

Show all steps in your calculations. Justify all answers. Write clearly.

Some constants: $hc = 12,400\text{eV}\cdot\text{\AA}$, $k_B = 1/11.600\text{eV}/\text{K}$, $m_e c^2 = 511,000\text{eV}$

Problem 1 (10 pts)

In an ideal gas, the average of the magnitude of the velocity of the molecules in the x direction, $\langle |v_x| \rangle$, is 200 m/s.

Note that $\langle |v_x| \rangle$ is not the same as $\sqrt{\langle v_x^2 \rangle}$

(a) Find $\sqrt{\langle v_x^2 \rangle}$, in m/s.

(b) If 1000 molecules have speed in the x direction of average magnitude, that is, 200m/s, how many molecules have speed in the x direction twice the average magnitude, i.e. 400m/s?

(c) If the temperature of this gas is increased by 100K, $\langle |v_x| \rangle$ is 300 m/s. What was the original temperature, in K?

Hint: you can calculate $\langle |v_x| \rangle$ by calculating $\langle v_x \rangle$ for positive v_x and multiplying the answer by 2. Use Appendix B1.

Hint 2: you can answer (c) even if you didn't answer (a) and (b), and you can answer (b) even if you didn't answer (a).

Problem 2 (10 pts)

The tungsten filament in a light bulb emits maximum power at wavelength 6000Å. The total power it emits is 40W.

(a) What is its surface area, in mm^2 ?

(b) What fraction of the power that it emits at 6000Å does it emit at 3000Å? (per unit wavelength).

(c) How many photons of wavelength between 3000Å and 3001Å does it emit for every 10,000 photons of wavelength between 6000Å and 6001Å that it emits?

Hint: $\lambda_m T = hc / (4.965k_B)$

Problem 3 (10 pts)

Photons of incident wavelength λ that are Compton-scattered by electrons have wavelengths in the range λ to 3λ for all scattering angles.

(a) What is λ , in Å?

(b) What is the electron kinetic energy when the scattered photon has wavelength 2λ ?

Give your answer in eV.

(c) What is the photon scattering angle when the scattered photon has wavelength 2λ ? Give your answer in degrees.

(d) What is the electron scattering angle when the scattered photon has wavelength 2λ ? Give your answer in degrees.

For extra credit: (3 pts) (e) What is the speed of the scattered electron when the scattered photon has wavelength 3λ ? Give your answer as v/c .