Atomic physics, photoelectric 2

1. Find the total electromagnetic energy emitted by the hydrogen atom if its electron jumps from the first orbital to the infinity!

Solution

The Rydberg formula for the hydrogen is used:

$$\frac{1}{\lambda_0} = R_\infty \left(\frac{1}{m^2} - \frac{1}{n^2} \right),,$$

where λ_0 is wavelength of electromagnetic radiation emitted in vacuum, R_∞ is the Rydberg frequency for hydrogen, *m* is principal quantum number for energy level, *m* is principal quantum number for energy level for the atomic electron transition (n > m). We have:

$$\Delta E = h\frac{1}{\lambda_0} = h \cdot R_\infty \left(\frac{1}{m^2} - \frac{1}{n^2} \right) = m \to \infty = -h \cdot R_\infty \frac{1}{n} = \to n = 1 \Rightarrow$$

$$\Delta E_{1,\infty} = -h \cdot R_\infty = -3.29 \cdot 10^{15}\, Hz \cdot 6.625 \cdot 10^{-34}\, J = -21.796 \cdot 10^{-19}\, J = \underline{\underline{-13.6\, eV}}$$

The total emitted energy is -13.6 eV.

2. The electron is accelerated with the electric field and then it collides with the hydrogen atom which is excited by collision to the second energy level. Find the potential of the electric field necessary to required electron's acceleration!

Solution

The energy of the first level is -13.6 eV, the energy for the second level is 3.1 eV:

$$\Delta E_{1,2} = E_2 - E_1 = (-3.4 + 13.6)\, eV = 10.2\, eV$$

$$\Delta E_{1,2} = e \cdot U \Rightarrow U = \frac{\Delta E_{1,2}}{e} = \frac{10.2\, eV}{e} = \underline{\underline{10.2 V}}$$

The required potential is 10.2 V.

3. The UV light $(\lambda = 150\,nm)$ is falling on the platinum plate (boundary frequency $f_0 = 12.8\cdot 10^{14}\,Hz$). Find the speed of the emitted electrons in the photoelectric effect!

Solution

$$f = \frac{c}{\lambda} = \left[\frac{3\cdot 10^{8}}{150\cdot 10^{-9}}\right] Hz = 2\cdot 10^{15}\,Hz$$

$$h\cdot f = h\cdot f_0 + \frac{1}{2} m_e v_e^2 \Rightarrow v_e = \sqrt{\frac{2h\left(f - f_0\right)}{m_e}}$$

$$v_e = \sqrt{\frac{2\cdot 6.625\cdot 10^{-34}\left(2\cdot 10^{15} - 12.8\cdot 10^{14}\right)}{9.1\cdot 10^{-31}}}\,m\,s^{-1} \approx \underline{\underline{10^{6}\,m\,s^{-1}}}$$

4. Find the boundary frequency for the nickel plate necessary for the photoelectric effect! The work of the electrons emitted from nickel is 5 eV.

Solution

$$W_e = h \cdot f_0 \Rightarrow f_0 = \frac{W_e}{h} = \frac{5 \cdot 1.602 \cdot 10^{-19}}{6.625 \cdot 10^{-34}} Hz \approx \underline{\underline{1.21 \cdot 10^{15} Hz}}$$