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DETERMINATION OF THE GROUND ELECTRONIC STATE OF LaO GAS

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LaO GAS**

**Berkeley, California**

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DETERMINATION OF THE GROUND ELECTRONIC STATE OF LaO GAS

Leo Brewer and Robert Walsh

February 1965

## Determination of the Ground Electronic State of LaO Gas

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The ground electronic states of most high temperature molecules are in question because spectra observed under conditions of high excitation can involve excited lower states. Even the observation of an absorption spectrum in a high temperature gas does not establish the ground state since low lying electronic states have sufficient populations in high temperature gases to give strong absorption spectra. In a molecular beam where re-excitation by collision is minimized, it is possible that all excited electronic states will decay to the ground state, at least for the heavier molecules where spin prohibitions are not strong. Thus a new method of establishing the ground electronic state is proposed by observation of absorption in a molecular beam at a sufficient distance from the source.

This method has been applied to a molecular beam of LaO which was generated by heating a mixture of La metal and  $\text{La}_2\text{O}_3$  in a tantalum Knudsen cell, with a rectangular orifice 1mm wide and 10mm long. The cell was nearly surrounded by a resistance heating element and by several radiation shields, which also defined the beam. The beam was, in effect, a cone of a solid angle of 0.14 steradian, with a rectangular cross-section. The background pressure was maintained at 2 to  $3 \times 10^{-5}$  mm Hg. At a point 10 cm above the cell orifice, light from a Sylvania "Sun Gun", a high temperature

tungsten filament lamp, was passed perpendicularly through the beam. Sufficient optical density for an absorption spectrum could be obtained by multiple reflections across the beam, but an equivalent result is obtained more simply by observation of the fluorescent spectrum due to a single pass of the light beam, using filters to insure that the fluorescence is not due to excitation by shorter wavelengths. The fluorescent light passing through a window perpendicular to the exciting light beam was dispersed by a Steinheil three-prism spectrograph adapted to accept Polaroid type 57 film. The interior of the vacuum chamber was blackened to minimize scattering of exciting light and light from the furnace into the entrance slit of the spectrograph.

With the cell temperature at about 1500°C, the (0,0) and (1,1) bands at 5600 and 5626A of the system analyzed as  $X^4\Sigma - B^2\Sigma$  by Akerlind<sup>1</sup> began

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(1) L. Akerlind, Arkiv för Fysik 22, 65-93 (1962).

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to appear. The red  $X^4\Sigma - A^2\Pi$  system, also analyzed by Akerlind for LaO in an arc source, was beyond the limit of the film used. Thermodynamic calculations show that this temperature corresponds to an equilibrium pressure of LaO of about 1 mm Hg. As the temperature was increased, more features appeared until at about 1750°C, three bands of the (1,0), four of the (0,0) and three of the (0,1) sequence were observed along with several atomic lines arising from the ground state of La. For comparison purposes, the spectrum of a carbon arc containing La was taken. The intensity of the fluorescent spectrum did not change when a Corning 3384 filter was placed in the exciting light beam. Since this filter substantially reduces the light intensity below 5200A, this eliminates the possibility that the

fluorescent spectrum was due to absorption from a level below the  $X^4\Sigma$  state.

At about  $2000^\circ\text{C}$  the light from the furnace becomes intense enough to produce fluorescence even when no exciting lamp is used. The intensity of this fluorescence could be changed by varying the effectiveness of the shielding. As some light always passes along the same path from the orifice as the molecular beam, some excitation from this source is always present but is small compared to excitation by the lamp as long as the lamp is appreciably brighter than the Knudsen cell.

The results of these experiments establish the level of LaO designated<sup>1</sup> as  $X^4\Sigma$  as the ground state. By analogy, one would expect that the lower states of the corresponding systems<sup>2,3</sup> of ScO and YO are also the ground states.

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(2) L. Akerlind, Arkiv för Fysik 22, 41-64 (1962).

(3) L. Akerlind, Arkiv för Fysik 19, 1-16 (1961).

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This method should prove useful for many other high temperature molecules for which low lying states have lifetimes shorter than  $10^{-3}$  to  $10^{-4}$  sec and can therefore decay in the time of transit of the molecules.<sup>4</sup>

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