Friday, May 17/13
Science 122

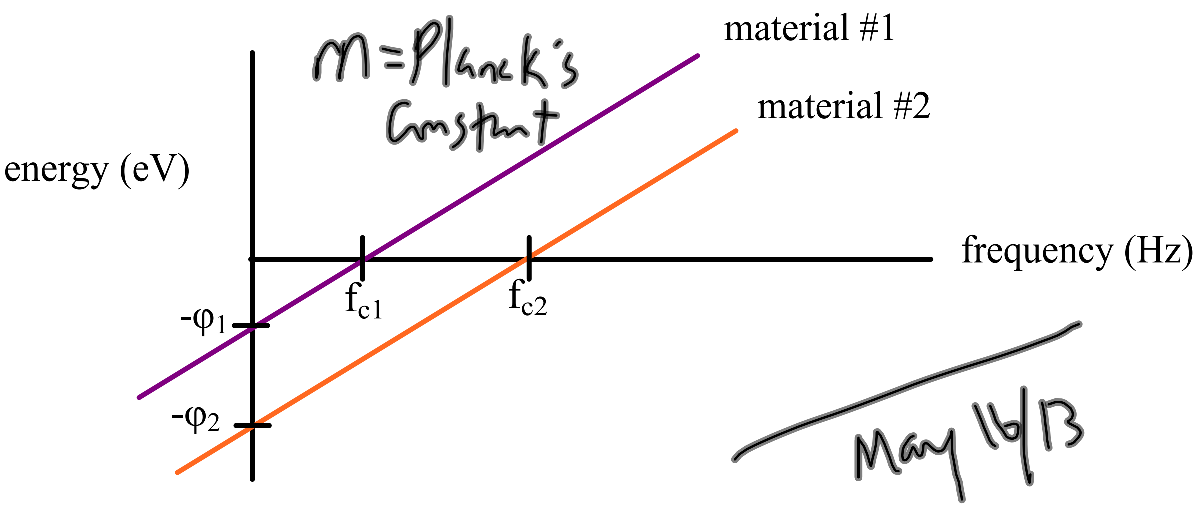
Announcements

** **Need an activity re a course topic before the end of May.**

1. Worksheets - Half-Life, Activity and Decay Constant #1
2. Photoelectric Effect - Continue
3. Wave-Particle Duality
4. Worksheet - Energy of Photons, Work Function, Etc. - HW
5. Atomic Structure
6. Energy Level Diagrams
7. Worksheet - Energy Levels - HW

The relationship between K_{max} of the photoelectrons and the frequency of the incident light is linear with a slope equal to Planck's constant, h. The only difference between the "curves" from different materials is the y-intercept of the curve, given by the material's specific work function. The x-intercept will be the cut-off frequency, f_c.

Energy vs. Frequency



The voltage that eventually causes the current to go to zero is called the stopping potential, V_s.

$$K_{max} = qV_s$$

K_{max} -> kinetic energy (J or eV)
q -> charge (C)
V_s -> stopping potential (V)

$$K_{max} = \frac{1}{2} m v_{max}^2$$

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Energy of Photons, Work Function, Etc.

1. What is the energy, in joules, of a photon that has a wavelength of 4.60×10^{2} nm? (4.32×10^{19} J)
2. What is the stopping voltage of an electron that has 7.30×10^{-19} J of kinetic energy? (4.56 V)
3. Light with a wavelength of 5.30×10^{-7} m falls on a photoelectric surface that has a workfunction of 1.70 eV. What is the maximum energy of the ejected electrons? (1.03×10^{-19} J)
4. Calculate the wavelength of an electron that has a speed of 2.25×10^{7} m/s. (3.23×10^{-11} m)
5. A photoelectric surface has a work function of 2.00 eV. What is the cut-off frequency (or threshold frequency) of this surface? (4.83×10^{14} Hz)
6. What is the energy of a photon that has a frequency of 4.50×10^{14} Hz? (2.98×10^{-19} J)
7. A photoelectric surface has a work function of 3.10 eV. What is the maximum wavelength of light that will cause photoelectron emission from this surface? (4.01×10^{-7} m)
8. What is the stopping voltage of an electron that has 5.40×10^{-19} J of kinetic energy? (3.38 V)
9. Radiation with a frequency of 7.52×10^{14} Hz is used to illuminate a photoelectric surface. If the work function of this surface is 2.20 eV, what voltage would be required to reduce the current to zero? (0.916 V)
10. Calculate the wavelength of a ball that has a mass of 1.30 kg and a speed of 3.2×10^{1} m/s. (1.6×10^{-35} m)
11. Calculate the frequency of electromagnetic radiation whose photons have a momentum of 2.80×10^{-27} kgm/s each. (1.27×10^{15} Hz)
12. Light with a frequency of 5.00×10^{14} Hz illuminates a photoelectric surface that has a work function of 2.10×10^{-19} J. What is the maximum energy of the ejected electrons? (1.22×10^{-19} J)
13. Light with a wavelength of 425 nm falls on a photoelectric surface that has a workfunction of 2.0 eV. What is the maximum speed of the ejected electrons? (5.7×10^{5} m/s)
14. Calculated the wavelength of an electron that has kinetic energy of 7.50×10^{-3} MeV. ($1.42 \text{ X } 10^{-11}$ m)
15. What is the kinetic energy of an alpha particle that has a wavelength of 1.46×10^{-15} m? (1.55×10^{-11} J)
16. Calculate the momentum of a photon whose frequency is 9.65×10^{14} Hz. (2.13×10^{-27} kgm/s)
17. If the energy of a photon is 3.60×10^{-14} J, what is its momentum? (1.20×10^{-22} kgm/s)
18. A photoelectric surface has a work function of 3.30×10^{-19} J. What is the cut-off frequency of the incident light? (4.98×10^{14} Hz)
19. Electrons are ejected from a photoelectric surface with maximum energy of 1.20 eV. If the incident light has a wavelength of 4.10×10^{2} nm, what is the work function of the surface? (2.93×10^{-19} J)
20. Electrons are ejected from a photoelectric surface with a maximum speed of 4.20×10^{5} m/s. If the work function of this surface is 2.55 eV, what is the wavelength of the incident light? (4.07×10^{-7} m)

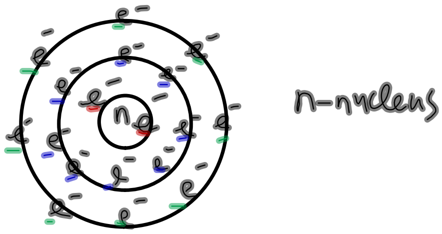
Niels Bohr and Atomic Structure

Bohr reached the following conclusions about atomic structure:

1. Within the atom there are certain allowed orbits (energy levels) around the nucleus, in which the electrons can move without giving off energy (ie/ the energy of the electron in an atom is quantized).

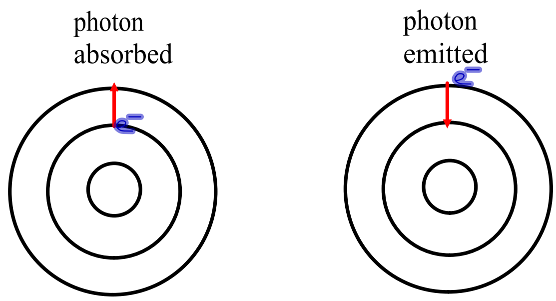
2. For the electron to occupy any one of the allowed orbits, it must possess the energy allowed for that orbit.

Bohr Atom



This model allows the electrons to move from one orbit to another.

"quantum jump"



Photons of only certain frequencies can be emitted or absorbed.

$$\Delta E = E_f - E_i$$

ΔE { positive when a photon is absorbed; negative when a photon is emitted

$$|\Delta E| = hf$$

$$E = hf$$

Energy Level Diagrams

Energy level diagrams can be used to analyze the transitions of electrons from one level to another.

The diagrams consist of a series of lines running up the page representing energy levels from the ground state (n=1) through all the excited states (n = 2, 3, ...∞).

Simulation

1st excited state → n=2
* energy level 2 → n=2

The energy necessary to free an electron from state n is $-E_n$. This energy is known as the binding energy of state n. The closer to the nucleus the electron is, the less energy it has.

(n = ∞ is assigned a value of 0 eV)

Using the Bohr model, the energy levels, E_n (in eV), are calculated with the formula below where Z represents the atomic number of an atom:

$$E_n = -13.6(Z^2/n^2)$$

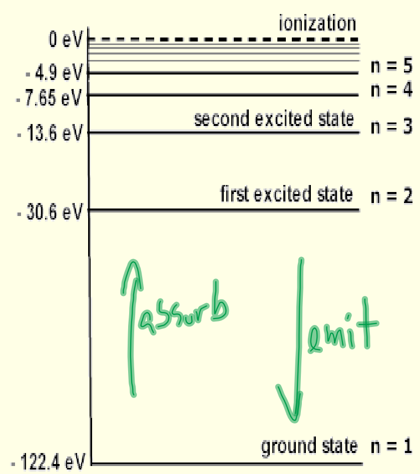
For hydrogen where Z = 1,

$$E_n = -13.6/n^2$$

NOTES: 1. As the value of n increases, the spacing between the adjacent levels decreases.
2. When the electron reaches n = ∞, it has been set free from the atom altogether and the atom is said to be ionized.

Example:

Using Bohr's formula, a hypothetical, doubly-ionized atom with Z = 3 could have the following energy level diagram.

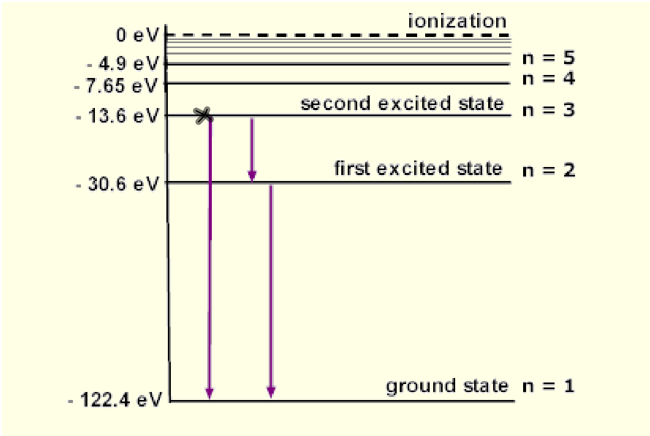


http://dev.physicslab.org/Document.aspx?doctype=3&filename=AtomicNuclear_EnergyLevelDiagrams.xml

Refer to the following information for the next three questions. $z=3$

Suppose an electron of our hypothetical atom has been excited to its second excited state (n = 3). When it falls back to its ground state it can do so through a total of three possible transitions. How much energy is released during each of these transitions?

$$\Delta E = E_f - E_i$$



n = 3 to n = 1

A -108.8 eV

S second excited state directly to its ground state releasing: ΔE = -122.4 -(-13.6) = -108.8 eV

n = 3 to n = 2

A -17 eV

S second excited state to first first excited state releasing: ΔE = -30.6 -(-13.6) = -17 eV

n = 2 to n = 1

A -91.8 eV

S first excited state to its ground state releasing: ΔE = -122.4 -(-30.6) = -91.8 eV

Example: $E_3 = -1.5\text{ eV}$ $E_2 = -3.4\text{ eV}$

An electron undergoes a transition from the 3rd level to the 2nd energy level in a hydrogen atom. What is the wavelength of the light that is emitted? (6.54×10^{-7}m)

$$\Delta E = E_f - E_i$$
$$\Delta E = E_2 - E_3$$
$$\Delta E = -3.4\text{ eV} - (-1.5\text{ eV})$$
$$\Delta E = -1.9\text{ eV}$$
$$-3.04 \times 10^{-19}\text{ J}$$
$$1\text{ eV} = 1.60 \times 10^{-19}\text{ J}$$

$$|\Delta E| = hf \qquad c = f\lambda$$
$$E = hf$$
$$E = \frac{hc}{\lambda}$$
$$\lambda = \frac{hc}{E}$$
$$\lambda = \frac{(6.63 \times 10^{-34}\text{ J s})(3.00 \times 10^{8}\text{ m/s})}{3.04 \times 10^{-19}\text{ J}}$$
$$\lambda = 6.54 \times 10^{-7}\text{ m}$$

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Nuclear - Energy Levels

1. Calculate the energy of the 2nd energy level of the hydrogen atom. (-3.40 eV)

2. An electron undergoes a transition from the 1st energy level to the 3rd energy level in a hydrogen atom. What is the wavelength of the radiation absorbed? (1.03×10^{-7} m)

3. An electron undergoes a transition from the 6th energy level to the 2nd energy level in a hydrogen atom. What is the frequency of the light emitted? (7.30×10^{14} Hz)

4. Calculate the energy require to ionize a hydrogen atom in which the electron is in the ground state. (13.6 eV)

5. An unexcited hydrogen atom (electron in the ground state) absorbed a photon of light that had a frequency of 3.09×10^{15} Hz. Through what transition did the electron in this atom undergo? (1 to 4)

6. A photon of light with a wavelength of 433 nm is emitted from an excited hydrogen atom in the 5th energy level. Through what transition did the electron in this atom undergo? (5 to 2)