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CALCULATION OF SPECTROSCOPIC PARAMETERS FOR Nd^{3+} ION IN STRONTIUM ACETATE SOLUTION

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From the observed spectral data, the values of Slater-Condon (F_2, F_4 & F_6), spin-orbit (ξ_{4f}) have been evaluated. Judd-Ofelt (T_2, T_4 & T_6) intensity parameters have been evaluated by the least squares fit method from the observed band intensities. The spectral intensities, which have been calculated from Judd-Ofelt and electric-magnetic dipole method are found to be good agreement with the experimental values. The radiative lifetimes (TR) for certain fluorescent levels such as $^4F_{3/2,5/2,9/2}$ $^2H_{11/2}$ $^4G_{5/2,7/2,9/2}$ and $^4D_{3/2}$ of the neodymium ion studied have been carried out theoretically from the absorption measurements.

Key Words : **Energy Levels; Oscillator Strengths; Predicted Radiative Lifetimes**

INTRODUCTION

THE spectral intensity measurements for Nd^{3+} ion in certain organic liquids have been carried out by Poluektove and Tishechenko[1] and Poluektove and Kononenk.[2] Tandon *et al.*[3] have studied the absorption spectra of Nd^{3+} in some organic complexes. Since no optical absorption studies have so far been reported in literature for Nd^{3+} in strontium acetate complex in solution, the authors have undertaken the present work.

EXPERIMENTAL

Neodymium embedded in strontium acetate complex was prepared by dissolving one mole per cent of Nd $(C_2H_3O_2)_3H_2O$ into the saturated solution of $Sr(C_2H_3O_2)_2$. Absorption spectrum of the complex studied was carried out in the UV-Visible regions on a Perkin-Elmer 551 recording spectrophotometer. Second derivative spectrum analysis of the complex was also carried out in the same wavelength by using a second derivative accessory of the spectrophotometer. The NIR spectrum of the complex was recorded on a Carl-Zeiss specord 61 recording spectrophotometer. Since there is no second derivative unit for the NIR spectrophotometer, only normal spectrum was recorded. The measurement of the refractive index of the complex studied has been carried out on a PZO Warszawava 3275 refractometer. Band intensities have been determined from the profiles of the bands observed.

Results and Analysis

Assignments of the hands of Nd^{3+} in strontium acetate have been made following the procedure of Dieke[5] and are presented in Table I. The energy values (in cm^{-1}) of the observed levels have been calculated from the following relation[4]

$$E_J = E_{oJ} + \sum_{k=2,4\,\&\,6} \frac{dE_J}{dF_k} \Delta F_k + \frac{dE_J}{d\xi_{4J}} \Delta\xi_{4J} \qquad \ldots(1)$$

where E_{oJ} is the zero-order energy. The zero-order energies and the partial derivatives are taken from the tables of Wong[4] and Narayana.[6] The observed energy

Table I

The experimental and calculated energies of the observed levels for Nd^{3+} : $Sr(C_2H_3O_2)_2$ in solution

Energy levels from the ground $^4I_{9/2}$	$E_{expt.}$ (cm^{-1})	$E_{calc.}$ (cm^{-1})	E_{Aq} (Ref 13) (cm^{-1})
$^4F_{3/2}$	11350	11476	11325
$^4F_{5/2}$	12407	12494	12434
$^4H_{9/2}$	12539	12738	12559
$^4F_{7/2}$	13441	13472	13509
$^4S_{3/2}$	13591	13564	13638
$^4F_{9/2}$	14749	14741	14766
$^4G_{5/2}$	17197	17303	17118
$^4G_{7/2}$	19121	19151	19151
$^4G_{9/2}$	19455	19567	19502
$^2G_{9/2}$	21008	21180	21046
$^2D_{3/2}$	21277	21443	21407
$^2P_{1/2}$	23310	23380	23412
$^4D_{3/2}$	27972	28115	28003
$^4D_{5/2}$	28349	28296	28400
$^4D_{1/2}$	28653	28593	28720
$^4D_{7/2}$	30303	30444	30379
$^2D_{3/2}$	33212	33208	33247
$^2D_{5/2}$	34330	34370	34272

R.M.S. Deviation of the Energies : $\pm$ 99cm^{-1}

values were substituted for E_J in the Taylor series expansion (eq. 1) to evaluate changes in F_2, F_4, F_6 and ξ_4. A least squares fit[7] (Gauss Method) was employed to evaluated ΔF_k and $\Delta\xi_{4j}$ values. These ΔF_k and $\Delta\xi_{4j}$ values have been added to the free ion values of F_2, F_4, F_6 and ξ_{4f} to evaluate the Slater-Condon (F_2, F_4, F_6) and Spin-orbit (ξ_{4f}) parameters as follows :—

$$\Delta F_k + F_k^o = F_k$$

$$\Delta\xi_{4f} + \xi_{4j}^o = \xi_{4f} \qquad \ldots(2)$$

The r.m.s. deviation is calculated from the formula

$$\sigma = \left(\frac{\Sigma\Delta_i^2}{N}\right)^{1/2}, \qquad \ldots(3)$$

where Δ_i is the deviation of j^{th} level and N is the number of levels fitted. The values of Slater-Condon parameters alongwith a few more spectroscopic parameters are given in Table II. The results presented in Table I are quite encouraging as the r.m.s. deviation of the energy levels is quite low.

TABLE II

Values of Slatér-Condon ($F_2F_4F_6$), *spin-orbit* (ξ_{4f}), *refractive index* (n), *Judd-Ofelt* ($T_2T_4T_6$) *and intensity* ($\Omega_2\Omega_4\Omega_6$) *parameters for* Nd^{3+} : Sr $(C_2H_3O_2)_2$ *in solution*

Parameters	Nd^{3+} : Sr $(C_2H_3O_2)_2$ Present work	Phenol	Nd^{3+} Glycine (Surana *et al.* 1975)[19]	Alanine
F_2	327.99	—	—	—
F_4	50.98	—	—	—
F_6	5.32	—	—	—
ξ_{4f}	855.88	—	—	—
E^1	5042.66	—	—	—
E^2	23.59	—	—	—
E^3	487.26	—	—	—
n	1.3389	—	—	—
$T_2\times10^9$	0.8929	6.18	6.92	7.14
$T_4\times10^9$	0.2597	3.98	4.50	4.55
$T_6\times11^9$	0.4334	4.82	4.91	4.82
$\Omega_2\times10^{20}$	8.0338	—	—	—
$\Omega_4\times10^{20}$	2.0053	—	—	—
$\Omega_6\times10^{20}$	3.3465	—	—	—

Spectral Intensities

Experimental determination of the spectral intensities of the observed bands has been carried out from the following relation[8]

$$f_{expt} = 4.32 \times 10^9 \int \epsilon(\nu)\, d\nu, \qquad \ldots(4)$$

where $\epsilon(\nu)$ is the molar absorptivity and $d\nu$ is the band-width at half height. The molar absorptivity is calculated from the Beer-Lambert law[8]

$$\epsilon = \frac{1}{Cl}\log\frac{I_o}{I}, \qquad \ldots(5)$$

where C is the concentration of the substance in moles/litre, 'l' is the light-path in the solution (cm) and $\log\frac{I_o}{I}$ is the absorptivity. Theoretical evaluation of spectral intensities has been carried out from the two method : (*i*) Judd-Ofelt theory method; and (*ii*) Electric-Magnetic dipole method.

Judd-Ofelt Theory

Judd[9] and Ofelt[10] have independently calculated the oscillator strengths of rare earth elements. They have shown that the oscillator strength of a transition may be related to the energy of the band ν (cm^{-1}) and square of the matrix elements of the unit tensor operator $\|U^\lambda\|$ connecting the initial and final state $(\psi J \longrightarrow \psi' J')$ *via* three phenomenological parameters $T\lambda(\lambda = 2, 4 \& 6)$. These three parameters are called as Judd-Ofelt parameters. Their theory is called as Judd-Ofelt Theory.

$$f_{cal}^{J0} = \sum_{\lambda=2,4\&6} T\lambda\nu(J^N\psi J \,\|U^\lambda\|\, J^N\psi' J'), \qquad \ldots(6)$$

where ν (cm^{-1}) is the mean energy of the transition $\|U^\lambda\|^2$ is a unit tensor operator of rank and the sum running over the three values $\lambda = 2, 4, 6$. The matrix elements U^λ were calculated in the LS basis using the relation

$$(J^N\alpha\, SLJ \,\|U^\lambda\|\, J^N\alpha\, S'L'J') = (-1)^{S+L+J'+\lambda}\,[(2J+1)(2J'+1)]^{1/2} \times \begin{Bmatrix} J & J' & \lambda \\ L' & L & S \end{Bmatrix} (J^N\alpha SL \,\|U^\lambda\|\, J^N\alpha S'L') \qquad \ldots(7)$$

The reduced matrix elements on the right hand side were taken from the Tables of Neilson *et al.*[11] The values of 6*j* symbols were taken from the Tables of Rotenberg *et al.*[12] From the above equation it is found that the sign of the numerical values depend on the S, L', J' and λ. The sign of the value does not play any significant role in the LS basis because, we always use only squared values of U^λ. But in the intermediate coupling case, the sign plays a dominant role because the states of F^N configuration are taken as linear combinations[8]

$$J^N\,\psi J> = \sum_{\alpha SL} C'(\alpha SL) f^N\alpha\, SLJ>, \qquad \ldots(8)$$

where $C(\alpha SL)$ are the numerical coefficient resulting from the diagonalization of the matrices. The eigenvalues and eigenvectors for Nd^{3+} complex have been computed on an IBM 370/155 computer using the evaluated parameters F_2, F_4, F_6 and ξ_{4f}. The computed eigenvalues and eigenvectors of Nd^{3+} complex Table III have been transformed from the LS basis states to the physical coupling scheme prior to being squared and substituted in Eq. 6. The squared reduced matrix elements $\|U^\lambda\|^2$ of Nd^{3+} : Sr $(C_2H_3O_2)_2$ are given in Table IV. The squares of U^2, U^4 and U^6 were substituted in Eq. 6 and using f_{expt} for f_{cal} the values of $T\lambda$ parameters were evaluated by a least squares fit method (Table II). The intensity parameters $\Omega\lambda$ were calculated from the equation[13]

$$\Omega\lambda(C_m^2) = \left[1.085 \times 10^{11}\,\frac{n(n^2+2)}{9}\right]^{-1}(2J+1)\,T\lambda \qquad \ldots(9)$$

where n is the refractive index of the solution and $T\lambda$ are the Judd-Ofelt parameters.

Electric-Magnetic Dipole Method : f_{cal}^{em}

The total oscillator strength of a band with energy ν (cm^{-1}) is given by

TABLE III

The computed eigenvalues and eigenvectors (cm^{-1}) *for the observed levels of* Nd^{3+} : $Sr(C_2H_3O_2)_2$ *in solution*

$^4I_{9/2}$ (0)	$^4F_{3/2}$ (11390)	$^4F_{5/2}$ (12395)	$^2H_{9/2}$ (12703)	$^4F_{7/2}$ (13366)
0.0028 (^4F)	−0.0491 (^4S)	70.0027 (^4D)	−0.3353 (^4F)	0.0029 (^4D)
0.0073 (^4G)	−0.0547 (^2P)	0.1411 (^2D)	−0.1436 (^4G)	0.9702 (^4F)
−0.0155 (^2G)	−0.0111 (^4D)	−0.0171 (^2D)	0.3303 (^2G)	−0.0372 (^2F)
0.0137 (^2G)	0.2135 (^2D)	0.9889 (^4F)	−0.2745 (^2G)	−0.0279 (^2F)
0.0538 (^2H)	−0.0567 (^2D)	−0.0301 (^2F)	−0.2813 (^2H)	0.0296 (^4G)
−0.1575 (^2H)	0.9725 (^4F)	−0.0259 (^2F)	0.7393 (^2H)	−0.1852 (^2G)
0.9858 (^4I)	0.9725 (^4F)	−0.0185 (^4G)	0.1445 (^4I)	0.1465 (^2G)

$^2G_{9/2}$ (20965) (cm^{-1})	$^2D_{3/2}$ (21162) (cm^{-1})	$^2P_{1/2}$ (23102) (cm^{-1})	$^4D_{3/2}$ (28160) (cm^{-1})	$^4D_{5/2}$ (28349) (cm^{-1})
0.2760 (^4F)	0.1869 (^4S)	0.9694 (^2P)	0.0186 (^4S)	0.9021 (^4D)
0.4414 (^4G)	−0.6626 (^2P)	0.2454 (^4D)	−0.1282 (^2P)	−0.0099 (^2D)
0.6379 (^2D)	−0.1292 (^4D)		0.9096 (^4D)	0.4119 (^2D)
−0.5141 (^2G)	0.6769 (^2D)		0.1154 (^2D)	0.0065 (^4F)
0.0067 (^2H)	−0.1293 (^2D)		0.3776 (^2D)	−0.0910 (^2F)
−0.2390 (^2H)	−0.1855 (^4F)		0.0008 (^4F)	−0.0850 (^4F)
−0.0254 (^4I)				0.0258 (^4G)

$^4S_{3/2}$ (13467)	$^4F_{9/2}$ (14630)	$^4G_{5/2}$ (17039)	$^4G_{7/2}$ (18952)	$^4G_{9/2}$ (19326)
0.9737 (^4S)	0.8659 (^4F)	−0.0075 (^4D)	−0.0068 (^4D)	−0.1591 (^4F)
0.2134 (^2P)	−0.0426 (^4G)	−0.0019 (^2D)	0.1407 (^4F)	0.8822 (^4G)
0.0139 (^4D)	−0.1139 (^2G)	−0.0143 (^2D)	0.0507 (^2F)	−0.2544 (^2G)
−0.0377 (^2D)	0.0737 (^2G)	0.0227 (^4F)	0.0443 (^2F)	0.2419 (^2G)
0.0024 (^2D)	0.1558 (^2H)	0.0759 (^2F)	0.7377 (^4G)	−0.1221 (^2H)
0.0697 (^4F)	0.4474 (^2H)	0.0735 (^2F)	0.5137 (^2G)	0.2395 (^2H)
	0.0650 (^4I)	0.9940 (^4G)	0.4095 (^2G)	0.0315 (^4I)

$^4D_{1/2}$ (28691)	$^4D_{7/2}$ (30340)	$^2D_{3/2}$ (33256)	$^2D_{5/2}$ (33756)
−0.2454 (^2P)	0.9948 (^4D)	−0.0094 (^4S)	−0.0128 (^4D)
0.9694 (^4D)	−0.0061 (^4F)	0.0876 (^2P)	0.9885 (^2D)
	−0.0557 (^2F)	−0.3848 (^4D)	0.0473 (^2D)
	−0.0831 (^2F)	0.1896 (^2D)	−0.1410 (^4F)
	0.0127 (^4G)	0.8990 (^2D)	−0.0100 (^2F)
	−0.1852 (^2G)	0.0109 (^4F)	−0.0197 (^2F)
	0.1465 (^2G)		0.0078 (^4G)

TABLE IV

The evaluated squared reduced matrix elements $\|U^{\lambda}\|^2$ *of* Nd^{3+} : $Sr(C_2H_3O_2)_2$ *in solution*

Energy Levels from the ground $^4I_{9/2}$	$(U^2)^2$	$(U^4)^2$	$(U^6)^2$
$^4F_{3/2}$	0	0.22895	0.05857
$^4F_{5/2}$	0.00081	0.23294	0.40109
$^2H_{9/2}$	0.00903	0.00729	0.10912
$^4F_{7/2}$	0.00880	0.04749	0.22396
$^4S_{3/2}$	0	0.00694	0.22918
$^4F_{9/2}$	0.00210	0.00983	0.04852
$^4G_{5/2}$	0.89865	0.41062	0.03495
$^4G_{7/2}$	0.05092	0.10318	0.06570
$^4G_{9/2}$	0.00133	0.01519	0.01122
$^2G_{9/2}$	0.00793	0.05632	0.05972
$^2D_{3/2}$	0	0.01782	0.00059
$^2P_{1/2}$	0	0.03502	0
$^4D_{3/2}$	0	0.20692	0.01590
$^4D_{5/2}$	0.00020	0.05788	0.02826
$^4D_{1/2}$	0	0.26176	0
$^4D_{7/2}$	0	0.00369	0.00810

$$f_{cal}^{em} = \frac{8\pi^2 mc\nu}{3hc^2(2J+1)}\left[\frac{(n^2+2)^2}{9n} S_{ed} + n\, S_{md}\right], \qquad \ldots(10)$$

where S_{ed}, S_{md} are the electric and magnetic dipole linestrengths respectively, m = mass of an electron, c = velocity of light, ν = wavenumber of the band in cm^{-1}, h = Planck's constant, e = electron charge in coulombs and j = value of the initial state.

The electric dipole linestrength (S_{ed}) is obtained from the following expression

$$S_{ed} = e^2 \sum_{\lambda=2}^{6} \Omega_\lambda \,(\psi J \,\|U^{\lambda}\|\, \psi' J')^2. \qquad \ldots(11)$$

The magnetic dipole linestrength (S_{md}) is calculated from the following relation

$$S_{md} = \frac{e^2h^2}{16\pi^2m^2c^2}\,(\psi J \,\|L + 2S\|\, \psi' J')^2. \qquad \ldots(12)$$

The values of $\|L + 2S\|^2$ are calculated by following the selection rule $\Delta J = 0 \pm 1$.

$J' = J$

$$(SLJ \,\|L + 2S\|\, SL, J') = gJ(J+1)(2J+1), \qquad \ldots(13)$$

where $$g = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}. \qquad \ldots(14)$$

$J' = J - 1$

$$(SLJ \| L + 2S \| SL, J - 1) = \frac{(S+J+L+1)(S+L+1-J)(J+S-L)(J+L-S)}{4J} \quad ...(15)$$

$J' = J + 1$

$$(SLJ \| L + 2S \| SL, J + 1) = \frac{(S+J+L+2)(S+J+1-L)(L+J+1-S)(S+L-J)}{4(J+1)} \quad ...(16)$$

The evaluated electric (S_{ed})-magnetic (S_{md}) dipole linestrengths of Nd^{3+} complex studied are presented in Table V.

TABLE V

Electronic dipole (S_{ed}) and magnetic dipole (S_{md}) linestrengths of Nd^{3+} : $Sr(C_2H_3O_2)_2$ *in solution*

Terms from the ground $^4I_{9/2}$	$S_{ed} \times 10^{-22}$	$S_{md} \times 10^{-22}$
$^4F_{3/2}$	65.51	0
$^4F_{5/2}$	181.18	0
$^2H_{9/2}$	40.72	0.1695
$^4F_{7/2}$	80.44	0.1494
$^4S_{3/2}$	78.09	0
$^4F_{9/2}$	18.82	0.1346
$^4G_{5/2}$	366.68	0
$^4G_{7/2}$	58.12	0.058
$^4G_{9/2}$	28.45	0.0782
$^2G_{9/2}$	7.21	0.0062
$^2D_{3/2}$	5.54	0
$^2P_{1/2}$	7.02	0
$^4D_{3/2}$	46.81	0
$^4D_{5/2}$	21.12	0
$^4D_{1/2}$	52.49	0
$^4D_{7/2}$	3.45	0.015

The experimental (f_{expt}) and calculated ($f_{cal}^{Jo}, f_{cal}^{em}$) spectral intensities for Nd^{3+}: $Sr(C_2H_3O_2)_2$ have been tabulated in Table VI. From this table it is interesting to note that a good agreement has been found between the experimental and calculated spectral intensities, since the r.m.s. deviation of the spectral intensities is quite resonable.

TABLE VI

Experimental and calculated spectral intensities of Nd^{3+} : $Sr(C_2H_3O_2)_2$ *in solution*

Terms from the ground $^4I_{9/2}$	$f_{expt}(\times 10^6)$	f_{cal}^{J0} $(\times 10^6)$	f_{cal}^{em} $(\times 10^6)$
$^4F_{3/2}$	1.285	0.963	0.962
$^4F_{5/2}$	2.815	2.911	2.910
$^2H_{9/2}$	1.852	0.661	0.664
$^4F_{7/2}$	1.263	1.517	1.519
$^4S_{3/2}$	1.071	1.375	1.223
$^4F_{9/2}$	0.302	0.359	0.360
$^4G_{5/2}$	8.164	8.167	8.150
$^4G_{7/2}$	1.539	1.440	1.440
$^4G_{9/2}$	0.789	0.717	0.718
$^2G_{9/2}$	0.217	0.196	0.196
$^2D_{3/2}$	0.162	0.153	0.152
$^2P_{1/2}$	0.332	0.212	0.212
$^4D_{3/2}$	1.632	1.696	1.695
$^4D_{5/2}$	0.933	0.776	0.775
$^4D_{1/2}$	1.693	1.948	1.947
$^4D_{7/2}$	0.138	0.136	0.136

RMS deviation of the intensities : $\pm$ 0.184.

DISCUSSION

Hypersensitive Transition

Transition where intensities are particularly sensitive to the host and follow the selection rule

$$\Delta J \leqslant 2, \quad \Delta L \leqslant 2 \text{ and } \quad \Delta S \leqslant 0 \qquad \ldots(17)$$

are termed as hypersensitive transition...For Nd^{3+} ion the transition $^4I_{9/2} \longrightarrow {}^4G_{5/2}$ is the hypersensitive transition.[14] A strong correlation exists between T_2 and the oscillator strengths of the observed bands, which has not been that much strong in the case of Judd-Ofelt T_4 and T_6 (it is because the above mentioned selection rules hold good for T_2). From Table IV, it may be interesting to note that the reduced matrix elements $\|U^2\|^2$ and $\|U^4\|^2$ greater in value compared to all other levels except for the hypersensitive transition $^4I_{9/2} \longrightarrow {}^4G_{5/2}$. For this transition, both the observed and calculated spectral intensity is much higher compared to the other levels presented in Table VI. The reasons for getting such a higher value for $^4G_{5/2}$ are being expalined due to the Judd-Ofelt parameter (T_2) and $\|U^2\|^2$ values. Similar observations were made by Tandon *et al.*[3] and Poluektov *et al.*[1,2] Table VI explains the validity of Judd-Ofelt theory. The experimentally observed spectral intensities are found to be in good agreement with the calculated spectral intensities obtained from Judd-Ofelt and Electric-Magnetic dipole linestrength method. The intensity of the hypersensitive transition $^4I_{9/2} \longrightarrow {}^4G_{5/2}$ is four times greater to

the some of the levels and seven or eight times in certain cases, as is seen from Table VI.

Radiative Lifetimes (T_R)

Dieke[5] reported that the electronic excited states such as $^4F_{3/2,5/2,9/2}$ $^2H_{11/2}$, $^4G_{5/2,7/2,9/2}$ and $^4D_{3/2}$ levels would exhibit fluorescence in Nd(III) : $LaCl_3$: Later on, Carnall *et al.*[8] have reportcd the radiative lifetimes of the fluorescent levels of Nd^{3+} : LaF_3 in solution. Since the present work is on solution, spectrum procedure of Carnall *et al.*[8] has been followed and evaluated the radiative lifetimes of fluorescent levels theoretically.

Radiative transition probabilities for the excited states of Nd^{3+} in the intermediate coupling scheme were calculated following the procedure or Reisfeld.[15] The reduced matrix elements $\|U^\lambda\|^3$ between each of the fluorescent levels and all the next lower levels were calculated in an intermediate coupling scheme. Following Carnall *et al.*[16] the total radiative transition probability $A(\psi J; \psi' J')$ has been calculated, using the intensity parameters Ω_λ got from the absorption measurements.

The total radiative relaxation (A_T) was calculated from

$$A_T(\psi J) = \sum_{\psi' J'} A(\psi J; \psi' J'), \qquad \ldots(18)$$

where the sum runs over all $\psi' J'$ lower in energy than ψJ. The radiative lifetimes of a state is given by

$$A_T(\psi J) = [A_T(\psi J)]^{-1}. \qquad \ldots(19)$$

Predicted lifetimes of the fluorescent levels of Nd^{3+} : Sr $(C_2H_3O_2)_2$ presented in Table VII. From this table, it is very interesting to note that the predicted lifetimes of the fluorescent levels may be classified in the following manner depending upon their lifetime (T_R) values

TABLE VII

Predicted radiative lifetimes (T_R) *of the electronic excited states of* Nd^{3+} : $Sr(C_2H_3O_2)_2$ *in solution*

Energy levels	Nd^{3+} : $Sr(C_2H_3O_2)_2$ T_R (μ sec) Present work (Theoretical)	Nd^{3+} : Different glasses T_R(μ sec) (after Krupke, 1974)[18]				Nd^{3+} : $PoCl_3$: $SnCl_4$ T_R (μ sec) (Theoretical) (Lakshman *et al.*, 1984)[20]
		3669A glass	533 glass	KD-2 glass	LSC-91H glass	
$^4F_{3/2}$	1240	1000	400	372	348	643
$^4F_{5/2}$	690	—	—	—	—	535
$^4F_{9/2}$	475	—	—	—	—	585
$^2H_{11/2}$	3695	—	—	—	—	6993
$^4G_{5/2}$	410	—	—	—	—	169
$^4G_{7/2}$	304	—	—	—	—	240
$^4G_{9/2}$	275	—	—	—	—	238
$^4D_{3/2}$	167	—	—	—	—	79

$$T_R(\mu \text{ sec}) : {}^2H_{11/2} > {}^4F_{3/2} > {}^4F_{5/2} > {}^4F_{9/2} > {}^4G_{5/2} > {}^4G_{7/2} > {}^4G_{9/2} > {}^4D_{3/2}$$

From Table VII, it is seen that the highest lifetime for ${}^2H_{11/2}$ and the lowest lifetime value for ${}^4D_{3/2}$ have been obtained. Similar results have earlier been reported by Buddhudu.[13] Since no detailed information is available in literature relating to the experimental determination of the lifetimes of the above eight fluorescent levels, the theoretically evaluated values of the ion studied could not be compared. However, the experimentally observed lifetime of ${}^4F_{3/2}$ of Nd^{3+} in different glasses have been presented in Table VII along with the predicted lifetimes of Nd^{3+} in laser liquid obtained by Lakshman *et al.*[20] A good agreement has been found between the data of Lakshman *et al.*[20] with the results of present paper. The theoretically obtained lifetime value for ${}^4F_{3/2}$ is found to be in good agreement with the experimental value of Krupke.[18]

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