Table 2.

Nucleus	State	Transition Energy (keV)	$T_{1/2}$ Present Work	B(E2) $e^2\,10^{-48}\,cm^4$	$Q_0\,10^{-24}\,cm^2$	β	I keV s² 10^{-39}	$I_{rig.}$ keV s² 10^{-39}	$I_{irr.}$ keV s² 10^{-39}	Enhancement Factor
$^{152}_{62}Sm_{90}$	2+	121.78	(1.35±.05) ns	0.737±.027	6.084	.318	11.14	28.97	2.4	215
	4+	244	(42± 18) ps	1.373±.6	8.304	.360	5.54	29.29	3.04	271

symmetric rotator. The contribution of the rigid and the irrotational part of the motion depends on the nuclear deformation parameter β. When the deformation is small, only the irrotational motion will dominate and when the deformation is large only the rigid motion will dominate.

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Relaxation of Diffused Zinc Atoms During Short-Range-Ordering in Cu-30% Zn Alloy

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The internal friction which is a diffusion dependent physical property has been used as a means to determine the kinetics of short range order in (Cu-30% Zn) alloy. Curves of relative (Q^{-1}/Q_0^{-1}) against annealing time have been plotted for various annealing temperatures. An average activation energy of 1.7 eV was found for the ordering process, which is equal to the activation energy for zinc diffusion in coarse grained copper.

When an alloy having short range order (SRO), is quenched from high temperatures, excess vacancies are liberated which will enhance diffusion, and hence the ordering rate during subsequent annealing. Due to this enhanced ordering rate, the equilibrium degree of short range order canbe achieved in reasonable times even at rather low temperatures, provided that vacancies are mobile at these temperatures. For copper-zinc alloys in the alpha phase, the existence of SRO has been theoretically [1] established and experimentally demonstrated by many workers (cf. Clarebrough et al. [2]). Evidence from diffuse X-ray and/or neutron scattering experiments is not available because of the small difference in scattering power of copper and zinc [3] atoms. Long range order in alpha brass above $-30\,^{\circ}C$ is improbable [3] because of the rather low ordering energy of the system.

1. Experimental Procedure and Results

Internal friction experiments were carried out using a torsion pendulum (test wire dia. 1 mm, length 6 cm). The free decay of the oscillations was observed at frequency 0.7 c/sec and strain amplitude 1×10^{-4}. The torsion pendulum is kept at 2×10^{-5} mm Hg vacuum.

Specimens used were prepared from high purity copper and zinc. The appropriate proportions of the two comonents were melted in closed graphite molds mechanically agitated for homogenization. The solid solutions were cold drawn into wires of 1 mm diameter. Subsequent chemical analysis allowed the precise determination of the zinc content. The specimens were given pre-anneal at 600 °C for 1 hour to produce relatively coarse grains ($\approx$ 0.2 mm) in order to eliminate relaxation by grain boundary diffusion.

The existence of SRO in the specimens was tested by measuring the change of internal friction at temperatures up to 500 °C. Results are shown in Figure 1. The peak in Fig. 1 shifts towards lower temperature as the zinc content in the specimen increases. Measure-

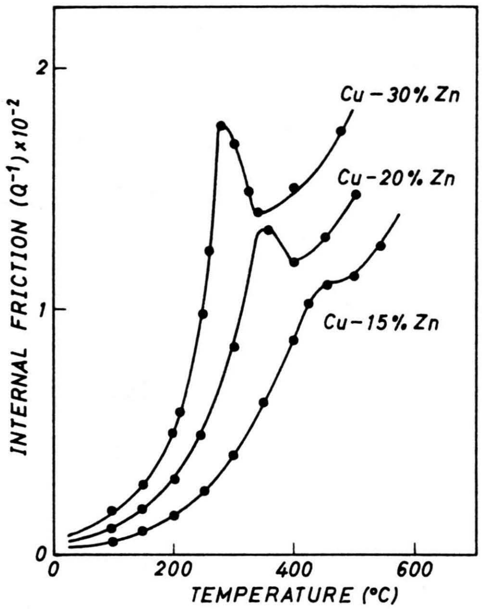

Fig. 1. The variation of the internal friction of annealed alloy specimens with temperature. The peaks demonstrate the existence of short-range order.

ments of the temperature dependence of internal friction were made in ordered and disordered specimens of Cu-30% Zn alloy. Ordering was effected by annealing at 560 °C for 1 hour, followed by slow cooling lasting for 6 hours, disordering by heating at 560 °C for 10 minutes, and immediate quenching in cold water (20 °C). Care was taken that no appreciable heat treatment was given to disordered specimens during the course of measurements. This was ensured by working at relatively low temperatures, and by keeping the specimen at the furnace temperature for the shortest possible time. Moreover, after each reading the specimen was requenched in order to bring the disordering condition to the same initial state. The results, shown in Fig. 2, indicate that the internal friction in the ordered state is higher than in the disordered state.

The disorder-order transition in Cu-30% Zn was followed by plotting the relative isothermal internal friction (Q^{-1}/Q_0^{-1}) for initially disordered samples against the effective reaction time, t, for constant annealing temperatures between 200, 260 °C (Q_0^{-1} is the internal friction of a disordered sample at zero

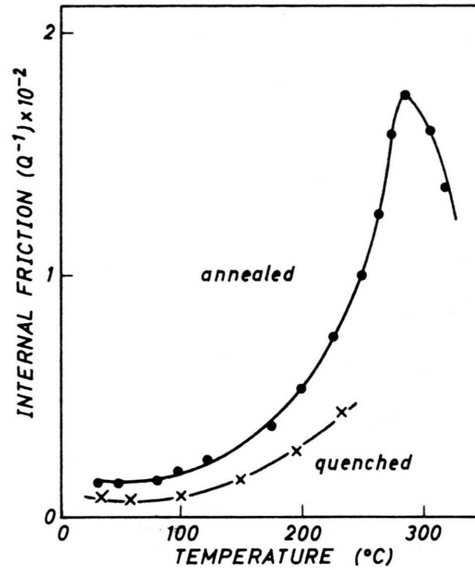

Fig. 2. Temperature dependence of the internal friction of annealed and quenched Cu-30% Zn alloy.

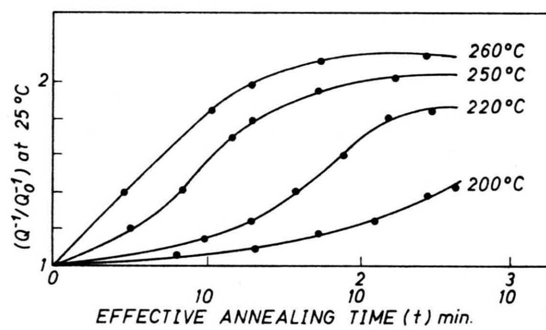

Fig. 3. Relative isothermal internal friction/time curves for ordering in Cu-30% Zn.

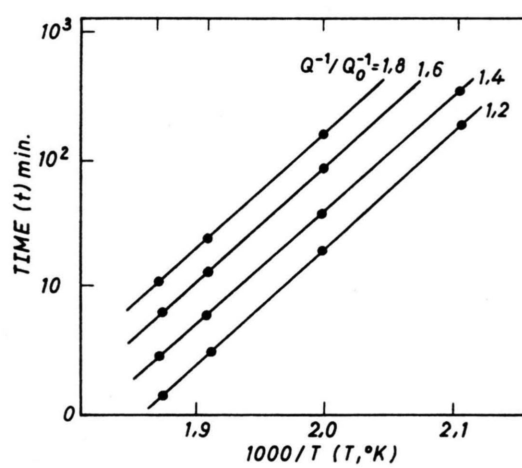

Fig. 4. Equivalent times and temperatures for the ordering process in Cu-30% Zn.

annealing time, and Q^{-1} that after isothermal annealing for the corresponding time and temperature). Typical results are shown in Figure 3. It must be noted that after finishing isothermal annealing at every temperature the specimen was requenched to bring it to an identical state as judged by constant values of internal friction at the beginning of each annealing run.

Equivalent times and temperatures for the ordering process as derived from Fig. 3 are illustrated in Figure 4. Each curve corresponds to a given value of (Q^{-1}/Q_0^{-1}). They are parallel straight lines independent of the value of (Q^{-1}/Q_0^{-1}) and give an activation energy of 1.7 eV for the SRO process.

2. Discussion

In accord to current theories which attribute an elastic effect in substitutional solid solutions to stress-induced changes in local order, the results in Fig. 1 support the view that SRO occurs in the tested specimens. Since the ordering process is a manifestation of solute atom diffusion, it is achieved more easily as the zinc content is increased. The relaxation process thus operates at lower temperature as found in Fig. 1, and this agrees with the increase in diffusion rate with increasing zinc content in copper-zinc alloys as has been reported by HINO et al.[4]. The peak height shown in Fig. 1 might be taken as a measure of the relaxation strength. It increases with increasing zinc content. This may be explained on the basis that vacancies are created by heating which increase the zinc diffusion rates and thus enhances SRO. The observed suppression of this relaxation in the cases of low zinc content could be due to the decreasing number of centers of SRO. This conclusion is supported by TAMMANN's[5] observations on resistivity changes in copper-zinc alloys.

The value of 1.7 eV for the activation energy for SRO in Cu-30% Zn is in reasonable agreement with the values given in the literature obtained from measurement of other physical properties (e. g. see LANG et al.[6]). It also agrees well with the activation energy for zinc diffusion in coarse grained Cu[7].

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