

AD-A070 438

VERMONT UNIV BURLINGTON DEPT OF CHEMISTRY

F/G 7/4

A STUDY OF THE VARIABLE-TEMPERATURE MAGNETIC SUSCEPTIBILITY OF --ETC(U)

JUN 79 J T WROBLESKI, D B BROWN

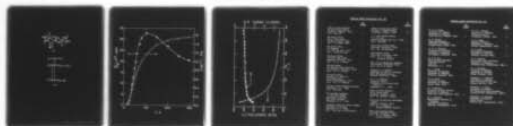
N00014-75-C-0756

UNCLASSIFIED

TR-17

NL

OF
AD
A070 438



END
DATE
FILMED
8-79
DDC

LEVEL

12

OFFICE OF NAVAL RESEARCH

Contract ¹⁵ ~~NO 0014-75-C-0756~~

Task No. NR 356-593

⁹ ~~TECHNICAL REPORT NO. 17~~

A Study of the Variable-Temperature Magnetic Susceptibility of Two Ti(III) Oxalate Complexes .

by

¹⁰ James T. Wrobleski ~~and~~ David B. Brown

Prepared for publication in

Inorganica Chimica Acta

University of Vermont

Department of Chemistry

Burlington, Vermont 05405

¹¹ ~~11 June 1979~~

DDC
RECEIVED
JUN 26 1979
C

¹⁴ TR-17

¹² 17p.

Reproduction in whole or in part is permitted for any purpose of the United States Government.

This document has been approved for public release and sale; its distribution is unlimited.

408 892 *gsm*

79 06 25 028

AD A 070 438

DDC FILE COPY

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 17	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) "A Study of the Variable-Temperature Magnetic Susceptibility of Two Ti(III) Oxalate Complexes"		5. TYPE OF REPORT & PERIOD COVERED Technical Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) James T. Wroblewski and David B. Brown		8. CONTRACT OR GRANT NUMBER(s) N00014-75-C-0756
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Chemistry University of Vermont Burlington, Vermont 05405		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Department of the Navy Arlington, Virginia 22217		12. REPORT DATE June 11, 1979
		13. NUMBER OF PAGES 12
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) This document has been approved for public release and sale; its distribution is unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Submitted for publication in Inorganica Chimica Acta		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Oxalate complexes, magnetic exchange, dimer, Ti(III) complexes		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Variable-temperature magnetic susceptibility data have been obtained for polycrystalline samples of two Ti(III) oxalate complexes, $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$ and $Ti_2(C_2O_4)_3(H_2O)_5$. The bridging oxalate dianion in the former complex (a seven-coordinate dimer with D_{2h} symmetry) provides an effective path for magnetic exchange between the two Ti(III) ions as evidenced by a rather large intramolecular exchange parameter $J = -60 \text{ cm}^{-1}$. The partially dehydrated complex, by contrast, exhibits weak intradimer magnetic		



delta

exchange interactions. Indeed, the variable-temperature magnetic susceptibility data for $Ti_2(C_2O_4)_3(H_2O)_5$ were fit to a distorted-octahedral, single-ion, spin-orbit coupling magnetic model with Δ (ground term splitting) = 300 cm^{-1} and k (orbital reduction factor) = 0.7 with $\lambda' = 155\text{ cm}^{-1}$. Room-temperature optical spectra of $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$ and $Ti_2(C_2O_4)_3(H_2O)_5$ were recorded and the resulting band assignments are consistent with D_{5h} and distorted octahedral ligand-field symmetries, respectively.

gamma

Accession For	
NTIS G&A/I	<input checked="" type="checkbox"/>
DDC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distributor/	
Availability Codes	
Dist	Avail and/or special
A	

A Study of the Variable-Temperature Magnetic Susceptibility of Two Ti(III)
Oxalate Complexes

JAMES T. WROBLESKI and DAVID B. BROWN*

Department of Chemistry, University of Vermont, Burlington, Vermont 05405

U.S.A.

Abstract

Variable-temperature magnetic susceptibility data have been obtained for polycrystalline samples of two Ti(III) oxalate complexes, $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$ and $Ti_2(C_2O_4)_3(H_2O)_5$. The bridging oxalate dianion in the former complex (a seven-coordinate dimer with D_{5h} symmetry) provides an effective path for magnetic exchange between the two Ti(III) ions as evidenced by a rather large intramolecular exchange parameter $J = -60 \text{ cm}^{-1}$. The partially dehydrated complex, by contrast, exhibits weak intradimer magnetic exchange interactions. Indeed, the variable-temperature magnetic susceptibility data for $Ti_2(C_2O_4)_3(H_2O)_5$ were fit to a distorted-octahedral, single-ion, spin-orbit coupling magnetic model with Δ (ground term splitting) = 300 cm^{-1} and k (orbital reduction factor) = 0.7 with $\lambda' = 155 \text{ cm}^{-1}$. Room-temperature optical spectra of $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$ and $Ti_2(C_2O_4)_3(H_2O)_5$ were recorded and the resulting band assignments are consistent with D_{5h} and distorted octahedral ligand-field symmetries, respectively.

Introduction

Study of the magnetic properties of ligand-bridged Ti(III) complexes could potentially provide a wealth of information about the mechanism of superexchange in paramagnetic oligomers. Unfortunately the coordination chemistry of this d^1 ion is not fully developed, principally because of the marked ease of aerial oxidation

of many Ti(III) complexes. However, the Ti(III) ion is stabilized by a number of ligands, including halides, and this stabilization is reflected in the types of Ti(III) complexes which have been studied by variable-temperature magnetic susceptibility. For example, several ionic hexahalide complexes of Ti(III) exhibit Curie-Weiss behavior above ~100K with Weiss constants which range from -50 to -100K. Some specific examples are $K_3[TiF_6]$ ($\mu_{eff}^{RT} = 1.70\mu_B$, $\theta = -50K$) [1], $(pyH)_3[TiCl_6]$ ($\mu_{eff}^{RT} = 1.58\mu_B$, $\theta = -80K$) [2], and $(pyH)_3[TiBr_6]$ ($\mu_{eff}^{RT} = 1.83\mu_B$, $\theta = -94K$) [3]. Unfortunately, there seems to be little agreement on details of the magnetic susceptibility of these compounds as evidenced by the range of room temperature values of μ_{eff} for $(pyH)_3[TiCl_6]$ [2-5]. Several other Ti(III) complexes with donors other than halides have also been studied by magnetic susceptibility measurements. These include $[Ti(H_2O)_6]Cl_3$ ($\mu_{eff}^{RT} = 1.79$, $\theta = -22K$) [6], $[Ti(urea)_6]Cl_3$ ($\mu_{eff}^{RT} = 1.79\mu_B$, $\theta = -38K$) [3], $Ti(acac)_3$ ($\mu_{eff}^{RT} = 1.73\mu_B$, $\theta = -34K$) [6], and $CsTi(SO_4)_2 \cdot 12H_2O$ ($\mu_{eff}^{RT} = 1.80\mu_B$, $\theta = -10K$) [7].

A smaller number of dimeric Ti(III) complexes has been characterized by magnetic susceptibility. Among these are the antiferromagnetic organometallic compounds $(Cp_2TiCl)_2$ [8], $(Cp_2Ti)_2SO_4$ [9], and $(Cp_2Ti)_2CO_3$ [9] and salts of the $(Ti_2Cl_9)^{3-}$ complex anion [10, 11]. The room temperature magnetic moment of $Cs_3[Ti_2Cl_9]$, for example, is reported to be $1.2-1.4\mu_B/Ti$ [12].

As part of our research effort in the area of the coordination chemistry of oxalate, squarate, and dihydroxybenzoquinone complexes [13-15] we have recently determined the variable-temperature magnetic susceptibility of $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$ and $Ti_2(C_2O_4)_3^5(H_2O)_5$. Results of these determinations are reported in this paper.

Experimental

μ -Oxalatobis(oxalato)hexaquodittanium(III) tetrahydrate, $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$, was prepared from oxalic acid (Aldrich) and a 20% aqueous solution of $TiCl_3$ (Baker) according to the procedure of Eve and Fowles [16] which is based on the

preparation of Stähler [17]. The X-ray powder pattern of this brown complex was consistent with the pattern expected for the published crystal data for $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$ [18]. This material was dehydrated at room temperature under a dynamic vacuum to yield an orange product with formula $Ti_2(C_2O_4)_3(H_2O)_5$. This partial dehydration required approximately 48 hours. C and H analyses were performed by Integral Microanalytical Laboratories, Raleigh, N.C. with the following results. Calcd for $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$: C, 13.35; H, 3.73. Found: C, 13.40; H, 3.69. Calcd for $Ti_2(C_2O_4)_3(H_2O)_5$: C, 16.02; H, 2.24. Found: C, 16.13; H, 2.37.

Magnetic susceptibility data were obtained with a conventional Faraday balance which has been described [13-15]. This balance was calibrated with $Hg[Co(NCS)_4]$ [19]. Experimental magnetic susceptibilities were fit to theoretical expressions by using the Simplex minimization algorithm [20]. Ligand diamagnetism was calculated from a table of Pascal's constants [21]. The underlying diamagnetism of Ti^{3+} was taken as -9×10^{-6} cgsu [22]. Optical spectra were recorded on a Cary 14 spectrophotometer. X-ray powder diffraction data were obtained with the Straumanis technique [$CuK\alpha, \lambda_{mean} = 1.5423A$].

Results and Discussion

The Ti(III) oxalate complexes prepared as above are slowly oxidized in air to give a white, diamagnetic product of undetermined composition. The partially-dehydrated product, $Ti_2(C_2O_4)_3(H_2O)_5$, is somewhat less stable than $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$, but both materials are sufficiently stable to permit their transfer in air. The mull optical spectrum of $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$ taken at room temperature consists of a strong absorption in the visible at 23800 cm^{-1} and two weak, near infrared bands at 12200 and 9600 cm^{-1} . These transitions may be assigned upon examination of the structure of $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$ [18] which is shown in Figure 1a. The effective microsymmetry about the seven-coordinate Ti(III) ion is D_{5h} .

The corresponding weak-field terms for a ligand field of D_{5h} symmetry are illustrated in Figure 1b. On the basis of this structure the absorptions at 9600 and 12200 cm^{-1} may be assigned to the ligand-field transitions $E_1'' \rightarrow E_2'$ and $E_1'' \rightarrow A_1'$, respectively. These assignments are identical with those previously made [18] for the diffuse reflectance spectrum of this complex. Because of the high intensity of the 23800 cm^{-1} band, it seems likely that this absorption corresponds to an intramolecular charge transfer transition.

The mull optical spectrum of $\text{Ti}_2(\text{C}_2\text{O}_4)_3(\text{H}_2\text{O})_5$ consists of an asymmetric absorption in the near infrared, centered at approximately 10500 cm^{-1} , and a relatively intense band in the visible at 23000 cm^{-1} . The former band is most likely a ligand-field transition whereas the latter is probably of the charge transfer type. Lack of a single-crystal structure of this material precludes a detailed assignment of this spectrum.

The temperature dependence of the magnetic susceptibility and effective magnetic moment per Ti of $\text{Ti}_2(\text{C}_2\text{O}_4)_3(\text{H}_2\text{O})_6 \cdot 4\text{H}_2\text{O}$ are illustrated in Figure 2 [23]. The value of $\mu_{\text{eff}}/\text{Ti}$ at 295K is $1.54\mu_B$, in good agreement with the value of $1.59\mu_B$ reported by Eve and Fowles [16]. The temperature dependence of the susceptibility of this compound is typical of an antiferromagnetically-coupled dimer in that the susceptibility shows a broad maximum in the vicinity of 100K and decreases to a very small value at 15K. This susceptibility behavior may be modeled by using eq. 1 which is the HDVV partition function for an $S_1 = S_2 = 1/2$ dimer. In eq. 1 the symbols have their usual meanings

$$\chi_M = (\text{N}\beta^2 g^2 / 3kT) [6x(1+3x)^{-1}] \quad (1)$$

and $x = \exp(2J/kT)$. In fitting eq. 1 to the data of Figure 2, the values $J = -60 \text{ cm}^{-1}$ and $g = 1.95$ are obtained. These values were used in calculating the theoretical χ_M vs. T curve shown as the solid line in Figure 2. The

substantial value of J found for $Ti_2(C_2O_4)_3(H_2O)_6 \cdot 4H_2O$ indicates that the bridging oxalate ligand provides an effective pathway for magnetic exchange in this compound. This value of the exchange parameter is significantly larger than that observed for Cu(II) and Ni(II) dimers which contain bridging oxalate dianions [24].

The temperature dependence of the magnetic susceptibility and effective magnetic moment of $Ti_2(C_2O_4)_3(H_2O)_5$ is as illustrated in Figure 3 [23]. The value of μ_{eff}/Ti drops from $1.65\mu_B$ at 17K. Application of the $S_1=S_2=1/2$ dimer expression (eq 2) results in an acceptable fit to the data only if a large temperature-independent paramagnetic correction, $N\alpha$, is applied. This fit is shown as the solid curve in Figure 3 with $J = 7.2 \text{ cm}^{-1}$, $g = 1.78$, and $N\alpha = 238 \times 10^{-6}$ cgsu. This "forced-fit" is clearly unrealistic in view of the untypical values of g and $N\alpha$. We therefore sought to apply the appropriate low-symmetry magnetic model of Figgis [25] to these data. The result of fitting this model to the data for $Ti_2(C_2O_4)_3(H_2O)_5$ is illustrated as the dashed line in Figure 3 and yields Δ (ground term splitting) = 300 cm^{-1} and \underline{k} (orbital reduction factor) = 0.7. (These values were calculated by assuming that the term spin-orbit coupling constant λ' was equal to the free ion value of 155 cm^{-1} [26]. See reference 25 for a more detailed discussion of these parameters.) These low-symmetry ligand-field parameters which were obtained for $Ti_2(C_2O_4)_3(H_2O)_5$ are similar to those found for similar distorted octahedral Ti(III) complexes. For example, magnetic susceptibility data for $[Ti(urea)_6]I_3$ were fit [26] to this model [25] with $\Delta = 480 \text{ cm}^{-1}$, $\underline{k} = 0.65$, and $\lambda = 160 \text{ cm}^{-1}$.

Conclusions

Magnetic susceptibility and optical spectroscopic data for $Ti_2(C_2O_4)_3(H_2O) \cdot 4H_2O$ are consistent with the observed seven-coordinate (D_{5h}) structure of this

complex. The bridging oxalate dianion provides an effective pathway for magnetic superexchange in this complex as evidenced by the value of \underline{J} ($= -60 \text{ cm}^{-1}$). In contrast, the partially-dehydrated material, $\text{Ti}_2(\text{C}_2\text{O}_4)_3(\text{H}_2\text{O})_5$, appears to be structurally characterized as a distorted octahedral complex, i.e. \underline{J} is small. The large difference in the magnitude of \underline{J} for these two complexes is a surprising result, given the presence of bridging oxalate in both materials. This difference is undoubtedly due to a major structural difference between the two compounds. It is conceivable that $\text{Ti}_2(\text{C}_2\text{O}_4)_3(\text{H}_2\text{O})_5$ is a polymeric material with a solid-state structure similar to that of $\text{Sc}_2(\text{C}_2\text{O}_4)_3 \cdot 6\text{H}_2\text{O}$ [27]. Although our data are consistent with this possibility, a single-crystal diffraction study will be required for final structure determination.

Acknowledgement: This work was supported in part by the Office of Naval Research.

References and Notes

1. P. Ehrlich, Angew. Chem., 64, 617 (1952).
2. D. J. Machin, K.S. Murray, and R. A. Walton, J. Chem. Soc., 195 (1968).
3. H. L. Schlafer, W. Lenz, and J. Staab, Z. Phys. Chem., 62, 290 (1968).
4. W. Giggenbach and C. H. Brubaker, Jr., Inorg. Chem., 7, 129 (1968).
5. G. W. A. Fowles and B. J. Russ, J. Chem. Soc. A, 517 (1967).
6. H. L. Schlafer and R. Gotz, Z. Phys. Chem. (Frankfurt), 41, 97 (1964).
7. B. N. Figgis, J. Lewis, and F. Mabbs, J. Chem. Soc., 2473 (1963).
8. R. L. Martin and G. Winter, J. Chem. Soc., 4709 (1965).
9. R. S. P. Coutts and P. C. Wailes, Aust. J. Chem., 21, 1181 (1968).
10. C. G. Barraclough and A. K. Gregson, J. Chem. Soc. Faraday Trans., 11, 177 (1972).
11. O. Kahn, Proc. XVI Int. Conf. Coord. Chem., 2.28a (1974).
12. R. Saillant and R. A. D. Wentworth, Inorg. Chem., 7, 1606 (1968).
13. J. T. Wroblewski and D. B. Brown, Inorg. Chem., 17, 2959 (1978).
14. J. T. Wroblewski and D. B. Brown, Inorg. Chem., 18, 498 (1979).
15. J. T. Wroblewski and D. B. Brown, Inorg. Chem., 18, 0000 (1979).
16. D. J. Eve and G. W. A. Fowles, J. Chem. Soc. A, 1183 (1966).
17. A. Stähler, Ber., 38, 2619 (1905).
18. M. G. B. Drew, G. W. A. Fowles, and D. F. Lewis, J. Chem. Soc. Chem. Commun., 876 (1969).
19. D. B. Brown, V. H. Crawford, J. W. Hall, and W. E. Hatfield, J. Phys. Chem., 81, 1303 (1977).
20. S. N. Deming and S. L. Morgan, Anal. Chem., 45, 278A (1973) and references therein.
21. F. E. Mabbs and D. J. Machin, "Magnetism and Transition Metal Complexes," Chapman and Hall, London (1973) p. 5.

22. L. N. Mulay "Theory and Applications of Molecular Paramagnetism,"
E. A. Boudreaux and L. N. Mulay, Ed., John Wiley and Sons, New York
(1976) p. 495.
23. A table of experimental and calculated magnetic susceptibilities and
effective magnetic moments is available, upon request, from the authors.
24. See, in particular, Table XIX of C. G. Pierpont, L. C. Francesconi, and
D. N. Hendrickson, Inorg. Chem., 16, 2367 (1977) and references therein.
25. B. N. Figgis, Trans. Faraday Soc., 57, 198 (1961).
26. A. T. Casey and S. Mitra, "Theory and Applications of Molecular Paramagnetism,"
E. A. Boudreaux and L. N. Mulay, Ed., John Wiley and Sons, New York
(1976) p. 140.
27. E. Hansson, Acta Chem. Scand., 26, 1337 (1972).

Figure Captions

Fig. 1. (a) Dimeric structure of $\text{Ti}_2(\text{C}_2\text{O}_4)_3(\text{H}_2\text{O})_6 \cdot 4\text{H}_2\text{O}$ [18]. Lattice waters are omitted. (b) Term level diagram for weak-field, ligand-field terms in D_{5h} symmetry.

Fig. 2. Molar magnetic susceptibility (○) and effective magnetic moment per Ti (●) vs. T for $\text{Ti}_2(\text{C}_2\text{O}_4)_3(\text{H}_2\text{O})_6 \cdot 4\text{H}_2\text{O}$. The solid line is a fit to the HDVV $S_1=S_2 = 1/2$ dimer model with $g = 1.95$ and $J = -60 \text{ cm}^{-1}$.

Fig. 3. Molar magnetic susceptibility (+) and effective magnetic moment per Ti (■) vs. T for $\text{Ti}_2(\text{C}_2\text{O}_4)_3(\text{H}_2\text{O})_5$. The solid line is a fit to the HDVV $S_1=S_2 = 1/2$ dimer model with $g = 1.78$, $J = -7.2 \text{ cm}^{-1}$, and $N\alpha = 238 \times 10^{-6} \text{ cgsu}$. The dashed line represents a fit to the low-symmetry model of ref. 25 $\Delta = 300 \text{ cm}^{-1}$ and $k = 0.7$.

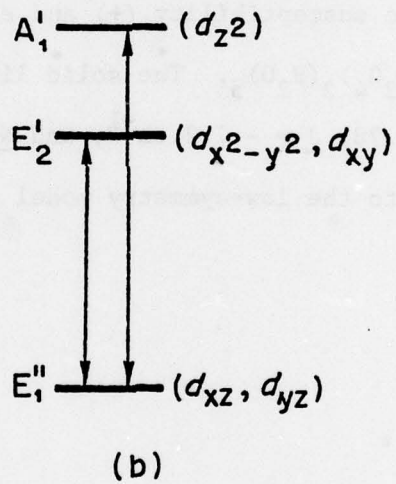
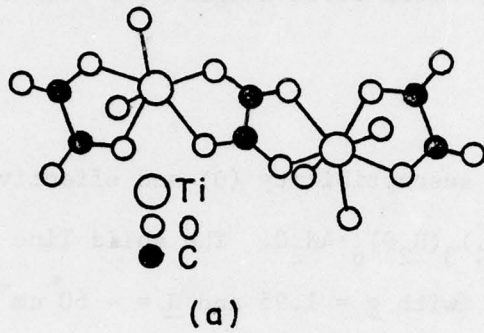


Fig 1. *ball-and-stick model + energy level diagram*

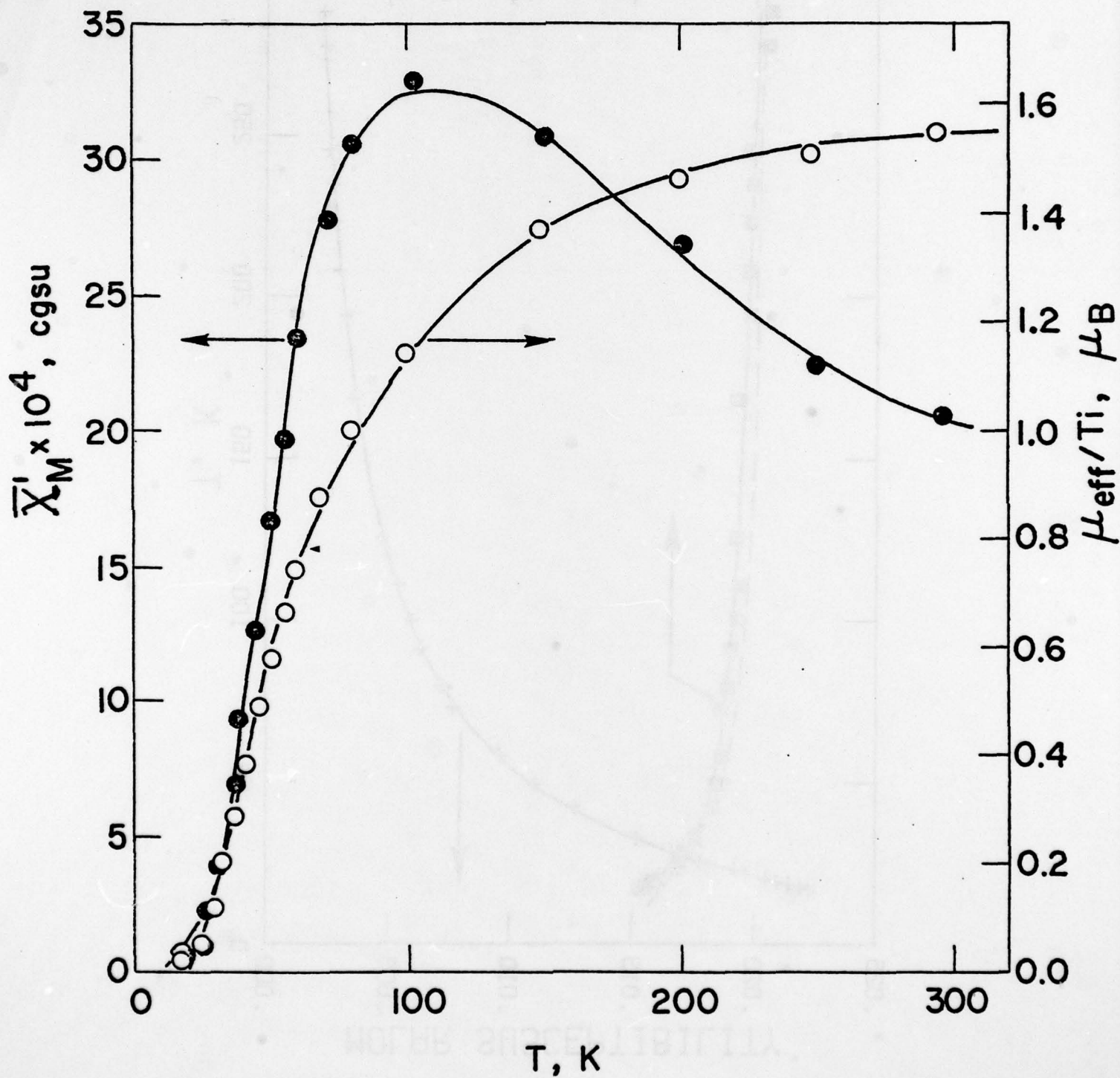
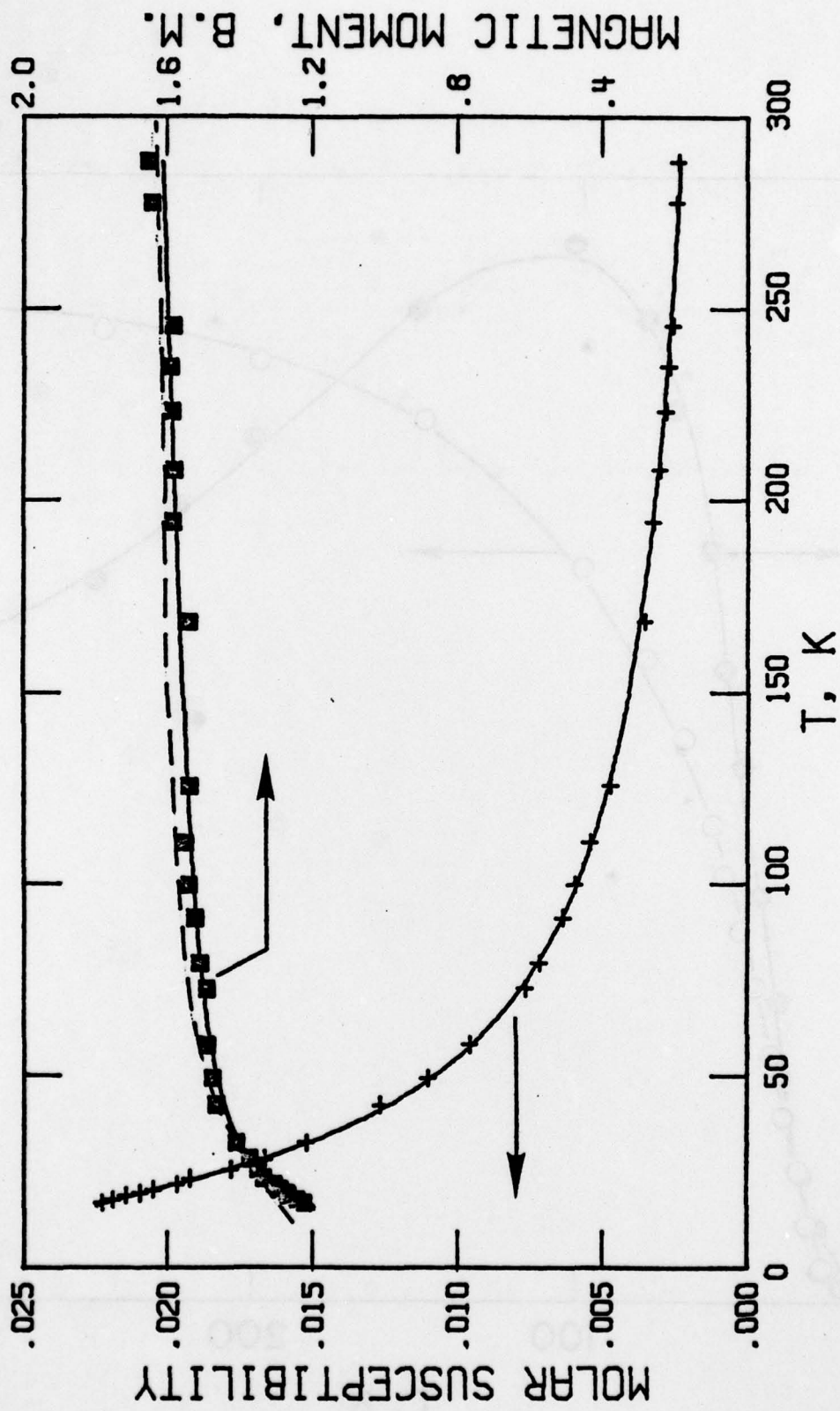


Fig. 7. $\mu_{\text{eff}}/\text{Ti}$ vs. T.



TECHNICAL REPORT DISTRIBUTION LIST, GEN

	<u>No.</u> <u>Copies</u>		<u>No.</u> <u>Copies</u>
Office of Naval Research 800 North Quincy Street Arlington, Virginia 22217 Attn: Code 472	2	Defense Documentation Center Building 5, Cameron Station Alexandria, Virginia 22314	12
ONR Branch Office 536 S. Clark Street Chicago, Illinois 60605 Attn: Dr. George Sandoz	1	U. S. Army Research Office P. O. Box 1211 Research Triangle Park, N.C. 27709 Attn: CRD-AA-IP	1
ONR Branch Office 715 Broadway New York, New York 10003 Attn: Scientific Dept.	1	Naval Ocean Systems Center San Diego, California 92152 Attn: Mr. Joe McCartney	1
ONR Branch Office 1030 East Green Street Pasadena, California 91106 Attn: Dr. R. J. Marcus	1	Naval Weapons Center China Lake, California 93555 Attn: Dr. A. B. Amster Chemistry Division	1
ONR Area Office One Hallidie Plaza, Suite 601 San Francisco, California 94102 Attn: Dr. P. A. Miller	1	Naval Civil Engineering Laboratory Port Hueneme, California 93401 Attn: Dr. R. W. Drisko	1
ONR Branch Office Building 114, Section D 666 Summer Street Boston, Massachusetts 02210 Attn: Dr. L. H. Peebles	1	Professor K. E. Woehler Department of Physics & Chemistry Naval Postgraduate School Monterey, California 93940	1
Director, Naval Research Laboratory Washington, D. C. 20390 Attn: Code 6100	1	Dr. A. L. Slafkosky Scientific Advisor Commandant of the Marine Corps (Code RD-1) Washington, D. C. 20380	1
The Assistant Secretary of the Navy (R,E&S) Department of the Navy Room 4E736, Pentagon Washington, D. C. 20350	1	Office of Naval Research 800 N. Quincy Street Arlington, Virginia 22217 Attn: Dr. Richard S. Miller	1
Commander, Naval Air Systems Command Department of the Navy Washington, D. C. 20360 Attn: Code 310C (H. Rosenwasser)	1	Naval Ship Research and Development Center Annapolis, Maryland 21401 Attn: Dr. G. Bosmajian Applied Chemistry Division	1
		Naval Ocean Systems Center San Diego, California 91232 Attn: Dr. S. Yamamoto, Marine Sciences Division	1

TECHNICAL REPORT DISTRIBUTION LIST, 053

	<u>No.</u> <u>Copies</u>		<u>No.</u> <u>Copies</u>
Dr. R. N. Grimes University of Virginia Department of Chemistry Charlottesville, Virginia 22901	1	Dr. M. H. Chisholm Department of Chemistry Indiana University Bloomington, Indiana 47401	1
Dr. M. Tsutsui Texas A&M University Department of Chemistry College Station, Texas 77843	1	Dr. B. Foxman Brandeis University Department of Chemistry Waltham, Massachusetts 02154	1
Dr. M. F. Hawthorne University of California Department of Chemistry Los Angeles, California 90024	1	Dr. T. Marks Northwestern University Department of Chemistry Evanston, Illinois 60201	1
Dr. W. B. Fox Naval Research Laboratory Chemistry Division Code 6130 Washington, D. C. 20375	1	Dr. G. Geoffrey Pennsylvania State University Department of Chemistry University Park, Pennsylvania 16802	1
Dr. J. Adcock University of Tennessee Department of Chemistry Knoxville, Tennessee 37916	1	Dr. J. Zuckerman University of Oklahoma Department of Chemistry Norman, Oklahoma 73019	1
Dr. A. Cowley University of Texas Department of Chemistry Austin, Texas 78712	1	Professor O. T. Beachley Department of Chemistry State University of New York Buffalo, New York 14214	1
Dr. W. Hatfield University of North Carolina Department of Chemistry Chapel Hill, North Carolina 27514	1	Professor P. S. Skell Department of Chemistry The Pennsylvania State University University Park, Pennsylvania 16802	1
Dr. D. Seyferth Massachusetts Institute of Technology Department of Chemistry Cambridge, Massachusetts 02139	1	Professor K. M. Nicholas Department of Chemistry Boston College Chestnut Hill, Massachusetts 02167	1