structure of the intermediate state in Faber's method is less reliable than the use of the inclined field method, in which one is able to observe the simplest layer structure. Faber also presents data obtained at one temperature using the inclined field method (see reference 10, Fig. 10), which, however, he does not use in the final results. Approximate treatment of this data using our formulae leads to the value $C_\Delta \times 10^5 = 12-14$, which is given in the table in brackets. The relationship between Δ and the value of the supercooling is then close to the case of Sn and In.

It is difficult at present to propose definite reasons for this small but systematic discrepancy. However, it would be stretching matters to ascribe it to accidental experimental errors.

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*During the calculation we attempted to estimate the effect of the specimen edges, i.e., the difference between the specimen and an infinite plate. The values of Δ, calculated using the formula for an ellipsoid inscribed in the specimen, are approximately 10% smaller than those obtained using the formula for an infinite plate (see reference 1). The true values will apparantly lie somewhere inside this range. Because accurate calculation is difficult for a disc, we used for calculation the formula for a flat ellipsoid of rotation having the same volume as our specimen (with axes 2.06 and 61.2 mm). The difference from the infinite case amounted in this instance to 8%. Introducing this correction into the results of reference 1, we obtained for tin

$$\Delta_{\rm Sn} = 2.3 \cdot 10^{-5} (1 - T/T_c)^{-1/2} \text{ cm for } 2.16° < T < 3.5°.$$

[1] Yu. V. Sharvin, JETP **33**, 1341 (1957), Soviet Phys. JETP **6**, 1031 (1958).

[2] V. L. Ginzburg and L. D. Landau, JETP **20**, 1064 (1950).

[3] V. L. Ginzburg, JETP **30**, 593 (1956), Soviet Phys. JETP **3**, 621 (1956).

[4] L. P. Gor'kov, JETP **36**, 1918 (1959), Soviet Phys. JETP **9**, 1364 (1959).

[5] V. L. Ginzburg, JETP **31**, 541 (1956), Soviet Phys. JETP **4**, 593 (1957).

[6] Yu. V. Sharvin, JETP **22**, 367 (1952).

[7] P. N. Dheer, Superconductivity, Conf. Roy. Soc. Mond Laboratory, Cambridge, (1959).

[8] T. E. Faber and A. B. Pippard, Proc. Roy. Soc. **A231**, 336 (1955).

[9] T. E. Faber, Proc. Roy. Soc. **A241**, 531 (1957).

[10] T. E. Faber, Proc. Roy. Soc. **A248**, 460 (1958).

[11] V. L. Ginzburg, JETP **36**, 1930 (1959), Soviet Phys. JETP **9**, 1372 (1959).

[12] E. Laurmann and D. Shoenberg, Proc. Roy. Soc. **A198**, 560 (1949).

[13] A. L. Schawlow and G. E. Devlin, Phys. Rev. **113**, 120 (1959).

Translated by K. F. Hulme
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SEVERAL POSSIBLE APPLICATIONS FOR THE RESONANT SCATTERING OF GAMMA RAYS

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BECAUSE of recoil during the emission of a gamma quantum by a free nucleus, the energy of the quantum is always less than the difference between the energy levels of the radiating nucleus. An analogous shift occurs in the absorption of a gamma quantum. This circumstance greatly hinders the observation of resonant scattering of gamma rays, which must occur with a large probability if this shift is absent or compensated.

Recently, however, Mössbauer[1,2] and others[3] have shown that at low temperatures the entire crystal takes up the recoil momentum in an observable fraction of the emissions and absorptions of low-energy gamma quanta. Under the indicated conditions the displacement of the gamma lines (as also the Doppler broadening) practically disappears, which makes possible the direct observation of resonant absorption. This was particularly clearly demonstrated by Mössbauer[2] and by Craig et al.,[3] who observed the dependence of the resonant-absorption cross section on the rate of change of the distance between source and absorber (Doppler effect). The experiments were performed with the 129-kev gamma rays of Ir-191. The lifetime of the excited state was shown to be equal to about 10^{-10} sec, which corresponds to a width $\Gamma = 10^{-5}$ ev and to a fractional width of about 10^{-10}. The influence of the Doppler effect manifests itself already at velocities of the order of 1 cm/sec.

In the work of Mössbauer[2] the described method is proposed for measuring the widths of gamma lines, and also for studying gamma-ray cascades since the resonant absorption can be observed only for transitions to the ground state of the nucleus. To us it appears possible to use resonant absorption also for investigating a diverse family of shifts and splittings of nuclear levels.* As an example we point out the transverse Doppler effect, the nuclear Zeeman effect,† and the shift in a gravitational field predicted by the general theory of relativity. The investigation of the first two effects is possible in the observation of shifts of the order of 10^{-7} to 10^{-8} ev. As for the shifts in a gravitational field, for a difference of about 10 m in the elevations of source and absorber, the relativistic shift will be about 10^{-15}, which for a quantum energy of 100 kev corresponds to an absolute shift of about 10^{-10} ev.

For observing such small shifts, it is necessary to work under conditions where the natural width of the gamma line is less than the shift being studied or is close to it and where the line is not broadened by incidental effects.‡ Preliminary estimates show, that the latter condition is attainable for a line with a width $\Gamma \sim 10^{-7}$ to 10^{-8} ev, and, perhaps, is attainable for $\Gamma \sim 10^{-10}$ ev, which corresponds to a lifetime of $\sim 10^{-5}$ sec.

Among the known isomeric states of stable nuclei there is one with a fractional width $\Gamma/E \sim 10^{-15}$ — the 92-kev level of Zn^{67} ($\tau = 9.3 \times 10^{-6}$ sec), excited as the result of K capture[4] by 78-hour Ga^{67}. In principle, the 92-kev gamma transition in Zn^{67} can be used for the observation of the above mentioned gravitational effect.**

At the present time, an experimental investigation of the possibilities indicated above by use of the resonant scattering of gamma rays appears to be expedient.

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*As has become known to us, analogous considerations were expressed by W. E. Lamb at the Conference on Quantum Electronics, held 14-16 October, 1959 in the USA, and by Alikhanov.

†We wish to point out, that the use of the nuclear Zeeman effect may afford the possibility of investigating the gamma transitions of polarized nuclei and the interactions with polarized gamma quanta.

‡Examples of such incidental effects are the Doppler broadening due to vibration of the source or absorber, and washed out or split lines due to magnetic or electric fields.

**In experiments it may be convenient to produce a shift of known magnitude with the aid of the Doppler effect (relatively large shifts) or of the nuclear Zeeman effect (small shifts).

[1] R. L. Mössbauer, Z. Physik **151**, 124 (1958).

[2] R. L. Mössbauer, Z. Naturforsch **14a**, 211 (1959).

[3] Craig, Dash, McGuire, and Nagle, Bull. Am. Phys. Soc. **4**, 373 (1959).

[4] B. S. Dzhelepov and L. K. Peker, Схемы распада радиоактивных ядер (Decay Schemes of Radioactive Nuclei) (1958).

Translated by J. Heberle
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POSSIBLE MAGNETIC EFFECTS FROM HIGH-ALTITUDE EXPLOSIONS OF ATOMIC BOMBS

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LET us consider an atomic explosion at such an altitude that the explosion products expand practically into a vacuum (e.g., an "Argus" explosion at an altitude of 500 km). In the explosion the bomb materials are heated to many ev and thus form a dense plasma, which then expands from the explosion center at the rate of several hundreds of kilometers per second. Thus, the plasma volume will be increased and the ion concentration correspondingly reduced. The expansion of the plasma through the magnetic field will cease as soon as the kinetic pressure of the plasma (or its "head"), which will be falling off as the expansion progresses because of the decrease in ion concentration, equals the magnetic pressure. Because of the diamagnetism of the plasma, the earth's magnetic field will be decreased in the volume occupied by the plasma and if the ion concentration is sufficient, it will be eliminated altogether. For the present purpose, this weakening or elimination of the field inside the plasma can be represented as the result of the establishment within the plasma volume of an effective magnetic dipole whose field within the plasma is opposite to the magnetic field of the earth. Once this effective dipole has appeared, it will create a noticeable magnetic field at great distances from the explosion center, and this field will be registered as the appearance of a magnetic disturbance ("storm") whose leading edge will have a rise time corresponding to the period of plasma expansion. As the plasma expands in the magnetic field, magnetohydrodynamic fluctuations may also be excited.