MÖSSBAUER EFFECT OF ^{57}Fe IN VARIOUS COMPOUNDS AT DIFFERENT TEMPERATURE

THESIS

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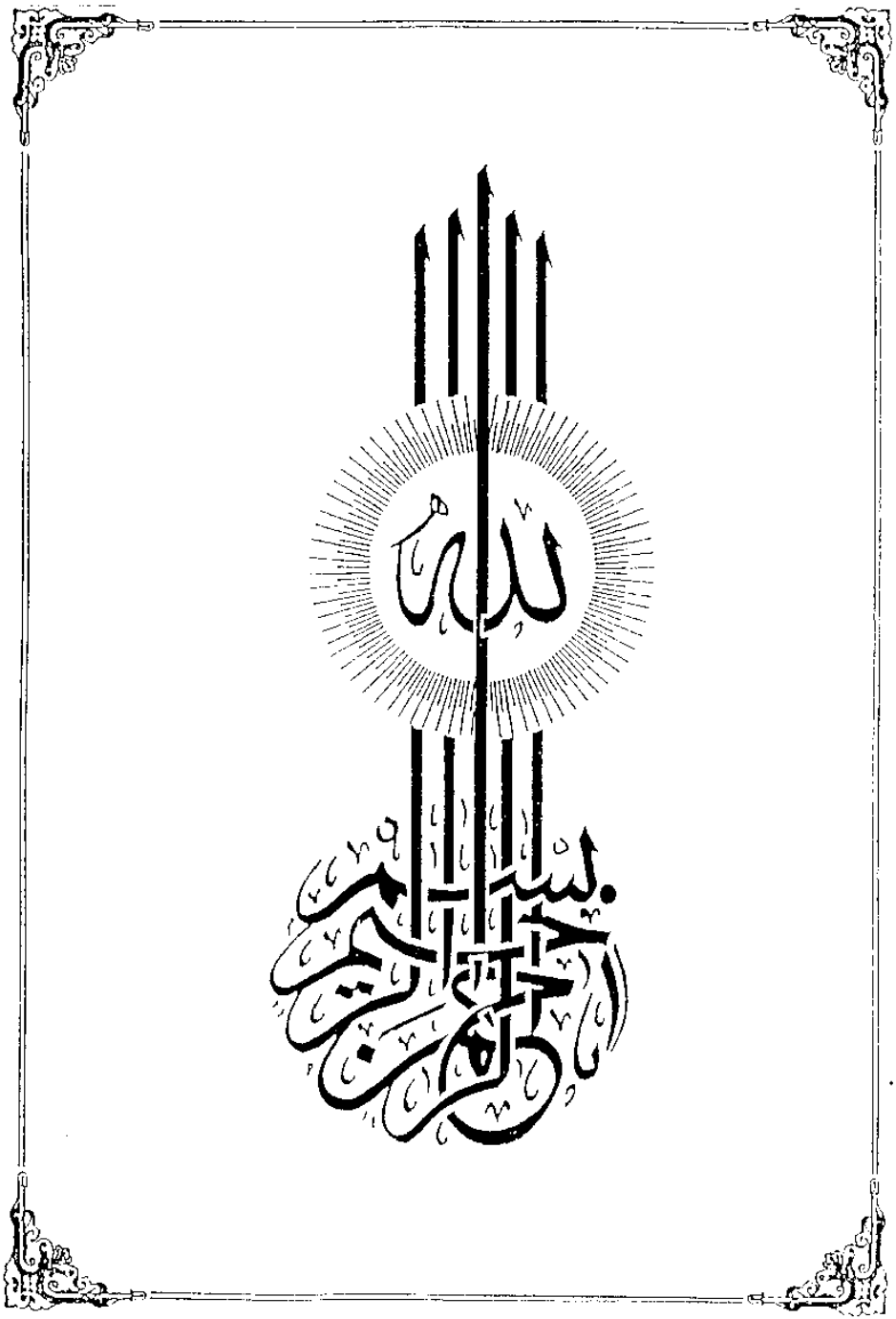

CONTENTS

Summary

This thesis included two fundamental parts consist of four chapters:-

The First Part included:-

Chapter one: Is a historical part about the Mössbauer effect, its uses and the technique used in each.

Chapter two: Included the theory and the theoritical parts which used in treating the subject.

Chapter three: Contains a description for the block diagram of the electronical circuit, its method of operation, a new technique for selecting the low energy gamma rays (14.4 k.e.v) from gamma rays whose energy 123 k.e.v by using two kind of crystals NaI (Tℓ) and plastic phosphour, coincidence circuit and delay line. This chapter contains also the effect of temperature on the Debye Waller factor f (Mössbauer effect) proposing the crystal as 3 N oscillators and by considering that the average energy associated with each oscillator is $= (\bar{n}_j + \frac{1}{2})\ \hbar\ \omega_j$. The average displacement was found to be equal to

$$\langle r^2 \rangle = \frac{\hbar}{NM\ \omega_j} \cdot \frac{n_j + \frac{1}{2}}{\omega_j}$$

$$\langle r^2 \rangle_{T=0} = \frac{6\hbar^2}{4\pi K \Theta_D} \left\{ 1 + \frac{2\pi^2}{3} \frac{T^2}{\Theta_D^2} \right\}$$ interms of

temperature T and Debye Waller angle Θ_D, from which the value of the fraction f (Mössbauer effect), was deduced for temperature less than the Debye temperature where

$$f = \exp \left[- \frac{E_R}{K \Theta_D} \left\{ \frac{3}{2} + \frac{\pi^2}{3} \frac{T^2}{\Theta_D^2} \right\} \right] ; \; T \ll \Theta_D .$$

The relation between f and $\frac{\Theta_D}{T}$ was given for different values of $\frac{R}{\Theta}$ from which the value of Debye Waller (Mössbauer effect) at any temperature can be found. Two different type of targets were used, the first is natural Fe and the second is an alloy of iron-Ni percent of Ni $\simeq$ 30%.

The absorption and the emission spectra were measured as a function of the relative velocity for each target which could be controlled by using set of gear wheels, and the calculated theoritical spectra results were in good agreement with the experimental results.

Debye Waller factor at 300° K was calculated and it is found to be equal to 0.72 for the first target (Fe). It is observed that the absorption spectra for the second target (Fe – Ni alloy) at 300°k have a striking feature that they have a strong paramagnetic absorption line due to the presence of the macroscopically ferromagnetic and the internal magnetic field, derived from ferromagnetic lines in these alloy. It is clear that the presence of the absorption line that lying in the middle in the case of an alloy are derived from ferromagnetic regions.

The second part included:

Chapter four: Which contain a proposition for constant velocity constant acceleration device and a description for the device and its method of operation. The equations of motion, velocity and acceleration were deduced and each of them was calculated for different parameters(γ = 0.01 to γ = 0.4). It was found that the acceleration have a constant value at an angle θ ranges between $\pm$ 20 at γ = 0.260 (γ geometry parameter = $\frac{r}{\ell}$) and a constant line at velocity in the range between 20° and 40°.

A modification was proposed for the last apparatus according to the previous results that by proposing a multibody (6 rotator) instead of a single rotator and the equations of motion, velocity and acceleration was calculated for $\lambda = 0.260$ and plotted interms of the angle. It is found that the acceleration is constant and independent on the angle and have a constant value equal to 0.72 as shown in the figures. The variation in velocity was found to be = 6.2×10^{-4} per turn which is much less smaller than the time required for detecting an event in case of using coincidence circuits and a source whose strength is 100 millicuri. The maximum displacement is 4.54 arbitrary unit per turn and the minimum is 4.52 unit i.e the displacement is equal to = 0.02 unit per turn.

The envelop of the displacement curve for the multibody rotator have the same shape like a full wave rectified high frequency current and the envelop for the acceleration curve have the same shape like the direct current interms of time so a high frequency oscillator can give the same result like the proposed device.

C H A P T E R I

I N T R O D U C T I O N

"1" Introduction:

The phenomenon of resonance of electromagnetic radiation in optics is well known. Khun[1] in 1929 pointed out that such a resonance should also occur, in the case of γ-rays as well. Malmfors[2] (1955) and Metzger[3] (1959) tried to observe the phenomenon but success was not recorded. Although the atomic resonance is very similar to the nuclear resonance, there exist some difficulties which were the main reason for the failure resonance experiments. In order to review these difficulties the nuclear resonance fluorescence process must be discussed in more detail.

1.1. Nuclear Resonance Fluorescence:

To explain what is meant by nuclear resonance fluorescence let us consider a free atomic or nuclear system, of mass M with two level A and B separted by an energy E_o. If the system emits a photon of energy E_γ, the law of conservation of momentum demands that the momentum of the photon should be equal and opposite to that of the recoiling system. The recoiling energy R is then given by:

$$R = \frac{P^2 \text{ recoiling system}}{2\ M} = \frac{P^2 \text{ photon}}{2\ M} = \frac{E_\gamma^2}{2Mc^2} \quad (1)$$

[illegible] can be treated non-relativistically [illegible] used since all γ-rays in atomic and nuclear reactions have energies that are small compared to the rest energy Mc^2 of the emitting atomic or nuclear system. One can assume that the recoil energy is very small compared to the γ-ray energy.

By applying the law of conservation of energy, E_c, E_γ and R are related by:

$$E_c = E_\gamma + R$$

since $R \ll E_\gamma$

So equation (1) becomes

$$R \simeq \frac{E_c^2}{2Mc^2} \qquad (2)$$

According to Heisenberg uncertainty relation, one can not measure the energy in the excited state, so assume that the mean life against decay of the state B is [illegible] and the width is [illegible], therefore the uncertainty in measuring the energy of the excited state B is given by.

[illegible] $= h$

where $2\pi\hbar$ is Plank's constant.

This makes the energy E of the state distributed about the center energy E_c as shown in figure (1-a), but the ground state energy is sharp. This means that in

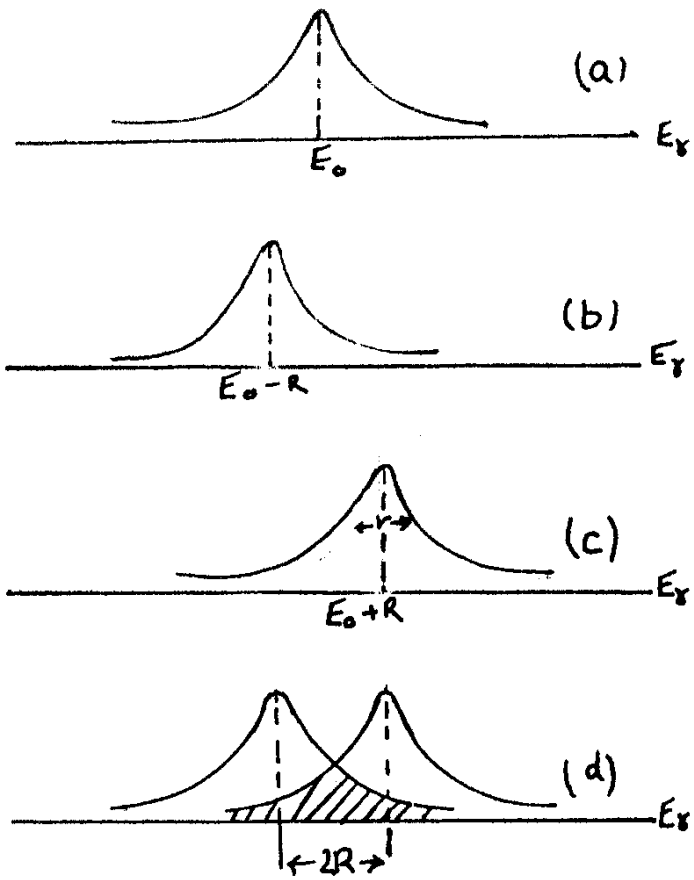

Fig. (1)

Energy distribution involved in resonance flouresence.
(a) Energy distributed of excited state $\mathcal{B}$
(b) Energy distributed of photons emitted in transitions.
(c) Energy spectrum required to excite state $\mathcal{B}$ in target and provide centre of mass energy $\mathcal{R}$.
(d) overlap of (b) and (c)

[illegible] transition from the excited state B to [illegible] and state A, the emitted photons will have a distribution energy E_γ, centered around E_0-R, and displaying a "natural line shape" of width Γ which can be defined as the energy spread at half the maximum intensity of the line figure (1-b).

In order to excite a level of energy E_0, the incoming γ-ray must have an energy $E_0 + R$ because the target must recoil with energy R too. Figure (1-c) shows the energy spectrum required to excite state B in target and provide centre of mass energy R. Unless the shift $2R = \frac{E_0^2}{Mc^2}$ is so small that there is appreciable overlap of the emission and absorption lines fig. (1-d) there will be no resonance effect. The condition of overlap is $2R \lesssim \Gamma$.

In discussion so far, we have assumed that the emitting and the absorbing system are at rest but this is not the case; the atoms of the emitting and absorbing system are in thermal motion which introduces an additional widening of the emission and absorption lines. If the emitting system atoms have a velocity V_s, the radiation of energy E_0 is subject to Doppler shift, and it is observed in the same direction of V_s as an energy $E_0 \left(1 \pm \frac{V_s}{c} \right)$.

[illegible] $E\ (1 \pm \frac{V_a}{c})$. In general V_a and V_s will have some particular distribution, e.g. in a source in which the velocities of the individual emitters are isotropic in direction and its distribution is Maxwillian, i.e given by $4\pi NA\ e^{-BmV_s^2}\ V_s^2\ d\ V_s$, where N is the number of individual emitters A, B are constants and m is the mass in gms of a single emitter, this additional broadening is of the order $D = 2\ (\bar{E}\ R)^{1/2}$, where $\bar{E}$ is the average value of the kinetic energy of the emitters.

1.2. The Mössbauer effect:

Mössbauer[4] (1958) discovered a different technique for observing nuclear resonant absorption. This technique is based on the fact that at low temperature, the recoil energy can be absorbed by the crystal in which the γ-ray emitting nucleus is embedded i.e, no phonon creation in the crystal.

Mössbauer demonstrated the existance of the nuclear absorption of the 129 kev γ-ray of ^{191}Ir in metallic Ir with source and absorber at a temperature of $80^{\circ}k$.

Making use of nuclear γ-ray with energies in the range 10-150 kev, the Mössbauer effect became a new form of high resolution spectroscopy and also a powerful,

[illegible] solid state physics, and [illegible] experiments which previously were considered very difficult.

The life time of the nuclear excited states giving rise to such γ-rays are of the order of 10^{-6} sec. i.e of the same order as the life times of atomic states giving rise to optical transition.

The fractional line width, which is the ratio of the width to the total energy of the γ-ray is an alternative way of expressing the line-width and is of the order of 10^{-3}. It is worth knowing that Mössbauer's sharp recoilless peak at energy E_o was implicit in Lamb's[5] (1939) theory of the absorption of neutrons in crystals, which is an analogous problem.

The Mössbauer effect can be understood very readily if the solid obeys the Einestein model, i.e. if N is the number of atoms in the solid, the vibrational modes are 3N, and each has the same frequency ω. At a given instant, the solid may be characterized by the quatum numbers of its oscillators. If the solid emits or absorbs any quanta of energy $\hbar\omega$, its state will change, and this change can be represented by the