JOURNAL OF RESEARCH of the National Bureau of Standards—A. Physics and Chemistry
Vol. 68A, No. 6, November–December 1964

Intercomparison of High-Energy X-Ray Intensity Measurements

John S. Pruitt and Steve R. Domen

(August 14, 1964)

This paper describes experimental comparison of the sensitivity of the NBS P2–4 ionization chamber and a replica of Wilson's Quantameter. The sensitivity ratios are used to compare calorimetric measurements of total x-ray beam energy made at the NBS and in the USSR between 20 and 90 MeV. The agreement is within the combined errors, but the source of an apparent 2 percent systematic difference has not been found.

1. Introduction

Several ionization chambers of various design have been calibrated in recent years to determine the total energy transported by a high-energy x-ray beam [1].[1] In general, these calibrations depend on k_0, the maximum photon energy, and although there have been some direct intercomparisons of different chambers when they have been calibrated in the same energy range, the task of intercomparisons of the measurements of different laboratories is by no means complete. The purpose of this paper is to report on comparison measurements made at the National Bureau of Standards between our standard chamber, P2–4 [2], and a Quantameter [3], a replica of the instrument which has been calorimetrically calibrated between 15 and 90 MeV by Komar, Kruglov, and Lopatin of the Academy of Sciences in the U.S.S.R. [4]. Despite the fact that the comparison was not direct, in the sense that a replica Quantameter was used, the profits have been severalfold. The agreement is a partial verification of the measurements of both laboratories, as well as of the energy dependence of these two chambers. Furthermore, the measurements of Komar, Kruglov, and Lopatin, when transferred to P2–4, have considerably reduced the uncertainty in its calibration.

2. The Ionization Chambers

Figure 1 is a schematic cross section of the Quantameter, an instrument which sums the ionization produced in twelve air cavities between 1-cm-thick copper plates. It is not large enough to absorb all of the secondary electrons, but compensates for the few percent leaking out the sides and back with peripheral air cavities and an oversize cavity at the rear. The internal cavities are alternately 2 mm and 1 mm thick, so that the measured ionization is proportional to a Simpson's rule approximate integration of the total ionization produced in a semi-infinite copper medium. The advantage of this design is that the chamber calibration (joules incident per coulomb collected) should be almost independent of k_0, since the ratio of cavity ionization to locally absorbed energy is known to vary very slowly with photon energy. This is apparently quite true for k_0 greater than about 100 MeV, but the data presented below indicates that the Simpson's rule approximation breaks down at lower k_0.

Figure 2 is a schematic cross section of P2–4, a chamber which measures ionization produced at a depth of 27 g/cm^2 in a medium of 2024 Dural (nominally 93.4% Al, 4.5% Cu, 1.5% Mg, and 0.6% Mn). Its design is based on the empirical fact that transition curves (cavity ionization as a function of depth) in water for k_0 between 10 and 40 MeV exhibit a common crossover point when normalized to include unit area [5], which implies that with proper selection of a front wall thickness it is possible to construct a chamber whose calibration is almost independent of k_0 over this energy range. Evidence presented below shows this to be true, although the calibration changes more rapidly with k_0 above about 100 MeV.

3. Experimental Arrangement and Method

Figure 3 is a schematic diagram of the apparatus used in the comparison measurements. X rays from the NBS 180 MeV synchrotron successively passed through the donut wall (4.1 g/cm^2 of Pyrex), a 0.3-in.-diam. beam forming aperture in a 12-in. lead block, a 4-in. lead baffle designed to stop stray secondary electrons and x rays without intercepting the main x-ray beam, an ionization chamber monitor (3.4 g/cm^2 of Al), and a second nonintercepting 4-in. lead baffle, before bombarding either P2–4 or the Quantameter. These two chambers were alternately

[1] Figures in brackets indicate the literature references at the end of this paper.

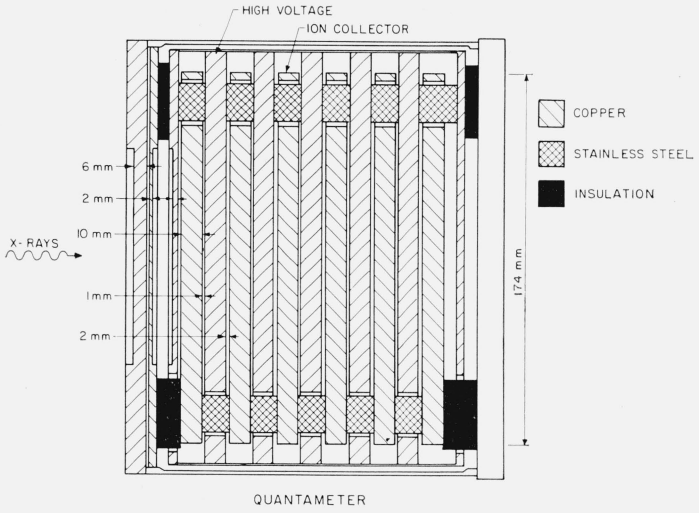

FIGURE 1. *Ionization collection sector of a copper Quantameter.*

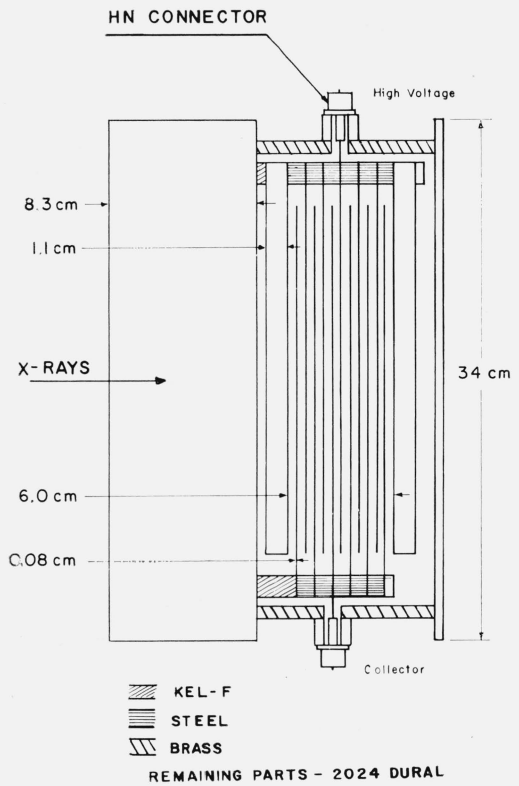

FIGURE 2. *Ionization collection sector of a Dural P2 chamber.*

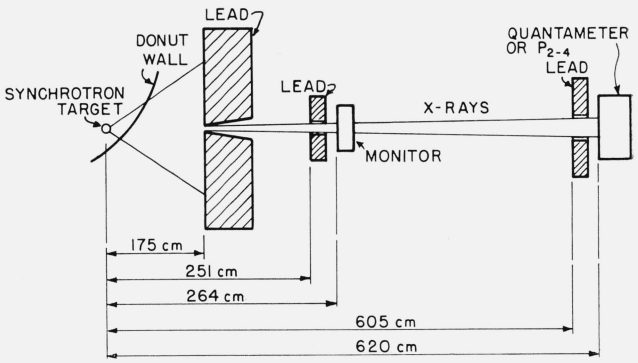

FIGURE 3. *Experimental arrangement for chamber intercomparisons.*

placed in the same position, and the ratio of their sensitivities per unit monitor response was determined at a variety of k_o.

The quantameter was used both with the recommended filling of 760 mm of argon plus 40 mm of carbon dioxide [3], and filled with air at atmospheric pressure. P2–4 was always open to the atmosphere. The sensitivities of the air-filled chambers were corrected to 20 °C, 760 mm.

Ionization measurements were made for both the monitor and the comparison chamber with Townsend balance circuits, using polystyrene capacitors to collect the charge, potentiometers to supply and measure the bucking voltages, and vibrating reed electrometers as null detectors.

4. Results and Corrections

The measured ratios of P2–4 sensitivity to Quantameter sensitivity are listed as a function of k_0 in table 1. The replica Quantameter had been constructed according to Wilson's original design, but when it was assembled, the air-cavity thicknesses were found to differ from the design dimensions by 0.03 to 0.08 mm with an average of 0.055 mm. If all of the cavities had been too thick (or too thin) by 0.055 mm, the measured sensitivity would have been in error by about 3.5 percent, but the Quantameter design is such that dimensional errors tend to cancel, and cavities which are too thick alternate with cavities which are too thin.

TABLE 1. *Ratio of P2–4 sensitivity (20 °C, 760 mm) to Quantameter sensitivity with* $A+CO_2$ *filling (20 °C, 800 mm) and with air filling (20 °C, 760 mm)*

k_0	Filling	
	$A+CO_2$	Air
MeV		
15	-------	3.120
20	1.951	3.106
25	1.949	3.093
30	1.940	3.079
35	1.934	3.081
40	1.936	3.082
45	1.940	3.092
50	1.937	3.098
55	-------	3.110
60	1.951	3.114
70	1.957	3.130
90	1.970	3.150
110	1.971	3.150
130	1.955	3.128
150	1.936	3.101
170	1.908	3.063

A correction for these deviations was calculated with the help of transition curves for copper obtained from Marshall, Rosenfeld, and Wright [6] at k_0= 46 MeV, and from Kruglov [7] at k_0=85 MeV. These were used to determine the relative contribution of each cavity to the total ionization, and it was found that the replica Quantameter sensitivity was higher than the design value, but only by 0.1 percent at each energy. Transition curves for lead [8] and for 2024 Dural [9], which cover a wider energy range, were used to show that the sensitivity correction caused by errors in the air-cavity thicknesses would have varied from 0.06 percent at 25 MeV to 0.17 percent at 170 MeV if the plates had been lead (of the same g/cm^2 thickness), and from 0.03 percent at 25 MeV to 0.05 percent at 170 MeV if they had been Dural. The correction for copper should be between these extremes, and was finally taken as 0 for $k_0<45$ MeV and 0.1 percent for larger k_0.

During the comparison measurements it was found that the ends of the bolts holding together the quantameter (not shown in fig. 1) collected enough charge from ionized air behind the chamber to raise the measured sensitivity by as much as 0.67 percent. This correction is included in the $A+CO_2$ ratios of table 1, which were obtained before this was discovered, and it was avoided in the measurements with air filling by covering these studs with rubber caps.

5. Quantameter Calibrations

TABLE 2. *Quantameter calibration (joules/coulomb) with* $A+CO_2$ *filling (20 °C, 800 mm) and with air filling (20 °C, 760 mm).*

k_0	Filling		Uncertainty
	$A+CO_2$	Air	
(*MeV*)			
20	8.12×10^5	12.92×10^5	±2.4%
26	8.00	12.70	2.7
31	7.99	12.69	1.8
36	7.95	12.66	1.5
41	7.92	12.61	2.1
45	7.80	12.43	1.8
50	7.74	12.36	1.8
60	7.69	12.27	1.8
70	7.56	12.08	2.7
90	7.49	11.97	2.7
110	7.58	12.10	2.7
130	7.46	11.92	1.5
150	7.40	11.85	1.8
170	7.39	11.85	1.8

Table 2 is a list of the Quantameter calibrations obtained by multiplying the corrected ratios of table 1 by the calorimetric calibrations of P2–4 measured earlier in this laboratory [2, 8], with uncertainties equal to those of the P2–4 calibrations plus 0.3 percent for these ratios and corrections. The calibrations are plotted as a function of k_0 in figure 4, which shows that in general, they agree with those of Komar et al. to within the stated errors. There is also agreement that the calibration increases with decreasing k_0 at these energies. The calibrations obtained at higher energies by comparing the $A+CO_2$ filled Quantameter with a thick-walled Cornell ionization chamber [1] indicate that the energy dependence does indeed disappear with increasing k_0.

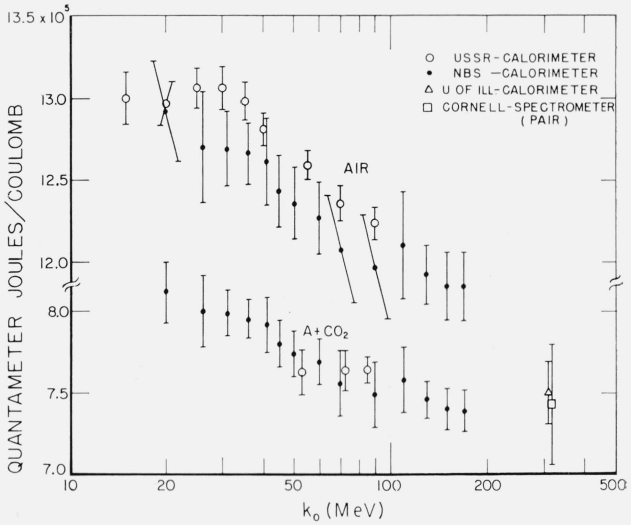

FIGURE 4. *Quantameter calibration in joules/coulomb.*

6. P2–4 Calibrations

TABLE 3. *P2–4 calibration (joules/coulomb) at 20 °C. 760 mm*

k_0	joules/coulomb	Uncertainty
(*MeV*)		
15	4.17×10^5	±1.5%
20	4.18	1.3
25	4.22	1.2
30	4.24	1.3
35	4.21	1.2
40	4.16	1.1
53	3.93	2.1
55	4.05	1.0
70	3.95	1.2
72	3.90	1.9
85	3.88	1.3
90	3.89	1.1

Table 3 is a listing of the P2–4 calibrations obtained by dividing the corrected ratios of table 1 into the Quantameter calibrations of Komar, et al [4]. They are plotted in figure 5 along with all other known P2–4 calibrations [1]. There are enough of these to warrant some statistical manipulation, and they have consequently been fitted to a curve of the type:

$$\text{P2–4 calibration}=\sum_{i=0}^{4} a_i\chi^i, \text{ joules/coulomb}$$

where $\chi=9.80 \log_{10} (k_0(\text{MeV})/43.2)$
with uncertainties expressed as:

$$\Delta(\%)=\sum_{i=0}^{4} \delta_i\chi^i.$$

The a_i and δ_i are listed in table 4. The a_i were obtained by least squares, with each calibration weighted with a factor equal to the inverse square of its uncertainty. The δ_i were calculated using Gauss' law for combining errors. The two curves of figure 5 represent the extreme predictions of this formula. There is no guarantee that the true P2–4 calibration lies between these curves, since they were obtained statistically, using weights which include both statistical and systematic uncertainties, but the good agreement between the calibrations obtained in several laboratories by several means supports this view.

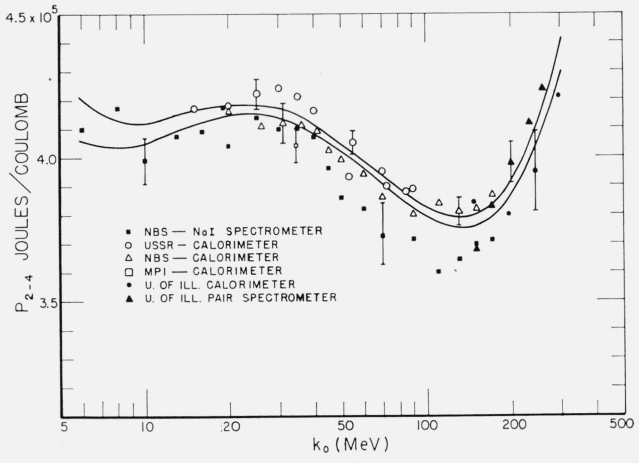

FIGURE 5. *P2–4 calibration in joules/coulomb.*

7. Comments

The NBS Quantameter calibrations of figure 4 agree with those of Komar et al. to within the combined uncertainties, but there is indication of a systematic discrepancy of about 2 percent between the measurements of these two laboratories. In each case, the original calibrations were made with calorimeters of about the same design, and an obvious place to look for systematic differences is in the corrections made to the calorimeter data for leakage of secondary photons and electrons. In the NBS case, this correction was based on scintillation measurements of backscattering plus photographic determinations of energy leaking from the other surfaces [8]. The Soviet correction is presumably based on ionization chamber measurements described earlier by Kruglov and Lopatin [10], which are presented in a form well suited for comparison. Their measurements indicate that for a 9-cm-diam 7.5 cm lead cylinder, such as we used, they would expect a leakage flux of 5.3 percent of the incident energy at $k_0=50$ MeV, and 5.1 percent at 85 MeV, while our own measurements indicate 5.4 percent at each of these energies. This difference is both too small and in the wrong direction to explain the 2 percent discrepancy.

TABLE 4. *Coefficients in* "P2−4 joules/coulomb$=\sum_{i=0}^{4} a_i\chi^i$," *and in* "$\Delta(\%)=\sum_{i=0}^{4}\delta_i\chi^i$," *where* $\chi=9.80 \log_{10} (k_0(MeV)/43.2)$

i	a_i	δ_i
0	4.077×10^5	0.39
1	−.0650	−.017
2	−.00971	.0001
3	.001187	−.00009
4	.0001809	.000243

The only other plausible source of a 2 percent systematic difference is the Quantameter dimensions, which should be controlled very carefully because of the thin air-cavity dimensions. A direct comparison of the two Quantameters would certainly help to clear up the reasons for this difference.

After these intercomparisons had been completed, it was found that Komar et al., have calibrated a replica P2 chamber [11] and have also found a difference of about 2 percent between the NBS and Soviet calibrations.

The authors thank the operators of the NBS synchrotron for their help with these intercomparisons.

8. References

[1] Methods of Experimental Physics, Vol. V, Pt. B, Sec. 2.8.2.4., ed. L. Marton (Academic Press, New York, N.Y., 1963).
[2] John S. Pruitt and Steve R. Domen, NBS Mono. 48 (1962).
[3] R. R. Wilson, Nuclear Instr. **1,** 101 (1957).
[4] A. P. Komar, S. P. Kruglov, and I. V. Lopatin, Dok. Akad. Nauk SSSR **145,** 309 (1962) [Soviet Phys.-Dok. **7,** 653 (1963)]; A. P. Komar and S. P. Kruglov, Zh. Tekh. Fiz. **30,** 1369 (1960) [Soviet Phys.–Tech. Phys. **5,** 1299 (1961)].
[5] Bernard Zendle, private communication.
[6] L. Marshall, A. H. Rosenfeld, and S. C. Wright, Phys. Rev. **83,** 305 (1951).
[7] S. P. Kruglov, Zh. Tekh. Fiz. **31,** 1451 (1961) [Soviet Phys.–Tech. Phys. **6,** 1060 (1962)].
[8] J. S. Pruitt and S. R. Domen, J. Res. NBS **66A** (Phys. and Chem.), 371 (1962).
[9] The data from which figure 16 in reference [2] was taken.
[10] S. P. Kruglov and I. V. Lopatin, Zh. Tekh. Fiz. **32,** 1399 (1962) [Soviet Phys.–Technical Phys. **7,** 1031 (1963)].
[11] A. P. Komar, S. P. Kruglov, and I. V. Lopatin, Zh. Eksper. i Teoret. Fiz. **45,** 825 (1963).

(Paper 68A6–319)

743-261—64——11

JOURNAL OF RESEARCH of the National Bureau of Standards—A. Physics and Chemistry
Vol. 68A, No. 6, November–December 1964

Publications of the National Bureau of Standards*

Selected Abstracts

Handbook of mathematical functions with formulas, graphs, and mathematical tables, Ed. M. Abramowitz and I. A. Stegun, *NBS Applied Math. Series 55, (June 1964), $6.50.*
This publication not only combines the material found in all former reference volumes on the subject; it additionally expands the work of past authors by increasing the number of functions covered, presenting more extensive numerical tables, and giving larger collections of mathematical properties of the tabulated functions. It also provides comparatively simple methods of obtaining values of functions outside the tabulated range.
As a result of scientific advances and, especially, the increasing use of automatic computers, a greater variety of functions and a higher accuracy of tabulation are now in demand by users of mathematical functions. The *Handbook* includes rational approximation formulas for all the functions, tailored to the modern computer and tables useful for a pre-programming survey of the access to a computer; for the researcher who does not, and who must do his own computations, they are, of course, indispensable. Subjects covered are included by the following chapter headings: Mathematical Constants; Physical Constants and Conversion Factors; Elementary Analytical Methods; Elementary Transcendental Functions-Logarithmic, Exponential, Circular, and Hyperbolic Functions; Exponential Integral and Related Functions; Gamma Function and Fresnel Integrals; Legendre Functions; Bessel Functions of Integer Order; Bessel Functions of Fractional Order; Integrals of Bessel Functions; Struve Functions and Related Functions; Confluent Hypergeometric Functions; Coulomb Wave Functions; Hypergeometic Functions; Jacobian Elliptic Functions and Theta Functions; Elliptic Integrals; Weierstrass Elliptic and Related Functions; Parabolic Cylinder Functions; Mathieu Functions; Spheroidal Wave Functions; Orthogonal Polynomials; Bernoulli and Euler Polynomials, Riemann Zeta Functions; Combinatorial Analysis; Numerical Interpolation, Differentiation, and Integration; Probability Functions; Miscellaneous Functions; Scales of Notation, and Laplace Transforms.

Infrared spectra of NF, NCl, and NBr, D. E. Milligan and M. E. Jacox, *J. Chem. Phys.* **40,** *No. 9, 2461–2466 (May 1, 1964).*
The infrared spectra of FN^3, ClN^3, and BrN^3 suspended in Ar and N^2 matrices have been observed at 4° and at 20° K. Ultraviolet photolysis of these systems results in the appearance of absorptions assigned to the free radicals NF, NCl, and NBr. Evidence is presented for the matrix deactivation of NBr to its ground $^3\Sigma^-$ state. Slow photolytic decomposition of NCl and NBr has been observed. Possible mechanisms are discussed for the origin of a green phosphorescence identified as resulting from N atoms trapped in the matrix.

Optical studies at high pressures, L. S. Whatley, E. R. Lippincott, A. Van Valkenburg, and C. E. Weir, *Science* **144,** *No. 3621, 968–976 (May 22, 1964).*
The development of a miniaturized high-pressure cell which is useful to pressures of 150 kbar and fits easily into the small sample areas of commercial optical equipment has greatly facilitated optical studies at high pressures. With this cell the nature and optical characteristics of polymorphic changes in transparent solids and liquids have been investigated. A microscope spectrophotometer with which absorption spectra of small areas of the compressed sample can be obtained has been devised. A camera attachment provides a convenient means of recording the visual observations. X-ray diffraction powder patterns have been recorded for low- and high-pressure forms of several substances, and new high-pressure forms have been discovered in some cases. The wide range of problems in which the cell is applicable, its miniature size, and the relative simplicity of the experimental techniques involved in its use make the development of the diamond cell a marked advance in high-pressure technology.

Refractive properties of barium fluoride, I. H. Malitson, *J. Opt. Soc. Am.* **54,** *No. 5, 628–632 (May 1964).*
Refractive properties of barium fluoride are discussed. The refractive index, n, was determined at 25 °C for 46 measured wavelengths from 0.2652μ in the ultraviolet to 10.346 in the infrared. The dispersion equation

$$n^2-1=\frac{0.643356\lambda^2}{\lambda^2-(0.057789)^2}+\frac{0.506762\lambda^2}{\lambda^2-(0.10968)^2}+\frac{3.8261\lambda^2}{\lambda^2-(46.3864)^2},$$

where λ is expressed in microns was found to fit the measured values with an average absolute residual of 1.91×10^{-5}. A tentative average thermal coefficient of index dn/dt for the measured spectral range is -12×10^{-6}/°C. Dispersive quantities which indicate the expected relative dispersion, chromatic aberration, and the effect of index on resolution are graphically presented. A review of transmittance data from the literature is also presented.

Statistical model for the beta zirconium hydrides, T. B. Douglas, *J. Chem. Phys.* **40,** *No. 8, 2248–2257 (Apr. 15, 1964).*
After consideration of the known structure of ZrH_2, it is postulated that the non-stoichiometric "beta" (bcc) Zr–H phases have four symmetrical hydrogen sites on each face of the unit cell, with simultaneous occupancy restricted to pairs not closer than twice the van der Waals radius of hydrogen. The configurational problem is solved for all concentrations by a simple process of building up the lattice, after making tests of the amount of detail required for accurate solutions in one and two dimensions. The total entropy, when decreased by the corresponding configurational entropy, corresponds to values of the hydrogen vibration frequency averaging 1440 cm^{-1} and showing no consistent trend with temperature or with a four-fold change in concentration. A semi-empirical energy model is constructed on the postulate that zirconium bonded to no hydrogen is "abnormally stable," and the two energy parameters are derived from the experimental data. The agreement with the curves derived from thermodynamic data is fairly good for the partial molal entropy and energy of hydrogen, and excellent for the hydrogen equilibrium pressures.

Optical constants of thin films from the characteristic electron energy losses, *R. E. LaVilla and H. Mendlowitz, J. Phys.* **25,** *114–118 (Jan. Feb. 1964).*
A method for obtaining the optical constants by employing the correlation between the characteristic electron energy absorption spectrum of a substance with its optical properties is described. This method is applied to a study of the optical properties in the far ultraviolet of aluminum, a metal, and of polystyrene, an organic compound. The information that is derived by this method lends itself to a study of the optical oscillator strengths.

Thermodynamics of solutions of deuterium chloride in heavy water from 5 to 50°, R. Gary, R. G. Bates, and R. A. Robinson, *J. Phys. Chem.* **68,** *1186–1190 (1964).*
The standard e.m.f. of the cell D_2 (g. 1 atm.), DCl in D_2O, AgCl; Ag has been determined from 5 to 50°. At 25° the

standard e.m.f. is lower by 9.78 mv. (on the molality scale) or 4.31 mv. (on the mole fraction scale) than the standard e.m.f. of the corresponding cell with a hydrogen electrode and a solution of hydrochloric acid in ordinary water. Thermodynamic quantities have been calculated for the reaction

$$1/2\ D_2\ (g.) + HCl\ (in\ H_2O) = 1/2\ H_2(g.) + DCl\ (in\ D_2O).$$

At 25°, ΔG is 418 j. mole^{-1}, $\Delta H°$ is -611 j. mole^{-1}, and $\Delta S°$ is -3.5 j. deg.$^{-1}$ mole^{-1}, when all four substances are in the standard state on the mole fraction scale. The mean ionic activity coefficient and relative partial molal enthalpy of DCl at molalities from 0.01 to 0.05 in heavy water have been obtained and are compared with those for HCl in H_2O. The activity coefficient of DCl in D_2O is slightly smaller than that of HCl in H_2O at the same molality; at $m=0.05$, $t=25°$, the difference in log $\gamma\pm$ is 0.0022.

Direct quantitative analysis of photomicrographs by a digital computer, G. A. Moore, *Photo. Sci. Eng.* **8,** *No. 3, 152–161 (May–June 1964).*

A program on the National Bureau of Standards SEAC Computer directly accepts photomicrographs or other pictures as the information input. Commands in English format cause compilation of operational orders as required to carry out modifications or analyses of the pictures. The 28 operations now functional include lineal and area analyses of whole pictures, sorting out of individual coherent objects, and determining 15 parameters of each. Special photographic precautions are necessary to supply only truthful information to the computer. Studies of complex niobium-tin superconductors and dispersed particle structures are shown. Probable applicability to biological problems and to photographic emulsions is considered.

Superconductivity in semiconducting $SrTiO_3$, J. R. Schooley, W. R. Hosler, and M. L. Cohen, *Phys. Rev. Letters* **12,** *474 (1964).*

Superconducting transitions have been observed in three specimens of strontium titanate, a semiconductor. The specimens were reduced to approximately 10^{20} charge carriers $(cc)^{-1}$ and showed degeneracy at liquid helium temperatures. Four-lead d.c. resistance measurements showed that the transitions are complete within less than 0.1 °K at about 0.26 °K, and that H_c is a few kilo-oersted. A.c. magnetic susceptibility measurements indivate that a bulk diamagnetism is present and that the first critical field is less that one oersted.

An engineering method for calculating protection afforded by structures against fallout radiation, C. Eisenhauer, *NBS Mono. 76 (July 2, 1964), 20 cents.*

This report is a discussion of the technical assumptions underlying the methods currently recommended by the Office of Civil Defense (OCD) for calculating protection afforded by structures against fallout radiation. It discusses methods for calculating the contributions from radioactive sources on the roof and on the ground surrounding a simple one-storied building. It shows in detail how each technical chart in the OCD Professional Manual is derived from basic data on radiation penetration developed by Dr. L. V. Spencer. Charts from the Professional Manual and relevant curves from Spencer's work are included in this report in order to make it self-contained.

Shielding for high-energy electron accelerator installations, *NBS Handbook 97 (July 1, 1964), 30 cents.*

This publication is intended to give a summary of the presently available data required to calculate the shielding for high-energy, high-intensity electron-accelerator installations. The report is not intended to present specific, all-inclusive recommendations since it is not felt that at the present time the "state of the art" has progressed to the point where such recommendations are feasible. This publication is aimed at outlining the present state of our knowledge about the factors governing the shielding required in the vicinity of these accelerators. The recommendations that are made have to do primarily with a procedure to be followed in establishing the required amount of shielding.

Absolute temperatures determined from measurements of the velocity of sound in helium gas, G. Cataland and H. H. Plumb, *Proc. Advisory Committee on Thermometry to the Intern. Bureau of Weights and Measures, 6th Session, p. 175 (Sept. 26–27, 1962).*

At 20 °K and below, the measurement of the speed of sound in helium gas appears to yield a more accurate determination of absolute temperatures than has been previously realized. In an ideal gas, the speed of sound is directly proportional to the square root of the absolute temperature; for a real gas, corrections must be made which involve virial coefficients of the gas expressed in a pressure expansion. Because these corrections increase with pressure, it is desirable that velocity measurements for absolute temperature determinations be conducted at the lowest practical pressures, where a real gas approaches the state of an ideal gas.

An acoustical interferometer has been used as a measuring instrument, and absolute temperature determinations at 2 °K and 20 °K have been investigated. The temperature, measured acoustically, at 2 °K is three millidegrees higher than the temperature associated with the T_{58} helium vapor pressure scale; at 20 °K, it is within 10 millidegrees of the equilibrium hydrogen vapor pressure-temperature scale of Woolley, Brickwedde and Scott. The work is being continued to determine an absolute temperature scale below 20 °K.

Some results and problems in calibrating the NBS photoelectric pyrometer of 1961, R. D. Lee, *Proc. Advisory Committee Thermometry to the Intern. Bureau Weights and Measures, 6th Session, pp. 79–90 (Sept. 26–27, 1962).*

The realization of the International Practical Temperature Scale (IPTS) above 1063 °C has been accomplished in the past with a disappearing filament optical pyrometer. Photoelectric means of detecting the equality of spectral radiance along the same principles of the visual optical pyrometer have been demonstrated to be considerably more precise, and this increased precision has been accomplished with a narrower spectral bandpass.

In the past few years photoelectric pyrometers have been developed at the National Bureau of Standards (NBS) and at other national standards laboratories. Some progress has been made toward the realization of the IPTS with the NBS pyrometer. This paper reports on the preliminary results and problems observed in this work.

Metastable levels in the continuum and the independent particle model, F. Prats and U. Fano, *Proc. IIIrd Intern. Conf. Physics of Electronic and Atomic Collisions, London, England, pp. 600–605 (July 22–26, 1963).*

Resonances in scattering processes and the related metastable levels of atoms, molecules or ions, which decay by autoionization, predissociation or Auger effect, are generally classified by quantum numbers of an independent particle model. This model often affords only a quantitatively very poor initial approximation, and one may wonder how to define operationally meaningful concepts, such as decay rates and line shapes, so that they be independent of the initial approximation. This definition can be achieved in terms of a reaction matrix or, equivalently, in terms of the matrix of the residual interaction in an intermediate representation which is obtained from the independent-particle states by a process of partial, or "preliminary", diagonalization.

Approximations to the pair correlation function for a hard-sphere fluid, M. Klein, *Phys. Fluids* **7,** *No. 3, 391–401 (Mar. 1964).*

The equation of state for hard spheres as predicted by a number of approximations to the pair correlation function are compared with each other and with a reference isotherm. The reference isotherm is given by the five known virial coefficients for ρa^3 0.5, by the molecular dynamics calculations of Alder and Wainwright for $\rho a^3 > 0.7$, and by a graphical interpolation between the two for 0.5 ρa^3 0.7. The approxi-

mations considered are the chain, watermelon, convolution-hypernetted chain, and Percus-Yevick approximation. The solutions to the integral equation of the convolution-hypernetted chain approximation can be used to define a sequence of diagrammatic approximations to the pair correlation function according to the number of parallel branches included. We shall designate these as the approximations $n=1, 2, \ldots$, etc. according to the number of branches included. We have found both the chain and watermelon approximations to yield equations of state which are only slight improvements over the linear correction to the ideal gas law. The equation of state of the convolution-hypernetted chain approximation was found to be a qualitatively good first approximation to the reference isotherm in our earlier work. We have now found the P–Y theory to be a further improvement over this for hard spheres in agreement with the results of Hoover and Poirier for hard cubes and of Broyles for several densities of the Lennard-Jones (12,6) gas. We have found the approximation $n=2$ to yield an equation of state in excellent quantitative agreement with the reference isotherm for densities up to 0.707 times the close packed density.

The sequence of approximations which starts with the chain approximation and ends with the CHNC approximation appears to be part of a uniform approach to the reference isotherm. At the same time, the representations of the known virial coefficients associated with each of these approximations do not approach the correct virial coefficients in a uniform fashion. It would thus appear that the sequence of infinite sums (i.e. over chains, etc.) forms an approximation scheme whose meaning cannot be found from an examination of the usual density series.

Effect of pressure in the radiolysis and photolysis of methane, P. Ausloos, R. Gorden, Jr., and S. T. Lias, *J. Chem. Phys.* **40,** *No. 7, 1854–1860 (Apr. 1, 1964).*

The photolysis and radiolysis of equimolar CH_4-CD_4 mixtures was investigated as a function of pressure. The fact that, in the presence of NO, the ethane fraction consists entirely of C_2D_6, $C_2D_4H_2$, $C_2H_4D_2$, and C_2H_6 in comparable amounts indicates that CH_2 and CD_2 are produced. The relative yield of these ethanes which are formed by insertion of methylene into methane increases with pressure in both the photolysis and radiolysis. In the radiolysis, the G value reaches a value of 0.35 $\pm$0.1 at pressures above 15 atmospheres. Information about the effect of pressure on the production of the methyl ion was obtained by investigating the radiolysis of CH_4-iso-C_4D_{10} and CD_4-C_3H_8 mixtures from 1.5 cm to 130 atmospheres. The data indicate that there is a gradual decrease of the methyl ion yield with increase in pressure while the parent ion yield increases with increase in pressure to a pressure of at least 15 atmospheres.

Intense resonance line sources for photochemical work in the vacuum ultraviolet region, H. Okabe, *J. Opt. Soc. Am.* **54,** *No. 4, 478–481 (Apr. 1964).*

A simple, completely sealed, discharge resonance lamp operated by 2450 mc/sec microwave power is described which emits atomic lines of sufficient intensity to be useful as a photochemical light source.

When a water impurity is present in the lamp, many emission lines appear in the region of wavelength from 1500 to 2000 A. These impurity lines can be effectively removed by means of a getter or by a suitable cold trap. The pressures of pure Xe or Kr in the resonance lamp, required to give maximum intensity (approximately 5 x 10^{14} quanta/sec), are 0.7 mm and 1.0 mm, respectively. The presence of a CO impurity does not affect the intensity of the resonance lines. After passing through a 1 mm LiF window, the intensity of the Xe resonance line at 1295 A is about 2 percent of that at 1470 A and the intensity of the Kr line at 1165 A is about 28 percent of that at 1236 A. A mixture of the rare gas and He gives more intense light than the pure gas. Lyman alpha (1216 A) line from excited atomic hydrogen and a group of lines at 1743–45 A from excited atomic nitrogen may be used as a photochemical light source.

Constants of the interpolation formula for platinum resistance thermometers, J. L. Riddle, *Proc. Advisory Committee Thermometry to the Intern. Bureau Weights and Measures, 6th Session, pp. 198–201 (Sept. 26–27, 1962).*

Values of the constants in the interpolation formula for a large number of thermometers recently submitted to the National Bureau of Standards for calibration are summarized. All thermometers suitable as standards which were received over a period of about one year during 1959 and 1960 are included. Limitations on such constants can serve either to make the International Practical Temperature Scale (IPTS) more precisely defined or to reduct the number of calibration points required for application over limited temperature ranges.

Other NBS Publications

J. Res. NBS 68C (Eng. and Instr.), No. 4 (Oct.–Dec. 1964), 75 cents.

Theory of mirror spectrographs. I. Astigmatic illumination of plane gratings and prisms. K. D. Mielenz.

Theory of mirror spectrographs. II. General theory of focal surfaces and slit curvatures. K. D. Mielenz.

Theory of mirror spectorgraphs. III. Focal surfaces and slit curvature of Ebert and Ebert-Fastie spectrographs. K. D. Mielenz.

Heat flow in a right circular cylinder with arbitrary temperature boundary conditions—applications to the determination of thermal conductivity. D. R. Flynn.

Digitized phasemeter. W. S. Epstein.

Active and passive direct-reading ratio sets for the comparison of audio-frequency admittances. R. D. Cutkosky.

Review of methods for the excitation of atomic and ionic spectra by means of high-frequency discharges and sliding sparks. Lennart Minnhagen.

Standards for the calibration of Q-meters 50 kHz to 45 MHz. R. N. Jones.

X-ray measurement of residual strains in individual grains of polycrystalline aluminum. C. J. Newton.

Ferrimagnetic resonance measurements using IF substitution techniques. W. E. Case, R. D. Harrington, and L. B. Schmidt.

A Pienkowsky-type calibration scheme for 5211-1 weight series using two knife-edge direct-reading balances. H. S. Peiser.

Reference tables for the Platinel II thermocouple. L. O. Olsen and P. D. Freeze.

Effects of cathodic currents on the corrosion of an aluminum alloy. W. J. Schwerdtfeger.

Photooxidation of asphalts in the presence of ozone. J. R. Wright and P. G. Campbell.

Designs for temperature and temperature gradient compensated capacitors smaller than ten picofarads. R. D. Cutkosky.

Radio Sci. J. Res. NBS/USNC–URSI, 68D, No. 11, (Nov. 1964), $1.00.

Interaction of an antenna with a hot plasma and the theory of resonance probes. J. A. Fejer.

Observations of earth-ionosphere cavity resonances and their interpretation in terms of a two-layer ionosphere model. F. W. Chapman and D. Llanwyn Jones.

On the theory of reflection of electromagnetic waves from the interface between a compressible magnetoplasma and a dielectric. J. R. Wait.

Propagation over plane earth through an exponential atomsphere. I. H. Gerks and R. M. Anderson.

Propagation in nonuniform waveguides with impedance walls. R. L. Gallawa.

Some approximate formulas concerning the reflection of electromagnetic waves from a stratified semi-infinite medium. R. Burman.

A VLF timing experiment. A. H. Morgan and O. J. Baltzer.

Phase and time variations in VLF propagation over long distances. D. D. Crombie.

Geometrical optics convergence coefficient for whistler propagation. G. McK. Allcock.

Errors induced by the atmosphere in microwave range measurements. H. B. Janes and M. C. Thompson.

Some features of Es-ionization of the equatorial ionosphere. P. Bandyopadhyay and H. Montes.

A note on the insulated loops antenna immersed in a conducting medium. J. R. Wait and K. P. Spies.

Observation and analysis of transequatorial propagation. J. A. Thomas and B. A. McInnes.

Radio Sci. J. Res. NBS/USNC–URSI, 68D, No. 12, (Dec. 1964), $1.00.

Experiment on the constancy of the velocity of electromagnetic radiation. P. Beckmann and P. Mandics.

Measurement of the phase velocity of VLF propagation in the earth-ionosphere waveguide. F. K. Steele and C. J. Chilton.

Wave hop theory of long distance propagation of low-frequency radio waves. L. A. Berry.

Wave propagation in a compressible ionosphere. Part I. S. R. Seshadri.

Wave propagation in a compressible ionosphere. Part II. S. R. Seshadri.

Spatial properties of the amplitude fading of continuous HF radio waves. J. Ames.

Physical properties of the polar winter mesosphere obtained from low-frequency propagation and partial reflection studies. J. S. Belrose, L. R. Bodé, and L. W. Hewitt.

Reply to the "Remarks by Donald H. Menzel With Reference to Bailey's Comments on Solar Electric Fields." V. A. Bailey.

Tables of chemical kinetics homogeneous reactions (Supplementary tables) NBS Mono. 34, Vol. 2 (July 1, 1964), $2.75.

Line parameters and computed spectra for water vapor bands at 2.7μ, D. M. Gates, R. F. Calfee, D. W. Hansen, and W. S. Benedict, NBS Mono. 71, (Aug. 3, 1964), $2.00.

Examination of farm milk tanks. A manual for weights and measures officials, M. W. Jensen, NBS Handb. 98, (May 22, 1964), 35 cents.

Foreign-lanuage and English dictionaries in the physical sciences and engineering. A selected bibliography 1952 to 1963, T. W. Marton, NBS Misc. Publ. 258 (July 24, 1964), $1.25.

Selection of camera filters for color photography, C. S. McCamy, NBS Misc. Publ. 259, (June 26, 1964), 5 cents.

Standard reference materials: Preparation of NBS white cast iron spectrochemical standards, R. E. Michaelis and L. L. Wyman, NBS Misc. Publ. 260–1, (June 19, 1964), 30 cents.

Quarterly radio noise data December 1962; January, February 1963, W. Q. Crichlow, R. T. Disney, and M. A. Jenkins, NBS Tech. Note 18–17 (May 21, 1964), 50 cents.

Absolute photometry of the light of the night sky. The zenith intensity of Haleakala (latitude N 20.7°) and at Fritz peak (latitude N 39.9°), F. E. Roach and L. L. Smith, NBS Tech. Note 214 (June 29, 1964), 35 cents.

Percentage points of the beta distribution, L. E. Vogler, NBS Tech. Note 215 (May 30, 1964), 25 cents.

Computation of Hankel functions, L. A. Berry, NBS Tech. Note 216 (June 12, 1964), 20 cents.

A bibliography of thermophysical properties of argon from 0 to 300 °K, L. A. Hall, J. G. Hurst, and A. L. Gosman, NBS Tech. Note 217 (June 12, 1964), 55 cents.

Average power dissipated in a diode swept along its reverse characteristic, H. A. Schafft, NBS Tech. Note 240 (Apr. 30, 1964), 20 cents.

Calculations for comparing two-point and four-point probe resistivity measurements on rectangular bar-shaped semiconductor samples, L. J. Swartzendruber, NBS Tech. Note 241 (June 1, 1964), 25 cents.

A fortran program for analysis of ellipsometer measurements and calculation of reflection coefficients from thin films, F. L. McCrackin and J. P. Colson, NBS Tech. Note 242 (May 27, 1964), 30 cents.

Survey of multiply charged ions, F. L. Mohler, NBS Tech. Note 243 (May 27, 1964), 10 cents.

An international comparison of voltage-transformer calibrations to 350 kv, F. K. Harris, W. C. Sze, N. L. Kusters, O. Petersons, and W. J. M. Moore, IEEE Trans. Commun. and Elec. No. 70, 13–19 (Jan. 1964).

The quest for design data, R. B. Stewart, Symp. The Role Cryogenics is Playing in Expanding Mechnical Engineering, Am. Soc. Refrigerating and Air Conditioning Engineers, New York, N.Y., Feb. 11–14, 1964, pp. 13–24 (1964).

A coaxial adjustable sliding termination, W. E. Little and J. P. Wakefield, IEEE Trans. Microwave Theory Tech. **MTT–12**, No. 2, 247–248 (Mar. 1964).

Effect of blowing variables on durability of coating grade asphalts, S. H. Greenfeld, Indust. & Eng. Chem. Prod. Res. & Dev. **3,** pp. 158–164 (June 1964).

Q Meter measurements up to 260 MHZ, M. G. Broadhurst (Proc. Conf. Electric Insulation) 1963 Annual Report, Natl. Acad. Sci.-Natl. Res. Council Publ. 1141, pp. 77–80 (1964).

Satellite scintillation observations at Boulder, Colorado, J. L. Jespersen and G. Kamas, J. Atmospheric Terrest. Phys. **26,** 457–473 (1964).

The reaction of methyl radicals with dimethylmercury, R. E. Rebbert and P. Ausloos, J. Am. Chem. Soc. **86,** No. 10, 2068–2069 (May 20, 1964).

The performance of point level sensors in liquid hydrogen, D. A. Burgeson, W. G. Pestalozzi, and R. J. Richards (Proc. 1963 Cryogenic Eng. Conf., Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering **9**, Paper G–5, pp. 416–422 (Plenum Press Inc., New York, N.Y. 1963).

On associated ions in polyelectrolytes and trapped Browian trajectories, J. L. Jackson and S. R. Coriell, J. Chem. Phys. **40,** No. 5, 1460–1461 (Mar. 1, 1964).

He-Ne laser with perpendicular end windows, K. D. Mielenz, K. F. Neffen, and K. Gillilland, J. Opt. Soc. Am. Letter to Editor **3,** No. 6, p. 785 (June 1964).

Functions for the calculation of entropy, enthalpy, and internal energy for real fluids using equations of state and specific heats, J. G. Hust and A. L. Gosman (Proc. 1963 Cryogenic Eng. Conf., Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering **9,** Paper D–8, 227–233 (Plenum Press, Inc., New York, N.Y., 1964).

Physical processes in the *D* region of the ionosphere, G. C. Reid, Rev. Geophys. **2,** No. 2, 311–333 (May 1964).

Observation of FeO in absorption by flash heating and kinetic spectroscopy, A. M. Bass, N. A. Kuebler, and L. S. Nelson, J. Chem. Phys. **40,** No. 10, 3121–3122 (May 15, 1964).

Computer simulation of traffic on nine blocks of a city street, M. C. Stark, (Proc. 41st Annual Meeting Highway Research Board, Jan. 8–12, 1962), Highway Res. Board Bull. 356, Publ. 1051, p. 40 (Natl. Acad. Sci.-Natl. Res. Council, Wash., D.C., 1962).

One man's opinion—a common language (nomenclature for rubbers), R. D. Stiehler, Rubber World **148,** No. 3, 119 (June 1963).

Long-lived effects in the *D* region after the high-altitude nuclear explosion of July 9, 1962, A. H. Brady, D. D. Crombie, A. G. Jean, A. C. Murphy, and F. K. Steele, J. Geophys. Res. **69,** No. 9, 1921–1924, (May 1, 1964).

Some remarks concerning non-reciprocity in radio propagation, J. R. Wait, IEEE Trans. Ant. Prop. **AP–12,** No. 3, 372–373 (May 1964).

Synthesis of diatomic radicals, H. E. Radford, J. Chem. Phys. **40,** No. 9, 2732–2733 (May 1, 1964).

The effective area of a guarded electrode, J. I. Lauritzen, Jr., (Proc. Conf. Electric Insulation) 1963 Annual Report, Natl. Acad. Sci.- Natl. Res. Council Publ. 1141, pp. 67–73 (1964).

On the measurement of radom chain scission by stress relaxation, H. Yu, Polymer Letter **2,** 631–635 (1964).

The listing of sudden ionospheric disturbances, J. V. Lincoln, Planet. Space Sci. **12,** 419–434 (1964).

Evidence of a stratified echoing region at 150 kilometers in the vicinity of the magnetic equator during daylight hours, B. B. Balsley, J. Geophys. Res. **69,** No. 9, 1925–1930 (May 1, 1964).

Electrical resistances of wires of low temperature-coefficient of resistance useful in calorimetry (10° K–380° K), G. T. Furukawa, M. L. Reilly, and W. G. Saba, Rev. Sci. Instr. **35,** No. 1, 113–114 (Jan. 1964).

Introduction, V. J. Johnson, Am. Soc. Refrigerating and Air Conditioning Engineers, Symp., The Role Cryogenics

is Playing in Expanding Mechanical Engineering at the semi-annual meeting of the Am. Soc. of Heating, Refrigerating and Air-Conditioning Engineers, New York, N.Y., Feb. 11–14, 1963, pp. III–IV (1964).

Measurement of the cross section for elastic scattering of slow electrons by hydrogen atoms, W. L. Wiese, VIth Intern. Conf. Ionization Phenomena in Gases I, 5–8 (Paris, 1963).

Mass spectrometric study of the isotopic exchange rate of oxygen atoms with O^2, NO, and NO_2, J. T. Herron and F. S. Klein, J. Chem. Phys. **40,** No. 9, 2731 (May 1, 1964).

Growth twins and branching of electrodeposited copper dendrites, F. Ogburn, J. Electrochem. Soc. **11,** No. 7, 870–872 (July 1964).

Ultrasonically induced nuclear spin transitions in antiferromagnetic $KMnF_3$ A. B. Denison, L. W. James, J. D. Currin, W. H. Tantilla, and R. J. Mahler, Phys. Rev. Letters **12,** 244–245, (1964).

Techniques for using the air-gap method for the precise determination of the dielectric constant and loss angle of solid disk specimens, A. H. Scott, (Proc. Conf. Electric Insulation) 1963 Annual Report, Natl. Acad. Sci.-Natl. Res. Council Publ. 1141, pp. 74–76 (1964).

Low-temperature infrared study of intermediates in the photolysis of HNCO and DNCO, M. E. Jacox and D. E. Milligan, J. Chem. Phys. **40,** No. 9, 2457–2460 (May 1, 1964).

N_2+ oscillators strength from arc spectroscopic measurements using an analog computer, J. B. Shumaker, Jr. (Proc. Sixth Intern, Symp. Ionization Phenomena in Gases VII, No. **15,** 311–313 (1963).

Ixiolite and other polymorphic types of $FeNbO_4$, R. S. Roth and J. L. Waring, Am. Mineralogist **49,** 242–246 (Mar.–Apr. 1964).

Separation and determination of zirconium in zirconia-yttria mixtures by precipitation with cupferron, E. J. Maienthal and J. K. Taylor, Anal. Chem. **36,** 1286–1287 (June 1964).

Analysis of the frost phenomena on a cryo-surface, R. V. Smith, D. K. Edmonds, E. G. F. Brentari, and R. J. Richards, (Proc. 1963 Cryogenic Eng. Conf. Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering **9,** Paper B-7, pp. 88–97 (Plenum Press Inc., New York, N.Y., 1964).

Free subgroups and normal subgroups of the modular group, M. Newman, Ill. J. Math. **8,** No. 2, 262–265 (June 1964).

The operating characteristics of Zener reference diodes and their measurements, W. G. Eicke, Jr., ISA Trans. **3,** No. 2, 93–99 (Apr. 1964).

Four critical fields in superconducting indium lead alloys, S. Gygax, J. L. Olsen, and R. H. Kropschot, Phys. Letters **8,** No. 4, 228–230 (1964).

The correlation of thermodynamic properties of cryogenic fluids, R. B. Stewart and K. D. Timmerhaus (Proc. 1963 Cryogenic Eng. Conf., Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering 9, Paper A–3, 20–27 (Plenum Press Inc. New York, N.Y., 1964.)

Modern methods of analysis for the design of cryogenic equipment and processes, T. R. Strobridge and D. B. Mann, Symp., The Role Cryogenics is Playing in Expanding Mechanical Engineering, Am. Soc. Refrigerating and Air Conditioning Engineers, New York, N.Y., Feb. 11–14, 1963 pp. 26–37 (1964).

Survey of current NBS work on properties of parahydrogen, R. D. Goodwin, D. E. Diller, W. J. Hall, H. M. Roder, L. A. Weber, and B. A. Younglove, (Proc. 1963 Cryogenic Eng. Conf., Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering **9,** Paper D–9, 234–242 (Plenum Press Inc., New York, N.Y., 1964).

The calorimeter and its influence on the development of chemistry, G. T. Armstrong, J. Chem. Educ. **41,** 297 (June 1964).

Presidential address before the Electrochemical Society meeting, Toronto, Canada, May 5, 1964, W. J. Hamer, J. Electrochem. Soc. **III,** No. 7, 145C–147C (July 1964).

Precise determination of the area of guarded electrodes for accurate dielectric measurements on solid-disk specimens, W. P. Harris, (Proc. Conf. Electric Insulation) 1963 Annual Report, Natl. Acad. Sci.-Natl. Res. Council Publ. 1141, p. 71 (1964).

Open-probe thermocouple control of radio-frequency heating, A. W. Ruff, Jr., Rev. Sci. Instr. **35,** No. 6, 760–761 (June 1964).

A new steady-state calorimeter for measuring heat transfer through cryogenic insulation, D. R. Beck, F. Kreith, and R. H. Kropschot (Proc. 1963 Cryogenic Eng. Conf. Univ. Colorado and National Bureau of Standards, Boulder, Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering **9,** Paper B–4, 64–70 (Plenum Press Inc., New York, N.Y., 1964).

Surface currents in type II superconductors, S. Gygax and R. H. Kropschot, Phys. Letters **9,** No. 2, p. 91, (Apr. 1, 1964).

A preliminary study of the orifice flow characteristics of liquid nitrogen and liquid hydrogen discharging into a vacuum, J. A. Brennan (Proc. 1963 Cryogenic Eng. Conf., Univ. Colorado and National Bureau of Standards, Boulder Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering 9, Paper E–6, p. 292–303, (Plenum Press, Inc., New York, N.Y., 1964).

Sieve techniques for obtaining small amounts of narrowly classified particles, C. M. Hunt and A. R. Woolf, Mater. Res. Std. Tech. Note 4, No. 7, 364 (July 1964).

Preliminary thermodynamic properties of neon, R. D. McCarty and R. B. Stewart (Proc. 1963 Cryogenic Eng. Conf. Univ. Colorado and National Bureau of Standards, Boulder Colo., Aug. 19–21, 1963), Book, Advances in Cryogenic Engineering **9,** Paper D–1, 161–167 (Plenum Press Inc., New York, N.Y., 1963).

The effect of coulomb collisions on incoherent scattering of radio waves by a plasma, D. T. Farley, Jr., J. Geophys. Res. **69,** No. 1, 197–200 (Jan. 1, 1964).

On the connection between the theories of collisions and of atomic spectra, U. Fano and F. Prats, Proc. Nat. Acad. Sci. India, **XXXIII,** Part IV, 553–562 (1963).

Electromagnetic scattering from a radially inhomogeneous sphere, J. R. Wait, J. Appl. Phys. Sec. B, **10,** 441–450 (Jan. 7, 1963).

An approach to the classification of electromagnetic surface waves, J. R. Wait, Book, Radio Waves and Circuits by S. Silver, Pt. 1, pp. 86–95 (Elsevier Publ. Co., Princeton, N.J., 1963).

Mass spectrometry, R. M. Reese and F. N. Harllee, Anal. Chem. **36,** No. 5, 278R–295R (April 1964).

Colorimetry in parafoveal fields I. Color-matching functions, I. Nimeroff, J. Opt. Soc. Am. **54,** No. 6, 824–832 (June 1964).

Colorimetry in parafoveal fields II. Additivity failure, I. Nimeroff, J. Opt. Soc. Am. **54,** No. 6, 833–838 (June 1964).

An experimental 350-kv, 1-picofarad air capacitor, A. E. Peterson, IEEE Trans. Commun. Elec. No. **71,** 129–131 (Mar. 1964).

The association of plane-wave electron-density irregularities with the equatorial electro jet, K. L. Bowles, J. Geophys. Res. **68,** No. 9, 2503–2525 (May 1, 1963).

Some results of the energy-dependent Milne problem for thermal neutrons and light gases, C. Eisenhauer, Nucl. Sci. Eng. **19,** 95–101 (1964).

Nitrogen NMR chemical shifts in the azide ion, R. A. Forman, J. Chem. Phys. **39,** No. 9, 2393 (Nov. 1, 1963).

Exact Faxén solution for centrifugation when sedimentation depends linearly on concentration, I. H. Billick and G. H. Weiss, Nature **201,** No. 4922, 912–913 (Feb. 29, 1964).

$4f^3$ and $4f^2\,5d$ configurations of doubly ionized praseodymium (Pr III), R. E. Trus, J. Opt. Soc. Am. **54,** No. 5, 651–657 (May 1964).

Distillation analysis, R. T. Leslie and E. C. Kuehner, Anal. Chem. **36,** 56R (Apr. 1964).

The second industrial revolution (Spanish translation), A. T. McPherson, Rev. Centro Estud. Ing. **132,** No. 669, 348–354 (1963).

A comparison of the TA_1 and the NBS—A atomic time scales, J. Bonanomi, P. Kartaschoff, J. Newman, J. A. Barnes, and W. R. Atkinson, Proc. IEEE **52,** No. 4, 439 (Apr. 1964).

Jet thinning device for preparation of Al_2O_3 electron microscope specimens, N. J. Tighe, Rev. Sci. Instr. **35,** No. 4, 520–521 (Apr. 1964).

Nuclear magnetic resonance in lead alloys, R. J. Snodgrass and L. H Bennett, Phys. Rev. **134,** No. 5A, A1294 (June 1, 1964).

Radar echoes from Venus at 50 Mc/sec, W. K. Klemperer, G. R. Ochs, and K. L. Bowles, Astron. J. **69,** No. 1 (1316) 22–28 (Feb. 1964).

On the theory of Schumann resonances in the earth-ionosphere cavity J. R. Wait, Can. J. Phys. **42,** 575–582 (Apr. 1964).

Absorption spectra of diatomic molecules in liquid and crystalline rare gases, G. L. Pollack and A. A. Pollack (Proc. 14th Annual Mid-America Spectroscopy Symp. Chicago, Ill., May 20–23, 1963), Book, Developments in Applied Spectroscopy **3,** 376–382 (Plenum Press, New York, N.Y., 1964) ed. J. E. Foreette and E. Lanterman.

A note on some quadrature formulas for the interval $(-\infty, \infty)$, S. Haber, Math, Computation **18,** No. 86, 313–314 (Apr. 1964).

Comments by J. R. Wait on the paper "Obstacle gain and shadow loss," by G. H. Crenier, to the Editor of Microwave J. **6,** No. 7, 83 (July 1963).

Microwave standards and measurements, a progress review 1960–1963, R. W. Beatty, IEEE Trans. Instr. Meas. **IM–12,** No. 3, 134–138 (Dec. 1963).

Absence of pronounced quadrupole effects in the nuclear resonance of In^{115} in a non-cubic environment, L. H. Bennett and R. J. Snodgrass, Phys. Rev. **134,** No. 5A, A1290 (June 1, 1964).

Kinetics and mechanism of the low-cubic to hexagonal phase transformation of silver iodide, J. Phys. Chem. **68,** No. 5, 1111–1113 (1964).

On the concentrations of vibrationally excited O_2 formed in the flash photolysis of NO_2, A. M. Bass and D. Garvin, J. Chem. Phys. **40,** No. 6, 1772–3 (Mar. 15, 1964).

Energy, temperature, and organisms, D. M. Gates, Sci. Teacher **31,** No. 4 (May 1964).

Some aspects of the coordination chemistry of boron, T. D. Coyle and F. G. A. Stone, Progr. Boron Chem. **1,** 83–166 (1964).

The relation between VLF propagation and *D*-layer characteristics, J. R. Wait, IEEE Trans. Ant. Prop. **AP–12,** No. 2 (Mar. 1964).

**Publications for which a price is indicated are available by purchase from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402 (foreign postage, one-fourth additional). Reprints from outside journals and the NBS Journal of Research may often be obtained directly from the authors.*