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Additional Remarks on a Theorem of M. Riesz[1]

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Let V be a real four-dimensional vector space, whose underlying geometry is the metric defined by the matrix

$$K=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

The following theorem is proved.

THEOREM: *If A and B are real, skew-symmetric, orthogonal (with respect to K) linear transformations on V, then $[A, B]=AB-BA$ is a multiple of a real, skew-symmetric, orthogonal (with respect to K), linear transformation on V.*

The theorem is proved by use of the first and second regular representations of the real quaternions. Methods are given for constructing all 4 × 4 matrices which are skew-symmetric and orthogonal with respect to K, and all 4 × 4 matrices which are skew-symmetric (in the Euclidean sense) and orthogonal with respect to K.

Key Words: Commutator, matrix, orthogonal, quaternions, skew-symmetric, regular representation.

1. Introduction

M. Riesz, in a series of lectures [4][2] dealing with Clifford algebras delivered at the University of Maryland (September, 1957, to February, 1958) proved the following theorem.

THEOREM: *If* A *and* B *are real, skew-symmetric, orthogonal linear transformations on* E_4 *(a real four-dimensional vector space on which there has been imposed a Euclidean metric), then* $[A, B]=AB-BA$ *is a multiple of a real, skew-symmetric, orthogonal transformation on* E_4.

Subsequently, M. Pearl [3] proved this theorem using only the properties of the matrices associated with these transformations and the first and second regular representations of the real quaternions. Furthermore, Pearl proved that if the underlying geometry is changed from the Euclidean metric to the Lorentzian metric then the theorem is satisfied vacuously.

The purpose of this paper is to prove the theorem in the remaining four-dimensional case. That is, when the underlying geometry of the vector space is the metric defined by the matrix

$$K=\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

The main tools used are the first and second regular representations of the real quaternions. Methods are given for constructing all 4 × 4 matrices which are skew-symmetric and orthogonal with respect to K, and for constructing all 4 × 4 matrices which are skew-symmetric (in the Euclidean sense) and orthogonal with respect to K.

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[1] This paper formed part of the author's thesis for the Master of Arts degree, University of Maryland, 1961.

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

2. Regular Representations

Consider any algebra $\mathfrak{A}$ over the field $\mathfrak{F}$. If $\mathfrak{A}$ has a basis consisting of $e_1, e_2, \ldots, e_n$ then

$$e_ie_j = \sum_{k=1}^{n} c_{ijk}e_k, \qquad c_{ijk} \in \mathfrak{F} \tag{1}$$

Using the method and notation of Pearl [3], if we define the $n \times n$ matrices $R_i = (c_{isr})$ and $S_i = (c_{ris})$, where r denotes the row index and s the column index, by associativity in $\mathfrak{A}$ we have

$$R_iR_j = \sum_{k=1}^{n} c_{ijk}R_k \tag{2}$$

$$S_iS_j = \sum_{k=1}^{n} c_{ijk}S_k \tag{3}$$

and

$$R_i'S_j = S_jR_i' \tag{4}$$

where R_i' is the transpose of R_i.

If for any element a of $\mathfrak{A}$,

$$a = \alpha_1e_1 + \alpha_2e_2 + \ldots + \alpha_ne_n, \quad \alpha_i \in \mathfrak{F}$$

we define

$$R(a) = \alpha_1R_1 + \alpha_2R_2 + \ldots + \alpha_nR_n,$$

$$S(a) = \alpha_1S_1 + \alpha_2S_2 + \ldots + \alpha_nS_n \tag{5}$$

then the mappings $a \to R(a)$ and $a \to S(a)$ of $\mathfrak{A}$ into the algebras of the matrices, $\mathfrak{R}$ and $\mathfrak{S}$, are homomorphisms called the first and second regular representations of $\mathfrak{A}$. Furthermore, if $\mathfrak{A}$ has an identity element, then these mappings are isomorphisms.

In the case in which $\mathfrak{A}$ is the algebra of the real quaternions, $\mathfrak{F}$ is the real field and $\mathfrak{A}$ has basis elements e_0, e_1, e_2, e_3 where e_0 is the identity element. It follows that $R_0 = S_0 = I$, the identity matrix, and

$$R_1 = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \end{bmatrix} \qquad R_2 = \begin{bmatrix} 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0 & 0 & 0 & -1 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

$$S_1 = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \end{bmatrix} \qquad S_2 = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{bmatrix}$$

$$S_3 = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \end{bmatrix} \tag{6}$$

Since $R_1, R_2, R_3, S_1, S_2, S_3$ clearly span the six dimensional vector space $\mathfrak{D}$ of 4×4 skew-symmetric matrices, it follows that they are linearly independent and form a basis for $\mathfrak{D}$.

Thus, every 4×4 skew-symmetric matrix Q has a unique representation as $R(a) + S(b)$ where a and b are pure quaternions. (A pure quaternion is a quaternion whose e_0 —coefficient is zero.)

3. Skew-Symmetric Matrices

Now let us consider some properties of skew-symmetric matrices, in particular, the matrices $R(a)$ and $S(b)$.

Since each of the R's and S's is skew-symmetric, (4) becomes $R(a)S(b) = S(b)R(a)$. Now consider the mapping σ of the real vector $\mathbf{a} = (\alpha_1, \alpha_2, \alpha_3)$ into the pure quaternion $a = \sigma(\mathbf{a})$. Using this, Pearl [3] proves the following:

LEMMA 1: *If* a *and* b *are orthogonal, pure quaternions* ($\mathbf{a} \cdot \mathbf{b} = 0$), *then* $\mathrm{R(a)R(b)} = -\mathrm{R(b)R(a)}$ *and* $\mathrm{S(a)S(b)} = -\mathrm{S(b)S(a)}$.

For the pure quaternion $a = \alpha_1e_1 + \alpha_2e_2 + \alpha_3e_3$ we define the norm, $N(a)$, to be $\alpha_1^2 + \alpha_2^2 + \alpha_3^2$. Clearly for any real number α, $N(\alpha a) = \alpha^2N(a)$ and furthermore $a^2 = -N(a)e_0$. Thus

$$R(a)^2 = S(a)^2 = -N(a)I. \tag{7}$$

For the skew-symmetric matrix $Q = R(a) + S(b)$ we define the conjugate, $\bar{Q}$, to be $R(a) - S(b)$, and the norm, $N(Q)$, to be $N(b) - N(a)$. Thus,

$$Q\bar{Q} = \bar{Q}Q = R(a)^2 - S(b)^2 = N(Q)I. \tag{8}$$

Furthermore, if $\mathbf{c}$ is any vector orthogonal to $\mathbf{b}$, then by lemma 1

$$S(c)QS(c)^{-1} = S(c)[R(a) + S(b)]S(c)^{-1} = R(a) - S(b) = \bar{Q} \tag{9}$$

Thus, $\bar{Q}$ and Q are similar and hence taking determinants of both sides of (8) we have

$$\text{Det } Q \text{ Det } \bar{Q} = (\text{Det } Q)^2 = N(Q)^4$$

and since the determinant of a real skew-symmetric matrix is nonnegative, we have

Lemma 2: *Det* $Q =$ *Det* $\bar{Q} = N(Q)^2$.

4. *K*-Skew-Symmetric, *K*-Orthogonal Matrices

Let the metric on the real four-dimensional vector space V be defined by the matrix

$$K = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

We defined a matrix A to be orthogonal with respect to K (K-orthogonal) if $A'KA = K$, and we define a matrix B to be skew-symmetric with respect to K (K-skew-symmetric) if $x'BKx = 0$ for every vector x in V. Thus B is K-skew-symmetric if and only if BK is skew-symmetric in the Euclidean sense.

Consider now a matrix A which is both K-skew-symmetric and K-orthogonal. Since A is K-skew-symmetric there exists a skew-symmetric matrix Q such that $AK = Q$ or $A = QK$. Thus we have

$$A' = KQ' = -KAK. \qquad (10)$$

Furthermore, since A is K-orthogonal, by definition $A'KA = K$ and hence by (10)

$$A^2 = -I.$$

Thus $$A^{-1} = -A. \qquad (11)$$

But also $$A^{-1} = (QK)^{-1} = KQ^{-1}. \qquad (12)$$

If we define the norm of A, $N(A)$, to be the norm of Q for $AK = Q$ we have

Lemma 3: *If the matrix* A *is* K*-skew-symmetric and* K*-orthogonal then* $N(A) = \pm 1$.

Proof: $A'KA = K$ and $AK = Q$. Hence $Q'KQ = K$, and taking determinants of the terms $(\det Q)^2 = 1$. Thus $\det Q = \pm 1$. Since Q is skew-symmetric $\det Q = 1$. By lemma 2, $\det Q = N(Q)^2$. Thus $N(A) = N(Q) = \pm 1$.

Lemma 4: $KR_iK = \pm R_i$, $KS_iK = \pm S_i$, $+$ *if* $i = 1$, $-$ *if* $i = 2, 3$. Now we may prove the following

Theorem 1: *The matrix* A *is* K*-skew-symmetric and* K*-orthogonal if and only if one of the following conditions is satisfied:*

1. $N(A) = 1$ *and* A *has the form* $\alpha_2 R_2 K + \alpha_3 R_3 K + \beta_1 S_1 K$.
2. $N(A) = -1$ *and* A *has the form* $\alpha_1 R_1 K + \beta_2 S_2 K + \beta_3 S_3 K$.

Proof: Let A be K-skew-symmetric and K-orthogonal. Then by (11) and (12), for $A = QK$ we have

$$A^{-1} = -QK = KQ^{-1}.$$

Thus by (8) $$-KQK = \frac{1}{N(Q)} \bar{Q}. \qquad (13)$$

Let $Q = R(a) + S(b)$ where $R(a) = \alpha_1 R_1 + \alpha_2 R_2 + \alpha_3 R_3$, and $S(b) = \beta_1 S_1 + \beta_2 S_2 + \beta_3 S_3$. Then we have two cases.

Case 1. $N(A) = N(Q) = +1$.

Substituting in (13) for Q and $\bar{Q}$ and applying lemma 4 we obtain

$$-2\alpha_1 R_1 + 2\beta_2 S_2 + 2\beta_3 S_3 = 0.$$

Since R_1, S_2, and S_3 are linearly independent, $\alpha_1 = \beta_2 = \beta_3 = 0$ and hence if $N(A) = 1$, $A = \alpha_2 R_2 K + \alpha_3 R_3 K + \beta_1 S_1 K$.

Case 2. $N(A) = N(Q) = -1$.

Again, substituting in (13) for Q and $\bar{Q}$ and applying lemma 4, we obtain $\alpha_2 = \alpha_3 = \beta_1 = 0$ and hence if $N(A) = -1$, $A = \alpha_1 R_1 K + \beta_2 S_2 K + \beta_3 S_3 K$.

Conversely, if $N(A) = 1$ and $A = \alpha_2 R_2 K + \alpha_3 R_3 K + \beta_1 S_1 K$, AK is skew-symmetric, and hence A is K-skew-symmetric. Furthermore,

$$A'KA = (-KQ)(KQK) = +KQ\bar{Q} \text{ by lemma 4}$$
$$= K[N(Q)I] = K.$$

Thus A is K-orthogonal. Similarly if $N(A) = -1$ and $A = \alpha_1 R_1 K + \beta_2 S_2 K + \beta_3 S_3 K$, A is K-skew-symmetric and K-orthogonal.

Using (6) and lemma 4 we may construct the following table of commutators.

[,]	R_1K	R_2K	R_3K	S_1K	S_2K	S_3K
R_1K	0	0	0	0	$2S_3K$	$2S_2K$
R_2K	0	0	$2S_1K$	$-2R_3K$	0	0
R_3K	0	$-2S_1K$	0	$-2R_2K$	0	0
S_1K	0	$2R_3K$	$2R_2K$	0	0	0
S_2K	$-2S_3K$	0	0	0	0	$2R_1K$
S_3K	$-2S_2K$	0	0	0	$-2R_1K$	0

We can now prove the analog to Riesz' Theorem. Let A and B be two K-skew-symmetric, K-orthogonal matrices. Then we have,

Case 1. $N(A) = N(B) = 1$. Using the linearity of commutators and the results of the table,

$$[A,\ B]=[\alpha_2R_2K+\alpha_3R_3K+\beta_1S_1K,\ \gamma_2R_2K$$

$$+\gamma_3R_3K+\delta_1S_1K]$$

$$=2(\beta_1\gamma_3-\alpha_3\delta_1)R_2K+2(\beta_1\gamma_2-\alpha_2\delta_1)R_3K$$

$$+2(\alpha_2\gamma_3-\alpha_2\gamma_2)S_1K$$

which is a multiple of a K-skew-symmetric, K-orthogonal matrix with norm 1, or zero if $A=\pm B$.

Case 2. $N(A)=N(B)=-1$.

$$[A,\ B]=[\alpha_1R_1K+B_2S_2K+\beta_3S_3K,\ \gamma_1R_1K+\delta_2S_2K$$

$$+\delta_3S_3K]=2(\beta_2\delta_3-\beta_3\delta_2)R_1K$$

$$+2(\alpha_1\delta_3-\beta_3\gamma_1)S_2K+2(\alpha_1\delta_2-\beta_2\gamma_1)S_3K$$

which is a multiple of a K-skew-symmetric, K-orthogonal matrix with norm -1, or zero if $A=\pm B$.

Case 3. $N(A)=-N(B)=-1$.

$$[A,\ B]=[\alpha_2R_2K+\alpha_3R_3K+\beta_1S_1K,\ \gamma_1R_1K$$

$$+\delta_2S_2K+\delta_3S_3K].$$

$$=0.$$

Thus the theorem is satisfied in all possible cases.

COROLLARY: *Let* A *and* B *be* K-*skew-symmetric,* K-*orthogonal matrices such that* $A\neq\pm B$. *Then* A *and* B *commute if and only if* $N(A)N(B)=-1$.

5. Skew-Symmetric, K-Orthogonal Matrices

Since we have a method for constructing all K-skew-symmetric, K-orthogonal matrices, and Pearl [3] gives a method for constructing all skew-symmetric, orthogonal matrices, the question arises, what is the form of a skew-symmetric, K-orthogonal matrix?

THEOREM 2: *The matrix* M *is skew-symmetric (in the Euclidean sense) and* K-*orthogonal if and only if* $M=AK$ *where* A *is a* K-*skew-symmetric,* K-*orthogonal matrix. (Thus by Theorem 1,* M *is either of the form*

$$\alpha_2R_2+\alpha_3R_3+\beta_1S_1,\ \beta_1^2-\alpha_2^2-\alpha_3^2=1,\ or$$

$$\alpha_1R_1+\beta_2S_2+\beta_3S_3,\ \beta_2^2+\beta_3^2-\alpha_1^2=-1.)$$

PROOF: If M is skew-symmetric and K-orthogonal, then M' and $-M$ and $M'KM=K$. Hence

$$(KM)^2=(MK)^2=-I$$

and thus
$$M^{-1}=-KMK$$

But by (8), $M^{-1}=\frac{1}{N(M)}\overline{M}$. Thus we have

$$-KMK=\frac{1}{N(M)}\overline{M}.$$

This is the same condition as (13). Thus $M=AK$ where A is a K-skew-symmetric, K-orthogonal matrix.

Conversely, if $M=AK$, where A is K-skew-symmetric and K-orthogonal, by definition M is skew-symmetric and since $A'KA=K$ we have $M'KM=K$.

6. Conclusion

This paper, together with Pearl's [3], completes the proof of Riesz' Theorem on all real, four-dimensional vector spaces, regardless of the metric imposed on the space.

Unfortunately, the methods of this paper are rather restricted, and it is not expected that they may be readily applied in the consideration of spaces of higher dimension.

7. References

[1] Dickson, L. E., Algebras and Their Arithmetics (Chicago, 1923).

[2] Katz, L., Olkin, I., Properties and factorizations of matrices defined by the operation of pseudo-transposition, Duke Math. J. **20**, 331–337 (1953).

[3] Pearl, M., On a Theorem of M. Riesz, J. of Res. NBS **62**, No. 3, 89–94 (1959) RP 2935.

[4] Riesz, M., Clifford Numbers and the Equation of Dirac, (unpublished lectures, University of Maryland, 1957–58).

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Vol. 71B, No. 1, January–March 1967

Publications of the National Bureau of Standards*

Selected Abstracts

New method and problems in combinatorial optimization, A. J. Goldman, *Washington Oper. Res. Council Newsletter* **5,** *No. 8, 4–8 (Apr. 1966).*

This paper describes recent progress at the National Bureau of Standards in the field of combinatorial optimization.

Other NBS Publications

J. Res. NBS 70A (Phys. and Chem.), No. 6 (Nov.–Dec. 1966), $1.00.

Absolute isotopic abundance ratios and atomic weight of magnesium. E. J. Catanzaro, T. J. Murphy, E. L. Garner, and W. R. Shields.
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Dissociation of some substituted phenols in 50-percent aqueous methanol as solvent. R. A. Robinson and R. G. Bates.

J. Res. NBS 71A (Phys. and Chem.), No. 1 (Jan.–Feb. 1967), $1.00.

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Standard Reference Materials: Determination of oxygen in ferrous materials SRM 1090, 1091, and 1092, O. Menis and J. T. Sterling, Misc. Publ. 260–14, (Sept. 23, 1966), 30 cents.
Hydraulic research in the United States 1966, ed. H. K. Middleton and G. Kulin, Misc. Publ. 280, (Sept. 8, 1966), $1.50.
High temperature properties and decomposition of inorganic salts. Part 1. Sulfates, K. H. Stern and E. L. Weise, NSRDS–NBS7, (Oct. 1, 1966), 35 cents.
Mat-formed wood particleboard, CS236–66, (Apr. 15, 1966), 10 cents.
A survey of some empirical and semi-empirical interatomic and intermolecular potentials, B. M. Axilrod, Tech. Note 246, (Oct. 3, 1966), 40 cents.
Research on crystal growth and characterization at the National Bureau of Standards June 1966, ed. H. C. Allen, Jr., Tech. Note 293, (Aug. 26, 1966), 25 cents.
Disclosures on: A transrotor engine, high temperature platinum resistance thermometer, dynamic analog correlation system, and combination metering and safety valve for filling sonde balloons with hydrogen, ed. D. Robbins and A. J. Englert, Tech. Note 295, (Oct. 21, 1966), 25 cents.
Observed phase-front distortion in simulated earth-to-space microwave transmissions, H. B. Janes and M. C. Thompson, Jr., Tech. Note 339 (May 12, 1966), 50 cents. (Formerly Central Radio Propagation Laboratory of the National Bureau of Standards, now Environmental Science Services Administration, Boulder, Colo.)
The long-term performance of two rubidium vapor frequency standards, B. E. Blair and A. H. Morgan, Tech. Note 341, (June 22, 1966), 25 cents.
Hydromagnetic wave propagation near 1c/s in the upper atmosphere and the properties and interpretation of Pc 1 micropulsations, J. A. Dawson, Tech. Note 342 (June 30, 1966), 40 cents. (Formerly Central Radio Propagation Laboratory of the National Bureau of Standards, now Environmental Science Services Administration, Boulder, Colo.)
A sensitive recording NMR ultrasonic spectrometer, L. W. James, Tech. Note 344, (Sept. 7, 1966), 20 cents.
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Electrochemical analysis: studies of acids, bases, and salts by EMF, conductance, optical, and kinetic methods July 1965 to June 1966, Ed. R. G. Bates, Tech. Note 400, (Sept. 6, 1966), 55 cents.
Activities of the NBS Spectrochemical Analysis Section July 1965 through June 1966, ed. B. F. Scribner, Tech. Note 401, (Sept. 30, 1966), 55 cents.
Microchemical Analysis Section: summary of activities July 1965 to June 1966, ed. J. K. Taylor, Tech. Note 403 (Sept. 1, 1966), 50 cents.
Organic chemistry: air pollution studies; kinetic behavior of sugars in solution; carbon-14- and tritium-labeled carbohydrates; characterization of chemical structures, phenylhydrazono-phenylazo tautomerism: synthesis of research materials, cyclopentitols and related substances; novel research materials; standard reference materials (organic) July 1965 through June 1966, ed. H. S. Isbell, Tech. Note 405 (Sept. 30, 1966), 60 cents.
Superconductive materials and some of their properties, B. W. Roberts, Tech. Note 408 (Sept. 26, 1966), 45 cents.
Improved Fortran program for single particle energy levels and wave functions in nuclear structure calculations, R. S. Caswell, Tech. Note 410 (Sept. 30, 1966), 25 cents.
Analysis of lanolin in soap, F. J. Linnig, Soap Chem. Specialties **XVLL,** No. 7, 55–57 (July 1966).
Analytical applications of microwave spectroscopy, D. R. Lide, Jr., Book, Advances in Analytical Chemistry and Instrumentation **5,** 235–277 (Interscience Publ., New York, N.Y., 1966).

Chemical substructure searching with linear notations, B. A. Marron, G. R. Boltsky, and S. J. Tauber, J. Chem. Doc. **6,** 92–95 (May 1966).

Determination of glycerol in paper, E. L. Graminski and B. W. Forshee, Tappi **49,** No. 7, 324–326 (July 1966).

Electron spin resonance studies of the reaction of water-soluble polymers with hydroxyl radicals, F. Sicilio, M. Dousset, R. E. Florin, and L. A. Wall (Proc. 150th American Chemical Society Meeting, Atlantic City, N.J., Sept. 12–17, 1965), Polymer Preprint **6,** No. 2, 958–964 (Sept. 1965).

Experimental and theoretical studies of photoionization efficiency curves for C_2H_2 and C_2D_2, R. Botter, V. H. Dibeler, J. A. Walker, and H. M. Rosenstock, J. Chem. Phys. **44,** No. 3, 1271–1278 (Feb. 1966).

Gas-phase radiolysis and photolysis of neopentane, S. G. Lias and P. Ausloos, J. Chem. Phys. **43,** No. 8, 2748–2759 (Oct. 1965).

Identification of inclusions with the electron probe microanalyzer, K. F. J. Heinrich, Am. Soc. Testing Mater. Spec. Tech. Publ. **393** (Jan. 1966).

Intramolecular insertion of isobutylidene in the vacuum ultraviolet photolysis of isobutane, E. Tschuikow-Roux and J. R. McNesby, Trans. Faraday Soc. **62,** No. 524, 2158–2163 (Aug. 1966).

Investigation of polymer pyrolysis with thermogravimetry, J. H. Flynn and L. A. Wall (Proc. 150th American Chemical Society Meeting, Atlantic City, N.J., Sept. 12–17, 1965), Polymer Preprint **6,** No. 2, 945–955 (Sept. 1965).

Mass spectrometric study of the reactions of O atoms with NO and NO_2, Erratum, J. T. Herron, J. Chem. Phys. **44,** No. 9, 3645 (May 1966).

Oxidation of asphalt flux with oxides of nitrogen, P. G. Campbell and J. R. Wright, Am. Chem. Soc. Div. Petroleum Chem. **10,** No. 1, 79–89 (Mar. 1965).

Phenylhydrazono-phenylazo tautomerism. Part I. *xylo*-4,5,6-trihydroxy-2-oxo-1,3-bis(phenylhydrazono) cyclohexane and 4-*oxo*-1-phenyl-5-phenylazo-3-pyridazine derivatives, H. S. Isbell and A. J. Fatiadi, Carbohydrate Res. **2,** No. 2, 204–215 (June 1966).

Polymerization and pyrolysis of poly-1,2-dihydronaphthalene, L. A. Wall, L. J. Fetters, and S. Straus (Proc. 150th American Chemical Society Meeting, Atlantic City, N.J., Sept. 12–17, 1965), Polymer Preprint **6,** No. 2, 930–939 (Sept. 1965).

Radiation-induced polymerization at high pressure of 3,3,3-trifluoropropene; 4,4,4,3,3-pentafluorobutene-1; and 5,5,5,4,4,3,3-heptafluoropentene-1, D. W. Brown (Proc. 150th American Chemical Society Meeting, Atlantic City, N.J., Sept. 12–17, 1965), Polymer Preprint **6,** No. 2, 965–976 (Sept. 1965).

Solid-vapor equilibrium in the system helium-methane, M. J. Hiza and A. J. Kidnay (Proc. 1965 Cryogenic Engineering Conf., Rice University, Houston, Tex., Aug 23–25, 1965), Book, Advances in Cryogenic Engineering 11, 338–348 (Plenum Press Inc., New York, N.Y., 1966).

Status of light-element heat-capacity calorimetry at the National Bureau of Standards: a review of the high-temperature thermodynamics of the BeO-H_2O system, T. B. Douglas, Proc. 4th Meeting Interagency Cehmical Rocket Propulsion Group, Working Group on Thermochemistry, Kennedy Space Flight Center, Florida, Mar. 16–17, 1966, I, No. 108, 27 (Chemistry Propulsion Information Agency, Silver Spring, Md., June 1966).

The crystal and molecular structure of dichloro(1,10-phenanthroline) zinc, C. W. Reimann, S. Block, and A. Perloff, Inorg. Chem. **5,** No. 7, 1185–1189 (July 1966).

The crystal structure of the high temperature form of barium borate, $BaO \cdot B_2O_3$, A. D. Mighell, A. Perloff, and S. Block, Acta Cryst. **20,** pt. 6, 819–823 (June 1966).

The determination of bound styrene in soluble high styrene-butadiene resins, M. A. Post, J. Paint Tech. Eng. Official Digest **38,** No. 497, 335–342 (June 1966).

The determination of heats of formation of refractory compounds, G. T. Armstrong and E. S. Domalski, Proc. 4th Meeting Interagency Chemical Rocket Propulsion Group, Working Group on Thermochemistry, Kennedy Space Flight Center, Fla.,March 16–18, 1966, I, No. 108, 15 (Chemistry Propulsion Information Agency, Silver Spring, Md., June 1966).

The determination of mercury in latex paints and paint films containing mercury fungicides, H. W. Berger, J. Paint Technol. **38,** No. 498, 371–376 (July 1966).

The evolution of the accuracy of isotopic analysis by thermal ionization from 2% to 0.2%, W. R. Shields (Proc. Symp. Nuclear Materials Management, IAEA, Vienna, Austria, Aug. 30–Sept. 3, 1965), Book, Nuclear Materials Management, pp. 737–746 (Intern. Atomic Energy Agency, Vienna, Austria, Feb. 1966).

The monomer-polymer equilibrium of alpha-trideuteromethyl-beta, beta-dideuterostyrene, L. J. Fetters and L. A. Wall (Proc. 150th American Chemical Society Meeting, Atlantic City, N.J., Sept. 12–17, 1965), Polymer Preprint **6,** No. 2, 899–903 (Sept. 1965).

The radiation induced polymerization of hexafluoropropylene at high temperature and pressure, R. E. Lowry, D. W. Brown, and L. A. Wall (Proc. 150th American Chemical Society Meeting, Atlantic City, N.J., Sept. 12–17, 1965), Polymer Preprint **6,** No. 2, 977–984 (Sept. 1965).

Thermal decomposition of hexamethylethane, 2,2,3-trimethylbutane and neopentane in a single pulse shock tube, W. Tsang, J. Chem. Phys. **44,** No. 11, 4283–4295 (June 1, 1966).

Thermolytic chain scission of linear polyethylene and an ethylene-propylene copolymer, H. Yu and L. A. Wall (Proc. 150th American Chemical Society Meeting, Atlantic City, N.J., Sept. 12–17, 1965), Polymer Preprint **6,** No. 2, 940–944 (Sept. 1965).

Vacuum-ultraviolet photolysis of paraffin hydrocarbons, J. R. McNesby, Book, Chemical and Biological Actions of Radiation, **IX,** ch. 2, 39–67 (Masson and Co., Editors and Publ., Paris, France, 1966).

Advances in cryogenic engineering, Book, K. D. Timmerhaus, editor, Proc. 1964 Cryogenic Engineering Conf., University of Pennsylvania, Philadelphia, Pa., Aug. 18–21, 1964, 10, Pt. 1 (Plenum Press, Inc., New York, N.Y., 1965).

Apparatus for studying the effects of atmospheric pollution and cyclic dew formation on the deterioration of materials, J. W. Pitts and D. G. Moore, Mater. Res. Std. **6,** No. 7, 328–333 (July 1966).

A cold moderator refrigerator incorporating a high-speed turbine expander, R. O. Voth, M. T. Norton, and W. A. Wilson (Proc. 1965 Cryogenic Engineering Conf., Rice University, Houston, Tex., Aug. 23–25, 1965), Book, Advances in Cryogenic Engineering 11, 126–138 (Plenum Press Inc., New York, N.Y., 1966).

A new near-zone electric field-strength meter, F. M. Greene (Proc. 8th IEEE Symp. Electromagnetic Compatibility, San Francisco, Calif., July 11–13, 1966), Symposium Digest New Ideas for Electromagnetic Compatibility, 1966.

A proposal for a supplement to the patent system, S. Henig, Design News Mag. **21,** No. 1, 84–89 (Jan. 5, 1966).

Bond with reinforcing steel, D. Watstein, ASTM Significance of Tests of Concrete and Concrete Making Materials, Am. Soc. Testing Mater. Spec. Tech. Publ. **169A,** pp. 239–245 (July 1966).

Chemical admixtures, B. E. Foster, ASTM Significance of Tests of Concrete and Concrete Making Materials, Am. Soc. Testing Mater. Spec. Tech. Publ. **169A,** pp. 556–564 (July 1966).

Comparative study of forced convection boiling heat transfer correlations for cryogenic fluids, P. J. Giarratano and R. V. Smith (Proc. 1965 Cryogenic Eng. Conf., Rice University, Houston, Tex., Aug. 23–25, 1965), Book, Advances in Cryogenic Engineering 11, 492–506 (Plenum Press Inc., New York, N.Y., 1966).

Floor coverings, T. H. Boone, Book, Building Construction Handbook, 2d edition, ed. F. S. Merritt, Sec. 13, pp. 13–1 – 13–8 (1965).

Free radical microwave absorption meter, H. E. Radford, Rev. Sci. Instr. **37,** No. 6, 790–792 (June 1966).

Instrumentation and measurements, H. E. Bussey and J. E. Gray, Digest of Literature on Dielectrics **28,** ch. I., 1–31 (1964); Natl. Acad. Sci.—Natl. Res. Council Publ. 1324 (Natl. Acad. Sci.—Natl. Res. Council, Washington, D.C., 1965).

International advances in cryogenic engineering, Book, K. D. Timmerhaus, editor, Proc. 1964 Cryogenic Engineering Conf., Univ. Pennsylvania, Philadelphia, Pa., Aug. 18–21, 1964, 10, Pt. 2 (Plenum Press, Inc., New York, N.Y., 1965).

Liquid-solid mixtures of hydrogen near the triple point, D. B. Mann, P. R. Ludtke, C. F. Sindt, and D. B. Chelton (Proc. 1965 Cryogenic Engineering Conf., Rice University, Houston, Tex., 23–25, 1966), Book, Advances in Cryogenic Engineering 11, 207–217 (Plenum Press Inc., New York, N.Y., 1966).

Message from outgoing editor, R. W. Beatty, IEEE Trans. Microwave Theory Tech. **MTT-14,** No. 4, 170 (Apr. 1966).

Metals for use in orthopedics, S. J. Rosenberg, Book, Orthotics Etcetera, ed. S. Licht, 9, 77–94 (E. Licht Publ., New Haven, Conn., 1966).

New standard for the calibration of microphones, W. Koidan, Mag. Std. **37,** No. 5, 141–144 (May 1966).

Resistance to weathering, H. T. Arni, ASTM Significance of Tests of

Concrete and Concrete Making Materials, Am. Soc. Testing Mater. Spec. Tech. Publ. **169A,** pp. 261–274 (1966).

Survey of infrared measurement techniques and computational methods in radiant heat transfer, S. T. Dunn, J. C. Richmond, and J. F. Parmer, J. Spacecraft Rockets **3,** No. 7, 961–975 (July 1966).

Voluntary product standards—what they mean to the consumer, M. Lonie, J. Home Econ. **58,** No. 1, 22 (Jan. 1966).

On the complex structure of the universe, E. H. Brown, J. Math. Phys. **7,** No. 3, 417–425 (Mar. 1966).

Atomic timekeeping and the statistics of precision signal generators, J. A. Barnes, Proc. IEEE **54,** No. 2, 207–220 (Feb. 1966).

A superconducting liquid-level sensor for slush hydrogen use, B. L. Knight, K. D. Timmerhaus, and T. M. Flynn (Proc. 1965 Cryogenic Engineering Conf., Rice University, Houston, Tex., Aug. 23–25, 1965), Book, Advances in Cryogenic Engineering 11, 218–222 (Plenum Press Inc., New York, N.Y., 1966).

Effects of long-term stability on the definition and measurement of short-term stability, J. A. Barnes and D. W. Allan, Proc. IEEE–NASA Symp. Definition and Measurement of Short-Term Frequency Stability, NASA Spec. Publ. No. 80, pp. 119–123 (Nov. 23–24, 1964).

Evaluation of a thallium atomic beam frequency standard at the National Bureau of Standards, R. E. Beehler and D. J. Glaze, IEEE Trans. Instr. Meas. **IM-15,** No. 1 & 2, 55–58 (Mar.–June 1966).

LF–VLF frequency and time services of the National Bureau of Standards, D. H. Andrews, IEEE Trans. Instr. Meas. **IM-14,** No. 4, 233–237 (Dec. 1965).

Optical methods of temperature measurement, G. A. Hornbeck, J. Appl. Opt. Lead Article **5,** No. 2, 179 (Feb. 1966).

Quantity control—A tool of industry, and arm of government, M. W. Jensen, Proc. Annual Conf. Society for the Advancement of Food Service Research, Washington, D.C. (Apr. 18, 1966).

Remote positioner for rotary switches, S. B. Lang, and A. M. Gray, Rev. Sci. Instr. **37,** No. 6, 799–801 (June 1966).

The performance and capability of cesium beam frequency standards at the National Bureau of Standards, R. E. Beehler and D. J. Glaze, IEEE Trans. Instr. Meas. **IM-15,** No. 1 & 2, 48–55 (Mar.–June 1966).

Time resolved microwave interferometry on diagnostic tool for decaying plasma afterglows, A. J. Estin and M. M. Anderson, Rev. Sci. Instr. **37,** No. 4, 468–470 (Apr. 1966).

Analyzing liquid H_2 with NMR, C. E. Miller, W. J. Alspach, and T. M. Flynn, Cryogenic Engr. News **1,** No. 8, 66 (June 1966).

Angular dependence of the one-phonon-nuclear quadrupole interactions, R. J. Mahler, J. Phys. Chem. Solids **27,** 871–879 (1966).

A suggested experiment to measure part of the transverse electromagnetic mass of the electron, E. A. Power, Proc. Roy. Soc. (London) **292,** No. 1430, 424–432 (May 31, 1966).

Brillouin scattering in liquids at 4880 Å, S. L. Shapiro, M. McClintock, D. A. Jennings, and R. L. Barger, IEEE Quantum Electronics **QE-2,** No. 5, 89–93 (May 1966).

Calculated line strengths for the transition array for $d^2s - d^2p$: application to Ni II, H. Mendlowitz, Astrophys. J. **143,** No. 2, 573–590 (Feb. 1966).

Calculated slant-path absorption and distribution of atmospheric water vapor, R. F. Calfee and D. M. Gates, Appl. Opt. **5,** No. 2, 287–292 (Feb. 1966).

Comments on the mechanism of the 377-micron CN laser, H. P. Broida, K. M. Evenson, and T. T. Kikuchi, J. Appl. Phys. **36,** No. 10, 3355 (Oct. 1965).

Comparison of the Lennard-Jones, Exp: 6, and Kihara potential functions from viscosity data of dilute argon, H. J. M. Halney, J. Chem. Phys. **44,** No. 11, 4219–4222 (June 1966).

Direct ratio readings from a universal ratio set, D. Ramaley and J. F. Schafer, Instr. Control Systems **39,** 73–74 (Jan. 1966).

Dielectric relaxation in molecular crystals: multiple site models, J. D. Hoffman, Book, Molecular Relaxation Processes, Chemical Society Spec. Publ. **20,** pp. 47–60 (The Chemical Society and Academic Press, New York, N.Y., 1966).

Electric quadrupole transition in the $A^1\Pi \leftarrow X^1\Sigma^+$ system of CO, J. D. Simmons and S. G. Tilford, J. Chem. Phys. **44,** No. 11, 4145–4147 (June 1966).

Electron impact ionization cross section data for atoms, atomic ions, and diatomic molecules: I. Experimental data, L. J. Kieffer and G. H. Dunn, Rev. Mod. Phys. **38,** No. 1, 1–33 (Jan. 1966).

Franck-Condon factors for the ionization of H_2 and D_2, G. H. Dunn, J. Chem. Phys. **44,** No. 7, 2592–2594 (Apr. 1966).

Fundamentals of ultrasonics, M. Greenspan, J. Acoust. Soc. Am. **37,** No. 1, 158–159 (July 1965).

Impact broadening of microwave spectra, A. Ben-Reuven, Phys. Rev. **145,** No. 1, 7–22 (May 1966).

Infrared spectra of HCl, DCl, HBr, and DBr in solid rare-gas matrices, D. E. Mann, N. Acquista, and D. White, J. Chem. Phys. **44,** No. 9, 3453–3467 (May 1966).

Infrasonic waves from aurorae, K. Maeda and J. M. Young, Nature **207,** No. 4994, 279–281 (July 1965).

Ion mobilities in helium, E. C. Beaty, J. C. Browne, and A. Dalgarno, Phys. Rev. Letters **16,** No. 17, 723–724 (Apr. 1966).

Low-temperature phase transformations, R. P. Reed and J. F. Breedis, Behavior of Materials at Cryogenic Temperatures, Am. Soc. Testing Mater. Spec. Tech. Publ. No. 387, pp. 60–132 (1966).

Low temperature speed of sound in single crystal ice, T. M. Proctor, Jr., J. Acoust. Soc. Am. **39,** No. 5, 972–977 (May 1966).

Magnetic core permeability measurement techniques, R. D. Harrington and A. L. Rasmussen, Proc. Magnetic Core Conf. **7,** 11–24 (1965).

Measurements of collisional energy transfer between rotational energy levels in CN, K. M. Evenson and H. P. Broida, J. Chem. Phys. **44,** No. 4, 1637–1641 (Feb. 15, 1966).

Measurements of the viscosity of parahydrogen, D. E. Diller (Proc. IXth Intern. Conf. Low Temperature Physics, Columbus, Ohio, Aug. 31–Sept. 4, 1964), Book, Low Temperature Physics, LT9, Pt. B, pp. 1227–1229 (Plenum Press Inc., New York, N.Y., 1965).

Nonlinear diffusion with recombination in an electron beam excited plasma, E. R. Mosburg, Jr., Phys. Fluids **9,** No. 4, 824–826 (Apr. 1966).

Nuclear spin relaxation in liquid hydrogen, C. E. Miller, T. M. Flynn, T. K. Grady, and J. S. Waugh, Physica **32,** No. 2, 244–251 (Feb. 1966).

One dimensional solution of the Ginzburg-Landau equations for thin superconducting films, V. D. Arp, R. S. Collier, R. A. Kamper, and H. Meissner, Phys. Rev. **145,** No. 1, 231–236 (May 6, 1966).

Physics of the *D* region at high latitudes, G. C. Reid (Proc. NATO Advanced Study Institute, Finse, Norway, April 1965), Book, Electron Density Profiles in Ionosphere and Exosphere, ed. J. Frihagen, pp. 17–26 (North Holland Publ. Co., Amsterdam, The Netherlands, 1966).

Polycrystalline spin wave theory of ferromagnetic resonance compared with the tilting experiment, A. S. Risley, E. G. Johnson, Jr., and H. E. Bussey, J. Appl. Phys. **37,** No. 2, 656–668 (Feb. 1966).

Radiation lifetime of the first $2_{p3/2}$ state of ionized calcium and magnesium by the Hanle effect, W. W. Smith and A. C. Gallagher, Phys. Rev. **145,** No. 1, 26–35 (May 6, 1966).

Saturation effects in the sensitized fluorescence of CaF_2(Ce, Mn), B. L. Danielson, Phys. Rev. **142,** No. 1, 228–230 (Feb. 4, 1966).

Soft x-ray spectrum of Ni and comparison with photoemission and ion neutralization results, J. R. Cuthill, A. J. McAlister, and M. L. Williams, Phys. Rev. Letters **16,** No. 22, 993–995 (May 30, 1966).

Some properties of the long-time values of the probability densities for moderately dense gases, R. A. Piccirelli, J. Math. Phys. **7,** 922 (1966).

Summary of recent determinations of the ultrasonic velocity in fluid parahydrogen, B. A. Younglove (Proc. IXth Intern. Conf. Low Temperature Physics, Columbus, Ohio, Aug. 31–Sept. 4, 1964), Book, Low Temperature Physics **LT9,** pt. B., pp. 1223–1226 (Plenum Press Inc., New York, N.Y., 1965).

The Chapman-Enskog solution of the generalized Boltzmann equation, M. S. Green, L. S. Garcia-Colin, and F. Chaos, Physica **32,** 450 (1966).

The flow field of a body-stabilized two-dimensional V-flame, F. W. Ruegg and W. W. Dorsey, Combustion and Flame **10,** No. 1, 1–10 (Dec. 1966).

The role of hydrogen in the stress-corrosion cracking of low carbon steel in a nitrate solution, H. L. Logan and H. T. Yolken, Proc. 2d Intern. Congress Metallic Corrosion, New York, N.Y., March 1963, p. 109 (Natl. Assoc. Corrosion Engr., Houston, Texas, 1966).

The spheroidal method in the theory of the orbit of an artificial satellite, J. P. Vinti, Proc. Symp. Celestial Mechanics, Mathematische Forschungsinstitut, Oberwolfach, Germany, March 1964, pp. 97–111 (1964).

The theory of chromospheric spectrum, J. T. Jefferies, Book, The Solar Spectrum, ed. C. DeJager, pp. 131-150 (D. Reidel Publ. Co., Dordrecht, The Netherlands, 1965).

Thermodynamics of the rigid-rotor at high temperature, J. E. Kilpatrick, Y. Fukuda, and S. Y. Larsen, J. Chem. Phys. **43,** No. 2, 430–432 (July 1965).

Thermophysical properties of metals at cryogenic temperatures, R. L. Powell, Behavior of Materials at Cryogenic Temperatures, Am. Soc. Testing Mater. Spec. Tech. Publ. No. 387, pp. 134–148 (1966).

Vacuum ultraviolet spectrum of neutral silicon, V. Kaufman, L. J. Radziemski, Jr., and K. L. Andres, J. Opt. Soc. Am. **56,** No. 7, 911–915 (July 1966).

Zero-point energy and Lamb shift, E. A. Power, Am. J. Phys. **34,** No. 6, 516–518 (June 1966).

Computed performance of moderate size, super-gain, end-fire antenna arrays, C. O. Stearns, IEEE Trans. Ant. Prop. **AP–14,** No. 2, 241–242 (Mar. 1966).

Electron precipitation and ionospheric radio absorption in the auroral zones, K. L. Hargreaves and R. D. Sharp, Planetary Space Sci. **13,** 1171–1183 (Dec. 1965).

Evidence of long-period acoustic-gravity waves launched into the *F* region by the Alaskan earthquake of March 28, 1964, R. V. Row, J. Geophys. Res. Letter **71,** 343–345 (Jan. 1966).

International URSIGRAM and world days service "report on activities in 1964," A. H. Shapley, URSI Info. Bull. No. 150, pp. 43–55 (May 1965).

Ionospheric effects of particles, G. C. Reid, Proc. COSPAR Polar Cap Panel Symp., Alpach, Austria, 1964, pp. 221–231 (Academic Press Inc., New York, N.Y., 1965).

Linear tuning of a microwave cavity, M. J. Vetter, IEEE Trans. Microwave Theory Tech. **MTT–13,** No. 6, 880 (Nov. 1965).

Observations of ionospheric irregularities and plasma resonances by the fixed-frequency topside sounder satellite, W. Calvert (Proc. NATO Advanced Study Institute, Finse, Norway, April 1965), Book, Electron Density Profiles in Ionosphere and Exosphere, ed. J. Frihagen, pp. 281-298 (North Holland Publ. Co., Amsterdam, The Netherlands, 1966).

Observations of the equatorial ionosphere using incoherent backscatter, D. T. Farley (Proc. NATO Advanced Study Institute, Finse, Norway, April 1965), Book, Electron Density Profiles in Ionosphere and Exosphere, ed. J. Frihagen, pp. 446–469 (North Holland Publ. Co., Amsterdam, The Netherlands, 1966).

Slow fluctuations between conjugate points in the auroral absorption of cosmic noise, H. J. A. Chivers and J. K. Hargreaves, J. Atmos. Terrest. Phys. **28,** 337–342 (1966).

SPACEWARN—an international mechanism for rapid distribution of information on satellites and space probes, A. H. Shapley, COSPAR Info. Bull. No. 24, pp. 30–55 (July 1965).

Spectral distribution of solar radiation at the earth's surface, D. M. Gates, Science **151,** No. 3710, 523–529 (Feb. 1966).

Statistics of atomic frequency standards, D. W. Allan, Proc. IEEE **54,** No. 2, 221–230 (Feb. 1966).

Swept-frequency antenna gain measurements, R. G. FitzGerrell, IEEE Trans. Ant. Prop. **AP–14,** No. 2, 173–178 (Mar. 1966).

The important atmospheric processes in the *D* region, G. C. Reid, Proc. COSPAR Polar Cap Panel, Alpach, Austria, 1964, pp. 15–19 (Academic Press Inc., New York, N.Y., 1965).

"Winter anomaly" in ionospheric absorption and stratospheric warnings, A. H. Shapley and W. J. G. Beynon, Nature **206,** 1242–1243 (June 1965).

Dissociation of acetic acid-d_4 in deuterium oxide from 5 to 50° and related isotope effects, M. Paabo, R. G. Bates, and R. A. Robinson, J. Phys. Chem. **70,** 2073–2077 (1966).

Effects of errors in the chemical literature on the compilation of critically evaluated data, W. H. Evans, J. Chem. Doc. **6,** No. 3, 135–136 (Aug. 1966).

Electronically excited NO by photodissociation of NO_2 and NOCl, K. H. Welge, J. Chem. Phys. **45,** No. 4, 1113–1117 (Aug. 15, 1966).

Gas-phase photolysis of isopentane at photon energies below and above the ionization energy, A. A. Scala and P. Ausloos, J. Chem. Phys. **45,** No. 3, 847–854 (Aug. 1, 1966).

Formation of $N_2(A^3\Sigma^+)$ and $N(^2D, {}^2P)$ by photodissociation of HN_3 and N_2O and their reactions with NO and N_2O, K. H. Welge, J. Chem. Phys. **45,** No. 1, 166–170 (July 1, 1966).

Glass-molten salt interactions, K. H. Stern, Chem. Rev. **66,** No. 4, 355–372 (July 25, 1966).

Ground state of bis-(acetylacetonato) copper (II), H. C. Allen, Jr., J. Chem. Phys. **45,** No. 2, 553–555 (July 15, 1966).

Interactions in aqueous nonelectrolyte solutions. I. Solute-solvent equilibria, R. H. Stokes and R. A. Robinson, J. Phys. Chem. **70,** 2126–2131 (1966).

K-absorption fine structures of sulfur in gaseous SF_6, R. E. LaVilla and R. D. Deslattes, J. Chem. Phys. **44,** No. 12, 4399–4400 (June 15, 1966).

Losses due to adsorption during filtration of aqueous solutions of polycyclic aromatic hydrocarbons, M. Inscoe, Nature **211,** No. 5053, 1083–1085 (Sept. 3, 1966).

Mass spectrometric study of the rates of the reactions of nitrogen atoms with olefins, J. T. Herron, Phys. Chem. **70,** No. 9, 2803–2807 (Sept. 1966).

Mass-spectrometric study of photoionization. IV. Ethylene and 1,2-dideuteroethylene, R. Botter, V. H. Dibeler, J. A. Walker, and H. M. Rosenstock, J. Chem. Phys. **45,** No. 4, 1298–1301 (Aug. 15, 1966).

Measurement of photochemical degradation in rigid poly(vinly chloride) by colour reactions with *N,N*-dimethyl-*p*-phenylenediamine, J. R. Wright and V. E. Gray (Proc. Conf. Plastics in Building Structures, London, England, June 14–16, 1965), Plastics Inst. Trans. J. Suppl. **1,** 113–118 (June 14, 1966).

Mossbauer spectrometry, J. R. DeVoe and J. J. Spijkerman, Anal. Chem. **38,** 382R–393R (1966).

Photoionization efficiency curve for SF_6 in the wavelength region 1050 to 600 Å, V. H. Dibeler and J. A. Walker, J. Chem. Phys. **44,** No. 12, 4405–4406 (June 15, 1966).

Photoinoization of *n*-butane at 1067–1048 Å. Decomposition of the parent ion and superexcited molecule, P. Ausloos and S. G. Lias, J. Chem. Phys. **45,** No. 2, 524–535 (July 15, 1966).

Study of D_2O ice as a cold-neutron source, J. J. Rush, D. W. Connor, and R. S. Carter, Nucl. Sci. Engr. **25,** 383–389 (1966).

An examination of the effects of heat transfer and compressible flow on the performance of laminar flowmeters, F. W. Ruegg and H. H. Allion, Proc. Flow Measurement Conf., Am. Soc. Mech. Eng. Fluid Meters Golden Anniversary, Pittsburgh, Pa., Sept. 26–28, 1966, pp. 253–273 (1966).

A high directivity, broadband coaxial coupler, P. A. Hudson, IEEE Trans. Microwave Theory Tech. **MTT–14,** No. 6, 293–294 (June 1966).

Development of performance standards, B. E. Foster, Military Engr. **58,** No. 385, 335–336 (Sept.–Oct. 1966).

Roofing research, T. H. Boone, Military Engr. **385,** 344–345 (Sept.–Oct. 1966).

Temperature effects on pressure transducers, J. W. Dean and T. M. Flynn, ISA Trans. **5,** No. 3, 223–232 (July 1966).

Analysis of multimode experimental data, H. Kurss, IEEE Trans. Ant. Prop. **AP–14,** No. 3, 401–402 (May 1966).

A network-simulation approach to the railroad freight train scheduling and car sorting problem, W. P. Allman, Proc. 4th Intern. Conf. Operational Research, Boston, Mass., Aug. 29–Sept. 2, 1966 (Arthur D. Little Inc., Cambridge, Mass., 1966).

A new guide for photographers, C. S. McCamy, Mag. Stds. **37,** No. 8, 223–224 (Aug. 1966).

Absorption spectrum of SF_6 in the far ultraviolet by electron impact, J. A. Simpson, C. E. Kuyatt, and S. R. Mielczarek, J. Chem. Phys. **44,** No. 12, 4403–4404 (June 15, 1966).

A simple non-scanning camera for x-ray diffraction contrast topography, H. P. Layer and R. D. Deslattes, J. Appl. Phys. **37,** No. 9, 3631–3632 (Aug. 1966).

Chemical and physical mechanisms of salt stress-corrosion cracking in the titanium 8-1-1 alloy, H. L. Logan, M. J. McBee, C. J. Bechtoldt, B. T. Sanderson, and G. M. Ugiansky (Proc. Stress Corrosion Cracking Symp., Seattle, Washington, Nov. 1965), Am. Soc. Testing Material Spec. Tech. Publ. **397,** pp. 215–229 (1966).

Commission on fundamental spectroscopic data, C. Moore-Sitterly, Trans. Intern. Astron. Union **XIIB,** 173–185 (1966).

Current algebras and matrix elements of the axialvector current, H. J. Lipkin, H. R. Rubinstein, and S. Meshkov, Phys. Rev. **148,** No. 4, 1405–1407 (Aug. 26, 1966).

Electron microscopy of irradiation-induced defect clusters in magnesium fluoride, D. J. Barber, Phys. Stat. Sol. **16,** 531–547 (1966).

Exchange and direct second virial coefficients for hard spheres, M. E. Boyd, S. Y. Larsen, and J. E. Kilpatrick, J. Chem. Phys. **45,** No. 2, 499–508 (July 15, 1966).

Fracture surface energy of soda-lime glass, S. M. Wiederhorn (Proc. Conf. Role of Grain Boundaries and Surface in Ceramics, North Carolina State University, Raleigh, N.C., Nov. 16–18, 1964), Book, Materials Science Research **3**, 503–528 (Plenum Press Inc., New York, N.Y., 1966).

Heat transfer to a subliming solid-vapor mixture of hydrogen below its triple point, M. C. Jones, T. T. Magamoto, and J. A. Brennan, A.I.Ch.E. J. **12**, No. 4, 790–795 (July 1966).

Higher symmetries and the 2^+ mesons, D. Horn, J. J. Coyne, S. Meshkov, and J. C. Carter, Phys. Rev. **147**, No. 4, 980–984 (July 29, 1966).

Ionization energies of the neutral rare earths, J. Reader and J. Sugar, J. Opt. Soc. Am. **56**, No. 9, 1189–1194 (Sept. 1966).

L-uncoupling effects on the electron-paramagnetic-resonance spectra of $N^{14}O^{16}$, R. L. Brown and H. E. Radford, Phys. Rev. **147**, No. 1, 6–12 (July 8, 1966).

Magnetization and critical fields of superconducting $SrTiO_3$, E. Ambler, J. H. Colwell, W. R. Hosler, and J. F. Schooley, Phys. Rev. **148**, No. 1, 280–286 (Aug. 5, 1966).

Melting temperatures of copolymers, J. P. Colson and R. K. Eby, J. Appl. Phys. **37**, No. 9, 3511–3514 (Sept. 1966).

Quench defects formed in a low-stacking-fault-energy silver-tin alloy, A. W. Ruff, Jr. and L. K. Ives, J. Appl. Phys. **37**, No. 8, 3073–3079 (July 1966).

Radiation absorption between the ultraviolet and x-ray bands, U. Fano, Science **153**, No. 3735, 522–525 (July 29, 1966).

Structure in the photoionization continuum of SF_6 below 630Å, K. Codling, J. Chem. Phys. **44**, No. 12, 4401–4402 (June 15, 1966).

Studies of some exploding wire light sources, E. C. Cassidy and S. Abramowitz, J. SMPTE **75**, No. 8, 735–737 (Aug. 1966).

SU_3 reaction predictions and symmetry breaking, S. Meshkov, Elementary Particles Conf., Institute for Theoretical Physics, University of Colorado, Boulder, Colo., Summer 1964, Lectures Theoret. Phys. **VII B**, 36–50 (1965).

Triple collision contribution to the transport coefficients of a rigid sphere gas, J. V. Sengers, Phys. Fluids **9**, No. 7, 1333–1347 (July 1966).

Viscoelastic behavior, H. Leaderman, Encyclopaedic Dictionary of Physics **7**, 633–634 (Pergamon Press Inc., London, England, 1962).

Medium-frequency sky wave propagation in middle and low latitudes, A. F. Barghausen, IEEE Trans. Broadcasting **BC-12**, No. 1, 1–14 (June 1966).

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