

HOMEWORK 4 SOLUTIONS

3-36) (a) $E = hf = \frac{hc}{\lambda} = \frac{1240 \text{ eV} \cdot \text{nm}}{0.0711 \text{ nm}} = \boxed{1.75 \times 10^4 \text{ eV}} = 17.5 \text{ keV}$

(b) For $\theta = 180^\circ$ $\cos\theta = -1$ so we get

$$\lambda_2 = \lambda_1 + \frac{h}{mc}(1 - \cos\theta)$$
$$= 0.0711 + [(1240 \text{ eV} \cdot \text{nm}) / (5.11 \times 10^5 \text{ eV})] (2)$$

$$\boxed{\lambda_2 = 0.0760 \text{ nm}}$$

(c) The corresponding photon energy is

$$E_2 = \frac{hc}{\lambda_2} = \frac{1240 \text{ eV} \cdot \text{nm}}{0.0760 \text{ nm}} = \boxed{1.63 \times 10^4 \text{ eV}} = 16.3 \text{ keV}$$

(d) Total energy is conserved, so the electrons K.E. is

$$E = 1.75 \times 10^4 \text{ eV} - 1.63 \times 10^4 \text{ eV}$$

$$\boxed{E = 1130 \text{ eV}} = 1.130 \text{ keV}$$

3-49) To get useful information from the data it's best to make a graph like Fig 3-13. The stopping potential is given by

$$q \cdot V_0 = hf - \phi$$
$$= hc/\lambda - \phi$$

So V_0 is a linear function of f or of $1/\lambda$. For each wavelength let's find the frequency using $\lambda f = c$

$$\lambda = 253.5 \text{ nm}$$

$$f = 1.183 \times 10^{15} / \text{s}$$

$$312.5$$

$$0.960 \text{ ''}$$

$$365.0$$

$$0.822 \text{ ''}$$

$$404.7$$

$$0.741 \text{ ''}$$

$$433.9$$

$$0.691 \text{ ''}$$

(a) The graph is on the next page. To get the work function draw a line through the points and extrapolate to $f=0$. At $f=0$ we have $qV_0 = -\phi \Rightarrow$ I get

$$\boxed{\phi \approx 2.3 \text{ eV}}$$

(b) We get Planck's constant from the slope. I get

$$h = \frac{1.2 \text{ eV}}{0.3 \times 10^{15} / \text{s}} \Rightarrow \boxed{h = 4.0 \times 10^{-15} \text{ eV} \cdot \text{s}}$$

(c) The work function for lead is 4.14 eV, which is $(4.14 - 2.3) \text{ eV} = 1.84 \text{ eV}$ greater than lithium \Rightarrow the electron energies would be smaller by 1.84 eV. We get emission only for 253.5 nm.

8-27) The average energy is given by Eq. 8-84

$$\langle E \rangle = \frac{hf}{e^{hf/kT} - 1}$$

$$= kT \left[\frac{hf/kT}{e^{hf/kT} - 1} \right]$$

(a) $T = 10 hf/k$
 $\Rightarrow hf/kT = 1/10$

$$\langle E \rangle = (kT) \frac{0.1}{e^{0.1} - 1}$$

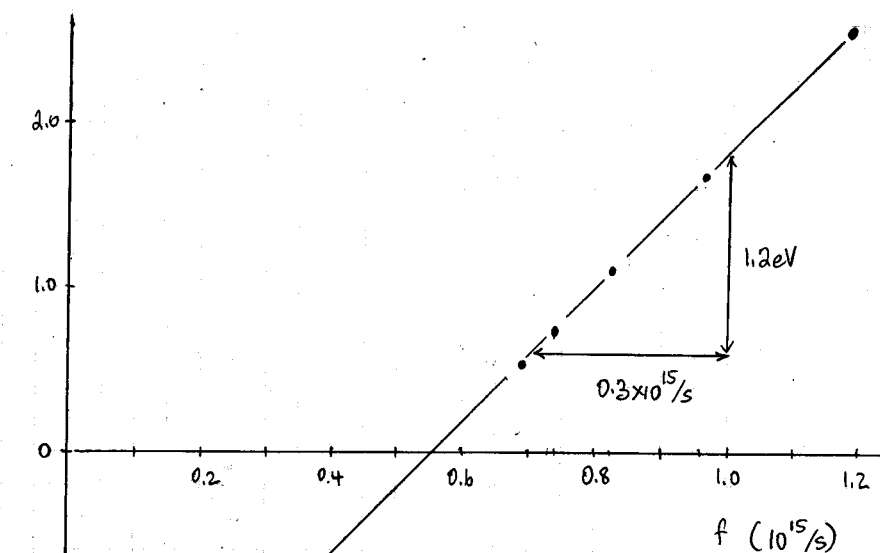
$$\boxed{\langle E \rangle = 0.951 kT}$$
 which is close to the equipartition value.

(b) $T = hf/k \Rightarrow hf/kT = 1$

$$\langle E \rangle = kT \frac{1}{e^1 - 1} = \boxed{\langle E \rangle = 0.582 kT}$$

(c) $T = 0.1 \frac{hf}{k} \Rightarrow \frac{hf}{kT} = 10$

$$\langle E \rangle = kT \frac{10}{e^{10} - 1} \Rightarrow \boxed{\langle E \rangle = 0.000454 kT}$$



8-31) From Eq. 8-86 we can find C_V at temperature $T = T_E$.

$$C_V = 3R \left(\frac{T_E}{T} \right)^2 \frac{e^{T_E/T}}{(e^{T_E/T} - 1)^2} = 3R (1)^2 \frac{e^1}{(e^1 - 1)^2}$$

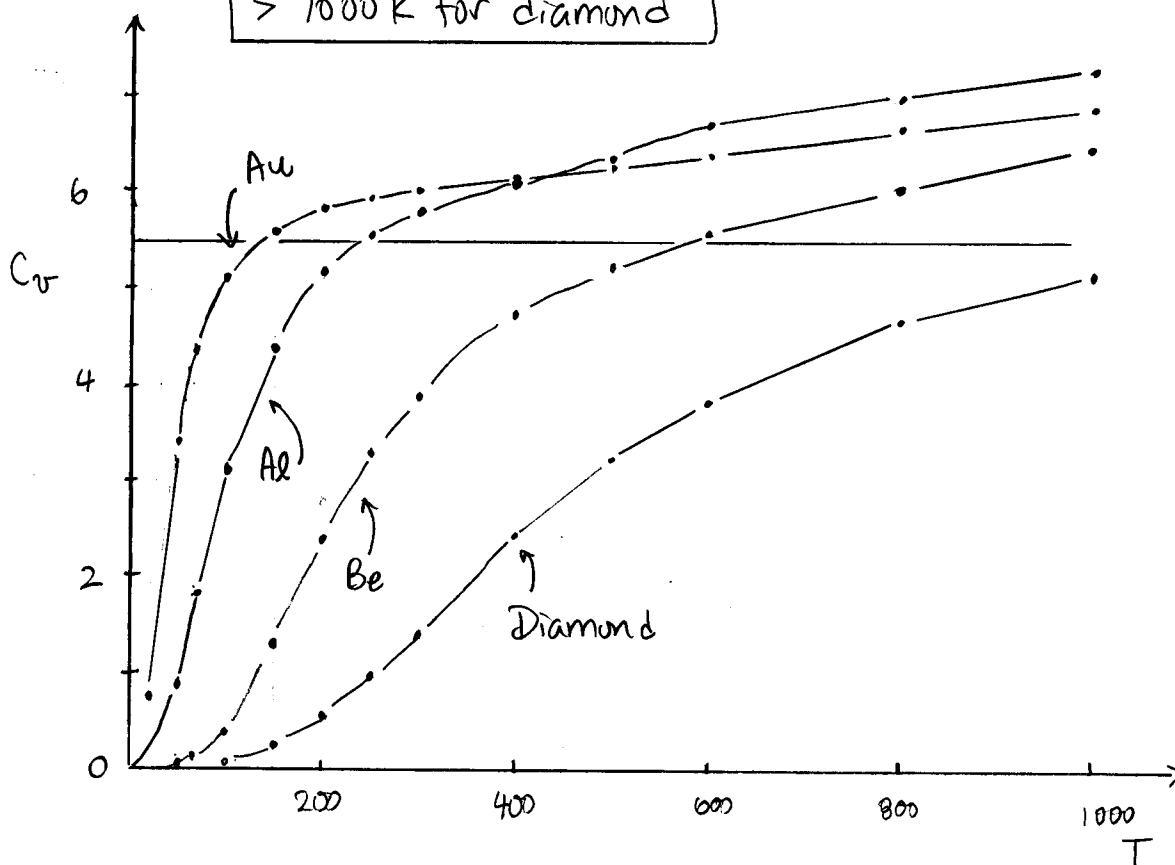
$$= 3R(0.92)$$

$$= 3(1.987 \text{ cal/mole} \cdot \text{K})(0.92) = 5.49 \text{ cal/mole} \cdot \text{K}$$

So T_E is roughly the temperature where $C_V = 5.5 \text{ cal}$.

From the graph I get

$T_E = 140 \text{ K}$ for gold 250 K for Al 580 K for Be $> 1000 \text{ K}$ for diamond
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4-5) The wavelengths are supposed to be given by the formula

$$\frac{1}{\lambda} = R \left(\frac{1}{m^2} - \frac{1}{n^2} \right) \quad n > m$$

where $R = 1.096776 \times 10^7 / \text{m} = 0.01096776 / \text{nm}$.

Trying random values I get

$$\lambda = 7460 \quad m=5, n=6$$

$$\lambda = 4654 \quad m=5, n=7$$

$$\lambda = 3741 \quad m=5, n=8$$

There is no way to get 4103 nm

4-14) From 4-19 $a_0 = \frac{\hbar^2}{mke^2}$. In the books notation ($k = \frac{1}{4\pi\epsilon_0}$) we have $\alpha = ke^2/\hbar c$ so we can write

$$a_0 = \frac{\hbar^2 c^2}{mc^2 ke^2} = \left(\frac{\hbar c}{mc^2}\right) \left(\frac{\hbar c}{ke^2}\right) = \left(\frac{\hbar c}{mc^2}\right) \frac{1}{\alpha} = \frac{\hbar}{2\pi mc} \frac{1}{\alpha}$$

So

$$\boxed{a_0 = \frac{\lambda_c}{2\pi} \frac{1}{\alpha}}$$

$$\lambda_c = \frac{h}{mc}$$

From 4-20

$$E_1 = -\frac{mk^2 z^2 e^4}{2\hbar^2 n^2}$$

So the magnitude of E_1 for hydrogen ($z=1$) is

$$|E_1| = \frac{1}{2} mc^2 \frac{k^2 e^4}{\hbar^2 c^2} \left(\frac{1}{1^2}\right) \Rightarrow \boxed{E_1 = \frac{1}{2} \alpha^2 mc^2}$$

4-15) The wavelengths are given by $\frac{1}{\lambda} = R \left[\frac{1}{n^2} - \frac{1}{m^2} \right]$ where $m > n$ (so m is the initial state and n is final state). For the Lyman series $n=1$. I get the following results

$$\boxed{\begin{array}{ll} m=2 & \lambda = 121.57 \\ m=3 & \lambda = 102.57 \\ m=4 & \lambda = 97.25 \end{array}}$$

The series limit (setting $m \rightarrow \infty$) is $\lambda = 91.18 \text{ nm}$

These are all well outside the visible region.

4-41) From 4-14 we had $a_0 = \frac{\hbar}{mc} \frac{1}{\alpha}$ so in general $r_n = \frac{\hbar}{mc} \frac{1}{\alpha} n^2$.

But $|L^z| = mrv = n\hbar \Rightarrow$

$$v = n\hbar/mr = (n\hbar/m) \left(\frac{mc}{\hbar}\right) \frac{\alpha}{n^2} \Rightarrow \boxed{v = \alpha c/n}$$