**PHYS 315 EXAM II** **10/20/05**

*Place your answers in the spaces provided. You must show your work for full credit. 10 pts each.*

**#1-** A quantum state is given by $\Psi = A\ [\ 2\,|\,\phi 1> + 3\,|\,\phi 2 > + \ i\ |\phi 3>\ ]$

with E1 = 1 eV, E2 = 2 eV anad E3 = 4 eV in energy.

(a) Find the normalization $A$. $A$ = ________

$A^2\ [\ 2^2 + 3^2 + (i)(-i)\ ] = 14$

$A = 1/\sqrt{14}$

(b) Find the probabilities for being in the n=1,2,3 states.

P1= __________

P2= __________

P3= __________

$P1 = (2/\sqrt{14})^2 = 0.29$

$P2 = (3/\sqrt{14})^2 = 0.65$

$P3 = (1/\sqrt{14})^2 = 0.07$

( c) Find the expectation value of the energy for this system.

<E> = ________ eV

$<E> = 0.29\ E1 + 0.65\ E2 + 0.07\ E3$

$\quad = (0.29 + 1.3 + 0.28)\ eV = 1.87\ eV$

**#2-** Calculate the DeBroglie $\lambda$ wavelength of an electron with kinetic energy 50 KeV.

$\lambda$ = ____________ m

$E = T + mc^2 = 50\ KeV + 511\ KeV = 561\ KeV$

$Pc = [\ E^2 - m^2c^4\ ]^{1/2} = 231.5\ KeV$

$\lambda = h/P = hc/\ 231.5\ KeV = (1240\ /\ 231500)\ nm = 0.0054\ nm$

**#3-** Two copper conductors are separated by an insulating layer of copper oxide representing a barrier height of 10eV and barrier width of a = 5 nm.

(Given the wave number $\kappa = 8.9\text{nm}^{-1}$. )

(a) What is the probability $T$ that a 7eV electron can tunnel through this barrier.

| |
|---|
| $\kappa a = (8.9\ 1/\text{nm})\ (5\text{nm}) = 44.5$<br>$T = \exp -2\ \kappa a$ = 2.2e-39 |

$T$ = ____________

(b) If $10^{19}$ electrons hit the barrier per second ($f = 10^{19}\ s^{-1}$) what is the tunneling rate $R$ ?

$R$ = ____________

| |
|---|
| $R = f\,T$ = *2.2 e-20 1/s* |

**#4-** Find the the x-ray energy of the $K_\alpha$ transition in $^{207}Pb_{82}$ .

hf = _____________

| |
|---|
| $E2 = -13.6\ (82-1)^2/2^2 = -22.3$ KeV<br>$E1 = -13.6\ (82-1)^2/1 = -89.2$ KeV<br><br>$hf = \Delta E_{21} = [-22.3 - (89.2)]$ KeV = 66.9 KeV |

**#5-** The sodium atom $^{22}Na_{11}$ has one valence electron in the *3s* level at E3 = -5.14 eV. Transitions between the 3s and 3p states form the *Sodium Doublet*.

(a) Record the angular momentum and spin states of this electron.

| | | | | | | |
|---|---|---|---|---|---|---|
| $\ell$ = | 0 | | | | | |
| $m_\ell$ = | 0 | | | | | |
| *S* = | 1/2 | | | | | |
| $m_s$ = | +1/2 | -1/2 | | | | |

(b) In a spectrum tube the Na atoms are excited to the *3p* level. Find the *J* and $M_J$ values of the two 3p states. Also identify the Spectroscopic notation for these states

| | | |
|---|---|---|
| *J* = | 3/2, 1/2 | |
| $M_J$ = | +-3/2 +-1/2 | +-1/2 |
| n $L_J$ | 2P3/2 | 3P1/2 |

( c) The lower of the 3p states is at E = -2.105 eV The higher 3p state is separated by by about 0.6 nm. Find the energy of the higher 3p state.

$\lambda 1$ = hc/E1 = 589.07 nm
$\lambda 2 = \lambda 1 + 0.6$ = 589.67 nm
E2 = hc/ $\lambda 2$ = 2.103

(d) Draw an energy level diagram, labeling the states with notation (n $L_J$). Draw in the doublet transitions. What are the doublet transition energies?

| | | |
|---|---|---|
| $\Delta E_1$ | 3.035 | eV |
| $\Delta E_2$ | 3.037 | eV |