Auger Electron Spectroscopy (AES)

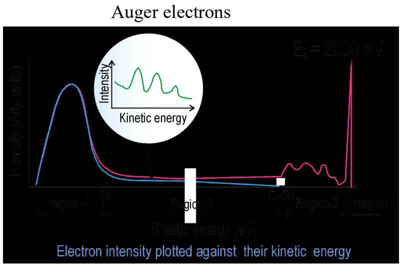
What is Auger ?

Auger Electron Spectroscopy (AES) is a widely used technique to investigate the chemical composition of surfaces.

The **Auger Effect** is named after its discoverer, Pierre Auger, who observed a tertiary effect while studying photoemission processes in the 1920s. **Auger electrons are emitted at discrete energies that allow the atom of origin to be identified.** The idea of using electron-stimulated Auger signals for surface analysis was first suggested in 1953 by J. J. Lander. The technique became practical for surface analysis after Larry Harris in 1967 demonstrated the use of differentiation to enhance the Auger signals.

Pierre Auger

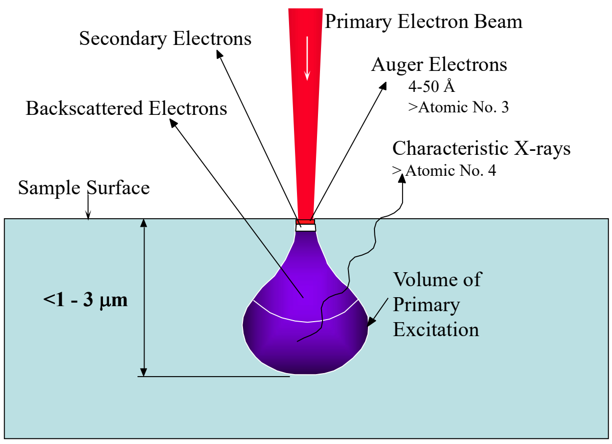
Distribution of Energies of Emitted Electrons

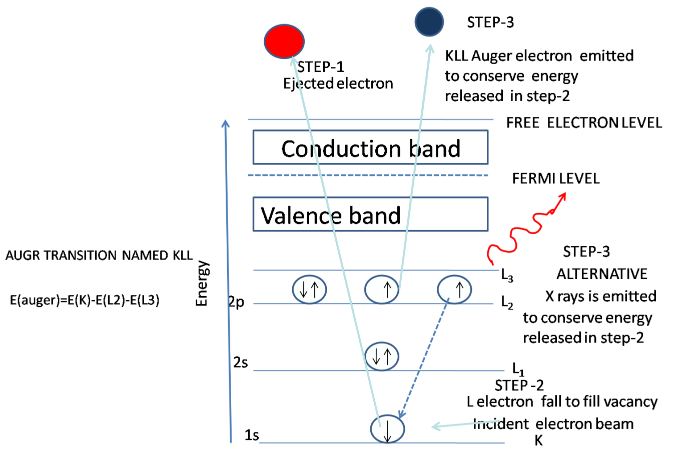


Electron intensity plotted against their kinetic energy

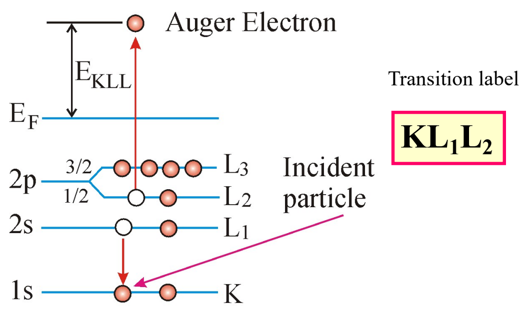
Today Auger electron spectroscopy is a powerful surface analytical tool to probe surfaces, thin films, and interfaces. This utility arises from the combination of surface specificity (0.5 to 10 nm), good spatial surface resolution (as good as 10 nm), periodic table coverage (except hydrogen and helium), and reasonable sensitivity (100 ppm for most elements).

Electron Beam - Sample Interaction





Nomenclature for Auger Transitions



The three symbols in the transition label correspond to the three energy levels involved in the transition.

N_{10}	$4f_{7/2}$
N_9	$4f_{5/2}$
N_8	$4f_{3/2}$
N_7	$4f_{1/2}$
N_6	$4d_{5/2}$
N_5	$4d_{3/2}$
N_4	$4d_{1/2}$
N_3	$4p_{3/2}$
N_2	$4p_{1/2}$
N_1	4s
M_6	$3d_{5/2}$
M_5	$3d_{3/2}$
M_4	$3d_{1/2}$
M_3	$3p_{3/2}$
M_2	$3p_{1/2}$
M_1	3s
L_3	$2p_{3/2}$
L_2	$2p_{1/2}$
L_1	2s
K	1s

Characteristic of AES

Characterstics	AES
Primary beam	Electron
Analyzed beam	Electron
Types of sample	Conductive
Area of analysis	10nm
Surface selectivity	1 to 5nm
Elemental identification	All except H and He
Sensitivity	.10%
Depth profiling	Elemental, Chemical
Destructive nature	none

AUGER ELECTRONS CAN BE PRODUCED IN TWO DIFFERENT WAYS

1. The X-Ray source can irradiate and remove the e^- from the core level causing the e^- to leave the atom.

- A higher level e^- will occupy the vacancy.
- The energy released is given to a third higher level e^-.
- This is the Auger electron that leaves the atom.

2. The electron gun can irradiate and remove the core e^- by collision. Once the core vacancy is created, the Auger electron process occurs the same way.

AES INSTRUMENT CONFIGURATION

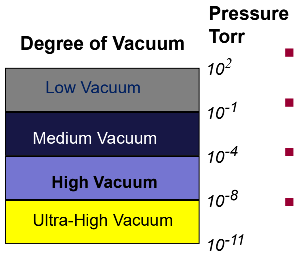
The main components of an AES

1. Ultra high vacuum environment
2. Electron gun
3. Electron energy analyzer
4. Electron detector
5. Data recording, processing, and output system

https://scienceinfo.com/auger-electron-spectroscopy/

1. Ultra-High Vacuum (UHV) System

Requirement of UHV for Surface Analysis



- Remove adsorbed gases from the sample.
- Eliminate adsorption of contaminants on the sample.
- Prevent arcing and high voltage breakdown.
- Increase the mean free path for electrons, ions and photons.

2. Electron Energy Analyser

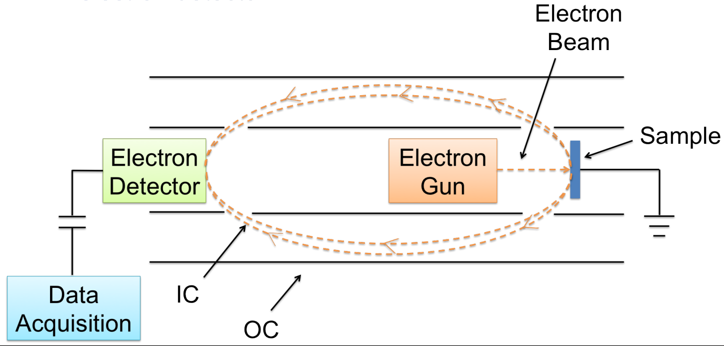
Generally Two Types

I. Cylindrical Mirror Analyzer(CMA)

II. Concentric Hemispherical Analyzer(HAS)

I. Cylindrical Mirror Analyzer(CMA)

A CMA is composed of
- An electron gun,
- Two cylinders, and
- An electron detector



Cylindrical Mirror Analyzer(CMA) Operation

The operation of a CMA involves an electron gun being directed at the sample.

An ejected electron enters the space between the inner and outer cylinders (IC and OC).

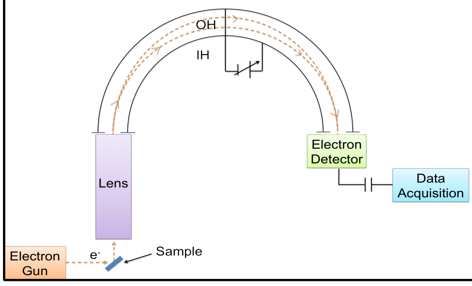
The inner cylinder is kept at ground potential, while the outer cylinder's potential is proportional to the kinetic energy of the electron. Due to its negative potential, the outer cylinder deflects the electron towards the electron detector.

Only electrons within the solid angle cone are detected. The resulting signal is proportional to the number of electrons detected as a function of kinetic energy.

I. Concentric Hemispherical sector Analyzer(CHA)

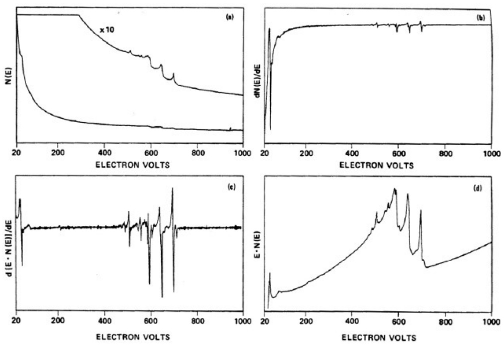
A CHA contains three parts:

- A retarding and focusing input lens assembly
- An inner and outer hemisphere (IH and OH)
- An electron detector



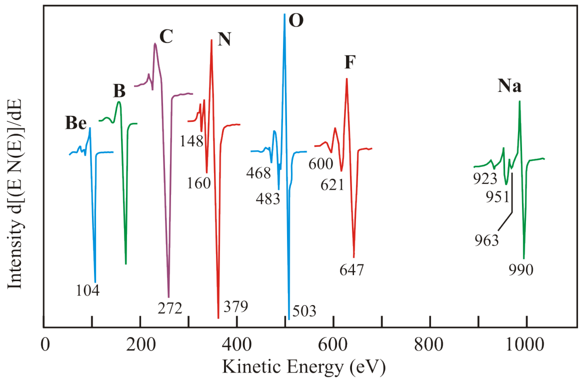
Ejected electrons are focused by the lense and are retarded to reduce their energy for better resolution. A potential difference is applied on the hemispheres so that only electrons with a small range of energy differences reach the exit.

FOUR ways to represent Auger spectra

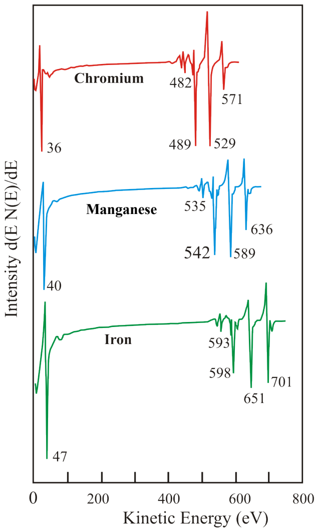


a) N(E) vs E, b) dN(E)/d(E)vs E, c)d(E.N(E)vs E, d) E.N(E)vs E

Auger Peaks



Auger spectra in the differential distribution characteristic of the lightest elements (The principal peak is $KL_{2,3}L_{2,3}$ and the relative intensities are not plotted to scale)

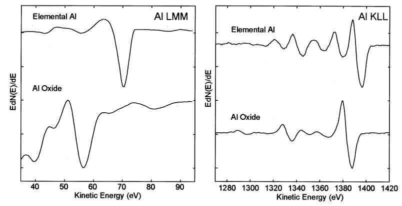


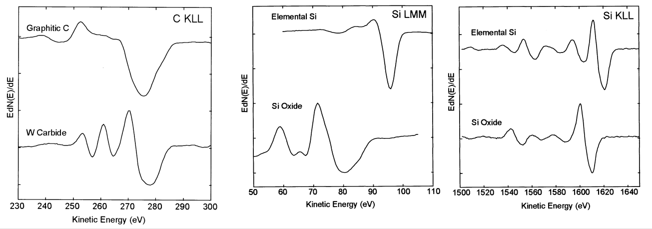
Auger Peaks

Differentiated Auger spectra of chromium, manganese, and iron

Chemical Information

The energy and shape of an Auger peak contains information about the chemical environment. Theoretical predictions are difficult and reference spectra are often used for comparison.





Applications of AES

AES has widespread use owing to its ability to analyze small spot sizes with diameters from 5 μm down to 10 nm. For instance,

- AES is commonly employed to study film growth and surface-chemical composition, as well as grain boundaries in metals and ceramics.
- It is also used for quality control surface analyses in integrated circuit production lines due to short acquisition times.
- Moreover, AES is used for areas that require high spatial resolution.
- AES can also be used in conjunction with transmission electron microscopy (TEM) and scanning electron microscopy (SEM) to obtain a comprehensive understanding of microscale materials, both chemically and structurally.

Limitations

- AES is a three-electron process, elements with less than three electrons (hydrogen and helium) cannot be detected and analyzed.
- The numerous transition peaks in heavier elements can cause peak overlap, as can the increased peak width of higher energy transitions.
- Another limitation is sample destruction by the high-energy electrons.
- Charging of the electron beam on insulating samples can deteriorate the sample and result in high-energy peak shifts or the appearance of large peaks.