Solutions – APChem PS#7

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6.4 (a) False. Electromagnetic radiation passes through water. See Figure 13.27.
(b) True.
(c) False. Infrared light has lower frequencies than visible light.
(d) False. A foghorn blast is a form of sound waves.

6.6 Wavelength of (a) gamma rays < (d) yellow (visible) light < (e) red (visible) light < (b) 93.1 MHz FM (radio) waves < (c) 680 kHz or 0.680 MHz AM (radio) waves

6.8 (a) $\nu = c/\lambda$; $\dfrac{2.998 \times 10^8\ \text{m}}{\text{s}} \times \dfrac{1}{589\ \text{nm}} \times \dfrac{1\ \text{nm}}{1 \times 10^{-9}\ \text{m}} = 5.10 \times 10^{14}\ \text{s}^{-1}$

(b) $\lambda = c/\nu$; $\dfrac{2.998 \times 10^8\ \text{m}}{\text{s}} \times \dfrac{1\ \text{s}}{1.2 \times 10^{13}} = 2.5 \times 10^{-5}\ \text{m}$

(c) Yes. The radiation in (b) is in the infrared range.

(d) $10\ \mu\text{s} \times \dfrac{1 \times 10^{-6}\ \text{s}}{1\ \mu\text{s}} \times \dfrac{2.998 \times 10^8\ \text{m}}{\text{s}} = 3.0 \times 10^3\ \text{m}$ (3.0 km)

6.11 (a) *Quantization* means that energy can only be absorbed or emitted in specific amounts or multiples of these amounts. This minimum amount of energy is called a quantum and is equal to a constant times the frequency of the radiation absorbed or emitted. $E = h\nu$.

(b) In everyday activities, we deal with macroscopic objects such as our bodies or our cars, which gain and lose total amounts of energy much larger than a single quantum, $h\nu$. The gain or loss of the relatively minuscule quantum of energy is unnoticed.

6.12 Planck's original hypothesis was that energy could only be gained or lost in discreet amounts (quanta) with a certain minimum size. The size of the minimum energy change is related to the frequency of the radiation absorbed or emitted, $\Delta E = h\nu$, and energy changes occur only in multiples of $h\nu$.
Einstein postulated that light itself is quantized, that the minimum energy of a photon (a quantum of light) is directly proportional to its frequency, $E = h\nu$. If a photon that strikes a metal surface has less than the threshold energy, no electron is emitted from the surface. If the photon has energy equal to or greater than the threshold energy, an electron is emitted and any excess energy becomes the kinetic energy of the electron.

6.16 $E = h\nu$

AM: $6.626 \times 10^{-34}\ \text{J}\cdot\text{s} \times \dfrac{1440 \times 10^3}{1\ \text{s}} = 9.54 \times 10^{-28}\ \text{J}$

FM: $6.626 \times 10^{-34}\ \text{J}\cdot\text{s} \times \dfrac{94.5 \times 10^6}{1\ \text{s}} = 6.26 \times 10^{-26}\ \text{J}$

The FM photon has about 66 times more energy than the AM photon.

6.25 *Analyze/Plan.* An isolated electron is assigned an energy of zero; the closer the electron comes to the nucleus, the more negative its energy. Thus, as an electron moves closer to the nucleus, the energy of the electron decreases and the excess energy is emitted. Conversely, as an electron moves further from the nucleus, the energy of the electron increases and energy must be absorbed. *Solve:*

(a) As the principle quantum number decreases, the electron moves toward the nucleus and energy is emitted.

(b) An increase in the radius of the orbit means the electron moves away from the nucleus; energy is absorbed.

(c) An isolated electron is assigned an energy of zero. As the electron moves to the n = 3 state closer to the H^+ nucleus, its energy becomes more negative (decreases) and energy is emitted.

6.28 (a) $\Delta E = -2.18 \times 10^{-18}\ \text{J}\left[\dfrac{1}{n_f^2} - \dfrac{1}{n_i^2}\right] = -2.18 \times 10^{-18}\ \text{J}\ (1/1 - 1/25) = -2.093 \times 10^{-18}$
$= -2.09 \times 10^{-18}\ \text{J}$

$\nu = E/h = \dfrac{2.093 \times 10^{-18}\ \text{J}}{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}} = 3.158 \times 10^{15} = 3.16 \times 10^{15}\ \text{s}^{-1}$

$\lambda = c/\nu = \dfrac{2.998 \times 10^8\ \text{m}}{1\ \text{s}} \times \dfrac{1\ \text{s}}{3.158 \times 10^{15}} = 9.49 \times 10^{-8}\ \text{m}$

Since the sign of ΔE is negative, radiation is emitted.

(b) $\Delta E = -2.18 \times 10^{-18}\ \text{J}(1/4 - 1/16) = -4.0875 \times 10^{-19} = -4.09 \times 10^{-19}\ \text{J}$

$\nu = \dfrac{4.0875 \times 10^{-19}\ \text{J}}{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}} = 6.1689 \times 10^{14} = 6.17 \times 10^{14}\ \text{s}^{-1}$; $\lambda = \dfrac{2.998 \times 10^8\ \text{m/s}}{6.1689 \times 10^{14}/\text{s}}$

$\lambda = 4.86 \times 10^{-7}$ m. Visible radiation is emitted.

(c) $\Delta E = -2.18 \times 10^{-18}\ \text{J}\ (1/36 - 1/16) = 7.5694 \times 10^{-20} = 7.57 \times 10^{-20}\ \text{J}$

$\nu = \dfrac{7.5694 \times 10^{-20}\ \text{J}}{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}} = 1.1424 \times 10^{14} = 1.14 \times 10^{14}\ \text{s}^{-1}$; $\lambda = \dfrac{2.998 \times 10^8\ \text{m/s}}{1.1424 \times 10^{14}/\text{s}}$

$\lambda = 2.62 \times 10^{-6}$ m. Radiation is absorbed.

6.33 (a) $\dfrac{50\ \text{km}}{1\ \text{hr}} \times \dfrac{1000\ \text{m}}{1\ \text{km}} \times \dfrac{1\ \text{hr}}{60\ \text{min}} \times \dfrac{1\ \text{min}}{60\ \text{s}} = 13.89 = 14\ \text{m/s}$

$\lambda = \dfrac{6.626 \times 10^{-34}\ \text{kg}\cdot\text{m}^2\cdot\text{s}}{1\ \text{s}^2} \times \dfrac{1}{85\ \text{kg}} \times \dfrac{1\ \text{s}}{13.89\ \text{m}} = 5.6 \times 10^{-37}\ \text{m}$

(b) $10.0\ \text{g} \times \dfrac{1\ \text{kg}}{1000\ \text{g}} = 0.0100\ \text{kg}$

$\lambda = \dfrac{6.626 \times 10^{-34}\ \text{kg}\cdot\text{m}^2\cdot\text{s}}{1\ \text{s}^2} \times \dfrac{1}{0.0100\ \text{kg}} \times \dfrac{1\ \text{s}}{250\ \text{m}} = 2.65 \times 10^{-34}\ \text{m}$

(c) We need to calculate the mass of a single Li atom in kg.

$\dfrac{6.94\ \text{g Li}}{1\ \text{mol Li}} \times \dfrac{1\ \text{kg}}{1000\ \text{g}} \times \dfrac{1\ \text{mol}}{6.022 \times 10^{23}\ \text{Li atoms}} = 1.152 \times 10^{-26} = 1.15 \times 10^{-26}\ \text{kg}$

$\lambda = \dfrac{6.626 \times 10^{-34}\ \text{kg}\cdot\text{m}^2\cdot\text{s}}{1\ \text{s}^2} \times \dfrac{1}{1.152 \times 10^{-26}\ \text{kg}} \times \dfrac{1\ \text{s}}{2.5 \times 10^5\ \text{m}} = 2.3 \times 10^{-13}\ \text{m}$

6.38 $\Delta x \geq h/4\pi m\Delta v$; use masses in kg, Δv in m/s.

(a) $\dfrac{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}}{4\pi(9.109 \times 10^{-31}\ \text{kg})(0.01 \times 10^5\ \text{m/s})} = 6 \times 10^{-8}\ \text{m}$

(b) $\dfrac{6.626 \times 10^{-34}\ \text{J}\cdot\text{s}}{4\pi(1.675 \times 10^{-27}\ \text{kg})(0.01 \times 10^5\ \text{m/s})} = 3 \times 10^{-11}\ \text{m}$

(c) For particles moving with the same uncertainty in velocity, the more massive neutron has a much smaller uncertainty in position than the lighter electron. In our model of the atom, we know where the massive particles in the nucleus are located, but we cannot know the location of the electrons with any certainty, if we know their speed.

P.S #8 KEY

6 Electronic Structure of Atoms — Solutions to Exercises

6.41 (a) The possible values of l are (n-1) to 0. $n = 4$, $l = 3, 2, 1, 0$

(b) The possible values of m_l are $-l$ to $+l$. $l = 2$, $m_l = -2, -1, 0, 1, 2$

6.42 (a) For $n = 3$, there are 3 l values (2, 1, 0) and 9 m_l values ($l = 2$; $m_l = -2, -1, 0, 1, 2$; $l = 1$, $m_l = -1, 0, 1$; $l = 0$, $m_l = 0$).

(b) For $n = 5$, there are 5 l values (4, 3, 2, 1, 0) and 25 m_l values ($l = 4$, $m_l = -4$ to $+4$; $l = 3$, $m_l = -3$ to $+3$; $l = 2$, $m_l = -2$ to $+2$; $l = 1$, $m_l = -1$ to $+1$; $l = 0$, $= 0$).

In general, for each principle quantum number n there are nl-values and n^2 m_l-values. For each shell, there are n kinds of orbitals and n^2 total orbitals.

6.43 (a) 3p: $n = 3$, $l = 1$ (b) 2s: $n = 2$, $l = 0$ (c) 4f: $n = 4$, $l = 3$ (d) 5d: $n = 5$, $l = 2$

6.46 (a) permissible, 2p (b) forbidden, for $l = 0$, m_l can only equal 0
(c) permissible, 4d (d) forbidden, for n = 3, the largest l value is 2

6.51 (a) In the hydrogen atom, orbitals with the same principle quantum number, n, have the same energy; they are degenerate.

(b) In a many-electron atom, for a given n-value, orbital energy increases with increasing l-value: s < p < d < f

6.52 (a) The electron with the greater average distance from the nucleus feels a smaller attraction for the nucleus and is higher in energy. Thus the 3p is higher in energy than 3s.

(b) Because it has a larger n value, a 3s electron has a greater average distance from the chlorine nucleus than a 2p electron. The 3s electron experiences a smaller attraction for the nucleus and requires less energy to remove from the chlorine atom.

6.53 (a) +1/2, - 1/2

(b) Electrons with opposite spins are affected differently by a strong inhomogeneous magnetic field. An apparatus similar to that in Figure 6.24 can be used to distinguish electrons with opposite spins.

(c) The Pauli exclusion principle states that no two electrons can have the same four quantum numbers. Two electrons in a 1s orbital have the same, n, l and m_l values. They must have different m_s values.

6.59 (a) Cs: $[Xe]6s^1$ (b) Ni: $[Ar]4s^2 3d^8$ (c) Se: $[Ar]4s^2 3d^{10} 4p^4$
(d) Cd: $[Kr]5s^2 4d^{10}$ (e) Ac: $[Rn]7s^2 6d^1$ (f) Pb: $[Xe]6s^2 4f^{14} 5d^{10} 6p^2$

6.60 (a) Al: $[Ne]3s^2 3p^1$ (b) Sc: $[Ar]4s^2 3d^1$ (c) Co: $[Ar]4s^2 3d^7$
(d) Br: $[Ar]4s^2 3d^{10} 4p^5$ (e) Ba: $[Xe]6s^2$ (f) Re: $[Xe]6s^2 4f^{14} 5d^5$
(g) Lu: $[Xe]6s^2 4f^{14} 5d^1$

6.66 Count the total number of electrons to assign the element.

(a) N: $[He]2s^2 2p^3$ (b) Se: $[Ar]4s^2 3d^{10} 4p^4$ (c) Rh: $[Kr]5s^2 4d^7$

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