CH 221 Chapter Six Part I Concept Guide

1. Radiation, Wavelength, and Frequency

Question

Is the frequency of the radiation used in a microwave oven higher or lower than that from an FM radio station broadcasting at 91.7 MHz (where 1 MHz = 10^6 s^{-1})?

Solution

Microwave radiation has a frequency on the order of 10^{10} Hz, compared to FM radio, which has a frequency on the order of 10^8 Hz. FM radio is, therefore, lower in frequency than microwaves.

2. The Relationship between Wavelength and Frequency

Question

What is the wavelength of orange light of frequency 4.85 x 10^{14} Hz?

Approach

We need to convert frequency to wavelength using the following relation:

$\lambda = c / \nu$

where λ is wavelength in meters, c is the speed of light, and ν is the frequency in s^{-1}.

Solution

$\lambda = c / \nu$

$\lambda = 3.00 \times 10^8$ m/s / 4.85×10^{14} s^{-1}

$\lambda = 6.19 \times 10^{-7}$ m = 619 nm

3. Planck's Law

Problem

Compare the energy of a mole of photons of green light (5.00 x 10^2 nm) with the energy of a mole of photons of microwave radiation having a frequency of 2.45 GHz (1 GHz = 10^9 s^{-1}). Which has greater energy? By what factor is one greater than the other?

Approach

First, we calculate the frequency of radiation of green light. Next, we calculate the energy of the green light and the energy of the microwave radiation. A ratio of energies will result in the factor by which one is greater than the other.

Solution

Step 1: Calculate the frequency of green light.

$\nu = c/\lambda = 3.00 \times 10^8$ m s^{-1} / 5.00×10^{-7} m = 6.00×10^{14} s^{-1}

Step 2: Calculate the energies of green light and microwave radiation.

E(green light) = hν = (6.626×10^{-34} J s/photon)(6.00×10^{14} s^{-1}) = 3.98×10^{-19} J/photon

E(microwave radiation) = hν = (6.626×10^{-34} J s/photon)(2.45×10^9 s^{-1}) = 1.62×10^{-24} J/photon

Green light has greater energy than microwave radiation.

Step 3: Use a ratio of energy values to calculate the factor by which the energy of green light is greater than that of microwave radiation.

E(green light) / E(microwave radiation)

= 3.98×10^{-19} J/photon / 1.62×10^{-24} J/photon = 2.45×10^5

Green light is almost a quarter of a million times more energetic than microwaves.

4. Matter as Waves

Question
Does a particle exhibiting wavelike behavior have a frequency as well as a wavelength?

Solution
All matter exhibits wavelike behavior. Recall that for all waves, $\lambda\nu = c$, where λ is the wavelength, ν is the frequency, and c is the speed of light. For waves, c is replaced by v, which is the velocity of the wave: $\lambda\nu = v$.

Thus, $\lambda = v/\nu$, and $v/\nu = h/mv$. Finally, $\nu = mv^2/h$.

5. Calculating Uncertainty in the Position of an Electron

Question
What is the smallest possible uncertainty in the position of an electron having a mass of 9.109×10^{-21} kg and a velocity of $3.0 \times 10^7 \pm 7.27 \times 10^5$ m/s? 1 Joule = 1 kg m^2/s^2.

Solution
The product of the uncertainty is momentum, $m\Delta v$, and the uncertainty in position, Δx, must be greater than h: $(m\Delta v)(\Delta x) > h$.

Therefore, $\Delta x > h/m\Delta v$.
$\Delta x > h/m\Delta v$
$\Delta x \sim (6.626 \times 10^{-34}\ \text{kg s m}^2/\text{s}^2) / (9.109 \times 10^{-21}\ \text{kg})(7.27 \times 10^5\ \text{m/s})$
$\Delta x \sim 10^{-19}$ m

6. Nodes

Question
The total number of nodes in an orbital is equal to the shell number, *n*, minus 1. These nodes are either nodal planes or nodal spheres. The number of nodal planes is equal to the value of *l* and the remainder are nodal spheres. What types of nodes exist in 3d orbitals and in 4d orbitals?

Approach
Find the total number of nodes from the shell number, the number of nodal planes for the value of *l*, and the number of nodal spheres by taking the difference.

Solution
A 3d orbital has $n = 3$, and a 4d orbital has $n = 4$, thus a 3d orbital has 2 nodes and a 4d orbital has 3 nodes. Both are d orbitals, therefore $l = 2$ and both 3d and 4d have 2 nodal planes. Finally, a 3d orbital has 2 nodes, of which 2 are nodal planes. This orbital has no nodal spheres. A 4d orbital, however, has 3 nodes, of which 2 are planes. A 4d orbital has 1 nodal sphere.

7. Quantum Numbers and Orbitals

Question
What values of the subshell quantum number correspond to the (a) d, (b) f, (c) s, (d) p, (e) g subshells?

Solution:
The first five subshells, l = 0, 1, 2, 3, 4, are identified by the letters s, p, d, f, and g.

(a) 2
(b) 3
(c) 0
(d) 1
(e) 4