TABLE I.

Isotope	a(mgc/sec.)	b(mgc/sec.)	$Q(10^{-26}$ cm$^2)$ (DFZZ)	$Q(10^{-26}$ cm$^2)$ (Townes)
Cl^{35}	205.2±4.6	55.2±1.2	−7.95±0.2	−6.7
Cl^{37}	170.6±3.9	43.1±1.0	−6.20±0.2	−5.1

(3) $(b/a)^{35}=0.269\pm0.006$;

(4) by observing the trajectory of the atoms giving rise to the line $(2, 0)\rightarrow(1, -1)$ we conclude that the magnetic moment of Cl^{35} is positive, confirming the observation of Kusch and Millman;[6]

(5) assuming their[6] value of $g^{35}/g^{37}=1.203\pm0.005$ to give a^{35}/a^{37}, we obtain the a and b values of Table I.

From atomic h.f.s. measurements of this sort, it is possible to obtain accurate values of the nuclear quadrupole moment Q, without resorting to fine structure data and estimates of an effective nuclear charge Z_i, since both the magnetic dipole and electric quadrupole interactions have the same r dependence on the electronic wave functions. From the formulae for a and b given by Casimir[7] neglecting relativity corrections, we obtain, in an obvious notation:

$$Q=-(b/a)g_I(\mu_0^2/e^2)(m/M_p)(L+1)(2L+3)/J(J+1),$$

and we get the Q values of Table I. The Q values given by Townes[4] are included for comparison.

In view of the fact that Q values can be determined quite accurately, we believe that the significance of these values lies not in the fact that they disagree with the estimates of Townes, but rather that, when combined with microwave spectroscopy measurements of $eQ\partial^2V/\partial z^2$, they provide a method of actually measuring $\partial^2V/\partial z^2$ at the position of the halogen nucleus in a wide variety of molecules.

Values for a and b of considerably greater accuracy can be obtained when the transitions $\Delta\nu_{3,2}=3a+b$ are found. We plan to apply this method to other halogens, including radioactive ones, and to measure the interaction constants to higher precision than the present apparatus can achieve. We believe that ultimately this method is suitable for observing these atomic interactions to a few cycle/sec., for atoms in concentration of less than 10^{-5}.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and the Office of Naval Research.

[1] L. Davis, Jr. and J. R. Zacharias, Bull. Am. Phys. Soc. **22**, No. 6, B2 (1947).
[2] C. H. Townes, A. N. Holden, J. Bardeen, and F. R. Merritt, Phys. Rev. **71**, 644 (1947).
[3] W. Gordy, J. W. Simmons, and A. G. Smith, Phys. Rev. **72**, 344 (1947).
[4] C. H. Townes, Phys. Rev. **71**, 909 (1947).
[5] J. R. Zacharias, Phys. Rev. **61**, 270 (1942).
[6] P. Kusch and S. Millman, Phys. Rev. **56**, 527 (1939).
[7] H. B. G. Casimir, *On the Interaction Between Atomic Nuclei and Electrons* (Teyler's Tweede Genootshap, Amsterdam, 1936).

Instantaneous Rates of Grain Growth

PAUL A. BECK, M. L. HOLZWORTH, AND HSUN HU
Department of Metallurgy, University of Notre Dame, Notre Dame, Indiana
January 9, 1948

PREVIOUS work[1,2] showed that the isothermal increase of the average grain size (D) with the annealing time (t) in high purity aluminum follows the relation

TABLE I. Heat treatment and grain size of specimens.

Specimen No.	Heat treatment	D mm
1	125 min. at 400°C	0.235
2	125 min. at 400°C and 120 min. at 450°C	0.340
3	5 min. at 450°C	0.230
4	125 min. at 450°C	0.344

$$D=K\cdot t^n, \qquad (1)$$

where K and n are parameters depending on the temperature. The exponent n increases from 0.056 at 350°C to 0.32 at 600°C. From (1) the instantaneous rate of growth is

$$dD/dt=nK\cdot t^{n-1}. \qquad (2)$$

Since $n<1$, dD/dt decreases with continued annealing. The absolute value of the negative exponent $n-1$ and, therefore, the rate of decay of dD/dt is increasing with decreasing temperature.

More recent experiments demonstrated that the rate of grain growth in high purity aluminum after 33 percent reduction of area by rolling depends only on the instantaneous grain size and on the temperature, but that it is independent of the particular prior heat treatment used to produce the instantaneous grain size considered. A typical experiment was the following. Four specimens 0.020 in. thick, from ingot No. 18 (see reference 2), were annealed at the temperatures and for the periods given in Table I. The table also gives the average grain sizes obtained.

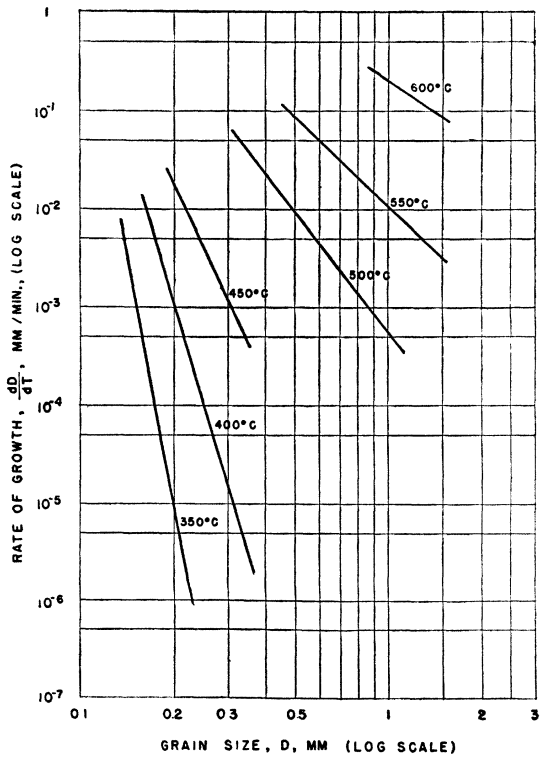

FIG. 1. Rate of grain growth as a function of grain size for aluminum.

It is seen that, in accordance with the earlier data,[2] annealing for 125 min. at 400°C produces a grain size equal to that produced by a 5 min. anneal at 450°C (specimens 1 and 3). The data also show (specimens 2 and 4) that the final grain size obtained by an anneal of 125 min. at 400°C and a subsequent anneal of 120 min. at 450°C was equal to that produced by a single anneal of 125 min. at 450°C. The period of annealing at 450°C necessary for increasing the grain size from 0.23 mm to 0.34 mm was, therefore, the same (120 min.) regardless of whether the initial grain size of 0.23 mm had been obtained by a prior 125-min. anneal at 400°C or by annealing for 5 min. at 450°C.

Since the rate of growth is determined by the instantaneous grain size and the temperature, it is desirable to express dD/dt as a function of these variables. From (1)

$$t=(D/K)^{1/n}.$$

By substituting this into (2) one obtains:

$$dD/dt=n\cdot K^{1/n}\cdot D^{1-1/n}, \tag{3}$$

or in logarithmic form:

$$\log(dD/dt)=\log n+1/n\,\log K+(1-1/n)\log D. \tag{4}$$

If $\log(dD/dt)$ is plotted *vs.* $\log D$, a straight line is obtained for each temperature with a slope of $1-1/n$. Figure 1 gives this plot for high purity aluminum at 350° to 600°C, from data previously published.[2] The slight initial deviations from the $D=K\cdot t^n$ relationship at the lowest temperatures are here neglected. It is seen that the rate of decay of dD/dt increases considerably with decreasing temperature.

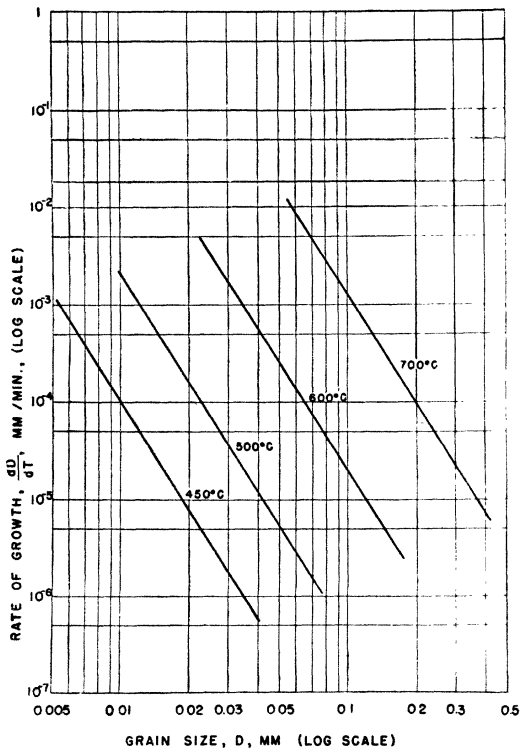

FIG. 2. Rate of grain growth as a function of grain size for 70-30 brass.

As shown in Fig. 1 by the variation of slope with temperature, the ratio of the instantaneous rates of growth at two different temperatures depends on the grain size. Since the temperature dependence of dD/dt varies with the grain size, the "heat of activation" which might be calculated from instantaneous rates will also be grain size dependent. For instance, the "heat of activation" calculated for dD/dt at $D=0.15$ mm is about 38 K cal./g atom, but at $D=0.5$ mm it is roughly 60 K cal./g atom. It has been shown previously[1] that for high purity aluminum, strictly speaking, no heat of activation value can be derived from the temperature dependence of the total time of growth to a certain grain size (average rate of growth), because the value obtained depends on the grain size. The above results show that the same difficulty is also encountered if, in accordance with a recent suggestion by Hollomon,[3] instantaneous rates of growth are used instead of average rates.

For 70-30 brass, where the exponent n is independent of temperature,[4] it is possible to derive a heat of activation value from *either* the total time for a certain grain size, *or* from the instantaneous rate dD/dt, as given in Fig. 2. It can be easily shown that both methods give the *same* numerical value of $Q=61.8$ K cal./g atom, which is independent of the grain size.

This work was supported by the Office of Naval Research, U. S. Navy.

[1] P. A. Beck, J. C. Kremer, and L. J. Demer, Phys. Rev. 71, 555 (1947).
[2] P. A. Beck, J. C. Kremer, L. J. Demer, and M. L. Holzworth, "Grain growth in high purity aluminum and in an aluminum-magnesium alloy," AIME Tech. Pub. No. 2280 Metals Technology, September 1947.
[3] Discussion of reference 2 by J. J. Hollomon.
[4] P. A. Beck, J. Towers, Jr., and W. D. Manly, "Grain growth in 70-30 brass," AIME Annual Meeting, February 1948.

Laue Photography of Neutron Diffraction

E. O. WOLLAN, C. G. SHULL, AND M. C. MARNEY
Clinton National Laboratory, Oak Ridge, Tennessee
January 19, 1948

THE photographic technique has played so important a role in the field of x-ray diffraction that it is of interest to develop this technique for use in neutron diffraction problems. With this idea in mind, we have obtained the Laue photograph, shown in Fig. 1, of the diffraction of neutrons by a NaCl crystal.

The experimental arrangement used in obtaining this and other Laue photographs with neutrons is shown schematically in Fig. 2. A collimated beam of thermal neutrons possessing a continuous wave-length distribution in the region from 0.5 to 3.0 angstroms was taken from the Clinton pile. The collimating system consisted of a hole through a 2½-foot shield block. The exit aperture of this hole was ¼ inch in diameter, and in order to increase the intensity it was successively stepped to larger diameters (up to ⅝ inch) toward the inside of the shield block. The final two inches of the collimating shield consisted of boron carbide impregnated plastic for strong neutron absorption.