Physics Exam – Fall 2013 – MASE 6402/MME 5401 Name___________

Problem 1. Circle the correct answers to the following questions (10 points)

1. **Can x-rays eject non-core electrons?**
   (a) Yes (b) No (c) Need more information
2. **What is the maximum depth of XPS?**
   (a) 1 nm (b) 10 nm (c) 20 nm
3. **What pressure is best when performing an XPS measurement?**
   (a) Rough vacuum: Atmosphere down to 1 mTorr
   (b) Medium high vacuum: from 10^{-6} Torr to 1 mTorr.
   (c) Ultra high vacuum: between 10^{-8} Torr to 10^{-9} Torr.
   (d) Extreme high vacuum: < 10^{-12} Torr
4. **In XPS, is the kinetic energy of the photoelectron dependent on the X-ray beam energy?**
   (a) Yes (b) No (c) Need more information
5. **In XRF, is the frequency of the emitted x ray dependent on incident X-ray frequency?**
   (a) Yes (b) No (c) Need more information
6. **What does the background of an XRF spectrum is composed of?**
   (a) secondary electrons (b) bremsstrahlung radiation (c) Mostly K Line x rays
7. **The reason of the 'stepping up'' of the XPS background toward larger binding energies is?**
   (a) secondary electrons (b) bremsstrahlung radiation (c) re-scattering of photoelectrons
8. **Can XRF be used to identify hydrogen?**
   (a) Yes (b) No (c) Need more information
9. **If the escape depth of a 20 eV electron in Ag is about 10 Å, what is the approximate mean free path of the electron?** (a) 30 Å (b) 10 Å (c) 3 Å (d) 1 Å
10. **The expected ratio of the intensities of a $4f_{7/2}$ and $4f_{5/2}$ XPS peaks is?**
    (a) 1:2 (b) 2:3 (c) 3:4 (d) 4:5 (e) 5:6 (f) 7:5

Problem 2. Oak Ridge National Lab's Neutron Spallation source produces thermal neutrons with a velocity of 2.2 km/s. What would be the interatomic distance these neutrons could be used to study?

Solution:

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{hc}{mc^2(v/c)} = \frac{1240 \times 10^{-9}\ eV\ m}{(939 \times 10^6 eV)\frac{2.2 \times 10^3 m/s}{3 \times 10^8 m/s}} = 1.8 \times 10^{-10} m$$

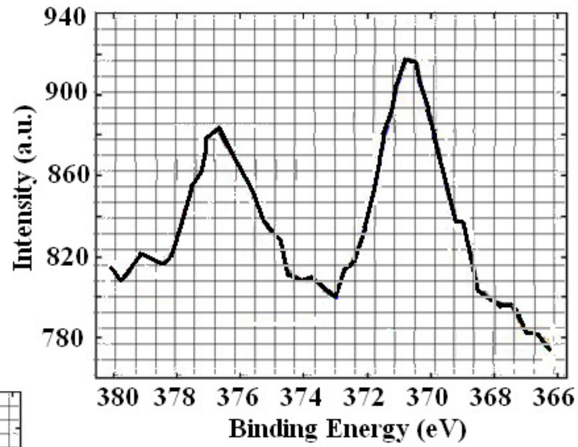
Such beam could be used to study any solid material as the interatomic distances is of the order of a few Angstroms.

Problem 3. The work function of Ag is 4.74 eV, what range of frequencies must electromagnetic radiation have in order to produce the photoelectric effect with silver?

Solution: $KE = hf - W \Rightarrow f = \frac{(KE+W)}{h} \Rightarrow f_{\text{Min}} = \frac{\text{W}}{\text{h}} = \frac{4.74\text{ eV}}{4.135\times10^{-15}\text{eV s}} = 1.14 \times 10^{-15}\text{Hz}$

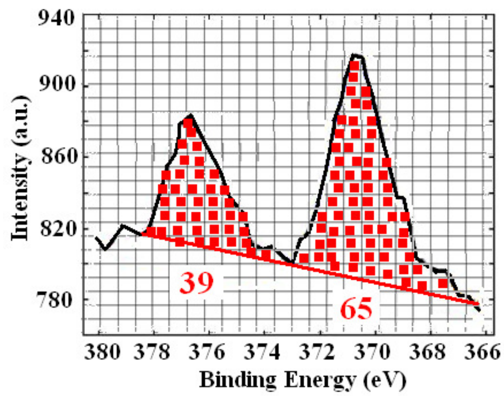
The frequency must be larger than 1.14×10^{-15} Hz.

Problem 4. 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 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 is Ag 3d with 374.94 eV.



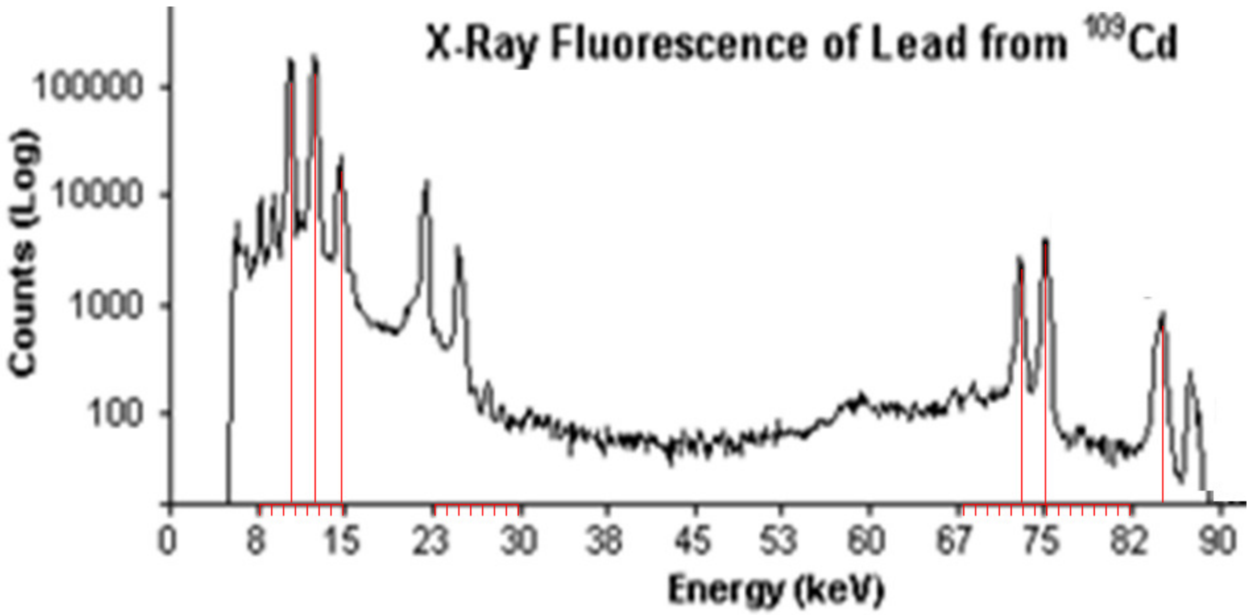
Electron Identity	Copper Cu	Silver Ag	Gold Au
1s	8983.9	25518	80725
2s	1102.9	3811.9	14353
2p	944.78	3414.6	12524
3s	125.42	723.48	3426.6
3p	80.88	587.54	2879.6
3d	10.62	374.94	2241.2
4s	7.7264	101.36	761.38
4p		64.49	578.85
4d		10.4	342.62
4f			85.92
5s		7.5762	109.36
5p			62.613
5d			11.66
6s			9.2257

Looking at the areas, the right peak is larger than the left peak as is expected in spin-orbit splits.

Left peak: approximate area: 39 squares
Right peak: approximate area: 65 squares
Ratio left to right = 39/65 = 0.6

Looking at the degeneracy of the different pairs of levels, we see that the degeneracy of 3d5/2 and 3d3/2 are 6 and 4, with a ratio of 4/6 = 0.667

With this we conclude that the element is silver and the peaks are the 3d5/2 (right) and 3d3/2 (left).



Problem 5

The graph shows the energy distribution of XRF photons emitted during an x ray irradiation of lead; the x rays used were Kα from Cd (λ = 0.0536 nm). Use the table of electron binding energies of Pb to identify the transitions that produced the six peaks indicated by the lines, label the peaks using the Siegbahn nomenclature (Kα, Kβ, …) and calculate the exact energies of such peaks.

Element	K 1s	L1 2s	L2 2p1/2	L3 2p3/2	M1 3s	M2 3p1/2	M3 3p3/2	M4 3d3/2	M5 3d5/2	N1 4s	N2 4p1/2	N3 4p3/2
82 Pb	88005	15861	15200	13035	3851	3554	3066	2586	2484	891.8†	761.9†	643.5†

<u>Solution</u>

From right to left:

- M2 → K → $K_{\beta 1}$: E = K – M2 = 88005 – 3554 = 84451 eV
- L3 → K → $K_{\alpha 2}$: E = K – L3 = 88005 – 13035 = 74970 eV
- L2 → K → $K_{\alpha 1}$: E = K – L2 = 88005 – 15200 = 72805 eV
- N2 → L1 → $L_{\beta 1}$: E = L1 – M2 = 15861 – 761.9 = 15099 eV
- M2 → L1 → $L_{\alpha 1}$: E = L1 – M2 = 15861 – 3554 = 12307 eV
- M5 → L3 → $L_{\alpha x}$: E = L3 – M5 = 13035 – 2484 = 10551 eV.
  Note: Transitions among several M and L levels yield energies close to this last value.