Chapter 22
Quantum Mechanics & Atomic Structure
22.1 Photon Theory of Light and The Photoelectric Effect Homework # 170

See Homework #95 in "Chapter 12-Electrostatics" for the table of "Useful Information" on atomic particles.

I

01. What is the energy of a photon of light with a wavelength of _____?
    a.) 400 nm b.) 700 nm

02. What is the wavelength of a 4.60-eV photon?

03. A local FM radio station has a carrier wave with a frequency of 104.3 MHz. What is the energy of the photons emitted from this station?

04. What is the minimum frequency of light that will emit electrons from the surface of gold which has a work function of 5.37 eV?

05. Aluminum has a work function of 4.25 eV.
    a.) What is the longest wavelength of light that will emit electrons from an aluminum surface?
    b.) Is this in the visible region?

II

06. A surface of cesium, which has a work function of 2.14 eV, is illuminated by light with a wavelength of 525 nm.
    a.) What is the maximum kinetic energy of the emitted electrons?
    b.) What is the maximum speed of the emitted electrons?

07. When UV light of wavelength 175 nm falls on a tungsten surface, the maximum kinetic energy of the emitted electrons is 2.50 eV. What is the work function of tungsten?

08. What is the maximum kinetic energy of electrons emitted from a platinum source (W_0 = 5.30 eV) when light of wavelength _____ strikes it?
    a.) 700 nm b.) 400 nm c.) 235 nm d.) 200 nm

09. When UV light of wavelength 225 nm falls on a lithium surface, the current through a photoelectric circuit is brought to rest by a stopping potential of 2.62 V. What is the work function of lithium?

10. What is the maximum speed of electrons emitted from the surface of potassium (W_0 = 2.30 eV) when light of wavelength _____ falls on it?
    a.) 700 nm b.) 400 nm c.) 235 nm d.) 200 nm

ANSWERS: **01.** a.) 3.11 eV b.) 1.78 eV **02.** 270 nm **03.** 4.32×10^{-7} eV **04.** 1.30×10^{15} Hz
05. a.) 293 nm b.) no **06.** a.) 0.228 eV b.) 2.83×10^{5} m/s **07.** 4.60 eV **08.** a.) 0 eV b.) 0 eV c.) 0 eV
08. d.) 0.916 eV **09.** 2.90 eV **10.** a.) 0 m/s b.) 5.33×10^{5} m/s c.) 1.02×10^{6} m/s d.) 1.17×10^{6} m/s

Chapter 22
Quantum Mechanics & Atomic Structure
22.2 Photon Interactions — Homework # 171

See Homework #95 in "Chapter 12-Electrostatics" for the table of "Useful Information" on atomic particles.

I

01. An X-ray photon has a wavelength of 0.475 nm.
    a.) What is the momentum of this photon?
    b.) What is the energy of this photon?
    c.) What is its effective mass?

02. A 3.75-MeV photon interacts with a nearby nucleus to produce an electron-positron pair. What total kinetic energy will this pair possess?

03. A μ^+-μ^- (muon-muon) pair are produced by a photon. The mass of each μ is 207 times that of an electron.
    a.) What is the minimum energy of the photon? b.) What is the wavelength of the photon?

II

04. A photon produces an electron-positron pair, each with a kinetic energy of 565 keV.
    a.) What is the energy of the photon? b.) What is the wavelength of the photon?

05. An electron is accelerated from rest through a potential difference of 5000 V. At this point it collides with a positron that was accelerated through the same potential difference? The two particles annihilate each other and form a photon. Assume classical physics-ignore relativistic effects.
    a.) What is the energy of the photon? b.) What is the wavelength of the photon?

06. A positron traveling at 1.95×10^7 m/s collides with and annihilates an electron traveling at 3.65×10^7 m/s. Assume classical physics-ignore relativistic effects.
    a.) What is the wavelength of the photon that forms? b.) What is the momentum of the photon that forms?

07. A 0.604-nm photon strikes a free electron, initially at rest, in a perfectly elastic head-on collision demonstrating the Compton effect. Assuming classical physics (ignore relativistic effects), what is the wavelength of the recoiling photon if the electron travels off at 2.40×10^6 m/s?

III

08. A 0.250-nm photon strikes a free electron, initially at rest, in a perfectly elastic head-on "collision" demonstrating the Compton effect. Assume classical physics-ignore relativistic effects.
    a.) What is the speed of the electron after the interaction with the photon?
    a.) What is the kinetic energy of the electron after the interaction with the photon?
    b.) What is the wavelength of the recoiling photon?

ANSWERS: **01.** a.) 1.40×10^{-24} kg·m/s b.) 4.19×10^{-16} J c.) 4.65×10^{-33} kg **02.** 2.73 MeV
03. a.) 212 MeV b.) 5.86×10^{-15} m **04.** a.) 2150 keV (2.15 MeV) b.) 5.77×10^{-13} m
05. a.) 1.03 MeV b.) 1.20×10^{-12} m **06.** a.) 1.21×10^{-12} m b.) 5.49×10^{-22} kg·m/s **07.** 0.608 nm
08. a.) 5.77×10^6 m b.) 94.7 eV c.) 0.255 nm

Chapter 22
Quantum Mechanics & Atomic Structure
22.3 de Broglie Wavelength of Matter Waves Homework # 172

See Homework #95 in "Chapter 12-Electrostatics" for the table of "Useful Information" on atomic particles.

I

01. A 140-g baseball is pitched at 32.7 m/s. What is the wavelength of this ball?

02. What is the wavelength of a proton traveling at 3250 m/s?

II

03. What is the wavelength of an electron with _____ of energy? Are any of these in the visible region?
    a.) 1 eV b.) 10 eV c.) 100 eV d.) 1000 eV

04. What is the wavelength of an electron that is accelerated across a voltage of _____?
    a.) 1 V b.) 10 V c.) 100 V d.) 1000 V

05. What is the wavelength of an proton with _____ of energy? Are any of these in the visible region?
    a.) 1 eV b.) 10 eV c.) 100 eV d.) 1000 eV

06. What is the wavelength of an proton that is accelerated across a voltage of _____?
    a.) 1 V b.) 10 V c.) 100 V d.) 1000 V

07. An electron and a proton have the same wavelength. What is the ratio of the speed of the electron to that of the proton? (Assume the speeds are much less than the speed of light.)

08. An electron and an proton have the same nonrelativistic kinetic energy. What is the ratio of their wavelengths?

III

09. Using the rms speed of an oxygen molecule at a room temperature of 25.0°C, determine its wavelength? Remember, $KE_{ave} = \frac{3}{2}kT = \frac{1}{2}mv^2$ (where, Boltzmann's constant, $k = 1.38 \times 10^{-23}$ J/K and Avogadro's number, $N_A = 6.02 \times 10^{23}$ molecules/mole).

10. A beam of electrons accelerated through a potential difference of 40,000 V passes through an aluminum foil, that consists of atoms about 10^{-10} m apart, onto a plate of film 10.0 cm away. Assuming a linear diffraction and interference pattern, how far apart would constructive interference peaks appear on the film? Note: the actual interference pattern more closely simulates a disk diffraction producing a concentric circular pattern of constructive and destructive inference.

ANSWERS: **01.** 1.45×10^{-34} m **02.** 0.122 nm **03.** a.) 1.23 nm b.) 3.88 nm c.) 12.3 nm d.) 38.8 nm **04.** a.) 1.23 nm b.) 3.88 nm c.) 12.3 nm d.) 38.8 nm **05.** a.) 0.286 Å b.) 0.907 Å c.) 2.86 Å **05.** d.) 9.07 Å **06.** a.) 0.286 Å b.) 0.907 Å c.) 2.86 Å d.) 9.07 Å **07.** 1830 **08.** 42.8 (0.0234) **09.** 2.59×10^{-11} m **10.** 3.27 cm

Chapter 22
Quantum Mechanics & Atomic Structure
22.4 The Bohr Model of Atomic Structure — Homework # 173

I

01. What is the wavelength of the third Balmer line ($n = 5$ to $n = 2$ transition)?

02. An hydrogen atom emits light that is the second longest wavelength in the Lyman series.
    a.) What transition does this represent? b.) What wavelength results from this transition?

03. How much energy is needed to ionize a hydrogen atom with an electron in the $n =$ _____ state?
    a.) 1 b.) 2 c.) 3 d.) 4

II

04. Construct the energy level diagram for the hydrogen atom and show the transitions for the Lyman, Balmer, and Paschen series. Include values for the first five energy levels.

05. Construct the energy level diagram for the He^{+} ion. Include values for the first five energy levels.

06. Construct the energy level diagram for the Li^{2+} ion. Include values for the first five energy levels.

07. What is the longest wavelength of light that can ionize a hydrogen atom in its ground state?

08. What are the potential and kinetic energies of an electron in the ground state of hydrogen?

09. The electron in a hydrogen atom de-excites from the $n = 7$ energy level to the $n = 4$ energy level.
    a.) How much energy is emitted by this transition?
    b.) What wavelength of light will be emitted by this transition?

10. The electron in a hydrogen atom de-excites from the $n = 9$ energy level to the $n = 5$ energy level.
    a.) How much energy is emitted by this transition?
    b.) What wavelength of light will be emitted by this transition?

11. A "blue" photon with a wavelength of 488 nm strikes the electron in a hydrogen atom and disappears. What energy level transition did this electron undergo?

12. A "UV" photon with a wavelength of 95.2 nm strikes the electron in a hydrogen atom and disappears. What energy level transition did this electron undergo?

13. A "infrared" photon with a wavelength of 1.10 μm strikes the electron in a hydrogen atom and disappears. What energy level transition did this electron undergo?

ANSWERS: **01.** 435 nm **02.** a.) $n = 3$ to $n = 1$ b.) 103 nm **03.** a.) 13.6 eV b.) 3.40 eV c.) 1.51 eV
03. d.) 0.85 eV **04.** $E_1 = 13.6$ eV, $E_2 = 3.40$ eV, $E_3 = 1.51$ eV, $E_4 = 0.85$ eV, $E_5 = 0.544$ eV
05. $E_1 = 54.4$ eV, $E_2 = 13.6$ eV, $E_3 = 6.04$ eV, $E_4 = 3.40$ eV, $E_5 = 2.176$ eV
06. $E_1 = 122.4$ eV, $E_2 = 30.6$ eV, $E_3 = 13.6$ eV, $E_4 = 7.65$ eV, $E_5 = 4.896$ eV **07.** 91.4 nm
08. $PE = -27.2$ eV, $KE = 13.6$ eV **09.** a.) 0.572 eV b.) 2.17 μm **10.** a.) 0.376 eV b.) 3.31 μm
11. $n = 4$ to $n = 2$ **12.** $n = 5$ to $n = 1$ **13.** $n = 6$ to $n = 3$

Chapter 22
Quantum Mechanics & Atomic Structure
22.5 Heisenberg Uncertainity Principle/Quantum Numbers Homework # 174

See Homework #95 in "Chapter 12-Electrostatics" for the table of "Useful Information" on atomic particles.

Heisenberg Uncertainity Principle

I

01. A proton's postion can be measured to an accuracy of 1.45×10^{-8} m. With what accuracy can its velocity be determined?

02. An electron is traveling with a speed of 6.750×10^{5} m/s with a possible error of $\pm$ 1.5×10^{3} m/s. What is the maximum accuracy with which its position can be determined?

03. An electron remains in an excited state of a hydrogen atom for an average of 10^{-8} s.
    a.) What is the minimum uncertainity in the energy of this electron?
    b.) What percentage of the ground state energy is this uncertainity?

II

04. Suppose a baseball with a mass of 140 g and an electron are traveling at the same speed of 32.7 m/s with the same unceratinity in this speed of 0.125 percent.
    a.) What is the uncertainity in the position of the baseball?
    b.) What is the uncertainity in the position of the electron?

Quantum Numbers

I

05. What values of l are possible for $n = 6$?

06. Electrons of an atom are being assigned possible quantum numbers. For the $n = 7$, $l = 3$ subshell, _____?
    a.) what are the possible values of m_l b.) how many electrons will it take to fill the subshell

07. List the possible states of the principal quantum number $n = 4$ and state how many possible states are present.

08. What is the maximum number of _____ that may occupy $n = 5$, $l = 2$ subshell?
    a.) magnetic quantum numbers b.) electrons

09. What is the maximum number of _____ that may occupy $n = 6$ energy level?
    a.) orbital quantum numbers b.) magnetic quantum numbers
    c.) electrons

10. List the quantum numbers for each electron in the ground state of an atom of calcium ($Z = 20$).

11. What is the magnitude of angular momentum of an electron in the $n = 6$, $l =$ _____ state of a hydrogen atom.
    a.) 2 b.) 3 c.) 4 d.) 5

12. Write the electron configuration notation for an atom in the ground state of the element _____?
    a.) C ($Z = 6$) b.) S ($Z = 16$) c.) Rb ($Z = 37$) d.) U ($Z = 92$)

ANSWERS: **01.** 4.36 m/s **02.** 7.72×10^{-8} m **03.** 6.59×10^{-8} eV b.) 4.85×10^{-7} % **04.** a.) 1.84×10^{-32} m **04.** b.) 2.83 mm **05.** 0, 1, 2, 3, 4, 5 **06.** a.) -3, -2, -1, 0, 1, 2, 3 b.) 14 **07.** 32 **08.** a.) 5 b.) 10 **09.** a.) 6 b.) 36 c.) 72 **11.** a.) 2.58×10^{-34} J·s b.) 3.66×10^{-34} J·s c.) 4.72×10^{-34} J·s d.) 5.78×10^{-34} J·s