CHEM 361B - Lecture 3 Activity

Quantization: A Scientific Revolution

1. Before Planck's theoretical work on blackbody radiation, Wien showed empirically that

$$\lambda_{max} T = 2.90 \times 10^{-3} \text{ m K}$$

where λ_{max} is the wavelength at which the blackbody spectrum has its maximum value at a Temperature T. This expression is called the Wien displacement law.

   (a) Sirius, one of the hottest known stars, has approximately a blackbody spectrum with $\lambda_{max} = 260$ nm. Estimate the surface temperature of Sirius to be 1.12×10^4 K.

   (b) The temperature of the fireball in a thermonuclear explosion can reach temperatures of approximately 10^7 K. Show that λ_{max} is 0.29 nm.

2. A photoelectric effect experiment is setup using a light that emits at a wavelength of 500 nm.

   (a) Using the data in the table, show that K is the only metal that would emit electrons

Metal	ϕ (J)
K	3.685×10^{-19}
Na	4.406×10^{-19}
Al	6.857×10^{-19}
Cu	7.45×10^{-19}
Fe	7.53×10^{-19}
Ag	7.578×10^{-19}
Au	8.17×10^{-19}

   (b) Does changing the intensity of the light change what metals would emit electrons? Explain.

   (c) Does decreasing the wavelength change what metals would emit electrons? Explain.

   (d) Under what condition(s) would all the metals emit electrons? Quantify your answer with numbers.

3. The statements below refer to a typical photoelectric effect experiment. Each statement is at least partially incorrect. Indicate what is wrong with each statement. Explain your reasoning. (Assume the light is on, but that changes can be made to the frequency, wavelength, or intensity of the light, as well as to the material of the electrodes.)

(a) Intensity is not in the equation $E_{photon} = \phi + E_K$, so adjusting it will not change the number of electrons emitted.

(b) If there are no electrons being emitted, increasing the frequency will result in at least some current. If there is some current, increasing the frequency will result in a maximum current.

4. Planck's principal assumption was that the energies of the electronic oscillators can have only the values of $E = nh\nu$ and that $\Delta E = h\nu$. As $\nu \to 0$, then $\Delta E \to 0$ and E is essentially continuous. Thus, we should expect the nonclassical Planck distribution to go over to the classical Rayleigh-Jeans distribution at low frequencies, where $\Delta E \to 0$. Show that

$$\rho_\nu(T)d\nu = \frac{8\pi h}{c^3}\frac{\nu^3 d\nu}{e^{h\nu/k_BT} - 1} \tag{1}$$

reduces to

$$\rho_\nu(T)d\nu = \frac{8\pi k_BT}{c^3}\nu^2 d\nu$$

as $\nu \to 0$. Use the fact that $e^x \approx 1 + x$ when x is small.