CH301H – Principles of Chemistry I: Honors
Fall 2013, Unique 52195

Exam 2
10 October 2013

Name: Key

You may use any material you wish provided it does not have a heartbeat nor does it connect to a wireless or cellular network.

Honor Code:

"The core values of the University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the University is expected to uphold these values through integrity, honesty, trust, fairness, and respect toward peers and community."

I certify that the work on this exam is entirely my own.

Signature Date

1. (15 points) Determine whether the following statements are true or false.

a. True **False** A particle confined to a one dimensional box of length L is in its lowest energy state when $n = 0$.

b. True False A normalized wavefunction is one that is continuous. Accept either - badly worded question

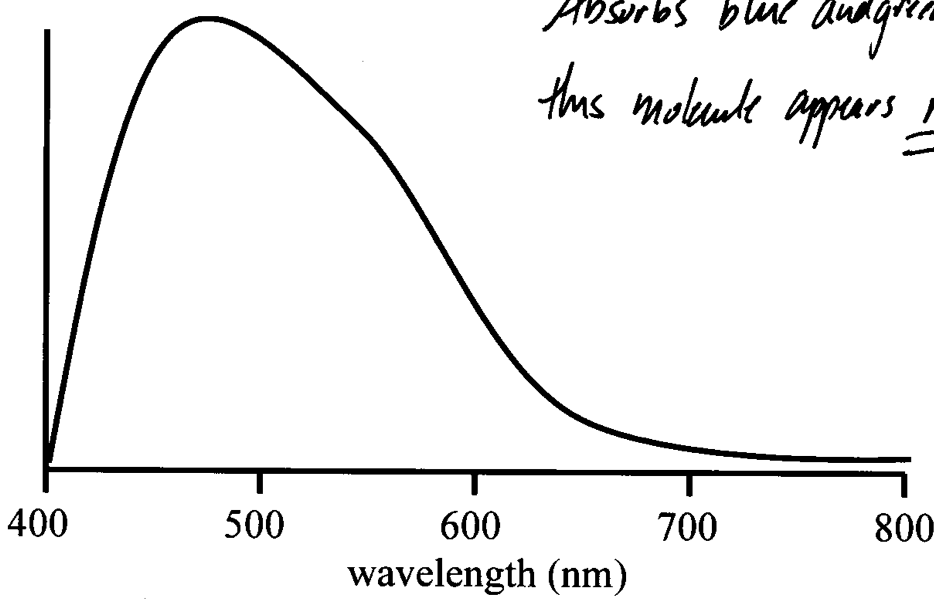
c. **True** False For a particle in a one dimensional box, when $n = 2$ there is equal probability of finding the particle in the left hand and right hand sides of the box.

d. True **False** The term "wave-particle duality" means that a photon can be thought of as either a particle or a wave, but not both.

e. **True** False Blue light is higher energy than green light.

2. (15 points) The absorption spectrum of a molecule that has been approved by the FDA for human consumption is shown below. This molecule is added to foods to dye them a particular color. What color will foods containing this dye appear to your eye?

Absorbs blue and green light, so this molecule appears red.



3. (20 points) You perform an experiment in which you shine light of a known color onto the surface of a copper electrode while measuring the amount (intensity) and kinetic energy of any ejected photoelectrons. You begin your experiment by illuminating the surface with red light, and no photoelectrons are measured. You gradually decrease the wavelength of the light, and at 620 nm you begin measuring photoelectrons ejected from the surface of the copper.

a) What is the threshold energy (in Joules) of photoelectrons in copper?

$$E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,J\cancel{s})(3.0\times10^{8}\,\cancel{m}/\cancel{s})}{(620\times10^{-9}\,\cancel{m})} = \boxed{3.23\times10^{-19}\,J = E(\text{threshold})}$$

b) You further decrease the wavelength of the illuminating light to 550 nm. What is the maximum kinetic energy (in Joules) of photoelectrons ejected from the copper at this wavelength?

$$KE = E(\text{in}) - E(\text{threshold})$$

$$KE = 3.61\times10^{-19}\,J - 3.23\times10^{-19}\,J = \boxed{3.84\times10^{-20}\,J = KE}$$

$$E(\text{in}) = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,Js)(3.0\times10^{8}\,m/s)}{(550\times10^{-9}\,m)} = 3.61\times10^{-19}\,J$$

c) You further decrease the wavelength of the illuminating light to 450 nm. What is the maximum kinetic energy (in Joules) of photoelectrons ejected from the copper at this wavelength?

$$E(\text{in}) = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,Js)(3.0\times10^{8}\,m/s)}{(450\times10^{-9}\,m)} = 4.42\times10^{-19}\,J$$

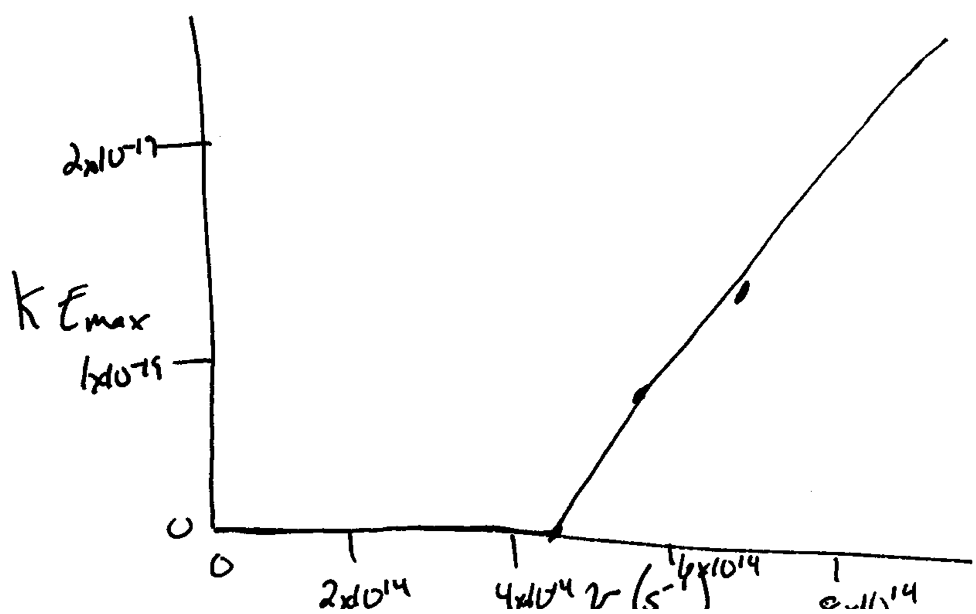
$$KE = 4.42\times10^{-19}\,J - 3.23\times10^{-19}\,J = \boxed{1.19\times10^{-19}\,J = KE}$$

d) With all of this information, draw a figure of maximum KE *versus* frequency for this experiment (i.e. put maximum KE on the *y*-axis and frequency on the *x*-axis). Be sure to clearly and carefully label your axes.

$\nu = \frac{c}{\lambda}$ 620nm : $4.84\times10^{14}\,s^{-1}$

550nm : $5.45\times10^{14}\,s^{-1}$

450nm : $6.67\times10^{14}\,s^{-1}$



4. (15 points) The Bohr model can be used to estimate the ionization energy of one of the electrons in carbon.

a) Which electron can be analyzed in this way?

the last e^-, C^{5+}

b) How much energy does it take to ionize this electron? How does this calculated ionization energy compare to the experimentally known value?

$IE = E(n=\infty) - E(n=1)$

$= -\left(-\frac{Z^2 e^4 m_e}{8\pi \varepsilon_0 h^2 n^2}\right)$

According to table 3.1 in the text book, IE_6 for Carbon atom = 489.99 eV/atom which is almost same to what we calculated

$= 2.18 \times 10^{-18} J \times \left(\frac{36}{1}\right) = 7.848 \times 10^{-17} J/atom = \boxed{489.887 eV/atom}$

5. (15 points) Solar flares are common events in which electrons and ionized atoms are ejected from the surface of the sun at velocities of around 1000 km s^{-1}. What is the de Broglie wavelength of a H^+ atom ejected during a solar flare?

$\lambda = \frac{h}{p}$; $p = mv$

$v = 1000$ km/s $= 1 \times 10^6$ m/s

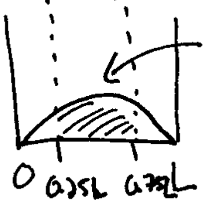
$m(H^+) = 1.67 \times 10^{-27}$ kg (mass of a proton)

$$\lambda = \frac{(6.626 \times 10^{-34} Js)}{(1.67 \times 10^{-27} kg)(1.0 \times 10^6 m/s)} = 3.97 \times 10^{-13} \frac{Js^2}{kgm} = \boxed{3.97 \times 10^{-13} m = \lambda}$$

6. (20 points) A particle confined to a one dimensional box of length L is defined by the following wavefunction:

$$\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right)$$

a) When the particle is in the $n = 1$ state, what is the probability of finding the particle between $x = 0.25L$ and $x = 0.75L$? You may solve this problem qualitatively or quantitatively (or both), but clearly state your strategy and any assumptions you make.



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or $\displaystyle\int_{0.25L}^{0.75L} \psi^2 \, dx$

b) If L = 10 nm, what is the frequency of the photon required to move the particle from $n = 2$ to $n = 3$?

$$\Delta E = E(n=3) - E(n=2)$$

$$= \frac{3^2 h^2}{8L^2 m} - \frac{2^2 h^2}{8L^2 m}$$

$$= \frac{(6.626 \times 10^{-34}\ \mathrm{J \cdot s})^2}{8 \times (10 \times 10^{-9}\ \mathrm{m})^2 \times (9.11 \times 10^{-31}\ \mathrm{kg})} \times (9-4)$$

$$\Delta E = 3.012 \times 10^{-21}\ \mathrm{J}$$

$$\Delta E = h\nu$$

$$\nu = \frac{3.012 \times 10^{-21}\ \mathrm{J}}{6.626 \times 10^{-34}\ \mathrm{J \cdot s}} = \text{~~[illegible]~~}\ 4.55 \times 10^{12}\ \mathrm{s^{-1}}\ (\mathrm{Hz})$$