Spectroscopy

In the most basic terms, spectroscopy is the study of absorption and emission of radiation by matter. Modern definition of the term further includes the study of interaction between particles like electrons, protons and ions.

Uses of Spectroscopy

- Development of fundamental theories of physics like Special and General Theory of Relativity, Quantum physics and Quantum electrodynamics.
- Radio Frequency Spectroscopy of nuclei is used in medical techniques like magnetic resource imaging.
- Microwave spectroscopy was used to discover three-degree blackbody radiation, the remnant of big bang.
- Optical Spectroscopy is used to study the chemical composition of matter.
- Spectroscopy techniques involving high energy accelerators are used to study the internal structure of proton, neutron and the state of early universe.

Spectroscopy techniques are very sensitive. Even a single atom or isotopes of atom can be detected accurately in the sample. Trace amount of pollutants can be detected effectively using spectroscopic techniques. Certain types of spectroscopy techniques are capable of sensing infinitesimal shift in frequency. Spectroscopy is actually a measurement of interaction of photon with matter as a function of photon energy. In cases where probe particle is not photon it is measurement of how the particle interact with test particle or the matter as a function of energy of probe particle.

Electron energy loss spectroscopy (EELS)

It is a surface analysis technique which is a very good example of particle spectroscopy. Electrons collide with the surface and excites the surface thus losing its energy. This energy loss of electron is used to measure the vibrational excitations associated with surface. On the other end when an electron collides with other particle at high speeds then a great amount of subatomic particle is produced. Particle physics is basically analyzing total production of total particles as function of incident energies of protons and electrons.

Optical Spectroscopy

General Principles

- Basic features of electromagnetic radiation

EMR is composed of oscillating electric and magnetic field which are perpendicular to each other and carries energy in space. Speed of wave is 299,792,458 m\s. They differ in frequency and wavelength. Spectroscopy fundamentally involves decomposition of electromagnetic radiation into its component wavelength.

- Basic properties of atoms

An isolated atom has certain discrete states called quantum states which have definite energy associated with them. Atomic energy levels are measured by observing transitions between two levels. These energy levels are identical for atoms of the same type. The analysis of discrete wavelengths emitted or absorbed by an atom was carried out using prism or grating spectrometers. They are sometimes called spectral lines.

Applications

- Useful in studying the structures of atoms and molecules by analyzing the wavelength emitted by them.
- Gives a precise analytical method to find the constituents in materials of known composition.
- The study of spectral emission lines of distant galaxies led to discovery of fact that universe is continuously expanding.
- Lead to discovery of isotropic microwave radiation.

General methods of spectroscopy

Production and analysis of spectrum usually involves the following:

- source of light
- a disperser to separate light into its component wavelength
- a detector to sense the presence of light after dispersion

Apparatus used for the above process is called spectrometer.

There are basically two types of spectra

- Absorption spectrum

It consists of continuously bright background with one or more dark lines. When a light falls on sample absorbs some wavelength that that excite atom from one energy level to other. Absorbed wavelength would be missing from the light spectrum after passing the sample. Atoms have unique energy levels which gave rise to unique absorption spectra.

- Emission spectrum

It consists of one or more bright lines in black background. Sample is excited and then it relaxes to lower energy levels emitting radiation corresponding to energy difference between the quantum levels of atoms. This radiation is compliment of the radiation missing in absorption spectrum. Emission lines are characteristic property of atom.

Types of electromagnetic sources

- Broadband-light sources

Flames and discharge tubes are unreliable methods of excitation therefore broadband come as a replacement in which generation of light is kept separated from the sample. It consists of light source in a metal filament heated to high temperature. Typical example is tungsten light bulb.

- Line sources

Emit radiation with discrete well-defined frequency. Early source was the arc lamp in sealed tune of gas with low pressure. Geissler discharge tube like neon lamp is a very good example of line source.

- Laser sources

They emit high intensity radiation over a very narrow frequency range. They hold advantage over other methods as light from a laser can be make monochromatic and laser light is much more intense.

Potential limitation to the resolution of spectroscopy of gases is due to motion of atoms and molecules relative to observer. The doppler shift widen any sharp spectral feature.