EXPERIMENTAL STUDY OF THE THERMAL CONDUCTIVITY OF LITHIUM VAPOR

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The thermal conductivity of lithium vapor is measured. Equations are derived for calculation of the effective thermal conductivity and its components over a wide range of temperature and pressure.

In recent years lithium has become an important material in a number of technological fields. It is used in atomic energy devices and in space vehicle construction. This has stimulated interest in the thermophysical properties of lithium vapor.

In the case of alkali metal vapors, divergence has been found between experimental and calculated data (increasing from cesium to sodium) for both the atomic component of thermal conductivity and the effect of the dimerization reaction.

Until the present, experimental data on the thermal conductivity of lithium vapor has been absent from the literature, because experiments with lithium involve serious technological problems, due to the element's high boiling point and reactivity.

The thermal conductivity of lithium vapor was studied by the coaxial cylinder method, used previously for other alkali metals. However, because of the unique features of lithium and the higher temperature interval involved, the construction of the apparatus was changed. The measurement cell was connected to an evaporator. All of its components were formed of niobium alloys with high corrosion resistance to alkali metal vapors. Measurements were performed with two different gaps between the cylinders - 0.20 and 0.66 mm (Table 1).

Vapor was supplied to the intercylinder gap by two tubes from the evaporator.

The vapor pressure was determined from the saturated vapor elasticity curve [1] with thermocouples installed in the evaporator:

\[ \lg P_v = 1.01325 \cdot 10^8 \left[ 8.5088 \frac{-8363}{T} - 1.02573 \lg T - 1.3091 \cdot 10^{-6} T + 1.08872 \exp \left( \frac{-2940}{T} \right) \right] \]  \hspace{1cm} (1)

The measurement cell was placed within a thermostatic chamber. The internal volume of the thermostat was filled with high purity argon at a pressure of about \(1 \cdot 10^5\) Pa to prevent oxidation of the niobium components. The argon also served as a heat-transport medium, decreasing the contact thermal resistance of the thermocouples. A detailed diagram of the apparatus and description of the construction were presented previously in [2].

To monitor the operation of the device the thermal conductivities of inert gases were measured. Thermal conductivity values for argon and neon, measured before and after experiments with lithium, agreed well with each other. This indicated normal operation of the equipment.

Using data from the inert gas experiments, the contact thermal resistance \(\Delta T_C\) was determined as a function of thermal flux liberated by the internal heater, and corrections were determined for the temperature head at the point of thermocouple attachment to the cylinder.
TABLE 1. Geometric Dimensions of Measurement Cylinders

| Quantity measured, mm | Device  
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Inner diam. of outer cylinder</td>
<td>12.10</td>
</tr>
<tr>
<td>Outer diam. of inner cylinder</td>
<td>11.70</td>
</tr>
<tr>
<td>Intercylinder gap</td>
<td>0.20</td>
</tr>
<tr>
<td>Length of active section</td>
<td>83.0</td>
</tr>
<tr>
<td>Cylinder length</td>
<td>200</td>
</tr>
<tr>
<td>Cylinder wall thickness</td>
<td>1.0</td>
</tr>
</tbody>
</table>

walls, which were then considered in calculating the thermal conductivity coefficient of the lithium vapor.

In measurements of the thermal conductivity of lithium vapor the indications of three external and three internal thermocouples located at various heights differed by no more than 0.1–0.2°C. Lithium vapor thermal conductivity was measured along isotherms at various pressures. Temperature heads from 12 to 26°C were used.

Preliminary experiments were performed at temperatures to 1340°C (series I) with an intercylinder gap of 0.20 mm. These experiments confirmed the possibility of measuring lithium vapor thermal conductivity with the equipment used. However, the correction ΔTC for lithium vapor is significantly larger than it is for vapors of the other alkali metals in measurements with the same gap. Therefore, to produce a significant reduction in this correction the gap was increased to 0.66 mm, which decreased the correction for contact temperature shift ΔTC to 12-16%.

The lithium used in the experiments was type LE-1, which, according to GOST 8774-75, has the following composition (mass %): Li > 99.5, Na < 0.06, Ca < 0.03, Mg < 0.02, Mn < 0.001, Fe < 0.005, Al < 0.003, silicon oxides <0.01, nitrides <0.05. Filtering of the experimental material in a barochamber with metalloceramic filters produced the following gaseous impurity content (mass %): O2, 0.01; N2, 0.006-0.02; C, 0.001-0.003; H2, 0.001.

Thermal conductivity of lithium vapor was studied over the temperature interval 1200-1450 °C at pressures from 4·10^2 to 80·10^2 Pa. Values of the thermal conductivity coefficient were calculated with the expression

\[ \lambda = A \frac{W - W_{rad}}{\Delta T - \Delta T_C} B, \]  

(2)

where \( A = (\ln D/d)/2\pi \) is the equipment geometric factor, \( B = 1 + \delta T_{sh} \) is the correction for temperature shift. The quantity of heat transferred by radiation was determined from the Stefan-Boltzmann expression.

The literature offers a large number of reliable experimental studies of the emissivity \( \varepsilon \) of niobium alloys [3]. The good agreement (within 1-2%) of inert gas thermal conductivity coefficients measured before and after lithium experiments with the different devices indicated that the emissivity of the cylinder materials did not change. The fraction of radiation in the total heat flux in series I (preliminary) experiments comprised from 8 to 15%, and 20-30% in series II-III.

The correction for temperature shift was calculated from the well-known expression [4]

\[ \delta T_{sh} = \frac{2n\sqrt{2\pi m_l R}}{P \alpha 2} \left( 2 - \alpha \right) V \frac{T}{R} \]  

(3)

It has been established in studies of the thermal conductivity of sodium, potassium, and cesium vapor that the accommodation coefficient for the system alkali metal–nickel is equal to unity independent of the temperature [5, 6]. On the basis of experimental data, Makhrov [7] demonstrated that the accommodation coefficient for alkali metal vapors on tungsten is equal to unity. This allows us to take \( \alpha = 1 \) in calculating the correction for temperature shift.

In the case of lithium vapor, the expression used to calculate the temperature shift \( \delta T_{sh} \) appearing in the correction to \( B \) of Eq. (2) has the form