DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
George K. Burgess, Director

RELATIONS BETWEEN THE TEMPERATURES, PRESSURES, AND DENSITIES OF GASES

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RELATIONS BETWEEN THE TEMPERATURES PRESSURES, AND DENSITIES OF GASES[1]

ABSTRACT

The attempt has been made, in discussing the relations between the temperatures, pressures, volumes, and weights of gases, to derive the formulas in a simple manner with the minimum requirements of theoretical knowledge on the part of the reader. The experimental data involving high pressures are presented in such a form that problems of this nature can be easily solved by introducing factors taken directly from curves. The significance of the equations of state of van der Waals, of Dieterici, and of Berthelot are discussed, and the manner in which these equations may be used to predict compressibilities is explained in detail. Comparisons of the calculated values with the experimental data for various gases are shown by means of a series of curves. There is included a rather extensive bibliography of the literature pertaining to the subjects herein discussed, together with a number of tables of conversion factors and equivalents.

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[1] Prepared by S. F. Pickering, associate chemist, Bureau of Standards of the Department of Commerce, Washington.

I. INTRODUCTION

That the calculations of the relations involving the temperatures, pressures, and volumes of gases, particularly where high pressures are concerned, are not without their difficulties is apparent from the large number of requests for such information which have been received by this bureau. These difficulties, no doubt, find their explanation, to a large extent, in the comparative lack of simple yet complete discussions of the subject. This is especially true with regard to compressed gases, for, although many data upon them have been published, they have been presented by so many different observers in so many different forms that the application of the results by the average user has been rendered especially difficult.

The primary purpose of this circular, therefore, is to show in as simple a manner as possible the methods by which these relations may be computed and to present the necessary experimental data in such a way that they can be directly and easily used for solving practical problems.

A survey of the literature revealed that information is lacking for several important gases under high pressures, which fact suggested the question as to how accurate are various equations of state for predicting compressibilities. A complete discussion of this subject, of course, would be of prohibitive length, but it did seem feasible to compare with existing data several of the best known equations in order that some idea of their reliability in this respect could be obtained. While these equations have been considered in detail in many textbooks, there have been very few discussions in which it is shown how to use them in making actual calculations.

For several of the important gases charts have been prepared showing the volumes of gases delivered from cylinders of the compressed gas when the gauge pressure and temperature are known.

Miscellaneous tables of constants and conversion factors, together with a bibliography, complete this paper, which, it is hoped, will be of service to many who have had difficulty with the subjects herein discussed.

The author is indebted to E. R. Weaver for his many valuable suggestions.

II. CALCULATIONS INVOLVING THE RELATIONS BETWEEN THE TEMPERATURES, PRESSURES, VOLUMES, AND WEIGHTS OF GASES

1. SIMPLE LAWS

Unlike a solid or liquid, any amount of gas completely fills the space in which it is confined, and the pressure which it exerts upon the confining walls depends upon the temperature. A quantity of gas can not, therefore, be specified in terms of volume only; all three factors—volume, temperature, and pressure—are of equal importance and must always be stated unless those not stated are certainly understood.

The relations between these three factors are expressed by means of the following equation,

$$pv = kT \tag{1}$$

in which p, v, and T represent simultaneous values of the pressure, volume, and absolute temperature of any definite quantity of gas, while k is a constant, the numerical value of which depends upon the quantity of gas considered and the units in which pressure, volume, and temperature are measured. This equation means that whatever one does to two of the three conditions—volume, temperature, and pressure—the third condition automatically varies in such a way that the equation is still true.

The significance of the absolute temperature is as follows: When the pressure remains constant, the volume of the gas varies directly as the temperature measured from a certain point called the absolute zero. This absolute zero is −273.1° C. (or −459.6° F.). In other words, if the temperature of a gas is changed from 0 C. to 1° C., its volume is increased by one two-hundred and seventy-third of its volume at 0° C. (If the increase in temperature is from 0 F. to 1° F., the increase in volume is one four-hundred and sixtieth of its volume at 0° F.). Similarly, if the temperature of the gas is increased from 100 to 101° C., the volume is increased by one three-hundred and seventy-third of its volume at 100° C.

Since zero points on the centigrade scale and on the Fahrenheit scale are 273.1° C. and 459.6° F., respectively, above the fixed absolute zero point (which is the same for both scales), the corresponding absolute temperatures are obtained by adding 273.1° to the temperature measured in degrees centigrade, or 459.6° to the temperature measured in degrees Fahrenheit. Inasmuch as the volumes and absolute temperatures are directly proportional, the ratio of the volumes of a definite quantity of a gas at constant pressure is equal to the ratio of the absolute temperatures of the gas. Similarly, the ratio of the absolute temperatures is equal to the ratio of the pressures at constant volume.

While the behavior of gases at atmospheric pressure closely approximates that represented by equation (1), the relation is not exact. The expansion of air, for example, is nearer one two-hundred and seventy-second of its volume at 0° C. per degree. For most practical purposes, however, such errors may be neglected.

For several reasons, it is generally convenient to make measurements or comparisons of quantities of gas in terms of the volume occupied under definite conditions of temperature and pressure rather than to fix the volume and measure quantity in units of pressure or temperature; when it is not possible to measure the volume under the chosen conditions, it is necessary to make corrections to determine what volume would be occupied under those conditions.

Ordinarily, "standard conditions" of temperature and pressure are chosen for the measurement of gas volume; for scientific work in which the metric system is employed the standard conditions generally chosen are 0° C. and 760 mm (29.92 inches) of mercury (at 0° C.)[2] pressure,[3] which is called 1 atmosphere.

In the manufactured fuel-gas industry 60° F. and 30 inches (762.0 mm) of mercury pressure are usually chosen. In other commercial and engineering work in this country 68 and 70° F. are in general use as standard temperatures, with a growing tendency to agree upon 68° F. (20° C.), which is also coming into use in scientific work.

From equation (1) it follows that

$$\frac{p_1v_1}{T_1}=k=\frac{p_2v_2}{T_2}$$

where p_1, v_1, T_1, and p_2, v_2, T_2, represent two sets of conditions of pressure, volume, and absolute temperature of the same quantity of gas. Hence

$$v_2=v_1\,\frac{p_1T_2}{p_2T_1} \tag{2}$$

If the temperatures are measured in degrees centigrade, equation (2) becomes

$$v_2=v_1\frac{p_1\ (273.1+t_2)}{p_2\ (273.1+t_1)} \tag{3}$$

If measured in degrees Fahrenheit, it becomes

$$v_2=v_1\frac{p_1\ (459.6+t_2)}{p_2\ (459.6+t_1)} \tag{4}$$

In these equations and subsequently throughout this circular, T, with or without subscript, is used to denote absolute temperature (on the centigrade scale unless otherwise stated), while t denotes temperature measured from the centigrade or Fahrenheit zero.

The foregoing equations are sufficient for making the usual conversions of volumes from one set of conditions to another, but do not show the relations connecting volumes and weights of gases.

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[2] In this paper the height of a mercury column when used to indicate a pressure will always refer to the height at 0° C.

[3] An exact definition of pressure must include the value of the acceleration of gravity, which is slightly different at different places on the earth's surface. In this paper the value 980.665 cm per second per second agreed upon by the International Conference on Weights and Measures for the acceleration of gravity is used. (Trav. et Mem. Bur. Int. Third Gen. Conference p. 66; 1902.) In commercial work with gases and in all except the most exact scientific work the differences in the acceleration of gravity at different places are negligible.

If now we consider weights of different gases proportional to their respective molecular weights, a new relation of the greatest importance develops: *The value of the constant in equation (1) is the same for each gas.* In scientific work it is customary to use, as the unit of quantity, the number of grams of gas equal to the molecular weight. This unit is called the mol; and when 1 mol is the quantity of gas considered, the resulting value of k is given the special designation R. The constant R so defined is one of the most important constants employed in physical and chemical science. It is commonly called "the gas constant," and will be used very frequently in this circular.

TABLE 1.—*Values of "the gas constant R" corresponding to different systems of units of temperature, pressure, and volume*

[R is defined by the equation $pv = NRT$, in which the mol is the unit of quantity of gas]

Units employed			Numerical value of R
Absolute temperature	Pressure	Volume	
°C.+273.1	Atmosphere	Liter	0.08206
°C.+273.1	mm of mercury	do	62.37
°C.+273.1	Gram per cm²	do	84.79
°C.+273.1	Megabar	do	.08315
°C.+273.1	Atmosphere	Cubic feet	.002898
°C.+273.1	mm of mercury	do	2.2024
°C.+273.1	Inches of mercury	do	.08671
°C.+273.1	Pounds per in.²	do	.04259
°F.+459.6	Atmosphere	Liter	.04559
°F.+459.6	do	Cubic feet	.001610
°F.+459.6	mm of mercury	do	1.2236
°F.+459.6	Inches of mercury	do	~~.04517~~ 0447
°F.+459.6	Pounds per in.²	do	.02366

When the mol is employed as the unit of quantity, equation (1) becomes

$$pv = NRT \tag{5}$$

in which N represents the number of mols in the quantity of gas under consideration. The numerical value of R depends upon the units in which pressure, volume, and temperature are expressed. Table 1 gives values of R in the different systems of units in common use in both scientific and commercial work. (The cubic centimeter and the cubic meter in which volumes of gas are frequently measured are respectively, one one-thousandth of and one thousand times the liter.)

By the use of equation (5), Table 1, and a table of molecular weights which will be found on page 60, the solution of any problem involving volumes, temperatures, pressures, and weights of gases is very simple, including problems requiring conversion from one set of units to another. For the purpose of solving various types of problems equation (5) may be put in the following forms:

$$v=\frac{NRT}{p} \tag{6}$$

$$N=\frac{pv}{RT} \tag{7}$$

$$\frac{p_1v_1}{R_1T_1}=\frac{p_2v_2}{R_2T_2} \text{ or } v_2=v_1\frac{p_1R_2T_2}{p_2R_1T_1} \tag{8}$$

In equation (8), v_1 represents the volume of any definite quantity of gas at pressure p_1, and absolute temperature T_1; v_2 represents the volume of the same quantity of gas at pressure p_2 and absolute temperature T_2, as in equation (2); and R_1 and R_2 represent the numerical values of the gas constant corresponding to the respective systems of units employed. If the same system of units is used in both gas measurements, R_1 and R_2 are identical and are eliminated from the equation which becomes identical with equation (2)

$$\frac{p_1v_1}{T_1}=\frac{p_2v_2}{T_2} \text{ or } v_2=v_1\frac{p_1T_2}{p_2T_1}$$

The use of these equations is illustrated by the following problems:

PROBLEM 1.—What volume in cubic feet will 900 g of oxygen occupy at a temperature of 82° F. and a pressure of 23 pounds per square inch?

Solution.—The molecular weight of oxygen is 32. The value of N is, therefore, $\frac{900}{32}$; the value of R for the system of units chosen is 0.02366 and we can, therefore, substitute at once in equation (6)

$$v=\frac{900}{32}\times\frac{0.02366\ (82+459.6)}{23}=15.76 \text{ cubic feet}$$

PROBLEM 2.—What would be the weight in pounds of 85 cubic meters of nitrogen at 27° C. and 740 mm pressure?

Solution.—Substituting in equation (7)

$$N=\frac{740\times 85\,000}{62.37\times(27+273.1)}=3358 \text{ mols}$$

The molecular weight of nitrogen is 28, and 1 pound corresponds to 453.6 g, hence the weight in pounds, w, of 3358 mols of nitrogen is

$$w=\frac{28\times 3358}{453.6}=207 \text{ pounds}$$

Problem 3.—A certain quantity of hydrogen at 80° F. and 150 lbs./in.^{2} occupies 1.3 cubic feet. What will be its volume in liters at 15° C. and a pressure of 1.8 atmospheres?

Solution.—Substitute in equation (8)

$$v_2 = 1.3 \times \frac{150 \times 0.08206\ (15+273.1)}{1.8 \times 0.02366\ (80+459.6)} = 201 \text{ liters}$$

Problem 4.—A quantity of gas occupies 8,800 cubic feet at 55° F. and a pressure of 28 inches of mercury. What volume will it occupy at 60° F. and 30 inches of mercury?

Solution.—Substitute in equation (2).

$$v_2 = 8{,}800 \times \frac{28\ (60+459.6)}{30\ (55+459.6)} = 8{,}300 \text{ cubic feet}$$

2. MIXTURES OF GASES; VAPOR PRESSURE AND THE EFFECT OF VAPOR PRESSURE UPON THE MEASUREMENT OF GAS

It was pointed out on page 2 that any quantity of gas completely fills the space in which it is confined and exerts a pressure upon the confining walls. If an additional quantity of the same gas is added, it has been shown in the discussion of the simple gas laws that the pressure is increased in direct proportion to the quantity added. The simplest way to look at this fact is to regard the pressure exerted by each portion of the total quantity of gas as independent of the presence of the remainder. This relation is equally true in case the second portion of gas introduced into the space has a different chemical composition from the first (Dalton's law) provided, of course, the two gases do not react chemically.

If a volatile liquid is introduced into a confined space, a portion of it evaporates (becomes gas) and exerts a pressure on the confining walls just as any other portion of gas does. The amount which evaporates and the pressure which it exerts are independent of the presence of any other gas in the space. If there is enough liquid present so that it does not all evaporate and if enough time is allowed for equilibrium to be reached, the pressure exerted is independent of the volume of space occupied and of the amount of liquid left unevaporated; but it does depend upon the temperature. For each volatile liquid there is therefore a definite saturation pressure or vapor pressure (both terms are widely used in technical literature) corresponding to every temperature. The phenomenon of vapor pressure is not confined to liquids. Many solids have appreciable vapor pressures at ordinary temperatures (witness naphthalene, which causes so much trouble for the gas companies), and almost all substances at sufficiently high temperatures have vapor pressures which can be detected. By a volatile substance we mean one which has an appreciable vapor pressure at the temperature considered.

When any quantity of gas is in contact with a volatile substance, the measured pressure is the sum of the pressure exerted by the gas and the vapor pressure of the volatile material. Assuming no change of temperature, this vapor pressure remains constant no matter how we change the total pressure. Hence for purposes of volume conversion the saturated gas may be considered as a dry gas, the pressure of which is the partial pressure of the gas, or its equivalent, the difference between the total pressure and the saturated vapor pressure of the volatile material.

If, for example, a gas is in contact with water at 30° C., the partial pressure of the water vapor is 31.86 mm of mercury or 0.0419 atmosphere; and assuming the total pressure to be 1 atmosphere, the partial pressure of the gas would be 0.9581 atmosphere. Upon being compressed to 2 atmospheres (the temperature remaining constant), half of the water vapor would be condensed (neglecting any deviations from the simple gas law), thus maintaining the partial pressure of the water vapor at 0.0419 atmosphere, while the partial pressure of the gas would become 1.9581 atmospheres. Upon expansion at constant temperature (still in contact with the water) water would evaporate until the partial pressure of the water vapor became equal to 0.0419 atmosphere, as before.

Whatever changes of pressure, temperature, and volume take place, the gas (as distinguished from the vapor which varies in quantity) behaves in accordance with the simple gas laws already stated, and these laws may be accordingly modified to include vapors by making the simple substitution

$$P = w + p \quad \text{or} \quad p = P - w$$

in which P is the total pressure exerted on the walls of the confining space, p is the partial pressure of the gas, and w is the vapor pressure of the liquid.

Replacing p_1 in equations (2), (3), and (4) by the value for its partial pressure, namely, $P_1 - w_1$, gives the corresponding equations, which can be used for converting from the saturated to the standard dry basis. These equations are

$$v_2 = v_1 \frac{(P_1 - w_1)\ T_2}{p_2\ T_1} \tag{9}$$

$$v_2 = v_1 \frac{(P_1 - w_1)\ (273.1 + t_2)}{p_2\ (273.1 + t_1)} \tag{10}$$

$$v_2 = v_1 \frac{(P_1 - w_1)\ (459.6 + t_2)}{p_2\ (459.6 + t_1)} \tag{11}$$

where w_1 is the saturated pressure of the vapor at temperature t_1.

For conversions to a standard saturated basis the term p_2 in the above equations is replaced by the value for its partial pressure, namely, P_2-w_2, where w_2 is the saturated pressure of the vapor at temperature t_2. The equations then become

$$v_2=v_1\frac{(P_1-w_1)\ T_2}{(P_2-w_2)\ T_1} \tag{12}$$

$$v_2=v_1\frac{(P_1-w_1)\ (273.1+t_2)}{(P_2-w_2)\ (273.1+t_1)} \tag{13}$$

$$v_2=v_1\frac{(\mathrm{P}_1-w_1)\ (459.6+t_2)}{(P_2-w_2)\ (459.6+t_1)} \tag{14}$$

The following problems illustrate the use of the above equations:

Problem 1.—The volume of a gas saturated with water vapor measured at a pressure of 741.6 mm of mercury and at 25° C. is 74.69 liters. What would be the volume of the dry gas at 760.0 mm and at 0° C.?

Solution.—From table 12, page 58, the vapor pressure of water at 25° C. is 23.8 mm.

Substituting in equation (10)

$$v_2=74.69\ \frac{(741.6-23.8)\ (273.1+0.0)}{760.0\ (273.1+25.0}=64.61 \text{ liters.}$$

Problem 2.—The volume of a gas measured with a wet meter is 432.7 cubic feet. The pressure is 29.67 inches of mercury and the temperature is 86° F. What volume would the saturated gas occupy at a pressure of 30 inches and 68° F.?

Solution.—From the table the vapor pressure of water is found to be 1.25 inches at 86° F. and 0.69 inch at 68° F.

Substituting in equation (14)

$$v_2=432.7\frac{(29.67-1.25)\ (459.6+68.0)}{(30.00-0.69)\ (459.6+86.0)}=405.8 \text{ cubic feet.}$$

Equations (6), (7), and (8) may likewise be modified by substituting P_1-w_1 and P_2-w_2 for p_1 and p_2.

3. VOLUME CONVERSIONS INVOLVING HIGH PRESSURES

In the measurement of gases at high pressures, for example, compressed oxygen or hydrogen as they are ordinarily sold on the market, the foregoing equations are inadequate; for such a pressure range (2,000 lbs./in.^{2}) the quantity pv is no longer constant at constant temperature, but varies with the pressure by amounts which differ for each gas. Consequently the relation

$$\frac{p_1v_1}{T_1}=\frac{p_2v_2}{T_2}$$

is no longer true.

In Figures 1 to 8 the values of $\frac{273.1}{T}pv$ are plotted against the pressure. These figures contain nearly all of the published data in this range of temperature and pressure, and the isothermals are drawn according to what appear to be the most probable values. This quantity $\frac{273.1}{T}pv$ is called the factor (F) and is discussed in the following paragraphs.

Let us consider for the time being the 0° C. isothermals only. These are plotted on the basis of pv at 0° C. and 1 atmosphere as being unity. Hence, the value of the factor for any pressure as given by the curve will represent the ratio of the value of pv at this pressure to the value of pv at 1 atmosphere; that is,

$$\frac{(pv)_{\mathrm{n}}}{(pv)_1}=F_{\mathrm{n}}$$

where F_{n} is the factor from the curve for n atmospheres. This relation, of course, holds for all pressures, therefore,

$$\frac{(pv)_{\mathrm{n}}}{(pv)_{\mathrm{m}}}=\frac{F_{\mathrm{n}}}{F_{\mathrm{m}}}$$

$$v_{\mathrm{m}}=v_{\mathrm{n}}\frac{P_{\mathrm{n}}}{P_{\mathrm{m}}}\frac{F_{\mathrm{m}}}{F_{\mathrm{n}}}$$

In other words, the corrections are made as though the substance behaved as a perfect gas, and the result is then multiplied by the ratio of the factor at the desired pressure to the factor at the measured pressure.

Suppose, for example, a cylinder whose volume is 1.372 cubic feet contains oxygen at 120 atmospheres (0° C.) and it is desired to calculate the volume occupied by the gas at 30 atmospheres (0° C.).

From Figure 8,

$$F_{120}=0.9140 \text{ and } F_{30}=0.9735$$

Hence,

$$v_{30\text{ atm.}}=1.372\ \frac{120}{30}\ \frac{0.9735}{0.9140}=5.85$$

The desired volume is, therefore, 5.85 cubic feet.

The volume occupied by the gas at 1 atmosphere (0° C.) would be

$$v_{1\text{ atm.}}=1.372\ \frac{120}{1}\ \frac{1.0000}{0.9140}=180.2 \text{ cubic feet.}$$

Inasmuch as the volume varies directly with the absolute temperature at a constant pressure of 1 atmosphere, the value for pv at 100° C. and 1 atmosphere would be 1.366 (approximately). If this isothermal were to be placed on the same chart with the 0° C. isothermal, the large range covered by pv ordinate would make it difficult to read variations in the values of pv for a given temperature with any degree of accuracy. By multiplying the pv values at each temperature T (°C. absolute) by $\frac{273.1}{T}$, however, this major temperature effect is eliminated, leaving only the deviations from the simple gas law.

Since

$$F = pv \frac{273.1}{T}$$

then

$$pv = F \frac{T}{273.1}$$

Hence, the value of pv for any temperature can be obtained by multiplying the factor obtained from the curve by the quotient of the absolute temperature divided by 273.1°.

In order to use the factors directly in computing the pressure, volume, and temperature relations an equation may be derived as follows:

$$F_1 = (p_1v_1) \frac{273.1}{T_1}$$

$$F_2 = (p_2v_2) \frac{273.1}{T_2}$$

$$\frac{F_1}{F_2} = \frac{(p_1v_1)}{(p_2v_2)} \frac{T_2}{T_1}$$

$$\therefore v_2 = v_1 \frac{p_1}{p_2} \frac{T_2}{T_1} \frac{F_2}{F_1} = v_1 \frac{p_1}{p_2} \frac{(273.1+t_2)}{(273.1+t_1)} \frac{F_2}{F_1} \tag{15}$$

This is the general equation for converting volumes at high pressures.

If the volume at 1 atmosphere is to be calculated, p_2 and F_2 become equal to unity and equation (15) is reduced to

$$v_2 = v_1p_1 \frac{(273.1+t_2)}{(273.1+t_1) F_1} \tag{16}$$

The values of F_1 for temperatures intermediate between those represented by the isothermals can be approximately found by interpolation from the values of the two isothermals above and below the temperature in question, but a more accurate method consists of plotting the values at different temperatures (pressure constant) and interpolating from the curve.

The following problems will illustrate the use of equations (15) and (16):

A cylinder whose volume is 1.528 cubic feet contains hydrogen at 2,000 lbs./in.^{2} gauge pressure, the temperature being 87° F. What is the volume of the hydrogen at 1,400 lbs./in.^{2} and at 50° F.?

For convenience in obtaining F_1 and F_2 it is best to convert the pressures and temperatures to atmospheres and ° C. These equivalents can be found in Tables 13 and 14.

2,000 lbs./in.^{2} = 137.0 atms. abs.
1,400 lbs./in.^{2} = 96.25 atms. abs.
87° F. = 30.6° C.
50° F. = 10° C.
F_2(96.25 atms. and 10° C.) = 1.060.
F_1(137.0 atms. and 30.6° C.) = 1.082.

Substituting in equation (15) gives

$$v_2 = 1.528 \frac{137.0}{96.25} \frac{283.1}{303.7} \frac{1.060}{1.082} = 1.988.$$

$v_2 = 1.988$ cu. ft.

To find the volume at 1 atmosphere and 68° F.

$p_2 = 1 \quad F_2 = 1 \quad 68°\ \text{F.} = 20°\text{C.}$

From equation (16)

$$v_2 = 1.528 \frac{137.0}{1} \frac{293.1}{303.7} \frac{1}{1.082} = 187.0.$$

$v_2 = 187.0$ cu. ft.

The volume of hydrogen delivered from the cylinder, if the final pressure in the cylinder became one atmosphere, would, of course, be 1.5 cubic feet less than the above figure because this much gas would remain in the cylinder.

The volume delivered by the cylinder would therefore be 185.5 cubic feet.

4. SUMMARY OF IMPORTANT EQUATIONS.

Symbols:

p_1, v_1, T_1, and p_2, v_2, T_2 represent two sets of conditions of pressure, volume, and *absolute* temperature (on either the centigrade or Fahrenheit scale).

t_1 and t_2 represent the corresponding temperatures measured in degrees centigrade or degrees Fahrenheit.

R_1 and R_2 represent the values for the gas constant expressed in the same units as the corresponding pressure, volume, and temperature. The values for these constants can be obtained from Table 1, page 5.

P is the total pressure of a mixture of gas and vapor.

w is the vapor pressure of the liquid (or solid) in contact with the gas.

F_1 and F_2 represent factors for conversions involving high pressures. These factors are obtained from Figures 1 to 8.

$$v_2 = v_1 \frac{p_1 T_2}{p_2 T_1} \qquad \text{Equation (2)}$$

$$v_2 = v_1 \frac{p_1(273.1 + t_2)}{p_2(273.1 + t_1)} \qquad \text{Equation (3)}$$

t_1 and t_2 expressed in degrees centigrade

$$v_2 = v_1 \frac{p_1(459.6+t_2)}{p_2(459.6+t_1)} \qquad \text{Equation (4)}$$

t_1 and t_2 expressed in degrees Fahrenheit

$$N = \frac{pv}{RT} \qquad \text{Equation (6)}$$

$$v_2 = v_1 \frac{p_1 R_2 T_2}{p_2 R_1 T_1} \qquad \text{Equation (8)}$$

$$v_2 = v_1 \frac{(P_1 - w_1)\, T_2}{p_2 T_1} \qquad \text{Equation (9)}$$

$$v_2 = v_1 \frac{(P_1 - w_1)\, T_2}{(P_2 - w_2)\, T} \qquad \text{Equation (12)}$$

$$v_2 = v_1 \frac{p_1}{p_2} \frac{T_2}{T_1} \frac{F_2}{F_1} \qquad \text{Equation (15)}$$

If v_2 is to be measured at 1 atmosphere, the equation becomes

$$v_2 = v_1 p_1 \frac{T_2}{T_1 F_1} \qquad \text{Equation (16)}$$

5. CURVES SHOWING THE COMPRESSIBILITIES OF GASES (0 TO 200 ATM.)

In Figures 1 to 8 the values of $\frac{273.1}{T}\,pv$ are plotted against the pressure. These charts contain nearly all of the published data covering this range of temperature and pressure, and the curves are drawn according to what appear to be the most probable values.

6. CHARTS SHOWING THE VOLUMES OF SEVERAL GASES DELIVERED FROM CYLINDERS CONTAINING THE GASES AT HIGH PRESSURES

Figures 9 to 13 show the volume (measured at 68° F. and 1 atmosphere) of gas delivered from a cylinder if the pressure and temperature of the gas in the cylinder are known.

In each case the volume of the cylinder is assumed to be 1.528 cubic feet, which is the volume of the so-called "200-foot" cylinder. For a cylinder of any other capacity the volume delivered would be proportional to the volume of the cylinder. In other words, the figure obtained from the chart should be multiplied by $\frac{V}{1.528}$ where V is the volume (in cubic feet) of the cylinder in question.

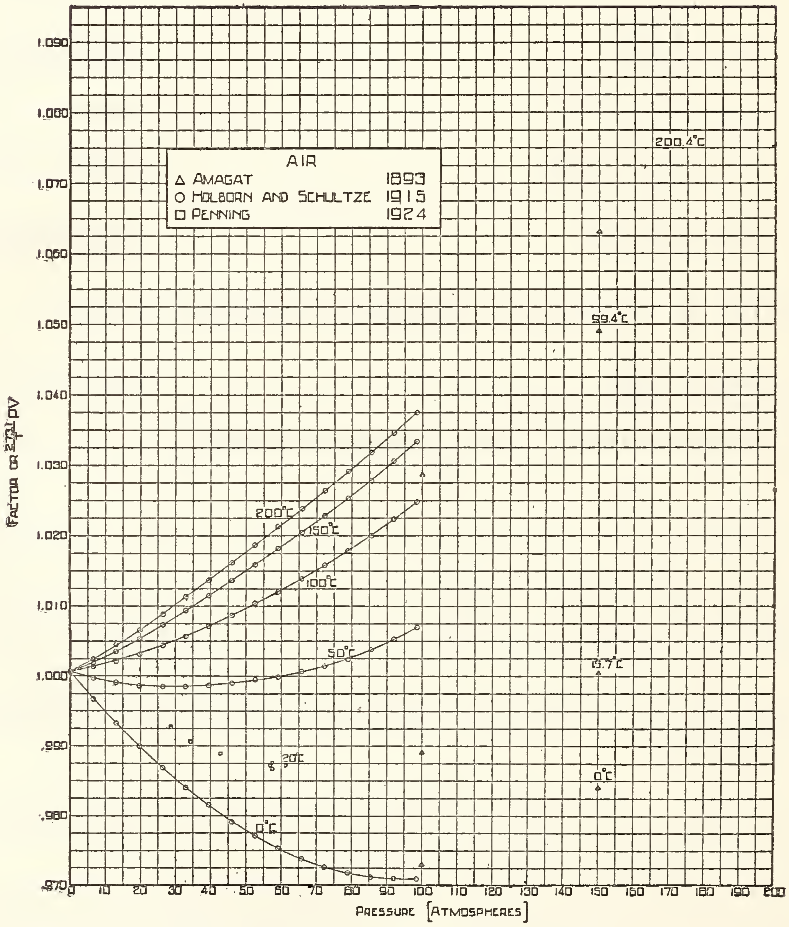

FIG. 1.—*The compressibility factors for air*

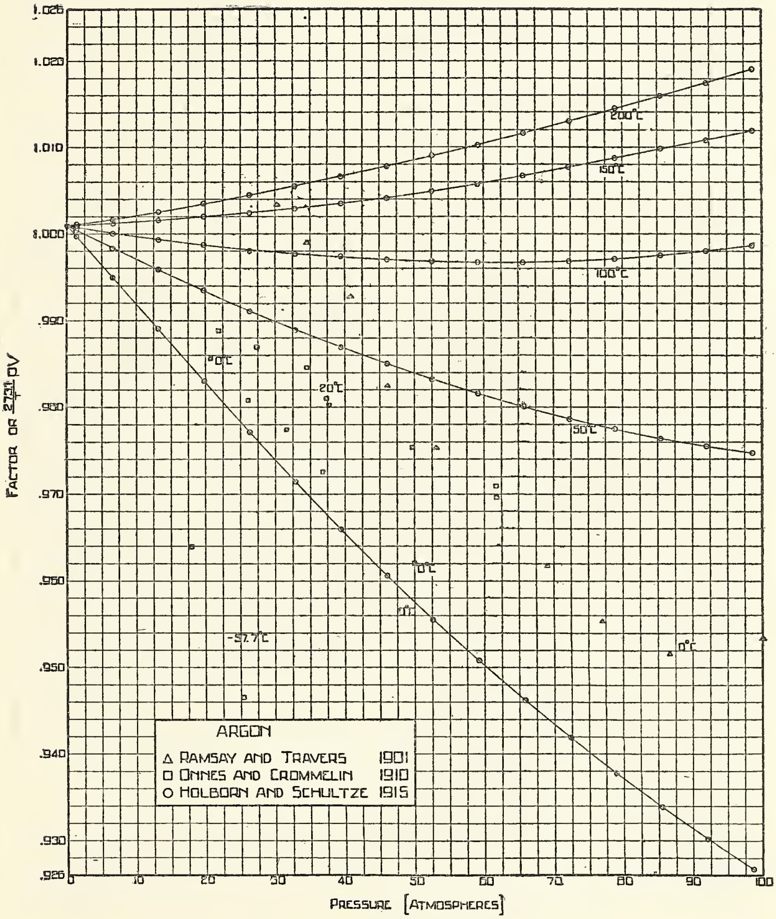

Fig. 2.—*The compressibility factors for argon*

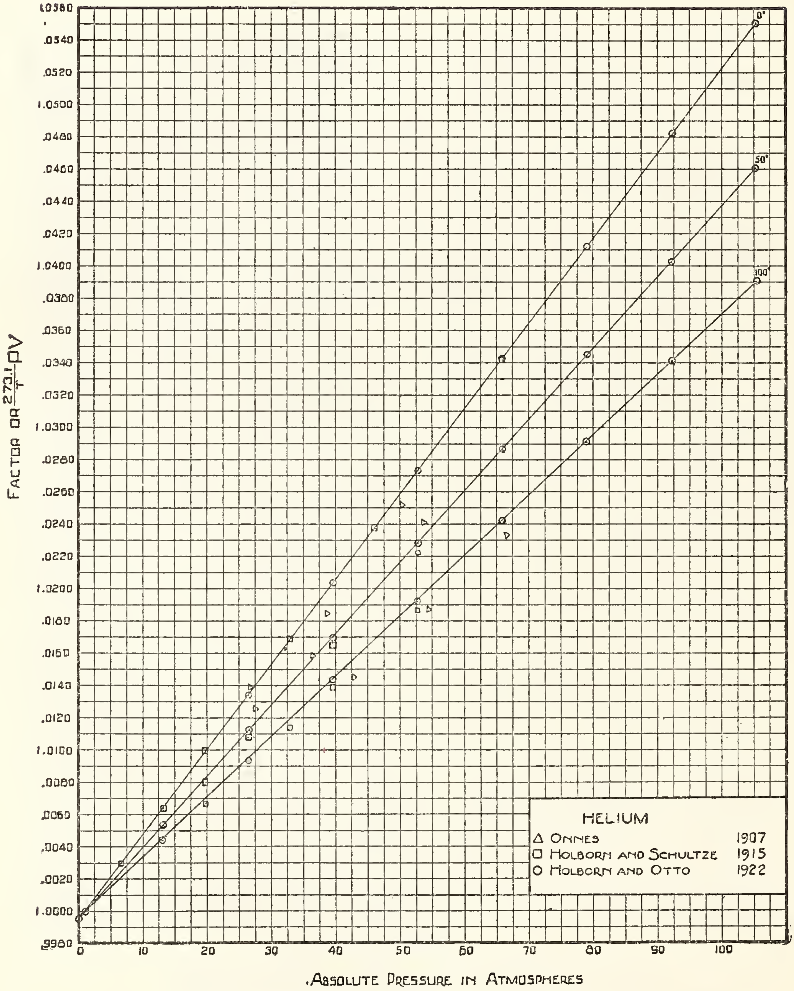

Fig. 3.—*The compressibility factors for helium*

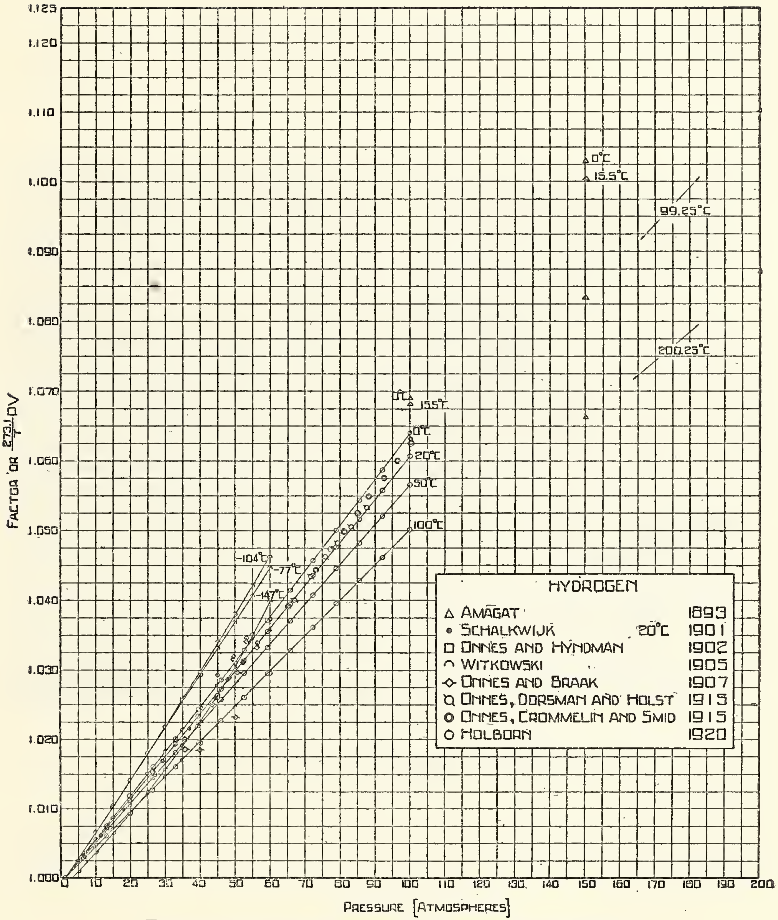

FIG. 4.—*The compressibility factors for hydrogen*

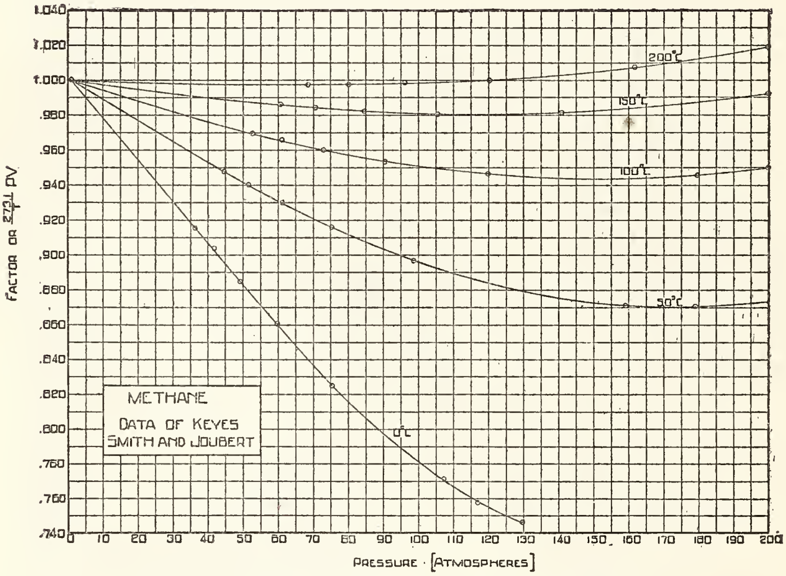

FIG. 5.—*The compressibility factors for methane*

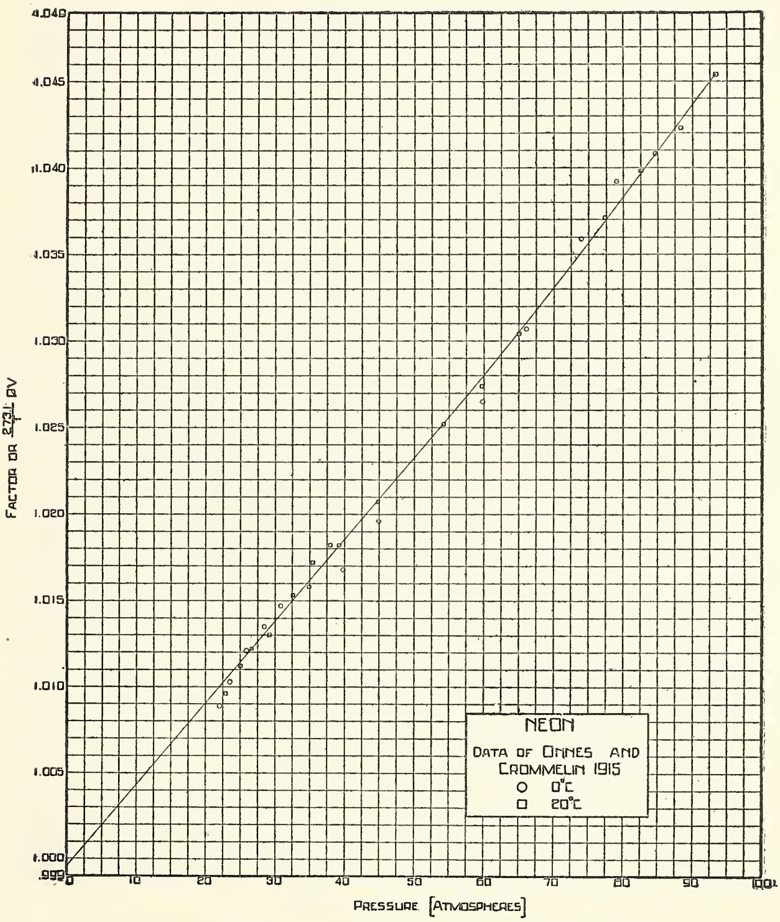

FIG. 6.—*The compressibility factors for neon*

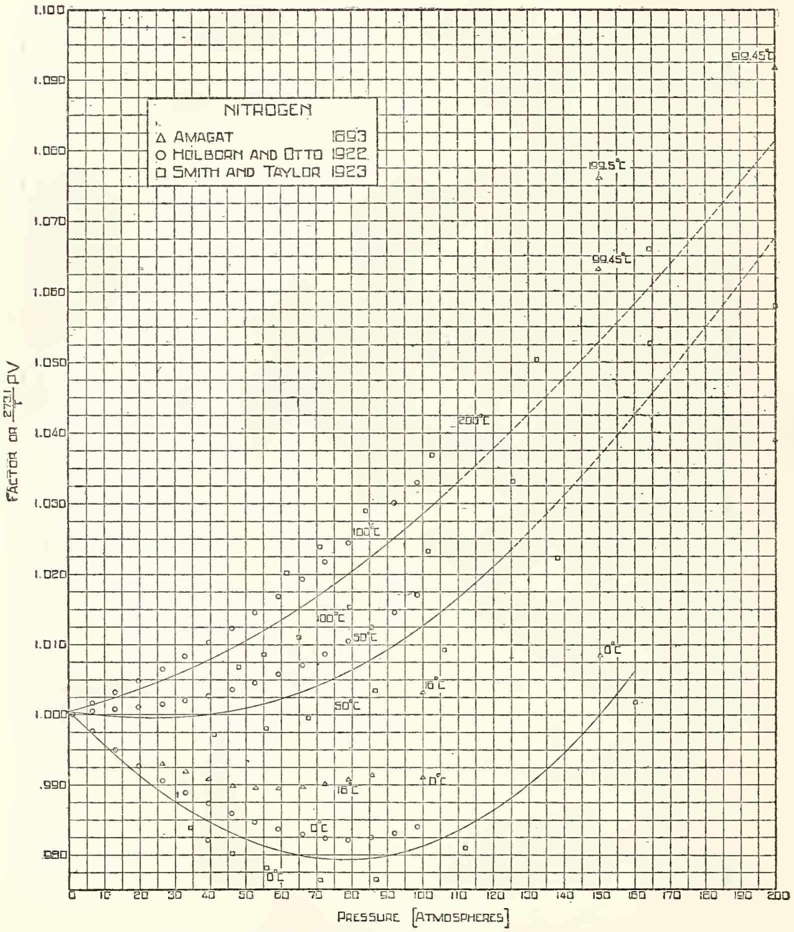

FIG. 7.—*The compressibility factors for nitrogen*

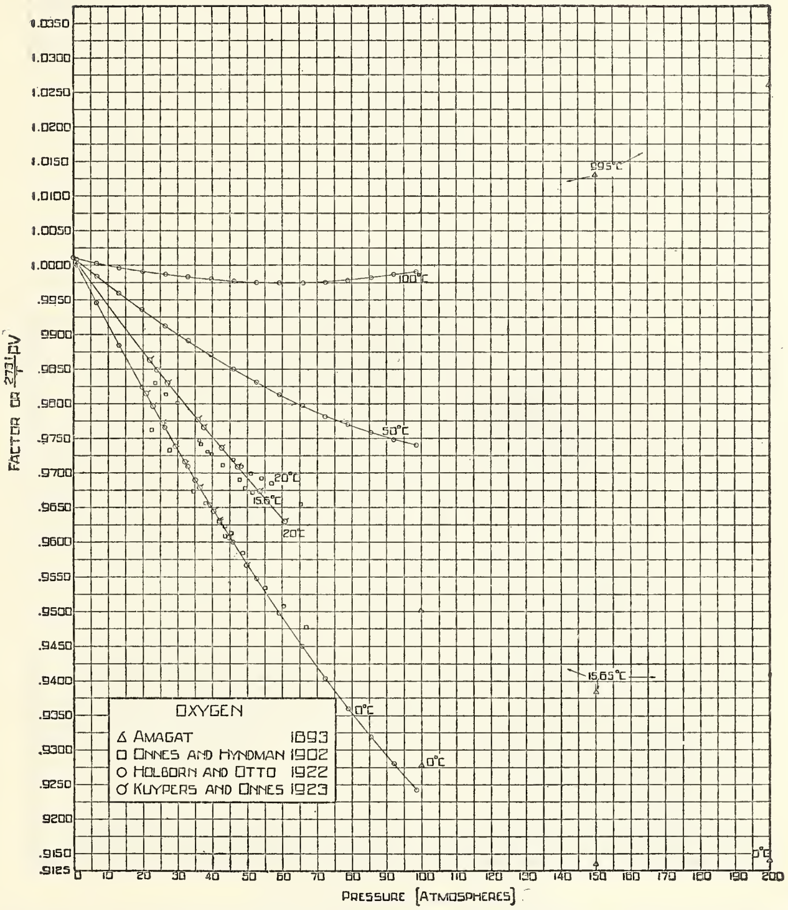

FIG. 8.—*The compressibility factors for oxygen*

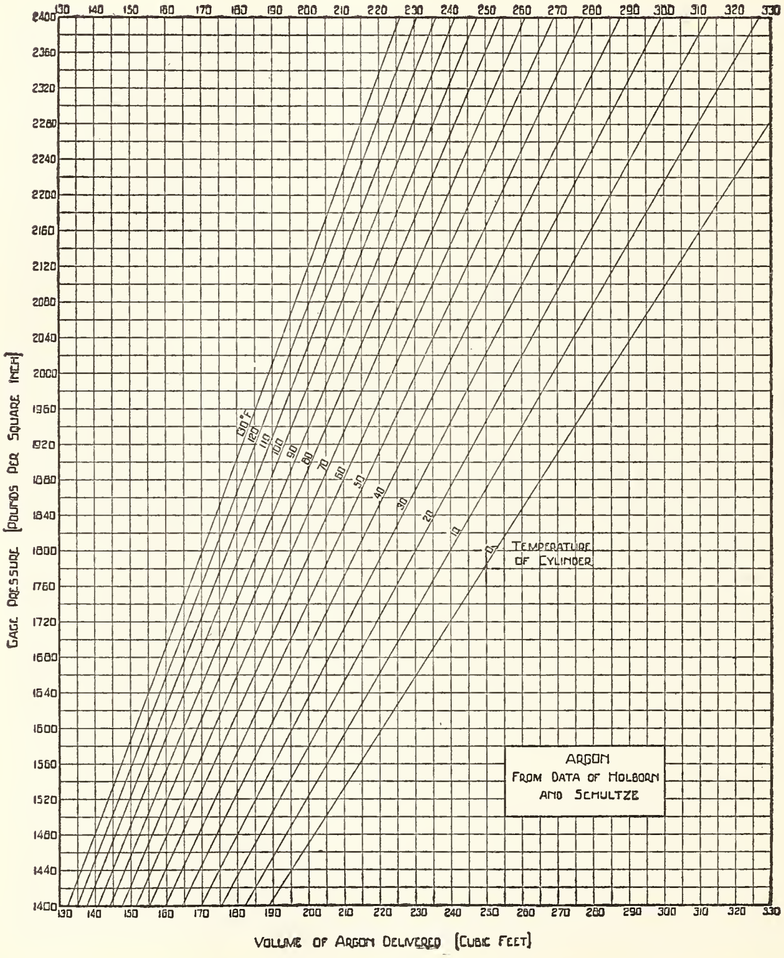

Fig. 9.—*Chart showing volume of argon (measured at 1 atm. and 68° F.) delivered from a cylinder whose volume is 1.528 cubic feet*

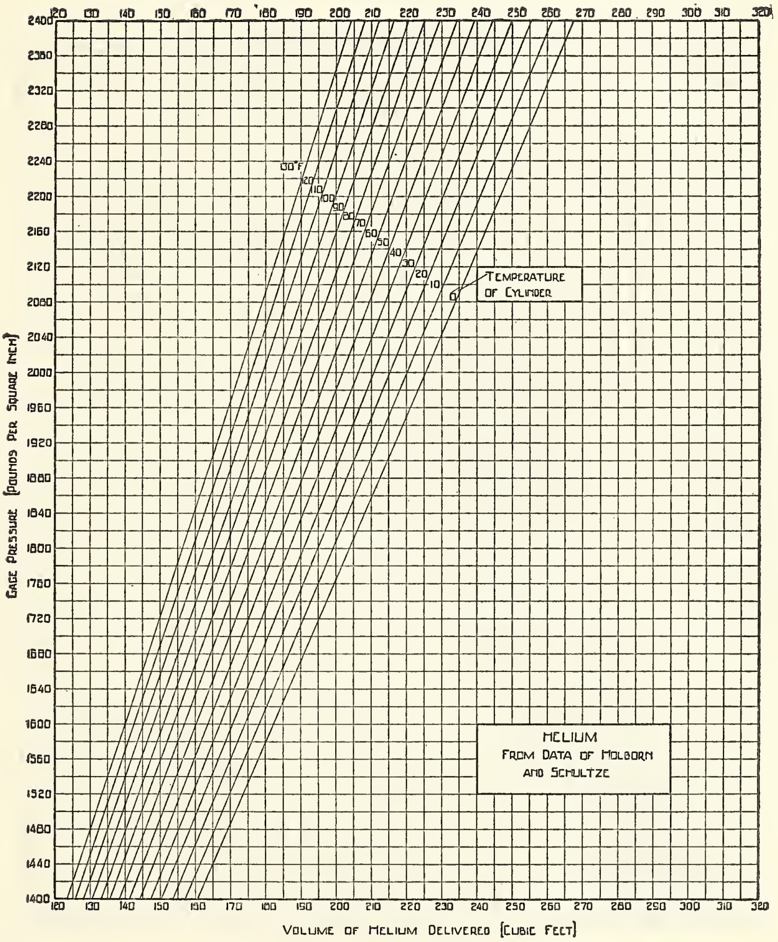

FIG. 10.—*Chart showing volume of helium (measured at 1 atm. and 68° F.) delivered from a cylinder whose volume is 1.528 cubic feet*

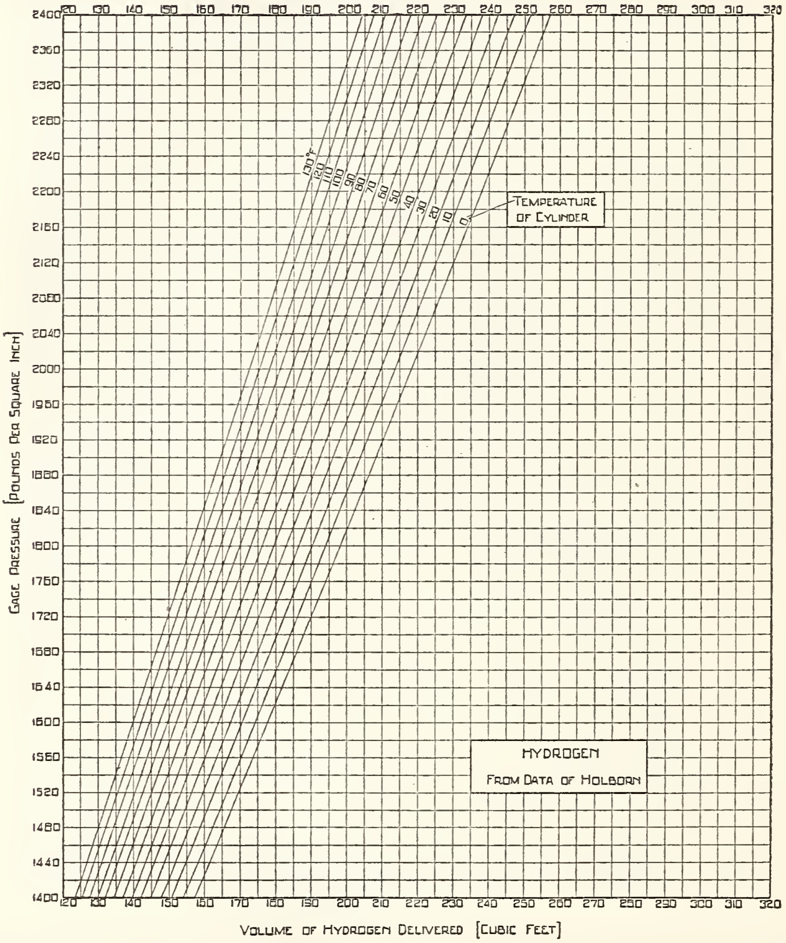

Fig. 11.—*Chart showing the volume of hydrogen (measured at 1 atm. and 68° F.) delivered from a cylinder whose volume is 1.528 cubic feet*

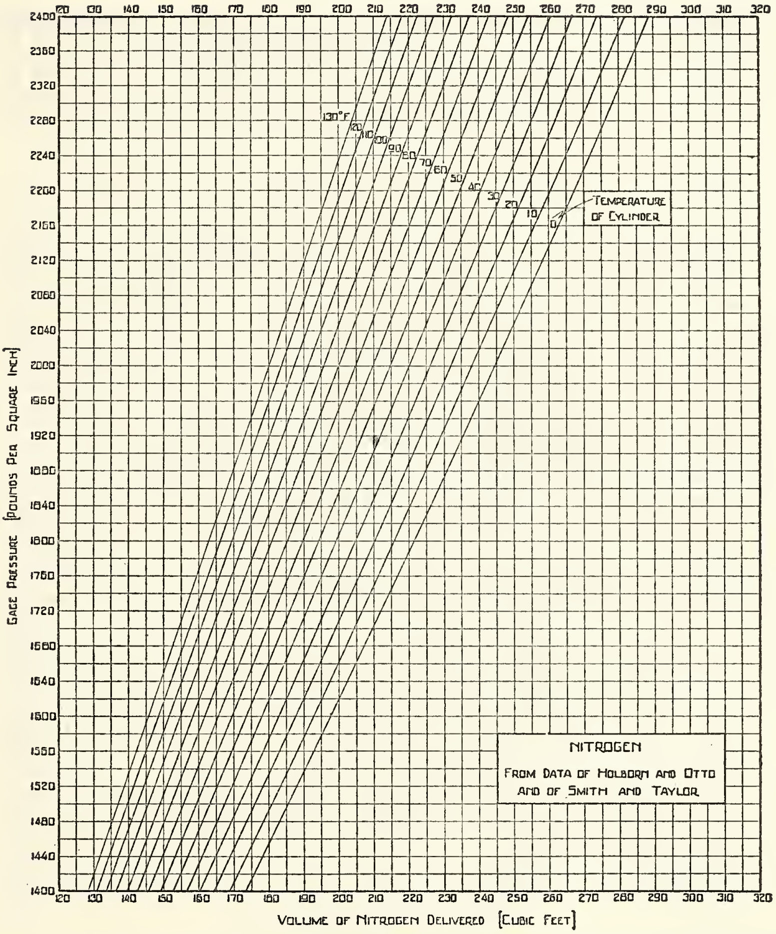

FIG. 12.—*Chart showing volume of nitrogen (measured at 1 atm. and 68° F.) delivered from a cylinder whose volume is 1.528 cubic feet*

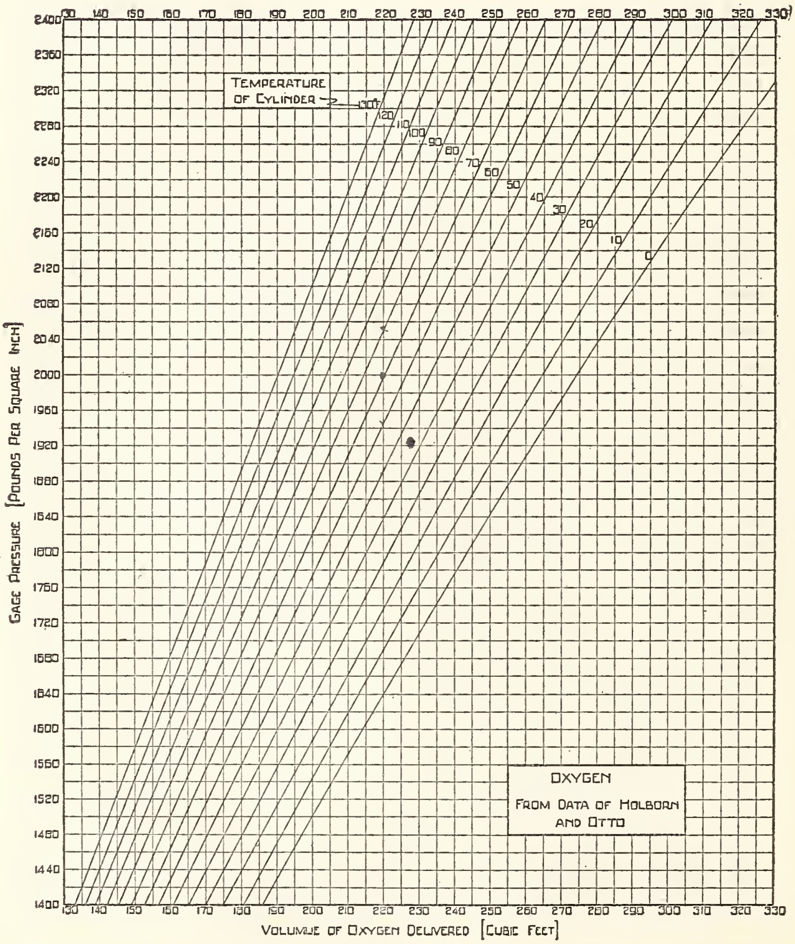

FIG. 13.—*Chart showing volume of oxygen (measured at 1 atm. and 68° F.) delivered from a cylinder whose volume is 1.528 cubic feet*

III. EQUATIONS OF STATE

1. SIMPLE LAWS

The pressure exerted by a gas on the walls of a container is explained by the kinetic theory as being due to the bombardment of the walls by the moving molecules of the gas. The velocities with which these molecules move are very large (the average velocity of the hydrogen molecules at 0° C. is about 1 mile per second) and become greater as the temperature is increased.

The general relations involving the temperature, pressure, and volume of a gas are expressed in the following well-known gas law:

$$pv = NRT \tag{17}$$

where p, v, and T represent the pressure, volume, and absolute temperature, respectively; R stands for a constant, which is the same for all gases; and N is the number of gram molecules of gas under consideration. A weight of a gas in grams numerically equal to the molecular weight is called a gram molecule of the gas (or mol). The derivation of the above relation can be found in most textbooks of physical chemistry and hence is not included in this paper.

This law is taken as part of the criteria of a perfect gas. The product of the pressure and volume of such a gas at constant temperature would be a constant at all pressures, while the expansion at either constant volume or constant pressure would be directly proportional to the temperature.

None of the actual gases, however, obey this law; although for most practical purposes nearly all of the common gases may be considered as ideal at or below atmospheric pressure and at temperatures reasonably higher than the condensation temperature. Ordinary corrections for temperature and pressure, for instance those which arise in measuring volumes of gases at normal room conditions, can be made without appreciable error. Such means of correction, however, can not be used when it is desired to know the volume of gas contained in a cylinder where the pressure may be around 1,800 lbs/in.^{2} or more. In such a case the product pv is no longer constant at different pressures, but may vary by 8 or 10 per cent.

It, therefore, becomes necessary either to use experimental data for making such calculations or to apply some equation which will predict with reasonable accuracy the behavior of a gas for which no compressibility data have been obtained.

The ideal gas law as derived involves the assumptions that there are no attractive forces between the molecules, and that the molecules themselves are mere points having no real volume. Since both of these assumptions are erroneous, it could hardly be expected that an equation based upon them would be accurate.

Over 100 equations of state, theoretical and empirical, have been devised to include these factors; but so far no satisfactory equation of general application has been presented whose constants are not empirical, thus requiring experimental data which it was desired to predict.

Fairly good approximations, however, are given by a few of the general equations, three of which will be considered here, namely, those of van der Waals, Dieterici, and Berthelot.

2. EQUATION OF VAN DER WAALS

Van der Waals, in taking into account the cohesive force between molecules, assumed that this force is proportional to the product of the masses of each volume element, this product being in turn proportional to the product of the densities. In the case of a pure gas the force would be proportional to the square of the densities or inversely proportional to the square of the volume. Inasmuch as this cohesive force diminishes the actual measured pressure, the theoretical pressure P in equation (17) is replaced by the term $\left(p+\frac{a}{v^2}\right)$. The actual free space for expansion of the gas would be the total volume less the volume of the molecules themselves, represented by (b) so that the term v in equation (17) is replaced by the term (v-b).

The equation of van der Waals, then, is

$$\left(p+\frac{a}{v^2}\right)(v-b)=NRT \tag{18}$$

where (a) and (b) are constants which are characteristic of each gas.

These constants can be evaluated in terms of the critical constants of the gas by introducing certain existing conditions at the critical point.[4] These relations are as follows:

$$a=\frac{27 N^2R^2T_c^2}{64 P_c} \tag{19}$$

$$b=\frac{NRT_c}{8P_c} \tag{20}$$

or

$$a=\frac{27}{8}NRT_c b \tag{21}$$

In these equations T_c and P_c represent critical temperature and pressure, respectively.

These relations have been derived with the elimination of the critical volume, for there is difficulty in accurately determining this quantity.

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[4] This derivation is given in many textbooks of physical chemistry, such as that of W. C. McC. Lewis, 1, p. 75.

Equation (18) can be more easily used for such computations by changing its form somewhat. Transposing, the equation gives

$$p=\frac{NRT}{v-b}-\frac{a}{v^2} \tag{22}$$

multiplying both sides by v

$$pv=\frac{NRT}{1-\frac{b}{v}}-\frac{a}{v}$$

Perhaps the most confusing difficulty connected with the use of the equations of state is the selection of proper units for the various terms in the equation. In some cases the values of (a) and (b) are given in tables of constants without indicating the units used. The empirical values for these constants are obtained by choosing two points on an isotherm and solving for the constants, and it is obvious that the shape of the curve obtained will depend upon the particular fixed points chosen.

In computing the curves of the three equations of state as shown in Figures 14 to 22, the value of pv at 0 atmosphere pressure and 0° C. is taken as unity. Since v becomes infinite

$$p_0v_\infty=\frac{NRT_0}{1-\frac{b}{\infty}}-\frac{a}{\infty}=NRT_0=1$$

that is, the gas acts as a perfect gas when

$$p=0$$

It follows that when $p_0v_\infty=1$

$$NR=\frac{1}{T_0}=\frac{1}{273.1}$$

and equations (20) and (19) become

$$b=\frac{T_c}{(273.1)8P_c},\ a=\frac{27T_c^2}{(273.1)^2\,64\,P_c}$$

This is the value of NR used to calculate (a) and (b), and naturally all three terms must be expressed in the same system of units. Since

$$NR=\frac{1}{273.1}$$

it follows that the values of T_c used for evaluating (a) and (b) must be expressed in ° C. absolute. For convenience p_c is expressed in atmospheres, thereby necessitating the use of this unit for all subsequent computations involving (p).

Substituting $\frac{1}{273.1}$ for NR in equation (22) gives

$$p=\frac{T}{273.1\ (v-b)}-\frac{a}{v^2} \tag{23}$$

which is a convenient form for calculating pv for all temperatures.

Inasmuch as the equation of van der Waals is a cubic with respect to v, it is simpler to assume values for v and calculate (p) by means of equation (23).

It will be seen from Figures 14 to 22 that this equation, while indicating qualitatively the pv relations, is very inaccurate quantitatively except in the case of the gas, neon. In reality, however, the quantities (a) and (b) are not constants, but are generally accepted as being functions of both temperature and pressure.[5] Calculations involving the corrections of these "constants" are too involved for use in practical calculations and will, therefore, be left out of consideration. Hence the discussions of these equations of state, apply only in so far as the constants (a) and (b) are calculated directly from the critical constants and are considered as invariants.

It is quite evident that while this equation has been of great service in the study of liquids and gases and is quite valuable in a general way, it is not particularly useful for the present purpose.

3. EQUATION OF DIETERICI

Referring to equation (22)

$$p=\frac{NRT}{v-b}-\frac{a}{v^2}$$

it is seen that the pressure is, according to van der Waals' term $\frac{NRT}{v-b}$, diminished, because of the attractive forces between the molecules, by the quantity $\frac{a}{v^2}$.

Dieterici,[6] instead of substracting a term from $\frac{NRT}{v-b}$, multiplies it by a quantity which at any pressure is never greater than unity. The term which he introduced is $e^{-\frac{A}{RTv}}$ where e is the base of the natural logarithms (2.7183), A the constant involving the cohesive effect of the molecules, and R, T, and v have their usual significance.

The equation thus becomes

$$p=\frac{NRT}{v-b}e^{-\frac{A}{RTv}} \tag{24}$$

a revised form being

$$p=\frac{NRT}{v-b}e^{-\frac{a}{T^{1.27}v}} \tag{25}$$

This equation was derived by assuming that since in the interior of the gas the cohesive forces are effective in all directions they are

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[5] F. H. MacDougal, J. Am. Chem. Soc., 38, p. 528; 1916. T. H. Richards, J. Am. Chem. Soc., 36, p. 617; 1914.

[6] Dieterici, Ann. Physik u. Chem., 11, p. 700; 1899; Ann. Physik, 5, p. 51; 1901.

neutralized, and hence do not affect the molecules. At the surface of the gas, however, the molecules are pulled toward the interior and the effective pressure would be reduced. This equation is fully discussed in a paper by F. H. MacDougal.[7]

The relations between a and b and the critical constants are as follows:

$$a = 4b\,T_c^{1.27} \tag{26}$$

$$b = \frac{NRT_c}{P_c\,e^2} \tag{27}$$

Multiplying equation (25) by v gives

$$pv = \frac{NRT}{1 - \frac{b}{v}}\,e^{-\frac{a}{T^{1.27}v}}$$

and when $p = o$ and $v = \infty$

$$pv = \frac{NRT_o}{1 - \frac{b}{\infty}}\,e^{-\frac{x}{T_o^{1.27}\infty}} = NRT_o$$

$$NR = \frac{1}{T_o} = \frac{1}{273.1}$$

as before

Substituting this value for NR in equation (27) gives

$$b = \frac{T_c}{273.1\,P_c\,e^2}$$

The same substitution in equation (25) gives

$$p = \frac{T}{273.1\,(v - b)}\,e^{-\frac{a}{T^{1.27}v}} \tag{28}$$

where

$$b = \frac{T_c}{273.1\,P_c\,e^2} \text{ and } a = 4b\ T_c^{\ 1.27}$$

For computing p at different volumes by means of equation (25) the values of $e^{-\frac{a}{T^{1.27}v}}$ can be conveniently obtained from mathematical tables after the exponent has been calculated.

From the accompanying figures it can be seen that Dieterici's equation, while not particularly applicable to gases at temperatures considerably above their critical temperatures, reproduces quite well the experimental data for gases in the neighborhood of their critical temperatures.

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[7] F. H. MacDougal, J. Am. Chem. Soc., 38, p. 528; 1916.

4. EQUATION OF BERTHELOT

The equation of Berthelot[8] was derived from van der Waals's equation by replacing the quantities (*a*) and (*b*) with their equivalent values in terms of the critical constants and by introducing an experimental relation in the place of a relation deduced from van der Waals's equation.[9]

Berthelot's equation may be stated as follows:

$$\left[\frac{p}{P_c}+\frac{16}{3}\frac{T_c}{T}\frac{V_c{}^2}{v^2}\right]-\left[\frac{v}{V_c}-\frac{1}{4}\right]=\frac{32}{9}\frac{T}{T_c} \tag{29}$$

The equation of Berthelot as sometimes given in textbooks

$$pv=NRT\left[1+\frac{9pT_c}{128P_cT}\left(1-6\frac{T_c{}^2}{T^2}\right)\right]$$

is a simplification of equation (29) and involves an assumption which is true only for small pressures. It can be seen from this equation that *pv* is a linear function of the pressure; that is, the isothermals would be straight lines. This equation, however, was derived for use in molecular weight determinations based upon the densities of gases and is to be used only over a pressure range of 0 to 1 atmosphere.

It is obvious that equation (29) does not hold at the critical point for then p, T, and v are replaced by P_c, T_c, and V_c, respectively, and the equation becomes

$$\left[1+\frac{16}{3}\right]\left[1-\frac{1}{4}\right]=\frac{32}{9}$$

or

$$\frac{171}{36}=\frac{128}{36}$$

Furthermore, the equation contains the undesirable term V_c. Upon solving the equation for *pv* and setting this term equal to unity when $p=o$, $v=\infty$, and $T=273.1$, there is obtained a relation between V_c, P_c, and T_c by means of which V_c can be eliminated from the original equation. The selection of 273.1° for the temperature at which $p_o\,v\infty$ equals unity is purely arbitrary and the relation of V_c to P_c and T_c would be different if some other temperature were used. In any case, however, V_c would always be proportional to $\frac{T_c}{P_c}$ and since the value of $p_o\,v\infty$ (when $T=273.1°$) is the unit the final results would be the same.

Transposing equation (29)

$$p=\frac{32}{9}\frac{TP_c}{T_c}\left(\frac{4V_c}{4v-V_c}\right)-\frac{16}{3}\frac{T_c}{T}\frac{V_c{}^2P_c}{v^2} \tag{30}$$

$$pv=\frac{32}{9}\frac{T}{T_c}P_c\left(\frac{4V_c}{4-\frac{V_c}{v}}\right)-\frac{16}{3}\frac{T_c}{T}\frac{V_c{}^2P_c}{v}$$

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[8] Berthelot Trav. et Mem. Bur. intern. Poids. et Mes., p. 113; 1903.

[9] Jellinck, Lehrbuch der Physikalischen Chemie, 2, p. 167.

setting $pv=1$, when $p=o$, $v=\infty$ and $T=273.1$

$$1=\frac{32}{9}\,\frac{(273.1)\,P_c V_c}{T_c}$$

or

$$V_c=\frac{9\,T_c}{32\,(273.1)\,P_c}=\frac{0.001030\,T_c}{P_c}$$

substituting in (30)

$$p=\frac{32}{9}\,\frac{TP_c}{T_c}\,\frac{4\,(9\,T_c)}{32\,(273.1)\,P_c\left(4\,V-\frac{0.001030\,T_c}{P_c}\right)}$$

$$-\frac{16}{3}\,\frac{T_c}{T}\,\frac{0.0000010605\,T_c^2\,P_c}{P_c^2\,v^2}$$

$$p=\frac{T}{273.1\left(v-\frac{0.0002575\,T_c}{P_c}\right)}-\frac{0.000005656\,T_c^3}{TP_c\,v^2} \qquad (31)$$

For the 0° C. isothermal

$$p=\frac{1}{v-\frac{0.0002575\,T_c}{P_c}}-\frac{0.00000002070\,T_c^3}{P_c\,v^2} \qquad (32)$$

Equation (31) can be put in the following form:

$$p=\frac{T}{273.1(v-b)}-\frac{a}{Tv^2} \qquad (33)$$

in which

$$b=\frac{0.0002575\,T_c}{P_c}$$

$$a=\frac{0.000005656\,T_c^3}{P_c}$$

This equation is seen to be similar to that of van der Waals, equation (23), excepting that the term T is introduced into the denominator of van der Waals' term $\frac{a}{v^2}$, and the constants (a) and (b) are different functions of the critical constants.

In most cases, however, this equation appears to fit better than the others the experimental data of gases at temperatures considerably above the critical. For gases such as ethylene and carbon dioxide at 0° C., however, that of Dieterici is to be preferred.

Table 2 indicates which of the three equations would probably give the best results for each of the various gases at ordinary temperatures, and gives for each gas the values of the constants (a) and (b). The evaluation of these constants necessitates a knowledge of the critical constants of the various gases, and because of the importance of these properties and the lack of recent reliable tables a critical review of the work in this field has been prepared from which the values given in Table 2 have been selected. This review will appear in a forthcoming publication of the Bureau of Standards.

TABLE 2

Gas	Critical temperature (°C.abs.)	Pressure range, atmospheres	Equation for 0° C. isothermal	Values of constants	
				$p_0 v_\infty = RT = 1$	
				a	*b*
Helium	5.2	Total	Berthelot	0.00035	0.00058
Hydrogen	33.2	do	do	.0162	.000668
Neon	44.4	do	Van der Waals	.000414	.000756
Nitrogen	126.0	0–200	Berthelot	.3377	.000969
Do		200–600	Van der Waals	.002677	.001720
Do		Above 600	Dieterici	3.467	.001865
Carbon monoxide	134.4	0–200	Berthelot	.3969	.001000
Do		200–600	Van der Waals	.002952	.001778
Do		Above 600.	Dieterici	3.887	.001925
Argon	151	0–200	Berthelot	.406	.000810
Oxygen	154.3	0–200	do	.4181	.000800
Do		200–600	Van der Waals	.002710	.001421
Do		Above 600	Dieterici	3.700	.001538
Nitric oxide	179	0–200	Berthelot	.4646	.000653
Methane	190.6	0–100	do	.8570	.001074
Do		100–300	Van der Waals	.00450	.00191
Ethylene	282.8	0–100	Dieterici	14.32	.00276
Carbon dioxide	304.1		Same for all gases with higher critical temperatures.	11.79	.00207
Ethane	305.2			17.73	.00310
Acetylene	309			14.4	.00247
Nitrous oxide	309.6			12.46	.00214
Hydrogen chloride	324.5			12.18	.00197
Propane	368.7			28.8	.0042
Ammonia	405.5			14.78	.00180
Chlorine	417.1			23.13	.00272

Van der Waals's equation—equation (23).
Dieterici's equation—equation (28).
Berthelot's equation—equation (33).

5. CURVES COMPARING EQUATIONS OF STATE WITH EXPERIMENTAL DATA

In Figures 14 to 22 the experimental data on the compressibilities of various gases for pressures up to 1,000 atmospheres are compared with the data calculated from the equations of state of van der Waals, of Dieterici, and of Berthelot.

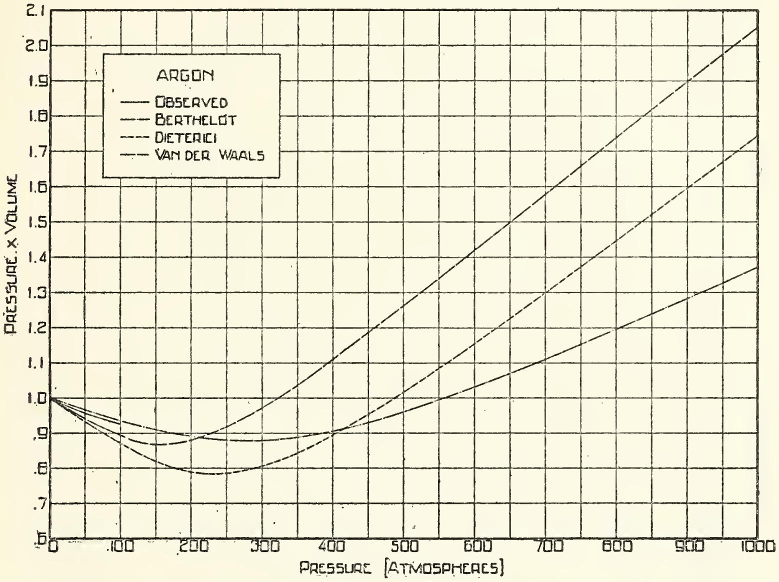

FIG. 14.—*Comparison of the experimental data on the compressibility of argon at 0° C. with those calculated from the equation of Berthelot, of Dieterici, and of van der Waals*

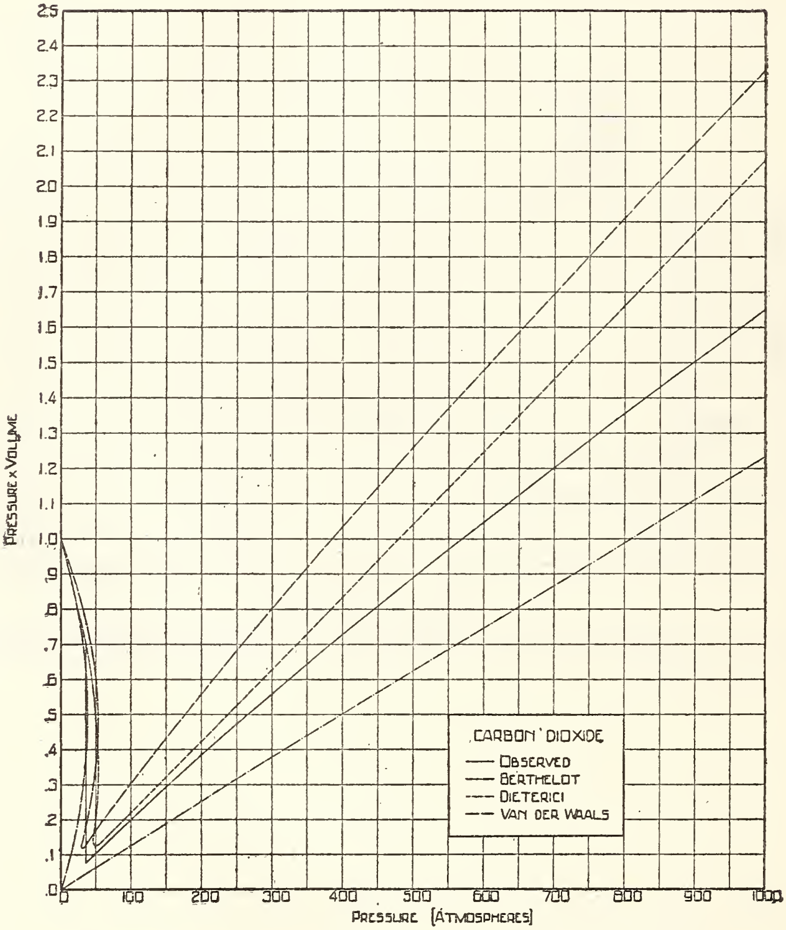

FIG. 15.—*Comparison of the experimental data on the compressibility of carbon dioxide at 0° C. with those calculated from the equation of Berthelot, of Dieterici, and of van der Waals*

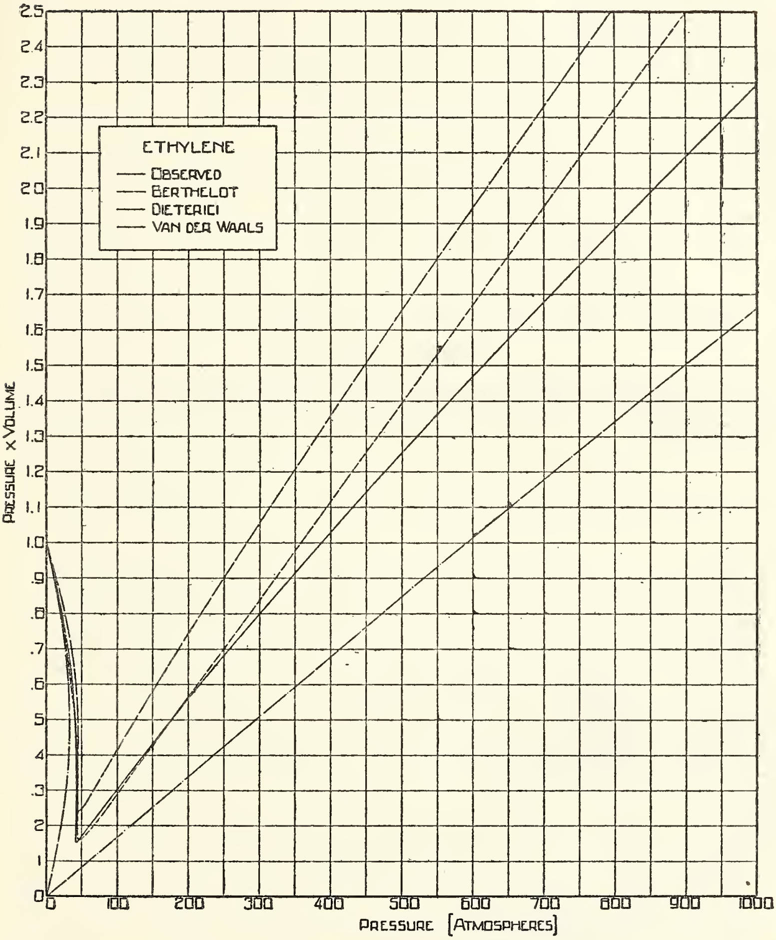

FIG. 16.—*Comparison of the experimental data on the compressibility of ethylene at 0° C. with those calculated from the equation of Berthelot, of Dieterici, and of van der Waals*

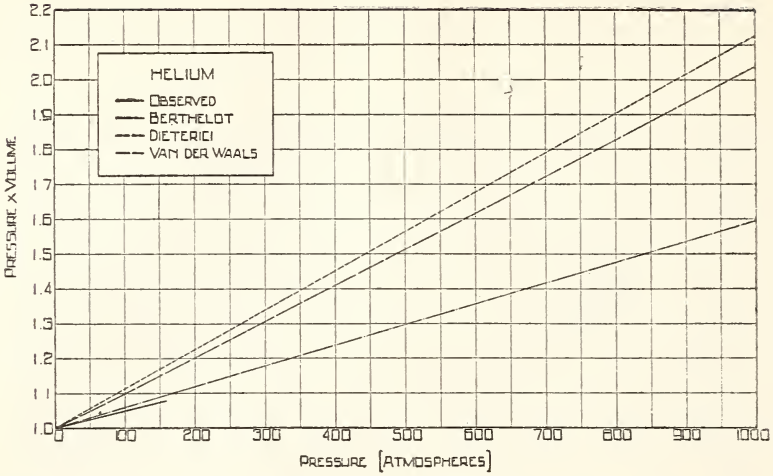

Fig. 17.—*Comparison of the experimental data on the compressibility of helium at 0° C. with those calculated from the equation of Berthelot, of Dieterici, and of van der Waals*

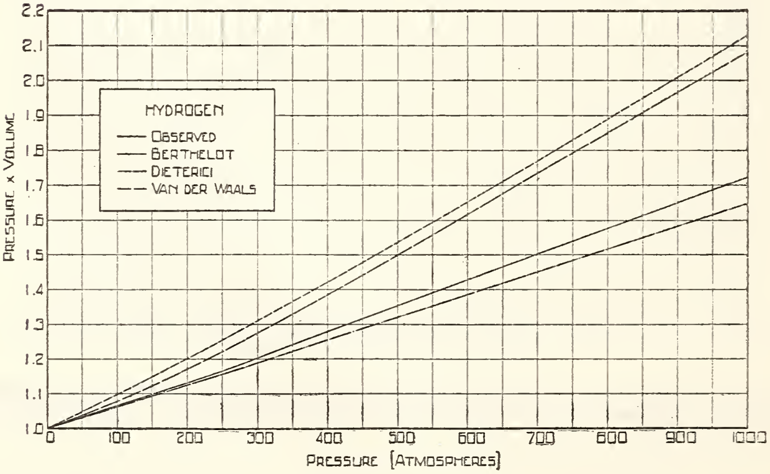

Fig. 18.—*Comparison of the experimental data on the compressibility of hydrogen at 0° C. with those calculated from the equation of Berthelot, of Dieterici, and of van der Waals*

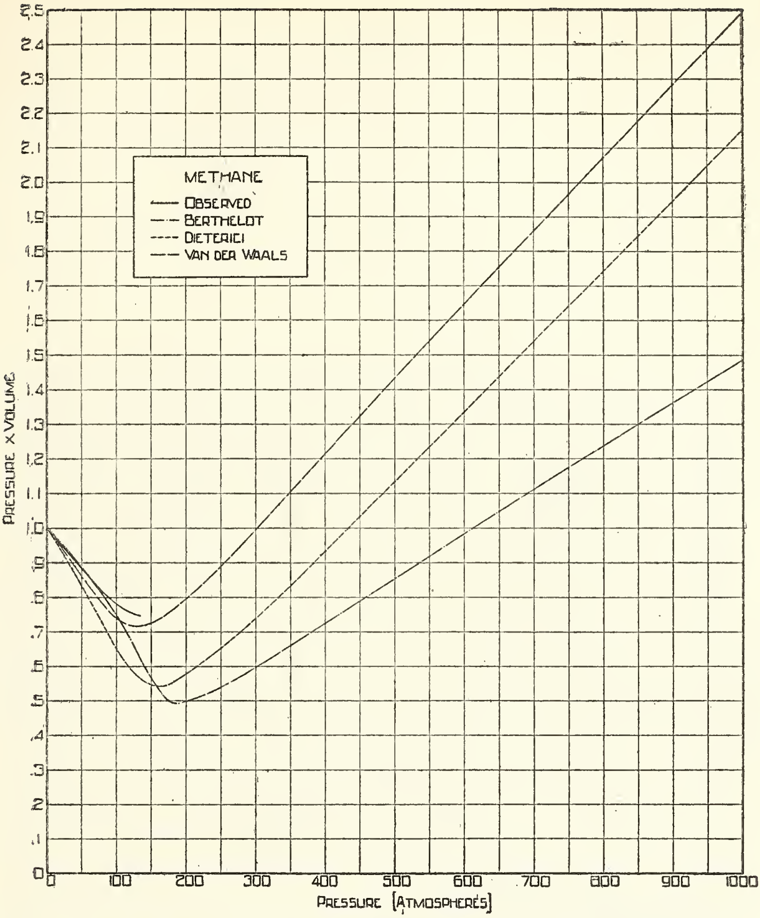

FIG. 19.—*Comparison of the experimental data on the compressibility of methane at 0° C. with those calculated from the equation of Berthelot, of Dieterici, and of van der Waals*

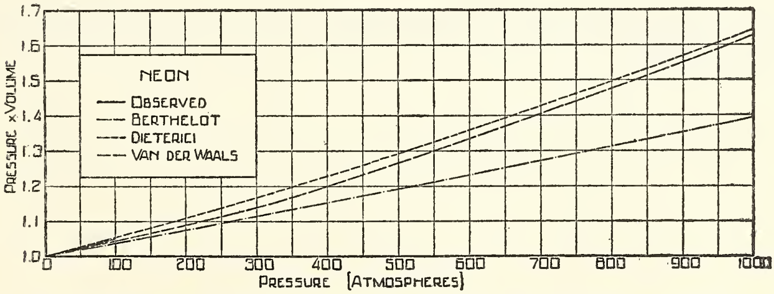

FIG. 20.—*Comparison of the experimental data on the compressibility of neon at 0° C. with those calculated from the equation of Berthelot, of Dieterici, and of van der Waals*

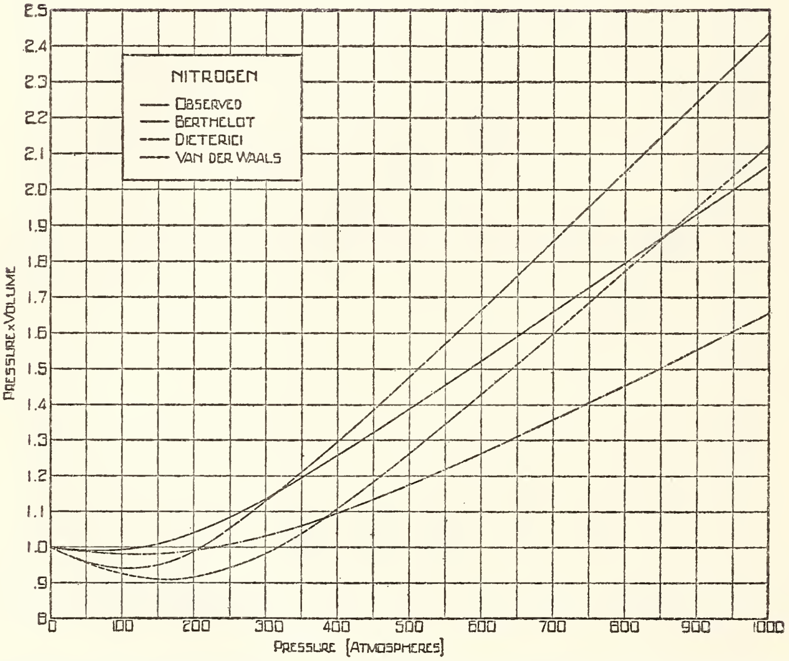

FIG. 21.—*Comparison of the experimental data on the compressibility of nitrogen at 0° C. with those calculated from the equation of Berthelot, of Dieterici, and of van der Waals*

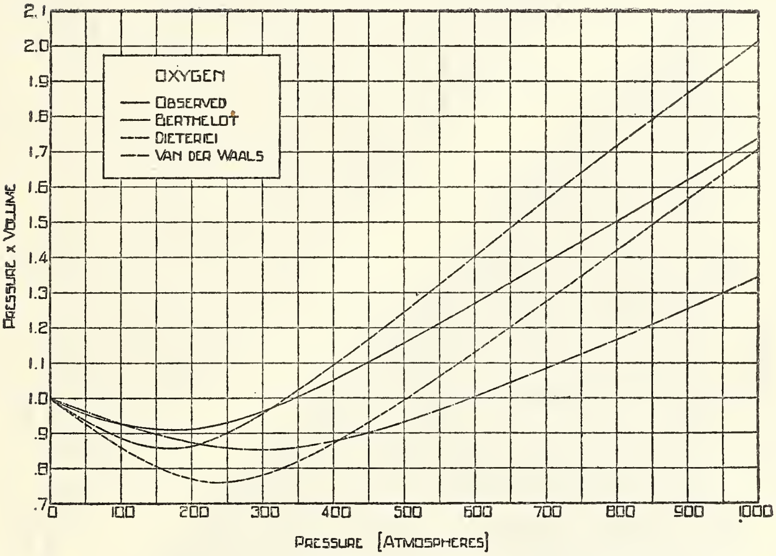

FIG. 22.—*Comparison of the experimental data on the compressibility of oxygen at 0° C. with those calculated from the equation of Berthelot, of Dieterici, and of van der Waals*

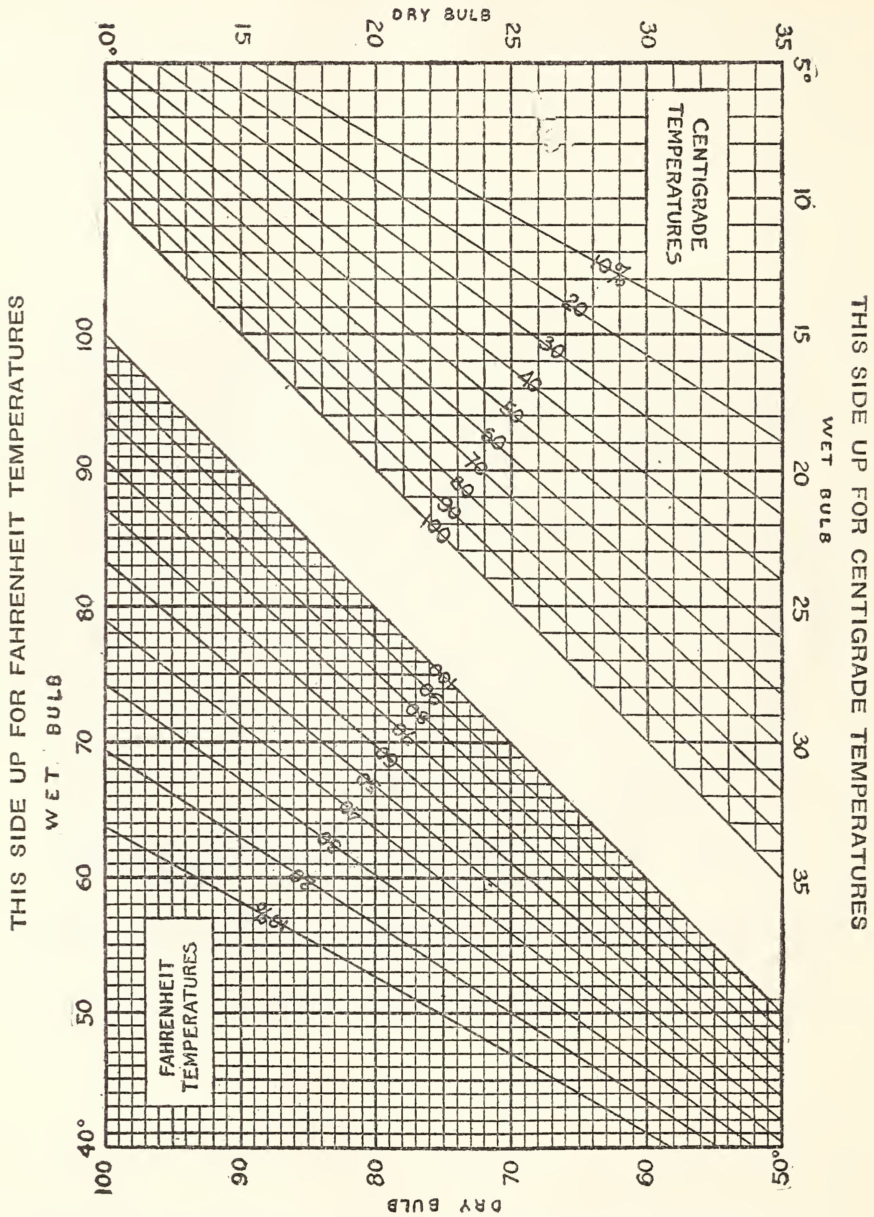

FIG. 23.—*Relative humidity from wet and dry bulb thermometer readings for psychrometer with rapid ventilation*

[Calculated for a barometer height of 755 mm. At altitudes of 6,000 feet or over the reduction in barometric pressure will cause an error of 5 per cent or over at very low humidities]

6. GAS CONSTANT *R* AND THE VOLUME OF A GRAM MOLECULE OF A PERFECT GAS

It is easy to obtain the value of the gas constant R and of the volume of a gram molecule of a perfect gas if the volume of a gram molecule of a particular gas at a given temperature and pressure is known, together with the value for the change in the product pv between the given pressure and zero pressure. The weights of a normal liter of the gases are given in Table 8 and the value of $\frac{p_0v_0}{p_1v_1}$ at 0° C. have been measured rather accurately for several of the gases so that the above-mentioned quantities can be calculated without introducing any considerations of the theoretical equations of state.

It might be of interest to compare the values of these constants as obtained from data on various gases.

$\frac{M}{L_n} = V_0$ for the particular gas at 1 atmosphere and 0° C.

where M = molecular weight

L_n = weight of 1 liter of gas at 0° C. and 760 mm (at 0° C.) where the acceleration of gravity is 980.665 cm per second per second.

V_0 = volume of 1 g molecule.

If p_0v_0 = value of pv of an actual gas at zero pressure 0° C., then, since an actual gas at zero pressure behaves as a perfect gas p_0v_0 = value of pv of perfect gas at 1 atmosphere (760 mm) 0° C.

Let p_1v_1 = value of pv of an actual gas at 1 atmosphere (760 mm) 0° C.; then $\frac{M}{L_n}\frac{p_0v_0}{p_1v_1} = V_0$ for a perfect gas at 1 atmosphere and 0° C. Since $pv = NRT$ for a perfect gas, and since $v = V_0$ when $N = 1$ and $p = p_1 = 1$

$$p_1V_0 = RT$$

$$R = \frac{p_1V_0}{T} = \frac{1}{273.1}\frac{M}{L_n}\frac{p_0v_0}{p_1v_1}$$

In Table 3 are given the values for R and for the gram molecular volume of a perfect gas at 1 atmosphere and 0° C. calculated from data on the gases hydrogen, nitrogen, oxygen, and carbon dioxide for which the most accurate figures have been obtained.

TABLE 3.—*0° C.=273.1°, absolute*

Gas	Weight of a normal liter in grams	Molecular weight [1]	$\frac{p_0v_0}{p_1v_1}$	Gram molecular volume (in liters) of perfect gas at 1 atmosphere and 0° C.	R, liters per gram molecular atmosphere
Hydrogen	0.08988	2.016	[2, 3, 4, 5] 0.99939	22.416	0.08208
Nitrogen	1.2506	28.016	[4, 6, 7, 8] 1.00052	22.414	.08207
Oxygen	1.4290	32.000	[3, 6, 7, 9, 10] 1.00094	22.414	.08207
Carbon dioxide	1.9769	44.000	[3] 1.00706	22.415	.08208
Means				22.415	.08208

[1] From International Atomic Weights for 1925.
[2] Holborn, Ann. Physik, **63**, p. 674; 1920.
[3] Guye and Batuecas, J. chim. phys., **20**, p. 308; 1923.
[4] Henning and Heuse, Z. Physik, **5**, p., 285; 1921.
[5] Onnes and Braak, Proc. Acad. Sci., Amsterdam, **10**, p. 413; 1908. Comm. Leyden, **100a**; 1908.
[6] Holborn and Otto, Z. Physik, **10**, p. 367; 1922.
[7] Maverick, Thesis Univ. of Geneva; 1923.
[8] Smith and Taylor, J. Am. Chem. Soc., **45**, p. 2107; 1923.
[9] Jaquerod and Scheuer, Compt. rend. **140**, p. 1384; 1905.
[10] Kuypers and Onnes, Comm. Leyden, **165c**; 1923.

Inasmuch, however, as the molecular weights of these gases are subject to change, it seems best to calculate these constants from the data on oxygen only as proposed by Henning[10] because this gas is the standard from which molecular weights are computed. The value for the *G. M. V.* of a perfect gas at 1 atmosphere and 0° C. then becomes

$$G.\ M.\ V. = 22.414$$

and

$$R = 0.08207$$

Berthelot,[11] by calculating from experimental data on the density and compressibility of several gases, obtained

$$G.\ M.\ V. = 22.412$$

Henning,[10] using 1.4291 g/L for L_n and 1.00099 for the coefficient of compressibility of oxygen, found

$$G.\ M.\ V. = 22.414$$

Keyes,[12] by means of his equation of state, the densities and molecular weights of several gases, found

$$G.\ M.\ V. = 22.413$$

The values for R given by these investigators are

	R	Absolutes
Berthelot	0.08207	using 0° C.=273.09
Henning	.08204	using 0° C.=273.2
Keyes	.08206	using 0° C.=273.134

The values adopted for use in the new International Critical Tables are

$$G.\ M.\ V. = 22.4115$$

$$R = 0.08206$$

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[10] Henning. Z. Physik, **6**, p. 69; 1921.
[11] Berthelot. Z. Elektrochemie, **10**, p. 621; 1904.
[12] Keyes. J. Am. Soc. Refrig. Eng., **8**, p. 505; 1922.

IV. SUPPLEMENTARY TABLES

TABLE 4.—*Relative volumes occupied by a given quantity of gas, dry and saturated, under various conditions of temperature and pressure*

	0° C., 760 mm, dry	0° C., 760 mm, saturated	20° C., 760 mm, dry	20° C., 760 mm, saturated	60° F.,30 inches, dry	60° F., 30 inches, saturated	68° F., 30 inches, dry	68° F, 30 inches, saturated	68° F., 15 pounds per square inch, dry	68° F., 15 pounds per square inch, saturated	70° F., 30 inches, dry	70° F., 30 inches, saturated
0° C., 760 mm, dry	1.0000	1.0061	1.0735	1.0989	1.0543	1.0730	1.0707	1.0960	1.0521	1.0769	1.0747	1.1019
0° C., 760 mm, saturated	.9940	1.0000	1.0671	1.0923	1.0480	1.0666	1.0642	1.0894	1.0457	1.0704	1.0682	1.0953
20° C., 760 mm, dry	.9316	.9372	1.0000	1.0236	.9822	.9996	.9973	1.0209	.9800	1.0032	1.0011	1.0265
20° C., 760 mm, saturated	.9100	.9156	.9769	1.0000	.9595	.9765	.9743	.9973	.9574	.9800	.9780	1.0027
60° F., 30 inches, dry	.9485	.9542	1.0181	1.0422	1.0000	1.0177	1.0154	1.0394	.9978	1.0214	1.0192	1.0451
60° F., 30 inches, saturated	.9319	.9376	1.0004	1.0240	.9826	1.0000	.9977	1.0213	.9804	1.0035	1.0015	1.0268
68° F., 30 inches, dry	.9341	.9397	1.0027	1.0264	.9848	1.0023	1.0000	1.0236	.9826	1.0058	1.0038	1.0292
68° F., 30 inches, saturated	.9125	.9180	.9795	1.0027	.9621	.9791	.9769	1.0000	.9599	.9826	.9806	1.0054
68° F., 15 pounds, per square inch, dry	.9506	.9563	1.0204	1.0445	1.0022	1.0200	1.0177	1.0417	1.0000	1.0236	1.0215	1.0474
68° F., 15 pounds per square inch, saturated	.9286	.9343	.9968	1.0204	.9791	.9965	.9942	1.0177	.9769	1.0000	.9979	1.0232
70° F., 30 inches, dry	.9306	.9362	.9989	1.0225	.9811	.9985	.9963	1.0198	.9789	1.0021	1.0000	1.0254
70° F., 30 inches, saturated	.9076	.9131	.9742	.9973	.9569	.9739	.9716	.9946	.9547	.9773	.9753	1.0000

TABLE 5.—*Correction*

[Multiply observed volumes of saturated gas by factor to correct to

Temperature (° C.)	Total gas pressure—millimeters of mercury													
	716	718	720	722	724	726	728	730	732	734	736	738	740	742
5	0.917	0.919	0.922	0.924	0.927	0.930	0.932	0.935	0.937	0.940	0.943	0.945	0.948	0.950
6	.913	.915	.918	.920	.923	.926	.928	.931	.933	.936	.939	.941	.944	.946
7	.909	.911	.914	.917	.919	.922	.924	.927	.930	.932	.935	.937	.940	.942
8	.905	.908	.910	.913	.915	.918	.920	.923	.926	.928	.931	.933	.936	.938
9	.901	.904	.906	.909	.911	.914	.916	.919	.921	.924	.926	.929	.932	.934
10	.897	.900	.902	.905	.907	.910	.912	.915	.917	.920	.922	.925	.928	.930
11	.893	.896	.898	.901	.903	.906	.908	.911	.913	.916	.918	.921	.924	.926
12	.889	.892	.894	.897	.899	.902	.904	.907	.909	.912	.914	.917	.919	.922
13	.885	.888	.890	.893	.895	.898	.900	.903	.905	.908	.910	.913	.915	.918
14	.881	.884	.886	.887	.891	.894	.896	.899	.901	.904	.906	.909	.911	.914
15	.877	.880	.882	.885	.887	.890	.892	.895	.897	.900	.902	.904	.907	.910
16	.873	.876	.878	.880	.883	.885	.888	.890	.893	.895	.898	.900	.903	.905
17	.869	.871	.874	.876	.879	.881	.884	.886	.889	.891	.894	.896	.898	.901
18	.865	.867	.870	.872	.874	.877	.880	.882	.884	.887	.889	.892	.894	.897
19	.860	.863	.865	.868	.870	.873	.875	.878	.880	.883	.885	.888	.890	.892
20	.856	.859	.861	.864	.866	.869	.871	.874	.876	.878	.881	.883	.886	.888
21	.852	.854	.857	.859	.862	.864	.867	.869	.872	.874	.876	.879	.881	.884
22	.848	.850	.853	.855	.857	.860	.862	.865	.867	.870	.872	.874	.877	.879
23	.843	.846	.848	.851	.853	.856	.858	.860	.863	.865	.868	.870	.872	.875
24	.839	.841	.844	.846	.848	.851	.853	.856	.858	.861	.863	.866	.868	.870
25	.834	.837	.839	.842	.844	.846	.849	.851	.854	.856	.858	.861	.863	.866
26	.830	.832	.835	.837	.840	.842	.844	.847	.847	.852	.854	.856	.859	.861
27	.825	.828	.830	.833	.835	.837	.840	.842	.842	.847	.847	.852	.854	.856
28	.821	.823	.825	.828	.830	.833	.835	.837	.839	.842	.844	.847	.849	.852
29	.816	.818	.821	.823	.825	.828	.830	.832	.835	.837	.840	.842	.844	.847
30	.811	.813	.816	.818	.821	.823	.825	.828	.830	.832	.835	.837	.840	.842
31	.806	.809	.811	.813	.816	.818	.820	.823	.825	.828	.830	.832	.835	.837
32	.801	.804	.806	.808	.811	.814	.815	.818	.820	.822	.825	.827	.830	.832
33	.796	.798	.801	.803	.806	.809	.810	.813	.815	.817	.820	.822	.824	.827
34	.791	.793	.796	.798	.800	.803	.805	.807	.810	.812	.814	.817	.819	.822
35	.786	.788	.790	.793	.795	.797	.800	.802	.804	.807	.809	.811	.814	.816
36	.781	.783	.785	.787	.790	.792	.794	.797	.799	.801	.804	.806	.808	.811
37	.775	.777	.780	.782	.784	.787	.789	.791	.794	.796	.798	.801	.803	.805
38	.770	.772	.774	.776	.779	.781	.783	.786	.788	.790	.793	.795	.796	.799
39	.764	.766	.768	.771	.773	.775	.778	.780	.782	.784	.787	.789	.790	.794
40	.758	.760	.763	.765	.767	.770	.772	.774	.776	.779	.781	.783	.786	.788
41	.752	.755	.757	.759	.761	.764	.766	.768	.771	.773	.775	.777	.780	.782
42	.746	.748	.751	.753	.755	.758	.760	.762	.764	.767	.769	.771	.774	.776
43	.740	.742	.745	.747	.749	.751	.754	.756	.758	.761	.763	.765	.767	.770
44	.734	.736	.738	.741	.743	.745	.747	.750	.752	.754	.756	.759	.761	.763
45	.727	.730	.732	.733	.736	.739	.741	.743	.745	.748	.750	.752	.754	.757
46	.721	.723	.725	.728	.730	.732	.734	.737	.739	.741	.743	.746	.748	.750
47	.714	.716	.719	.721	.723	.725	.728	.730	.732	.734	.737	.739	.741	.743
48	.707	.710	.712	.714	.716	.718	.721	.723	.725	.727	.730	.732	.734	.736
49	.701	.703	.705	.707	.709	.712	.714	.716	.718	.720	.723	.725	.727	.729

factors for gas volume

volume of dry gas at 760 mm of mercury pressure (0° C.) and 0° C.]

Total gas pressure—millimeters of mercury—Continued													
744	746	748	750	752	754	756	758	760	762	764	766	768	770
0.953	0.956	0.958	0.961	0.963	0.966	0.968	0.971	0.974	0.976	0.979	0.981	0.984	0.986
.949	.952	.954	.957	.959	.962	.964	.967	.970	.972	.975	.977	.980	.982
.945	.948	.950	.952	.955	.958	.960	.963	.965	.968	.971	.973	.976	.978
.941	.943	.946	.948	.951	.954	.956	.959	.961	.964	.966	.969	.972	.974
.937	.939	.942	.944	.947	.950	.952	.954	.957	.960	.962	.965	.967	.970
.933	.935	.938	.940	.943	.945	.948	.950	.953	.956	.958	.961	.963	.966
.929	.931	.934	.936	.939	.941	.944	.946	.949	.951	.954	.956	.959	.962
.924	.927	.930	.932	.934	.937	.940	.942	.945	.947	.950	.952	.955	.957
.920	.923	.925	.928	.930	.933	.935	.938	.940	.943	.946	.948	.950	.953
.916	.919	.921	.924	.926	.929	.931	.934	.936	.939	.941	.944	.946	.949
.912	.914	.917	.920	.922	.924	.927	.929	.932	.934	.937	.940	.942	.944
.908	.910	.913	.915	.918	.920	.923	.925	.928	.930	.933	.935	.938	.940
.904	.906	.908	.911	.913	.916	.918	.921	.923	.926	.928	.931	.933	.936
.899	.902	.904	.907	.909	.912	.914	.916	.919	.922	.924	.925	.929	.931
.895	.897	.900	.902	.905	.907	.910	.912	.915	.917	.920	.921	.924	.927
.891	.893	.896	.898	.900	.903	.905	.908	.910	.913	.915	.918	.920	.922
.886	.889	.891	.894	.896	.898	.901	.903	.906	.908	.911	.913	.916	.918
.882	.884	.887	.888	.892	.894	.895	.899	.901	.904	.906	.909	.911	.913
.877	.880	.882	.885	.887	.889	.892	.894	.897	.899	.902	.904	.906	.909
.873	.875	.878	.880	.882	.885	.887	.890	.892	.895	.897	.899	.902	.904
.868	.871	.873	.875	.878	.880	.883	.885	.888	.890	.892	.895	.897	.899
.864	.866	.868	.871	.873	.876	.878	.880	.883	.885	.888	.890	.892	.895
.859	.861	.864	.866	.868	.871	.873	.876	.878	.880	.883	.885	.888	.890
.854	.856	.859	.861	.864	.866	.868	.871	.873	.876	.878	.880	.883	.885
.849	.852	.854	.856	.859	.861	.864	.866	.868	.870	.873	.875	.878	.880
.844	.847	.849	.851	.854	.856	.858	.861	.863	.865	.868	.870	.873	.875
.839	.842	.844	.846	.849	.851	.854	.856	.858	.860	.863	.865	.868	.870
.834	.836	.839	.841	.844	.846	.848	.851	.853	.855	.858	.860	.862	.865
.829	.831	.834	.836	.838	.841	.843	.845	.848	.850	.852	.855	.857	.860
.824	.826	.828	.831	.833	.836	.838	.840	.842	.845	.847	.850	.852	.854
.818	.821	.823	.825	.829	.830	.832	.835	.837	.839	.842	.844	.846	.849
.813	.815	.818	.820	.823	.825	.827	.829	.832	.834	.835	.839	.841	.843
.808	.810	.812	.814	.817	.819	.821	.824	.826	.828	.831	.833	.835	.838
.802	.804	.806	.809	.811	.813	.816	.818	.820	.823	.825	.827	.830	.832
.796	.798	.801	.803	.805	.808	.810	.812	.814	.817	.819	.821	.824	.826
.790	.793	.795	.797	.799	.802	.804	.806	.809	.811	.813	.816	.818	.820
.784	.786	.789	.791	.793	.796	.798	.800	.803	.805	.807	.809	.812	.814
.778	.780	.783	.785	.787	.790	.792	.794	.796	.799	.801	.803	.806	.808
.772	.774	.777	.779	.781	.783	.786	.788	.790	.792	.795	.797	.799	.802
.766	.768	.770	.772	.775	.777	.779	.781	.784	.786	.788	.791	.793	.795
.759	.761	.764	.766	.768	.770	.773	.775	.777	.779	.783	.784	.786	.788
.752	.755	.757	.759	.762	.764	.766	.768	.770	.773	.775	.777	.780	.782
.746	.748	.750	.752	.755	.757	.759	.761	.764	.766	.768	.770	.773	.775
.739	.741	.743	.745	.748	.750	.752	.754	.756	.759	.761	.763	.766	.768
.732	.734	.736	.738	.741	.743	.745	.747	.750	.752	.754	.756	.758	.761

TABLE 6.—*Correction*

[Multiply observed volume of saturated gas by factor to correct to

Temperature (° F.)	Total gas pressure—inches of mercury											
	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0	29.1
55	0.928	0.931	0.935	0.939	0.942	0.944	0.947	0.951	0.954	0.958	0.961	0.965
56	.926	.929	.933	.936	.939	.942	.945	.948	.952	.955	.959	.962
57	.923	.927	.930	.933	.937	.940	.943	.946	.949	.953	.956	.960
58	.921	.924	.928	.931	.935	.938	.941	.944	.947	.951	.954	.957
59	.919	.922	.925	.929	.932	.936	.939	.942	.945	.948	.952	.955
60	.916	.920	.923	.926	.930	.933	.937	.940	.942	.946	.949	.952
61	.914	.917	.920	.924	.927	.931	.934	.937	.940	.944	.947	.950
62	.911	.915	.918	.921	.925	.928	.932	.935	.938	.942	.944	.947
63	.909	.912	.916	.919	.922	.926	.929	.932	.936	.939	.942	.945
64	.906	.910	.913	.916	.920	.923	.927	.930	.933	.937	.940	.942
65	.904	.907	.911	.914	.917	.921	.924	.928	.931	.934	.938	.940
66	.901	.905	.908	.912	.915	.918	.922	.925	.928	.932	.935	.938
67	.899	.902	.906	.909	.912	.916	.919	.922	.926	.929	.932	.936
68	.896	.900	.903	.906	.910	.913	.916	.920	.923	.926	.930	.933
69	.894	.897	.901	.904	.907	.911	.914	.917	.921	.924	.927	.931
70	.891	.895	.898	.901	.905	.908	.911	.915	.918	.921	.925	.928
71	.889	.892	.896	.899	.902	.906	.909	.912	.915	.919	.922	.925
72	.886	.890	.894	.896	.900	.903	.906	.910	.913	.916	.920	.923
73	.884	.887	.890	.894	.897	.900	.904	.907	.910	.914	.917	.920
74	.882	.885	.888	.891	.894	.898	.901	.904	.908	.911	.914	.917
75	.879	.883	.885	.888	.892	.895	.898	.902	.905	.908	.912	.915
76	.877	.880	.883	.886	.889	.892	.896	.899	.902	.905	.909	.912
77	.874	.877	.881	.884	.886	.890	.893	.896	.900	.903	.906	.909
78	.872	.875	.878	.881	.884	.887	.890	.894	.897	.900	.903	.907
79	.869	.872	.875	.879	.882	.884	.888	.891	.894	.897	.900	.904
80	.866	.869	.873	.876	.879	.882	.885	.888	.891	.894	.898	.901
81	.863	.867	.870	.873	.876	.880	.883	.885	.888	.892	.895	.898
82	.861	.864	.867	.870	.874	.877	.880	.883	.886	.889	.892	.895
83	.858	.861	.864	.868	.871	.874	.877	.881	.884	.886	.889	.893
84	.855	.858	.861	.865	.868	.871	.875	.878	.881	.884	.886	.890
85	.852	.855	.859	.862	.865	.868	.872	.875	.878	.881	.884	.887
86	.849	.853	.856	.859	.862	.865	.869	.872	.875	.878	.882	.884
87	.846	.850	.853	.856	.858	.863	.866	.869	.872	.875	.879	.882
88	.844	.847	.850	.853	.857	.860	.863	.866	.869	.873	.876	.879
89	.841	.844	.847	.850	.853	.857	.860	.863	.866	.870	.873	.876
90	.838	.841	.844	.847	.851	.854	.857	.860	.863	.867	.870	.873
91	.835	.838	.841	.844	.847	.851	.854	.857	.860	.863	.867	.870
92	.832	.835	.838	.841	.845	.848	.851	.854	.857	.860	.864	.867
93	.829	.832	.835	.838	.841	.845	.848	.851	.854	.857	.861	.864
94	.826	.829	.832	.835	.838	.841	.845	.848	.851	.854	.857	.861
95	.823	.826	.829	.832	.835	.838	.841	.845	.848	.851	.854	.857
96	.820	.823	.826	.829	.832	.835	.838	.841	.845	.848	.851	.854
97	.817	.820	.823	.826	.829	.832	.835	.838	.841	.845	.848	.851
98	.814	.817	.820	.823	.826	.829	.832	.835	.838	.841	.845	.848
99	.811	.814	.817	.820	.823	.825	.829	.832	.835	.838	.841	.844
100	.807	.810	.813	.816	.819	.822	.826	.828	.831	.834	.837	.840
101	.803	.807	.810	.813	.816	.819	.823	.826	.828	.831	.834	.836
102	.800	.803	.806	.810	.812	.815	.819	.822	.825	.828	.830	.833
103	.797	.800	.803	.806	.809	.812	.816	.819	.822	.825	.827	.830
104	.793	.796	.800	.803	.806	.809	.812	.815	.818	.821	.824	.827
105	.790	.793	.796	.799	.802	.805	.809	.812	.815	.818	.821	.824
106	.786	.789	.792	.796	.799	.802	.805	.808	.811	.814	.818	.821
107	.783	.785	.789	.792	.795	.798	.801	.804	.807	.811	.814	.817
108	.779	.782	.785	.788	.791	.795	.798	.801	.804	.807	.810	.813
109	.775	.778	.781	.784	.787	.791	.794	.797	.800	.803	.806	.809

factors for gas volume

volume of dry gas at 30 inches of mercury pressure (32° F.) and 60° F.]

Total gas pressure—inches of mercury—Continued													
29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5
0.968	0.971	0.975	0.978	0.982	0.985	0.988	0.992	0.995	0.999	1.001	1.005	1.008	1.011
.965	.969	.972	.976	.980	.983	.986	.990	.993	.996	.999	1.002	1.005	1.008
.963	.967	.970	.973	.977	.980	.984	.987	.990	.994	.997	1.000	1.003	1.006
.961	.964	.968	.971	.975	.978	.981	.985	.988	.992	.995	.998	1.001	1.004
.958	.962	.965	.969	.972	.975	.979	.983	.985	.989	.992	.995	.998	1.001
.956	.959	.963	.966	.969	.973	.976	.980	.983	.986	.990	.993	.996	.999
.953	.957	.960	.963	.967	.970	.974	.977	.980	.984	.987	.991	.994	.997
.951	.954	.958	.961	.964	.968	.971	.975	.978	.981	.985	.988	.991	.995
.948	.952	.955	.958	.962	.965	.969	.972	.975	.979	.982	.985	.989	.992
.946	.949	.953	.956	.959	.963	.966	.969	.973	.976	.979	.983	.986	.990
.943	.947	.950	.953	.957	.960	.963	.967	.970	.973	.977	.980	.984	.987
.941	.944	.947	.951	.954	.957	.961	.964	.967	.971	.974	.978	.981	.984
.939	.942	.945	.948	.951	.955	.958	.962	.965	.968	.972	.975	.978	.982
.936	.940	.942	.945	.949	.952	.956	.959	.962	.966	.969	.972	.976	.979
.934	.937	.940	.943	.946	.950	.953	.956	.960	.963	.966	.970	.973	.976
.931	.935	.938	.941	.944	.947	.950	.954	.957	.960	.964	.967	.970	.974
.929	.932	.935	.939	.942	.944	.949	.951	.954	.958	.961	.964	.968	.971
.926	.929	.933	.936	.939	.942	.945	.948	.952	.955	.958	.961	.965	.968
.923	.927	.930	.933	.937	.940	.942	.946	.949	.952	.955	.959	.962	.965
.921	.924	.927	.931	.934	.937	.940	.943	.946	.949	.953	.956	.959	.963
.918	.921	.925	.928	.931	.934	.938	.941	.943	.947	.950	.953	.957	.960
.915	.919	.922	.925	.928	.932	.935	.938	.941	.944	.947	.951	.954	.957
.913	.916	.919	.922	.926	.929	.932	.936	.939	.941	.944	.948	.951	.954
.910	.913	.916	.920	.923	.926	.930	.933	.936	.939	.942	.945	.948	.951
.907	.910	.914	.917	.920	.924	.927	.930	.933	.936	.940	.942	.945	.949
.904	.908	.911	.914	.917	.921	.924	.927	.930	.934	.937	.940	.943	.946
.902	.905	.908	.911	.914	.918	.921	.924	.928	.931	.934	.937	.941	.943
.899	.902	.905	.908	.912	.915	.918	.921	.925	.928	.931	.934	.938	.941
.896	.899	.902	.906	.909	.912	.915	.918	.922	.925	.928	.932	.935	.938
.893	.896	.899	.903	.906	.909	.912	.916	.919	.922	.925	.929	.932	.935
.890	.893	.896	.900	.903	.906	.909	.913	.916	.919	.922	.926	.929	.932
.887	.890	.894	.897	.900	.903	.906	.910	.913	.916	.919	.923	.926	.929
.884	.887	.891	.894	.897	.900	.903	.907	.910	.913	.916	.920	.923	.926
.882	.884	.888	.891	.894	.897	.900	.904	.907	.910	.913	.917	.920	.923
.879	.882	.885	.888	.891	.894	.898	.901	.904	.907	.910	.914	.917	.920
.876	.879	.882	.885	.888	.891	.894	.898	.901	.904	.907	.910	.914	.917
.873	.876	.879	.883	.885	.888	.891	.894	.898	.901	.904	.907	.910	.914
.870	.873	.876	.880	.883	.885	.888	.891	.895	.898	.901	.904	.907	.911
.867	.870	.873	.877	.880	.883	.885	.888	.892	.895	.898	.901	.904	.907
.864	.867	.870	.873	.877	.880	.883	.885	.888	.891	.895	.898	.901	.904
.861	.864	.867	.870	.873	.877	.880	.883	.885	.888	.891	.895	.898	.901
.857	.861	.864	.867	.870	.873	.876	.880	.883	.885	.888	.891	.894	.898
.854	.857	.861	.864	.867	.870	.873	.876	.879	.883	.885	.888	.891	.894
.851	.854	.857	.860	.864	.867	.870	.873	.876	.879	.883	.885	.888	.891
.848	.851	.854	.857	.860	.863	.867	.870	.873	.876	.879	.882	.884	.888
.844	.847	.850	.853	.856	.859	.862	.865	.868	.871	.875	.878	.881	.884
.840	.843	.847	.850	.853	.856	.859	.862	.865	.868	.872	.875	.878	.881
.836	.839	.843	.846	.849	.852	.855	.858	.861	.864	.868	.871	.874	.877
.833	.836	.840	.843	.846	.849	.852	.855	.858	.861	.865	.868	.871	.874
.830	.833	.836	.839	.843	.846	.849	.852	.855	.858	.861	.864	.867	.871
.827	.830	.833	.836	.839	.842	.845	.848	.851	.854	.857	.860	.864	.867
.824	.827	.829	.831	.836	.838	.841	.844	.847	.850	.853	.856	.860	.863
.820	.823	.826	.828	.832	.835	.838	.841	.844	.847	.849	.853	.856	.860
.816	.819	.822	.825	.828	.831	.834	.837	.840	.843	.845	.849	.853	.856
.812	.815	.818	.822	.825	.827	.830	.833	.836	.839	.842	.845	.849	.852

TABLE 7.—*Correction*

[Multiply observed volume of saturated gas by factor to correct to

Temperature (° F.)	Total gas pressure—inches of mercury											
	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0	29.1
55	0.944	0.947	0.951	0.954	0.958	0.961	0.964	0.968	0.971	0.975	0.978	0.982
56	.942	.945	.949	.952	.955	.959	.962	.965	.969	.972	.976	.979
57	.939	.943	.946	.949	.953	.956	.960	.963	.966	.970	.973	.977
58	.937	.940	.944	.947	.951	.954	.957	.961	.964	.968	.971	.974
59	.935	.938	.941	.945	.948	.952	.955	.958	.962	.965	.969	.972
60	.932	.936	.939	.942	.946	.949	.953	.956	.959	.963	.966	.969
61	.930	.933	.936	.940	.943	.947	.950	.953	.957	.960	.964	.967
62	.927	.931	.934	.937	.941	.944	.948	.951	.954	.958	.961	.964
63	.925	.928	.932	.935	.938	.942	.945	.948	.952	.955	.959	.962
64	.922	.926	.929	.932	.936	.939	.943	.946	.949	.953	.956	.959
65	.920	.923	.927	.930	.933	.937	.940	.944	.947	.950	.954	.957
66	.917	.921	.924	.928	.931	.934	.938	.941	.944	.948	.951	.954
67	.915	.918	.922	.925	.928	.932	.935	.938	.942	.945	.948	.952
68	.912	.916	.919	.922	.926	.929	.932	.936	.939	.942	.946	.949
69	.910	.913	.917	.920	.923	.927	.930	.933	.937	.940	.943	.947
70	.907	.911	.914	.917	.921	.924	.927	.931	.934	.937	.941	.944
71	.905	.908	.912	.915	.918	.922	.925	.928	.931	.935	.938	.941
72	.902	.906	.909	.912	.916	.919	.922	.926	.929	.932	.936	.939
73	.900	.903	.906	.910	.913	.916	.920	.923	.926	.930	.933	.936
74	.897	.900	.904	.907	.910	.914	.917	.920	.924	.927	.930	.933
75	.894	.898	.901	.904	.908	.911	.914	.918	.921	.924	.928	.931
76	.892	.895	.898	.902	.905	.908	.912	.915	.918	.921	.925	.928
77	.889	.892	.896	.899	.902	.906	.909	.912	.916	.919	.922	.925
78	.887	.890	.893	.896	.900	.903	.906	.910	.913	.916	.919	.923
79	.884	.887	.890	.894	.897	.900	.904	.907	.910	.913	.916	.920
80	.881	.884	.888	.891	.894	.897	.901	.904	.907	.910	.914	.917
81	.878	.882	.885	.888	.891	.895	.898	.901	.904	.908	.911	.914
82	.876	.879	.882	.885	.889	.892	.895	.898	.902	.905	.908	.911
83	.873	.876	.879	.883	.886	.889	.892	.896	.899	.902	.905	.909
84	.870	.873	.876	.880	.883	.886	.890	.893	.896	.899	.902	.906
85	.867	.870	.874	.877	.880	.883	.887	.890	.893	.896	.900	.903
86	.864	.868	.871	.874	.877	.880	.884	.887	.890	.893	.897	.900
87	.861	.865	.868	.871	.874	.878	.881	.884	.887	.890	.894	.897
88	.859	.862	.865	.868	.872	.875	.878	.881	.884	.888	.891	.894
89	.856	.859	.862	.865	.868	.872	.875	.878	.881	.885	.888	.891
90	.853	.856	.859	.862	.866	.869	.872	.875	.878	.882	.885	.888
91	.850	.853	.856	.859	.862	.866	.869	.872	.875	.878	.882	.885
92	.847	.850	.853	.856	.860	.863	.886	.869	.872	.875	.879	.882
93	.844	.847	.850	.853	.856	.860	.863	.866	.869	.872	.876	.879
94	.841	.844	.847	.850	.853	.856	.860	.863	.866	.869	.872	.876
95	.837	.841	.844	.847	.850	.853	.856	.860	.863	.866	.869	.872
96	.834	.838	.841	.844	.847	.850	.853	.856	.860	.863	.866	.869
97	.831	.834	.838	.841	.844	.847	.850	.853	.856	.860	.863	.866
98	.828	.831	.834	.838	.841	.844	.847	.850	.853	.856	.860	.863
99	.825	.828	.831	.834	.837	.840	.844	.847	.850	.853	.856	.859
100	.821	.824	.827	.830	.833	.836	.840	.843	.846	.849	.852	.855
101	.818	.821	.824	.827	.830	.833	.837	.840	.843	.846	.849	.851
102	.814	.817	.820	.824	.826	.829	.833	.836	.839	.842	.845	.848
103	.811	.814	.817	.820	.823	.826	.830	.833	.836	.839	.842	.845
104	.807	.810	.814	.817	.820	.823	.826	.829	.832	.835	.839	.842
105	.804	.807	.810	.813	.816	.819	.823	.826	.829	.832	.835	.838
106	.800	.803	.806	.810	.813	.816	.819	.822	.825	.828	.832	.835
107	.797	.799	.803	.806	.809	.812	.815	.818	.821	.825	.828	.831
108	.793	.796	.799	.802	.805	.809	.812	.815	.818	.821	.824	.827
109	.789	.792	.795	.798	.801	.805	.808	.811	.814	.817	.820	.823

factors for gas volume

volume of saturated gas at 30 inches of mercury pressure (32° F.)and 60° F.]

Total gas pressure—inches of mercury—Continued													
29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5
0.985	0.988	0.992	0.995	0.999	1.002	1.006	1.009	1.012	1.016	1.019	1.023	1.026	1.029
.982	.986	.989	.993	.997	1.000	1.003	1.007	1.010	1.013	1.016	1.020	1.023	1.026
.980	.984	.987	.990	.994	.997	1.001	1.004	1.007	1.011	1.014	1.018	1.021	1.024
.978	.981	.985	.988	.992	.995	.998	1.002	1.005	1.009	1.012	1.015	1.019	1.022
.975	.979	.982	.986	.989	.992	.996	.999	1.003	1.006	1.009	1.013	1.016	1.019
.973	.976	.980	.983	.986	.990	.993	.997	1.000	1.003	1.007	1.010	1.014	1.017
.970	.974	.977	.980	.984	.987	.991	.994	.997	1.001	1.004	1.008	1.011	1.014
.968	.971	.975	.978	.981	.985	.988	.992	.995	.998	1.002	1.005	1.008	1.012
.965	.969	.972	.975	.979	.982	.986	.989	.992	.996	.999	1.002	1.006	1.009
.963	.966	.970	.973	.976	.980	.983	.986	.990	.993	.996	1.000	1.003	1.007
.960	.964	.967	.970	.974	.977	.980	.984	.987	.990	.994	.997	1.001	1.004
.958	.961	.964	.968	.971	.974	.978	.981	.984	.988	.991	.995	.998	1.001
.955	.958	.962	.965	.968	.972	.975	.979	.982	.985	.989	.992	.995	.999
.952	.956	.959	.962	.966	.969	.973	.976	.979	.983	.986	.989	.993	.996
.950	.953	.957	.960	.963	.967	.970	.973	.977	.980	.983	.987	.990	.993
.947	.951	.954	.957	.961	.964	.967	.971	.974	.977	.981	.984	.987	.991
.945	.948	.951	.955	.958	.961	.965	.968	.971	.975	.978	.981	.985	.988
.942	.945	.949	.952	.955	.959	.962	.965	.969	.972	.975	.978	.982	.985
.939	.943	.946	.949	.953	.956	.959	.963	.966	.969	.972	.976	.979	.982
.937	.940	.943	.947	.950	.953	.957	.960	.963	.966	.970	.973	.976	.980
.934	.937	.941	.944	.947	.950	.954	.957	.960	.964	.967	.970	.974	.977
.931	.935	.938	.941	.944	.948	.951	.954	.958	.961	.964	.968	.971	.974
.929	.932	.935	.938	.942	.945	.948	.952	.955	.958	.961	.965	.968	.971
.926	.929	.932	.936	.939	.942	.946	.949	.952	.955	.959	.962	.965	.968
.923	.926	.930	.933	.936	.940	.943	.946	.949	.952	.956	.959	.962	.966
.920	.924	.927	.930	.933	.937	.940	.943	.946	.950	.953	.956	.960	.963
.918	.921	.924	.927	.930	.934	.937	.940	.944	.947	.950	.953	.957	.960
.915	.918	.921	.924	.928	.931	.934	.937	.941	.944	.947	.950	.954	.957
.912	.915	.918	.922	.925	.928	.931	.934	.938	.941	.944	.948	.951	.954
.909	.912	.915	.919	.922	.925	.928	.932	.935	.938	.941	.945	.948	.951
.906	.909	.912	.916	.919	.922	.925	.929	.932	.935	.938	.942	.945	.948
.903	.906	.910	.913	.916	.919	.922	.926	.929	.932	.935	.939	.942	.945
.900	.903	.907	.910	.913	.916	.920	.923	.926	.929	.932	.936	.939	.942
.897	.900	.904	.907	.910	.913	.916	.920	.923	.926	.929	.933	.936	.939
.894	.897	.901	.904	.907	.910	.914	.917	.920	.923	.926	.930	.933	.936
.891	.894	.898	.901	.904	.907	.910	.914	.917	.920	.923	.926	.930	.933
.888	.891	.894	.898	.901	.904	.907	.910	.914	.917	.920	.923	.926	.930
.885	.888	.891	.895	.898	.901	.904	.907	.911	.914	.917	.920	.923	.927
.882	.885	.888	.892	.895	.898	.901	.904	.908	.911	.914	.917	.920	.923
.879	.882	.885	.888	.892	.895	.898	.901	.904	.907	.911	.914	.917	.920
.876	.879	.882	.885	.888	.892	.895	.898	.901	.904	.907	.911	.914	.917
.872	.876	.879	.882	.885	.888	.891	.895	.898	.901	.904	.907	.910	.914
.869	.872	.876	.879	.882	.885	.888	.891	.894	.898	.901	.904	.907	.910
.866	.869	.872	.875	.879	.882	.885	.888	.891	.894	.898	.901	.904	.907
.863	.866	.869	.872	.875	.878	.882	.885	.888	.891	.894	.897	.900	.904
.859	.862	.865	.868	.871	.874	.878	.881	.884	.887	.890	.893	.896	.899
.855	.858	.862	.865	.868	.871	.874	.877	.880	.883	.887	.890	.893	.896
.851	.854	.858	.861	.864	.867	.870	.873	.876	.879	.883	.886	.889	.892
.848	.851	.855	.858	.861	.864	.867	.870	.873	.876	.880	.883	.886	.889
.845	.848	.851	.854	.858	.861	.864	.867	.870	.873	.876	.879	.882	.886
.841	.844	.848	.851	.854	.857	.860	.863	.866	.869	.872	.875	.879	.882
.838	.841	.844	.846	.851	.853	.856	.859	.862	.865	.868	.871	.875	.878
.834	.837	.840	.843	.847	.850	.853	.856	.859	.862	.864	.868	.871	.875
.830	.833	.836	.839	.843	.846	.849	.852	.855	.858	.860	.864	.868	.871
.826	.829	.832	.836	.839	.842	.845	.848	.851	.854	.857	.860	.864	.867

TABLE 8.—*Correction*

[Multiply observed volume of saturated gas by factor to correct to

Temperature (° F.)	Total gas pressure—inches of mercury											
	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0	29.1
55	0.942	0.945	0.949	0.952	0.956	0.959	0.963	0.966	0.969	0.973	0.976	0.980
56	.940	.943	.947	.950	.953	.957	.960	.963	.967	.970	.974	.977
57	.937	.941	.944	.947	.951	.954	.958	.961	.964	.968	.971	.975
58	.935	.938	.942	.945	.949	.952	.955	.959	.962	.966	.969	.972
59	.933	.936	.939	.943	.946	.950	.953	.956	.960	.963	.967	.970
60	.930	.934	.937	.940	.944	.947	.951	.954	.957	.961	.964	.967
61	.928	.931	.934	.938	.941	.945	.948	.951	.955	.958	.962	.965
62	.925	.929	.932	.935	.939	.942	.946	.949	.952	.956	.959	.962
63	.923	.926	.930	.933	.936	.940	.943	.946	.950	.953	.957	.960
64	.920	.924	.927	.930	.934	.937	.941	.944	.947	.951	.954	.957
65	.918	.921	.925	.928	.931	.935	.938	.942	.945	.948	.952	.955
66	.915	.919	.922	.926	.929	.932	.936	.939	.942	.946	.949	.952
67	.913	.916	.920	.923	.926	.930	.933	.936	.940	.943	.946	.950
68	.910	.914	.917	.920	.924	.927	.930	.934	.937	.940	.944	.947
69	.908	.910	.915	.918	.921	.925	.928	.931	.935	.938	.941	.945
70	.905	.909	.912	.915	.919	.922	.925	.929	.932	.935	.939	.942
71	.903	.906	.910	.913	.916	.920	.923	.926	.929	.933	.936	.939
72	.900	.904	.907	.910	.914	.917	.920	.924	.927	.930	.934	.937
73	.898	.901	.904	.908	.911	.914	.918	.921	.924	.928	.931	.934
74	.895	.898	.902	.905	.908	.912	.915	.918	.922	.925	.928	.931
75	.892	.896	.899	.902	.906	.909	.912	.916	.919	.922	.926	.929
76	.890	.893	.896	.900	.903	.906	.910	.913	.916	.919	.923	.926
77	.887	.890	.894	.897	.900	.904	.907	.910	.914	.917	.920	.923
78	.885	.888	.891	.894	.898	.901	.904	.908	.911	.914	.917	.921
79	.882	.885	.888	.892	.895	.898	.902	.905	.908	.911	.914	.918
80	.879	.882	.886	.889	.892	.895	.899	.902	.905	.908	.912	.915
81	.876	.880	.883	.886	.889	.893	.896	.899	.902	.906	.909	.912
82	.874	.877	.880	.883	.887	.890	.893	.896	.900	.903	.906	.909
83	.871	.874	.877	.881	.884	.887	.890	.894	.897	.900	.903	.907
84	.868	.871	.874	.878	.881	.884	.888	.891	.894	.897	.900	.904
85	.965	.868	.872	.875	.878	.881	.885	.888	.891	.894	.898	.901
86	.862	.866	.869	.872	.875	.878	.882	.885	.888	.891	.895	.898
87	.859	.863	.866	.869	.872	.876	.879	.882	.885	.888	.892	.895
88	.857	.860	.863	.866	.870	.873	.876	.879	.882	.886	.889	.892
89	.854	.857	.860	.863	.866	.870	.873	.876	.879	.883	.886	.889
90	.851	.854	.857	.860	.864	.867	.870	.873	.876	.880	.883	.886
91	.848	.851	.854	.857	.862	.864	.867	.870	.873	.876	.880	.883
92	.845	.848	.851	.854	.858	.861	.864	.867	.870	.873	.877	.880
93	.842	.845	.848	.851	.854	.858	.861	.864	.867	.870	.874	.877
94	.839	.842	.845	.848	.851	.854	.858	.861	.864	.867	.870	.874
95	.835	.839	.842	.845	.848	.851	.854	.858	.861	.864	.867	.870
96	.832	.836	.839	.842	.845	.848	.851	.854	.858	.861	.864	.867
97	.829	.832	.836	.839	.842	.845	.848	.851	.954	.858	.861	.864
98	.826	.829	.832	.836	.839	.842	.845	.848	.851	.854	.858	.861
99	.823	.826	.829	.832	.835	.838	.842	.845	.848	.851	.854	.857
100	.819	.822	.825	.828	.831	.834	.838	.841	.844	.847	.850	.853
101	.816	.819	.822	.825	.828	.831	.835	.838	.841	.844	.847	.849
102	.812	.815	.818	.822	.824	.827	.831	.834	.837	.840	.843	.846
103	.809	.812	.815	.818	.821	.824	.828	.831	.834	.837	.840	.843
104	.805	.808	.812	.815	.818	.821	.824	.827	.830	.833	.837	.840
105	.802	.805	.808	.811	.814	.817	.821	.824	.827	.830	.833	.836
106	.798	.801	.804	.808	.811	.814	.817	.820	.823	.826	.830	.833
107	.795	.797	.801	.804	.807	.810	.813	.816	.819	.823	.826	.829
108	.791	.794	.797	.800	.803	.807	.810	.813	.816	.819	.822	.825
109	.787	.790	.793	.796	.799	.803	.806	.809	.812	.815	.818	.820

factors for gas volume

volume of dry gas at 30 inches of mercury pressure (32° F.) and (68° F.)]

Total gas pressure — inches of mercury—Continued													
29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5
0.983	0.986	0.990	0.993	0.997	1.000	1.004	1.007	1.010	1.014	1.017	1.021	1.024	1.027
.980	.984	.987	.991	.995	.998	1.001	1.005	1.008	1.011	1.014	1.018	1.021	1.024
.978	.982	.985	.988	.992	.995	.999	1.002	1.005	1.009	1.012	1.016	1.019	1.022
.976	.979	.983	.986	.990	.993	.996	1.000	1.003	1.007	1.010	1.013	1.017	1.020
.973	.977	.980	.984	.987	.990	.994	.997	1.001	1.004	1.007	1.011	1.014	1.017
.971	.974	.978	.981	.984	.988	.991	.995	.998	1.001	1.005	1.008	1.012	1.015
.968	.972	.975	.978	.982	.985	.989	.992	.995	.999	1.002	1.006	1.009	1.012
.966	.969	.973	.976	.979	.983	.986	.990	.993	.996	1.000	1.003	1.006	1.010
.963	.967	.970	.973	.977	.980	.984	.987	.990	.994	.997	1.000	1.004	1.007
.961	.964	.968	.971	.974	.978	.981	.984	.988	.991	.994	.998	1.001	1.005
.958	.962	.965	.968	.972	.975	.978	.982	.985	.988	.992	.995	.999	1.002
.956	.959	.962	.966	.969	.972	.976	.979	.982	.986	.989	.993	.996	.999
.953	.956	.960	.963	.966	.970	.973	.977	.980	.983	.987	.990	.993	997
.950	.954	.957	.960	.964	.967	.971	.974	.977	.981	.984	.987	.991	.994
.948	.951	.955	.958	.961	.965	.968	.971	.975	.978	.981	.985	.988	.991
.945	.949	.952	.955	.959	.962	.965	.969	.972	.975	.979	.982	.985	.989
.943	.946	.949	.953	.956	.959	.963	.966	.969	.973	.976	.979	.983	.986
.940	.943	.947	.950	.953	.957	.960	.963	.967	.970	.973	.976	.980	.983
.937	.941	.944	.947	.951	.954	.957	.961	.964	.967	.970	.974	.977	.980
.935	.938	.941	.945	.948	.951	.955	.958	.961	.964	.968	.971	.974	.978
.932	.935	.939	.942	.945	.948	.952	.955	.958	.962	.965	.968	.972	.975
.929	.933	.936	.939	.942	.946	.949	.952	.956	.959	.962	.966	.969	.972
.927	.930	.933	.936	.940	.943	.946	.950	.953	.956	.959	.963	.966	.969
.924	.927	.930	.934	.937	.940	.944	.947	.950	.953	.957	.960	.963	.966
.921	.924	.928	.931	.934	.938	.941	.944	.947	.950	.955	.957	.960	.964
.918	.922	.925	.928	.931	.935	.938	.941	.944	.948	.951	.954	.958	.961
.916	.919	.922	.925	.928	.932	.935	.938	.942	.945	.948	.951	.955	.958
.913	.916	.919	.922	.926	.929	.932	.935	.939	.942	.945	.948	.952	.955
.910	.913	.916	.920	.923	.926	.929	.932	.936	.939	.942	.946	.949	.952
.907	.910	.913	.917	.920	.923	.926	.930	.933	.936	.939	.943	.946	.949
.904	.907	.910	.914	.917	.920	.923	.927	.930	.933	.936	.940	.943	.946
.901	.904	.908	.911	.914	.917	.920	.924	.927	.930	.933	.937	.940	.943
.898	.901	.905	.908	.911	.914	.918	.921	.924	.927	.930	.934	.937	.940
.895	.898	.902	.905	.908	.911	.914	.918	.921	.924	.927	.931	.934	.937
.892	.895	.899	.902	.905	.908	.912	.915	.918	.921	.924	.928	.931	.934
.889	.892	.896	.899	.902	.905	.908	.912	.915	.918	.921	.924	.928	.931
.886	.889	.892	.896	.899	.902	.905	.908	.912	.915	.918	.921	.924	.928
.883	.886	.889	.893	.896	.899	.902	.905	.909	.912	.915	.918	.921	.925
.880	.883	.886	.890	.893	.896	.899	.902	.906	.909	.912	.915	.918	.921
.877	.880	.883	.886	.890	.893	.896	.899	.902	.905	.909	.912	.915	.918
.874	.877	.880	.883	.886	.890	.893	.896	.899	.902	.905	.909	.912	.915
.870	.874	.877	.880	.883	.886	.889	.893	.896	.899	.902	.905	.908	.912
.867	.870	.874	.877	.880	.883	.886	.889	.892	.896	.899	.902	.905	.908
.864	.867	.870	.873	.877	.880	.883	.886	.889	.892	.896	.899	.902	.905
.861	.864	.867	.870	.873	.876	.880	.883	.886	.889	.892	.895	.898	.902
.857	.860	.863	.866	.869	.872	.876	.879	.881	.884	.888	.891	.894	.897
.853	.856	.860	.863	.866	.869	.872	.875	.878	.881	.885	.888	.891	.894
.849	.852	.856	.859	.862	.865	.868	.871	.874	.877	.881	.884	.887	.890
.846	.849	.853	.856	.859	.862	.865	.868	.871	.874	.878	.881	.884	.887
.843	.846	.849	.852	.856	.859	.862	.865	.868	.871	.874	.877	.880	.884
.839	.842	.846	.849	.852	.855	.858	.861	.864	.867	.870	.873	.877	.880
.836	.839	.842	.844	.849	.851	.854	.857	.860	.863	.866	.869	.873	.876
.832	.835	.838	.841	.845	.848	.851	.854	.857	.860	.862	.866	.869	.873
.828	.831	.834	.837	.841	.844	.847	.850	.853	.856	.858	.862	.866	.869
.824	.827	.830	.834	.837	.840	.843	.846	.849	.852	.855	.858	.862	.865

TABLE 9.—*Correction*

[Multiply observed volume of saturated gas by factor to correct to

Temperature (° F.)	Total gas pressure—Inches of mercury											
	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0	29.1
55	0.964	0.968	0.971	0.975	0.978	0.982	0.985	0.989	0.992	0.996	0.999	1.003
56	.962	.965	.969	.972	.975	.980	.983	.986	.990	.993	.997	1.000
57	.959	.963	.966	.969	.973	.976	.981	.984	.987	.991	.994	.998
58	.957	.960	.964	.967	.971	.974	.977	.982	.985	.989	.992	.995
59	.955	.958	.961	.965	.968	.972	.975	.979	.983	.986	.990	.993
60	.952	.956	.959	.962	.966	.969	.973	.976	.980	.984	.987	.990
61	.950	.953	.956	.960	.963	.967	.970	.973	.977	.981	.985	.988
62	.947	.951	.954	.957	.961	.964	.968	.971	.974	.979	.982	.985
63	.945	.948	.952	.955	.958	.962	.965	.968	.972	.975	.980	.983
64	.942	.946	.949	.952	.956	.959	.963	.966	.969	.973	.977	.980
65	.940	.943	.947	.950	.953	.957	.960	.964	.967	.970	.974	.977
66	.937	.941	.944	.948	.951	.954	.958	.961	.964	.968	.971	.974
67	.935	.938	.942	.945	.948	.952	.955	.958	.962	.965	.968	.972
68	.932	.936	.939	.942	.946	.949	.952	.956	.959	.962	.966	.969
69	.929	.933	.937	.940	.943	.947	.850	.953	.957	.960	.963	.967
70	.926	.930	.934	.937	.941.	.944	.947	.951	.954	.957	.961	.964
71	.924	.927	.932	.935	.938	.942	.945	.948	.951	.955	.958	.961
72	.921	.925	.928	.932	.936	.939	.942	.946	.949	.952	.956	.959
73	.919	.922	.925	.929	.933	.936	.940	.943	.946	.950	.953	.956
74	.916	.919	.923	.926	.930	.934	.937	.940	.944	.947	.950	.953
75	.913	.917	.920	.923	.927	.930	.934	.938	.941	.944	.948	.951
76	.911	.914	.917	.921	.924	.927	.932	.935	.938	.941	.945	.948
77	.908	.911	.915	.918	.921	.925	.928	.932	.936	.939	.942	.945
78	.906	.909	.912	.915	.919	.922	.925	.929	.933	.936	.939	.943
79	.904	.906	.909	.913	.916	.919	.923	.926	.929	.933	.936	.940
80	.900	.903	.907	.910	.913	.916	.920	.923	.926	.929	.934	.937
81	.897	.901	.904	.907	.910	.914	.917	.920	.923	.927	.930	.934
82	.895	.898	.901	.904	.908	.911	.914	.917	.921	.924	.927	.931
83	.892	.895	.898	.902	.905	.908	.911	.915	.918	.921	.924	.928
84	.889	.892	.895	.899	.902	.905	.909	.912	.915	.918	.921	.925
85	.886	.889	.893	.896	.899	.902	.906	.909	.912	.915	.919	.922
86	.883	.887	.890	.893	.896	.899	.903	.906	.909	.912	.916	.919
87	.879	.884	.887	.890	.893	.897	.900	.903	.906	.909	.913	.916
88	.877	.880	.884	.887	.891	.894	.897	.900	.903	.907	.910	.913
89	.874	.877	.880	.884	.887	.891	.894	.897	.900	.904	.907	.910
90	.871	.874	.877	.880	.885	.888	.891	.894	.897	.901	.904	.907
91	.868	.871	.874	.877	.881	.885	.888	.891	.894	.897	.901	.904
92	.865	.868	.871	.874	.878	.881	.885	.888	.891	.894	.898	.901
93	.862	.865	.868	.871	.874	.878	.881	.885	.888	.891	.895	.898
94	.859	.862	.865	.868	.871	.874	.878	.881	.885	.888	.891	.895
95	.855	.859	.862	.865	.868	.871	.874	.878	.881	.885	.888	.891
96	.852	.856	.859	.862	.865	.868	.871	.874	.878	.881	.885	.888
97	.849	.852	.856	.859	.862	.865	.868	.871	.874	.878	.881	.885
98	.846	.849	.852	.856	.859	.862	.865	.868	.871	.874	.878	.881
99	.843	.846	.849	.852	.855	.858	.862	.865	.868	.871	.874	.877
100	.839	.842	.845	.848	.851	.854	.858	.861	.864	.867	.870	.874
101	.836	.839	.842	.845	.848	.851	.855	.858	.861	.864	.867	.870
102	.831	.835	.838.	.842	.844	.847	.851	.854	.857	.860	.863	.867
103	.828	.831	.835	.838	.841	.844	.848	.851	.854	.857	.860	.863
104	.824	.828	.831	.835	.838	.841	.844	.847	.850	.853	.857	.860
105	.821	.824	.827	.831	.834	.837	.841	.844	.847	.850	.853	.856
106	.817	.821	.823	.827	.830	.834	.837	.840	.843	.846	.850	.853
107	.814	.817	.820	.823	.826	.829	.833	.836	.839	.843	.846	.849
108	.810	.813	.816	.819	.822	.826	.829	.833	.836	.839	.842	.845
109	.806	.810	.813	.816	.819	.822	.825	.828	.832	.835	.838	.841

factors for gas volume

volume of saturated gas at 30 inches of mercury pressure (32° F.) and (68° F.)]

Total gas pressure — inches of mercury—Continued													
29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5
1.006	1.009	1.013	1.016	1.020	1.023	1.027	1.031	1.034	1.038	1.041	1.045	1.048	1.051
1,003	1.007	1.010	1.014	1.018	1.021	1.024	1.029	1.032	1.035	1.038	1.042	1.045	1.048
1.001	1.005	1.008	1.011	1.015	1.018	1.022	1.026	1.029	1.033	1.036	1.040	1.043	1.046
.999	1.002	1.006	1.009	1.013	1.016	1.019	1.023	1.027	1.031	1.034	1.037	1.041	1.044
.996	1.000	1.003	1.007	1.010	1.013	1.017	1.020	1.024	1.028	1.031	1.035	1.038	1.041
.994	.997	1.001	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.029	1.032	1.036	1.039
.991	.995	.998	1.001	1.005	1.008	1.012	1.015	1.018	1.022	1.026	1.030	1.033	1.036
.989	.992	.996	.999	1.002	1.006	1.009	1.013	1.016	1.019	1.023	1.027	1.030	1.034
.986	.990	.993	.996	1.000	1.003	1.007	1.010	1.013	1.017	1.020	1.024	1.028	1.031
.984	.987	.991	.994	.997	1.001	1.004	1.007	1.011	1.014	1.017	1.021	1.025	1.029
.981	.985	.988	.991	.995	.998	1.001	1.005	1.008	1.011	1.015	1.018	1.022	1.026
.979	.982	.985	.989	.992	.995	.999	1.002	1.005	1.009	1.012	1.016	1.019	1.023
.976	.979	.983	.986	.989	.993	.996	1.000	1.003	1.006	1.010	1,013	1.016	1.020
.973	.977	.980	.983	.987	.990	.994	.997	1.000	1.004	1.007	1.010	1.014	1.017
.970	.974	.978	.981	.984	.988	.991	.994	.998	1.001	1.004	1.008	1.011	1.014
.967	.971	.974	.978	.982	.985	.988	.992	.995	.998	1.002	1.005	1.008	1.012
.965	.968	.972	.976	.979	.982	.986	.989	.992	.996	.999	1.002	1.006	1.009
.962	.965	.969	.973	.976	.980	.983	.986	.990	.993	.996	.999	1.003	1.006
.959	.963	.966	.970	.973	.977	.980	.984	.987	.990	.993	.997	1.000	1.003
.957	.960	.963	.967	.970	.974	.978	.981	.984	.987	.991	.994	.997	1.001
.954	.957	.961	.964	.967	.971	.974	.978	.981	.985	.988	.991	.995	.998
.951	.955	.958	.961	.964	.968	.971	.975	.979	.982	.985	.989	.992	.995
.949	.952	.955	.958	.962	.965	.968	.972	.976	.979	.982	.986	.989	.992
.946	.949	.952	.956	.959	.962	.966	.969	.973	.976	.980	.983	.986	.989
.943	.946	.950	.953	.956	.960	.963	.966	.970	.973	.977	.980	.983	.987
.940	.944	.947	.950	.953	.957	.960	.963	.966	.970	.973	.977	.980	.984
.938	.941	.944	.947	.950	.954	.957	.960	.964	.967	.970	.973	.977	.981
.935	.938	.941	.944	.948	.951	.954	.957	.961	.964	.967	.970	.974	.978
.932	.935	.938	.942	.945	.948	.951	.954	.958	.961	.964	.968	.971	.974
.928	.932	.935	.939	.942	.945	.948	.952	.955	.958	.961	.965	.968	.971
.925	.928	.932	.936	.939	.942	.945	.949	.952	.955	.958	.962	.965	.968
.922	.925	.930	.933	.936	.939	.942	.946	.949	.952	.955	.959	.962	.965
.919	.922	.926	.930	.933	.936	.939	.943	.946	.949	.952	.956	.959	.962
.916	.919	.923	.927	.930	.933	.936	.940	.943	.946	.949	.953	.956	.959
.913	.916	.920	.923	.926	.930	.933	.937	.940	.943	.946	.950	.953	.956
.910	.913	.917	.920	.923	.926	.930	.934	.937	.940	.943	.946	.950	.953
.907	.910	.913	.917	.920	.923	.926	.930	.934	.937	.940	.943	.946	.950
.904	.907	.910	.914	.917	.920	.923	.927	.931	.934	.937	.940	.943	.947
.901	.904	.907	.911	.914	.917	.920	.923	.927	.931	.934	.937	.940	.943
.898	.901	.904	.907	.911	.914	.917	.920	.923	.927	.931	.934	.937	.940
.895	.898	.901	.904	.907	.911	.914	.917	.920	.923	.927	.931	.934	.937
.891	.895	.898	.901	.904	.907	.910	.914	.917	.920	.923	.927	.930	.934
.888	.891	.895	.898	.901	.904	.907	.910	.913	.917	.920	.923	.926	.930
.885	.888	.891	.894	.898	.901	.904	.907	.910	.913	.917	.920	.923	.926
.882	.885	.888	.891	.894	.897	.901	.904	.907	.910	.913	.916	.919	.923
.878	.881	.884	.887	.890	.893	.896	.900	.903	.906	.909	.912	.915	.918
.874	.876	.880	.884	.887	.890	.893	.896	.899	.902	.906	.909	.912	.915
.870	.872	.876	.880	.883	.886	.889	.892	.895	.898	.902	.905	.908	.911
.866	.869	.873	.876	.879	.883	.886	.889	.892	.895	.899	.902	.905	.908
.863	.866	.869	.872	.876	.880	.883	.886	.889	.892	.895	.898	.901	.905
.859	.862	.866	.869	.872	.876	.878	.882	.885	.888	.891	.894	.898	.901
.856	.859	.862	.864	.869	.872	.874	.878	.881	.884	.887	.890	.894	.897
.852	.855	.858	.861	.865	.869	.871	.874	.877	.880	.883	.887	.890	.894
.848	.851	.854	.857	.861	.865	.867	.870	.873	.876	.880	.883	.887	.891
.844	.848	.851	.854	.857	.860	.863	.866	.870	.873	.876	.879	.882	.886

TABLE 10.—*Inches to millimeters*

Inches	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
27.0	685.8	686.1	686.3	686.6	686.8	687.1	687.3	687.6	687.8	688.1
27.1	688.3	688.6	688.8	689.1	689.4	689.6	689.9	690.1	690.4	690.6
27.2	690.9	691.1	691.4	691.6	691.9	692.2	692.4	692.7	692.9	693.2
27.3	693.4	693.7	693.9	694.2	694.4	694.7	694.9	695.2	695.5	695.7
27.4	696.0	696.2	696.5	696.7	697.0	697.2	697.5	697.7	698.0	698.2
27.5	698.5	698.8	699.0	699.3	699.5	699.8	700.0	700.3	700.5	700.8
27.6	701.0	701.3	701.5	701.8	702.1	702.3	702.6	702.8	703.1	703.3
27.7	703.6	703.8	704.1	704.3	704.6	704.9	705.1	705.4	705.6	705.9
27.8	706.1	706.4	706.6	706.9	707.1	707.4	707.6	707.9	708.2	708.4
27.9	708.7	708.9	709.2	709.4	709.7	709.9	710.2	710.4	710.7	710.9
28.0	711.2	711.5	711.7	712.0	712.2	712.5	712.7	713.0	713.2	713.5
28.1	713.7	714.0	714.2	714.5	714.8	715.0	715.3	715.5	715.8	716.0
28.2	716.3	716.5	716.8	717.0	717.3	717.6	717.8	718.1	718.3	718.6
28.3	718.8	719.1	719.3	719.6	719.8	720.1	720.3	720.6	720.9	721.1
28.4	721.4	721.6	721.9	722.1	722.4	722.6	722.9	723.1	723.4	723.6
28.5	723.9	724.2	724.4	724.7	724.9	725.2	725.4	725.7	725.9	726.2
28.6	726.4	726.7	727.0	727.2	727.5	727.7	728.0	728.2	728.5	728.7
28.7	729.0	729.2	729.5	729.7	730.0	730.2	730.5	730.7	731.0	731.2
28.8	731.5	731.8	732.0	732.3	732.5	732.8	733.0	733.3	733.5	733.8
28.9	734.0	734.3	734.5	734.8	735.0	735.3	735.5	735.8	736.0	736.3
29.0	736.5	736.8	737.1	737.3	737.6	737.8	738.1	738.3	738.5	738.8
29.1	739.0	739.3	739.5	739.8	740.0	740.3	740.6	740.8	741.1	741.4
29.2	741.6	741.8	742.1	742.3	742.6	742.8	743.1	743.4	743.6	743.9
29.3	744.1	744.4	744.6	744.9	745.2	745.4	745.7	745.9	746.2	746.4
29.4	746.7	746.9	747.2	747.5	747.7	748.0	748.2	748.5	748.7	749.0
29.5	749.3	749.5	749.8	750.0	750.3	750.5	750.8	751.0	751.3	751.5
29.6	751.8	752.0	752.3	752.6	752.8	753.1	753.3	753.6	753.8	754.1
29.7	754.3	754.6	754.8	755.1	755.4	755.6	755.9	756.1	756.4	756.6
29.8	756.9	757.1	757.4	757.7	757.9	758.2	758.4	758.7	758.9	759.2
29.9	759.4	759.7	759.9	760.2	760.4	760.7	760.9	761.2	761.5	761.7
30.0	762.0	762.2	762.5	762.7	763.0	763.2	763.5	763.7	764.0	764.2
30.1	764.5	764.7	765.0	765.3	765.5	765.8	766.0	766.3	766.5	766.8
30.2	767.0	767.3	767.6	767.8	768.1	768.4	768.6	768.9	769.1	769.4
30.3	769.6	769.9	770.1	770.4	770.6	770.9	771.1	771.4	771.7	771.9
30.4	772.2	772.4	772.7	772.9	773.2	733.4	773.7	773.9	774.2	774.4
30.5	774.7	775.0	775.2	775.5	775.7	776.0	776.2	776.5	776.7	777.0

TABLE 11.—*The equivalent of inches of water pressure in inches of mercury and ounces per square inch*

Inches of water	Inches of mercury	Ounces per square inch	Inches of water	Inches of mercury	Ounces per square inch	Inches of water	Inches of mercury	Ounces per square inch	Inches of water	Inches of mercury	Ounces per square inch
0.0	--------	--------	3.5	0.258	2.023	7.0	0.515	4.05	10.5	0.772	6.07
0.1	0.007	0.058	3.6	.265	2.081	7.1	.522	4.10	10.6	.780	6.13
0.2	.015	.116	3.7	.272	2.138	7.2	.530	4.16	10.7	.787	6.18
0.3	.022	.173	3.8	.280	2.196	7.3	.537	4.22	10.8	.794	6.24
0.4	.029	.231	3.9	.287	2.254	7.4	.544	4.28	10.9	.802	6.30
0.5	.037	.289	4.0	.294	2.312	7.5	.552	4.33	11.0	.809	6.36
0.6	.044	.347	4.1	.302	2.370	7.6	.559	4.39	11.1	.816	6.41
0.7	.052	.404	4.2	.309	2.427	7.7	.566	4.45	11.2	.824	6.47
0.8	.059	.462	4.3	.316	2.485	7.8	.574	4.51	11.3	.831	6.53
0.9	.066	.520	4.4	.324	2.543	7.9	.581	4.57	11.4	.838	6.59
1.0	.074	.578	4.5	.331	2.601	8.0	.588	4.62	11.5	.846	6.65
1.1	.081	.636	4.6	.338	2.659	8.1	.596	4.68	11.6	.853	6.70
1.2	.088	.693	4.7	.346	2.716	8.2	.603	4.74	11.7	.861	6.76
1.3	.096	.751	4.8	.353	2.774	8.3	.611	4.80	11.8	.868	6.82
1.4	.103	.809	4.9	.360	2.832	8.4	.618	4.85	11.9	.875	6.88
1.5	.110	.867	5.0	.368	2.890	8.5	.625	4.91	12.0	.883	6.94
1.6	.118	.925	5.1	.375	2.948	8.6	.633	4.97	12.1	.890	6.99
1.7	.125	.982	5.2	.383	3.00	8.7	.640	5.03	12.2	.897	7.05
1.8	.132	1.040	5.3	.390	3.06	8.8	.647	5.09	12.3	.905	7.11
1.9	.140	1.098	5.4	.397	3.12	8.9	.655	5.14	12.4	.912	7.17
2.0	.147	1.156	5.5	.405	3.18	9.0	.662	5.20	12.5	.920	7.22
2.1	.154	1.214	5.6	.412	3.24	9.1	.669	5.26	12.6	.927	7.28
2.2	.162	1.271	5.7	.419	3.29	9.2	.677	5.32	12.7	.934	7.34
2.3	.169	1.329	5.8	.427	3.35	9.3	.684	5.37	12.8	.941	7.40
2.4	.177	1.387	5.9	.434	3.41	9.4	.691	5.43	12.9	.949	7.45
2.5	.184	1.445	6.0	.442	3.47	9.5	.699	5.49	13.0	.956	7.51
2.6	.191	1.503	6.1	.449	3.53	9.6	.706	5.55	13.1	.964	7.57
2.7	.199	1.560	6.2	.456	3.58	9.7	.713	5.61	13.2	.971	7.63
2.8	.206	1.618	6.3	.464	3.64	9.8	.721	5.66	13.3	.978	7.69
2.9	.213	1.676	6.4	.471	3.70	9.9	.728	5.72	13.4	.986	7.74
3.0	.221	1.734	6.5	.478	3.76	10.0	.736	5.78	13.5	.993	7.80
3.1	.228	1.792	6.6	.486	3.81	10.1	.743	5.84	13.6	1.000	7.86
3.2	.235	1.849	6.7	.493	3.87	10.2	.750	5.89	13.7	1.008	7.92
3.3	.243	1.907	6.8	.500	3.93	10.3	.758	5.95	13.8	1.015	7.98
3.4	.250	1.965	6.9	.508	3.99	10.4	.765	6.01	13.9	1.022	8.03

TABLE 12.—*The vapor pressure of water* [1]

Temperature (°F.)	Pressure		Temperature (°F.)	Pressure		Temperature (°F.)	Pressure	
	Inches of mercury	mm of mercury		Inches of mercury	mm of mercury		Inches of mercury	mm of mercury
32	0.180	4.580	58	0.486	12.34	83	1.139	28.93
33	.188	4.766	59	.504	12.79	84	1.176	29.88
34	.195	4.964	60	.522	13.25	85	1.215	30.86
35	.203	5.166	61	.541	13.74	86	1.254	31.86
36	.212	5.376	62	.560	14.23	87	1.295	32.89
37	.220	5.592	63	.581	14.75	88	1.337	33.95
38	.229	5.818	64	.601	15.26	89	1.379	35.04
39	.238	6.052	65	.622	15.81	90	1.423	36.15
40	.248	6.290	66	.644	16.37	91	1.469	37.31
41	.258	6.541	67	.667	16.95	92	1.515	38.49
42	.268	6.799	68	.691	17.55	93	1.563	39.70
43	.278	7.066	69	.715	18.15	94	1.612	40.94
44	.289	7.343	70	.740	18.79	95	1.663	42.23
45	.300	7.627	71	.765	19.43	96	1.715	43.56
46	.312	7.923	72	.792	20.11	97	1.767	44.88
47	.324	8.230	73	.819	20.81	98	1.822	46.28
48	.336	8.546	74	.847	21.51	99	1.878	47.69
49	.349	8.868	75	.876	22.25	100	1.935	49.16
50	.363	9.21	76	.906	23.00	101	1.994	50.66
51	.376	9.56	77	.936	23.78	102	2.055	52.20
52	.391	9.92	78	.966	24.57	103	2.117	53.77
53	.405	10.29	79	1.000	25.40	104	2.181	55.40
54	.420	10.67	80	1.033	26.24	105	2.246	57.04
55	.436	11.08	81	1.067	27.11	106	2.313	58.76
56	.452	11.48	82	1.103	28.02	107	2.382	60.51
57	.469	11.90						

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[1] Smithsonian Meteorological Tables, 4th ed., 1918.

TABLE 13.—*Gauge pressure (pounds per square inch) to atmospheres (absolute)*

Pounds per square inch	0	10	20	30	40	50	60	70	80	90
0	1.00	1.68	2.36	3.04	3.72	4.40	5.08	5.76	6.44	7.12
100	7.80	8.48	9.17	9.85	10.53	11.21	11.89	12.57	13.25	13.93
200	14.61	15.29	15.97	16.65	17.33	18.01	18.69	19.37	20.05	20.73
300	21.41	22.09	22.77	23.45	24.14	24.82	25.50	26.18	26.86	27.54
400	28.22	28.90	29.58	30.26	30.94	31.62	32.30	32.98	33.66	34.34
500	35.02	35.70	36.38	37.06	37.74	38.42	39.11	39.79	40.47	41.15
600	41.83	42.51	43.19	43.87	44.55	45.23	45.91	46.59	47.27	47.95
700	48.63	49.31	49.99	50.67	51.35	52.03	52.71	53.39	54.08	54.76
800	55.44	56.12	56.80	57.48	58.16	58.84	59.52	60.20	60.88	61.56
900	62.24	62.92	63.60	64.28	64.96	65.64	66.32	67.00	67.68	68.36
1,000	69.04	69.73	70.41	71.09	71.77	72.45	73.13	73.81	74.49	75.17
1,100	75.85	76.53	77.21	77.89	78.57	79.25	79.93	80.61	81.29	81.97
1,200	82.65	83.34	84.01	84.70	85.38	86.06	86.74	87.42	88.10	88.78
1,300	89.46	90.14	90.82	91.50	92.18	92.86	93.54	94.22	94.90	95.58
1,400	96.27	96.95	97.63	98.31	98.98	99.67	100.3	101.0	101.7	102.4
1,500	103.0	103.7	104.4	105.1	105.8	106.5	107.1	107.8	108.5	109.2
1,600	109.9	110.6	111.3	111.9	112.6	113.3	114.0	114.6	115.3	116.0
1,700	116.7	117.4	118.0	118.7	119.4	120.1	120.8	121.4	122.1	122.8
1,800	123.5	124.1	124.8	125.5	126.2	126.9	127.6	128.2	128.9	129.6
1,900	130.3	131.0	131.6	132.3	133.0	133.7	134.4	135.0	135.7	136.4
2,000	137.1	137.8	138.4	139.1	139.8	140.5	141.2	141.9	142.5	143.2
2,100	143.9	144.6	145.2	145.9	146.6	147.3	148.0	148.7	149.3	150.0
2,200	150.7	151.4	152.1	152.7	153.4	154.1	154.8	155.5	156.1	156.8
2,300	157.5	158.2	158.9	159.5	160.2	160.9	161.6	162.3	162.9	163.6
2,400	164.3	165.0	165.7	166.3	167.0	167.7	168.4	169.1	169.8	170.4
2,500	171.1	171.8	172.5	173.2	173.8	174.5	175.2	175.9	176.6	177.2
2,600	177.9	178.6	179.3	180.0	180.6	181.3	182.0	182.7	183.4	184.0
2,700	184.7	185.4	186.1	186.8	187.4	188.1	188.8	189.5	190.2	190.8
2,800	191.5	192.2	192.9	193.6	194.2	194.9	195.6	196.3	197.0	197.7
2,900	198.3	199.0	199.7	200.4	201.1	201.7	202.4	203.1	203.8	204.4

TABLE 14.—*Table of equivalent temperatures on the centigrade and Fahrenheit scales*

° F.	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.	° C.	° F.	° C.
55.0	12.8	60.0	15.6	65.0	18.3	70.0	21.1	75.0	23.9	80.0	26.7	85.0	29.4	90.0	32.2
.1	.8	.1	.6	.1	.4	.1	.2	.1	.9	.1	.7	.1	.5	.1	.3
.2	.9	.2	.7	.2	.4	.2	.2	.2	24.0	.2	.8	.2	.6	.2	.3
.3	.9	.3	.7	.5	.5	.3	.3	.3	.0	.3	.8	.3	.6	.3	.4
.4	13.0	.4	.8	.4	.6	.4	.3	.4	.1	.4	.9	.4	.7	.4	.4
.5	.1	.5	.8	.5	.6	.5	.4	.5	.2	.5	.9	.5	.7	.5	.5
.6	.1	.6	.9	.6	.7	.6	.4	.6	.2	.6	27.0	.6	.8	.6	.6
.7	.2	.7	.9	.7	.7	.7	.5	.7	.3	.7	.0	.7	.8	.7	.6
.8	.2	.8	16.0	.8	.8	.8	.6	.8	.3	.8	.1	.8	.9	.8	.7
.9	.3	.9	.0	.9	.8	.9	.6	.9	.4	.9	.2	.9	.9	.9	.7
56.0	.3	61.0	.1	66.0	.9	71.0	.7	76.0	.4	81.0	.2	86.0	30.0	91.0	.8
.1	.4	.1	.2	.1	.9	.1	.7	.1	.5	.1	.3	.1	.0	.1	.8
.2	.4	.2	.2	.2	19.0	.2	.8	.2	.6	.2	.3	.2	.1	.2	.9
.3	.5	.3	.3	.3	.0	.3	.8	.3	.6	.3	.4	.3	.2	.3	.9
.4	.6	.4	.3	.4	.1	.4	.9	.4	.7	.4	.4	.4	.2	.4	33.0
.5	.6	.5	.4	.5	.2	.5	.9	.5	.7	.5	.5	.5	.3	.5	.0
.6	.7	.6	.4	.6	.2	.6	22.0	.6	.8	.6	.6	.6	.3	.6	.1
.7	.7	.7	.5	.7	.3	.7	.0	.7	.8	.7	.6	.7	.4	.7	.2
.8	.8	.8	.5	.8	.3	.8	.1	.8	.9	.8	.7	.8	.4	.8	.2
.9	.8	.9	.6	.9	.4	.9	.2	.9	.9	.9	.7	.9	.5	.9	.3
57.0	.9	62.0	.7	67.0	.4	72.0	.2	77.0	25.0	82.0	.8	87.0	.6	92.0	.3
.1	.9	.1	.7	.1	.5	.1	.3	.1	.0	.1	.8	.1	.6	.1	.4
.2	14.0	.2	.8	.2	.6	.2	.3	.2	.1	.2	.9	.2	.7	.2	.4
.3	.0	.3	.8	.3	.6	.3	.4	.3	.2	.3	.9	.3	.7	.3	.5
.4	.1	.4	.9	.4	.7	.4	.4	.4	.2	.4	28.0	.4	.8	.4	.6
.5	.2	.5	.9	.5	.7	.5	.5	.5	.3	.5	.0	.5	.8	.5	.6
.6	.2	.6	17.0	.6	.8	.6	.6	.6	.3	.6	.1	.6	.9	.6	.7
.7	.3	.7	.0	.7	.8	.7	.6	.7	.4	.7	.2	.7	.9	.7	.7
.8	.3	.8	.1	.8	.9	.8	.7	.8	.4	.8	.2	.8	31.0	.8	.8
.9	.4	.9	.2	.9	.9	.9	.7	.9	.5	.9	.3	.9	.0	.9	.8
58.0	.4	63.0	.2	68.0	20.0	73.0	.8	78.0	.6	83.0	.3	88.0	.1	93.0	.9
.1	.5	.1	.3	.1	.0	.1	.8	.1	.6	.1	.4	.1	.2	.1	.9
.2	.6	.2	.3	.2	.1	.2	.9	.2	.7	.2	.4	.2	.2	.2	34.0
.3	.6	.3	.4	.3	.2	.3	.9	.3	.7	.3	.5	.3	.3	.3	.0
.4	.7	.4	.4	.4	.2	.4	23.0	.4	.8	.4	.6	.4	.3	.4	.1
.5	.7	.5	.5	.5	.3	.5	.0	.5	.8	.5	.6	.5	.4	.5	.2
.6	.8	.6	.5	.6	.3	.6	.1	.6	.9	.6	.7	.6	.4	.6	.2
.7	.8	.7	.6	.7	.4	.7	.2	.7	.9	.7	.7	.7	.5	.7	.3
.8	.9	.8	.7	.8	.4	.8	.2	.8	26.0	.8	.8	.8	.6	.8	.3
.9	.9	.9	.7	.9	.5	.9	.3	.9	.0	.9	.8	.9	.6	.9	.4
59.0	15.0	64.0	.8	69.0	.6	74.0	.3	79.0	.1	84.0	.9	89.0	.7	94.0	.4
.1	.0	.1	.8	.1	.6	.1	.4	.1	.2	.1	.9	.1	.7	.1	.5
.2	.1	.2	.9	.2	.7	.2	.4	.2	.2	.2	29.0	.2	.8	.2	.6
.3	.2	.3	.9	.3	.7	.3	.5	.3	.3	.3	.0	.3	.8	.3	.6
.4	.2	.4	18.0	.4	.8	.4	.6	.4	.3	.4	.1	.4	.9	.4	.7
.5	.3	.5	.0	.5	.8	.5	.6	.5	.4	.5	.2	.5	.9	.5	.7
.6	.3	.6	.1	.6	.9	.6	.7	.6	.4	.6	.2	.6	32.0	.6	.8
.7	.4	.7	.1	.7	.9	.7	.7	.7	.5	.7	.3	.7	.0	.7	.8
.8	.4	.8	.2	.8	21.0	.8	.8	.8	.6	.8	.3	.8	.1	.8	.9
.9	.5	.9	.3	.9	.0	.9	.8	.9	.6	.9	.4	.9	.2	.9	.9

TABLE 15.—*Weights of a normal liter of various gases*

[In selecting these values an extensive critical review of the literature has been made. This review will appear in a later publication of this bureau]

L_n = Weight in grams of a normal liter of gas at 0° C. and at a pressure of 760 mm of mercury (at 0° C.), the acceleration of gravity being taken as 980.665 cm per second per second.

Gas	Formula	Molecular weight [1]	L_n	Specific gravity, air=1
Acetylene	C_2H_2	26.016	1.179	0.912
Air			1.2929	1.0000
Ammonia	NH_3	17.032	.7710	.5963
Argon	A	39.91	1.7825	1.3787
Arsene	AsH_3	77.98	3.48	2.69
Iso-Butane	C_4H_{10}	58.08	2.673	2.067
Carbon dioxide	CO_2	44.000	1.9769	1.5290
Carbon monoxide	CO	28.000	1.2504	.9671
Carbon oxysulphide	COS	60.064	2.72	2.10
Chlorine	Cl_2	70.914	3.214	2.486
Chlorine monoxide	Cl_2O	86.914	3.89	3.01
Ethane	C_2H_6	30.048	1.3566	1.0493
Ethylene	C_2H_4	28.032	1.2604	.9749
Fluorine	F_2	38.00	1.695	1.311
Helium	He	4.00	.1785	.1381
Hydrogen	H_2	2.016	.08988	.06952
Hydrogen bromide	HBr	80.924	3.6445	2.8189
Hydrogen chloride	HCl	36.465	1.6392	1.2678
Hydrogen iodide	HI	127.940	5.79	4.48
Hydrogen selenide	H_2Se	81.2	3.670	2.839
Hydrogen sulphide	H_2S	34.080	1.539	1.190
Krypton	Kr	82.9	3.708	2.868
Methane	CH_4	16.032	.7168	.5544
Methyl chloride	CH_3Cl	50.481	2.3046	1.7825
di-Methyl ether	$(CH_3)_2O$	46.048	2.1098	1.6318
Methyl fluoride	CH_3F	34.02	1.5452	1.1951
Neon	Ne	20.2	.9002	.6963
Nitric oxide	NO	30.008	1.3402	1.0366
Nitrogen (chem.)	N_2	28.016	1.25057	.96724
Nitrogen (atm.)			1.2569	.9722
Nitrosyl chloride	NOCl	65.465	2.992	2.314
Nitrous oxide	N_2O	44.016	1.9778	1.5297
Oxygen	O_2	32.000	1.42904	1.10527
Phosphine	PH_3	34.051	1.5294	1.1829
Propane	C_3H_8	44.064	2.020	1.562
mono-Silane	SiH_4	32.09	1.44	1.11
Silicon tetrafluoride	SiF_4	104.06	4.684	3.623
Sulphur dioxide	SO_2	64.064	2.9269	2.2638
Xenon	X	130.2	5.851	4.525

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[1] From International Table of Atomic Weights for 1925.

TABLE 16.—*Critical constants of substances*

[In selecting these figures an extensive critical review of the literature has been made. This review will appear in a later publication of this bureau]

Substance	Critical ° C.	Temperature ° C. absolute [1]	Critical pressure atmosphere	Critical density g/cc
Acetylene	36	309	62	0.231
Air	−140.7	132.4	37.2	[2] .35 [3] .31
Allylene	128	401	----------	----------
Ammonia	132.4	405.5	111.5	.235
Argon	−122	151	48	.53
iso-Butane	134	407	37	----------
n-Butane	153	426	36	----------
Carbon dioxide	31.0	304.1	72.9	.460
Carbon monoxide	−138.7	134.4	34.6	.311
Carbon oxysulphide	105	378	61	----------
Chlorine	144	417	76	.573
Cyanogen	128	401	59	----------
Ethane	32.1	305.2	48.8	.21
Ethyl chloride	187.2	460.3	52	----------
Ethylene	9.7	282.8	50.9	.22
Helium	−267.9	5.2	2.3	.066
Hydrogen	−239.9	33.2	12.8	.0310
Hydrogen bromide	90	363	84	----------
Hydrogen chloride	51.4	324.5	81.6	----------
Hydrogen iodide	151	424	82	----------
Hydrogen sulphide	100.4	373.5	88.9	----------
Krypton	−63?	210?	54?	.78?
Methane	−82.5	190.6	45.8	.162
Methyl chloride	143.1	416.2	65.8	.37?
Neon	−228.7	44.4	25.9	.484
Nitric oxide	−94?	179?	65?	----------
Nitrogen	−147.1	126.0	33.5	.3110
Nitrous oxide	36.5	309.6	71.7	.45?
Oxygen	−118.8	154.3	49.7	.430
Ozone	−5?	268?	92?	----------
Phosgene	183?	456?	----------	----------
Phosphine	52	325	65	----------
Propane	95.6	368.7	43	----------
Propylene	92.3	365.4	45.0	----------
Silicon tetrafluoride	−1	272	50	----------
Sulphur dioxide	157.2	430.3	77.7	.52?
Xenon	17	290	58	1.155

[1] The absolute zero is taken as −273.1° C.
[2] "Plait point."
[3] "Critical point of contact."

NOTE.—Doubtful values are indicated by question marks.

V. BIBLIOGRAPHY

1. EXPANSION

Lahire, Mém. de l'acad.; 1708: Expansion of air.

Roy, Colonel, Trans. Roy. Soc. London; 1777: Expansion of air.

Monge, Berthollet, and Vandermonde, Mém. de l'acad.; 1786: Expansion of air and hydrogen.

De Prony, R., J. de l'Ecole Polytechnique, 2d pt., p. 24; 1795: Law of expansion of gases.

Gay-Lussac, J. Roy. Inst., **1**, p. 196; 1802; Gilbert Ann. **12**, p. 257; 1803; Nicholson, J., **3**, p. 207; 1802: On the expansion of gases and vapors.

Gilbert, L. W., Gilbert Ann., **12**, p. 396; 1803: Expansion of gases. (Correction of Gay-Lussac's results.)

Gilbert, L. W., Gilbert Ann., **14**, p. 266; **15**, p. 25; 1803: Expansion of gases.

Parrot, G. F., Gilbert Ann., **17**, p. 82; 1804; **25**, p. 434; 1807: Expansion of gases.

Dalton, J., Mem. Phil. Soc. Manchester, **1**, p. 425; 1805: Expansion of dry and moist air.

Gough, J., Nicholson J., **23**, p. 182; 1809: Expansion of moist air.

Paoli, D., Brugnatelli J. of Phy. Chem. and Nat., **4**, p. 187; 1811: Expansion of gases.

Dulong and Petit, Ann. de Chimie and de Physique (2), **2**, p. 240; 1816; Ann. chim. phys., (2) **7**, p. 113; 1817: Expansion of gases.

Gay-Lussac, L. J., and Welter, J. J., Ann. chim. phys., **19**, p. 436; 1821: Expansion of air.

Davy, Sir H., Trans. Roy. Soc. London, p. 204; 1823: Expansion of gases.

Biggs, M., Thomson's Annals of Philosophy, **6**, p. 415; 1823; **7**, p. 133; 1824: Expansion of gases.

Prout, W., Brit. Assoc. Advancement Sci. Repts., p. 566; 1831: Expansion of air.

Meikle, H., Phil. Mag., **11**, p. 243; 1832: Expansion of gases.

Strehlke, F., Pogg. Ann., **42**, p. 175; 1837: Expansion of dry air.

Rudberg, F., Pogg. Ann., **43**, p. 587; 1838: Expansion of dry air.

Rudberg, F., Pogg. Ann., **41**, pp. 271, 558; 1837; **44**, p. 119; 1838: Coefficient of expansion of air.

Rudberg, F., Lieb. Ann., **28**, p. 143; 1838: Expansion of dry air.

Delarwi, A., Bbl. Universelle des Sciences (Geneva), **36**, p. 409; 1841: Expansion of gases.

Regnault, Compt. rend., **13**, p. 1077; 1841; Bibl. Universelle des Sciences (Geneva) **36**, p. 196; 1841; J. Prak. Chem., **25**, p. 298; 1842; Pogg. Ann., **55**, p. 141; 1842: On the coefficient of expansion of gases.

Regnault, Compt. rend., **15**, p. 391; 1842: Remarks on the expansion of air and mercury.

Regnault, Ann. chim. phys., **4**, p. 5; 1842; **5**, p. 52; 1842; J. Prak. Chem., **26**, p. 1, 287; 1842; Compt. rend., **14**, p. 204, 595; 1842; Pogg. Ann. **55**, pp. 391, 557; 1842; **57**, p. 115; 1842: Researches on the expansion of gases.

Magnus, Pogg. Ann., **55**, p. 1; 1842; Compt. rend., **14**, p. 165; 1842; Ann. chim. phys., (3) **4**, p. 330; 1842; Pogg. Ann., **57**, p. 177; 1842; Ann. chim. phys., (3), **6**, p. 353; 1842: Expansion of gases.

Majacchi, G. A., Ann. di. Fis., Chim., Mat., etc. (Milano), **7**, p. 268; 1842: Expansion of gases.

Regnault, Mém. de l'acad., **21**, p. 1; 1847; Ann. chim. phys. (3) **5**, p. 52; 1842; Pogg. Ann. **57**, p. 118; 1842: Expansion of gases.

Regnault, Ann. chim. phys., **26**, p. 257; 1849; J. Prak. Chem., **47**, p. 188; 1849. Note on the boiling points of carbon dioxide and nitric oxide at atmospheric pressure, and on the coefficients of expansion at low temperatures and different pressures of air and hydrogen.

Petrie, W., Edin. New Phil. J., **51**, p. 120; 1851: Expansion of gases.

Joule, J. P., Mem. Phil. Soc. of Manchester, **15**, p. 143; 1860: Dalton's determination of the expansion of air.

Stewart, B., Trans. Roy. Soc. London, **153**, p. 425; 1863: Expansion of air.

Stuart, L. C., Pogg. Ann., **119**, p. 327; 1863: Relation between laws of Boyle, Gay-Lussac, and Joule.

Recknagel, Pogg. Ann., **123**, p. 115; 1864: Expansion of air.

Potter, R., Phil. Mag., **28**, p. 271; 1864: Expansion of gases.

Cazin, A., Compt. rend., **69**, p. 400; 1869; Ann. chim. phys., **20**, p. 251; 1870: Expansion of gases.

Regnault, Compt. rend., **69**, p. 780; 1869; Mém. Acad. Sci., **37**, pt. 2, p. 579; 1870; Arch. sci. phys. nat., **42**, p. 382; 1871: Memoir on the expansion of gases.

Dubrunfaut, Compt. rend., **70**, p. 754; 1870: Expansion of gases.

Crova, A., Mém Acad. Sci. et Lettres de Montpellier, 8, p. 81; 1872–1875: Expansion of gases.

Von Jolly, Pogg Ann. Jubelband., p. 82; 1874: Expansion of gases.

Carhart, H. S., Van Nostrand's Eng. Mag., **12**, p. 207; 1875: Expansion of gases.

Amagat, Compt. rend., **74**, p. 1299; 1872: On the expansion of moist air.

Robinsin, S. W., Van Nostrand's Eng. Mg., **13**, p. 435; 1875: Expansion of gases.

Usov, S. A., J. Russ. Phys. Chem. Soc., pt. 1, p. 207; 1876: Expansion of air.

Hautefeuille, P., and Troost, L., Compt. rend., **83**, p. 333; 1876: Compressibility and expansion coefficients of vapors.

Mendeléeff and Kajander., Ber., **8**, p. 1681; 1875; **9**, p. 1311; 1876; **10**, p. 81; 1877; Compt. rend., **82**, p. 450; 1876: Expansion of gases.

Radau, R., Le Moniteur Scientifique, **18**, p. 643; 1876: Expansion of air.

Mendeléeff, D., Ber., **10**, p. 81; 1877: Expansion of air at constant pressure.

Vincent and Delachanal, Ann. chimie phys., **16**, p. 427; 1879: Determination of the density and coefficient of expansion of methyl chloride (liquid).

Ilosvay, M., Bull. soc. chim. (n. s.) **37**, p. 294; 1882: Ber., **15**, p. 1186; 1882: Expansion of carbon oxysulphide.

Amagat, Ann. chim. phys., **28**, p. 464; 1883: Memoir on the compressibility of air and carbon dioxide.

Lucas, F., Compt. rend., **103**, p. 1251; 1886: Expansion of gases.

Callendar, Trans. Roy. Soc. London, **178A**, p. 161; 1887; Proc. Roy. Soc. (London), **41**, p. 231; 1887; **50**, p. 247; 1891: Comparison of platinum and gas thermometers.

Chappuis, Trav. et Mem. Bur. intern. Poids et Mes., **6**; 1888; Archives des Sciences, **20**, pp. 5, 153; 248; 1888; Rapports du Congres International de Physique Paris, **1900**, p. 131: Expansion coefficients of gases.

Wiebe and Böttcher, Z. fur Instrumentenk, **10**, pp. 16, 233; 1890: Expansion of air.

Puschl, C., Sitzb. Akad. Wiss. Wien., **96**, (Ab 2) p. 54; 1888: Behavior of gases toward laws of Mariotte and Gay-Lussac.

Puschl, C., Anz. Akad. Wiss. Wien., **25**, p. 43; 1889; Sitz. Akad. Wiss. Wien., **98**, Ab, 2a, pp. 757, 1337; 1890: Expansion of gases.

Amagat, E. H., Compt. rend., **111**, p. 871; 1890: New method for the study of the compressibility and dilatation of liquids and gases. Results for the gases: oxygen, hydrogen, nitrogen, and air.

Callendar and Griffiths, Trans. Roy. Soc. London, **182A**, p. 119; 1891: Expansion of air.

Leonhardt, Exner. Rpm. der Phys., **27**, p. 253; 1891: Expansion of gases.

Melander, Wied. Ann., **47**, p. 135; 1892; Acta Soc. Ferm., **19**, No. 7; 1891: Behavior of gases at low pressures.

Leduc, A., Compt. rend., **117**, p. 221; 1893: Density of sulphur dioxide, its compressibility and its expansion at normal conditions.

Baly and Ramsay, Phil. Mag. (5), **38**, p. 301; 1894: Expansion of gases at low temperatures.

Kuenen and Randall, Proc. Roy. Soc. (London), **59**, p. 60; 1895: Expansion of argon and helium.

Nyreu, M., Pub. Observ. Central Nicolas, **2**, p. 8; 1896: Expansion of air.

Leduc, A., Compt. rend., **125**, p. 768; 1897: Expansion of gases.

Morley, E. W., and Miller, D. C., Proc. Am. Assoc. Adv. of Sci., p. 123; 1897: Expansion of gases.

Hoffmann, W., Ann. Physik., **66**, p. 224; 1898: Expansion and pressure coefficient of air.

Sundell, A. F., Helsingf. Öfv., **41**, p. 105; 1900: Expansion and pressure coefficient.

Harker, J. A. and Chappuis, P., Trans. Roy. Soc. London, **194**, p. 37; 1900: A comparison of platinum and gas thermometers, including a determination of the boiling point of sulphur on the nitrogen scale.

Ramsay and Travers, Trans. Roy. Soc. London, **197**, p. 79; 1901: Argon and its companions.

Schenck, R., Leibigs Ann. Chem., **316**, p. 1; 1901: On sulphur trioxide.

Travers, M. W., and Senter, G., Brit. Assoc. Adv. of Sci. Repts., p. 546; 1901: Comparison of the constant volume and constant pressure scales for hydrogen between 0° C. and —190° C.

Travers, M. W., Senter, G., and Jaquerod, A., Proc. Roy. Soc. (London), **70**, p. 484; 1902; Trans. Roy. Soc. London, **200A**, p. 105; 1903: On the measurement of temperature. I. On the pressure coefficients of hydrogen and helium at constant volume and at different initial pressures.

Randall, W. W., Amer. Book Co., 166 pp.; 1902: The expansion of gases by heat. (Memoirs by, and biographical sketches of Dalton, Gay-Lussac, Regnault, and Chappuis.)

Travers, M. W., and Jaquerod, A., Arch. Sci. Phys. Nat. (4), **14**, p. 697; 1902: Coefficient of expansion of hydrogen and helium.

Travers, M. W., and Jaquerod, A., Proc. Roy. Soc. (London), **70**, p. 484; 1902: Expansion of helium.

Travers, M. W., and Jaquerod, A., Chem. News, **86**, p. 61; 1902: The pressure coefficients of hydrogen and helium at constant volume and at different initial pressures.

Moss, S. A., Sibley J. Engin., **17**, p. 215; 1903: Free expansion of a perfect gas.

Chappuis, P., Trav. et Mém. Bur. intern. Poids et Mes., **13**, p. 190; 1903: Relation between gas thermometer scale at constant pressure and at constant volume.

Ramsay, W., and Steele, B. D., Phil. Mag., (6) **6**, p. 506; 1903: Expansion of oxygen.

Richards, T. W., and Mark, K. L., Proc. Amer. Acad. Arts Sci., **38**, p. 417; 1902; Z. physik. Chem., **43**, p. 475; 1903: An apparatus for the measurement of the expansion of gases by heat under constant pressure.

Travers, M. W., Senter, and Jaquerod, A., Trans. Roy. Soc. London, **200A**, p. 105; 1903: On the measurement of temperature. I. On the pressure coefficients of hydrogen and helium at constant volume and at different initial pressures.

Makower, W., and Noble, H., Proc. Roy. Soc. (London), 72, p. 379; 1903: On the measurement of the pressure coefficient of oxygen at constant volume and different initial pressures.

Vaubel, W., J. Prakt. Chem. (N. F.), **70**, p. 503; 1904: On the relation between the values of molecular complexes and the expansion coefficient in the different aggregate states.

Jaquerod, A., and Perrot, F. L., Compt. rend., **138**, p. 1032; 1904: Fusion point of gold and expansion of some gases between 0° and 1,000°.

Witkowski, A. W., Z. komprimierte flüssige Gase Pressluft-Ind., **9**, pp. 83, 124, 131; 1905: Expansion of hydrogen.

Richards, T. W., and Mark, K. L., Proc. Amer. Acad. Arts Sci., **41**, p. 115; 1905: Thermal expansion of hydrogen and carbon dioxide under constant pressure.

Jaquerod, A., and Perrot, F. L., Compt. rend. **140**, p. 1542; 1905: Expansion of air, oxygen, nitrogen, carbon dioxide, and carbon monoxide between 0° and 1,067° at rather low pressures.

Perman, E. P., and Davies, J. H., Proc. Roy. Soc. (London), **78**, p. 28; 1906: Coefficient of expansion of ammonia.

Bahrdt, W., Z. physik. chem. Unterricht, **20**, p. 17; 1907: Expansion of gases by heat.

Moulin, H., J. Phys. (4), **6**, p. 111; 1907: Relations between volume and covolume.

De Ball, L., Bull. Astr., **24**, p. 209; 1907: The coefficient of expansion of air and the influence of humidity on astronomical refractivity.

Von Hagen, D., Z. physik. chem. Unterricht, **21**, p. 29; 1908: An apparatus for the demonstration of the relations between volume, pressure, and temperature of the gases.

Pier, M., Z. Physik. Chem., **62**, p. 385; 1908: Expansion coefficient of chlorine.

Mix, C., Chem. Ztg., **32**, p. 67; 1908: External work and the cooling by expansion of gases.

Leduc, A., Compt. rend., **148**, p. 1173; 1909: Coefficients of expansion of some gases.

Adwentowski, K., Z. komprimierte flüssige Gase Pressluft-Ind., **13**, pp. 1, 19; 1910: Expansion of nitric oxide by heat.

Lichty, D. M., Orig. Com. 8th Intern. Congr. Appl. Chem., **22**, p. 205; 1912: Some physical constants of sulphur trioxide; melting and boiling points, density, coefficient of expansion, and molecular weight.

Wertheimer, E., Z. Physik. Chem., **83**, p. 260; 1913: The dependence of the coefficients of expansion at constant pressure and compressibility at constant volume of steam upon the temperature and pressure.

Estreicher and Bobotch, Bull. Intern. acad. sci. Cracovie, 451; 1913: The behavior of carbon monoxide at low temperatures.

Keyes, F. G., J. Am. Soc. Refrig. Eng. **1**, p. 9; 1914: A new equation of state applied to ammonia and other substances.

Leduc, A., Ann. phys., **5**, p. 185; 1916: Coefficients of expansion of gases.

Leduc, A., Compt. rend., **164**, p. 1003; 1917: Dilatability of argon and neon. Internal pressure of monatomic gases.

Leduc, A., Ann. phys., **9**, p. 5; 1918: Compressibility and dilatability of gases.

Keyes, F. G., and Felsing, W. A., J. Am. Chem. Soc., **41**, p. 589; 1919: The equation of state for liquids and vapors. I. The vapor phase of ethylether.

Jenkin, C. F., Proc. Roy. Soc. (London), **98A**, p. 170; 1920: Dilation and compressibility of liquid carbonic acid.

Keyes, F. G., J. Am. Soc. Refrig. Eng., **7**, p. 371; 1921: The isometrics of the ammonia superheated region and the vapor pressure of liquid ammonia.

Henning, F., and Heuse, W., Z. Physik, **5**, p. 285; 1921: Pressure and volume expansion coefficients for helium, hydrogen, and nitrogen.

Keyes, F. G., Smith, L. B., and Joubert, D. B., J. Math. Phys. M. I. T., **1**, p. 191; 1922: The equation of state for methane gas phase.

Smith and Taylor, J. Am. Chem. Soc., **45**, p. 2107; 1923: The equation of state for pure nitrogen gas phase.

2. COMPRESSIBILITY

Natterer, Wien, Ber. (2), **5**, p. 351; 1850; **7**, p. 557, 1851; **12**, p. 199; 1854; Pogg. Annal., **94**, p. 436; 1855: Compressibility of gases.

Rankin, W. J. M., Phil. Mag., **15**, p. 303; 1858; **29**, p. 283; 1865: Elasticity of carbon dioxide. Elasticity of gases and vapors.

Cailletet, L., Compt. rend., **75**, p. 1271; 1872: Researches on liquid carbon dioxide.

Amagat, Ann. chim. phys. (4), **28**, p. 274; 1873; Compt. rend., **75**, p. 479; 1872: Compressibility of air and hydrogen at high temperatures.

Amagat, Compt. rend., **82**, p. 914: 1876; Ann. chim. phys., (5) 8, p. 270; 1876: Research on the elasticity of air at low pressures.

Amagat, Compt. rend., **89**, p. 437; 1879: On the compressibility of different gases at high pressures.

Van der Waals, J. D., Verslag. Akad. Wettenschappen Amsterdam, **15**, p. 426; 1880: Beibl. Ann. Physik, **4**, p. 704; 1880: Compressibility of ethylene.

Amagat, E. H., Ann. chim. phys. (5), **19**, p. 345; 1880: Memoir on the compressibility of gases at high pressures.

Amagat, Compt. rend., **91**, p. 812; 1880: On the compressibility of oxygen and the action of this gas on mercury.

Amagat, Ann. Chim. et Phys. (5), **22**, p. 353; 1881: Memoir on the compressibility of gases at high pressures.

Amagat, Compt. rend., **93**, p. 306; 1881: On the compressibility of carbon dioxide and air at low pressures and high temperatures.

Amagat, Compt. rend., **95**, p. 638; 1882: On the compressibility of nitrogen gas.

Amagat, Ann. chim. phys. (5), **28**, p. 464; 1883: Memoir on the compressibility of air and carbon dioxide.

Wroblewski, S., and Olszewski, K., Compt. rend., **96**, pp. 1140, 1255; 1883; Repertorium, **19**, p. 494; 1883; Chem. News, **47**, p. 193; 1883; J. prakt. Chem., **28**, p. 57; 1883; Anz. Akad. Wiss. Wien., **20**, p. 74; 1883: On the liquefaction of oxygen and nitrogen and the solidification of carbon disulphide and alcohol.

Langer and Meyer, V. Ber., **18**, p. 1803; 1885: Compressibility of sulphur dioxide.

Amagat, Compt. rend., **102**, p. 1100; 1886: On the atomic volume of hydrogen.

Chappuis, J., and Rivière, C., Compt. rend., **104**, p. 1433; 1887: Compressibility of cyanogen.

Antoine, C., Compt. rend., **102**, p. 863; 1886; Compressibility of gas and steam.

Antoine, C., Compt. rend., **110**, p. 131; 1890: Calculation of compressibility of nitrogen to 3,000 atmospheres.

Antoine, C., Compt. rend., **110**, p. 1122; 1890: Characteristic equation of nitrogen.

Wroblewski, S., Wiener Ber., **97**, 2A, p. 1321; 1888: The compressibility of hydrogen.

Wroblewski, S., Monatsh., p. 1067; 1888; Sitz. Akad. Wiss. Wien., **97**, p. 1321; 1889: Compressibility of hydrogen.

Puschl, C., Sitz. Akad. Wiss. Wien., **96**, (2) p. 313; 1888: Behavior of hydrogen with reference to Mariotte's law.

Amagat, Compt. rend., **107**, p. 522; 1888: Compressibility of gases–ogygen, hydrogen, nitrogen, and air up to 3,000 atmospheres.

Antoine, C., Compt. rend., **108**, pp. 141 and 896; 1889: Compressibility of air and carbon dioxide.

Lala, U., Compt. rend., **111**, p. 819; 1890: Compressibility of mixtures of air and carbon dioxide.

Tait, P. G., Proc. Roy. Soc. Edinburgh, **18**, p. 255; 1892: Isothermals of ethyl oxide.

Young, S., Phil. Mag. (5), **33**, p. 153; 1892; **37**, p. 1; 1894: On the generalizations of van der Waals' regarding "corresponding" temperatures, pressures, and volumes.

Leduc, A., Compt. rend., **117**, p. 219; 1893: Density of sulphur dioxide. Its compressibility and its expansion at normal conditions.

Amagat, E. H., Ann. chim., phys. (6), **29**, p. 68; 1893: Memoir on the elasticity and expansion of fluids up to very high pressures.

Kuenen, J. P., Z. physik Chem., **11**, p. 38; 1893: Isothermals of a mixture of carbon dioxide and methyl chloride.

Campetti, A., Atti. accad. sci. Torino., **31**, p. 52; 1895: Compressibility of oxygen at low pressures.

Witkowski, A. W., Phil. Mag., **41**, p. 288; 1896: Isotherms for air.

Leduc, A., Compt. rend., **123**, p. 743; 1896: On the compressibility of some gases at 0° and at about atmospheric pressure.

Sarran, Proc. Soc. Phys. et Nat. de Bordeaux., p. 158; 1897–98: Compressibility of nitrogen.

Rose-Innes, Phil. Mag., **44**, p. 76; 1897; **45**, p. 102; 1898: Isothermals of ether and iso-pentane.

Leduc, A., Ann. chim. phys. (7), **15**, p. 5; 1898; **19**, p. 441: Compressibility of gases: Molecular volumes and atomic weights.

Rayleigh, Trans. Roy. Soc. London, **196A**, p. 205; 1901: On a new manometer and on the law of the pressure of gases between 1.5 and 0.01 millimeters of mercury.

Ramsay, W., and Travers, M. W., Trans. Roy. Soc. London, **197**, p. 47; 1901: Z. physik. Chem., **38**, p. 679; 1901: Argon and its companions.

Quint, G. Z. N., Z. physik. Chem., **39**, p. 14; 1901: Isotherms of mixtures of hydrochloric acid gas and ethane.

Ponsot, A., Compt. rend., **132**, p. 1401; 1901: Laws of Gay Lussac and the dissociation of gaseous compounds.

Onnes, H. K., and Boudin, M., Proc. Acad. Sci. Amsterdam, **3**, p. 299; 1901: Versl. Akad. Wetenschappen Amsterdam, **9**, p. 224; Comm. Leiden, No. 60; 1901: Z. Instrumentenk, **21**, p. 121; 1901: Coefficient of pressure variation of pure hydrogen between 0° and 100°.

Amagat, E. H., Phil. Mag. (6), **2**, p. 651; 1901: Note on the isothermals of fluids and in particular of hydrogen.

Rayleigh, Trans. Roy. Soc. London, **198A**, p. 417; 1902: On the law of the pressure of gases between 75 and 150 mm. of mercury.

Onnes, H. K., and Hyndman, H. H. F., Proc. Acad. Sci. Amsterdam, **4**, p. 761; 1902; Verslag Akad. Wetenschappen Amsterdam, **10**, p. 809; 1902; Comm. Leiden, No. 78; 1902: Isotherms of diatomic gases and their binary mixtures. II. The determination of density with the piezometer of variable volume for low temperatures. III. The isotherms of oxygen at 20.0° C., 15.6° C., 0.0° C. IV. The compressibility of hydrogen at 0.0° C., and 20.0° C., determined by the piezometers with variable volume for low temperatures.

Kuenen, J. P., and Robson, W. G., Phil. Mag., (6) **3**, p. 622; 1902: Behavior of carbon dioxide with regard to the law of corresponding states. Volumes of saturated vapor of carbon dioxide below 0°. Latent heat of evaporation. Latent heat of sublimation at the triple point and at the boiling point.

Van Laar, J. J., Proc. Acad. Sci. Amsterdam, **5**, p. 573; 1903; Verslag Akad. Wetenschappen Amsterdam, **11**, p. 713; 1903: On the course of the values of *b* for hydrogen (calculated from experiments by Amagat on the compressibility of hydrogen at high temperatures and different pressures).

Travers, M. W., and Jaquerod, A., Z. physik. Chem., **45**, p. 385; 1903: On the measurement of temperature.

Siegmund, J. Z., Kohlensäure Ind., **9**, p. 139; 1903: Formula for the temperature function for the pressure curve in the liquefaction of hydrogen.

Keesom, W. F., Verslag. Akad. Wetenschappen Amsterdam, **12**, pp. 391, 553, 616, 621; 1903; Comm. Leiden, No. 88; 1904; Proc. Acad. Sci. Amsterdam, **6**, p. 532; 1904: Isothermals of mixtures of oxygen and carbon dioxide. I. Calibration of manometer and piezometer tubes. II. The preparation of the mixtures and the compressibilities at small densities. III. The determination of isothermals between −15° C. and +60° C. IV. Isothermals of pure carbon dioxide between 25° C. and 60° C, between 60 and 140 atmospheres. V. Isothermals of mixtures of the molecular compositions 0.1047 and 0.1994 of oxygen and the comparison of them with those of pure carbon dioxide. VI. Influence of gravitation on the phenomena in the neighborhood of the plait point for binary mixtures.

Rayleigh, L., Proc. Roy. Soc. (London), **73**, p. 153; 1904: On the compressibilities of oxygen, hydrogen, nitrogen, and carbon monoxide between 1 atmosphere and half an atmosphere of pressure and on the atomic weights of the elements concerned.

Rayleigh, L., Trans. Roy. Soc. London (A), **204**, p. 351; 1905: Proc. Roy. Soc. (London), **74**, p. 446; 1905: Compressibility of gases (air, carbon dioxide, and nitrous oxide) between 1 atmosphere and half an atmosphere of pressure.

Jaquerod, A., and Scheuer, O., Compt. rend., **140**, p. 1384; 1905: Compressibility of different gases below atmospheric pressure and determination of their molecular weights.

Verschaffelt, J. E., Arch. Neérland, **11**, p. 358; 1906: Researches on the compressibility and condensation of mixtures of carbon dioxide and hydrogen.

Briner, E., J. chim. phys., **4**, p. 476; 1906: Compressibilities of mixtures of gases. Vapor pressures and critical constants of gases. Hydrogen chloride, phosphine, and sulphur dioxide.

Ritzel, A., Z. physik. Chem., **60**, p. 319; 1907: Gas solubility, compressibility, and surface tension.

Berthelot, D., Compt. rend., **144**, p. 194; 1907; **145**, p. 317; 1907: Calculation of the compressibility of a gas in the neighborhood of atmospheric pressure by means of critical constants.

Keesom, W. H., Handl. Ned. Nat. Geneesk, Congres, **11**, p. 169; 1907; Comm. Leiden, Suppl. 18 No. 97–108, p. 9; 1908: The properties of helium mixtures.

Briner, E., and Cardoso, E., Compt. rend., **144**, p. 911; 1907: The compressibility and vapor pressure of mixtures of methyl oxide and sulphur dioxide.

Onnes, H. K., and Braak, C., Verslag. Akad. Wetenschappen Amsterdam, **16**, p. 427; 1907; Proc. Acad, Sci. Amsterdam, **10**, p. 429; 1908; Comm. Leiden, No. **101b**, p. 11; 1908: On the measurement of very low temperatures. XVIII. The determination of the absolute zero according to the hydrogen thermometer of constant volume and the reduction of the readings on the normal hydrogen thermometer to the absolute scale.

Onnes, H. K., Proc. Acad. Sci. Amsterdam, **10**, p. 741; 1908: Isotherms of helium at −253° C. and −259° C.

Onnes, H. K., Proc. Acad. Sci. Amsterdam, **10**, p. 445; 1908: Isotherms of helium between +100° C. and −217° C.

Onnes, H. K., and Braak, C., Verslag. Akad. Wetenschappen Amsterdam, **16**, p. 411; 1907; Proc. Acad. Sci. Amsterdam, **10**, p. 413; 1908; Comm. Leiden, No. **100a**, p. 1; 1908: Isotherms of hydrogen between −104° C. and −217° C., and between 0° C. and 20° C.

Onnes, H. K., and Braak, C., Proc. Acad. Sci. Amsterdam, **10**, p. 204, 413; 1907: Isotherms of hydrogen between −104° and −217°.

Onnes, H. K., and Braak, C., Verslag. Akad. Wetenschappen Amsterdam, **15**, p. 668; 1907; **16**, p. 817; 1908; Proc. Acad. Sci. Amsterdam, **9**, p. 775; **10**, p. 743; 1908; Comm. Leiden, **97b, 102d**; On the measurement of very low temperatures. XIV. Reduction of the readings of the hydrogen thermometer of constant volume to the absolute scale. XV–XX. Influence of the deviation from the law of Boyle-Charles on the temperature measured with the scale of the gas thermometer of constant volume according to the observations with this apparatus.

Onnes, H. K., and Braak, C., Verslag. Akad. Wetenschappen Amsterdam, **16**, p. 890; 1908; Proc. Acad. Sci. Amsterdam, **11**, p. 30; 1908; Comm. Leiden, No. **106**; 1908: Isotherms of diatomic gases and their binary mixtures. VIII. The breaking stress of glass and the use of glass tubes in measurements under high pressures at ordinary and low temperatures.

Onnes, H. K., Verslag. Akad. Wetenschappen Amsterdam, **16**, p. 501; 1908; Proc. Acad. Sci. Amsterdam, **10**, p. 589; 1908; Comm. Leiden, No. **102b**; 1908: On the measurement of very low temperatures. XIX. Derivation of the pressure coefficient of helium for the international helium thermometer and the reduction of the readings of the helium thermometer to the absolute scale.

Onnes, H. K., Verslag. Akad. Wetenschappen Amsterdam, **16**, p. 495; 1908; Proc. Acad. Sci. Amsterdam, **10**, p. 445; 1908; Comm. Leiden, No. **102**: 1908: Isotherms of monatomic gases and their binary mixtures. I. Isotherms of helium between 100° C. and −217° C. II. Isotherms of helium between −253° C. and −259° C.

Baume, G., J. chim. phys., **6**, p. 1; 1908: Experimental researches on the gases, sulphur dioxide, methyl ether, and methyl chloride.

Jaquerod and Scheuer, Mem. soc. phys. hist. nat. Genéve, **35**, p. 668; 1908: Compressibility of helium at 0° between 1 and 0 atmosphere.

Guye, P. A., J. chim. phys., **6**, p. 769; 1908: Recent experimental determination of deviation from Avogadro's Law.

Gray and Burt, F. P., J. Chem. Soc., **95**, p. 1657; 1909: The compressibilities of oxygen and hydrogen chloride.

Onnes, H. K., Verslag. Akad. Wetenschappen Amsterdam, **18**, p. 168; 1909; Proc. Acad. Sci. Amsterdam, **12**, p. 175; 1909; Comm. Leiden, No. **112**; 1909: Isotherms of monatomic gases and their binary mixtures. Data concerning neon and helium.

Leduc, A., Compt. rend., **148**, p. 407; 1909: Compressibility of gases between 0 and 3 atmospheres at all temperatures.

Guye, P. A., et al., Mem. soc. phys. hist. nat. Genéve, **35**, p. 547: Experimental researches on the physicochemical properties of certain gases.

Leduc, A., Ann. chim. phys. (8), **19**, p. 441; 1910: Compressibility of gases. Molecular volumes and atomic weights.

Knott, C. G., Proc. Roy. Soc. Edinburgh, **30**, p. 1; 1910: Andrews' measurements of the compression of mixtures of carbon dioxide and nitrogen.

Burt, F. P., Trans. Faraday Soc., **6**, p. 19; 1910: The compressibilities of helium and neon.

Crommelin, Verslag. Akad. Wetenschappen Amsterdam, **18**, p. 924; 1909; **19**, p. 390; 1910; Proc. Acad. Sci. Amsterdam, **13**, pp. 54, 607; 1910; Comm. Leiden, **115**, p. 1; 1910; **118**, p. 1; 1911: Isotherms of monatomic gases and their binary mixtures. Coexistent liquid phases and vapor densities of argon.

Onnes, H. K., and Crommelin, C., Verslag. Akad. Wetenschappen Amsterdam, **19**, p. 582; 1911; Proc. Acad. Sci. Amsterdam, **13**, p. 614; 1911; Comm. Leiden, **118**, 1911: Isotherms of argon between +20° C. and −150° C.

Onnes, H. K., and Crommelin, C., Verslag. Akad. Wetenschappen Amsterdam, **19**, p. 1177; 1911; Proc. Acad. Sci. Amsterdam, **13**, p. 1012; 1911; Comm. Leiden, **120**, p. 1; 1911: Isotherms of monatomic substances and of their binary mixtures. The behavior of argon with regard to the law of corresponding states.

Onnes, H. K., Verslag. Akad. Wetenschappen Amsterdam, **19**, p. 1187; 1911; Proc. Acad. Sci. Amsterdam, **13**, p. 1093; 1911; Comm. Leiden, **119**, p. 1; 1911: Experiments with liquid helium. Isotherms of monatomic gases and their binary mixtures. VIII. Thermal properties of helium.

Wourtzel, E., Compt. rend., **155**, p. 152; 1912: Density and compressibility of nitrosyl chloride.

Keesom, W. H., Proc. Acad. Sci. Amsterdam, **15**, p. 417; 1912: Second virial coefficient for diatomic gases.

Onnes, H. K., and de Haas, W. J., Proc. Acad. Sci. Amsterdam, **15**, p. 405; 1913; Comm. Leiden, No. 127c; 1912: The compressibility of hydrogen vapor at and below the boiling point.

Baume, G., and Wourtzel, E., J. chim. phys., **10**, p. 520; 1912; J. Chem. Soc., **104**, II, p. 113; 1913: Compressibility of gases.

Onnes, H. K., and Crommelin, C., Proc. Acad. Sci. Amsterdam, **15**, p 952; 1912; J. Chem. Soc., **104**, II, p. 474; 1913: Isotherms of monatomic substances and of their binary mixtures. XIV. Calculation of some thermal quantities for argon.

Amagat, E. H., Compt. rend., **154**, p. 911; 1912: Variation of coefficient of pressure with temperature.

Onnes, H. K., and Crommelin, C., Verslag. Akad. Wetenschappen Amsterdam, **21**, p. 256: Isotherms of monatomic substances and their binary mixtures. XIII. The empirically derived equation of state for argon.

Estreicher, T., and Bobotch, J., Bull. intern. l'acad. sci. Cracovie, **1913** (A) p. 451: The behavior of carbon monoxide at low temperatures.

Keyes, F. G., J. Am. Soc. Refrig. Eng., **1**, p. 9; 1914: A new equation of state applied to ammonia and other substances.

Kohnstamm, P., and Walstra, K. W., Proc. Acad. Sci. Amsterdam, **17**, p. 203; 1914; Verslag. Akad. Wetenschappen Amsterdam, **22**, p. 1366: Measurements of the isotherms of hydrogen at 20° and 15.5°.

Onnes, H. K., Dorsmann, C., and Holst, G., Proc. Acad. Sci. Amsterdam, **18**, p. 458; 1915: Isothermals of diatomic substances and their binary mixtures. XVII. Preliminary measurements concerning the isothermal of hydrogen at 20° C.

Onnes, H. K., Crommelin, C. A., and Smid, E. I., Proc. Acad. Sci. Amsterdam, **18**, p. 465; 1915: Isothermals of diatomic substances and their binary mixtures. XVIII. The isothermal of hydrogen from 60 to 90 atmospheres.

Onnes, H. K., and Crommelin, C. A., Proc. Acad. Sci. Amsterdam, **18**, p. 515; 1915: Isothermals of monatomic gases and their binary mixtures. XVII. Isothermals of neon, and preliminary determinations concerning the liquid condition of neon.

Holst, G., Bull. assoc. intern. froid., **6**, p. 48; 1915: New measurements on the thermodynamic properties of ammonia and methyl chloride.

Holborn, L., and Schultze, H., Ann. Physik., **47**, p. 1089; 1915: Isothermals of air, argon, and helium between 0° and 200°.

Leinweber, B., Z. Ver. Deut. Ing., **60**, p. 363; 1916: Characteristic curves for carbon dioxide, sulphur dioxide, ammonia, and steam.

Burrell, G. A., and Robertson, I. W., Bur. Mines Tech. Paper 131; 1916: The compressibility of natural gas at high pressures.

Onnes, H. K., Crommelin, C. A., and Cath, P. G., Proc. Acad. Sci. Amsterdam, **19**, p. 1058; 1916: Isothermals of monatomic substances and their binary mixtures. Preliminary determinations of critical point of neon.

Keyes, F. G., Proc. Nat. Acad. Sci., **3**, p. 323; 1917: A new equation of continuity.

Burrell, G. A., and Robertson, I. W., Bur. Mines Tech. Paper 158; 1917: The compressibility of natural gas and its constituents, with analysis of natural gas from 31 cities in the United States.

Mewes, R., Z. Sauerstoff Stickstoff Ind., **10**, p. 81; 1918: Gaseous volumes at low temperatures.

Leduc, A., Ann. Phys., **9**, p. 5; 1918: Compressibility and dilatability of gases.

Leduc, A., Compt. rend., **167**, p. 70; 1918: Density, compressibility, and atomic mass of argon.

Onnes, H. K., Crommelin, C. A., and Cath, P. G., Proc. Acad. Sci. Amsterdam, **20**, p. 178; 1918: Isothermals of diatomic substances and their binary mixtures. XIX. Preliminary determination of the critical point of hydrogen.

Cath, P. G., and Onnes, H. K., Proc. Acad. Sci. Amsterdam, **20**, p. 1160; 1918: Isotherms of monatomic substances and their binary mixtures. XIX. Vapor pressure of neon between the boiling point and the critical point.

Keyes, F. G., and Felsing, W. A., J. Am. Chem. Soc., **41**, p. 589; 1919: The equation of state for liquids and vapors. I. The vapor phase of ethyl ether.

Crommelin, C. A., Martinez, J. P., and Onnes, H. K., Verslag. Akad. Wetenschappen Amsterdam, **27**, p. 1316; 1919: Isotherms of monatomic substances and their binary mixtures XIX. Isotherms of neon from 20° to −217°.

Neumann, K., Z. ver deut. Ing., **63**, p. 1002; 1919: Adiabatic compression of carbon dioxide at high temperatures.

Mewes, R., Z. Sauerstoff Stickstoff Ind., **11**, pp. 13, 73, 93; 1919; **12**, p. 10; 1920: Investigation of Mewes' Law of the relation between the volume of a gas and the temperature.

Burrell, G. A., and Jones, G. W., Bur. Mines Reports of Investigations No. 2276: Pressure volume deviation of methane, ethane, propane, and carbon dioxide at elevated pressures.

Adams, L. H., and Williamson, E. D., J. Wash. Acad. Sci., **9**, p. 30; 1919: Some physical constants of mustard gas.

Holborn, L., Ann. Physik., **63**, p. 674; 1920: The isotherms of hydrogen.

Jenkin, C. F., Proc. Roy. Soc. (London), **98A**, p. 170; 1920: Dilatation and compressibility of liquid carbonic acid.

Cardoso, E., J. Chim. phys., **19**, p. 217; 1921: Researches in absolute piezometry. I. Comparison of the weight manometer with a glass deformation manometer.

Keyes, F. G., J. Am. Soc. Refrig. Eng., **7**, p. 371; 1921: The isometrics of the ammonia superheated region and the vapor pressure of liquid ammonia.

Batuecas, T., Anales soc. españ fís quím., **20**, p. 441; 1922: The compressibility of gases at the 0° and at less than 1 atmosphere, and the deviation from Avogadro's law.

Batuecas, T., Helvetica Chim. Acta., **5**, p. 544; 1922: The compressibility of several gases at 0° and up to 1 atmosphere and the deviation from Avogadro's law. II. Ethylene.

Guye, P. A., and Batuecas, T., Helvetica. Chim. Acta., **5**, p. 532; 1922: The compressibility of several gases at 0° and up to 1 atmosphere and the deviation from Avogadro's law. I. Oxygen, hydrogen, and carbon dioxide.

Holborn, L., and Otto, J., Z. Physik., **10**, p. 367; 1922: Isotherms of nitrogen, oxygen, and helium.

Keyes, Smith, and Joubert, J. Math. Phys. M. I. T., **1**, p. 191; 1922: An equation of state for methane gas.

Smith and Taylor., J. Am. Chem. Soc., **45**, p. 2107, 1923: The equation of state for pure nitrogen gas phase.

Guye, A., and Batuecas, T., J. chim. phys., **20**, p. 308; 1923: On the compressibility at 0° and in the neighborhood of 1 atmosphere and the deviations of several gases from the law of Avogadro.

Bridgeman, P. W., Proc. Nat. Acad. Sci., **9**, p. 370; 1923: The volume changes of five gases under high pressures.

Bridgeman, P., Rec. trav. chim., p. 568; 1923: The compressibility of hydrogen at high pressures.

3. VAPOR PRESSURE

Sajatechunki, Wied Beibl., **3**, p. 741; 1879: Vapor tension of saturated vapor at high temperature.

Meyer and Hainlen, Ber., **27**, p. 2767; 1894: Preparation of ethane.

Ramsay, W., and Travers, M. W., Trans. Roy. Soc. London, **197**, p. 47; 1901: Argon and its companions.

Schreinmakers, F. H. H., Arch. Neerl. Sci. Soc. Holl., (2) **4**, p. 346; 1899; (2) **6**, p. 170; 1901: Vapor pressures of binary and ternary mixtures.

Travers, M. W., Senter, G., and Jaquerod, A., Trans. Roy. Soc. London, **200** p. 105; 1902: On the measurement of temperature.

Kuenen, J. P., and Robson, W. G., Phil. Mag., (6) **4**, p. 116; 1902: Observations on mixtures with maximum or minimum vapor pressures.

Kuenen, J. P., and Robson, W. G., Phil. Mag., (6) **3**, pp. 156, 628; 1902: Physical constants of acetylene.

Kuenen, J. P., and Robson, W. G., Phil. Mag., (6) **3**, p. 149; 1902: Vapor pressures of carbon dioxide and of ethane at temperatures below 0° C.

Jaquerod, A., Verh. Schweiz. Natf. Ges., **85**, p. 57; 1902; Arch. sci. phys. nat. (4) **14**, p. 401; 1902: The vapor tension of liquid oxygen below its boiling point.

Andrews, L. W., J. Am. Chem. Soc., **24**, p. 864; 1902: On a method for the determination of very small vapor tensions in certain circumstances.

Travers, M. W., and Jaquerod, A., Z. physik. Chem., **45**, p. 445; 1903: Notice on the vapor pressure of solid neon.

Travers, M. W., and Jaquerod, A., Z. physik. Chem., **45**, p. 416; 1903: On temperature measurement. III. On the vapor pressure of liquid hydrogen at temperatures below its boiling point according to the hydrogen and helium scale with constant volume.

Travers, M. W., and Fox, C. J., J. chim. phys., **1**, p. 545; 1903: Vapor pressure of liquid oxygen measured by the oxygen thermometer at constant volume and different initial pressures.

Travers, M. W., and Fox, C. J., J. chim. phys. **1**, p. 515; 1903: Vapor tension of liquid oxygen measured by the oxygen thermometer at constant volume with different initial pressures.

Mollier, R., Z. Eis-Kälte-Ind., **10**, p. 125; 1903: Vapor pressure tables for liquid SO_2.

Rebenstorff, H., Z. physik. chem. Unterr., **17**, p. 19; 1904: Demonstration experiments with air of different humidity. I. Demonstration of the unequal temperature changes of saturated and unsaturated air as a consequence of pressure change. II. Determination of vapor pressure in the air.

McIntosh, D., and Steele, B. D., Proc. Roy. Soc. (London), **73**, p. 450; 1904: Vapor pressures of liquid hydrogen chloride, hydrogen bromide, hydrogen iodide, hydrogen sulphide, and hydrogen phosphide.

Hutchinson, J. J., Sci. Proc. Roy. Dublin Soc., **10**, p. 325; 1904: Vapor-pressure apparatus.

Steele, B. D., McIntosh, D., and Archibald, E. H., Trans. Roy. Soc. London, **205**, p. 99; 1905: The halogen hydrides as conducting solvents.

Steele, McIntosh, and Archibald, Z. physik. Chem., **55**, p. 129; 1906: Vapor tension of liquefied hydrobromic acid.

Stahli, Apoth. Zeit., **21**, p. 928; 1906: The vapor pressure of carbon dioxide at low temperatures.

Henning, F., Ann. Physik., **22**, p. 609; 1906: On the tension of saturated water vapor.

McIntosh, D., and Steele, B. D., Z. physik. Chem., **55**, p. 129; 1906: The vapor pressure, density, surface energies, and viscosities of pure solvents.

Guye, P. A., Z. physik. Chem., **56**, p. 461; 1906: Vapor pressure.

Du Bois, H., Physik. Z., **7**, p. 930; 1906: Vapor pressure of carbon dioxide snow.

Brill, Otto, Ann. Physik., **21**, p. 170; 1906: On the vapor pressure of liquid ammonia.

Briner, E., and Cardoso, E., Compt. rend., **144**, p. 911; 1907: The compressibility and vapor pressure of mixture of methyl oxide and sulphur dioxide.

Zeleny, J., Phys. Rev., **25**, p. 490, 1907: Vapor pressure of carbonic acid.

Zeleny, J., and Smith, Roy H., Phys. Rev., **24**, p. 22; 1907; Physik. Z., **7**, p. 667; 1906: The vapor pressure of carbon dioxide at low temperature.

Moss, S. A., Phys. Rev., **25**, p. 453; 1907; **26**, p. 439; 1908: General law of vapor pressures. Vapor pressure of carbon dioxide.

McIntosh, D., J. Phys. Chem., **11**, p. 306; 1907: Preparation and physical constants of acetylene.

Du Bois, H., Phys. Rev., **24**, p. 445; 1907: Vapor pressure of solid carbonic acid.

Onnes, H. K., and Braak, Versl. Wis. Nat. Afd. K. Akad. Wet., **17**, p. 86; 1908; Proc. Acad. Sci. Amsterdam, **11**, p. 333; 1908; Comm. Physic. Lab. Leiden, No. 107a, p. 1; 1909: Vapor pressure of oxygen at three different temperatures.

Falck, E., Physik. Z., **9**, p. 433; 1908: Theoretical determination of the vapor pressure of solid and liquid carbon dioxide.

Bose, Emil, Physik. Z., **8**, p. 944; 1908: A vapor pressure interpolation formula.

Crommelin, C. A., K. Akad. Wetenschappen, **18**, p. 924; 1909; through Chem. Zentr., 1910, II, p. 67: Isotherms of monatomic gases and their binary mixtures. IV. Remarks on the preparation of argon. V. Vapor pressure above −140°; critical temperature and critical pressure.

Plank, R., Physik. Z., **11**, p. 633; 1910: Equations and tables for saturated and superheated nitrogen vapor.

Young, S., Sci. Proc. Roy. Dublin Soc., **12**, p. 374; 1910: Vapor pressures, specific volumes, heats of vaporization, and critical constants of 30 pure substances.

Smith, A., J. Am. Chem. Soc., **32**, p. 1412; 1910: Vapor pressures.

Steele, B. D., and Bagster, L. S., J. Chem. Soc., **97**, p. 2607; 1910: Proc. Chem. Soc., **26**, p. 253; 1910: Binary mixtures of some liquefied gases.

Kohnstaunn, P., Z. physik. Chem., **75**, p. 527; 1910: Vapor pressure of binary mixtures in the light of the theory of van der Waals.

Holborn, L., and Baumann, A., Ann. Physik., **31**, p. 945; 1910: The saturation pressure of water vapor above 200°.

Cederberg, I. W., Z. physik. Chem., **77**, p. 498; 1911: General relation between the heat of vaporization, vapor pressure, and temperature.

Crafts, J. chim. phys., **11**, p. 430; 1912: Vapor tension.

Schlumberger, E., J. Gasbel, **55**, p. 1257; 1912: The vapor pressure of naphthalene and the determination of naphthalene in purified illuminating gas.

Scheffer, F. E. C., and Treub, J. P., Z. physik. Chem., **81**, p. 308; 1912: The vapor-pressure curve of nitrogen peroxide.

Uleber, S., Verslag Akad. Wetenschappen, **22**, p. 380; 1913: Vapor tension at very low temperatures and the vapor pressure of carbon dioxide from −140° to −160°.

Stern, O., Physik. Z., **14**, p. 629; 1913: The kinetic theory of the vapor pressure of a monatomic solid and a discussion of the entropy constant of a monatomic gas.

Russ, F., Z. physik. Chem., **82**, p. 217; 1913: Vapor-pressure curve of solid nitrogen peroxide.

Schultz, A., Ber. physik. Ges., p. 488; 1913: Association phenomena in gas mixtures.

Siemens, H., Ann. Physik., **42** (4), p. 871; 1913: Vapor pressures and thermometry at low temperatures.

Schulze, A., Physik. Z., **14**, p. 922; 1913: Vapor pressures of carbon compounds.

Germann, F. E. E., Physik. Z., **14**, p. 857; 1913: Determination of the vapor pressure and density curves for oxygen, and the construction of an apparatus for the determination of critical data.

Bulle, F., Physik. Z., **14**, p. 860; 1913: Vapor-pressure curve of oxygen, and a determination of the critical data of hydrogen.

Onnes, H. K., and Keesom, W. H., Proc. Acad. Sci. Amsterdam, **16**, p. 440; 1913: Measurements of very low temperatures XXIII. The vapor pressure of hydrogen from the boiling point down to near the triple point.

Centnerszwer, M., Z. physik. Chem., **85**, p. 99; 1913: Evaporation of phosphorus in oxygen and other gases.

Cardoso, E., and Germann, A. F. O., J. chim. phys., **11**, p. 632; 1913: Vapor pressure of hydrogen chloride.

Onnes, H. K., and Weber, S., Verslag Akad. Wetenschappen, **22**, p. 226; 1913: Vapor pressures of substances of low critical temperature at low temperatures. I. Vapor pressure of carbon dioxide in the region between −160° and −183°.

Egerton, A. C. G., J. Chem. Soc., **105**, p. 647; 1914: Proc. Chem. Soc., **30**, p. 5; 1914: Vapor pressure of nitrogen peroxide.

Wohl, A., Z. physik. Chem., **87**, p. 1; 1914: Investigation of the condition equation.

Onnes, H. K., Dorsman, C., and Holst, G., Verslag. K. Akad. Wetenschappen, **23**, p. 982; 1914: Isotherms of diatomic gases and their binary mixtures.

Crommelin, C. A., Verslag. K. Akad. Wetenschappen, **23**, p. 991; 1914: Isotherms of diatomic substances and their binary mixtures. XVI. Vapor pressure of nitrogen between the critical point and the boiling point.

Maass, O., and McIntosh, D., J. Am. Chem. Soc., **36**, p. 737; 1914: Some physical properties of ethane, ethylene, and acetylene.

Seibert, F. M., and Burrell, G. A., J. Am. Chem. Soc., **37**, p. 2683; 1915: Critical constants of normal butane, isobutane, and propylene and their vapor pressures between 0° and 120°.

Pellaton, M., J. chim. phys., **13**, p. 426; 1915: Physical constants of chlorine.

Onnes, H. K., and Weber, S., Proc. Acad. Sci. Amsterdam, **18**, p. 493; 1915: Further experiments with liquid helium. On the measurement of very low temperatures. XXV. The determination of the temperatures which are obtained with liquid helium, especially in connection with the measurement of the vapor pressure of helium.

Onnes, H. K., and Crommelin, C. A., Proc. Acad. Sci. Amsterdam, **18**, p. 515; 1915: Isothermals of monatomic gases and their binary mixtures. Isothermals of neon and preliminary determinations concerning liquid condition of neon.

Maass, O., and McIntosh, D., Trans. Roy. Soc. Can. Inst., **8**, Sect. III, p. 65; 1915: The vapor pressure of the halogen hydrides and of hydrogen sulphide.

Cardoso, E., J. chim. phys., **13**, p. 331; 1915: Arch. sci. phys. nat., **36**, p. 97; 1913: Atti accad. Lincei V, 24 I., p. 1133; 1915: Vapor pressure of methane.

Campbell, P. H., Trans. Faraday Soc., **10**, p. 197; 1915: Vapor pressure of liquids in the presence of gases.

Burrell, G. A., and Robertson, I. W., J. Am. Chem. Soc., **37**, p. 2188; 1915: Vapor pressures of propane, propylene, and normal butane at low temperatures.

Burrell, G. A., and Robertson, I. W., J. Am. Chem. Soc., **37**, p. 2691; 1915: Vapor pressures of sulphur dioxide and nitrous acid at temperatures below their normal boiling points.

Burrell, G. A., and Robertson, I. W., J. Am. Chem. Soc., **37**, p. 2482; 1915: Vapor pressures of acetylene, ammonia, and isobutane at temperatures below their normal boiling points.

Burrell, G. A., and Robertson, I. W., J. Am. Chem. Soc., **37**, p. 1893; 1915: Vapor pressures of ethane and ethylene at temperatures below their normal boiling points.

Holst, G., and Hamburger, L., Proc. Acad. Sci. Amsterdam, **18**, p. 872; 1916; Z. physik. Chem., **91**, p. 513; 1916: Investigation of the equilibrium liquid vapor of the system argon-nitrogen.

Holst, G., Proc. Acad. Sci. Amsterdam, **18**, p. 829; 1916: Measurements of very low temperatures. XXVI. The vapor pressure of oxygen and nitrogen according to the pressure measurements of von Siemens and the temperature determinations of Kammerlingh Onnes.

Kuenen, J. P., and Clark, A. L., Proc. Acad. Sci. Amsterdam, **19**, p. 1088; 1917: Critical-point phenomena and a few condensation constants of air.

Brunelli, P. E., Nuovo cimento, **14**, p. 55; 1917: Vapor pressure.

Keyes, F. G., and Brownlee, R. B., J. Am. Chem. Soc., **40**, p. 25; 1918: Vapor pressure of liquid ammonia up to the critical temperature.

Cath, P. G., and Onnes, H. K., Proc. Acad. Sci. Amsterdam, **20**, p. 1160; 1918: Isothermals of monatomic substances and their binary mixtures. XIX. Vapor pressure of neon between the boiling point and the critical point.

Cath, P. G., and Onnes, H. K., Proc. Acad. Sci. Amsterdam, **20**, p. 1155; 1918: The measurement of low temperatures. XXVII. Vapor pressure of hydrogen in the neighborhood of the boiling point and between the boiling point and the critical point.

Schreiber, P., Physik. Z., **20**, p. 496; 1919: Approximation formula for the vapor pressure of water.

Prici, T. M., J. Chem. Soc., **115**, pp. 1116 to 1919: Vapor pressures and densities of mixtures of acetone and methylethyl ketone.

Moles, E., and Batuecas, T., J. chim. phys., **17**, p. 537; 1919: Researches on the gas, methyl fluoride.

McTaggart, H. A., and Edwards, E., Trans. Roy. Soc. Can., **13**, Sec. III, p. 57; 1919: Composition of the vapor and liquid phases of the system methane-nitrogen.

Dolezalek, F., Z. physik. Chem., **93**, p. 585; 1919: Theory of binary mixtures. V. Vapor tension and constitution of liquid argon and argon nitrogen mixtures.

Cath, P. G., Proc. Acad. Sci. Amsterdam, **21**, p. 656; 1919: Measurement of very low temperatures. XXIX. Vapor pressures of oxygen and nitrogen for obtaining fixed points on the temperature scale below 0° C

Westphal, W. H., Z. Physik., **1**, p. 92; 1920: Measurements with the radiometer.

Westphal, W. H., Z. Physik., **1**, p. 431; 1920: Radiometer measurements.

Schames, L., Z. Physik., **1**, p. 198; 1920: Results of the study of vapor pressure problems.

Menzies, A. W. C., J. Am. Chem. Soc., **42**, p. 978; 1920: A surface condensation error in certain measurements of vapor pressure by the gas current saturation method.

Daniels, F., and Bright, A. C., J. Am. Chem. Soc., **42**, p. 1131; 1920: Pressure measurements of corrosive gases; the vapor pressure of nitrogen pentoxide.

Nikitin, N. I., J. Russ. Phys. Chem. Soc., **52**, p. 235; 1920: Pressure of saturated carbonyl chloride vapor.

Cragoe, C. S., Meyers, C. H., and Taylor, C. S., Bureau Standards Sci. Paper No. 369, 33 pp.; 1920. Vapor pressure of ammonia.

Cragoe, C. S., Meyers, C. H., and Taylor, C. S., J. Am. Chem. Soc., **42**, p. 206; 1920: The vapor pressure of ammonia.

Maass and Wright, J. Am. Chem. Soc., **43**, p. 1098; 1921: Some physical properties of hydrocarbons containing two or three carbon atoms.

Wilson, Robert E., J. Ind. Eng. Chem., **13**, p. 328; 1921: Humidity control by means of sulphuric acid solutions with critical compilation of vapor pressure data.

Stock, A., Henning, F., and Kuss, E., Ber., **54B**, p. 1119; 1921: Vapor pressure tables for temperature determinations between +25° and −185°.

Shaxby, J. H., Phil. Mag., **41**, p. 441; 1921: Vapor pressures and the isothermals of vapors.

Porter, Alfred W., Trans. Faraday Soc., **16**, p. 336; 1921: The vapor pressures of mixtures.

Herz, W., Z. Electrochem., **27**, p. 216; 1921: Vapor pressure regularities.

Herz, W., Z. Elektrochem., **27**, p. 125; 1921: Vapor pressure regularities, IV and V.

Henning, F., and Stock, A., Z. Physik., **4**, p. 226; 1921: Saturation pressures of some vapors between 10° and −181°.

Henglein, F. A., Z. physik. Chem., **98**, p. 1; 1921: A vapor pressure formula with a general integration constant.

Cardoso, E., Gazz. chim. ital., **51**, I, p. 153; 1921: The vapor tension of hydrogen sulphide.

Taylor, R. S., and Smith, L. B., J. Am. Chem. Soc., **44**, p. 2450; 1922: Vapor pressures, densities, and some derived quantities for ether at low temperatures.

Keyes, F. G., Taylor, R. S., and Smith, L. B., J. Math. Phys. Mass. Inst. Tech., **1**, p. 211; 1922: The thermodynamic properties of methane.

Porter, A. W., Trans. Faraday Soc., **18**, p. 19; 1922: The vapor pressures of ternary mixtures.

Mortimer, F. S., J. Am. Chem. Soc., **44**, p. 1429; 1922: Vapor pressures and heats of vaporization of nonassociated liquids.

Martinez, J. P., and Onnes, H. K., Arch. Néerland sci., **6**, p. 31; 1922: Measurements at very low temperatures. XXXI. Vapor pressure of hydrogen and some new thermometric determinations in the domain of liquid hydrogen.

Henglein, F. A., Rosenberg, G. V., and Muchlinski, A., Z. Physik., **11**, p. 1; 1922: The vapor pressure of solid and liquid chlorine and bromine.

Cassel, H., Z. physik. Chem., **101**, p. 104; 1922: Vapor pressure of binary mixtures.

Born, F., Ann. Physik., **69**, p. 473; 1922: Vapor pressure of pure argon.

Bergstrom, F. W., J. Phys. Chem., **26**, p. 358; 1922: The vapor pressure of sulphur dioxide and ammonia.

Masson, I., and Dolley, L. G. F., Proc. Roy. Soc. (London), **103**, p. 524; 1923: Pressure of gaseous mixtures.

Keyes, D. B., J. Ind. Eng. Chem., **15**, p. 525; 1923: A new modification of Dühring's relation.

Stock, A., Z. Elektrochem., **29**, p. 354; 1923: Vapor-pressure thermometer.

Anon, Bur. Standards Cir. No. 142, 47 pp.; 1923: Tables of thermodynamic properties of ammonia.

Riesenfeld, E. H., and Beja, M., Medd. Vetenskapsakad Nobelinck, **6**, No. 7; 1923: The vapor pressure of pure ozone.

Burrell, G. A., and Robertson, I. W., Bur. Mines Tech. Paper No. 142; 1916: Vapor pressures of various compounds at low temperatures.

Goldschmidt, H., Z. Physik., **20**, p. 159; 1923: The vapor pressure of nitric oxide.

4. EQUATIONS OF STATE

Meyer-Bjerum, Kr., Z. physik Chem., **32**, p. 1; 1900: The corresponding states of substances.

Verschaffelt, J. E., Z. komprimierte flüssige Gase Pressluft-Ind., **4**, p. 178; 1901: Contribution to the knowledge of the surface Ψ of van der Waals' equation: The law of corresponding states in mixtures of carbon dioxide and hydrogen.

Van der Waals, J. D., Arch. Néerland sci. (2), **6**, p. 47; 1901: On an exact formula expressing the variation of *b* with volume.

Van der Waals, J. D., Proc. Acad. Sci. Amsterdam, **3**, pp. 515, 571, 643; 1901: Verslag. Akad. Wetenschappen Amsterdam, **9**, pp. 586, 614, 701; 1901: Arch. Néerland sci. (2), **4**, p. 231; 1901; Z. physik. Chem., **38**, 257; 1901: The equation of state and the theory of cyclic motion.

Reuiganum, M., Ann. Physik. (4), **6**, p. 533; 1901: On the theory of the equation of state of slightly compressed gases.

Reuiganum, M., Physik. Z., **2**, p. 241; 1901; Ann. Physik. (4) **6**, p. 533; 1901: On the theory of the equation of state and the internal friction of gases.

Van Laar, J. J., Proc. Acad. Sci. Amsterdam, **14**, pp. 278, 428, 563, 711: Variability of the quantity *b* in the equation of state of van der Waals and its relation to the critical constants.

Van Laar, J. J., Arch. Meis. Teyler (2), **7**, 185; 1901: On the influence of corrections to the value (*b*) in van der Waals' equation of state on the critical data of a simple body.

Onnes, H. K., Proc. Acad. Sci. Amsterdam, **3**, p. 275; 1901; Verslag. Akad. Wetenschappen Amsterdam, **9**, p. 199; 1901; Comm. Leiden, No. 59, No. 66: Contributions to the knowledge of van der Waals' surface.

Kohnstamm, P., Z. physik. Chem., **36**, p. 41; 1901: On the vapor pressure of binary mixtures treated in the light of van der Waals' theory.

Verschaffelt, J. E., Proc. Acad. Sci. Amsterdam, **5**, p. 321; 1902; Verslag. Akad. Wetenschappen Amsterdam, **11**, pp. 255, 328; 1903; Comm. Leiden, **81**, p. 1; 1903: Contributions to the knowledge of van der Waals' Ψ surface. The equation of state and the ψ surface in the immediate neighborhood of the critical state for binary mixtures with a small proportion of one of the components.

Verschaffelt, J. E., Verslag. Akad. Wetenschappen Amsterdam, **11**, pp. 255, 328, 663; 1902; Proc. Acad. Sci. Amsterdam, **5**, p. 321; 1902; **6**, pp. 59, 105; 1903; Comm. Leiden, **81**, p. 3; Suppl. No. 6, p. 1: The equation of state of the surface Ψ of van der Waals in the immediate vicinity of the critical state for binary mixtures containing a small amount of one of the components.

Turmlirz, O., Sitz. Akad. Wiss. Wien, **111**, Abt. IIa, p. 524; 1902: A summary of van der Waals' theory of cohesion pressure.

Traube, I., Physik. Z., **4**, p. 50; 1902: Contribution to the van der Waals' theory.

Onnes, H. K., Proc. Akad. Sci. Amsterdam, **4**, p. 125; 1902; Verslag. Akad. Wetenschappen Amsterdam, **10**, p. 136; 1902; Comm. Leiden, No. 71; 1901; Arch Néerland sci. (2), **6**, p. 874; 1901: Expression of the equation of state of gases and liquids by means of series.

Verschaffelt, J. E., Proc. Acad. Sci. Amsterdam, **6**, pp. 59, 115; 1903; Verslag. Akad. Wetenschappen Amsterdam, **11**, p. 663; 1903; **12**, p. 69; 1904; Comm. Leiden, Suppl. No. 6 to No. 73–84: The equations of state and the Ψ surface in the immediate neighborhood of the critical state for binary mixtures with a small proportion of one of the components.

Van der Waals, J. D., Proc. Acad. Sci. Amsterdam, **6**, p. 123; 1903; Verslag. Akad. Wetenschappen Amsterdam, **12**, p. 82; 1904: Inquiry into the continuity between the liquid and the gaseous state of matter and into the equation of condition.

Van der Waals, J. D., Proc. Acad. Sci. Amsterdam, **5**, p. 487; 1903; Verslag. Akad. Wetenschappen Amsterdam, **11**, p. 640; 1903; Arch. Néerland sci. (2), **8**, p. 285; 1903: The variability with the density of the quantity *b* in the equation of state.

Van der Waals, J. D., Proc. Acad. Sci. Amsterdam, **6**, p. 123; 1903; Verslag. Akad. Wetenschappen Amsterdam, **12**, p. 82; 1904: On the course of the values of *b* for hydrogen.

Van Laar, J. J., Proc. Acad. Sci. Amsterdam, **5**, p. 573; 1903; Verslag. Akad. Wetenschappen Amsterdam, **11**, p. 713; 1903: On the course of the values of *b* for hydrogen in connection with a recent formula of van der Waals.

Bouzat, A., Compt. rend., **137**, p. 322; 1903: Curve of pressure of a univariant system which comprises one gaseous phase.

Berthelot, D., J. phys. (4), **2**, p. 186; 1903; Bull. seán. soc. franc. phys., p. 36; 1903: On the motion of corresponding states and on several other points worthy of mention.

Van der Waals, J. D., Arch. Néerland sci. (2), **9**, p. 381; 1904: The variation of the value *b* of the equation of state considered as the apparent diminution of the molecule.

Traube, I., Z. anorg. Chem., **38**, p. 399; 1904: Theory of critical state. Difference between gaseous and liquid matter.

Onnes, H. K., and Zahrzewski, C., Proc. Acad. Sci. Amsterdam, **7**, p. 233; 1904; Verslag. Akad. Wetenschappen, **13**, p. 199; 1905; Comm. Leiden, **92**, p. 1; 1904: The determination of the conditions of coexistence of vapor and liquid phases of mixtures of gases at low temperatures.

Onnes, H. K., and Zahrzewski, C., Arch. Néerland sci. (2), **12**, p. 423; 1907; Verslag. Akad. Wetenschappen Amsterdam, **12**, p. 885; 1904; **13**, pp. 207, 380; 1904; Proc. Acad. Sci. Amsterdam, **7**, pp. 222, 285; 1904; Comm. Leiden, Suppl. No. 8, p. 1; **92**, p. 1; 1904: The conditions of coexistence of liquid and vapor phases of a binary mixture.

Van Laar, J. J., Arch. Néerland sci. (2), **9**, p. 389; 1904: Verifications of a recent formula of van der Waals.

Kohnstamm, P., Proc. Acad. Sci. Amsterdam, **6**, p. 794; 1904; Verslag. Akad. Wetenschappen Amsterdam, **12**, p. 948; 1904: On van der Waals' equation of state.

Kohnstamm, P., Proc. Acad. Sci. Amsterdam, **6**, p. 787; 1904; Verslag. Akad. Wetenschappen Amsterdam, **12**, p. 961; 1904: On the equation of Clausius and van der Waals for the mean length of path and the number of collisions.

Goebel, J. B., Z. physik. Chem., **50**, p. 238; 1904: Exact equation of state of gases.

Goebel, J. B., Z. physik. Chem., **47**, p. 471; 1904; **49**, p. 129; 1904: On the exact equation of state of gases.

Berthelot, M. D., Z. Elektrochem., **10**, p. 621; 1904: On the most probable value for the gas constant R for perfect gases.

Van Laar, J. J., Arch. Meis. Teyler (2), **9**, p. 413; 1905: Some remarks on the equation of state.

Kuenen, J. P., Ann. Physik. (4), **17**, p. 189; 1905: On the calculation of the constants a and b of van der Waals' equation from the critical values.

Haeutschel, Drude's Ann., **16**, p. 565; 1905: On the calculation of the constants a and b of van der Waals' equation from the critical constants.

Bouzat, A., Ann. chim. phys. (8), **4**, p. 145; 1905: Pressure curves of invariant systems which include one gaseous phase.

Verschaffelt, J. E., Proc. Acad. Sci. Amsterdam, **8**, p. 743; 1906; Verslag. Akad. Wetenschappen Amsterdam, **14**, p. 686; 1906; Comm. Leiden, Suppl. No. 11–12; 1906: Contributions to the knowledge of van der Waals Ψ surface.

Verschaffelt, J. E., Arch. Néerland sci. (2), **13**, p. 1; 1908; Verslag. Akad. Wetenschappen Amsterdam, **14**, p. 686; 1906; Proc. Acad. Sci. Amsterdam, **8**, p. 743; 1906: Contribution to the knowledge of the surface Ψ of van der Waals. On the possibility of predicting the properties of mixtures from those of the substances which compose them.

Happel, H., Ann. Physik., (4), **21**, p. 342; 1906: Theory and proof of the equation of state.

Fuchs, K., Ann. Physik., **21**, p. 814; 1906; **22**, p. 469; 1907; **23**, p. 385; 1907: Van der Waals' formula.

Keindorff, A., Z. physik. Chem., **55**, p. 1; 1906: The equation of state of vapors, liquids, and gases.

Traube, I., Chem. Zeit., **31**, p. 1167; 1907; Johannes Diderik van der Waals and his universal law: The equation of State.

Onnes, H. K., and Keesom, W. H., Verslag. Akad. Wetenschappen Amsterdam, **15**, p. 507; 1907; Proc. Acad. Sci. Amsterdam, **9**, p. 501; 1907; Comm. Leiden, **96**, p. 9; 1907: Contributions to the knowledge of the Ψ surface of van der Waals. Gas phase sinking in the liquid phase for binary mixtures.

Lehmann, O., Ann. Physik. (4), **22**, p. 469; 1907: Concerning the van der Waals equation and the continuity of the states of aggregation: Reply to K. Fuchs.

Adler, F. W., Ann. Physik., **23**, p. 975; 1907: Remark on the paper "The significance of the equation $PV=RT$."

Wobsa, G., Z. Kälte Ind., **14**, p. 61; 1907: Equation of state of ammonia gas and its chemical properties.

Laemmel, R., Ann. Physik., **23**, p. 591; 1907: The significance of the equation $PV=RT$.

Adler, F. W., Ann. Physik., **22**, p. 782; 1907: On the formulation of the first law of energetics for gases.

Laemmel, R., Ann. Physik., **23**, p. 591; 1907: The meaning of the equation $pv=RT$.

Von Jüptner, H., Z. physik. Chem., **63**, p. 579; 1908: Vaporization studies. II.

Ornstein, L. S., Verslag. Akad. Wetenschappen Amsterdam, **17**, p. 107; 1908; Proc. Acad. Sci. Amsterdam, **11**, p. 116; 1908: Calculation of the pressure of a mixture of two gases by means of Gibbs's statistical mechanics.

Wobsa, G., Z. Kälte Ind., **15**, p. 11; 1908: Vapor pressure tables and curves of ammonia. Equation of sate.

Onnes, H. R., and Keeson, W. H., Proc. Acad. Sci. Amsterdam, **10**, p. 603; 1908: The equation of state of a substance in the neighborhood of the critical point liquid gas.

Happel, H., Physik. Z., **10**, p. 1026; 1909: Equation of state of gases. Notes on the dissertation of G. van Ry.

Postma, O., Verslag. Akad. Wetenschappen Amsterdam, **11**, p. 781; 1909: The calculation of the pressure of a gas by the aid of the assumption of a canonical ensemble.

Leduc, A., Compt. rend., **148**, p. 1391; 1909: Internal pressure in gases.

Leduc, A., Compt. rend., **148**, p. 1670; 1909: A new form of the characteristic equation of gases.

Walden, P., Z. physik. Chem., **66**, p. 389; 1909: The connection between the surface tension, the internal pressure, and the constants *a* and *b* of van der Waals' equation

Meyer, F. K., Z. physik. Chem., **71**, p. 325; 1910: Corresponding states of substances.

Drucker, K., Z. physik. Chem., **68**, p. 616; 1909: Foundations for a general equation of state.

Webster, A. G., and Rosanoff, M. A., Phys. Rev., **29**, p. 304; 1909: Definition of an ideal gas.

Happel, H., Ann. Physik., **32**, p. 868; 1910: The noble gases and the equation of state.

Guye, P. A., J. Chem. Phys., **8**, p. 222; 1910: On one cause of discordance between the different methods of calculating the deviation from the law of Avogadro.

Leduc, A., Compt. rend., **153**, p. 179; 1911: Internal pressures of gases: Equations of state and the law of molecular attraction.

Dieterici, C., Ann. Physik., **35**, p. 220; 1911: Theory of the equation of state.

Buckingham, E., Bull. Bur. Standards, **6**, p. 409; 1910: The definition of the ideal gas.

Von Lippmann, E. O., Chem. Zeit., **35**, pp. 41, 62, 70; 1911: The history of the name "gas."

Kleeman, R. D., Phil. Mag. (6), **20**, p. 665; 1910: Equation of continuity of the liquid and gaseous state of matter.

Bakker, G., Phys. Rev., **31**, p. 589; 1910: Definition of a perfect gas.

Van der Waals, J. D., Proc. Acad. Sci. Amsterdam, **13**, p. 1211; 1911: The value of critical quantities.

Thorkelsson, T., Physik. Z., **12**, p. 633; 1911: Three forms of the equation of state and the internal heat of vaporization.

Farnau, E. F., Phys. Rev., **35**, p. 47; 1912: The definition of an ideal gas.

Keesom, W. H., Proc. Acad. Sci. Amsterdam, **15**, pp. 240, 256; 1912: Deduction of the equation of state from Boltzmann's entropy principle. Deduction from Boltzmann's entropy principle of the second virial coefficient for material particles which exert central attractive forces upon each other, and for rigid spheres of central symmetry containing an electric doublet at their center.

Van Laar, J. J., Proc. Acad. Sci. Amsterdam, **14**, pp. 278, 771, 1091; 1912: Variability of the quantity *b* in van der Waals' equation of state, also in connection with the critical quantities.

Wicksell, S. D., Phil. Mag., **24**, p. 869; 1912; Chem. Zentr., 1913, I, p. 494: The gas equation.

Keesom, W. H., Physik. Z., **14**, p. 665; 1913: The condition equation of an ideal monatomic gas according to the quantum theory.

Peczalski, T., Compt. rend., **157**, p. 113; 1913: New forms of the characteristic equation for gases.

Peczalski, T., Compt. rend., **156**, p. 1884; 1913: Relation between law of compressibility of gases and their coefficients of expansion.

Mathews, A. P., J. Phys. Chem., **17**, p. 154; 1913: A method of determining *a* of van der Waals' equation from the surface tension.

Van Laar, J. J., Verslag. Akad. Wetenschappen Amsterdam, **22**, p. 793; 1913: A new relation between the critical quantities and the unity of all substances in thermal behavior.

Van der Waals, J. D., Chem. Weekblad, **10**, p. 628; 1913: The diminishing of b of the equation of state with the decrease in volume.

Fuchs, P., Z. physik. Chem., **84**, p. 755; 1913: The constants a and b in van der Waals' equation.

Sackur, O., Z. Elektrochem., **20**, p. 563; 1914: Equation of state of gases and the quantum theory.

Wohl, A., Z. physik. Chem., **87**, p. 1; 1914: Investigation of the condition equation.

Schames, L., Verh. Deut. physik. Ges., **16**, p. 486; 1914: Theory of the equation of state and the Nernst theorem.

Rosanoff, M. A., J. Am. Chem. Soc., **36**, p. 1408; 1914: Is the Duhem Mayules equation dependent on the ideal gas laws?

Richards, T. W., J. Am. Chem. Soc., **36**, p. 617; 1914: Critical pressure and significance of quantity b in equation of van der Waals.

Sackur, O., Ber., **47**, p. 1318; 1914: Condition equation of gases at low temperatures.

Planck, M., Verh. Deut. physik. Ges., **17**, p. 418; 1915: Entropy constants of diatomic gases.

Metcalf, W. V., J. Phys. Chem., **19**, p. 705; 1915: An interpretation of van der Waals' equation from the standpoint of volume determined by equilibrium pressures.

Holborn and Schultze, Z. Elektrochem., **21**, p. 286; 1915: Work of the Physikalische-Technische Reichansalt. Equation of state of air and argon.

Holborn and Schultze, Z. Elektrochem., **21**, p. 501; 1915: Work of the Physikalische-Technische Reichansalt in 1914. Equation of state of gases.

Godbeer, S., Engineering, **99**, p. 290; 1915: Formula connecting pressure and temperature of saturated steam.

Kat, J., Phil. Mag., **31**, p. 22; 1916: A criticism of van der Waals' equation and some new equations derived therefrom.

MacDougall, F. H., J. Am. Chem. Soc., **38**, p. 525; 1916: Equation of state for gases and liquids.

Schames, L., Beibl. Ann. Physik., **40**, p. 7; 1916: Comparison of the van der Waals equation with the purely thermodynamic equation of state and a new method of determining the critical data, limiting density and inversion curves.

Metcalf, W. V., J. Phys. Chem., **20**, p. 177; 1916: van der Waals' equation.

Van Laar, J. J., J. chim. phys., **14**, p. 3; 1916; Proc. Acad. Sci. Amsterdam, **18**, p. 1220; 1916: Additivity of the values of $\sqrt{a}$ and b in the equation of state, and the relations of the fundamental constants to the periodic system.

Van Laar, J. J., Proc. Acad. Sci. Amsterdam, **19**, p. 295; 1916: The fundamental values of the quantities b and $\sqrt{a}$ for different elements in connection with the periodic system. IV. Elements of the halogen, oxygen, and nitrogen groups.

Schimank, H., Physik. Z., **17**, p. 393; 1916: The applicability of Daniel Berthelot's equation of state to the behavior of gases.

Van Laar, J. J., Proc. Acad. Sci. Amsterdam, **19**, p. 287; 1916: The fundamental values of the quantities b and $\sqrt{a}$ for different elements in connection with periodic system.

MacDougall, F. H., J. Am. Chem. Soc., **39**, p. 1229; 1917: The Dieterici equation of state.

Jakob, M., Ann. physik., **55**, p. 527; 1918: Joule-Thomson effect and the equation of state for gases at small pressures.

Venator, O., Z. physik. Chem., **93**, p. 242; 1918: Relationships between the absolute temperature and absolute pressure in kilograms per square centimeter for moist vapors.

Schames, L., Ann. Physik., **57**, p. 321; 1918: Three curves for ideal gases.

Shaha, M. N., and Baschu, S. M., Phil. Mag., **36**, p. 199; 1918: Influence of the finite volume of molecules on the equation of state.

Van Laar, J. J., Proc. Acad. Sci. Amsterdam, **20**, pp. 750, 1195; 1918; Verslag. Akad. Wetenschappen Amsterdam, **26**, pp. 1305, 1445; 1918: The values of *a* and *b* for hydrogen at different temperatures and pressures.

Van Laar, J. J., Z. anorg. allgem. Chem., **104**, p. 57; 1918: The additiveness of the quantities *b* and $\sqrt{a}$ of the equation of state and the fundamental values of these quantities for different substances in relation to the periodic system.

Van Laar, J. J., Proc. Acad. Sci. Amsterdam, **21**, p. 2; 1918: Course of the values of *a* and *b* for hydrogen at different temperatures and volumes.

Kam, J., Phil. Mag., **37**, p. 65; 1919: Molecular attraction and attraction of mass and some new gas equations.

Wertheimer, E., Ber. der physik. Ges., **21**, p. 435; 1919: Theory of gases.

Webster, A. G., Proc. Nat. Acad. Sci., **5**, p. 286; 1919: Possible form of the equation of state for powder gases.

Weber, R. H., Ann. Physik., **60**, p. 291; 1919: Gay-Lussac and Boyle temperatures.

Hoppe, E., Z. Elektrochem., **25**, pp. 216, 324; 1919: Reason for the use of the letter *R* for the constant in the condition equation.

Holm, E. A., Nobelnist Meddel, **5**, No. 27, p. 1; 1919: The modified van der Waals equation of state for the quasi-diminution of the molecules.

Bacon, N. T., J. Phys. Chem., **23**, p. 469; 1919: Some new hypotheses as to different states of matter.

Mollier, A., Physik., **21**, p. 457; 1920: A graphic presentation of the equation of state.

Edwards, F. G., Chem. News, **121**, p. 3; 1920: Equation of state.

Edwards, F. G., Chem. News, **120**, p. 4; 1920: Equation of condition.

Dieterici, C., Ann. Physik., **62**, p. 75; 1920: The equation of state.

Steinwehr, H. V., Z. Physik., **3**, p. 466; 1920: An equation of state for saturated and superheated steam between 30° and 180°.

Schreber, K., Physik. Z., **21**, p. 430; 1920: Liquefaction of air and the equation of state.

Applebey, M. P., and Chapman, D. L., Phil. Mag., **40**, p. 197; 1920: The equation of state.

Herz, W., Z. Elektrochem., **27**, p. 373; 1921: Relation of the van der Waals constants.

Byk, A., Ann. Physik., **66**, p. 157; 1921: Theorem of corresponding states and quantum theory of gases and liquids.

Becker, R., Z. Physik., **4**, p. 393; 1921: An equation of state for nitrogen at high density.

Mache, H., Z. Physik., **5**, p. 363; 1921: Theory of imperfect gases.

Schames, L., Physik. Z., **22**, p. 630; 1921: General improvement of the equation of condition.

Leduc, A., Compt. rend., **172**, p. 1167; 1921: A new equation of state for gases, based upon a knowledge of internal pressures.

Schames, L., Physik. Z., **22**, p. 644; 1921: Simple improvement of law of corresponding states.

Wohl, A., Z. physik. Chem., **99**, p. 207; 1921: Investigation of condition equation.

Verschaffelt, J. E., Natuurwetenschapp. Tijdschr., **3**, p. 97; 1921: The equation of state of van der Waals in the neighborhood of zero absolute.

Morley, T. B., Engineering, **112**, p. 202; 1921: The nomographic chart for gases.

Keesom, W. H., Physik. Z., **22**, p. 643; 1921: The van der Waals attractive force.

Bordoni, U., Nuovo cimento, **22**, p. 246; 1921: Isentropic transformations of saturated vapors (water vapor and sulphur dioxide).

De Wisniewsky, F. T., Arch. sci. phys. nat., **3**, p. 256; 1921: Mechanical definition of the liquid and gaseous states.

Katayama, M., J. Chem. Soc. Japan, **43**, p. 609; 1922: Characteristic equation of isopentane.

Boynton, W. P., and Bramley, A., Phys. Rev., **20**, p. 46; 1922: Modification of van der Waals' equation.

Fischer, V., Ann. Physik., **69**, pp. 4, 315; 1922: Differential equation of state at high pressures.

Verschaffelt, J. E., Natuurwetenschapp. Tijdschr., **3**, p. 164; 1922: The equilibrium fluid vapor according to van der Waals.

Schames, L., Physik. Z., **22**, p. 630; 1922: Equation of condition, special equation of condition for hydrogen.

Mewes, R., Z. Sauerstoff Stickstoff Ind., **12**, p. 10; 1922: Gas volume and temperature; law of Mewes.

Van Laar, J. J., Proc. Acad. Sci. Amsterdam, **24**, p. 294; 1922: The equation of state for arbitrary temperatures and volumes. III. The law of force between the molecules of monatomic substances.

Core, A. F., Phil. Mag., **45**, p. 622; 1923: The meaning of *a* and *b* in the equation of state.

Leduc, A., Compt. rend., **176**, p. 1456; 1923: The theoretical isotherm of J. Thomson and the new equation of state for gases.

Leduc, A., Compt. rend., **176**, p. 830; 1923: A new modification of the equation of state of a gas.

Holm, E. A., Arkiv. Mat. Astron. Fysik., **17**, No. 1: Comparison of van der Waals' equation as modified for the quasi-contraction of molecules with Amagat's isotherms for O_2, N_2, and H_2, and with the critical constants for these gases.

Porter, A. W., Phil. Mag., **44**, p. 1020; 1922: A revised equation of state.

Leduc, A., Compt. rend., **176**, p. 1132; 1923: A new equation of state for gases.

Haag, J., Compt. rend., **176**, p. 372; 1923: A distribution of molecules in a gas; application to the van der Waals equation.

Jeans, J. H., Nature, **112**, p. 798; 1923: The equation of van der Waals.

Herz, W., Z. Elektrochem., **29**, p. 527; 1923: The *b* of van der Waals' equation.

5. CONTAINERS, TRANSPORTATION, ETC.

Habermann, J., and Oesterreicher, A., Z. anal. Chem., **40**, p. 767; 1901: A modification of the Pepys gasometer.

Pollak, L., Chem. Zeit., **26**, p. 310; 1902: Mercury gasometer with an automatic closing valve.

Albrecht, A., J. Gasbel., **46**, p. 101; 1903: Causes of untimely destruction of wet gas holders and its prevention.

Wrightson, N., German Patent 199106; 1906: A container for carbon dioxide.

Reckleben, H., and Lockemann, G., Z. chem. Apparat., **1**, p. 238; 1906: A gasometer flask with gas tight closure.

Wüstenfeld, H., Chem. Zeit., **33**, p. 412; 1909: An apparatus for preventing an overflow in open water fed gas holders.

Spelter, Natur u. Kultur, **7**, p. 474; 1910: Gasometer.

Lenhard, W., Chem. Zeit., **34**, p. 776; 1910: Holder for gas collecting vessels and reservoirs.

Lenhard, W., Chem. Zeit., **34**, p. 471; 1910: Gas-filling apparatus for lecture purposes.

Müller, F. C. G., Z. physik. chem. Unterricht., **23**, p. 287; 1910: A mercury gasometer.

Rochereau, Ann. pharm. (Louvain), 1912; through Repért pharm., (3) **24**, p. 267: New universal gasometer.

Mecklenbleck, H. A., J. Gasbel., **55**, p. 1117, 1144; 1912: Pressure changes in gas holders and gas holder cups in theory and practice.

Milbauer, J., Z. anal. Chem., **57**, p. 161; 1918: J. Soc. Chem. Ind., **37**, p. 443A: Universal gas holder.

Korting, E., J. Gasbel., **62**, p. 744; 1919: Painting gas holders.

Speter, M., Schweiz. Apoth. Zeit., **58**, p. 123; 1920: History of the use of mercury as a trap in collecting gases.

Bennertz, F., Rhun, G., and Kurze, B., Ann. Physik., **6**, p. 113; 1920: Investigation of the fundamentals of the design of flasks for transporting liquefied gases.

Bartlett, D. K., Chem. Age (N. Y.), **29**, p. 397; 1921: Handling liquid chlorine.

Grempe, P. M., Chem. Zeit., **45**, p. 867; 1921: The transportation of compressed gases.

Carpenter, H. C. H., et al., Dept. Sci. Ind. Research (Brit.); 1921: First report of the Gas Cylinders Research Committee.

Barthelemy, H., Rev. prod. chim., **25**, p. 649; 1922: Technic of the use of liquid chlorine.

Reed, R. R., Chem. Met. Eng., **26**, p. 1164; 1922: A simple type of glass-pressure bottle.

Petitpierre, E. E., British Patent 187600; 1922: Storing gases and inflammable liquids.

Fleisch, Gas Age Record, **50**, p. 225; 1922: Tankless gas holder experience.

Roberts, M. H., U. S. Patent 1439911; 1922: Storing oxygen or other gases.

Bonnet, E., Gas f., **159**, p. 268; 1922: A waterless gas holder.

Benjamin, E. O., Chem. Age, **30**, p. 91; 1922: Industrial gases and their containers. The compressed gas cylinder and a method for testing it.

Anon. J. Soc. Chem. Ind., **41**, p. 37R; 1922: First Report of Gas Cylinders Research Committee. Cylinders for storing "permanent" gases.

Edwards, H. D., Refrigerating Eng., **11**, p. 114; 1924: Properties of refrigerants.

6. EXPLOSIONS AND HAZARDS

Lucchini, V., Annuario Soc. Chim., **7**, p. 22; 1901: Some causes of explosion of acetylene gas apparatus.

Rasch, H., Acetylen, **4**, p. 179; 1901: Artificial blowing up of steel cylinders containing acetylene.

Von Carbo, Acetylen, **4**, p. 160; 1901: The influence of speed of generation on accidents in acetylene works.

Vogel, J. H., Acetylen, **4**, p. 49; 1901: Acetylene explosions.

Vogel, J. H., Acetylen, **4**, p. 267; 1901: What causes acetylene explosions?

Knappich, J., Acetylen, **4**, p. 157; 1901: Direct and indirect causes of acetylene explosions.

Knappich, J., Acetylen, **5**, p. 17; 1902: Inexplosive acetylene.

Gaud, F., Compt. rend., **134**, p. 175; 1902: On the decomposition of acetylene during its combustion.

Erich, O. H., Acetylen, **5**, p. 619; 1902: Causes of gas explosion with special reference to acetylene and methods of prevention.

Russig, F., Z. angew. Chem., **15**, p. 434; 1902: On the spontaneous combustion of a flask of compressed oxygen caused by opening the valves.

Russig, F., Z. angew. Chem., **15**, p. 717; 1902: Explosions caused by compressed oxygen.

Michaelis, J., Z. angew. Chem., **15**, p. 759; 1902: Explosions caused by compressed oxygen.

Claussen, Z. Kohlensäure Ind., **8**, p. 831; 1902: Explosion in an oxygen compressor.

Claussen, Z. angew. Chem., **15**, pp. 559, 1233; 1902: Explosion in an oxygen compressor.

Beyard, A., Jahreshefte Ver. Natk., **59**, p. LXXVII; 1903: Spontaneous combustion in compressed oxygen.

Lange, A., Z. komprimierte flüssige Gase Pressluft-Ind., **7**, p. 49; 1903: Danger of explosion by gases compressed in a closed bomb.

Eschenburg, Pharm. Ztg., **48**, p. 690; 1903: Compressed oxygen in medicine and in industry.

Rasch, H., Z. komprimierte flüssige Gase Pressluft-Ind., **7**, p. 141; 1904: Spontaneous ignition in compressed oxygen.

Bosshard, E., and Häuptli, A., Z. angew. Chem., **18**, p. 1531; 1905: Explosion of an oxygen cylinder.

Ludin, Verh. Schweiz. Natf. Ges., **1905**, p. 67: Explosion of an oxygen flask.

Tiscenko, V. E., Zurn. russ. fis.-chim. Obsc., **37**, p. 1145; 1905: The explosion of an oxygen bomb.

Nowicki, R., Z. Kohlensaure Ind., **12**, p. 225; 1906: Oxygen cylinder explosions.

Caro, N., Verh. Ver. Gewerbefl., **85**, pp. 205, 245; 1906: The causes of the explosion of acetylene.

Claude, G., Compt. rend., **145**, p. 387; 1907: Accidents occurring during the manipulation of compressed oxygen and how to avoid them.

Stein, Chem. Ztg., **31**, p. 845; 1907: Accidents with oxygen bomb.

Fraenkel, A., Acetylen, **11**, p. 126; 1908: Cloud formation in the combustion of acetylene.

Lucas, L., Z. Ver. D. Ing., **53**, p. 1270; 1909: Danger of explosion from compressed oxygen and hydrogen.

Rasch, H., Z. Ver. D. Ing., **53**, p. 1767; 1909: Danger from explosion with compressed oxygen and hydrogen.

Wöhler, L., Z. angew. Chem, **30**, p. 174; 1917: J. Soc. Chem. Ind., **36**, p. 917: Oxyhydrogen gas explosions in compressed gas cylinders.

Wedger, W. L., Fire and Water Eng., **72**, p. 286; 1922: Hazard of explosion from oil in compression of oxygen.

Garner, M. E., and Matsuno, K., J. Chem. Soc., **121**, p. 1729; 1922: The explosion of acetylene and nitrogen.

Sargent, C. E., Power, **57**, March 20, 1923: Hydrogen gas and electric boilers.

Ormandy, W. R., J. Soc. Chem. Ind., **42**, p. 139; 42T; 1923: Explosions in liquid air rectification plant. Discussion.

Risteen, A. D., Chem. Met. Eng., **28**, p. 632; 1923: Hazards in gas compression.

Schreitmuller, W., Chem. Appl., **10**, p. 77; 1923: A disregarded danger of explosion in vessels (flasks, bombs) for compressed and liquefied gases.

Pothmann, Ph., Z. Ver. deut. Ing., **66**, p. 938; 1922: Spontaneous ignition of escaping hydrogen.

Mabbs, J. K., Compressed Gas Mfrs. Assoc. Bull. Tech. Series, **1923**, pp. 234–243 T. S: Oxygen regulator design and seat materials.

WASHINGTON, June 17, 1925.