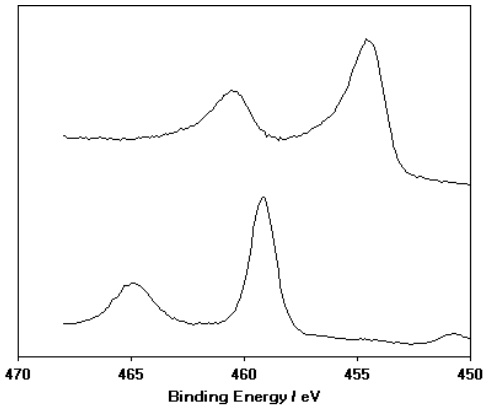
1) XPS and Auger photoelectron spectroscopy.

a) Explain briefly how an X-ray gun works.
b) In X-ray photoelectron spectroscopy setups x-ray guns are usually equipped with two anodes made of different materials (e.g. Mn and Al). Why?
c) Although AES is an element-specific technique, it can't detect elemental H and He. Why? Explain schematically.
d) How can insulating samples be measured with XPS and AES? Why is that a problem?

2) XPS

The X-ray photoelectron spectra show the Ti2p peaks of metallic Ti and TiO_2.

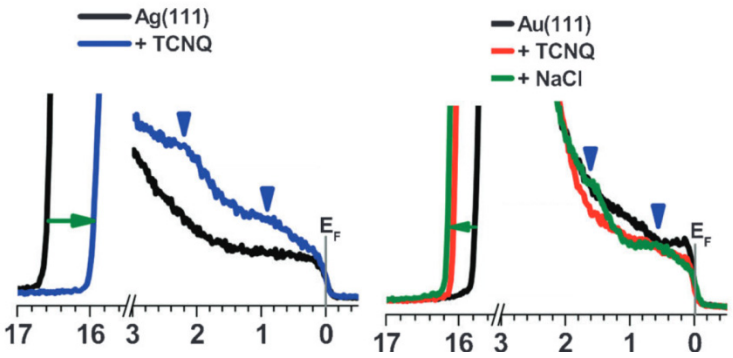
a) Why do you have two peaks in each spectrum?
b) Assign the spectra to Ti and TiO_2 and briefly name the reason why you did so.



3) Ultraviolet Photoelectron Spectroscopy

In the figure below UPS spectra are shown.

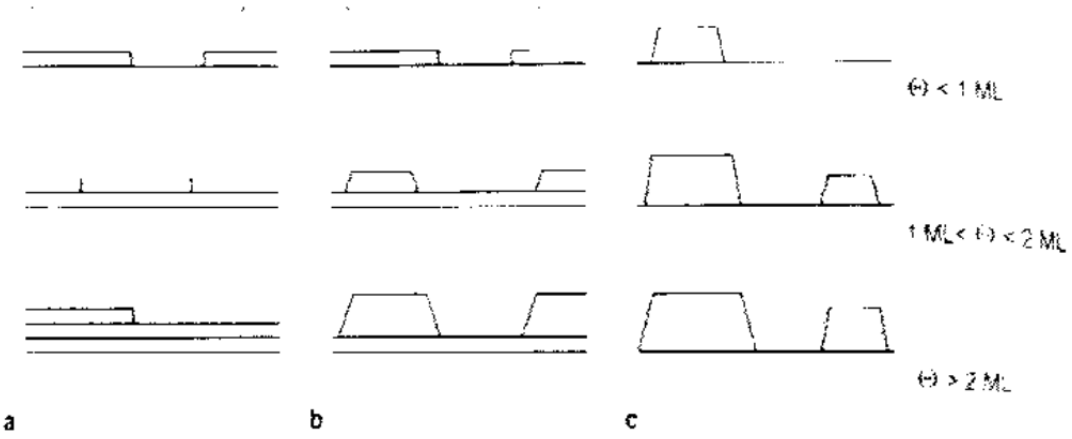
a) The left one is of Ag(111) surface before (black) and after (blue) TCNQ deposition. What can we conclude from the changes in the spectra, marked with green and blue arrows.
b) In the right one three spectra are shown – of clean Au(111) surface (black) after TCNQ deposition (red) and subsequent NaCl deposition (green). Explain the changes in the spectra after each step.
c) Explain the differences between the behavior of TCNQ molecules on Au and Ag substrates.



4) Diffusion

Random-walk diffusion of Ag atoms occurs over the Si(111) $\sqrt{3}x\sqrt{3}$ -Ag surface. Estimate the mean displacement of the atom in a time of 1 s, 1 min and 1 hour at a substrate temperature of 450 °C. (D0 = 10-3 cm2s-1, Ediff = 0.33 eV)

5) Thin film growth + XPS



i) Name the three growth modes shown above.
ii) Solve the practical problem shown below.

You encounter the following experimental challenge: in case of heteroepitaxy of Co on Cu(001), you need to know if the Co grows layer-by-layer or island-like. Your available experimental method is XPS. Assume an electron mean free path of 1 nm in both Cu and Co at the relevant kinetic energies (Cu2p and Co2p). Assume that the Cu2p intensity measured before Co evaporation (i.e. clean) is 100'000 counts. Note that the X-ray mean free path is in the order of µm and can be neglected.

a) In case of an ideal layer-by-layer growth and a thickness of 1 nm, what is the expected reduction in the Cu ratio as observed in XPS when measured in normal emission (the electrons leave the sample in a 90° angle).
b) In case of an island-like growth with a Co thickness of 2 nm and 50% of the surface being covered, what is the expected Cu intensity?
c) In the experiment which could give an outcome as described in a) or b), you find a Cu2p intensity of 45'000 counts. Argue on the growth mode based on your surface science knowledge.
d) In b) and c), you knew the thickness of the Co layer, because usually the amount (but not the growth mode) of evaporated material is known. In case you do not know the amount, how can you determine/estimate the growth mode with XPS?