attribute the temperature behavior of the line-width to this transition.

The resonance line with a g factor of 1.985 cannot be explained from the behavior of Eu^{+++}, which is in the $4f^6$ configuration with the ground state $^7F_0$. The first excited state, $^7F_1$, which in the free ion is 480°K above the ground state, would give a resonance with a Landé g factor of $g = 9/8$. The paramagnetic resonance experiment confirms, therefore, the metallurgical[6] and magnetic[2] evidence for the divalent state of metallic europium. Below the antiferromagnetic anomaly (which is also borne out by electrical conductivity measurements on europium wire reported by Olsen[7]) the magnetic behavior is at present not well understood. Unlike the case of an antiferromagnet, the magnetization continues to increase. But we found no further magnetic resonance even at helium temperature. With the present apparatus, we could, however, not have seen a resonance with a g value smaller than 1.3. It is, therefore, not impossible that the resonance could have appeared at lower frequencies. If, on the other hand, this anomalous magnetic behavior were of similar origin to the one reported for cerium[8] (promotion of $4f$ electron into the $5d$ band), then observation of a resonance would be difficult because of the fast relaxation of the d electrons.

The intermetallic compound $EuIr_2$ crystallizes in the cubic Laves phase ($C15$) and from its lattice constant Zachariasen[9] concluded that Eu is here indeed in its trivalent state. Though it may become ferromagnetic, its saturation moment is almost vanishing.[10] In agreement with this evidence we have seen no paramagnetic resonance in this compound. $GdIr_2$, on the other hand, which is isomorphous with $EuIr_2$ and of course also trivalent, shows an absorption due to Gd which is 1500 gauss wide. This resonance increases in strength with decreasing temperature and has been followed to below the Curie point, where the resonance broadens to a point where observation is no longer feasible.

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DESTRUCTION OF DIATOMIC BONDS BY PRESSURE*

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The pressure necessary to destroy the directional character of chemical bonds has been discussed theoretically in connection with hydrogen.[1,2] This phenomenon has now been experimentally observed in iodine as a first-order phase transition, since the delocalization of the electrons causes the diatomic molecular crystal to be converted into a monatomic metal. The results for iodine can be used to evaluate the predictions made for hydrogen.

The experiments were carried out by standard single-shock experiments[3] on polycrystalline iodine at an initial density within 1% of the single-crystal density. The measured shock velocity, u_s, versus particle velocity, u_p, is shown in Fig. 1. The experiments again conform within the accuracy of the data to the empirical linear relation between these two quantities. Moreover, the line extrapolates properly to the experimental sound speed (1.35 mm/μsec) at zero particle velocity. The square points are from slightly less accurate experiments. The
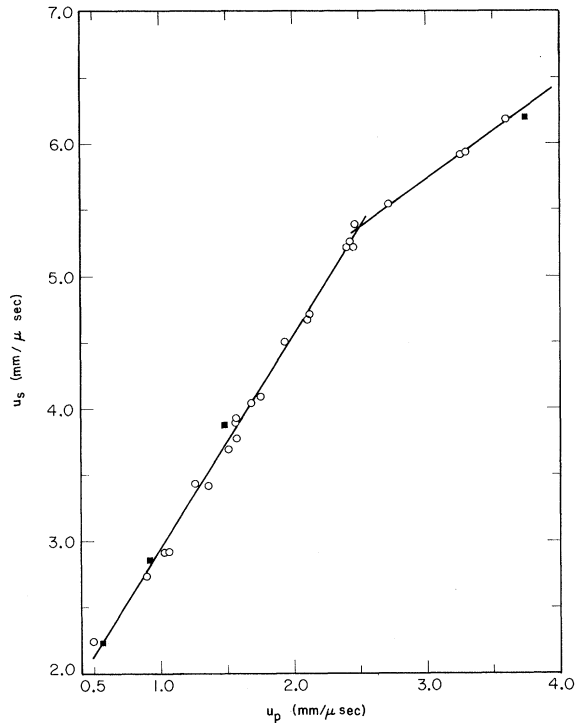
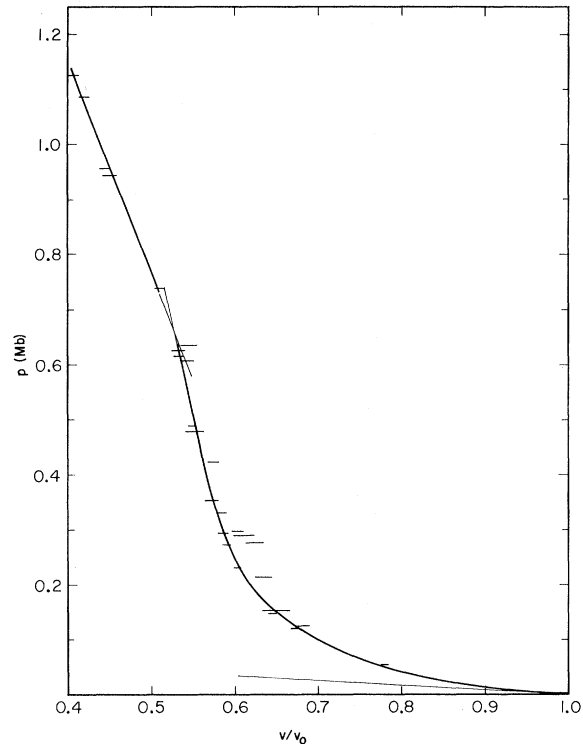FIG. 1. The shock velocity, u_s, versus the particle velocity, u_p, in iodine.

FIG. 2. The Hugoniot equation of state of iodine.

intersection between the two linear segments is used to locate the transition. From u_s and u_p the Hugoniot equation of state is calculated, with the result as shown in Fig. 2. The pressure, p, is in megabars and v/v_0 is the volume relative to the volume at 1 atmosphere, v_0. The length of the horizontal lines indicates the probable error of each experiment. In calculating the probable error no account has been taken of variation in initial density. The early experiments near 0.3 megabar had a low initial density and hence were not heavily weighted in drawing the curve. The lightly drawn parts of the curve are extrapolations near the transition which occurs approximately at a pressure of 0.7 megabar and at a relative volume of 0.53.

Upon converting the Hugoniot curve to an isothermal equation of state using the assumptions of a constant heat capacity, $c_v = 6Nk$, and a Grüneisen constant, $\gamma = 2.07$, in connection with the theory of reference 3, it is found that at the transition point the temperature is almost 1 ev and that the room temperature transition pressure would be approximately 0.3 megabar at $v/v_0 = 0.53$. This does not mean that upon hydrostatic compression iodine would necessarily have

the phase transition at that pressure, since the temperature dependence and the rate of transition of the phase change have to be considered.

The temperature of about 1 ev is comparable to the dissociation energy of the iodine molecule (1.53 ev) and hence could have a considerable effect in reducing the pressure of the phase change. By further work using double-shock techniques, the temperature at a given pressure can be considerably lowered and the temperature dependence of the phase transition can be established. As for the rate of transformation, these dynamic experiments require that the phase change take place in less then 1 μsec, namely within the time the iodine is subjected to the pressure. Thus, in order to see any transformation at all the system may have to be overdriven to the pressure and temperature conditions where it will occur that fast. Previous experience[4] has indicated that these simpler phase changes in solids can take place that rapidly without overdriving. Static isothermal experiments, on the other hand, may also have to be overdriven in order for the rate of transformation to be observable in a finite time.

To make sure that the observed phase change

is the one postulated, some physical property of the new phase would have to be measured. The obvious one under shock conditions might be the conductivity; however, the conductivity might be metallic before the existence of a monatomic lattice if the conduction band overlaps the valence band in the diatomic system. This change might be difficult to detect in the Hugoniot equation of state. Although conductivity measurements have been made at low pressures to show the narrowing down of the energy gap, the present experimental techniques in any case do not allow the determination of very low resistances existing for such short times.

However, an empirical rule for the lengthening of diatomic bonds to metallic bonds can be used to calculate at what volume iodine should have its transition and thus confirm the suggestion made. The empirical evidence can be obtained from the alkali metals which have a diatomic species in the vapor phase and condense into a body-centered cubic metal lattice. From the known interatomic distances[5] it is found that the Li spacing expands by 13.7%, Na by 20.7%, and K and Cs both expand by 15.8%. From the known diatomic distance in iodine and the assumed expansion of 15.8% in interatomic spacing for the heavy elements and also assuming a body-centered structure for the metallic iodine phase, the phase transition for iodine would be predicted to occur at $v/v_0 = 0.53$. This is in agreement with the experimental value. Other ele-

ments for which this expansion in spacing is known all fall into the 10 to 20% region.

Earlier theoretical calculations on metallic hydrogen[2] have predicted this expansion of the bond to be about 80%. From quantum mechanical calculations on the metal-like triatomic hydrogen system[6] it can be made plausible that here also the expansion should be near 20%. A 20% expansion over the diatomic distance would mean that, for the monatomic phase of hydrogen to exist, the normal solid phase would have to be compressed by a factor of 30 instead of 10 as previously predicted. The pressure of this transition is then calculated by the Wigner method[1] to be near 20 megabars instead of the 1 megabar estimated earlier.

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NEUTRON SMALL-ANGLE SCATTERING BY SPIN WAVES IN IRON

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Neutron small-angle scattering by spin waves in iron has been observed in virtual isolation at an intensity of several thousand counts per minute, the various other effects that normally complicate such a measurement having been rendered negligible. The theoretical dependence of the scattered intensity on neutron wavelength and scattering angle and on specimen temperature, setting, and magnetization has been confirmed. If iron be regarded as a Heisenberg-Bloch ferromagnet, the cutoff angle of the scattering gives a value of 0.018 ev for the effective exchange integral, in agreement with the value obtained by fitting a $T^{3/2}$ law to the saturation

magnetization at low temperatures.

Although it is well known that neutron scattering techniques provide a sensitive means for the detection of spin waves, experiments have been performed on three substances only — magnetite,[1] hematite,[2] and iron.[3] A source of complication is that the spin-wave scattering associated with any planes of nonzero hkl in a magnetic crystal is accompanied by phonon scattering whose response to changes in magnetization and temperature must be allowed for. In the present experiment we have avoided this difficulty by studying the scattering at positions close to the main beam, where 1-magnon inelastic scattering is