gave Bohr the 1922 Nobel Prize in Physics.

Using the conservation of energy and the conservation of angular momentum, Bohr derived:

Orbital radius for hydrogen atom

$$\boxed{r_n = (5.29\text{x}10^{-11}\text{ m})\, n^2}$$

where: n is the quantum number (ie. orbital level number) 1,2,3,etc.

$5.29\text{x}10^{-11}$m is the Bohr radius (when n=1 for hydrogen)

Electron Energy for hydrogen

$$E_n = \frac{-2.18 \times 10^{-18}\text{ J}}{n^2}$$

$$\boxed{E_n = \frac{-13.6\text{ eV}}{n^2}}$$

Why electrons don't lose energy and spiral into the nucleus.

Briefly! It can be explained with Bohr's model and the energy levels being negative. The electron has negative energy and can be viewed as being in an energy well. The electron would need to gain energy to escape from the well. Since it has less energy in the lower orbital levels, it must gain energy to jump to a higher orbital level (ie. further from the nucleus)

Ionization energy - the magnitude of energy needed to remove an electron completely from the nucleus (r = infinity).

This energy is also equal in magnitude to that of the energy of the ground state (n = 0).

PART A: MULTIPLE CHOICE

1. What is the energy of the emitted photon when an electron drops from the third energy level to the second energy level?

(A) 1.51 eV
(B) 1.89 eV
(C) 2.27 eV
(D) 4.91 eV

2. What is the radius of the fourth Bohr orbital in hydrogen?

(A) 3.31×10^{-12} m
(B) 1.32×10^{-11} m
(C) 2.12×10^{-10} m
(D) 8.46×10^{-10} m

3. What is the change in energy when an electron drops from $n = 3$ to $n = 1$?

(A) 1.5 eV
(B) 12.1 eV
(C) 13.6 eV
(D) 15.1 eV

4. If the orbital radius of an electron in a hydrogen atom is 2.12×10^{-10} m, at what energy level is the electron?

(A) 1_{st}
(B) 2_{nd}
(C) 4_{th}
(D) 8_{th}

5. If the smallest orbital radius of an electron in a hydrogen atom is r_1, what is the radius of the third orbit?

(A) $1.7\ r_1$
(B) $3\ r_1$
(C) $6\ r_1$
(D) $9\ r_1$

6. Which transition of an electron in a hydrogen atom will result in an energy release of 0.306 eV?

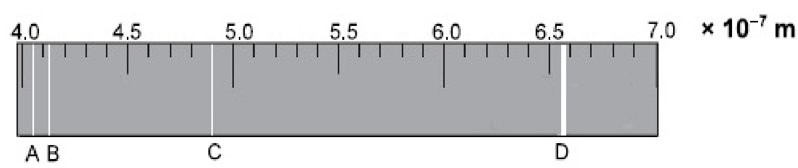
(A) n = 3 to n = 4
(B) n = 4 to n = 3
(C) n = 4 to n = 5
(D) n = 5 to n = 4

7. What is the orbital radius of an electron in the third energy level of a hydrogen atom?

(A) 1.76×10^{-11} m
(B) 5.29×10^{-11} m
(C) 1.59×10^{-10} m
(D) 4.76×10^{-10} m

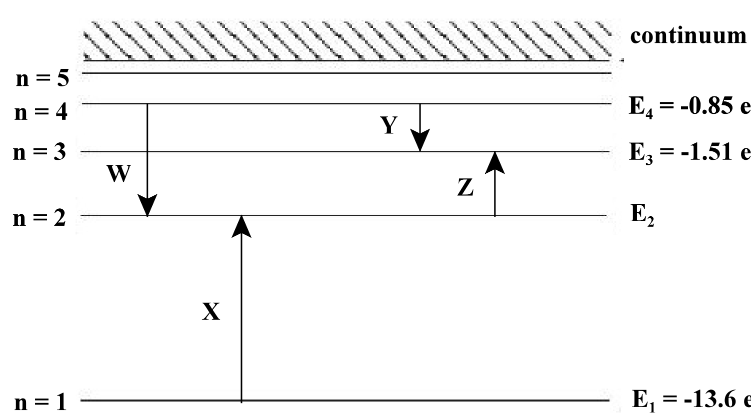
8. The diagram below shows spectral lines for hydrogen when viewed through a spectroscope. Which line corresponds to an electron transition from energy level 3 to energy level 2?

(A) A
(B) B
(C) C
(D) D

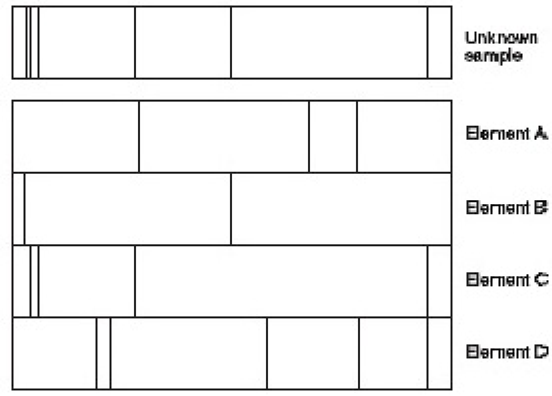


9. The diagram below shows the energy level diagram of a hydrogen atom. The arrows (W, X, Y, Z) indicate transitions of electrons in the atom. Which transition would cause the emission of a photon with the shortest wavelength?

(A) W
(B) X
(C) Y
(D) Z



10. The diagram below shows the bright line spectra of four elements along with the spectrum of an unknown gaseous sample. Which elements are found in the unknown sample?



(A) A and C
(B) A and D
(C) B and C
(D) B and D

11. What is the energy of an electron in the third energy level of a hydrogen atom?

(A) −13.6 eV
(B) −4.53 eV
(C) −2.27 eV
(D) −1.51 eV

12. Which best explains why each atom in the periodic table has a unique set of spectral lines?

(A) Each atom has a unique neutron to proton ratio.
(B) Each atom has a unique set of energy levels.
(C) The electrons in atoms are in constant motion.
(D) The electrons in atoms orbit the nucleus

13. If r_1 is the smallest orbital radius around a single proton, what is r_6?

(A) 2.5 r_1
(B) 6.0 r_1
(C) 12 r_1
(D) 36 r_1

PART B: WRITTEN RESPONSE

1. hydrogen atom in the first excited state (n =2) absorbs a photon and moves to the second excited state (n =3). What is the frequency of the absorbed photon?

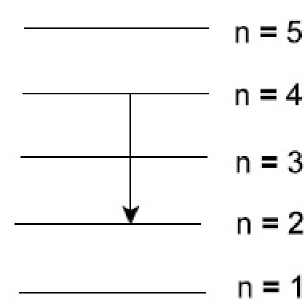
2. A hydrogen atom in the first excited state (n = 2) relaxes to its ground state by emitting a photon. What is the energy of the emitted photon?

3. A photon of light is emitted from a hydrogen lamp when an electron falls from the third energy level to the second energy level. Calculate the energy and the wavelength for this photon.

4. Use Bohr energy levels to explain fluorescence and phosphorescence. AUGUST 2009

5. An electron in a hydrogen atom gains 0.966 eV of energy as it jumps from one energy level to another. Calculate what energy level the electron moves to if it starts at energy level 3. JUNE 2009

6. The diagram below shows the first five energy levels of an electron orbiting the nucleus of a hydrogen atom. Calculate the wavelength of the emitted photon for the electron transition indicated by the arrow in the diagram.

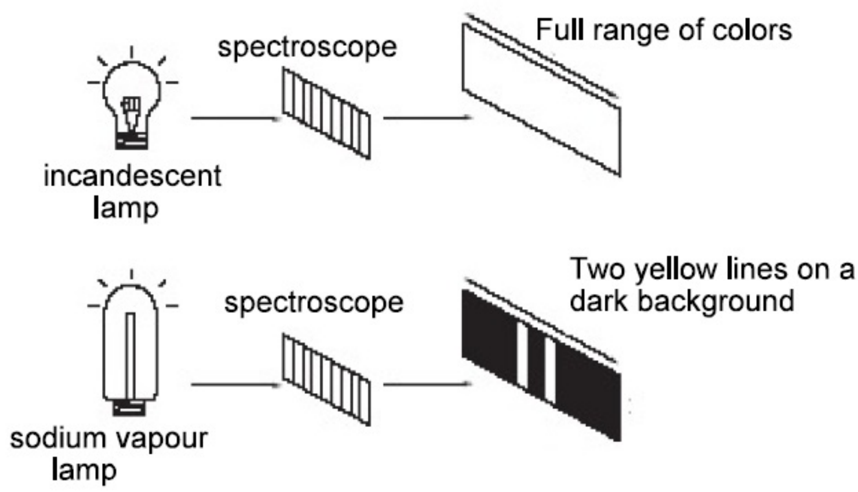


7. Calculate the energy (in Joules) gained by an electron in a hydrogen atom as it moves from the second to the fifth energy level. JUNE 2007

8. A photon of light is emitted from a hydrogen lamp when an electron falls from the third energy level to the second energy level. Calculate the energy and the wavelength for this photon. JUNE 2006

9. A hydrogen atom in the first excited state (n = 2) relaxes to its ground state by emitting a photon. What is the energy of the emitted photon? JUNE 2005

10. The spectra of two light sources through spectroscopes are shown in the diagram below. AUGUST 2008

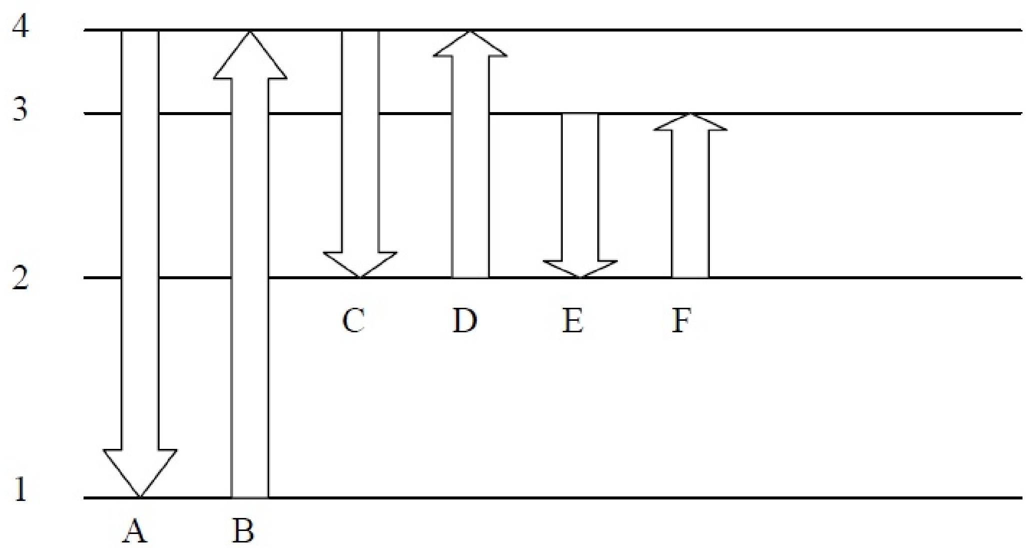


i) What type of spectra is produced in each case?

ii) Explain why the observed spectra are different.

11. A hydrogen atom in the first excited state (n =2) absorbs a photon and moves to the second excited state (n =3). What is the frequency of the absorbed photon? AUGUST 2004

12. The quantum level occupied by an electron in an atom depends on the energy of the electron. Changes in quantum level are related to absorption or emission of energy. The figure below represents the four lowest energy levels of an atom. (n = 1 to 4). The six lettered arrows represent changes in the energy level of an electron.



A. Why do these energy levels mean that the atom will show an emission spectrum of discrete lines rather than a continuous spectrum of emitted light?

B. Which three of the lettered energy changes involve absorption of energy by the atom?

C. Which three of the lettered energy changes involve emission of light energy by the atom?

D. Of the three energy changes that involve emission , one results in the emission of blue light, one results in yellow light, and one results in ultraviolet light.

a. Which lettered change involves the emission of blue light?

b. Which lettered change involves the emission of yellow light?

c. Which lettered change involves the emission of ultraviolet light?

Light of different colors or types will be light of different energies. "And anyone who thinks they can talk about quantum theory without feeling dizzy hasn't yet understood the first thing about it."

– Niels Bohr