SOVIET PHYSICS JETP VOLUME 11, NUMBER 6 DECEMBER, 1960

THE DENSITY OF LIQUID OXYGEN ON THE SATURATION CURVE

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Submitted to JETP editor February 6, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **38**, 1729-1732 (June, 1960)

The results of density measurements of liquid oxygen on the saturation curve are presented and compared with data in the literature.

THE density of liquid oxygen on the saturation curve at different temperatures has been insufficiently studied. In the existing literature[1-6] the maximum discrepancies among the values of density amount to 5% (at −210°C). The discrepancy between the results of the most reliable studies[5,6] is 1.2%.

We have studied the temperature and pressure dependence of the density of liquid oxygen along the isochores, in a constant-volume piezometer. What one obtains directly from an experiment are quasi-isochores, because of the presence of the stray volume involved in the communication system. A correction for the stray volume was applied by the "sealed capillary" method[7] and did not exceed 0.2%.

When changing from one isochore to another, some oxygen was liberated from the piezometer. The quantity of oxygen liberated was measured (in the gaseous state) in a dry gasometer. The saturation curve was determined in $p - t$ coordinates from the kink in the quasi-isochores. (The pressure p is given below in kg/cm² throughout, and the temperature t in degrees C.)

The density on an isochore was calculated from the formula $\rho = G_i/V_p$, where G_i is the quantity of oxygen in the piezometer, determined by inverse summation of the amounts liberated, corrected for the stray volume of the piezometer, and V_p is the piezometer volume.

The heavy-walled piezometer and gasometer (Fig. 1) were placed in a cryostat and a thermostatic bath, respectively. The basic elements of the apparatus were made of stainless steel. The piezometer volume (in cm³) was determined from the formula

$$V_p = V_0 [1 + 3\bar{\alpha}_t t + \beta (p - 1)], \qquad (1)$$

where $V_0 = 541.65$ cm³ and $\beta = 7.29 \times 10^{-6}$ cm²/kg. The mean coefficient of linear expansion $\bar{\alpha}_t$ for the material of the piezometer, which we obtained experimentally over the temperature interval $t = 0°$ to −200°C, is given by the formula

$$10^6 \cdot 3\bar{\alpha}_t = 51{,}03 + 0.66 \left(\frac{t}{100}\right) - 3{,}18 \left(\frac{t}{100}\right)^2. \qquad (2)$$

The coefficient of isothermal compressibility β in (1) was obtained numerically from the geometric dimensions of the piezometer, using the theory of thick-walled shells.[9]

The oxygen pressure in the piezometer was measured with a piston manometer. The gasometer pressure was measured with a precision open mercury manometer with a mirror indicator. The temperature of the oxygen in the cryostat and thermostatic bath were measured with standard resistance thermometers made of spectrally pure platinum. Liquid nitrogen and Freon-12 were used in turn as thermostatic liquids in the cryostat. The temperature field within the cryostat was monitored with copper-constantan thermocouples — three in the upper portion and a movable one inside the volume.

A total of 184 experimental points were obtained, spaced uniformly on 10 quasi-isochores and the saturation curve, and 57 liberations of oxygen were made into the gasometer.

The density of the gaseous oxygen within the gasometer, at room temperature and a pressure not exceeding 3.5 kg/cm², was determined from Meyer's tables.[8] In this region of the parameters of state, oxygen differs little from a perfect gas

t,° C	p, kg/cm²	ρ, g/cm³
—194.03	0.27	1.1879
—153.50	10.20	0,9712
—151.73	11,28	0,9589
—147.03	14.66	0.9272
—141.50	19,44	0.8847
—132.04	29,44	0,7972
—129.48	33,31	0,7673
—125.21	39,72	0.7086
—121.06	46,72	0.6227
—119.70	49,14	0.5795

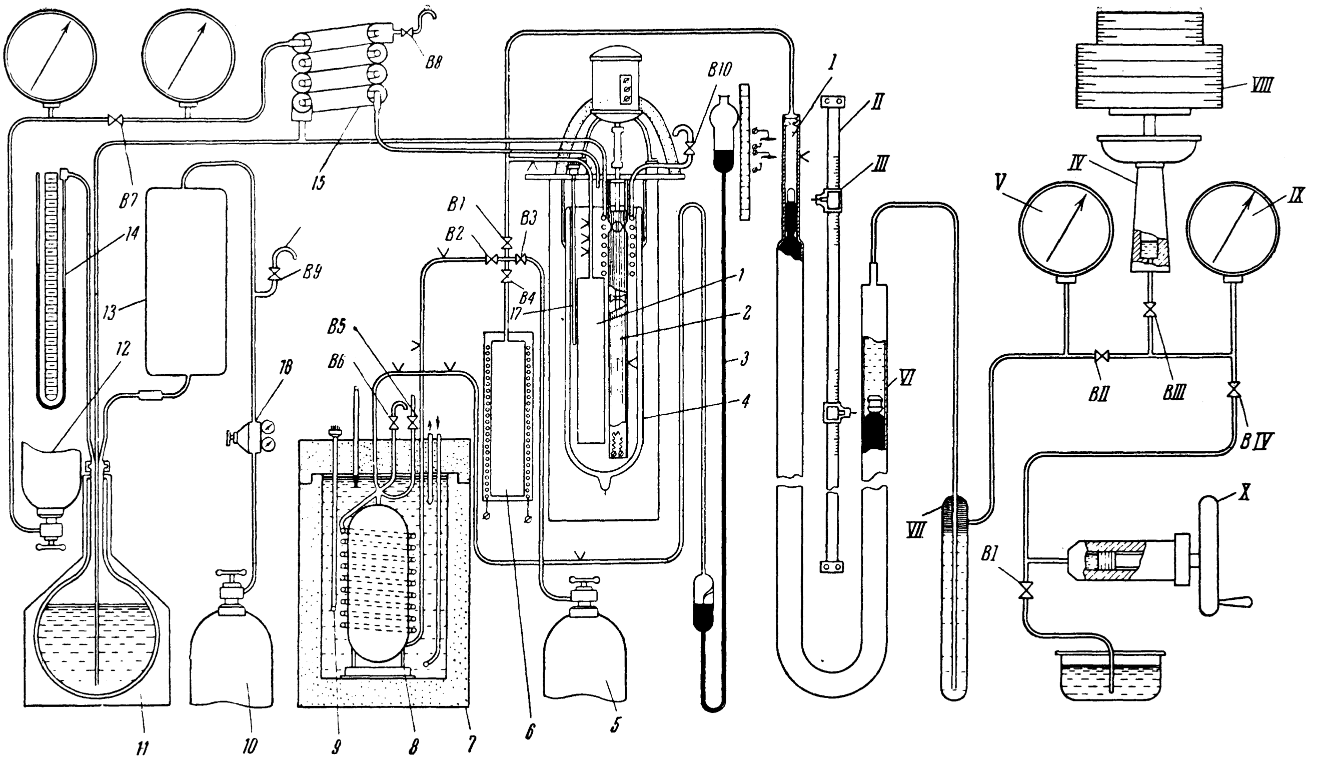

FIG. 1. Diagram of experimental arrangement. 1 – piezometer with attached capillary; 2 – stirrer with cooling element and heater; 3 – open mercury manometer with flexible tube; 4 – glass Dewar vessel; 5 – oxygen cylinder; 6 – thermomultiplier; 7 – thermostat; 8 – gasometer; 9 – standard platinum resistance thermometer; 10 – nitrogen cylinder; 11 – metal Dewar flask containing liquid nitrogen; 12 – cylinder of Freon-12; 13 – intermediate volume; 14 – open mercury manometer; 15 – nitrogen-Freon heat exchanger; 16 – reducing valve; 17 – standard platinum resistance thermometer; I – left leg of differential mercury manometer, with small magnet; II – measuring scale of differential manometer; III – measuring follower-indicator; IV – right leg of differential mercury manometer, with large magnet; V – standard Bourdon spring manometer; VI – piston manometer; VII – oil-water separator; VIII – weights for the piston manometer; IX – technical Bourdon spring manometer; X – oil screw-press; B1 – main throttle valve; B2 – safety shut-off valve for gasometer; B3 – oxygen filling valve; B4 – thermo-multiplier valve; B5 – valve from gasometer to vacuum pump; B6 – oxygen vent to atmosphere; B7 – Freon supply valve; B8 – heat exchanger valve; B9 – pressure relief valve; B10 – cooling element valve; BI – oil supply valve; BII – piezometer system valve; BIII – piston manometer valve; BIV – oil press valve; V – locations of sealed-in thermocouples.

and has been quite well studied experimentally. The error in the determination of its density is therefore negligibly small.

Of the experimental values of oxygen density which we obtained, the ones which refer to the saturation line are given in the table. An analysis of the inaccuracies of the experiment showed that the maximum relative error of our measurements amounts to ±0.15%.

Figure 2 gives a comparison of our data with the results of other workers. Of all these, the values obtained by Biltz et al.[6] by the pycnometer

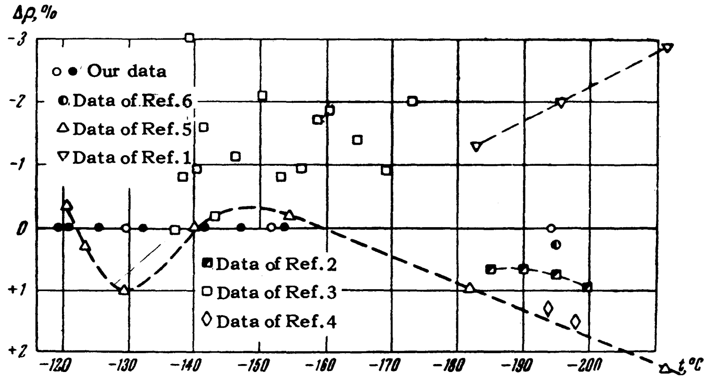

FIG. 2. Discrepancies between experimental data of various authors and the results of the present work: ○ – first series of experiments; ● – second series of experiments.

method agree the best with our data. The discrepancy in this case does not exceed 0.25%. The results of Mathias and Kamerlingh-Onnes are sometimes lower and sometimes higher than our density values. The greatest discrepancy occurs at low pressures and at pressures ~30 kg/cm^2, amounting to 1.7% at t ~ −200°C. The discrepancies with the data of other investigators[1-4] appear to be quite chaotic over the entire extent of the saturation curve, and vary between +2 and −3%.

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Translated by D. C. West
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