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The Comparative Study of One and Two Phonon Relaxation Rate with Mixed Spin Relaxation Rate

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ABSTRACT The present research work discusses the different types of the relaxation process and calculates the relaxation time due to mixed spin relaxation rate, one phonon relaxation rate, Indirect two phonon relaxation rate and direct two phonon relaxation rate and their comparative study.

KEYWORDS Relaxation time, Phonon.

INTRODUCTION

Heitler and Teller (1936) and Fertz (1938) treated the modulation of the crystalline electric fields by the lattice vibrations. These effects could be accounted the discrepancies between Waller's theory and their experimental results [1]. They did not attempt actually quantitative calculations, but did show that modulation of the crystalline field led to spin-lattice interactions much longer than that of modulations of the magnetic dipolar interactions. Krong (1939) and Van Vleck (1939-1940) showed in their research paper on the spin-lattice interaction that the effect of modulation of the crystalline due to electric field in the iron group alums [2]. Orbach (1961) explained the spin-lattice relaxation times observed in rare earth salts, to estimate their magnitudes and predicted quantitatively their field and temperature dependence [3]. L. Cianchi et al. (1987) discussed regarding the role of the mixed spin relaxation Process for the material $ZnCo_3Fe_{+2}$ [4]. Habasaki J. et al. (1998) studied the relaxation process and the mixed alkali effect in alkali metasilicate glasses [5]. Hans J. Reich (2017) gave the relaxation time usig NMR Spectroscopy [6].

In the present work, we have discussed the different types of the relaxation process and calculated the relaxation time due to mixed spin relaxation rate, one phonon relaxation rate, Indirect two phonon relaxation rate and direct two phonon relaxation rate and their comparative study.

MODEL USED

The model for the relaxation rate is given by the following equation.

$$\frac{1}{T_{O\ell}} = \frac{6\pi\Delta^2 KT}{\rho\hbar^4 v^5}\left(8G'^2 + 9E'^2\right) \quad (1)$$

On taking into account the terms $\left(S_x S_y + S_y S_x\right)$ and $\left(S_z S_y + S_y S_z\right)$ of H_{sp} and assuming that $f' \simeq R' \simeq G'$ the rate will be twice this value, that is

$$\frac{1}{T_{O\ell}} or \frac{1}{T_{S\ell}} = \frac{12\pi\Delta^2 KT}{\rho\hbar^4 v^5}\left(8G'^2 + 9E'^2\right) \quad (2)$$

The equation for relaxation rate taking Hamiltonian formalism is

$$\frac{1}{T_{sp}} = 1.8\times10^{-8} T^5 s^{-1} \quad (3)$$

The equation for two phonon spin-relaxation rate is given by the following equation

$$\frac{1}{T_{sp}} = 7.1\times10^{-8} T^7 s^{-1} \quad (4)$$

The equation for Mixed spin relaxation rate is given by the following equation

$$\frac{1}{T_{CR}} = 2.4\times10^7 \left(T^2 \left[2\exp\left(\frac{\Delta_c}{K_B T}\right) + 1 \right]^{-1} \right) \quad (5)$$

The result is like this, mixed relaxation rate

DATA USED

Using the value of

$\rho = 4gm^{-3}cm^{-3}$, $\hbar = 10^{-27}$, $v = 4\times10^5 cms^{-1}$, $E' = G' = 0.2cm^{-1} = 0.2\times1.95\times10^{-16} erg$,

$K = 1.38\times10^{-16}$, $\Delta = 3cm^{-1}$

COMPARATIVE STUDY OF RELAXATION RATES DUE TO DIFFERENT MODELS

The relaxation rate for our specimen on different relaxation models is tabulated below:

T(K)	Mixed spin relaxation rate	One phonon relaxation rate	Indirect two phonon relaxation rate	Direct two phonon relaxation rate
1K	$2.4 \times10^6 s^{-1}$	$2.35\times10^3 s^{-1}$	$1.8\times10^{-8} s^{-1}$	$7.1\times10^{-8} s^{-1}$
2K	$1.8 \times10^7 s^{-1}$	$4.7 \times10^3 s^{-1}$	$5.7 \times10^{-7} s^{-1}$	$9.08 \times10^{-6} s^{-1}$
3K	$3.7 \times10^7 s^{-1}$	$7.05 \times10^3 s^{-1}$	$2.43 \times10^{-6} s^{-1}$	$2.18 \times10^{-5} s^{-1}$
10K	$1.3 \times10^8 s^{-1}$	$2.35 \times10^4 s^{-1}$	$1.8 \times10^{-3} s^{-1}$	$7.1 \times10^{-1} s^{-1}$
20K	$2.8 \times10^9 s^{-1}$	$4.7 \times10^4 s^{-1}$	$5.76 \times10^{-2} s^{-1}$	$3 \times10^3 s^{-1}$
30K	$6.5 \times10^9 s^{-1}$	$7.05 \times10^4 s^{-1}$	$4.37 \times10^{-1} s^{-1}$	$3.6 \times10^3 s^{-1}$
100K	$1.3 \times10^9 s^{-1}$	$2.35 \times10^5 s^{-1}$	$1.8 \times10^{-2} s^{-1}$	$7.1 \times10^6 s^{-1}$
200K	$2.8 \times10^{10} s^{-1}$	$4.7 \times10^5 s^{-1}$	$5.7 \times10^{-6} s^{-1}$	$3 \times10^4 s^{-1}$
300K	$6.5 \times10^{10} s^{-1}$	$7.05 \times10^5 s^{-1}$	$2.43 \times10^{-5} s^{-1}$	$3.6 \times10^4 s^{-1}$

RESULTS AND DISCUSSION

In the work, we have discussed the different types of the relaxation process and calculated the relaxation time due to mixed spin relaxation rate, one phonon relaxation rate, Indirect two phonon relaxation rate and direct two phonon relaxation rate.

From the comparative study chart, we observed that the relaxation rate increases with increase of the temperature for all the proposed models. The increasing rate of the relaxation rate due to two phonon direct/indirect relaxation process is very slow to that of the direct one ophonon relaxation process and mixed spin relaxation process.

From the observation of our result available in the table, we see that the relaxation rate due to mixed spin relaxation process is geater than to that of the one phonon relaxation process.

From the comparison of the relaxation rate for Fe^{3+} ion on different relaxation models, it is clear that the mixed relaxation rate is in good agreement with the experimental results. So this process may be considered as a competing mode for exchange of energy between electronic spins and phonons at low temperature.

CONCLUSION

The relaxation rate due to two phonon direct/indirect relaxation process is very slow and it is very difficult to observe, while the relaxation rate due to one phonon relaxation process and mixed spin relaxation process is easily observable with that of the relaxation rate due to two phonon direct/indirect relaxation process

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