

dynes/cm². for the freshly annealed wire, to 10.7×10^{11} dynes/cm². for the same wire after an eight months' rest.

PHOTO-ELECTRIC EFFECTS IN ALUMINUM AS A FUNCTION OF THE
WAVE-LENGTH OF THE INCIDENT LIGHT.¹

By J. R. WRIGHT.

RECENTLY R. A. Millikan² has shown that the values of the positive potential assumed by a metal in a vacuum when illuminated by ultra-violet light increase enormously with long exposure to a very intense light. The increase for five metals investigated was from ten to thirty times the values obtained for the same metals before illumination.

The relation between these new positive potentials and the wave-length of the incident light has been investigated. An aluminum disk which showed an initial positive potential of 0.25 volt was illuminated intermittently for a period of three weeks, the positive potential gradually increasing to a maximum value of 14.1 volts. Tests were then made on the relation between this high positive potential and the wave-length of the incident light. Contrary to the results obtained by E. Ladenburg³ and by A. W. Hull,⁴ who worked with the low values of the positive potentials, the positive potential was found to reach a definite maximum at $\lambda 2166$. Changes in the intensity of the light used was without effect on the maximum value of the potential. Using different sources of light was also without effect either on the value or the position in the spectrum of the maximum point.

RYERSON PHYSICAL LABORATORY,
CHICAGO, ILL.

THE RATIO OF THE TWO HEAT CAPACITIES OF CARBON DIOXIDE AS
A FUNCTION OF THE PRESSURE AND THE TEMPERATURE.⁵

By A. G. WORTHING.

THE method employed is the null method first described and used by Maneuvrier.⁶ It is based on the perfectly general theorem due to Reech. The ratio of the two heat capacities of a substance is expressed as follows:

¹Abstract of a paper presented at the Chicago meeting of the Physical Society, November 26, 1910.

²Paper presented at the Boston meeting of the Physical Society, December 28-31, 1909.

³E. Ladenburg, *Phys. Zeits.*, VIII., p. 590, 1906.

⁴A. W. Hull, *Am. Jour. of Sc.*, XXVIII., p. 251, 1909.

⁵Abstract of a paper presented at the Minneapolis meeting of the Physical Society, December 27-30, 1910.

⁶*Ann. de Chim. et de Phys.* (7), 6, 321, 1895.

$$\gamma = \frac{\left(\frac{\partial P}{\partial v}\right)_Q}{\left(\frac{\partial P}{\partial v}\right)_\theta}.$$

Q and θ represent respectively quantity of heat and temperature, and as subscripts indicate respectively a reversible adiabatic process and an isothermal process. Technically the expression used in this work differed somewhat from the above. It was

$$\gamma = \frac{\Delta P_Q}{\Delta P_\theta},$$

where ΔP_Q and ΔP_θ are the reversible adiabatic and the isothermal changes in pressure which result from the same small change in specific volume. ΔP_Q was measured experimentally, being read directly on a differential mercury manometer which also served as the manoscope. ΔP_θ was computed with the aid of the empirical equation given for carbon dioxide by Kamerlingh Onnes.¹ Some values obtained from the smoothed curves are indicated in the following table.

γ for Carbon Dioxide.

	10 Atmos.	20 Atmos.	30 Atmos.	40 Atmos.	50 Atmos.	57 Atmos.
.2° C.	1.362	1.502	1.75			
31.0° C.	1.330	1.409	1.536	1.733	2.01	2.37
50.0° C.	1.314	1.375	1.462	1.580		
98.5° C.	1.265	1.288	1.329	1.383	1.45	

The following interesting table was obtained by assuming that an equation of the form $Pv^{\gamma'} = \text{constant}$ holds for the reversible adiabatic processes made use of in this work.

γ' of Equation $Pv^{\gamma'} = \text{Constant}$ for CO_2 .

Pressures in Atmos.	7.78	14.62	21.52	28.52	35.52	42.34	49.36	57.0
0.0° C.	1.263		1.232	1.238				
31.0° C.	{ 1.268 1.258 }	1.255	1.262	1.256		1.259		1.282
50.0° C.	1.252	1.261	1.261	1.262	1.266			
98.5° C.	1.241	1.230		1.236	1.219	1.260	1.250	

¹Comm. No. 74 from Phys. Lab. of Univ. of Leiden, 1901.

The approximate constancy of γ' for a given temperature is remarkable and is worthy of further consideration. A γ' , of course, is not to be interpreted as a ratio of the two heat capacities of the gas excepting for the gas under zero pressure in a condition indicated, perhaps, by the same adiabat or perhaps by the same temperature. These suppositions would lead to the holding of the following relation generally:

$$\frac{\gamma - \gamma'}{\gamma'} = -\frac{P}{v} \left(\frac{\partial v}{\partial P} \right)_\theta - 1 = \text{departure from Boyle's law.}$$

PHYSICAL LABORATORY,
UNIVERSITY OF MICHIGAN.

THE FREE-EXPANSION AND JOULE-KELVIN EFFECTS IN AIR AND IN CARBON-DIOXIDE.¹

BY A. G. WORTHING.

THE two following perfectly general formulæ for the free-expansion and Joule-Kelvin effects have been used. For the former,

$$\eta = \frac{\theta - P \left(\frac{\partial \theta}{\partial P} \right)_v}{\frac{\gamma}{\gamma - 1} \theta \left(\frac{\partial P}{\partial \theta} \right)_v - P},$$

for the latter,

$$\mu = \frac{\gamma - 1}{\gamma} \frac{\theta - v \left(\frac{\partial \theta}{\partial v} \right)_P}{\theta \left(\frac{\partial P}{\partial \theta} \right)_v}.$$

θ and γ respectively represent the thermodynamic temperature and the ratio of the two heat capacities of a substance.

For air, compressibility data by Witkowski,² γ data by Koch,³ and an empirical equation of state given by Kamerlingh Onnes⁴ were used. The computed Joule-Kelvin effects for air under low pressures at 0° C. based on Witkowski's data do not agree with experimental data, those based on Kamerlingh Onnes's equation agree very well with experimental data. The trend of the curve obtained using Kamerlingh Onnes's equation indicates that the results based on Witkowski's data for the higher pressures are nearly correct. The writer knows of no experiments with which

¹Abstract of a paper presented at the Minneapolis meeting of the Physical Society, December 27-30, 1910.

²Phil. Mag. (5), 41, 309, 1896.

³Ann. d. Phys. (4), 26, 551, and 27, 311, 1908.

⁴Comm. No. 109c from the Phys. Lab. of Univ. of Leiden.