Influence Of Modifier Oxide On Spectroscopic Characteristics Of Neodymium Ion In Lithium Borate Glass System

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Abstract- Lithium borate glasses of composition 30Li2O-10MO-59B2O3:1Nd2O3 (MO= ZnO, CaO and CdO) were prepared by conventional melt quenching method. The amorphous nature of these glasses was confirmed by X-ray diffraction. Differential scanning calorimetry analysis revealed reasonably good forming tendency of the glass composition. FTIR spectra were used to analyze the presence of BO3 and BO4 functional groups in the glass. Optical absorption spectra of these glasses were investigated. Judd-Ofelt intensity parameters Ωi (λ=2,4,6) are evaluated from the intensities of various absorption bands of optical absorption spectra. The comparison of Ω2 parameter for the present three glasses shows the highest value for ZnBNd glass, indicating the highest covalent character of this glass.

Index Terms- FTIR spectra, Optical absorption, Judd–Ofelt parameters, Borate glasses, Neodymium ions.

1. INTRODUCTION

Among the conventional glass families, borate glasses have been known to be excellent host matrices for the rare earth [RE] oxides because of their good glass forming nature compared to several other conventional systems like phosphate, germanate, vanadate and tellurite glass families. Optical properties of rare-earth doped glasses are extensively studied for their potential applications in the fields of lasers, fluorescent display devices, optical detectors, waveguides and fibre amplifiers. There has been a considerable attention in the study on optical, structural and dielectric behavior of RE doped borate based glasses.

Boric acid (B2O3) is one of the good glass formers and can form glass alone with good transparency, high chemical durability, thermal stability and good rare-earth ion solubility. Among the three modifier oxides chosen to mix in the present glass system, viz., CaO, ZnO and CdO, ZnO is expected to shorten the time taken for solidification of glasses during the quenching process and glasses containing ZnO have high chemical stability and less thermal expansion. Their wide band gap, large exciton binding energy and intrinsic emitting property make them as promising candidates for the development of optoelectronic devices, solar energy concentrators, ultraviolet emitting lasers and gas sensors. ZnO imparts a unique combination of optical, electrical and magnetic properties when used in glass matrices like borate. It reduces the coefficient of thermal expansion, imparts high brilliance, luster and high stability against deformation under stress of the glass and makes the glasses nongyrophotonic and nontoxic. Both ZnO and CdO are thermally stable and appreciably covalent in character. Resistance to the moisture of these glasses is expected to increase by addition of the alkaline-earth oxide CaO into these glass matrices. The glasses mixed with Li2O as network modifier was seen as moisture resistant, highly stable, and bubble free, is suitable for a good systematic optical analysis.

Neodymium ion doped glasses have attracted much attention mainly due to their advantages such as excellent mechanical and thermal stability, large solubility of rare earth ions, good capacity of glass configuration, low cost. In the present work, the trivalent Neodymium ion (Nd3+) has been chosen which has 4f electronic configuration with 4I13/2 ground state. The transition 4I13/2→2F7/2 of Nd3+ ion in the absorption spectra is a characteristic of coordination of this ion. The effective coordination of this ion is found to be varying between 8 and 9 with the variations in the transition energy from 23,200-23,400 cm−1. The J-O theory works very well for this ion and the radiative parameters can therefore be conveniently evaluated from J-O parameters.

Recently, the optical properties of Nd3+ doped bismuth zinc borate glasses were reported by Shanmugavelu et al. Spectroscopic properties of Nd3+ doped borate glasses were reported by Vijaya Kumar et al. Recently, the optical and structural investigation of Eu3+ ions in Nd3+ co-doped magnesium lead borosilicate glasses.
Further, owing to the commercial importance of Nd$^{3+}$ doped glass lasers, many studies on optical properties and the structural role of Nd$^{3+}$ ions and its interaction with the other ions in the different glass matrices have been carried out$^{26-28}$. Due to the increasing academic and technological importance of neodymium ion and the advantages of above research, the Nd$_2$O$_3$ doped Li$_2$O-MO-B$_2$O$_3$ (MO=ZnO, CaO and CdO) glasses have been prepared and investigated. The present study i) determines the J–O intensity parameters for trivalent neodymium ions, ii) studies the luminescence efficiencies with the aid of IR spectra data.

2. MATERIAL AND METHODS

2.1 Glass Preparation

Undoped and following Nd$^{3+}$ ion doped glasses are prepared by using standard melting and quenching techniques and used for the present study.$^{29-31}$

ZnBNd : 30 Li$_2$O-10 ZnO-59 B$_2$O$_3$:1Nd$_2$O$_3$,
CaBNd : 30 Li$_2$O-10 CaO-59 B$_2$O$_3$:1Nd$_2$O$_3$ and
CdBNd : 30 Li$_2$O-10 CdO-59 B$_2$O$_3$:Nd$_2$O$_3$.

Appropriate amounts of raw materials ZnO, CaCO$_3$, CdO, H$_2$BO$_3$, Li$_2$CO$_3$ and Nd$_2$O$_3$ (all in mole %) were thoroughly mixed and grounded in an agate mortar and melted in a platinum crucible. The high purity (99.9%) chemicals were used in this work. All these chemicals with the said compositions were heated in a PID temperature controlled furnace at 450°C for 2 hour for the decorbonization from CaCO$_3$ and Li$_2$CO$_3$ and then the temperature maintained within the range 1000-1050 °C and kept the melt at this temperature for an hour till a bubble free liquid was formed. For the homogeneous mixing of all the constituents the crucibles were shaken frequently. The resultant melt was poured on a rectangular brass mould held at room temperature. The samples were subsequently annealed at glass transition temperature in another furnace to remove mechanical stress and were polished. Bubble free and optically transparent glasses were selected for optical studies.

2.2. Differential Scanning Calorimetry

Differential scanning calorimetry (DSC) traces of these glasses were recorded using universal V23C TA differential scanning calorimeter with a programmed heating rate of 15°C per minute in the temperature range 30-750°C and the glass transition temperatures $T_g$ and crystallization temperature $T_c$ of these glasses were determined (to an accuracy of ± 1°C).

2.3 Optical Absorption And IR Spectra

The optical absorption spectra of the glasses were recorded using Shimadzu-3100 UV-VIS-NIR Spectrophotometer in the wavelength range 300-900 nm at room temperature. Infrared transmission spectra for these glasses were recorded using a Perkin Elmer Spectrometer by KBr pellet method in the wavenumber range 400-4000 cm$^{-1}$.

3. RESULTS AND DISCUSSION

3.1 Characterization

The existence of glass transition temperature $T_g$ and crystallization temperature $T_c$ in differential scanning calorimetry (DSC) study curves and absence of peaks in X-ray diffraction pattern indicate that the glasses prepared were of high quality glasses.

Fig.1 shows the differential scanning calorimetry traces of three glasses. All the glasses exhibit an endothermic change between 533°C and 548.3°C, which is attributed to the glass transition temperature $T_g$. At still higher temperature, $T_c$ an exothermic peak due to the crystal growth followed by another endothermic effect at temperature $T_m$ due to the re-melting of the glass are also observed. The appearance of single peak due to the glass transition temperature in DSC pattern of all the glasses indicates the high homogeneity of the glasses prepared. From the measured values of $T_g$, $T_c$ and $T_m$, the parameters, $T_d/T_m$, $(T_c-T_g)/T_c$, $(T_c-T_g)/T_m$ and glass forming ability parameter known as Hruby's parameter $K_{gl} = (T_c-T_g)/(T_m-T_c)$, are evaluated and presented in Table 1. The highest values of these parameters are obtained for ZnO-modifier glass (ZnBNd) indicating it's relatively high glass forming ability among the three glasses.

<table>
<thead>
<tr>
<th>Glass</th>
<th>$T_g$ (°C)</th>
<th>$T_c$ (°C)</th>
<th>$T_m$ (°C)</th>
<th>$T_d/T_m$</th>
<th>$(T_c-T_g)/T_c$</th>
<th>$(T_c-T_g)/T_m$</th>
<th>$K_{gl}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZnBNd</td>
<td>548.3</td>
<td>629</td>
<td>685.2</td>
<td>0.800</td>
<td>80.7</td>
<td>0.118</td>
<td>1.436</td>
</tr>
<tr>
<td>CaBNd</td>
<td>538.6</td>
<td>615</td>
<td>678</td>
<td>0.794</td>
<td>76.4</td>
<td>0.113</td>
<td>1.213</td>
</tr>
<tr>
<td>CdBNd</td>
<td>533.0</td>
<td>608.5</td>
<td>675</td>
<td>0.786</td>
<td>75.5</td>
<td>0.111</td>
<td>1.086</td>
</tr>
</tbody>
</table>
3.2 Optical Absorption Spectra

The optical absorption spectra recorded at room temperature for Nd³⁺ doped glasses have exhibited the following absorption bands and Fig. 2. shows the absorption spectra of Nd³⁺ ion in Li₂O-ZnO-B₂O₃ glasses.

\[ ^{4}I_{9/2} \rightarrow ^{4}F_{5/2}, ^{4}F_{7/2}, ^{4}F_{9/2}, ^{4}G_{5/2}, ^{4}G_{7/2}, ^{4}G_{9/2}, ^{4}G_{11/2}, ^{5}P_{1/2} \text{ and } ^{5}D_{5/2} \]

All above transitions are based on the assignments of lanthanide spectra reported by Carnall et al. The Judd-Ofelt theory is used to characterize the spectral intensities of the absorption bands in these glasses. The best fit Judd-Ofelt intensity parameters \( \Omega \) and the oscillator strengths of Nd³⁺ doped Li₂O-MO-B₂O₃ glasses are presented in Table 2. From these absorption spectral profiles, it is observed that a particular transition \( ^{4}I_{9/2} \rightarrow ^{4}G_{5/2} \) is more intense than any other transition. This is obviously because of better validity of the selection rules: \( \Delta J < 2, \Delta L < 2 \text{ and } \Delta S = 0 \). For this transition, the magnitude of \( ||\text{U}||^2 \) of this level is also considered as an important value for the hypersensitivity nature of this level.

In solid state laser hosts there is a shielding of the 4f electrons of the rare-earth ions and this shielding allow these rare-earth ions to serve as active centres. These ions exhibit sharp absorption and...
luminescence transitions as surrounding ligand atoms weakly perturb them. The spectral intensities for the observed bands of these glasses that are often expressed in terms of oscillator strength of forced electronic dipole transitions have been analyzed with the help of Judd-Ofelt theory

\[
f_{\text{cal}} = \frac{8\pi^2 m v (n_d^2 + 2)^2}{3h(2J+1)} \sum_{\lambda} \int \alpha_{\lambda} \left( \psi_j \right)^2 \left( \psi_f \right)^2 d\lambda
\]

where \((2J+1)\) is the multiplicity of the lower states, \((n_d^2 + 2)/n_d\) is a factor for the effective field at the well-localized centre in a medium of isotropic refractive index, \(m\) is the mass of electron, \(c\) is the velocity of light in vacuum, \(h\) is the Planck’s constant, \(n_d\) is the refractive index of glass, \(v\) is the frequency of the \(\psi_j \rightarrow \psi_f\) transition, \(\Omega_\lambda (\lambda=2, 4, 6)\) are the J-O intensity parameters and \(\left\| \Omega^2 \right\|^2\) are the doubly reduced matrix elements of the unit tensor operator of the rank \(\lambda = 2, 4\) and 6 which are calculated from the intermediate coupling approximation for a transition \(\psi_j \rightarrow \psi_f\).

Experimental values of oscillator strengths were evaluated from the expression:

\[
f_{\text{exp}} = 2.302 \left( \frac{mc^2}{\hbar^2} \right) \int \epsilon(\nu) d\nu = 4.318 \times \int \epsilon(\nu) d\nu
\]

where \(N_A\) is the Avogadro’s number and \(\epsilon(\nu)\) is the molar absorption coefficient. There is a reasonable agreement between the experimental and calculated values of oscillator strengths (Table 2).

### Table 2 Measured \(f_{\text{exp}}\) (10\(^{-6}\)) and calculated \(f_{\text{cal}}\) (10\(^{-6}\)) oscillator strengths of Nd\(^{3+}\) doped Li\(_2\)O-MO-B\(_2\)O\(_3\) glasses.

<table>
<thead>
<tr>
<th>Transition from (^1\Omega_g)</th>
<th>ZnBNd (f_{\text{exp}})</th>
<th>CaBNd (f_{\text{exp}})</th>
<th>CdBNd (f_{\text{exp}})</th>
<th>ZnBNd (f_{\text{cal}})</th>
<th>CaBNd (f_{\text{cal}})</th>
<th>CdBNd (f_{\text{cal}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^4)F(_{3/2})</td>
<td>2.21</td>
<td>1.41</td>
<td>2.98</td>
<td>1.90</td>
<td>2.78</td>
<td>1.42</td>
</tr>
<tr>
<td>(^4)F(_{5/2})</td>
<td>2.44</td>
<td>3.25</td>
<td>2.65</td>
<td>3.50</td>
<td>2.56</td>
<td>3.01</td>
</tr>
<tr>
<td>(^4)F(_{7/2})</td>
<td>2.52</td>
<td>1.25</td>
<td>2.74</td>
<td>1.05</td>
<td>2.61</td>
<td>1.06</td>
</tr>
<tr>
<td>(^4)F(_{9/2})</td>
<td>0.42</td>
<td>0.31</td>
<td>0.46</td>
<td>0.29</td>
<td>0.45</td>
<td>0.27</td>
</tr>
<tr>
<td>(^4)G(_{5/2})</td>
<td>1.49</td>
<td>9.73</td>
<td>1.77</td>
<td>10.58</td>
<td>1.65</td>
<td>8.94</td>
</tr>
<tr>
<td>(^4)G(_{7/2})</td>
<td>1.85</td>
<td>2.17</td>
<td>2.67</td>
<td>2.37</td>
<td>2.37</td>
<td>2.11</td>
</tr>
<tr>
<td>(^4)G(_{9/2})</td>
<td>1.49</td>
<td>0.87</td>
<td>1.75</td>
<td>1.06</td>
<td>1.03</td>
<td>0.84</td>
</tr>
<tr>
<td>(^4)G(_{11/2})</td>
<td>0.09</td>
<td>0.12</td>
<td>0.10</td>
<td>0.13</td>
<td>0.09</td>
<td>0.11</td>
</tr>
<tr>
<td>(^2)P(_{3/2})</td>
<td>0.26</td>
<td>0.95</td>
<td>2.36</td>
<td>2.01</td>
<td>1.02</td>
<td>2.56</td>
</tr>
</tbody>
</table>

r.m.s deviation ±1.0540 ±1.1168 ±0.9445

Similar trends are observed in the intensities of transitions found in all the three glasses. The r.m.s deviations of oscillator strengths of experimental and calculated values are presented in Table 2. The observed relatively small values of these deviations confirm the validity and applicability of Judd-Ofelt theory for the present glasses.

The Judd-Ofelt parameters \(\Omega_2\), \(\Omega_4\) and \(\Omega_6\) are computed by the least square fitting analysis of the experimental oscillator strengths using matrix elements\(^{32}\) and spectroscopic quality factor (SQF) are presented in Table 3. The values of \(\Omega_4\) show the following order for all the three glasses: \(\Omega_4 > \Omega_2 > \Omega_6\). The comparison of J-O parameters shows the highest value of \(\Omega_4\) for ZnBNd glasses. The bonding parameter, \(\delta'\)\(^{36,37}\) is also calculated for all the three glasses. The computation shows the highest \(\delta'\) value for ZnBNd glass.

### Table 3 Judd-Ofelt parameters \(\Omega_\lambda\) (10\(^{-20}\) cm\(^3\)), spectroscopic quality factor and the bonding parameter \(\delta'\) of Nd\(^{3+}\) ions doped Li\(_2\)O-MO-B\(_2\)O\(_3\) glasses.

<table>
<thead>
<tr>
<th>Glass</th>
<th>(\Omega_2)</th>
<th>(\Omega_4)</th>
<th>(\Omega_6)</th>
<th>SQF ((\Omega_4/\Omega_6))</th>
<th>(\delta')</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZnBNd</td>
<td>4.47</td>
<td>4.82</td>
<td>4.24</td>
<td>1.14</td>
<td>0.4809</td>
</tr>
<tr>
<td>CaBNd</td>
<td>4.16</td>
<td>7.05</td>
<td>3.54</td>
<td>1.99</td>
<td>0.4357</td>
</tr>
<tr>
<td>CdBNd</td>
<td>3.87</td>
<td>5.01</td>
<td>3.60</td>
<td>1.39</td>
<td>0.4136</td>
</tr>
</tbody>
</table>

The parameter \(\Omega_2\) is related to the covalency and structural changes in the vicinity of the Nd\(^{3+}\) ion (short-range effect) and \(\Omega_4\) and \(\Omega_6\) are related to the long-range effects. Reported values of \(\Omega_\lambda\) parameters of for Nd\(^{3+}\) ions doped glasses in the present glasses and in number of other glass systems are also presented in Table 4 for comparison. The comparison of \(\Omega_2\) parameter for the present three glasses shows the highest value for ZnBNd glass, indicating the highest covalent character of this glass. The larger modifier ion (Cd\(^{2+}\) ionic radius, 1.03 Å) give rise to a large average distance between the BO\(_4\) chains which results in the average Nd-O distance to increase, therefore producing a weaker field around the Nd\(^{3+}\) ion leading to a low value of \(\Omega_2\) when compared with that of CaBNd (Ca\(^{2+}\) ionic
radius, 0.99 Å) and ZnBNd (Zn$^{3+}$ ionic radius, 0.74 Å). A similar conclusion can also be drawn from the values of $\Omega_6$, which is related to the rigidity of the host$^{45}$. Further support for this argument can also be cited from the value of the bonding parameter $\delta'$, the value of $\delta'$ for these glasses follows the order CdBNd$<$CaBNd$<$ZnBNd indicating the high covalent environment for Nd$^{3+}$ ions in ZnBNd glasses.

<table>
<thead>
<tr>
<th>Glass type</th>
<th>Ref.</th>
<th>$\Omega_2$</th>
<th>$\Omega_4$</th>
<th>$\Omega_6$</th>
<th>$\Omega_4/\Omega_6$</th>
<th>Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZnBNd</td>
<td>Present work</td>
<td>4.47</td>
<td>4.82</td>
<td>4.24</td>
<td>1.14</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>CaBNd</td>
<td>Present work</td>
<td>4.16</td>
<td>7.05</td>
<td>3.54</td>
<td>1.19</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>CdBNd</td>
<td>Present work</td>
<td>3.87</td>
<td>5.01</td>
<td>3.60</td>
<td>1.19</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>CaLiBO</td>
<td>[38]</td>
<td>7.85</td>
<td>6.75</td>
<td>7.61</td>
<td>0.89</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>SrLiBO</td>
<td>[38]</td>
<td>6.52</td>
<td>5.00</td>
<td>6.16</td>
<td>0.81</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
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<tr>
<td>25 Bi$_2$O$_3$-25PbO-49 B$_2$O$_3$</td>
<td>[39]</td>
<td>1.577</td>
<td>4.483</td>
<td>3.333</td>
<td>1.35</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>97 [30 Bi$_2$O$_3$ : 70B$_2$O$_3$]</td>
<td>[39]</td>
<td>4.646</td>
<td>2.898</td>
<td>5.854</td>
<td>0.50</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>33.3ZnO-66.6TeO$_2$</td>
<td>[40]</td>
<td>4.24</td>
<td>0.88</td>
<td>7.05</td>
<td>0.12</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>BZBNd10</td>
<td>[21]</td>
<td>2.67</td>
<td>3.31</td>
<td>3.98</td>
<td>0.83</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>BINLAB5</td>
<td>[22]</td>
<td>1.30</td>
<td>4.09</td>
<td>5.23</td>
<td>0.78</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>GeO2-PbO-Bi2O3</td>
<td>[41]</td>
<td>2.95</td>
<td>5.01</td>
<td>3.93</td>
<td>1.27</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>LGBNd</td>
<td>[42]</td>
<td>4.84</td>
<td>5.97</td>
<td>4.59</td>
<td>1.30</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>NGBNd</td>
<td>[42]</td>
<td>5.75</td>
<td>3.44</td>
<td>3.73</td>
<td>0.92</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>TZN10</td>
<td>[43]</td>
<td>3.80</td>
<td>4.94</td>
<td>4.54</td>
<td>1.09</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
<tr>
<td>TLF</td>
<td>[44]</td>
<td>5.61</td>
<td>4.17</td>
<td>5.44</td>
<td>0.77</td>
<td>$\Omega_4 &gt; \Omega_2 &gt; \Omega_6$</td>
</tr>
</tbody>
</table>

### 3.3 Infrared Spectroscopy

Fig. 3 represents infrared transmission (IR) spectra of the pure as well as Nd$^{3+}$ doped Li$_2$O-ZnO-B$_2$O$_3$ glasses. The infrared transmission spectra of Nd$^{3+}$ doped glasses exhibit three groups of bands: (i) in the region 1320-1360 cm$^{-1}$, (ii) in the region 960-1020 cm$^{-1}$ and (iii) a band at about 710 cm$^{-1}$. It is well known that the effect of introduction of alkali oxides into B$_2$O$_3$ glass is the conversion of sp$^3$ planar BO$_3$ units into more stable sp$^2$ tetrahedral BO$_4$ units and may also create non-bridging oxygens. Each BO$_4$ unit is linked to two such other units and one oxygen from each unit with a rare earth ion and the structure leads to the formation of long tetrahedron chains. The second group of bands is attributed to such BO$_4$ units where as the first group of bands is identified as due to the stretching relaxation of the B-O bond of the trigonal BO$_3$ units and the band at 710 cm$^{-1}$ is due to the bending vibrations of B-O-B linkages in the borate network$^{46-49}$. The weak band observed around 456 cm$^{-1}$ is an indicative of the presence of ZnO$_4$ units in the zinc borate glass network$^{50,51}$.

When the glasses are doped with Nd$_2$O$_3$, the intensity of the second group of bands (band due to the trigonal BO$_3$ units) is found to increase at the expense of first group of bands (bands due to tetrahedral BO$_4$ units) with the increase of atomic number of rare earth ions with the shifting of meta-centres of first and second group of bands, respectively towards slightly lower and higher wave number for all the three series of glasses. No significant change in position and intensity of the other bands is observed in the spectra of all the three series of the glasses by introducing the Nd$^{3+}$ ion. The summary of the data on the positions of various bands in the IR spectra of Nd$^{3+}$ doped Li$_2$O-MO-B$_2$O$_3$ glasses are presented in Table 5.

<table>
<thead>
<tr>
<th>Glass type</th>
<th>Band due to B-O bond stretching in BO$_3$ units</th>
<th>Band due to B-O bond stretching in BO$_4$ units</th>
<th>Band due to B-O-B linkage in borate network</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZnBNd</td>
<td>1360</td>
<td>963</td>
<td>710</td>
</tr>
<tr>
<td>CaBNd</td>
<td>1336</td>
<td>992</td>
<td>710</td>
</tr>
<tr>
<td>CdBNd</td>
<td>1323</td>
<td>1019</td>
<td>710</td>
</tr>
</tbody>
</table>
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