1 Introduction

Lithium and its compounds as national strategic resources are extensively used in national defense, industrial and agricultural production. As we know, the salt lakes in the western of China are famous for its high concentration of lithium and borate that provide sufficient raw materials for the exploitation and utilization of lithium resources. Therefore, it is of great significance to study the thermodynamic properties of lithium borate system for optimizing the process on separation and production of lithium-borate containing brines.

So far, research interest has been raised on lithium borates due to its special properties. There are many kinds of hydrous or anhydrous lithium borates from ternary system (Li₂O - B₂O₃ - H₂O) such as metaborate, tetraborate, pentaborate found in the laboratory or nature fields. Li et al. successfully synthesized LiBO₂·xH₂O (x=2, 8), Li₂B₄O₇·3H₂O, Li₃B₅O₈·5H₂O, Li₃B₅O₈(OH)₂ (I, II) and Li₄[B₈O₁₃(OH)₂]·3H₂O in the laboratory (Li, 1998; Li, 2010; Li, 2012), and determined the enthalpies of solution of the hydrated lithium borates in approximately 1 mol·dm⁻³ aqueous hydrochloric acid at T=298.15 K by calorimetric method. Combined with the standard molar enthalpies of formation of LiCl·H₂O(s), H₃BO₃(s) and H₂O (l), the standard molar enthalpies of formation of hydrated lithium borates were obtained and shown in Table 1. According to the structural types of hydrated borates (Bassett, 1976; Mattigod, 1983), the standard molar enthalpies of formation of hydrated lithium borates were divided into three parts, the cations in aqueous, borate polyanions, liquid water. The unknown standard molar enthalpies of formation of hydrated lithium borates could be estimated by this way when the structures are known. Furthermore, the standard molar entropies of formation and the standard molar Gibbs free energy of formation of the lithium borates were also obtained by group contribution method in the Table 1.

In addition, the thermodynamic properties of lithium borates in aqueous solution systems had been widely reported in the literature. Yin et al. (2005) determined the enthalpies of dilution for aqueous Li₂B₄O₇ solutions from the concentration range from 0.0212 to 2.153 mol·kg⁻¹ at T=298.15 K by calorimetric method. The relative molar enthalpies and relative partial molar enthalpies of the solvent and solute were also obtained by the experiment data. For the aqueous Li₂B₄O₇ solution, Zhang et al. (2006) measured the molar heat capacities with the concentration of 0.3492 mol·kg⁻¹ in the temperature range from 80 K to 356 K by an adiabatic calorimeter. For the quaternary system (Li₂B₄O₇ + MgCl₂ + H₂O), Zhang et al. (2004) measured the isopiestic molalities and the water activities, and then calculate the water vapor pressures and the osmotic coefficients of the lithium containing system in the ion-strength range from 0.0581 mol·kg⁻¹ to 0.6320 mol·kg⁻¹ at T=298.15 K by isopiestic method. For the aqueous Li₂B₄O₇+ solution, Zhang et al. (2006) measured the molar heat capacities with the concentration of 0.3492 mol·kg⁻¹ in the temperature range from 80 K to 356 K by an adiabatic calorimeter.

2 Conclusions

In the paper, the thermodynamic properties including

<table>
<thead>
<tr>
<th>Borate</th>
<th>ΔH_m/(kJ·mol⁻¹)</th>
<th>ΔG_m/(kJ·mol⁻¹)</th>
<th>ΔS_m/(J·K⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiBO₂·H₂O</td>
<td>-1627.46 ± 0.90</td>
<td>-1453.17</td>
<td>-584.57</td>
</tr>
<tr>
<td>LiBO₂·8H₂O</td>
<td>-3397.00 ± 0.94</td>
<td>-2876.85</td>
<td>-1744.59</td>
</tr>
<tr>
<td>Li₂B₄O₇·3H₂O</td>
<td>-4290.86 ± 3.31</td>
<td>-3619.25</td>
<td>-1744.59</td>
</tr>
<tr>
<td>LiB₅O₈·5H₂O</td>
<td>-5130.25 ± 4.05</td>
<td>-4558.85</td>
<td>-1744.59</td>
</tr>
<tr>
<td>Li₃B₅O₈(OH)₂(I)</td>
<td>-4724.1 ± 4.2</td>
<td>NG</td>
<td>NG</td>
</tr>
<tr>
<td>Li₃B₅O₈(OH)₂(II)</td>
<td>-4723.8 ± 4.2</td>
<td>NG</td>
<td>NG</td>
</tr>
<tr>
<td>Li₄[B₈O₁₃(OH)₂]·3H₂O</td>
<td>-7953.8 ± 6.6</td>
<td>NG</td>
<td>NG</td>
</tr>
</tbody>
</table>

Note: “NG” represents for “not give”.

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the standard molar enthalpies of formation, the standard molar entropies of formation and the standard molar Gibbs free energy of formation of hydrated lithium borates and the enthalpy of dilution, the molar heat capacity of aqueous lithium borate solution systems were reviewed and the new trend in the future was also pointed out.

**Keywords:** thermodynamic properties, lithium borates, standard molar enthalpy, entropy, Gibbs energy

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**References**