

The study of *f-f* electronic transition spectra of ternary complexes of Sm (III) with some crown ethers and some amino acids

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Abstract: The ternary complexes [Sm-CW-AA] have been prepared by interacting the Sm (III) metal ion [M] with the crown ethers [L₁]: 18-Crown-6, benzo-18-Crown-6 & dibenzo-18-Crown-6 & the amino acids [L₂]: glycine, β-alanine & L-arginine, respectively, in various metal- ligands stoichiometries [M:L₁:L₂] ratio. The electronic spectra of these complexes have been recorded in visible region, in solution. The intensity of the nine selected bands of the *f-f* electronic transition spectra have been analyzed & characterized. The spectra have been quantified in terms of intensity parameters: Oscillator strength (P_{osc}) & Judd-Ofelt (T_2 , T_4 & T_6) and the bonding parameters: Nephelauxetic ratio (β) & co-valency ($b^{1/2}$). All these parameters have been computed using partial and multiple regression methods given by Wong and others. The variation in these parameters for the complexes with respect to the free ion shows the complexation reaction, change in symmetry around metal ion, structure of the complexes/ligand, nature of metal-ligand bond etc. Typically, the T_2 parameter is associated with short-range coordination effects. Nevertheless, the other two parameters, T_4 & T_6 , depend on long range effects. Also these are crucial for evaluating their performance as the laser or photoluminescent material. The metal-ligands stoichiometries [Sm: CW: AA] ratio of these complexes have also been determined using Mole Ratio method. This was found to be [1:3:2], in general.

Keywords: metal ternary complexes, Sm (III) metal-ion, amino acids, crown ethers, electronic spectra, intensity and bonding parameters,

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I. Introduction

In the recent past the quest for getting new organic ligand for the formation of lanthanide complexes has increased manifold due to their unique photoluminescent, magnetic and other properties. Because they are being used in the fields [1-7] of optoelectronics, electroluminescent devices, (OLED, LCD etc.), Lanthanide Luminescent Biological probe (LLBs-immunoassay, drug design, MRI etc.), telecommunication (signal amplifier), industries (optical glass, computers, Smartphone, electronics etc.) etc. The *f-f* transitions in the lanthanides are parity forbidden and hence, search for new organic ligands is inevitable, which can enhance the photoluminescent properties through complexation [8]. A photoluminescent lanthanide complex requires a ligand for transferring the energy to the metal ion for excitation as sensitizer/antenna or Light Harvesting Centre (LHC) which fills coordination sphere and other one as neutral donor ligand as Non Absorbing Ligand (NAL) which removes the remaining water molecules to avoid radiationless deactivation or quenching [9-11]. So, to prepared ternary complex with such ligands, so optimization of the desired photoluminescent or other properties can be achieved. The photoluminescent properties of a complex is estimated by calculating the values of Judd-Ofelt parameter (T_2) using the *f-f* electronic transition spectra [12]. This paper describes the preparation of such nine ternary complexes of Sm (III) by taking crown ethers as NAL: 18-crown-6, benzo-18-crown-6 & dibenzo-18-crown-6 for amino acids as LCH: glycine, β-alanine & arginine. The *f-f* transition spectra have been recorded & analyzed and the parameters: intensity: Oscillator strength (P_{osc}) & Judd-Ofelt (T_2 , T_4 & T_6) & bonding parameters: covalence parameter ($b^{1/2}$) and nephelauxetic ratio (β) have been calculated to explain the symmetry, ligand environment around the Sm (III), nature of Sm (III) ligand bonding. The such ternary complexes are also suitable the cleavage of phosphodiester bond, studying toxic effect of metal ion & detoxification etc.

II. Experimental

2.1-Reagents & solvents -All reagents, Sm (III) acetate (Otto Chemika), crown ethers (Aldrich), amino acids (Himedia Lab, Biochemika) were of the highest purity (AR grade). The solvents Methyl cyanide (Qualikem) and methyl alcohol (Uvasol:Sigma-Aldrich) were of spectroscopic grade. Deionised water was used throughout.

2.2-Preparation of stock solutions-The stock solutions (0.01M) of the ligands: Crown ethers [L₁] namely, 18-Crown-6 [CE], Benzo 18-Crown-6 [CB] and dibenzo 18-Crown-6 [CD] and amino acids [L₂], namely, β-Alanine [AL], glycine [GY], and L-Arginine [AR] were prepared by dissolving the calculated mass of each of them in a minimum quantity of the mixture of CH₃OH and CH₃CN (whenever necessary) or in distilled water. The metal ion solution (0.01M) was prepared by dissolving the salt of Sm (III) in double distilled water and was standardized by the conventional complexometric method.

2.3-Recording the Spectra: The sample solutions were prepared by taking the metal ion solution [M] and the ligand solutions [L₁] & [L₂] in stoichiometric ratio [M:L₁:L₂] of [1:3:1], [1:3:2], [1:1:3] and [1:2:3] to record the spectra. The electronic absorption spectra of Sm (III) metal ion in the presence of ligands environment, i.e. Crown Ethers [L₁] ,(CE, CB or CD) ,& amino acids [L₂] ,(AL, GY or AR), have been recorded by the measuring the absorbance (A) at different wavelengths, i.e., in the visible range for each sample solution having 1:3:1, 1:3:2, 1:2:3 or 1:1:3 [M:L₁:L₂] metal-ligand stoichiometry at room temperature. The absorbance (A) of sample solution having 1:3:2 metal-ligand ratio have been found to be the maximum and this indicate the stoichiometry where there is maximum stacking of ligands around the metal ion, i.e complexation has taken place.

III. Results And Discussion

The intra *f-f* electronic transitions are responsible for the absorption spectra. These transitions are Laporte forbidden transitions of very weak intensity. The Judd-Ofelt theory enabled to interpret the low intensities of these transitions. The *f-f* transitions peak shift toward longer wavelength in the ligand environment as compared to free ion. This indicates an interaction of the stereo-environment and the central metal ion. A lot of information can be derived from the various interelectronic, spin-spin, spin-orbit, mixing of metal-ligand orbitals, nature of bonding etc. The nine bands corresponding to ⁶P_{7/2} , [⁴L_{15/2}, ⁴K_{11/2}], ⁶F_{1/2}, [(⁶P, ⁶P)_{5/2}], ⁴G_{9/2}, ⁴I_{13/2} , [⁴M_{15/2}, ⁴I_{11/2}], ⁴G_{7/2} and ⁴G_{5/2}, transitions were identified in the visible range for [1:3:2] metal-ligand stoichiometry .The absorbance & the intensity is maximum for hypersensitive transition (⁶H_{5/2} → ⁶F_{1/2}) and the shift is linked with degree of metal-ligand bond covalency. The changes in values of all the parameters in all the metal-ligand complexes, as compared to the free ion and also in the various metal and ligand [M:L₁:L₂] ratios i.e.[1:3:1, 1:3:2, 1:1:3, 1:2:3] is not much appreciable. Further, this shows that ligands have little effect on the spectral pattern thereby indicating largely outer sphere (high spin) complexation and also metal- ligands interaction is not merely ionic. The absorption spectra have been analyzed to derive various spectral parameters. The values of energies (E) for peaks of various *f-f* transition bands, intensity & bonding, parameters of all the metal-ligand complexes are summarized in Table-1 & 2.

3.1-Intensity Parameters

The spectrophotometric method is very convenient for the determination of the Judd-Oflet (T_λ) intensity parameters. The low intensity of transitions is expressed in terms of oscillator strength (P_{obs}) and this was explained by Judd-Oflet theory.

3.1.1-Oscillator Strength: The low intensity of bands of Laporte forbidden *f-f* transitions have been explained by Judd-Ofelt. The observed intensity is due to the contributions of induced electric dipole (P_{ed}), and other contributions of magnetic dipole (P_{md}) & electric quadruple (P_{eq}) are very small. This is measured in terms of oscillator strength (P_{osc}). The theoretical oscillator strength (P_{cal}) of electric dipole transition (between states SLJ & S'L'J') with f^N configuration can be calculated using equation (1)-.

$$P_{cal} = \frac{8n^2 m c \sigma}{3h(2j+1)} \chi \sum_{\lambda=2,4,6} T_{\lambda} |\langle SLJ || U^{\lambda} || S'L'J' \rangle|^2 \quad (1)$$

Where **m** is electron mass, **c** is speed of light, **h** is Plank constant, **χ** is field correction factor $\chi = (n^2+2)^2/9n$, where **n** is the refractive index, **σ** transitive wave number & **2J + 1**, the degeneracy of |SLJ> & || U^λ ||² represent the square of the reduced matrix element of the tensor operator U^λ connecting initial and final state[13-15]. The experimental oscillator strength of each band the *f-f* transition has been computed using the following equation(2)

$$P_{exp} = 4.138 \times 10^{-9} \int \epsilon_{max} (v_{1/2}) \cdot \Delta v_{1/2} \quad (2)$$

Where **v^{1/2}**= half band width and **ε_{max}** = molar extinction coefficient.

The values are summarized in the Table-1 for all the metal-complexes.

3.1.2-RMS Deviation (σ_{rms}): The σ_{rms} values [16-17] for Sm (III) metal-complexes range from 0.528 × 10⁻⁶ to 1.310 × 10⁻⁶ for different metal-ligand stoichiometry, respectively. The σ_{rms} values have been summarized in Table-1. The small values of σ_{rms} deviations indicate the suitability of the relations used.

3.1.3-Judd-Ofelt Parameters-These Judd-Ofelt (T_{λ,λ=2,4&6}) parameters are indicative of stereoenvironment around the metal ion. The trend of Judd-Ofelt parameters have been found in Sm (III) complexes is T₂<T₄<T₆. The values of T₄ /T₆ ratio for Sm (III)-complexes range from 1.076 to 1.273 in different metal-ligand stoichiometry, respectively. These values indicate co-ordination through oxygen in all the metal complexes. The

values of the Judd-Ofelt Parameter, T_2 , also used to estimate the photoluminescent property of the metal ion, higher the value of T_2 greater is the luminescence properties. The changes in values of T_λ parameters of the metal complexes indicate slight variation in stereoenvironment around central metal- ion. The values of the Judd-Ofelt parameter (T_λ) have been summarized in Table 2.

3.2-Bonding Parameters

3.2.1-Nephelauxetic ratio (β): In Sm (III) complexes the nephelauxetic ratio (β) have been calculated using following equation(3)-

$$\beta = \nu_c / \nu_f \quad (3)$$

where ν_c and ν_f are energies (in cm^{-1}) of the hypersensitive transition in the complex and free-ion, respectively. For all the ternary complexes, the values of β are less than 1.0 which suggest that there is covalency. The values of β have been found in the range of 0.973 to 0.982. The values of nephelauxetic parameters, (β) have been evaluated and collected in Table-1

3.2.2-Covalency Parameters ($b^{1/2}$): It also throws light on nature of metal-ligand bonding and its positive value indicates covalency. This is a measure of the amount of $4f$ -metal and ligand orbitals mixing in a complex. The bonding parameter ($b^{1/2}$) is also related to nephelauxetic ratio (β) by the equation (4)-

$$b^{1/2} = [1/2 (1-\beta)]^{1/2} \quad (4)$$

The minimum and maximum values of $b^{1/2}$ have been found to be 0.104 to 0.108 respectively. This indicates the metal ligand interaction is not merely an ionic but there is a mixing of metal and ligands orbitals and hence covalent nature of metal-ligand bond (Ln-O) may be concluded [18]. The values of bonding parameters, ($b^{1/2}$) have been evaluated and are collected in Table-1

IV. Conclusions

The interaction of Sm (III) ions with crown ethers and amino acids is not just ionic but the various parameters evaluated advocate covalency in the bonding. In case of both the Sm (III) metal ion complexes, the absorption was highest for 1:3:2 metal ligand stoichiometric ratio. On the basis of bonding parameter the order of covalency of the Sm (III) metal ion complexes with these ligand is follows-

CE-GY > CE-AL > CE-AR > CB-GY > CB-AL > CB-AR > CD-GY > CD-AL > CD-AR.

The complexation and covalency have been related to spectral intensity i.e. oscillator strength. The metal-ligand stoichiometry affects the oscillator strength; higher the value of oscillator strength, higher will be complexation and covalency. This is in an agreement with earlier findings [19-22]

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References

- [1] N.P.Kuzmina and S.V.Eliseeva, Photo and electroluminescence of lanthanide (III) complexes, Journal of Inorganic Chemistry, 51, 2006, 73.
- [2] G.Vicentini, L.B.Zinner and J.Z-Schpector and K. Zinner, Luminescence and structure of europium compounds, Coordination Chemistry Review., 196(1) ,2000,353.
- [3] J. Kido and Y. Okamoto, Organo lanthanide metal complexes for electroluminescent materials, Chemical Review, 102,2002, 2357.
- [4] T.Gunnlaugsson and F.Stomeo, Recent advances in the formation of luminescent lanthanide architectures and self-assemblies from structurally defined ligands, Organic & Biomolecular Chemistry, 5(13) ,2007 1999-2009
- [5] S. Comby and J-C.G.Bunzli, Lanthanide NIR luminescence in molecular probes & devices, in K.A.Gschneidner, J-C Bunzli, V.Pecharsk(Eds.), Handbook on Physics & Chemistry of Rare Earth, Volume 37, Chapter 235 (BV Amsterdam:Elsevier science,2007) 217-470.
- [6] H.Tsukube and S.Shinoda, Luminescent lanthanide complexes as analytical tools in anion sensing , pH-indication & protein recognition, Analyst, 136 (3),2011, 431-435.
- [7] E.G.Moore, A.P.S. Samuel and K.N. Raymond, From Antenna to Assay : Lessons learned in Lanthanide Luminescence, Accounts of Chemical Research., 42(4) 2009, 542-552.
- [8] A.N.Gusev, V.F.Shulgin, B.Svetlana et al, Structural and photophysical studies on ternary Sm (III), Nd (III), Yb (III) and Er (III) complexes containing pyridyltriazole ligands. Polyhedron., 47(1),2012, 37-45.
- [9] J.P Leonard and T.Gunnlangsson, Luminescent Eu(III), and Tb(III) complexes: Developing Lanthanide Luminescent-Based devices. Journal of Fluorescence, 15(4) ,2005, 585-595.
- [10] F. Xue, Y. Ma, L. Fu, R. Hao et al, A Europium complex with enhanced long-wavelength sensitized luminescent properties. Physical Chemistry Chemical Physics, 12 (13),2010, 3195-3202
- [11] I.I.C. S.Stan, C. Peptu & N. Marofle, Photoluminescent properties of Novel Y (III), Sm (III), Eu (III), Gd (III) and Tb (III) complexes with 2-(1 H-1,2,4-Triazol-3-4l) pyridine, Inorganica Chimica Acta, 429,2015, 160.
- [12] A.P.Pushkarev, N.N.Yablonsky & PA Yanin, Features of Spectral properties of Sm^{+3} complexes with dithia and diseleno phosphinate ligands.; Spectrochimica Acta Part A: Molecular & Biomolecular Spectroscopy., 163,2016,134-139.
- [13] W.T.Carnall, P.R Fields & B.G.Wybourne, Spectral intensities of the trivalent lanthanide and actinides in solution-I- Pr^{+3} , Nd^{+3} , Er^{+3} , Tm^{+3} and Yb^{+3} , Journal of Chemical Physics, 42 (11),1965, 3797-3806.

- [14] W.T.Carnall, P.R Fields & K.Rajnak,(a)Spectral intensities of the trivalent lanthanide & actinides in solution-II,Pm⁺³, Sm⁺³, Eu⁺³, Gd⁺³, Tb⁺³, Dy⁺³ & Ho⁺³, Journal of Chemical Physics,49(11),1968,4412.(b) Electronic energy level of the trivalent lanthanide & aquo ions -I: Pr⁺³, Nd⁺³, Pm⁺³, Sm⁺³, Dy⁺³, Ho⁺³, Er⁺³ & Tm⁺³. Journal of Chemical Physics,49 (10),1968. 4424.(c) Electronic energy levels of the trivalent lanthanide aquo ions-II.Gd⁺³,Journal of Chemical Physics,49 (1968) 4443.(d) Electronic energy levels of the trivalent lanthanide aquo ions-III.Tb⁺³,Journal of Chemical Physics,49(10),1968,4447.(e) Electronic energy levels of the trivalent lanthanide aquo ions-IV.Tb⁺³,Journal of Chemical Physics,49(10),1968,4450.
- [15] W.T.Carnall, Absorption & fluorescence Spectra of rare-earth ions in solution, in K.A.Gschneider Jr & L.Erying (Eds),Handbook on Physics & Chemistry of rare earth. Volume 3,(North Holland Pub.Co.Netherlands,1979), 171,
- [16] B.G.Wybourn, Spectroscopic properties of rare earths(New York,USA Interscience, 1965).
- [17] E.Y.Wong, (a) Taylor series expansion of intermediate coupling energy level of Nd⁺³ and Er⁺³, Journal of Chemical Physics, 35 (2), 1961, 544-546. (b) Configuration interaction of the Pr⁺³ ion., Journal of Chemical Physics, 38 (4),1963, 976.
- [18] S.P.Tandon and P.C.Mehta, Study of some Nd⁺³ complexes: "Interelectronic repulsion , spin-orbit interactions, Bonding & energy level, Journal of Chemical Physics, 52(9),1970,4896.
- [19] M.H.A Al-Amery, B.Al-Amery, M.K Abayati, I.Al-Abdaly,Synthesis, characterization & antibacterial activity of new complexes of some lanthanide ions with 15-Crown-5 and 18-Crown-6,The Oriental Journal of Chemistry,32(2)2016,1025-1028.
- [20] R.S.Verma, R.Gupta & G.K.Joshi,Calculation of Judd-Ofelt intensity (T) Parameters in some Er III doped system by using statistical methods,Journal of Indian Chemical Society, 79, 2002,802.
- [21] N.Yaiphaba,Comparative 4f-4f absorption spectral study for the interactions of Pr(III) with selected urea and thiourea: Energy and electric dipole intensity parameters, Journal of Chemical and Pharmaceutical Research, 5(10), 2013,377-385
- [22] K.Tandon, S.P Tandon, Kirti Mathur et al,Spectral and electrical studies of neodymium & erbium doped phosphate glasses,Indian Journal of.Pure and Applied . Physics, 21,1983,747.

Table –1:The values of Oscillator strength, Energies (in cm⁻¹) & peak values of the selected bands of Sm (III) complexes with Crown Ethers(CW):CE, CB or CD and Amino Acids(AA): AL, GY or AR

Crown ether (L ₁)	Amino acid (L ₂)	Wave-length Oscillator Strength Energy	Levels								R.M.S Deviation ± (σ _{r.m.s}) × 10 ⁶	Nephelauxetic ratio (β)	Covalence Parameter (b ^{1/2})	
			⁶ P _{7/2}	⁴ L _{15/2} , ⁴ K _{11/2}	⁶ F _{1/2} *	(⁶ P _{3/2} , ⁴ P) _{5/2}	⁴ G _{9/2}	⁴ I _{13/2}	⁴ M _{15/2} , ⁴ I _{11/2}	⁴ G _{7/2}				⁴ G _{5/2}
CE	β-Alanine	λ _{max} (nm)	379.0	392.2	407.2	421.2	446.5	468.2	480.2	500.2	555.0	1.310	0.974	0.107
		P _{exp} × 10 ⁶	2.372	1.182	4.411	1.311	0.631	0.620	1.067	0.521	0.411			
		P _{cal} × 10 ⁶	1.681	0.911	3.983	0.591	0.072	0.541	0.808	0.087	0.174			
		E _{exp} (cm ⁻¹)	28984	27549	26738	25574	24876	24097	22521	21551	20877			
	Glycine	λ _{max} (nm)	379.4	392.6	407.4	421.6	446.3	468.2	480.3	500.2	555.0	1.001	0.973	0.108
		P _{exp} × 10 ⁶	2.385	1.195	4.421	1.321	0.643	0.631	1.078	0.532	0.423			
		P _{cal} × 10 ⁶	1.690	0.923	4.013	0.607	0.081	0.553	0.823	0.091	0.182			
		E _{exp} (cm ⁻¹)	28985	27550	26739	25575	24877	24098	22522	21552	20878			
	L-Arginine	λ _{max} (nm)	379.2	392.1	407.1	421.1	446.4	468.3	480.2	500.2	555.0	0.988	0.974	0.107
		P _{exp} × 10 ⁶	2.321	1.132	4.370	1.261	0.582	0.571	1.013	0.471	0.366			
		P _{cal} × 10 ⁶	1.631	0.873	3.471	0.538	0.067	0.491	0.744	0.034	0.124			
		E _{exp} (cm ⁻¹)	28983	27548	26737	25573	24875	24096	22520	21550	20876			
CB	β-Alanine	λ _{max} (nm)	379.0	392.1	406.5	421.1	446.4	468.3	480.2	500.2	555.0	0.954	0.976	0.106
		P _{exp} × 10 ⁶	1.995	0.885	3.566	1.131	0.511	0.391	0.831	0.321	0.221			
		P _{cal} × 10 ⁶	1.440	0.755	3.299	0.505	0.059	0.390	0.630	0.074	0.015			
		E _{exp} (cm ⁻¹)	28968	27532	26722	25563	24864	24085	22512	21543	20867			
	Glycine	λ _{max} (nm)	379.4	392.4	406.6	421.4	446.8	468.6	480.5	500.4	555.4	1.021	0.975	0.106
		P _{exp} × 10 ⁶	2.014	0.893	3.573	1.141	0.522	0.403	0.841	0.333	0.233			
		P _{cal} × 10 ⁶	1.456	0.768	3.309	0.513	0.066	0.401	0.638	0.084	0.016			
		E _{exp} (cm ⁻¹)	28970	27534	26725	25565	24866	24087	22515	21545	20870			
	L-Arginine	λ _{max} (nm)	379.1	392.0	406.4	421.0	446.2	468.1	480.0	500.1	555.0	0.983	0.978	0.105
		P _{exp} × 10 ⁶	1.941	0.833	3.511	1.084	0.471	0.361	0.796	0.282	0.195			
		P _{cal} × 10 ⁶	1.390	0.711	3.241	0.441	0.048	0.380	0.581	0.054	0.012			
		E _{exp} (cm ⁻¹)	28966	27530	26720	25552	24860	24084	22512	21542	20865			
CD	β-Alanine	λ _{max} (nm)	375.3	388.4	405.6	416.7	442.4	464.4	476.2	496.2	551.3	0.528	0.981	0.104
		P _{exp} × 10 ⁶	1.750	0.751	3.113	0.873	0.361	0.331	0.733	0.275	0.171			
		P _{cal} × 10 ⁶	1.341	0.704	2.990	0.452	0.0598	0.371	0.578	0.119	0.551			
		E _{exp} (cm ⁻¹)	28964	27529	26720	25562	24862	24085	22513	21542	20868			
	Glycine	λ _{max} (nm)	375.4	388.5	405.8	416.8	442.6	464.5	476.3	496.3	551.4	0.713	0.979	0.105
		P _{exp} × 10 ⁶	1.760	0.769	3.123	0.889	0.371	0.341	0.744	0.285	0.181			
		P _{cal} × 10 ⁶	1.354	0.714	3.010	0.462	0.069	0.382	0.589	0.125	0.561			
		E _{exp} (cm ⁻¹)	28965	27530	26721	25563	24863	24086	22514	21543	20869			
	L-Arginine	λ _{max} (nm)	375.2	388.2	405.4	416.6	442.3	464.3	476.1	496.1	551.2	0.589	0.982	0.104
		P _{exp} × 10 ⁶	1.708	0.706	3.058	0.831	0.351	0.283	0.681	0.238	0.138			
		P _{cal} × 10 ⁶	1.309	0.652	2.943	0.401	0.0567	0.325	0.527	0.078	0.510			

Crown ether (L ₁)	Amino acid (L ₂)	Wave-length Oscillator Strength Energy	Levels							R.M.S Deviation $\pm (\sigma_{r.m.s}) \times 10^6$	Nephelauxetic ratio (β)	Covalence Parameter ($b^{1/2}$)	
			⁶ P _{7/2}	⁴ L _{15/2} , ⁴ K _{11/2}	⁶ F _{1/2} *	⁽⁶ P, ⁴ P) _{5/2}	⁴ G _{9/2}	⁴ I _{13/2}	⁴ M _{15/2} , ⁴ I _{11/2}				⁴ G _{7/2}
		<i>E_{exp}(cm⁻¹)</i>	28963	27528	26719	2556 ₁	24861	24084	22513	21542	20867		

Table- 2: Computed values of Judd-Ofelt Parameter (T_i) for Sm (III) complexes with Crown Ethers (CW):CE, CB or CD and Amino Acids(AA): AL, GY or AR

Crown ether (L ₁)	Amino acid (L ₂)	Parameters T _i × 10 ⁹			
		T ₂	T ₄	T ₆	T ₄ /T ₆
CE	AL	17.187	0.765	0.679	1.125
	GY	17.412	0.676	0.589	1.148
	AR	15.296	0.748	0.700	1.068
CB	AL	16.629	0.718	0.658	1.091
	GY	16.940	0.745	0.657	1.133
	AR	13.500	0.628	0.531	1.183
CD	AL	18.373	0.777	0.635	1.223
	GY	18.483	0.717	0.563	1.273
	AR	15.875	0.681	0.633	1.076

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