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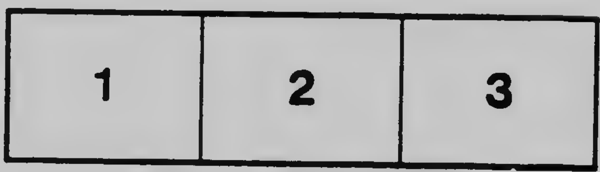

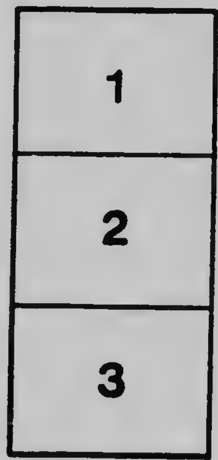

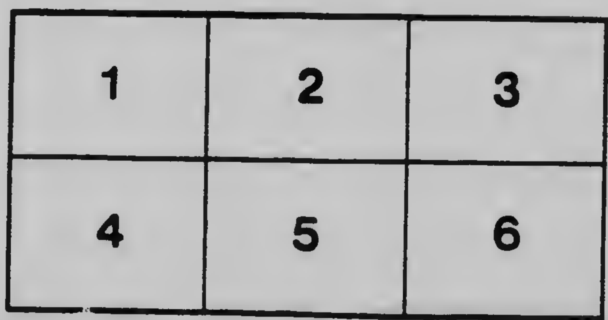

UNIVERSITY OF TORONTO STUDIES

PAPERS FROM THE PHYSICAL LABORATORIES

No. 65: THE USE OF THE JAMIN INTERFEROMETER FOR THE ESTIMATION OF SMALL AMOUNTS OF HELIUM OR HYDROGEN IN AIR, BY J. C. McLENNAN AND R. T. ELWORTHY

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University of Toronto Studies

The Use of the Jamin Interferometer for the Estimation of Small Amounts of Helium or Hydrogen in Air[1]

By PROFESSOR J. C. MCLENNAN, F.R.S., and R. T. ELWORTHY, B.Sc.

(Read May Meeting, 1919.)

INTRODUCTORY

In the determination of the permeability of balloon fabrics to helium and to hydrogen a method was required for the estimation of small amounts of these gas in air.

Various types of interferometer have been employed in similar work on other gases. Frenzel,[2] for example, used a Rayleigh Zeiss instrument for hydrogen-air mixtures, and the same instrument has been adopted at the United States Bureau of Standards[3] in the course of work on the permeability of balloon fabrics to hydrogen. Several other observers[4] have used the Jamin interferometer for the determination of refractive indices and dispersions in various gases.

W. Burton[5] in a determination of the refractive indices and the dispersion in argon and helium, made use of the relation

$$N_0 - 1 = \frac{(1+\alpha t)\ 76 \cdot f\ \lambda}{P.L}$$

where N_0 = refractive index

f — number of bands passing a standard line

λ = wave length of standard line

P — change of pressure

L = length of tubes of interferometer.

In Burton's work, two brass tubes of equal length, fitted with worked plane-glass ends of equal thickness contained respectively

[1] Communicated by permission of the Admiralty.

[2] Frenzel. Zeit fur Flugtechnik und Motor Luftschiffahrt, 5–264–1914.

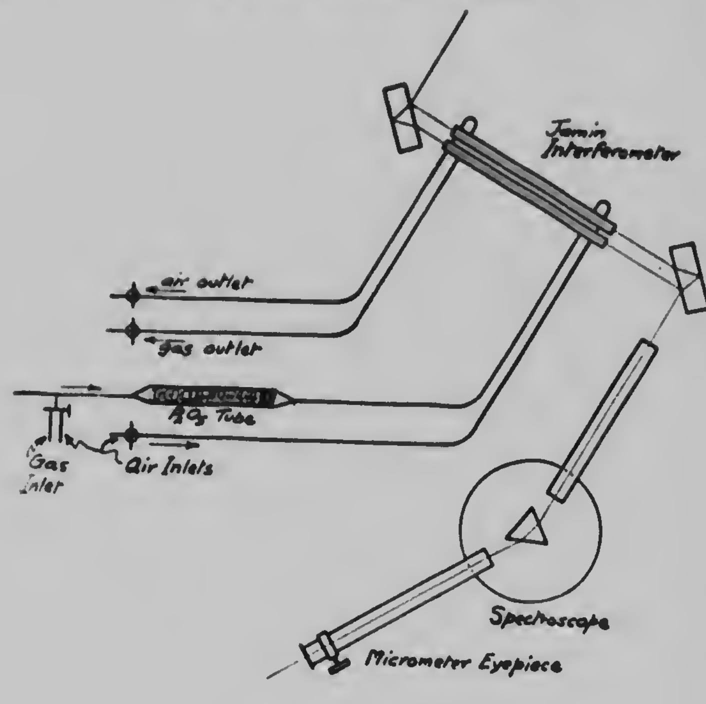
[3] United States Bureau of Standards. Tech. Paper. No. 113, 1918.

[4] "The Refractive Indices of gaseous nitric oxide, sulphur dioxide and sulphur trioxide." Cuthbertson & Metcalf, Proc. Roy. Soc. A 80–406–1907–1908.

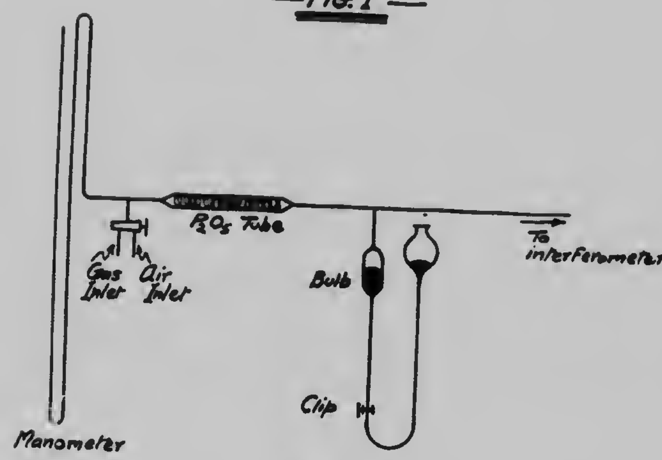
"On the dispersion of gaseous mercury, sulphur, phosphorus and helium." Cuthbertson and Metcalf. Proc. Roy. Soc. A 80–411–1907–1908.

"On the refraction and dispersion of Krypton and Xenon and their relation to that of Helium and Argon." Cuthbertson. Proc. Roy. Soc. A 81–440–1908.

[5] "The refractive index and dispersion of light in Argon and Helium." W. Burton. Proc. Roy. Soc. A 80–390–1908.


Jamin
Interferometer
air outlet
Gas outlet
P2O5 Tube
Gas
Inlet
Air Inlets
Spectroscope
Micrometer Eyepiece

—FIG. 1—


P2O5 Tube
To
interferometer
Gas
Inlet
Air
Inlet
Bulb
Clip
Manometer

—FIG. 2—

the standard gas and the gas whose refractive index was required. The pressure on the gas was changed by varying amounts up to ten atmospheres, the corresponding shift of bands being measured and the refractivity calculated from the relation just given. Burton found for argon, that 300 bands passed the cross line in the spectroscope for a change of pressure of two-thirds of an atmosphere, while for helium a shift of the same number of bands required five atmospheres change in pressure.

Method Adopted

In the method described in this paper estimations had to be made every few minutes. Burton's procedure proved unsuitable and was modified, as it was found it could be, by using a much smaller pressure change. The greater refractivity of air, and of low percentage helium-air mixtures, gave a correspondingly greater shift of bands than pure helium would, for the smaller pressure change and therefore measurements of the same accuracy could be made. By the use of a micrometer eyepiece in the observing telescope, the shift of bands could be measured to one hundredth of the distance between two bands.

From a knowledge of the shift of bands caused by a definite pressure change, the refractivity of a mixture of helium and air or hydrogen and air was found by means of the formula just given. The percentage of hydrogen or helium was then calculated from the refractivity as described later.

During preliminary experiments with this method it was observed that the displacement of air by the gas mixture in one tube of the interferometer gave a sufficiently large shift of bands for accurate measurement, without making a pressure change.

From the relation $(N_a - N_x)\ L = f\ \lambda$ where

N_a = refractive index of dry air at Pcms. and t°C
N_x = refractive index of a 1% gas mixture at the pressure and temperature
L = length of interferometer tubes
f = shift of bands past the cross line
λ = wave length of the standard line.

Curves were plotted for various pressures and temperatures showing the relation between the difference in refractive index of air and of a 1% gas mixture and the shift of bands.

N_a and N_x were calculated from the relation

$$N_t P - 1 = \frac{(N_o - 1)\,P}{(1+\alpha t)\,76} \quad \text{where}$$

N_o = refractive index at 0°C and 76 cms.
$\alpha = 0{\cdot}00365$

The refractive indices of the 1% hydrogen-air and 1% helium-air mixtures at 0° and 76 cms. were found by using the ordinary additive law for the refractive index of a mixture, the validity of which has been established for similar gas mixtures by several observers.[1]

The factors N_a and N_x in the formula $(N_a - N_x)L = f\,\lambda$ were thus obtained; f was therefore calculated for various temperatures and pressures at which readings were to be made.

As $(N_a - N_x)$ is proportional to the percentage of hydrogen or of helium in the mixture, such percentages were plotted directly against the values obtained for f as shown in Fig. 3.

The following refractive indices were employed in the various calculations:

	Refractive index at 0° & 760 mm. for $\gamma = 5461\text{x}\ 10^{-8}$ cm.	Observer	Reference
Air	1·0002936	Cuthbertson	Proc. Roy. Soc. A. 83–151–1909.
Helium	1·000034525	"	Proc. Roy. Soc. A. 80–411–1908.
		W. Burton	Proc. Roy. Soc. A. 80–390–1908.
Hydrogen	1·000139	Cuthbertson	Proc. Roy. Soc. A. 81–444–1908.

Arrangement of Apparatus

The arrangement of apparatus is shown diagrammatically in Fig. 1. It consisted essentially of the interferometer, spectroscope to observe the bands and the necessary connecting tubes.

The Jamin interferometer—made by Adam Hilger Ltd., London —consisted of the usual two parallel glass blocks of equal thickness, silvered at the back and mounted on a heavy metal base. The two 25 cm. glass tubes, fitted with plane parallel ends, supported in rests between the mirrors were each joined by side tubes to the respective inlet and outlet taps, drying tubes and manometer, as shown in the figure.

A parallel beam of light from an Ediswan Pointolite lamp after reflection from the mirrors and passage through the tubes fell on the

[1] Ramsay and Travers. Proc. Roy. Soc. 62–225, 1897.
Jones and Partington. Phil. Mag. 28–29–1915.

slit of a Hilger glass prism spectroscope and the bands were observed in the field of the micrometer eyepiece.

The telescope of the spectroscope was set in such a position that the moveable cross hair in the micrometer eyepiece when set at 500 on the scale, was focussed on the green mercury line, $\lambda = 5461 \times 10^{-8}$ cm., which served as the standard line.

Procedure in Taking Readings

For measurements, both interferometer tubes were initially filled at atmospheric pressure and temperature with dry air. The spectroscope was then adjusted so that the centre of a band coincided with the cross hair, set at 500.

The gas mixture to be examined, was then passed through the gas tube of the interferometer until the air was completely swept out. When this was accomplished the bands remained stationary. Usually the gas flow was continued for three to five minutes. The inlet taps of both gas and air tubes were then closed, and the outlet taps left open so that atmospheric pressure was established in both tubes. The movement of the bands, the centre of which coincided with the standard line when both tubes contained air, was then measured as well as the distance between the centres of two bands adjacent to the zero position. The shift was calculated as a percentage of the distance between the two bands.

From the appropriate curve, shown in Fig. 3, the percentage of gas was obtained.

Calibration

The theoretical method of calibration employed has already been discussed under "Method Adopted." As a check on this method a further one, proposed by J. D. Edwards[1], was employed.

After dry air had been passed through both tubes and atmospheric pressure established, the gas tube was closed and the pressure in the tubes lowered by successive amounts by letting mercury slowly run out of the bulb in Fig. 2, through the screw slip. The shift of bands for each pressure change was measured. The refractive index of the air at each pressure was calculated and also the composition of the helium-air or hydrogen-air mixture that would have a similar refractive index at the initial atmospheric pressure and temperature. The percentage of helium or hydrogen thus found was plotted against the shift of bands. The curves so plotted agreed with those obtained by the first method.

[1] J. D. Edwards. Jour. Amer. Chem. Soc., 2382–1917.

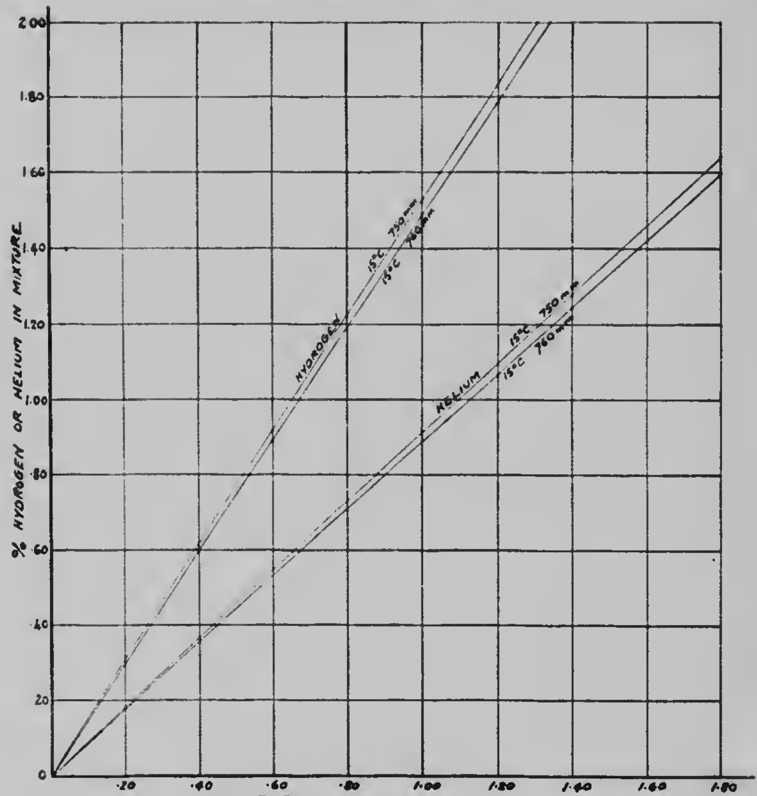


FIG. 3.—SHIFT OF BANDS R.P.L. 303

CHECK OF CALIBRATION BY MEANS OF KNOWN MIXTURES

Several mixtures of hydrogen and air and of helium and air were made up from dry air, pure hydrogen and pure helium, in a water-jacketted burette fitted with a compensation tube. The mixtures were then passed into the gas tube of the interferometer in the usual way and readings were made.

The following table shows some of the results obtained:

Hydrogen—Air		Helium—Air	
By Volume	By Interferometer	By Volume	By Interferometer
%	%	%	%
1·61	1·55	0·39	0·42
1·38	1·35	0·16	0·15
0·09	0·07	0·13	0·13

Accuracy of the Determination

The mean error of setting the cross hairs of the micrometer eye-piece on the centre of a band was about 11-100 of the distance between two bands. For mixtures up to 0·2% helium and 0·4% hydrogen this would give an error of about 4% on the result. For percentages up to 1% of either gas, the error due to this cause would be about 2% on the result. Slight changes of position of the metal parts of the interferometer, owing tc temperature changes caused greater errors on some occasions, manifested by a considerable zero shift during readings, which could not always be allowed for. Such errors could be made negligible by using longer interferometer tubes and by keeping the instrument at a constant temperature.

Altogether it was considered that determinations of percentages in mixtures containing less than 1% hydrogen or helium were made with a mean error of ±5%.

Summary

1. A method for the determination of small percentages of helium or of hydrogen in air has been described, making use of a Jamin interferometer.

2. Two methods of calibrating the instrument have been outlined; one based on the relation between the difference in path, caused by the displacement of air in one of the tubes by the mixture and the resulting shift of bands; the second, a method based on the change of refractive index of the air in one tube caused by lowering the pressure on the air.

3. With the instrument that was used the accuracy with which determinations were made, was about ± 5% on the result. With longer tubes a greater accuracy could be obtained.

The work was carried out at the Admiralty Physical Laboratory, South Kensington.

April 15th, 1919.

UNIVERSITY OF TORONTO STUDIES

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