I thank B. Rossi and P. Morrison, of the Massachusetts Institute of Technology, and M. Annis and J. W. Carpenter, of American Science and Engineering, for advice.

OSCAR P. MANLEY

American Science and Engineering, Inc.,
Cambridge, Massachusetts.

[1] Gursky, H., Giacconi, R., Paolini, R., and Rossi, B., *Phys. Rev. Letters*, **11**, 530 (1963).
[2] Bowyer, S., Byram, E. T., Chubb, T. A., and Friedman, H., *Nature*, **201**, 1307 (1964).
[3] Bowyer, S., Byram, E. T., Chubb, T. A., and Friedman, H., *Science*, **147**, 394 (1965).
[4] Clark, G. W., Garmire, G., Oda, M., Wada, M., Giacconi, R., Gursky, H., and Waters, J., *Nature*, **205**, 554 (1965).
[5] Morrison, P., and Sartori, L., *Phys. Rev. Letters*, **14**, 771 (1965).
[6] Woltjer, L., *Astrophys. J.*, **140**, 1309 (1964).
[7] Feenberg, E., and Primakoff, H., *Phys. Rev.*, **72**, 449 (1948).
[8] Hewish, A., and Okoye, S., *Nature*, **207**, 59 (1965).
[9] Jones, F. C., *Phys. Rev.*, **137**, B1306 (1965).
[10] Parker, E., *Phys. Rev. Letters*, **14**, 55 (1965).

PHYSICS

Intensity Distribution of the Lyman–Birge–Hopfield Band System of N_2

RECENT rocket investigations of the vacuum ultraviolet radiation emitted from the aurora and airglow have shown up the need for laboratory measurements of molecular band intensities in this spectral region. Such laboratory investigations have until now been hampered by a lack of suitable intensity standards. One prominent band system of importance in this region is the Lyman–Birge–Hopfield (LBH) ($a\ {}^1\Pi_g - X\ {}^1\Sigma_g^+$) system of N_2, which lies between 2000 Å and 1200 Å. It has recently been observed in auroral spectra taken by rocket-borne spectrometers[1,2]. The only laboratory measurements of intensities of bands of the LBH system in emission are estimates of photographic plate blackenings[3], where no account has been taken of variation of instrumental response with wave-length.

Franck–Condon factors $q_{v'v''}$ have recently been calculated for this band system[4] using realistic Rydberg–Klein–Rees potentials. These can be used together with measured band intensities $I_{v'v''}$ to determine the variation of the electronic transition moment $Re(r)$ over the band system and thereby to provide band strengths $S_{v'v''}$, since:

$$\left.\begin{aligned} I_{v'v''} &= K\, N_{v'}\, \nu^4\, R_e^2(\bar{r}_{v'v''})\, q_{v'v''}; \\ S_{v'v''} &= R_e^2\, (\bar{r}_{v'v''})\, q_{v'v''} \end{aligned}\right\} \quad (1)$$

where K is a constant including units and geometry, $N_{v'}$ is the population of the upper state, and ν is the frequency of the band and $\bar{r}_{v'v''}$ is the r-centroid of the band. $R_e(r)$, the electronic transition moment, is assumed to be a smoothly varying function of internuclear separation.

This communication reports the results of relative intensity measurements of fifty of the major bands of the LBH system excited in a high-voltage a.c. discharge through nitrogen. A Hilger 3 m vacuum spectrograph with a photoelectric detector was used and the relative sensitivity of the instrument as a function of wave-length was established using a combination of standards including a carbon arc and a number of atomic lines the intensities of which could be calculated. Details of the calibration techniques will shortly be published.

From (1) it is seen that a plot of

$$\left(\frac{I}{q\nu^4\ N_{v'}}\right)^{\frac{1}{2}}_{v'v''}$$

versus $\bar{r}_{v'v''}$ or wave-length (to which it is monotomically related[5]) for each band delineates the variation of $R_e(r)$ over the band system. This plot was made for bands from the first four levels of the upper state ($v' = 0$ to 3) with the appropriate Franck–Condon factors[4] and population factors determined by inspection of the relative separation between the plots of $(I/q\nu^4)^{\frac{1}{2}}$ versus $\bar{r}$ for $v' = 0, 1, 2, 3$. No significant variation of $R_e(r)$ over the band system was observed. Hence to within the accuracy of the intensity measurements ($\pm$ 20 per cent) the electronic transition moment can be considered constant over the LBH system, and thus the calculated Franck–Condon factors directly indicate the relative band strengths. This conclusion had previously been tentatively suggested from an empirical observation on eye estimates of photographic blackening[6]. It is of considerable significance in identifying LBH bands in the spectra of such sources as the aurora and in determining source conditions.

This work was supported by research grants from the U.S. Air Force Office of Scientific Research (*AF–AFOSR 62–236A*), the National Aeronautics and Space Administration and the National Research Council of Canada, and a contract from the Defence Research Board of Canada.

D. J. MCEWEN*
R. W. NICHOLLS†

Department of Physics,
University of Western Ontario,
London, Ontario.

* Present address: Defence Research Telecommunications Establishment, Ottawa.
† Present address: Department of Physics, and Centre for Research in Experimental Space Science, York University, Toronto.

[1] Crosswhite, H. M., Zepf, E. C., and Fastie, W. G., *J. Opt. Soc. Amer.*, **52**, 643 (1962).
[2] Isler, R. C., and Fastie, W. G., *J. Geophys. Res.*, **70**, 2613 (1965).
[3] Birge, R. T., and Hopfield, J. J., *Astrophys. J.*, **68**, 257 (1928).
[4] Zare, R. N., Larsson, E. O., and Berg, R. A., *J. Mol. Spec.*, **15**, 117 (1965).
[5] Nicholls, R. W., *Proc. Phys. Soc.*, **85**, 159 (1965).
[6] Nicholls, R. W., *Nature*, **186**, 958 (1960).

Simplified Bulb Tracer System for Argon Analyses

THIS communication describes a simplified and inexpensive bulb-tracer system used for argon analyses in the potassium–argon age-determination laboratory of the United States Geological Survey. The system is easy to build and operate, and is portable. The cost of the tracer system, including the argon-38, is less than 50.00 dollars, so the unit cost per tracer is low. In the past year we have made more than 300 tracers, and we expect to make at least 300 more before refilling the bulb.

The tracer system (Fig. 1) consists of three 2-mm bore mercury-seal stopcocks connected to a 2-l. 'Pyrex' boiling flask. The gas pipette, D, is the volume between control stopcocks B and C. Stopcock A is a safety stopcock that allows the system to be removed from a vacuum line without exposing stopcock B to the atmosphere. The stopcocks are greased with high-vacuum silicone grease, which has a vapour pressure of about 10^{-7} mm Hg, to which we have added a very small amount of molybdenum sulphide. The molybdenum sulphide helps to prevent the

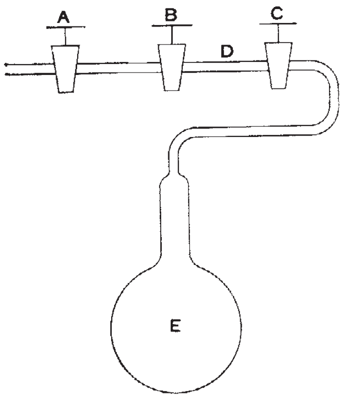

Fig. 1. Schematic diagram of the simplified bulb-tracer system for argon analyses. A, Safety stopcock; B and C, control stopcocks; D, gas pipette; and E, gas reservoir