Paramagnetic Properties of Some Ternary Rare Earth Compounds

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Magnetic susceptibility, Lattice constants, Rare earth ferrites

Some paramagnetic properties are given for a number of ternary rare earth compounds isomorphous with Sr2EuFeO5. Temperature variation of magnetic susceptibility obeys the Curie-Weiss law with exceptions for europium and samarium. Magnetic moments exhibited are close to that theoretically expected for the free ion except for europium whose value is a little higher.

Introduction

In our recent paper1 we reported on the series of the compounds with chemical formula Sr2RE(Al,Fe)O5 where RE represents rare earth element.

This work is concerned with the similar series of the chemical composition Sr2REGaO5 with RE (Pr, Nd, Sm, Eu, Gd). Attempts to prepare phases with heavier rare earth elements failed probably because these ions are too small to stabilize this type of structure.

This group of compounds has similar structural and magnetic properties as Sr2AlREO5 compounds. They are tetragonal most probably with 4I/mmm space group2. Their magnetic properties are similar to the Sr2AlREO5 compounds concerning paramagnetic behavior due to localized electrons.

Experimental

In order to prepare the Sr2GaREO5 compounds, equimolar amounts of SrCO3, RE2O3 and Ga2O3 were homogenized, pressed in pellets and fired at 1400 °C for 6 h in air. To ensure homogeneity, fired samples were crushed, mixed, repressed and fired again several times. Equilibrium was considered to have been attained when X-ray diffraction patterns of successively heated samples showed no further change. The microstructures of samples were examined in order to confirm purity of phases.

A diffractometer using Ni filtered CuKa radiation was used to obtain structural data. The diffraction data of the compounds were indexed on the basis of Sr2EuFeO5 pattern1. Lattice parameters were refined by the least square method. Magnetic susceptibility measurements of powdered polycrystalline samples were carried out using Faraday method equipped with a Cahn RG Electrobalance over the temperature 80-300 °K. The instrument was calibrated with mercury(II)-thiocyanato-cobaltate(II).

The measurements and temperature control were very similar to those described by Danley and Mulay3. Each susceptibility value at one temperature point was taken as an average obtained by measurements at five magnetic fields.

Results and Discussion

Lattice parameters of the studied compounds are similar to the previously reported tetragonal group of compounds1'2, with slightly larger parameters due to Al3+ replaced by larger Ga3+ ions. Lattice parameters are given in Table I.

Table I. Lattice parameters of some rare earth compounds.

<table>
<thead>
<tr>
<th>Compound</th>
<th>a [Å]</th>
<th>b [Å]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sr2PrGaO5</td>
<td>6.8347</td>
<td>11.2235</td>
</tr>
<tr>
<td>Sr2NdGaO5</td>
<td>6.8183</td>
<td>11.2148</td>
</tr>
<tr>
<td>Sr2SmGaO5</td>
<td>6.7931</td>
<td>11.1764</td>
</tr>
<tr>
<td>Sr2EuGaO5</td>
<td>6.7504</td>
<td>11.1292</td>
</tr>
<tr>
<td>Sr2GdGaO5</td>
<td>6.7470</td>
<td>11.1108</td>
</tr>
</tbody>
</table>

The studied rare earth compounds exhibited normal paramagnetic behavior in the measured temperature range. Curie-Weiss behavior was
observed with effective moments in agreement with that expected \([gJ\beta \sqrt{J(J+1)}]\) for free three positive ions with a positive Weiss constants \(\theta\) (Table II).

Table II. Curie-Weiss behaviour of some rare earth compounds.

<table>
<thead>
<tr>
<th>Compound</th>
<th>(C)</th>
<th>(\theta)</th>
<th>(\mu_{\text{exp}})</th>
<th>(\mu_{\text{calc}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{Sr}_2\text{PrGaO}_5)</td>
<td>1.63</td>
<td>46.8</td>
<td>3.61</td>
<td>3.58</td>
</tr>
<tr>
<td>(\text{Sr}_2\text{NdGaO}_5)</td>
<td>1.71</td>
<td>51.3</td>
<td>3.69</td>
<td>3.62</td>
</tr>
<tr>
<td>(\text{Sr}_2\text{SmGaO}_5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\text{Sr}_2\text{EuGaO}_5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\text{Sr}_2\text{GdGaO}_5)</td>
<td>8.00</td>
<td>5.2</td>
<td>8.05</td>
<td>7.94</td>
</tr>
</tbody>
</table>

The well-known exceptions to this behavior are trivalent samarium and europium ions. The susceptibility of both ions can be described according to the Van Vleck\(^4\) theory for closely spaced multiplets. Taking measured values\(^5,6\) for the energy positions of the lowest laying multiplets the magnetic susceptibility of these ions may be calculated using expression

\[
N\sum \left\{ \frac{[gJ^2\beta^2J(J+1)/3kT] + a_J}{J} \right\} (2J+1) \exp \left( -\frac{W_J^0 kT}{J} \right)
\]

\[
= \frac{\sum (2J+1) \exp \left( -\frac{W_J^0 kT}{J} \right)}{J}
\]

where

\[
a_J = \frac{\beta^2}{6(2J+1)} \left[ \frac{F(J+1)}{W(J+1;J)} \right] - \frac{F(J)}{W(J;J-1)}
\]

and

\[
F(J) = \frac{1}{2} [(S+L+1)^2 - J^2][J^2(S-L)^2]
\]

Measured results and those calculated from expression (1) are represented on Figs. 1 and 2. The agreement is seen to be quite good for Sm\(^3+\) whereas for Eu\(^3+\) the measured values are higher than calculated.

It seems that europium in this type of compounds cannot be treated as essentially ionic and cannot be characterized by an absence of covalent or cooperative effects\(^6\). In fact the same behavior could be observed in \(\text{Sr}_2\text{AlEuO}_5\).\(^1\)

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