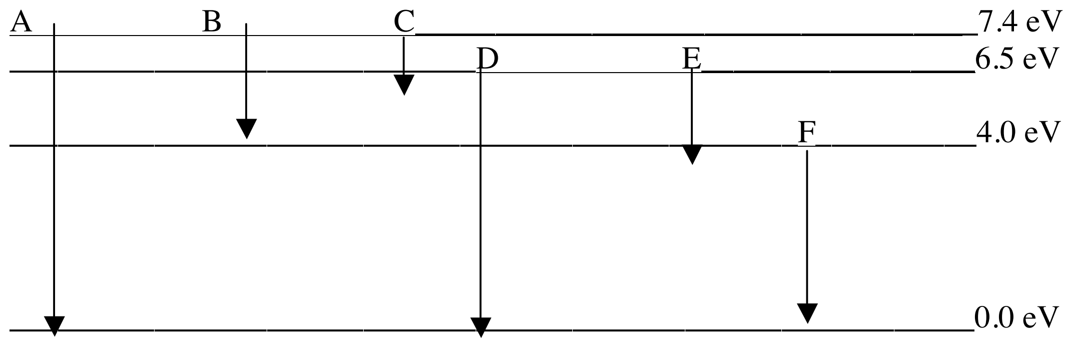
Ch.17 Solutions to selected problems

17.1. (I) Calculate (a) the energies in joules and (b) frequencies in Hz, of the photons emitted as the electrons transition to a lower excited states for transition A, C, and F in *Fig. 17.18*. (c) Identify the type of light of the emitted photons.

(a) Calculate the energy in joules of the photon given off when an electron makes the following transitions; A,C, F



Note that the energy of the photon in electron-volts is the difference in energies of the two levels involved in the transition. This shouldn't surprise those of you who believe in the conservation of energy.

Transition A: $7.4 \text{ eV} \left(1.6 \times 10^{-19} \frac{\text{joules}}{\text{eV}} \right) = 1.18 \times 10^{-18} \text{ joules}$

Transition C: $0.90 \text{ eV} \left(1.6 \times 10^{-19} \frac{\text{joules}}{\text{eV}} \right) = 1.44 \times 10^{-19} \text{ joules}$

Transition F: $4 \text{ eV} \left(1.6 \times 10^{-19} \frac{\text{joules}}{\text{eV}} \right) = 6.4 \times 10^{-19} \text{ joules}$

(**b)** Calculate the frequency of the photon emitted if an electron undergoes transition A, C or F.

Solving E = hf for f, we get: $f = \frac{E}{h}$

Transition A: $f = \frac{E}{h} = \frac{1.18 \times 10^{-18} \text{J}}{6.626 \times 10^{-34} \text{J} \cdot \text{S}} = \frac{1.78 \times 10^{15}}{\text{sec}} = 1.78 \times 10^{15} \text{ Hz}$

Transition C: $f = \frac{E}{h} = \frac{1.44 \times 10^{-19} \text{J}}{6.626 \times 10^{-34} \text{J} \cdot \text{S}} = \frac{2.17 \times 10^{14}}{\text{sec}} = 2.17 \times 10^{14} \text{ Hz}$

Transition F: $f = \frac{E}{h} = \frac{6.4 \times 10^{-19} \text{J}}{6.626 \times 10^{-34} \text{J} \cdot \text{S}} = \frac{9.66 \times 10^{14}}{\text{sec}} = 9.66 \times 10^{14} \text{ Hz}$

Problem 17.1 continued.

(c) Calculate the wavelength (in nanometers) of the photon emitted and then name that photon.

Solving $c = f\lambda$ for λ, we find that $\lambda = \frac{c}{f}$

Transition A: $\lambda = \frac{c}{f} = \frac{3 \text{ x } 10^8 \frac{m}{sec}}{\frac{1.78 \text{ x } 10^{15}}{sec}} = 1.69 \text{ x } 10^{-7} m = 169 \text{ nm}$: **Ultraviolet**

Transition C: $\lambda = \frac{c}{f} = \frac{3 \text{ x } 10^8 \frac{m}{sec}}{\frac{2.17 \text{ x } 10^{14}}{sec}} = 1.38 \text{ x } 10^{-6} m = 1380 \text{ nm}$: **Infrared**

Transition F: $\lambda = \frac{c}{f} = \frac{3 \text{ x } 10^8 \frac{m}{sec}}{\frac{9.66 \text{ x } 10^{14}}{sec}} = 3.11 \text{ x } 10^{-7} m = 311 \text{nm}$: **Ultraviolet**-very close to being visible light, violet in color.

17.2. (I) Calculate the (a) maximum and (b) minimum photon energies produced by a hot gas having the energy level scheme shown in *Figure 17.18*. What types of radiation are these two extremes?

(a) We see from problem 17.1 that the maximum energy transition is A. An ultraviolet photon with:

$7.4 \text{ eV} = 1.18 \text{ x } 10^{-18}$ joules of energy.

(b) We see from problem 17.1 that the minimum energy transition is C. An infrared photon with:

$0.90 \text{ eV} \left(1.6 \text{ x } 10^{-19} \frac{\text{joules}}{\text{eV}} \right) = 1.44 \text{ x } 10^{-19} \text{ joules}$

17.3. (I) If one of the excited states of the atom having the energy level scheme shown in *Figure 17.18* is metastable, then a laser may be constructed from this material. If the 4.0-eV state is metastable, what wavelength EM radiation would the laser produce?

Transition F would occur. It will produce a photon with energy:
$4 \text{ eV} = 6.4 \text{ x } 10^{-19}$ joules.
In order to solve for the wavelength, note that E = hf and from $c = f\lambda$, we know that the frequency $f = \frac{c}{\lambda}$. Substituting for f in the energy statement results in:

$$E = hf = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E} = \frac{6.626 \text{ x } 10^{-34} j \cdot s \left(3 \text{ x } 10^8 \frac{m}{s} \right)}{6.4 \text{ x } 10^{-19} \text{ joules}} = 3.11 \text{ x } 10^{-7} m = 311 \text{ nm}$$

A photon of wavelength with wavelength of 311nm, is an ultraviolet photon.

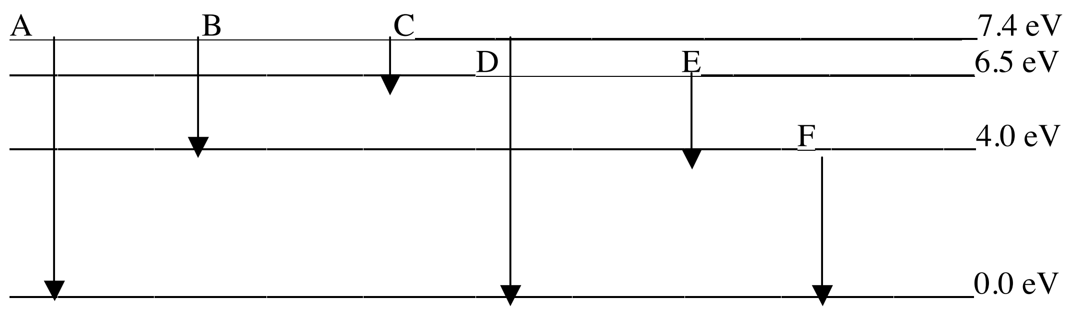
Ch.17 Solutions to selected problems

17.4 (I) Calculate the wavelength of a 10-g marble traveling at a speed of 5.0 m/sec in a children's marble game. Is it likely to exhibit any wave effects?

$$\lambda = \frac{h}{mv} = \frac{6.626 \text{ x } 10^{-34}\, \text{j} \cdot \text{s}}{.01 \text{ kg}(5\frac{\text{m}}{\text{sec}})} = 1.33 \text{ x } 10^{-32} \text{ m}$$

There will not be any noticeable wave effects.

17.5 (II) Calculate the frequencies and wavelengths of the photons emitted in transitions B, D, and E in *Figure 17.18*. What types of radiation are produced by these three transitions?



Transition B:

Energy of transition B is 7.4 eV-4 eV = 3.4 eV.

Converting the energy to joules:

Energy: $3.4 \text{ eV } (1.6 \text{ x } 10^{-19} \frac{\text{joules}}{\text{eV}}) = 5.44 \text{ x } 10^{-19} \text{ joules}$

Frequency: E = hf; Solving for f we find that:

$$f = \frac{E}{h} = \frac{5.44 \text{ x } 10^{-19} \text{ joules}}{6.626 \text{ x } 10^{-34} \text{ joule} \cdot \text{sec}} = \frac{8.21 \text{ x } 10^{14}}{\text{sec}}$$

Wavelength:

From $c = f\lambda$ we find that $\lambda = \frac{c}{f} = \frac{3 \text{ x } 10^{8} \frac{\text{m}}{\text{sec}}}{8.21 \text{ x } 10^{14} \text{sec}} = 3.65 \text{ x } 10^{-7} \text{ m}$

Wavelength: $\lambda = 365$ nm

Type of light: ultraviolet light-very close to violet.

Transition D:

Energy: The energy of transition D is 6.5 eV – 0.0 eV = 6.5 eV

Converting the energy to joules:

$$6.4 \text{ eV } (1.6 \text{ x } 10^{-19} \frac{\text{joules}}{\text{eV}}) = 1.04 \text{ x } 10^{-18} \text{ joules}$$

Frequency: $f = \frac{E}{h} = \frac{1.04 \text{ x } 10^{-18} \text{ joules}}{6.626 \text{ x } 10^{-34} \text{ joule} \cdot \text{sec}} = \frac{1.57 \text{ x } 10^{15}}{\text{sec}}$

Wavelength:

From $c = f\lambda$ we find that $\lambda = \frac{c}{f} = \frac{3 \text{ x } 10^{8} \frac{\text{m}}{\text{sec}}}{\frac{1.57 \text{ x } 10^{15}}{\text{sec}}} = 1.91 \text{ x } 10^{-7} \text{m}$

$\lambda = 191$ nm **Type of light:** Ultraviolet.

Transition E:

Energy: The energy of transition E is 2.5 eV.
Converting to joules:

$$2.5 \text{ eV } (1.6 \times 10^{-19} \frac{\text{joules}}{\text{eV}}) = 4.0 \times 10^{-19} \text{ joules}$$

Frequency: $f = \frac{E}{h} = \frac{4.0 \times 10^{-19} \text{ joules}}{6.626 \times 10^{-34} \text{ joule} \cdot \text{sec}} = \frac{6.04 \times 10^{14}}{\text{sec}}$

Wavelength: From c = hf we find:

$$\lambda = \frac{c}{f} = \frac{3 \times 10^{8} \frac{\text{m}}{\text{sec}}}{\frac{6.04 \times 10^{14}}{\text{sec}}} = 4.97 \times 10^{-7} \text{m} \mathbf{= 497 \text{ nm}}$$

Type of light: visible.

(II) What wavelengths of EM radiation are produced by a hot gas of atoms having the energy level scheme in *Figure 17.18*? Which if any of these photons are hazardous to humans?

To find the wavelength of a photon, we recommend that you do the following substitution for each part of this problem.

The energy of a photon is given by E = hf;

Solve for f in the following equation: $c = f\lambda$

$$f = \frac{c}{\lambda}$$

Substitute for f in the energy equation:

$$E = \frac{hc}{\lambda}$$

Now solve for the wavelength lambda in order to get our working equation:

$$\lambda = \frac{hc}{E}$$

Also note that since h is in units of $\text{joule} \cdot \text{seconds}$, the energy must be in joules.

Transition A:

$$\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34} \text{ j} \cdot \text{s } (3 \times 10^{8} \frac{\text{m}}{\text{s}})}{7.4 \text{ eV}} (\frac{1 \text{ eV}}{1.6 \times 10^{-19} \text{ j}}) = 1.68 \times 10^{-7} \text{ m} = 168 \text{ nm}$$

168 nm is in the ultraviolet region and should be considered harmful.

Transition B:

$$\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34} \text{ j} \cdot \text{s } (3 \times 10^{8} \frac{\text{m}}{\text{s}})}{3.4 \text{ eV}} (\frac{1 \text{ eV}}{1.6 \times 10^{-19} \text{ j}}) = 3.65 \times 10^{-7} \text{m} = 365 \text{ nm}$$

365 nm is in the ultraviolet-violet region.

Transition C:

$$\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34}\, j\cdot s\,(3 \times 10^{8}\,\frac{m}{s})}{0.9\ eV}\left(\frac{1\ eV}{1.6 \times 10^{-19}\ j}\right) = 1.38 \times 10^{-6}\ m = 1380\ nm$$

1380 nm is in the infrared part of the spectrum.

Transition D:

$$\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34}\, j\cdot s\,(3 \times 10^{8}\,\frac{m}{s})}{6.5\ eV}\left(\frac{1\ eV}{1.6 \times 10^{-19}\ j}\right) = 1.91 \times 10^{-7}\ m = 191\ nm$$

191 nm is in the ultraviolet region of the electromagnetic spectrum and should be considered harmful.

Transition E:

$$\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34}\, j\cdot s\,(3 \times 10^{8}\,\frac{m}{s})}{2.5\ eV}\left(\frac{1\ eV}{1.6 \times 10^{-19}\ j}\right) = 4.97 \times 10^{-7}\ m = 497\ nm$$

497 nm is in the visible part of the electromagnetic spectrum.

Transition F:

$$\lambda = \frac{hc}{E} = \frac{6.626 \times 10^{-34}\, j\cdot s\,(3 \times 10^{8}\,\frac{m}{s})}{4.0\ eV}\left(\frac{1\ eV}{1.6 \times 10^{-19}\ j}\right) = 3.11 \times 10^{-7}\ m = 311\ nm$$

311 nm is in the ultraviolet part of the electromagnetic spectrum.

(II) (a) Which transition in an atom with the level scheme shown in *Figure 17.18* produces photons of wavelength 1.38×10^{-6} m? (b) Which produces photons of frequency 1.57×10^{15} Hz?

(a) Which transition in an atom with the energy level scheme shown in *Figure 17.18* produces photons of wavelength 1.38×10^{-6} m?
Looking through the solutions in problem 6, we see that **transition C** has a wavelength of 1.38×10^{-6} m = 1380 nm.
(b) Which produces a photon with frequency 1.57×10^{15} Hz?
Since we have already calculated all of the wavelengths for problem 6, just solve $c = f\lambda$ for wavelength.

$$c = f\lambda;\ \lambda = \frac{c}{f} = \frac{3 \times 10^{8}\,\frac{m}{s}}{\frac{1.57 \times 10^{15}}{s}} = 1.91 \times 10^{-7}\ m$$

Looking at our solutions for problem 6, we see that **transition D** had a wavelength of 1.91×10^{-7} m and therefore has a frequency of 1.57×10^{15} Hz.