Physics Exam – Fall 2012 – MASE 6402/MME 5401 Name___________

Problem 1

Oak Ridge National Lab's Neutron Spallation source sends neutrons through a pool of liquid helium to slow them down enough to use them to study the structure in NaCl, what should the final temperature of the neutrons be as they come out from the He pool? Take the interatomic distance in NaCl as 0.3 nm.

Solution:

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2m\left(\frac{3kT}{2}\right)}} = \frac{h}{\sqrt{3mkT}}$$

$$\Rightarrow T = \frac{h^2}{\lambda^2 3mk} = \frac{(6.62 \times 10^{-34}\, kg\, m/s)^2}{(0.3 \times 10^{-9} m)^2 3(1.674 \times 10^{-27}\, kg)(1.38 \times 10^{-23}\, m^2\, kg/s^2 K)} = 70\, K$$

Problem 2

A metal is illuminated with electromagnetic radiation of wavelength of 470 nm producing electrons with a kinetic energy of 5.4468×10^{-20} J . What kinetic energy will the electrons have if radiation of 330 nm is used?

Solution: $KE_1 = hf_1 - W \Rightarrow W = hf_1 - KE_1$

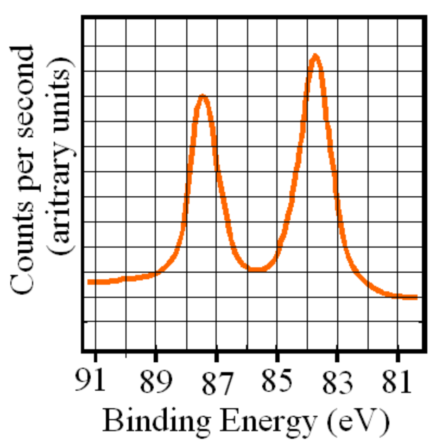
$$KE_2 = hf_2 - W = hf_2 - hf_1 + KE_1 = hc\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) + KE_1$$

$$= (6.62 \times 10^{-34}\, Js)\left(2.99 \times \frac{10^8 m}{s}\right)\left(\frac{1}{330 \times 10^{-9} m} - \frac{1}{470 \times 10^{-9} m}\right)$$

$$+ 5.4468 \times 10^{-20}\, J = 2.33 \times 10^{-19}\, J = 1.4\, eV$$

Problem 3

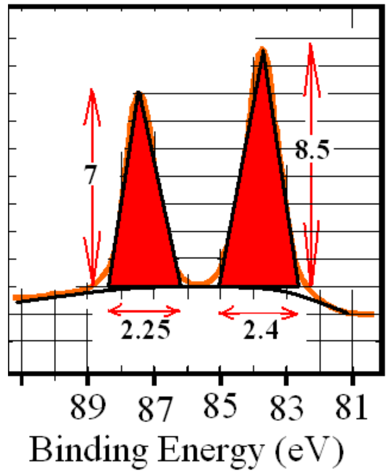
An alloy of Cu, Ag and Au was studied with XPS and part of the spectrum showed the two peaks of the figure. Look at the energies of the peaks, their relative areas and the binding energy tables of the Appendix to determine the



Electron Identity	Copper Cu	Silver Ag	Gold Au
1s	8983.9	25518	80725
2s	1102.9	3811.9	14353
2p	944.78	3414.6	12524
3s	125.42	723.48	3426.6
3p	80.88	587.54	2879.6
3d	10.62	374.94	2241.2
4s	7.7264	101.36	761.38
4p		64.49	578.85
4d		10.4	342.62
4f			85.92
5s		7.5762	109.36
5p			62.613
5d			11.66
6s			9.2257

element(s) and the energy levels to which the two peaks correspond.

Solution: Looking at the table we see it does not list the spin-orbit splits. The closest to the peaks are Cu 3p with 80.88 eV, and Au 4f with 85.92; the Cu energy is to the right of the two peaks while the Au is in the middle. Looking at the areas, the right peak is larger than the left peak as is expected in spin-orbit splits.



Left peak: approximate area:

½ base x height=½×2.25×7 = 7.875

Right peak: approximate area:

½ base x height=½×2.4×8.5 = 10.2

Ratio right to left = 10.2/7.875 = 1.29.

Looking at the degeneracy of the different pairs of levels, we see that the degeneracy of 4f5/2 and 4f7/2 are 6 and 8, with a ratio of 6/8 = 1.33 ≈ 1.29.

With this we conclude that the element is gold and the peaks are the 4f5/2 and 4f 7/2.

Problem 4

A sample of 12 mm by 8 mm is to be irradiated in an UHV chamber containing *argon* at 294 K and with a density of 3.28×10^{13} atoms/m^3. Determine the number of atoms that hit the sample surface per unit time. Take $M_{Argon} = 40 \times 10^{-3} kg/mol$.

Solution 1

The rate of arrival is $R = \frac{1}{4}n\langle v\rangle$, the density is given and

$$\langle v\rangle = \sqrt{\frac{8kT}{\pi m}} = \sqrt{\frac{8 \times 1.38 \times 10^{-23} \times 294\ K}{\pi(M/N_A)}}$$

$$= \sqrt{\frac{8 \times (1.38 \times 10^{-23} J/K) \times (294\ K) \times (6.022 \times 10^{23}\frac{particles}{mol})}{\pi \times 40 \times 10^{-3} kg/mol}} =$$

$$= 394.38\ m/s$$

Thus R is

$$R = \frac{1}{4}n\langle v\rangle = \frac{1}{4}(3.28 \times 10^{13} atoms/m^3)(394.38\ m/s) = 3.234 \times 10^{15} atoms/m^2 s$$

And the number of atoms that hit the sample surface per unit time is

$R \times \text{Area} = 3.234 \times 10^{15} atoms/m^2 s \times 0.012\ m \times 0.008\ \text{m} = 3.10 \times 10^{11} atoms/s$

Solution 2

The rate of arrival is

$$R = \frac{p}{\sqrt{TM}}\sqrt{\frac{N_A}{2\pi k}} = \frac{\rho kT}{\sqrt{TM}}\sqrt{\frac{N_A}{2\pi k}} = \rho\sqrt{\frac{kTN_A}{2\pi M}}$$

$$= \left(3.28 \times \frac{10^{13} atoms}{m^3}\right)\sqrt{\frac{\left(1.38 \times \frac{10^{-23} J}{K}\right)(294\ K)\left(6.022 \times 10^{23}\ \frac{particles}{mol}\right)}{2\pi \times 40 \times \frac{10^{-3} kg}{mol}}}$$

$$= 3.2347 \times 10^{15} atoms/m^2 s$$

And the number of atoms that hit the sample surface per unit time is

$R \times$ Area $= 3.234 \times 10^{15} atoms/m^2 s \times 0.012\ m \times 0.008$ m $= 3.10 \times 10^{11} atoms/s$

Problem 5

A sample suspected to have some Cu is studied using XRF, list the energy of all possible lines in the XRF spectrum that would indicate the presence of copper. Use the proper Siegbahn nomenclature to label the lines (e.g. K_α, K_β, L_α, L_β, etc..). The Cu electron binding energies are:

Shell	Orbital	energy (eV)	Shell	Orbital	energy (eV)	Shell	Orbital	energy (eV)	Shell	Orbital	energy (eV)
K	1s	8979	L_{II}	2p1/2	952.3	M_I	3s	122.5	M_{III}	303/2	75.1
L_I	2s	1096.7	L_{III}	2p3/2	932.7	M_{II}	3p1/2	77.3			

Solution

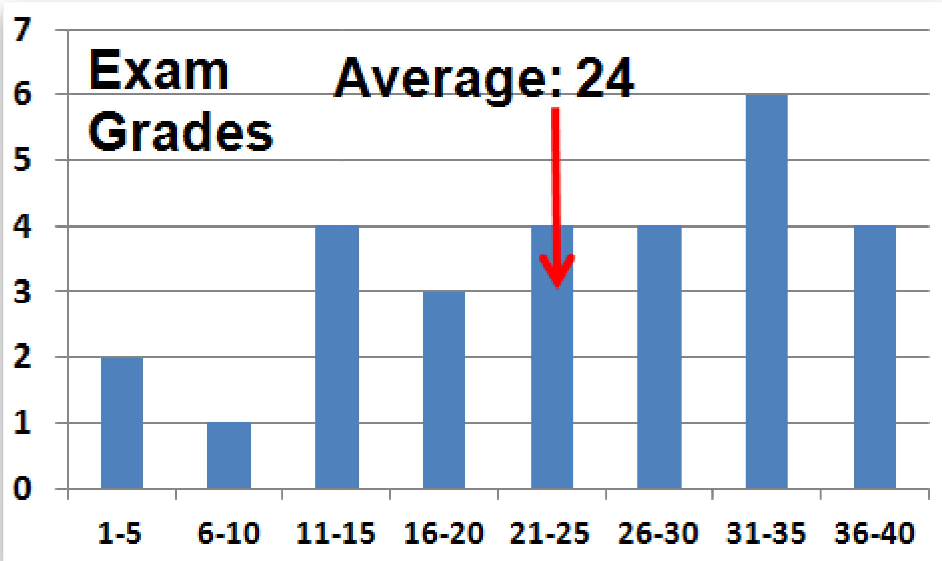
- L_I → K is a from 2s to 1s with Δ*l* =0 and it is forbidden by rule Δ*l* = ± 1
- L_{II} → K is 2p1/2 → 1s: $K_{\alpha 1}$: E = K–L_{II} = 8979–952.3 =8026.7 eV
- L_{III} → K is 2p3/2 → 1s: $K_{\alpha 2}$: E = K–L_{III} = 8979–932.7 = 8046.3 eV

- M_I → K is 3s → 1s with Δ*l* =0 and it is forbidden by rule Δ*l* = ± 1
- M_{II} → K is 3p1/2 → 1s: $K_{\beta 1}$: E = K–M_{II} = 8979–77.3 = 8901.7 eV
- M_{III} → K is 3p3/2 → 1s: $K_{\beta 2}$: E = K–M_{III} = 8979–75.1 = 8903.9 eV

- M_I → L_I is 3s → 2s with Δ*l* =0 and it is forbidden by rule Δ*l* = ± 1
- M_I → L_{II} is 3s →2p1/2: $L_{\beta 1}$: E = L_{II}–M_I = 952.3–122.5 = 829.8 eV
- M_I → L_{III} is 3s →2p3/2: $L_{\beta 2}$: E = L_{III}–M_I = 932.7–122.5 = 810.2 eV

- M_{II} → L_I is 3p1/2 → 2s: $L_{\beta 3}$: E = L_I–M_{II} =1096.7–77.3 =1019.4 eV
- M_{II} → L_{II} is 3p1/2 →2p1/2 with Δ*l* =0 and it is forbidden by rule Δ*l* = ± 1
- M_{II} → L_{III} is 3p1/2 →2p3/2 with Δ*l* =0 and it is forbidden by rule Δ*l* = ± 1

- M_{III} → L_I is 3p3/2 → 2s: $L_{\beta 4}$: E = L_I–M_{II} =1096.7–75.1 = 1021.6 eV
- M_{III} → L_{II} is 3p3/2 →2p1/2 with Δ*l* =0 and it is forbidden by rule Δ*l* = ± 1
- M_{III} → L_{III} is 3p3/2 →2p3/2 with Δ*l* =0 and it is forbidden by rule Δ*l* = ± 1


Exam
Grades
Average: 24
7
6
5
4
3
2
1
0
1-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40