Intrinsic Diffusion and Vacancy Wind Effects in Silver-Cadmium Alloys

by

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ABSTRACT

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Diffusion in the silver-cadmium system was investigated at 600°C with vapor-solid and solid-solid diffusion couples in the alpha phase for the determination of intrinsic diffusion coefficients, atomic mobilities and interdiffusion coefficients. Intrinsic diffusion coefficients, D_{Cd} and D_{Ag} , determined experimentally, were compared with those predicted from the models of Darken, Manning, and Dayananda with the aid of tracer diffusion and thermodynamic data. The experimental coefficients for various alpha alloys were found to be higher than those evaluated from each of the three models. On the other hand, the experimental values of the ratio, D_{Cd}/D_{Ag} , were found to be in good agreement with the models of Manning and Dayananda where the vacancy wind effects on intrinsic diffusion are taken into account. Darken's relations are considered inadequate to interrelate tracer and intrinsic diffusion coefficients in the Ag-Cd system, since vacancy wind effects are found to be appreciable in this system.

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INTRODUCTION

The original analysis by Darken⁽¹⁾ of isothermal diffusion in binary systems has over the years provided a convenient basis for the determination of intrinsic diffusion coefficients and to relate intrinsic and tracer diffusion coefficients through thermodynamic data. A modification of Darken's analysis was proposed by Manning⁽²⁾ to include a vacancy wind term in the equations relating the Kirkendall shift to the tracer diffusion coefficients. In a later paper, Manning⁽³⁾ showed how vacancy fluxes can affect intrinsic diffusion and derived relations between intrinsic and tracer coefficients which incorporated vacancy wind effects. Following the treatment of Manning, Dayananda⁽⁴⁾ developed an analysis for an experimental determination of vacancy wind contributions to intrinsic fluxes. In his analysis, the atomic mobilities of the components as well as the vacancy wind parameter may be determined with the aid of a pair of independent diffusion couples with marker planes of identical composition, regardless of the number of components.

The use of Darken's relations without vacancy wind correction terms has been found inadequate in the case of α Cu-Zn alloys by Schmatz, Domian and Aaronson⁽⁵⁾ who applied Darken's equations with Manning's modification to determine the tracer diffusion coefficients of copper and zinc, D_{Cu}^* and D_{Zn}^* . They found that the D_{Zn}^*/D_{Cu}^* ratios evaluated from Manning's equations at various zinc concentrations agreed well with the corresponding ratios determined from tracer diffusivities. However, individual values of D_{Zn}^* and D_{Cu}^* evaluated from Manning's relations differed significantly from those experimentally determined by tracer diffusion studies.

Kohn et al.⁽⁶⁾ determined tracer as well as intrinsic diffusion coefficients in the Fe-Ni and Fe-Co systems at 1200°C. The Kirkendall shifts

observed by them in these systems were found to be greater than those predicted by either Darken's or Manning's model. The experimentally determined intrinsic diffusion coefficients and those evaluated on the basis of Manning's treatment differed as much as 170 percent in the case of D_{Ni} and 50 percent for D_{Fe} . Also, the ratios, D_{Fe}/D_{Ni} , calculated from Manning's analysis were 20 to 70 percent lower than those experimentally determined.

This study involves binary diffusion in the silver-cadmium system at 600°C with both solid-solid and vapor-solid diffusion couples. The main objective of this study is to investigate the phenomenon of intrinsic diffusion in alphas (fcc) Ag-Cd alloys of selected compositions and to compare the experimentally determined intrinsic diffusion coefficients with those predicted from a knowledge of thermodynamic and tracer diffusion data on the basis of Darken's original relations and the modified expressions of Manning and Dayananda.

The Ag-Cd system was chosen for this investigation for several reasons. First, previous diffusion studies^(7,8) in this system have shown that the intrinsic diffusion coefficient of cadmium is significantly greater than that of silver. This implies that appreciable Kirkendall shifts reflecting large vacancy fluxes can be expected in the diffusion zone. Second, the system has a large alpha phase field⁽⁹⁾ at 600°C. Third, the high vapor pressure of cadmium in contrast to the negligible vapor pressure of silver satisfies the requirement⁽¹⁰⁾ for assembling vapor-solid diffusion couples. Finally, there exist considerable tracer diffusivity^(11,12) and thermodynamic data^(13,14) in the literature for the Ag-Cd system.

RELATIONSHIP BETWEEN INTRINSIC AND TRACER DIFFUSION COEFFICIENTS

The well-known Darken's relation⁽¹⁾ relating intrinsic and tracer diffusivities for a binary alloy is given by

$$D_i = D_i^* \phi \quad (i = 1, 2) \quad [1]$$

where D_i and D_i^* are, respectively, the intrinsic diffusion coefficient and tracer diffusion coefficient for component i ; ϕ , referred to as the thermodynamic factor, is expressed by

$$\phi = \left(1 + \frac{\partial \ln \gamma_i}{\partial \ln N_i}\right) \quad [2]$$

where γ_i and N_i refer to the activity coefficient and atom fraction of i for the alloy. To include the contributions to the intrinsic flows arising from the vacancy wind effect, Manning⁽³⁾ modified Eq. [1] and showed on the basis of a random alloy model that the intrinsic diffusion coefficients, D_1 and D_2 , can be expressed by

$$D_1 = D_1^* \phi (1 + V_1) \quad [3]$$

$$D_2 = D_2^* \phi (1 - V_2) \quad [4]$$

where

$$V_i = \frac{2N_i (D_1^* - D_2^*)}{M_0 (N_1 D_1^* + N_2 D_2^*)} \quad [5]$$

and arises from vacancy wind effect. M_0 is a constant that depends on the crystal structure and is 7.15 for fcc structures. Eqs. [3], [4] and [5] show that the V_1 term increases the intrinsic diffusion coefficient for the faster diffusing component 1, while it decreases the corresponding coefficient for the slower diffusing component 2.

Following Manning, Dayananda⁽⁴⁾ utilizes the equation for the intrinsic flux

$$J_1 = -C_1 \beta_1 \frac{\partial \mu_1}{\partial x} + J_{iv} \quad [6]$$

where β_i is the mobility of component i and the contribution J_{iv} is related to the vacancy flux J_v by

$$J_{iv} = -\alpha N_i \beta_i J_v \quad [7]$$

The constant of proportionality, α , in Eq. [7] referred to as the vacancy wind parameter is a function of composition and crystal structure. On the basis of local thermodynamic equilibrium, Dayananda has shown that for an n -component system

$$\alpha = \frac{\sum_{i=1}^n J_i / \beta_i}{\sum_{i=1}^n \beta_i}$$

and

$$J_1 = - \sum_{j=1}^n C_j \beta_j \left[\delta_{1j} + \eta N_i \beta_i \right] \frac{\partial \mu_j}{\partial x} \quad (i=1,2,\dots,n) \quad [9]$$

where

$$\eta = \frac{\alpha}{1-\alpha \sum_{i=1}^n N_i \beta_i} \quad [10]$$

For a binary system, Eq. [9] yields with the aid of Gibbs-Duhem relation:

$$J_1 = -C_1 \beta_1 \left[1 + \eta N_1 (\beta_1 - \beta_2) \right] \frac{\partial \mu_1}{\partial x} \quad [11]$$

and

$$J_2 = C_1 \beta_2 \left[1 - \eta N_2 (\beta_1 - \beta_2) \right] \frac{\partial \mu_1}{\partial x} \quad [12]$$

Comparing Eqs. [11] and [12] with Fick's Law

$$J_1 = -D_1 \frac{\partial c_1}{\partial x} \quad [13]$$

one gets

$$D_1 = c_1 \beta_1 \psi_1 \frac{\partial \mu_1}{\partial c_1} \quad [14]$$

$$D_2 = c_1 \beta_2 \psi_2 \frac{\partial \mu_1}{\partial c_1} \quad [15]$$

where

$$\psi_1 = 1 + n N_1 (\beta_1 - \beta_2) \quad [16]$$

$$\psi_2 = 1 - n N_2 (\beta_1 - \beta_2) \quad [17]$$

For the case where the molar volume is assumed constant, Eqs. [14] and [15] become

$$D_1 = N_1 \beta_1 \psi_1 \frac{\partial \mu_1}{\partial N_1} \quad [18]$$

$$D_2 = N_1 \beta_2 \psi_2 \frac{\partial \mu_1}{\partial N_1} \quad [19]$$

EXPERIMENTAL PROCEDURE

Binary Ag-Cd alloys of selected compositions were made by induction melting pure silver (99.99 pct) and high purity cadmium (99.999 pct) in alumina crucibles under an argon atmosphere which helped reduce the loss of cadmium by evaporation. The alloys were quenched in water and the ingots were machined to fine chips with acetone as coolant. Degassing of the chips was carried out at 150°C for 24 hr. Alloy disks about 7 mm thick were also cut from alloy ingots and were machined to have their faces parallel and were polished through 0.05 μ alumina. The analysis of the various alloys is given in Table I.

Diffusion disks about 7 mm thick were cut from the silver rods, 3/4 inch in diameter. The disks were machined to have parallel faces and mechanically polished through 0.05 μ alumina. To insure a large grain size, the silver disks were annealed for 24 hours at 800°C in an evacuated Vycor capsule previously flushed with dry hydrogen. The silver disks were repolished through 0.05 μ alumina, immersed in a thin slurry of 1 μ alumina powder in absolute alcohol and allowed to dry for the placement of inert markers on their surfaces.

Both vapor-solid and solid-solid couples were employed in this study. The vapor-solid couples consisted of a silver disk exposed to alloy chips serving as vapor source, while the solid-solid couples were assembled by clamping an alloy disk and a silver disk together with the aid of Kovar clamps. The assembled solid-solid couple and the silver disk were placed in a Vycor capsule, one inch in diameter and 12 inches long, along with about 100 grams of chips of the alloy employed in the couple. The chips were placed in the form of compacts on either side of the silver disk which served as a sink for the vapor-solid couple. The open end of the Vycor capsule was closed

off under a continuous flow of argon to prevent oxidation of the materials. The capsule was then flushed several times with dry hydrogen, evacuated to a hydrogen pressure of less than one micron, and sealed.

All the diffusion anneals were carried out at 600°C in a Marshall Model 1017 tubular furnace equipped with Barber-Coleman SCR controllers. The temperature was controlled to $\pm 0.5^\circ\text{C}$ with a temperature gradient of 1°C over about 8 inches. Diffusion anneals were made for two or five days, and the diffused capsules were air cooled.

The surfaces of vapor-solid couples were examined with a scanning electron microscope and were electroplated with a 25μ layer of copper in an aqueous solution⁽¹⁵⁾ of CuCN , NaCN , and Na_2CO_3 . These disks and the solid-solid couples were all mounted in diallyl phthalate conducting resin, sectioned, and metallographically polished through 0.05μ alumina. The final polish was obtained by electropolishing in an aqueous solution⁽¹⁶⁾ of AgCN , KCN , and K_2CO_3 for 30 to 60 seconds at room temperature. The couples were etched with an aqueous solution⁽¹⁷⁾ of 0.2 percent each of H_2CrO_4 and H_2SO_4 for 3 to 5 seconds. The depth of burial of the inert markers from the vapor-solid interface was measured with a microscope equipped with a micrometer stage and a calibrated eyepiece.

The couples were repolished with 0.25μ diamond paste perpendicular to the direction of diffusion to remove any smeared or etched layer. The couples were analyzed for the concentration profile of cadmium by means of a point-to-point counting technique with an ARL-AMX electron microprobe; measurements were made of the intensity of the cadmium L_α x-radiation ($\lambda = 3.956\text{ \AA}$). At least two probe traces were taken for each couple, one on each side, to check on the similarity of the concentration profiles. The conversion of the x-ray intensities to concentrations was accomplished by means of Ziebold's⁽¹⁸⁾ conversion procedure with the aid of Ag-Cd alloy standards.

RESULTS AND DISCUSSION

Diffusion Couples and Diffusion Coefficients

The results of all vapor-solid (V/S) and solid-solid (S/S) diffusion experiments are given in Table II. The motion of markers is reported for all couples, while the motion of the vapor-solid interface is indicated for vapor-solid couples. These movements are considered parabolic with time, as can be seen from the data for the D/Ag couple diffused for 2 and 5 days.

Figures 1 and 2 show typical concentration profiles of a vapor-solid (C/Ag) couple and a solid-solid (A/Ag) couple, respectively. Intrinsic diffusion coefficients were evaluated by Heumann's method⁽¹⁹⁾ at the compositions of marker planes of the various couples from the relations:

$$A_{Cd} = - 2t D_{Cd} \left. \frac{\partial C_{Cd}}{\partial x} \right]_{\text{marker plane}} \quad [20]$$

$$A_{Ag} = + 2t D_{Ag} \left. \frac{\partial C_{Cd}}{\partial x} \right]_{\text{marker plane}} \quad [21]$$

where A_{Cd} and A_{Ag} refer to the cumulative intrinsic fluxes of cadmium and silver, respectively, past the plane of markers in time t . These data are presented in Table III. Interdiffusion coefficients $\tilde{D}$ calculated with the aid of Darken's relation

$$\tilde{D} = N_1 D_2 + N_2 D_1 \quad [22]$$

and the $\tilde{D}$ values evaluated by Matano analysis of the profile in Figure 1 are included in Table III.

Vacancy Wind Contribution to Intrinsic Diffusion

The primary objective of this investigation has been to determine if an appreciable vacancy wind effect on intrinsic diffusion exists in the Ag-Cd

system. Consequently, analyses of the experimentally determined diffusion coefficients are made with the aid of Darken's model and the models of Manning and Dayananda. Such analyses require accurate tracer diffusivity and thermodynamic data for the Ag-Cd system.

Figure 3 shows data on silver and cadmium tracer diffusion coefficients D_{Ag}^* and D_{Cd}^* , as a function of cadmium concentration at 600°C. The values for D_{Cd}^* are from the work of Schoen⁽²⁰⁾, who investigated several Ag-Cd alloys in the alpha region between 505°C and 908°C. Values for D_{Ag}^* were interpolated from the data of Gertsricken and Yatsenko⁽²¹⁾, Schoen⁽²⁰⁾ and Gardner et al.⁽¹²⁾ Additional data on self-diffusion and interdiffusion coefficients can be found in the compilations of Askill⁽¹¹⁾ and Smithells⁽²²⁾. Figure 4 shows plots of logarithm of the activity coefficient of Cd as a function of Cd concentration on the basis of the data of Filby and Pratt⁽¹⁴⁾ and Scatchard and Boyd⁽¹³⁾ with liquid cadmium as the standard state. These two plots yield, respectively, values of 7.3 and 6.6 for $\partial \ln \gamma_{Cd} / \partial N_{Cd}$.

Table IV presents values of D_{Cd} and D_{Ag} calculated on the basis of both Darken's relation (Eq. [1]) and Manning's treatment (Eqs. [3], [4], and [5]) from tracer diffusivities and thermodynamic data. The thermodynamic factor, ϕ , employed in the calculations is based on the data of Filby and Pratt⁽¹⁴⁾. The use of Scatchard and Boyd's data would affect the calculated diffusivities by less than 6 percent.

A comparison of the experimental intrinsic diffusivities with those calculated from various models is presented in Figures 5 and 6. Darken's relation predicts D_{Cd} and D_{Ag} lower than the experimental values, and this difference is as much as 220 percent for D_{Cd} at a cadmium concentration of 34 atom pct.; this is well beyond the uncertainty of 20 percent in the

experimental D_{Cd} . Similar observations hold for difference between the predicted and observed D_{Ag} values.

Values for Manning's vacancy wind terms⁽³⁾ which were calculated on the basis that M_0 in Eq. [5] is 7.15 for fcc alloys are shown as a function of Cd concentration in Figure 7. It may be noted that the vacancy wind effect slows down the slower diffusing component, silver, to a greater degree than it enhances the diffusion of the faster diffusing component, cadmium. For an alloy of 34 atom percent cadmium, the diffusivity of silver is decreased by 23 percent, while that of cadmium is increased by 12 percent.

Values of D_{Cd} based on Manning's treatment are found to be higher than those predicted by Darken's relation as shown in Figure 5. This is expected since the vacancy wind effect enhances the diffusivity of the faster diffusing component. The difference between the predictions of the two models increases as the cadmium concentration increases. This reflects the fact that the magnitude as well as the effect of the vacancy flux increases as the cadmium concentration increases. Manning's vacancy wind corrections to Darken's relations raise the predicted D_{Cd} values closer to the experimental ones, but the differences between the two sets of values are still appreciable, especially at high cadmium concentrations. On the other hand, D_{Ag} values predicted from Manning's model are lower than those of Darken, as shown in Figure 6, since the vacancy wind term decreases the diffusivity of silver.

The mismatch between the experimental and predicted diffusivities may be caused by errors in the tracer diffusivity and thermodynamic data employed in the calculations, and by uncertainties in the determination of concentration gradients. In this study, the experimental quantity that can

be determined with minimum error is the ratio, D_{Cd}/D_{Ag} ; this ratio is obtained directly from the ratio of cumulative intrinsic fluxes (see Eqs. [20] and [21]) and can be measured with less than 5 percent uncertainty. In addition, the prediction of D_{Cd}/D_{Ag} from the relations of either Darken or Manning does not require a knowledge of thermodynamic data as can be seen from Eqs. [1], [3] and [4]. Consequently, uncertainties in the values of Φ and concentration gradients are circumvented in a comparison between the experimental values of D_{Cd}/D_{Ag} and the corresponding values of the ratio predicted from tracer diffusion data on the basis of Darken's or Manning's relations. Such a comparison is presented in Figure 8 which shows that for cadmium concentrations greater than 15 atom percent, the disagreement between the experimental results and Darken's predictions is considerable; the difference is as much as 46 percent at 34 atom percent cadmium. This disagreement cannot be attributed to errors in the experimental diffusivity ratios which were less than 5 percent. On the other hand, Manning's predictions are closer to the experimental data as shown in Figure 8, although the predicted values can be either higher or lower than the observed ones depending on the alloy composition. It is apparent that Manning's vacancy wind terms are important for the Ag-Cd system.

The method of Dayananda⁽⁴⁾ can be employed for the determination of vacancy wind terms on the basis of the experimental cumulative intrinsic fluxes and the atomic mobilities β_i obtained from the expression, D_i^*/kT . The vacancy wind parameter, α , is calculated from the relation and is utilized in the determination of the vacancy wind terms, ψ_i , given by Eqs. [16] and [17]. Table V reports the calculated values of ψ_{Cd} and ψ_{Ag} , while Figure 9 shows a plot of these quantities as a function of composition. Since ψ_{Cd} and ψ_{Ag} are measures of the vacancy wind effect on the two com-

ponents, the effect appears small up to 15 atom percent cadmium but becomes increasingly appreciable with higher cadmium concentration. At 34 atom percent cadmium, the vacancy wind terms enhance the diffusivity of cadmium by 13 percent and decrease the diffusivity of silver by 26 percent. A comparison of Figures 7 and 9 indicates that ψ_{Cd} and ψ_{Ag} are equivalent to, but not equal to, $(1 + V_{\text{Cd}})$ and $(1 - V_{\text{Ag}})$, respectively. Both measure the extent of the vacancy wind effect, but their magnitudes as well as their variations with composition differ.

D_{Cd} and D_{Ag} evaluated from Eqs. [18] and [19] are included in Table V and compared with the experimental values in Figures 5 and 6. These calculated values are close to those of Manning's treatment and lower than the experimental data. However, it should be noted that the $D_{\text{Cd}}/D_{\text{Ag}}$ ratios calculated from Dayananda's model are identical to the experimental values, since the determination of the vacancy wind parameter, α , from Eq. [23] ensures such a match. Hence, the disagreement between the experimental intrinsic coefficients and those from Dayananda's model can be a consequence of errors in the available thermodynamic data for the Ag-Cd system.

Both of the treatments of Manning and Dayananda provide correction terms based on the vacancy wind effect to Darken's relations. In applying these two treatments in this study, Manning's relation (Eq. [5]) is restricted by the fact that a constant, M_0 (7.15 for fcc), has been used for all compositions. On the other hand, Dayananda's method needs no empirical constant. Instead, it makes use of tracer diffusivities and experimentally determined cumulative fluxes for the direct determination of the vacancy wind effect on intrinsic diffusion.

In the above analysis of the experimental results, uncertainties in the reported D^* values have been ignored, as they cannot be assessed. However, this investigation clearly shows that the models of Manning and Dayananda

offer better predictions of the diffusivity ratios than that of Darken. This is in conformity with similar results of Schmatz, et al.⁽⁵⁾ in the Cu-Zn system. These observations indicate that vacancy wind effects can be appreciable in binary diffusion.

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TABLE I

Analyses of Silver-Cadmium Alloys

Alloy Designation	Phase	Composition (Weight%)	
		Cadmium	Silver
A	α	10.00	90.00
B	α	16.35	83.65
C	α	29.50	70.50
D	α	38.90	61.10

TABLE II
Diffusion Experiments at 600°C

Experiment Number	Type of Couple	Couple Designation	Diffusion Time (Days)	Motion of V/S Interface (Microns)	Movement of Markers (Microns)
1	S/S	A/Ag	5	---	2.0
2	V/S	A/Ag	5	4.0	1.3
3	S/S	B/Ag	5	---	10.0
4	V/S	B/Ag	5	9.7	4.2
5	S/S	C/Ag	5	---	16.0
6	V/S	C/Ag	5	35.2	23.2
7	S/S	D/Ag	5	----	63.0
8	S/S	D/Ag	2	----	41.0
9	V/S	D/Ag	5	84.0	60.0
10	V/S	D/Ag	2	56.7	41.7

TABLE III

Intrinsic and Interdiffusion Coefficients for Ag-Cd Alloys at 600°C

Experiment Number	Composition of Marker Plane (N_{Cd})	D_{Cd} ($\text{cm}^2/\text{sec}) \times 10^{10}$	D_{Ag} ($\text{cm}^2/\text{sec}) \times 10^{10}$	$\tilde{D}^\dagger$ ($\text{cm}^2/\text{sec}) \times 10^{10}$	$\tilde{D}^*$ ($\text{cm}^2/\text{sec}) \times 10^{10}$
1	.055	.35	.25	.34	.45
2	.080	.53	.35	.52	.56
3	.098	.77	.48	.74	.63
4	.148	1.28	.67	1.2	1.5
5	.189	1.96	.77	1.7	3.3
6	.248	8.86	2.48	7.3	6.2
7	.277	10.1	2.66	8.04	---
9	.338	64.2	13.3	47.0	---

[†] Evaluated from Eq. [22]^{*} Evaluated by Matano analysis from profile in Fig. 1

TABLE IV

Intrinsic Diffusion Coefficients Calculated from Darken's and Manning's Equations at 600°C

Composition (N _{Cd})	D _{Cd} [*] (cm ² /sec) x 10 ¹⁰	D _{Ag} [*] (cm ² /sec) x 10 ¹⁰	Φ	D _{Cd} [†] (cm ² /sec x 10 ¹⁰	D _{Ag} [†] (cm ² /sec x 10 ¹⁰	†† 1 + V _{Cd}	†† 1 - V _{Ag}	D _{Cd} ^{††} (cm ² /sec x 10 ¹⁰	D _{Ag} ^{††} (cm ² /sec x 10 ¹⁰
.055	.207	.153	1.40	.290	.214	1.004	.934	.291	.200
.080	.251	.172	1.58	.397	.272	1.010	.886	.401	.241
.098	.295	.191	1.72	.507	.329	1.014	.870	.514	.286
.148	.500	.270	2.08	1.04	.562	1.031	.820	1.07	.461
.189	.795	.383	2.38	1.89	.912	1.047	.797	1.98	.727
.248	1.66	.660	2.81	4.61	1.91	1.073	.780	4.94	1.49
.277	2.42	.920	3.02	7.31	2.78	1.087	.773	7.95	2.15
.327	4.90	1.63	3.39	16.6	5.53	1.111	.772	18.4	4.27
.340	6.00	1.90	3.48	20.9	6.61	1.118	.770	23.4	5.09

† Calculated on the basis of Darken's Model

†† Calculated on the basis of Manning's Model

TABLE V

Intrinsic Diffusion Coefficients Calculated
from Dayananda's Equations at 600°C

Composition (N_{Cd})	$\beta_{\text{Cd}}^{\dagger}$ (cm/dyne-sec) $\times 10^{-3}$	$\beta_{\text{Ag}}^{\dagger}$ (cm/dyne-sec) $\times 10^{-3}$	α $\times 10^3$	η $\times 10^3$	ψ_{Cd}	ψ_{Ag}	$\left. \frac{\partial \mu}{\partial N} \right _{x_m}$ ($\frac{\text{ergs}}{\text{atom}}$) $\times 10^{-2}$	D_{Cd} (cm^2/sec) $\times 10^{10}$	D_{Ag} (cm^2/sec) $\times 10^{10}$
.055	.172	.127	.717	.790	1.002	.966	3.06	.29	.21
.080	.208	.143	.455	.488	1.003	.971	2.37	.40	.26
.098	.245	.158	.383	.409	1.004	.968	2.11	.51	.32
.148	.415	.224	.158	.165	1.005	.973	1.69	1.04	.55
.189	.660	.318	.449	.542	1.035	.850	1.51	1.95	.77
.248	1.38	.548	.300	.389	1.070	.758	1.36	5.00	1.40
.277	2.01	.763	.208	.270	1.093	.757	1.31	7.97	2.10
.338	4.90	1.56	.089	.116	1.131	.744	1.24	23.1	4.85

$\beta_i^{\dagger}$ were calculated from D_i^*/kT

FIGURE CAPTIONS

- Fig. 1. Concentration profile of cadmium for vapor-solid couple, C/Ag, diffused for 5 days at 600°C.
- Fig. 2. Concentration profile of cadmium for solid-solid couple, A/Ag, diffused for 5 days at 600°C.
- Fig. 3. Tracer diffusion coefficient of silver and cadmium for silver-cadmium alloys at 600°C.
- Fig. 4. Logarithm of activity coefficient of cadmium as a function of Cd concentration at 600°C.
- Fig. 5. Comparison of experimental values of D_{Cd} with those predicted from various models at 600°C.
- Fig. 6. Comparison of experimental values of D_{Ag} with those predicted from various models at 600°C.
- Fig. 7. Vacancy wind terms for silver and cadmium as a function of cadmium concentration from Manning's treatment at 600°C.
- Fig. 8. Comparison of experimental D_{Cd}/D_{Ag} ratios with those predicted from Darken's and Manning's treatments at 600°C.
- Fig. 9. Vacancy wind terms for silver and cadmium as a function of cadmium concentration from Dayananda's treatment at 600°C.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9