cuiting effect of He^3 spin relaxation at the container walls. For these experiments T_1 was about 10^3 sec. We estimate that with the much slower wall relaxation to be expected from impermeable container materials, a polarization of the order of 10% might now be possible by this method. Of course such an estimate ignores the (so far unknown) effect of rubidium on the surface relaxation behavior. We are currently investigating this question and plan to repeat the experiment of Bouchiat, Carver, and Varnum.

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TEMPERATURE DEPENDENCE OF POSITRON MEAN LIVES IN METALS

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The dependence of positron lifetimes on sample temperature has been studied in several metals over a range from room temperature to the melting point or to 400°C. Marked effects, amounting to as much as a 30% increase in lifetime, are noted in most of the low-melting-point metals. Lattice vacancies are considered to be the likely cause of these effects.

The lifetime of positrons in certain metals exhibits a marked dependence on sample temperature in the range from room temperature to 400°C. This result is closely related to the previously reported temperature dependence of the angular correlation of annihilation radiation.[1] We attribute the effect to lattice defects induced by temperature, and hence, it is also related to the recently observed dependence of both lifetime[2] and angular correlation[3] on plastic deformation.

The measurements reported here were obtained on a fast-slow coincidence system employing an overlap time-to-amplitude converter, pulse-height compensation, and pile-up rejection. With energy selection appropriate for lifetime studies, the system yielded a resolution of 410 psec on a ^{60}Co source, the approximately exponential slopes corresponding to mean lifetimes of 90 and 103 psec.

All samples studied were of at least 4 nines purity and were annealed and etched before insertion in the Pyrex sample chamber which operated with a helium atmosphere. The chamber was heated externally and a cooling system ensured that the scintillators and photomultipliers were not allowed to introduce false temperature-dependent effects. The simplest proof of the effectiveness of these precautions is in the markedly different results observed with the various metals but we also measured the temperature in the detector enclosures and held the variation below 10°C.

We observed two components in the decay of each metal. This is invariably the case when using a sandwich arrangement with a separate source between two samples, but it has been clearly demonstrated that the low-intensity tail is due to surface effects.[4] Although the tail is not of primary interest, we must make a reasonably accurate measurement of its slope and intensity in order to evaluate the main slope.

Our procedure is to carry out a long measurement at room temperature and at the upper temperature limit for each metal. We find that the slope and intensity of the tail agree within the experimental error in each case as indicated in Table I. The average value of these quantities is computed and the data at intermediate temperatures are constrained to fit these values for the tail. Runs at the temperature extremes were of about 7 h duration, while most of the intermediate points were obtained in about 1 h.

Results are presented in Fig. 1 for all of the metals investigated to date. The upper temperature reached is determined either by the melting point of the sample or by limitations of the sample chamber. The smooth curves are merely visual fits and are influenced by the results obtained for the same metals in the angular correlation studies.[1]

We wish to emphasize several features of the results:

(1) Copper shows a weak temperature dependence several times stronger than we might expect from the lowering of valence-electron density associated with thermal expansion of the lattice. The other metals may also include a similar component, but it is masked by the larger effect.

(2) The mean life increases smoothly with temperature in a way that is qualitatively similar in all metals other than copper. (We assume that the aluminum curve must flatten at higher temperatures.)

(3) Although it is not evident from Fig. 1, we have found no measurable hysteresis on the time scale required for these measurements. The lifetime appears to be a single-valued function of sample temperature in these metals.

(4) The extent of the lifetime increase is similar in the metals other than copper, but the temperature at which the increase begins is a characteristic of the metal.

(5) Plots of the annihilation rate versus temperature for Cd, In, and Zn have much the same shape as the plots of tail intensity versus temperature in the angular correlation.[1] The tail is usually considered to arise from annihilation with core electrons in these metals.

We have sought an explanation of these anomalous effects in a great variety of chemical and physical properties of the various metals. The only link we have found lies in the equilibrium density of point defects; we rule out dislocations as a prime cause mainly because of the lack of hysteresis in the measurements.

Table I. Analysis of time spectra at temperature extremes.

Metal	Temp. (°C)	τ_1 (psec)	τ_2 (nsec)	Tail intensity (%)
Al	21	175±4	1.10±0.15	1.8±0.6
Al	368	228±6	1.31±0.24	1.8
Cd	29	196±3	1.02±0.12	2.1
Cd	296	232±6	0.92±0.12	2.9
Cu	21	147±3	0.75±0.06	4.2
In	21	203±5	0.95±0.13	2.2
In	122	250±5	0.85±0.23	2.8
Zn	21	179±5	0.97±0.15	2.0
Zn	375	240±9	0.95±0.27	1.8

The particular defect of interest is presumably the vacancy site since interstitials are not only much fewer but would probably have the wrong effect. Vacancy density should increase continuously up to the melting point in accord with the Boltzmann factor. We do not understand why they should become less effective as they become more numerous (as indicated by the tendency of the lifetime to be tem-

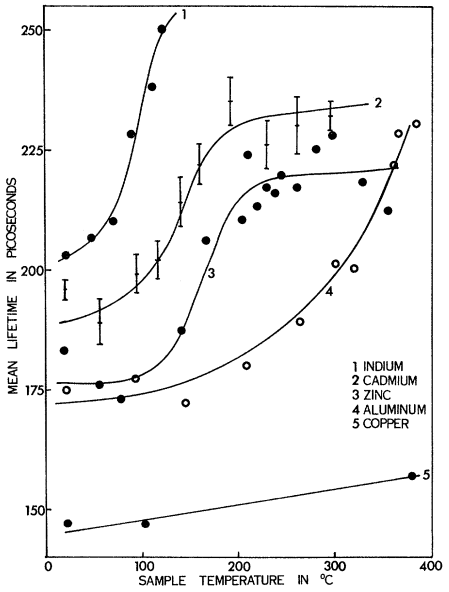

FIG. 1. Positron mean lifetimes in several metals as a function of temperature. Error bars, based on statistical consideration alone, are similar for all samples but are presented only for cadmium. The shapes of the smooth curves are influenced by related data on angular correlation.

perature independent at higher temperatures), but the effect of the vacancies at low concentrations seems to be qualitatively predictable. We consider an individual vacancy as a region considerably smaller than the ion it replaces since the lattice is known to relax inward on a vacancy. The region, being deficient one positive ion, can be treated as a unit negative charge which will attract positrons. However, because the potential well is not deep, it is unlikely that it can restrain a positron within the small volume available and form a bound state. Instead, it merely increases the probability that the positron will annihilate with electrons in vacancy sites and thereby decreases the chance of annihilation with the competing core electrons and normal valence electrons. Since electron density in vacancy sites should be lower than elsewhere in the lattice, we can expect a general lowering of the annihilation rate as the vacancy density increases.

Quantitative correlation of our results with the activation energy of vacancies in the various metals[5] will certainly require a sophisticated model, but a compelling qualitative correlation is evident. It is a little surprising that we observe an effect in aluminum which has a vacancy activation energy of 0.76 eV, and this may imply that the positron itself collaborates in vacancy formation.

The data indicate that the positron may be a useful tool for studying metallic defects. In addition there is a clear warning that if lifetime measurements are to be used as a check on theory, they should be carried out on annealed samples at temperatures such that vacancy density is negligible.

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MAGNETO-OPTICAL PROPERTIES OF TRANSPARENT $RbFeF_3$

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In this Letter we wish to report on some unusual magneto-optic effects in perovskite crystals of $RbFeF_3$. We believe that this is the first example of a ferromagnetic[1] crystal which (1) is transparent in the bulk to visible light, (2) has a very low saturation magnetization (≈ 250 G), (3) has a large magnetic rotation in the uv, visible, and near infrared at a temperature below 85°K, and (4) has good optical quality. To the best of our knowledge, no one of the previously reported[2-5] ferromagnets that are transparent in the visible has all four of these properties. Therefore, this material looks very interesting from the point of view of studies such as visual observations of domain structures[6] and some possible applications of these magneto-optic effects.[7-9] The work described in this Letter includes measurements on magnetic rotation, Cotton-Mouton effect, and optical absorption of $RbFeF_3$ at 82°K.

It has been established only recently[1,10] that $RbFeF_3$ remains paramagnetic from room temperature down to 102°K, becomes antiferromagnetic between 102 and 87°K, and then undergoes a transition to a state having a magnetization in zero field below 87°K. Testardi, Levinstein, and Guggenheim[11] have shown that the transition at 102°K is accompanied by a distortion to tetragonal symmetry. A distortion to an orthorhombic symmetry occurs at 86°K, and a further decrease in symmetry to a monoclinic-structure class occurs at 45°K.

All of our measurements were made on x-ray oriented single crystals of $RbFeF_3$ that were grown by a method described elsewhere.[1]