Ferromagnetism in the Manganese-Indium System

WALTER V. GOEDDEL* AND DON M. YOST
Gates and Crellin Laboratories of Chemistry, California Institute of Technology, Pasadena, California
(Received March 26, 1951)

WE recently undertook an investigation of the phase equilibria in the previously unreported manganese-indium system. About twenty-five alloys, varying in manganese content from 3 to 91 weight percent in steps of about 4 weight percent, have been prepared, and over half of these specimens have been found to be ferromagnetic.

The alloys were prepared by melting 40-gram to 70-gram mixtures of the metals under argon in an induction furnace, using a Westinghouse 10-kw rf generator as a source of power. "Triangle RR recrystallized alumina" crucibles (Morgan, England) and alumina-silica thermocouple protective tubes, sealed off at one end with packed magnesia, were used. Indium of 99.97 percent purity was obtained from the Indium Corporation of America and electrolytic manganese of purity greater than 99.9 percent was obtained from the U. S. Bureau of Mines. Chemical analysis showed both materials to be at least 99.9 percent pure. A chromel-alumel thermocouple, calibrated at the freezing points of tin, zinc, silver, copper, and copper-silver eutectic alloy, was used in conjunction with a Brown recording potentiometer to obtain the cooling curves of the alloys. All specimens were chemically analyzed to make sure that they were homogeneous and to determine their exact composition.

The existence of ferromagnetism in this system was suggested by Hames and Eppelsheimer, but no data were given.[1] While we have made only qualitative magnetic measurements with a small Alnico magnet, the intensity of magnetization appears to increase regularly from 3 to about 50 weight percent manganese, and then to die out completely. An alloy containing 53.2 percent manganese is strongly ferromagnetic, while one containing 59.4 percent manganese is unaffected by the magnet, as are the subsequent alloys of increasing manganese content. The same range of ferromagnetism holds for alloys annealed and quenched from temperatures between 850 and 950°C. On the basis of these, plus incomplete thermal and metallographic data, we believe the ferromagnetism is due to a single phase, the compound Mn_2In. The alloys containing up to 49 percent manganese appear to be composed of indium plus Mn_2In, no eutectic mixture being formed (the solidus is at the freezing point of indium, 157.5°C).

In a private communication, Dr. R. M. Bozorth has pointed out to us that there are now definitely known about sixteen binary systems, containing no ferromagnetic elements, which show ferromagnetism. Of these binary systems, both components are metals in eight cases. The manganese-indium system described here provides a new additional case.

Thermal and metallographic measurements are being continued, as a thorough knowledge of the phase relations is needed before proceeding to further measurements of magnetic and other properties.

The authors gratefully acknowledge a grant from the Research Corporation which aided this investigation.

* Present address: Atomic Energy Research Department, North American Aviation, Inc., Downey, California.
[1] F. A. Hames and D. S. Eppelsheimer, Nature 162, 968 (1948). See also R. R. Grinstead and D. M. Yost, Phys. Rev. 75, 984 (1949) on ferromagnetism in the Mn-Cu-In system.

Erratum: The $Li^6(n,\alpha)H^3$ Reaction Spectrum

[Phys. Rev. 81, 475 (1951)]

UGO FACCHINI, EMILIO GATTI, AND ELIO GERMAGNOLI
Laboratori C.I.S.E., Piazzale Cimitero Monumentale, Milan, Italy

THE sentence on lines 10 and 11 of the right-hand side of page 476 in the above article should read, "Deviations from ideal behavior of the whole apparatus are in any case less than 0.3 percent."

Least-Squares Adjusted Values of the Atomic Constants as of December, 1950

JESSE W. M. DUMOND
California Institute of Technology, Pasadena, California
AND
E. RICHARD COHEN
North American Aviation Inc., Downey, California
(Received March 8, 1951)

AS part of the work of the National Research Council Committee on Constants and Conversion Factors of Physics and at the request of its chairman, E. U. Condon, we have prepared a report,[1] dated December, 1950, giving a complete re-evaluation of the atomic constants in the light of the wealth of important new and very accurate data obtained since our previous study of January, 1948. As input data we have used the most recent results of Kusch and Prodell[2] on the hydrogen hyperfine shift; of Hipple and his N.B.S. associates[3] and also of Bloch and Jefferies of Stanford[4] on the proton cyclotron frequency; of Gardner and Purcell[5] on the electron cyclotron frequency; of Craig and Hoffman[6] (N.B.S.) on the faraday by electrolysis of sodium oxalate; of Bearden and associates[7] on h/e (which latter have recently also been verified at 25 kv at this Institute by the work[8] of Gaelen Felt and John Harris); of Birge[9] on λ_g/λ_s and on N obtained in 1945 from a study of all experimental evidence; of the four independent sources, Hansen and Bol,[10] Bergstrand,[11] Aslakson,[12] and Essen,[13] on the velocity of light; and of Cohen[14] on a re-evaluation of R_∞ in the light of the Lamb shift.

As a result of making a number of trial adjustments, we soon discovered that the new data are likely to lead to observational equations whose observed numerics are not independent but are observationally correlated. If such correlations are ignored, a serious error of method is committed and wrong results[15] are obtained, because the error (or the weight) to attach to each equation cannot then be described by a single number. Instead an error matrix must be used to describe the error situation with all the intercorrelations between equations. The classical procedure for forming the normal equations of least squares no longer applies, but one of us has shown[16] how a generalization in matrix algebra can be used.

A simpler method may be, as we have shown in our report, to recast the equations so as to diagonalize the error and weight matrices,[17] thus removing the correlations between equations. To do this completely, it may be (and in this case was) necessary to transfer some of the observational data from the category of fixed auxiliary constants to that of the unknowns to be adjusted. For this and other more involved reasons discussed in the above report we finally concluded that a solution in the following six unknowns was required: N, e, m, h, c, and λ_g/λ_s. The present data permit of setting up, with a diagonalized error matrix, nine observational equations in these six unknowns (including equations for the direct observations on c and λ_g/λ_s) so that the overdetermination is sufficient to yield an index of the presence or absence of systematic errors in the data from a study of the residues. The consistency of the data, so adjusted, is excellent. The somewhat abridged Table I gives the resulting adjusted values of the six primary unknowns and of other useful quantities which can be computed from them, the probable errors being all computed by the ellipsoid method. The adjusted value of λ_g/λ_s turns out to be a little lower than our input value, while that for c is a little higher.

These values must still be regarded as tentative, partly because not all of the input data are as yet quite finally settled, and also because the theoretical formula,[18] connecting the hydrogen fine structure shift with Sommerfeld's α, is not yet known, as regards certain correction terms,[18,19] with the accuracy which the observational data warrant. The Bethe-Longmire correction terms give only "orders of magnitude" and *may*, according to H. Bethe, have to be modified by many parts in 10^6. (See Γ-coefficients in Table I). We are also suspicious regarding the magnitude of the higher order corrections[19] giving the electron moment in Bohr magnetons for hydrogen. This ratio is probably Z-dependent, and we are informed