combination, ν_6 should be at about 1260 cm^{-1}, where absorption has been reported by Rollefson.[3]

The absorption is so weak that, with few exceptions, only the lines originating in antisymmetric states are observed. The inability to observe many of the lines involving the levels of low j values has made it impossible to construct the term values. Consequently it has been necessary to obtain the moments of inertia by successive approximations, employing easily identified transitions between levels of higher j values. This procedure has reached the stage where the identification of all the strong lines is possible, and the final approximation will be made by least squares. It is hoped to include an approximate correction for the distortion of the molecule by rotation. The final results will be used to calculate the entropy.

Details of the experimental results, procedure of analysis, and entropy calculation will be published in the near future.

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August 27, 1934.

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Evidence of an Excited State in the Alpha-Particle

It has been shown[1] that lithium bombarded with protons gives rise to a gamma-ray of about 12 m.e.v. and probably a second gamma-ray of about 4 m.e.v. energy. The 12 m.e.v. component we ascribe to the process

$$_3Li^7+_1H^1\rightarrow 2\ _2He^4$$

because this appears to be the only reaction involving lithium and protons in which sufficient energy is released. This gamma-ray is particularly interesting, for presumably the only possible source of the radiation is the final product, He^4. That such strong radiation could be emitted in the impact of the protons on the lithium nuclei seems very improbable, both from theoretical considerations and from experimental data at present available, though a small probability for the emission of radiation during the impact cannot be excluded. Analogous cases are known which give strong support to the belief that a gamma-ray is in general to be associated with an excitation level in one of the final products of the reaction. These are the cases in which a given product can be produced by more than one combination of initial particles, for example,

$$_5B^{10}+_2He^4\rightarrow{}_6C^{13}+_1H^1+\gamma,$$
$$_6C^{12}+_1H^2\rightarrow{}_6C^{13}+_1H^1+\gamma.$$

The first of these was studied by Bothe and Becker[2] and the second by ourselves,[3] and in both instances the quantum energy of the gamma-rays was found to be a little over 3 m.e.v. Since only the products are common to the two reactions, it seems certain that the energy 3 m.e.v. represents a level in the C^{13} nucleus. Other equally good examples are B^{10} produced by Li^7 He^4 and by Be^9 H^2. Both of these have been studied[4, 5] and found to give gamma-rays which are of the same energy (0.6 to 0.7 m.e.v.) and therefore presumably characteristic of the final product, B^{10}.

It is more difficult to account for the 4 m.e.v. radiation arising from lithium bombarded with protons. We have not observed it in other reactions in which alpha-particles are given off with more than 4 m.e.v. and less than 12 m.e.v. energy, as in Be, B and F bombarded with protons. Two suggestions as to its origin can be made, which are in keeping with these data. It could be due to an excitation level in He^3, or it could be due to an additional level in the alpha-particle, lying above the 12 m.e.v. level already discussed.

Oliphant, Kinsey and Rutherford[6] have observed the production of He^3 in the reaction

$$_3Li^6+_1H^1\rightarrow{}_2He^4+_2He^3$$

and have given as the ranges of the particles 7 and 12 mm, when the energy contributed by the bombarding protons was about 0.2 m.e.v. In our experiment sufficient energy is available to excite the He^3 to 4 m.e.v., but there would be very little energy left to appear in the form of kinetic energy of the two particles, and hence they would not be easy to observe. The only other reaction in which He^3 is known to be a product is

$$_1H^2+_1H^2\rightarrow{}_2He^3+_0n^1,$$

but only about 2.5 m.e.v. of energy is available and we should therefore not expect to find the 4 m.e.v. gamma-rays unless deutons of very high energy are used.

If, on the other hand, we ascribe the 4 m.e.v. gamma-ray to a second level in the alpha-particle, we must assume that it lies above the 12 m.e.v. level, in order to account for the fact that it is not found in processes where more than 4 but less than 12 m.e.v. are available. The alpha-particle would, then, in the case of lithium, come off excited to 16 m.e.v. and emit successively a 4 and a 12 m.e.v. quantum. In this case the alpha-particles would have less than 1 m.e.v. (3 mm range) each, and would be difficult to observe. If only the 12 m.e.v. level were excited, the alpha-particle would have about 1 cm range and might correspond to the 9 mm particles reported by Kirchner and Neuert.[7]

If our speculation as to the origin of the 12 m.e.v. gamma-ray is correct, there should be the possibility of finding the same gamma-ray in several other accessible processes in which alpha-particles are given off with high energy. This would be the case, for example, when boron and nitrogen are bombarded by deutons, the reactions being

$$_5B^{10}+_1H^2\rightarrow 3\ _2He^4 \qquad (+20 \text{ m.e.v.}),$$
$$_7N^{14}+_1H^2\rightarrow{}_6C^{12}+_2He^4 \quad (+15 \text{ m.e.v.}).$$

Having a sufficient amount of energy available, however, may not be the only condition which must be satisfied to make possible the excitation of the resulting alpha-particle to a particular level.

Experiments are now under way to determine, by means of a Wilson cloud chamber, the energy spectra of recoil electrons due to boron and nitrogen disintegrated by deutons, both of which should yield more information concerning the possibility of an excitation level in the alpha-particle.

We wish to thank Professor J. R. Oppenheimer and Professor R. C. Tolman for many valuable suggestions given us in connection with this problem.

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Thermal Expansions of Alloyed Bi Crystals in the Region of the Eutectic Melting Point

Single bismuth crystals grown from melts having 1 to 5 percent of lead show a discontinuity in the thermal expansion as the crystals pass through the region of 125°C, the temperature at which the eutectic alloy (49 percent Pb, 51 percent Bi) melts.[1] Fig. 1 shows the type of curve

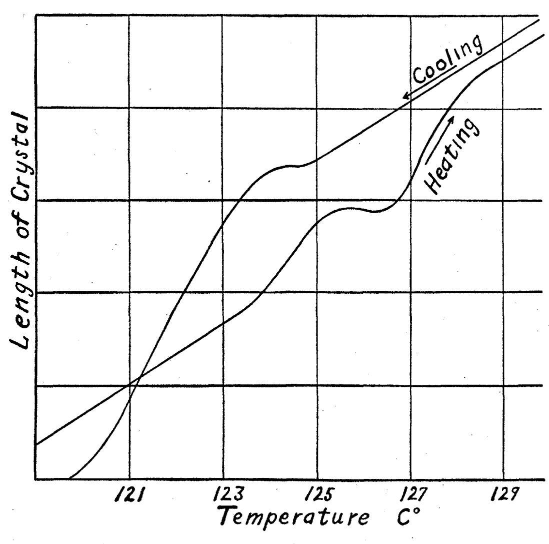

Fig. 1.

obtained. The curves shown were obtained on a crystal specimen which was grown from a melt containing 4.88 percent Pb. The crystal had been heated above 125°C several times. The curves first obtained contained discontinuities that were larger than those shown, the crystals showing more contraction on a part of the heating curve and more expansion on the cooling curve. After numerous heatings, the discontinuities became less marked than those shown in Fig. 1. The cooling curves differ from those obtained on heating but the characteristics of both curves are consistently obtained.

Crystals of various orientations give similar results. All usual tests show the specimens (2 cm long) to be single crystals. They were grown at the rate of 5 mm/min. by the method described by Goetz.[2] Work[3] done in this laboratory indicates that impurities are driven along the melt ahead of the region of crystallization so that it is very likely some of the specimens used had a smaller percentage of foreign atoms than in the melt. Crystals grown from melts containing 1 percent Pb show discontinuities somewhat less pronounced than those shown in Fig. 1.

Somewhat similar curves are obtained for Bi–Sn crystals containing a low percentage of Sn. The discontinuities are somewhat less pronounced. They occur in the region of 135°C, the temperature at which the eutectic alloy (56 percent Sn, 44 percent Bi) melts.

After heating the Bi–Pb crystals a number of times through the 125°C point, tiny drops of material are "sweated" out on the surface of the crystal. An approximate polarograph analysis gave 17 and 35 percent Pb in the droplets from crystals grown from melts containing 2.56 and 4.88 percent Pb, respectively.

This indicates that the foreign admixture is not uniformly distributed over the crystal lattice, although the concentrations in all cases are within the limits of solid solubility.[1]

These observations seem to be interesting due to the facts: that these specimens appear in the usual tests perfectly uniform and monocrystalline; that x-ray measurements do not show a discontinuity of the lattice parameter in this temperature interval, and that the diamagnetic qualities of such alloyed crystals are not changed by repeated transgressions of these temperatures, even not by "sweating." This indicates that the admixtures are partly precipitated within certain regions of the lattice in concentrations above the solubility limit, and furthermore that these precipitations are *uniformly* distributed over the volume of the crystal (since the melting of occasional local inclosures would not change the total length of the crystal), and that the geometric arrangement of this precipitation is such that it does not interfere with the single-crystalline habitus of the specimen. It may finally be added that such phenomena contribute necessarily to the discrepancy between the macroscopic and the lattice expansion of single crystals.

We are obliged to Dr. M. F. Hasler for the performance of the polarographic analyses.

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August 11, 1934.

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* On leave from the University of Minnesota.