1. (50pts.)

A) Define ionization energy, electron affinity, and electronegativity?

B) Rank the following elements in terms of EA, IE, EN (1=highest, 3=lowest) Cesium (Cs), Boron (B) and Fluorine (F)?

C) Why do alkali metals have lower ionization energies than halogens?

6 a.) Ionization energy is the energy required to bring a valence electron from it's ground state to infinitely far away from the nucleus

8 Electron affinity is the energy required to turn an anion into a neutral atom by bringing the valence electron of the anion to infinity.

8 Electronegativity is the tendency of an atom to attract a bonding pair of electrons.

b.) EA: F B Cs (1 2 3)

IE: F, B, Cs

EN: F, B, CS

18

c.) Alkali metals have lower ionization energies than halogens because the valence electrons in alkali metals experience significant shielding from lower-level electrons while experiencing a relatively low nuclear charge. For a halogen in the same period of that alkali metal, the valence electron experiences a similar amount of shielding, but a greater nuclear charge, so Zeff is greater and it takes more energy to bring the electron to infinity. Thus, halogens have greater ionization energies than alkali metals.

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2. (50 pts)

A) Calculate the kinetic energy of electrons ejected from a Thallium surface. The work function $\phi=5.447\times10^{-19}$ J, and the wavelength of the incident light is 250 nm?

B) How will doubling the intensity of the light (the number of photons with energy hν per second per unit area) change Kinetic energy of the ejected electron and number of ejected electrons per second?

C) What is de Broglie wavelength of the ejected electron from part A)?

a.) $E = \frac{hc}{\lambda} - \phi$

$= \frac{(6.626\times10^{-34})(3\times10^{8})}{(250\times10^{-9})} - 5.447\times10^{-19} = 2.5\times10^{-19} J$ ✓

b.) Doubling the intensity of the light will not change ✓ the Kinetic energy of the ejected electron. It will double the number of ejected electrons per second.

c.) $\frac{1}{2}mv^2 = 2.5\times10^{-19}$

$\frac{1}{2}(9.1\times10^{-31})v^2 = 2.5\times10^{-19}$

$V = \sqrt{5.49\times10^{11}} \frac{m}{s}$

$\lambda = \frac{h}{p} = \frac{h}{m_e V} = \frac{6.626\times10^{-34}}{(9.1\times10^{-31})(5.49\times10^{11})}$

$= 1.3\times10^{-15} M$

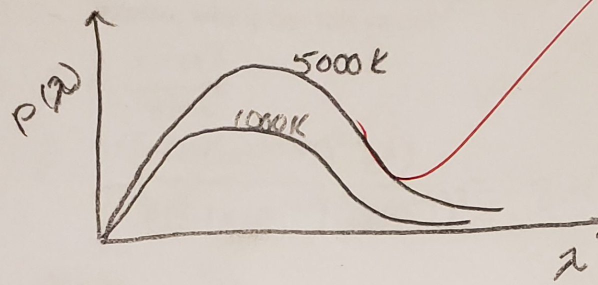
3. (50 pts)

A) Sketch the black body radiation energy density $\rho(\lambda)$ as a function of wavelength for two temperatures: 1000K and 5000K on the same graph?

B) Given 2 black bodies, one with temperature T=1000K and the other at T=5000K, using Wien's Law, $\lambda_{max} = 2.9 \times 10^{-3}/T\ mK^{-1}$, what are the frequencies of the brightest, i.e., highest intensity, radiation.

C) Explain what Planck did to solve the ultraviolet catastrophe problem?

a.)



b) $\lambda_{max} = \dfrac{2.9 \times 10^{-3}}{T}$

$\lambda_{5000} = \dfrac{2.9 \times 10^{-3}}{5000} = 5.8 \times 10^{-7} M$

$C = \lambda \nu \Rightarrow \nu = \dfrac{C}{\lambda} \Rightarrow \nu = \dfrac{3.0 \times 10^{8}}{5.8 \times 10^{-7}} = 5.2 \times 10^{14}\ s^{-1}$ — 10

c.) To solve the UV catastrophe problem, Planck incorporated the probability that the electrons will be excited into the equation. He hypothesized that at extremely low wavelengths, the probability of electrons in the black body emitting those wavelengths [...]ely low, so the intensity at those wavelengths approaches zero

$$P_T(\nu) = \frac{8\pi h\nu^3}{c^3} \underbrace{\frac{1}{e^{\frac{h\nu}{k_B T}} - 1}}_{\text{probability}}$$

— 10

As $\nu \to \infty$, $P_T(\nu) \to 0$ at a fixed T

+27.5

4. (50pts.)

A) An electron in a 1-D square well potential box of length L=1.0 nm, is excited to 2nd excited state, what is the energy (eigen value) of this state?

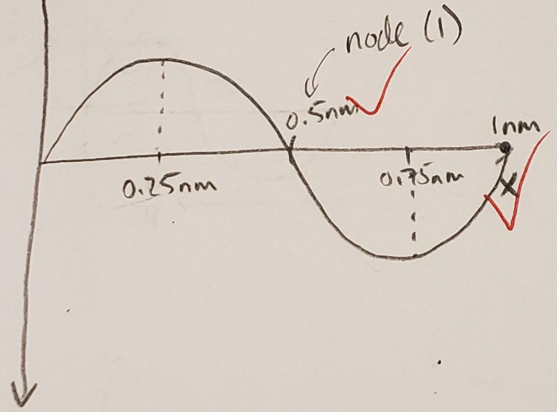
B) Sketch the $\psi_n(x)$, (eigen function) for this state, showing the nodes, how many nodes are there and where are they located, i.e., what is the distance of each node from x=0?

C) Finally, what is the probability of finding the electron at a node and explain why it has this value?

a.) $E = \frac{h^2 n^2}{8mL^2}$ $n=3$

$E = \frac{(6.626\times10^{-34})^2(2^2)}{8(9.1\times10^{-31})(1\times10^{-9})^2} = 2.4\times10^{-19}\ J$ −15

b.) $\psi(x)$



c.) the probability of finding an electron at a node is zero because $P(x) = |\psi(x)|^2$ and $\psi(x) = 0$ at a node by definition. Therefore $P(x) = |0|^2 = 0$ at a node.

−7.5