Introduction

The assignment consists of two separate parts: first, the experimental setup is used to measure a $L_{2,3}M_{2,3}M_{2,3}$ Auger spectrum of argon using electron gun excitation source. Secondly, the acquired data is handled with the Igor Pro software, the relevant data peaks are fitted. The fit results are reported and compared with the theoretical predictions.

Theory

![Diagram](image)

Fig.1 Two views of the Auger process. (a) illustrates sequentially the steps involved in Auger deexcitation. An incident electron (or photon) creates a core hole in the 1s level. An electron from the 2s level fills in the 1s hole and the transition energy is imparted to a 2p electron which is emitted. The final atomic state thus has two holes, one in the 2s orbital and the other in the 2p orbital. (b) illustrates the same process using spectroscopic notation, $KL_1L_{2,3}$. 
The experimental instrumentation

The primary parts are the electron gun (Specs) used for creation beam of electrons, the electron energy analyzer (Sciena SES-200 hemispherical dispersive analyzer), the requisite additional hardware such as the pressure gauges, vacuum pumps, gas line hardware and other supporting instrumentation. The sample is contained within a commercial bottle – the contents are directed in the chamber via a regulator.

The excitation source

The electron gun

In this work, the employed electron gun is a commercial unit manufactured by Specs. The electron gun consists of separate sections, which are depicted in Fig. 2. The main operation is as follows: electrons are thermally emitted from the filament emission), the Wehnelt cup draws them towards the lens system, which focuses, accelerates, and deflects the electron beam according to the applied voltages. Thus the user may obtain an electron beam with variable properties. The electron gun’s current may be observed by placing a Faraday cup on the opposite side, which collects the electrons. This provides means to calibrate the beam parameters in order to maximize the observed current – the amount of incident electron charges per unit time.

The electron energy analyzer

The electron spectrometer is a commercial unit by VG Scienta. It consists of the actual hemispherical part, where the electrons are spatially dispersed according to their kinetic energies. The spectrometer itself begins near the interaction with the lens system, which has several electrostatic lenses operated with variable potentials. The lens system's voltages are automatically adjusted by the measurement software, real-time. The
hemispherical dispersion operates on the principle of Lorentz force:

\[ F = q \left( E + v \times B \right), \]

where \( F \), \( E \), and \( B \) represent the force, electric field, and magnetic field vectors, respectively, and \( q \) is the particle's charge. The hemispherical part consists of two hemispheres, the inner and the outer, and the hemisphere potentials are adjusted so, that the electrons of set kinetic energy – the center energy \( E_{k}^{c} \) – are passed through. In addition, electrons with kinetic energies around this center energy are also passed through, and they are spatially dispersed around the center energy position. With a position sensitive detector, these energies can then be recorded according to their positions at the detector end. The electron spectrometer is operated in the so-called fixed pass energy mode, which means that the lens system either accelerates or retards the incoming electrons – this is done in order to obtain a constant resolution through different kinetic energies. The spectrometer itself is an example of an instrument, where high resolution is obtainable with the cost transmission. The transmission is typically inversely proportional to resolution, which means that by sacrificing the amount of detected electrons, more detail may be resolved. The spectrometer contains a slit carousel, which essentially acts as a collimation element for incoming electrons, smaller slits result in better resolution, but lower transmission. The operating settings such as the pass energy, slit size, and hemisphere radius have an impact on the resolving power. The instrument itself creates a Gaussian broadening to the actual electron signal, which may be approximated with

\[ \Delta E = \frac{E_{p} \times \text{slit}}{2R}, \]

where \( \Delta E \) [eV] is the instrumental broadening, \( E_{p} \) [eV] is the used pass energy, slit is the collimating slit size [mm], and \( R \) is the hemispherical mean radius [cm].

The SES-200 has a position sensitive charge coupled device (CCD) camera detector. The dispersed electrons initially enter a micro-channel plate (MCP) stack, where the single electron hits are multiplied and directed towards a fluorescent, which then transmits the optical range photons towards the camera detector. These counts may then be observed in realtime on the camera display of the control software.

The spectrometer – or more accurately, the voltage rack – is controlled with the SES program.

The examined sample is argon, which has the electron configuration of \( 1s^{2}2s^{2}2p^{6}3s^{2}3p^{6} \). LS coupling gives 6 experimental Auger lines. The purpose is record the Auger spectrum using electron impact excitation.

**Instructions for the experiment**

The measurement begins at the stage, where the vacuum setup is in an operational readiness. This means that the background pressure is low enough to withstand insertion of the sample gas – in other words, the background pressure should be in the range of \( 1.0 \times 10^{-7} \) – \( 1.0 \times 10^{-6} \) mbar. The gas line is prepared so that the line itself is already prepumped to vacuum before argon is inserted – this way the argon may be released into the chamber simply by manipulating the leak valve in the gas line. The amount of argon may be fairly, but the total pressure should not exceed \( 6.0 \times 10^{-6} \) mbar. The absolute limitation of \( 2.0 \times 10^{-5} \) mbar is based on a limitation set by the MCP pack in the detector, which may be easily damaged in pressures higher than this.
NOTE: When the chamber pressure is subjected to any major change, the SES-200 rack should have its high voltage (HV) switch OFF. This is done in case something surprising happens, which may result in a rapid pressure increase, which, in turn, may damage the SES-200 detector.

After the argon flow is adjusted, gun’s functionality may be examined. This involves the adjustment of the emission current, acceleration energy, and the x and y deflections. The relation between the deflection voltages and optimal beam current depend strongly on the applied Wehnelt and acceleration voltages. When these are changed, the optimal deflection voltages must be searched again with the aid of a current meter. Depending on the setup’s details, the assistant will provide additional instructions regarding the electron gun’s settings. The goal: to find some acceleration voltage, that is, a kinetic energy for the electrons, which maximizes the amount of detected current. The electron collision-induced transitions have a maximum value for the transition cross-section at some point of kinetic energy. Depending on the experimental setup, further complications may be introduced. In essence, you want to use electron energies, which have the greatest likelihood of creating the initial transition, which subsequently produces the previously mentioned decay.

After the pressure has stabilized and the electron gun is operational, the SES-200 voltages may be turned on (HV switch ON), and the SES program may be used for fast diagnostics to see if everything is functioning. If so, the measurements can be made. The assistant will guide the experimenter's with the SES software. Different groups will make measurement with one of the pass energies listed below

1) 5 eV, slit 0,2mm
2) 10 eV, slit 0,4mm
3) 50 eV, slit 0,4mm.

After the data has been acquired, the setup is to be moved back to the standby state. First, the SES-200 voltages should be turned off, then the electron gun should be stopped and the gas line leak valve can be closed.

Data handling

Calculate following values:

**Normalized intensity**

\[ I_N = \frac{\text{max.int.}}{t(s)} \times I_{FC} (\mu A) \times p(\text{mbar}) \]

\( t \) - total measurement time for one data point
\( I_{FC} \) – Faraday cup current
\( p \) – pressure in the gas cell, estimated 90 times higher compared to the vacuum pressure in the chamber

**Analyzer transmission**

if it is assumed that each 2p ionization leading LMM Auger Electron emission, Auger electrons generated sample volume per unit of time

\[ F = N_e \times \sigma \times N/A \]
where \( N_e = \frac{I_{Fe}}{e} \) number of electrons

\( \sigma \) – argon 2p electron cross-section (1Mbarn=10^{-22})

\( N \) – number of atoms in sample volume

\( A \) – effective sample area (area of the electron beam) depends on the size of the slit

Total amount of generated electrons \( F_t = \text{measurement time} \times F \)

Transmission \( T = \frac{\text{observed electrons}}{F_t} \)

**Broadening the line shape**

Shape of the spectrum is convolution of Lorenzian function (natural line width) and Gaussian function (experimental broadening). Argon 2p\( _{1/2} \) and 2p\( _{3/2} \) life-time broadening is 118 meV. When a spectra fitted using constant Lorenz width gives the Gauss distribution and using it calculate Doppler part of the linewidth

Doppler contribution can be calculated using the formula

\[
\Gamma_D = 0.7215 \times \sqrt{\frac{E_k T}{M}}
\]

\( E_k \) (eV) – kinetic energy of the electron

\( T \) – temperature of the sample

\( M \) (amu) mass of the atom

The assistant will provide access to a computer with the Igor Pro software and the required fitting macros. The assistant will aid in fitting the data. The purpose is to fit Lorentzian-Gaussian (Voigt) peaks in the two recorded photoelectron lines. A figure of the fit and the fit parameters for these are to be included in the report. The most important values are the fit goodness, Lorentzian and Gaussian FWHMs (Full Width at Half Maximum), and the peak areas.

**Things required in the report**

The report needs to include a description of the experiment, what was done, and how the data was handled. The experimenter is also required to consider the implications of the used spectrometer settings with regard to the observed peak shapes,