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Mossbauer Spectroscopy

The phenomenon of the emission or absorption of a γ-ray photon without loss of energy due to recoil of the nucleus and without thermal ~~broad~~ broadening is known as the Mossbauer effect. It was discovered by R. L. Mossbauer in 1957 and he received Nobel prize in 1961.

It concerns with transition between energy levels within the nuclei of atoms. The Mossbauer spectroscopy involves the emission or absorption of gamma rays and hence the technique is also known as Nuclear Gamma Resonance spectroscopy. The condition for absorption depends upon the electron density around the nucleus and the number of peaks obtained ~~is~~ related to the symmetry of the compound. As a result structural information can be obtained. The technique can detect the relative percentage of different charged states of the same atom.

eg Fe^{2+}, Fe^{3+} present in the material.

(2) Mossbauer spectroscopy

make use of low energy γ-rays emitted by nuclei for studying the properties of solids. No Mossbauer effect is noticed in the case of liquids and gases. In Mossbauer studies 14.4 keV γ-rays of ^{57}Fe are used in most cases, although other Mossbauer isotopes like ^{119}Sn and ^{121}Sb can also be used for studies of bronze or glass containing tin or antimony. ^{197}Au has recently been used for studying celtic gold coins. Though fifty isotopes exhibits this effect, only twenty three of them can give useful information without extreme experimental difficulties. In Mossbauer spectroscopy, gamma ray energy from a radioactive nuclei is modulated by imparting Doppler velocity to the source and resonantly absorbed by absorber nuclei.

Decay scheme of ^{57}Co to ^{57}Fe

In ^{57}Fe Mossbauer spectroscopy one uses source of radioactive ^{57}Co which decays to ^{57}Fe by electron capture with a half life period of 270 days. During this process, 91% of the stable ^{57}Fe nuclei arrive in their ground state i.e $I = 1/2$ via $I = 3/2$ excited state

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and emit low energy gamma rays with $E_\gamma = 14.4$ kev.

An important point to be noted that, the source ^{57}Co is usually incorporated or fixed in Rh matrix.

Then γ-ray photon emitted when nuclei undergo transition from excited state to ground state have the right energy to be resonantly absorbed by nuclei of same isotope, causing these to undergo transition from ground state to excited state.

~~Then Mossbauer spectroscopy consists of a source which emit Gamma radiation. The Gamma radiations are absorbed by the sample. The amount of radiation absorbed is measured.~~

When Gamma rays are emitted by the source nucleus, the emitted γ-rays have energies in the range 10 to 100 Kev and are given by the equation

$$E_\gamma = E_r + D - R$$

E_r – Energy difference between the excited state and ground state of source nucleus

D – Doppler shift due the translation motion of the nucleus

R – Recoil energy of the nucleus

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The recoil energy is similar to the recoil associated with that of a bullet leaving a gun and is generally in the range of 10^{-2} to 10^{-5} ev. The Recoil energy is given by the equation

$$R = \frac{E_{\gamma}^2}{2mc^2}$$

m - mass of the nucleus
c - velocity of light

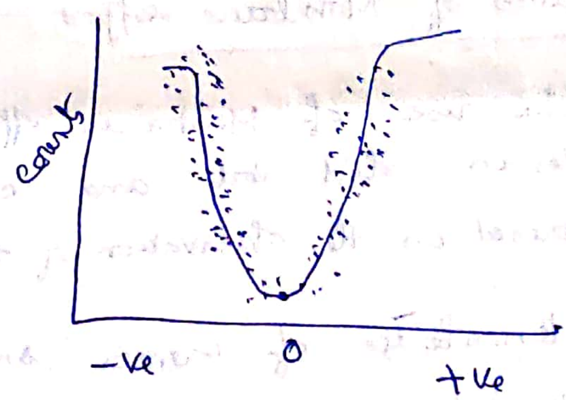
In MB spectroscopy the energy of the γ-ray absorbed for transition in the sample is given by

$$E_{\gamma} = E_{r} + D + R$$

It appears that there is only a very slight probability that the γ-ray energy from the source, will match that required for absorption by the sample. The main cause for nonmatching of γ-ray energies is the recoil energy which is the range of $\sim 10^{-1}$ ev, being very much larger than the typical Doppler energy. The source would have to move with a velocity of 2×10^{4} cm/sec to obtain a Doppler effect large enough to make source and sample energies matching to have a higher probability of absorption. The higher the velocity at which the source is moved towards the sample the higher the average energy of the emitted γ-rays.

In order to obtain MB spectrum the source is moved relative to the sample, and the source velocity at which maximum absorption of γ-rays occurs is determined.

A representation of MB spectrum is shown in the figure.



The source is moved relative to fixed sample and the absorption of γ-rays is plotted as a function of source velocity. The peak corresponds to source velocities at which maximum γ-ray absorption by the sample occurs. Negative relative velocities correspond to moving the source away from the sample and positive relative velocities correspond to moving the source toward the sample. The relative velocity at which the source ~~~~ being moved is plotted along the abscissa and this quantity is related to the energy of the γ-rays.

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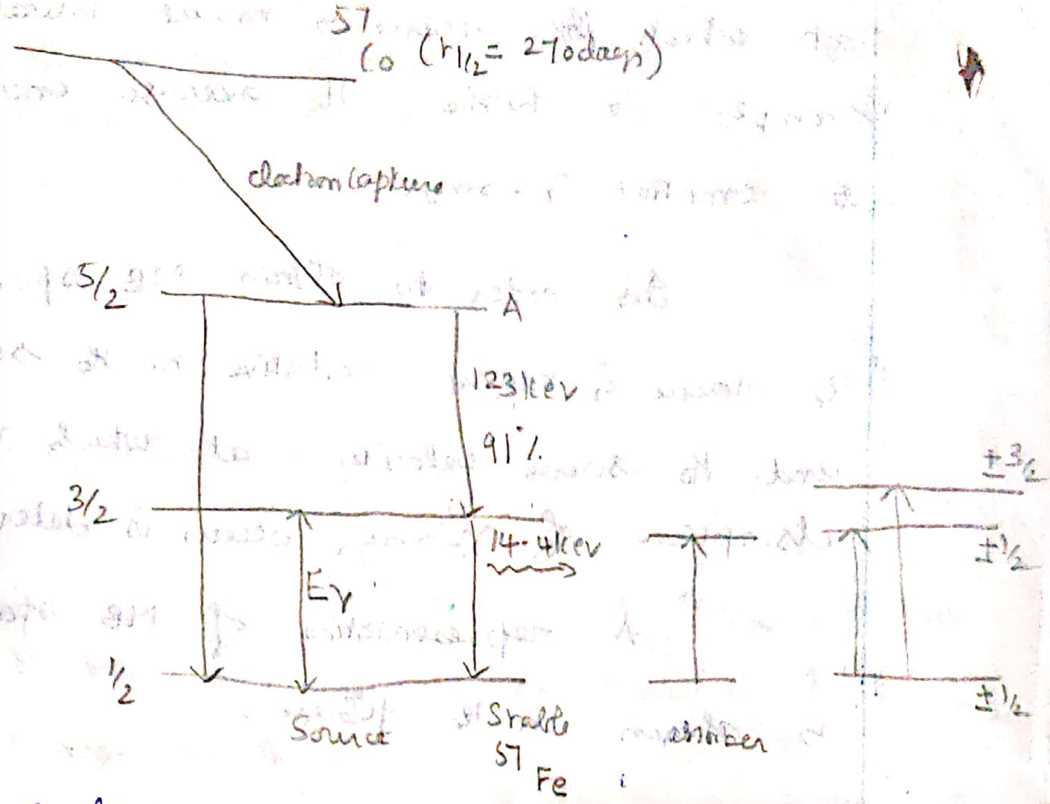

Applications of Mossbauer effect

The uses of Mossbauer effect, as a tool for studies in solid state and chemistry is mainly based on the observation of hyperfine structure

1. From a knowledge of isomer shift, it is possible to get relative s- electron density and from it one can estimate the type of bond of atoms chemically bonded to the Mossbauer nucleus

2. Hyperfine interaction in Mossbauer effect allows the estimation of nuclear quadrupole moment and the asymmetry parameter η. The nature of the split spectra and an estimate of electric field gradient can often be used for the elucidation of molecular structure

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3. ~~From~~ ~~the~~ The study of quadrupole interactions gives detailed information about the crystal symmetry.

4. Several important aspects relating to surfaces can also be studied by Mossbauer spectroscopy. Mossbauer spectrum recorded by scattering methods can effectively be used to study phenomena such as adsorption, catalysis at solid-liquid and solid-gas interfaces etc.

5. It is used to find the different oxidation state of the ~~Fe~~ atoms.

Biological applications

1. ~~1~~ Iron plays an important role in biological systems. It is present in haemoglobin which transports oxygen through blood. The Mossbauer effect is used to examine several of the iron containing proteins. The study of their immediate environment yields considerable information about the type of chemical reaction involved in biological process.

2. Useful in the study of structure of Haemoglobin

3. Mossbauer work on biological molecules has also been carried out on iron-sulphur protein

4. It is useful in the study of structure of Ferridoxin. The Ferridoxin are nothing but enzymes which catalyse photochemical reaction in plants and photosynthetic bacteria.