

THE SOLUBILITY OF CARBON IN SOLID GOLD,
COPPER, AND SILVER

Rex B. McLellan
Department of Mechanical and Aerospace
Engineering and Materials Science
Rice University, Houston, Texas

(Received April 3, 1969)

The temperature dependence of the equilibrium solid solubility of carbon in solid gold, copper, and silver with respect to graphite has been measured by a vapor transport technique used recently to study Co-C, Ni-C (1) and Pt-C and Pd-C (2) solid solutions.

Thin foils of the metal (~ 0.001 " thick) were sealed together with reactor grade graphite in silica ampoules with a small (~ 1 mm Hg) residual pressure of air. The ampoules were annealed at a constant temperature, leading to the formation of a CO/CO_2 gas atmosphere in contact with the metal foil. Since the carbon atoms in the gas phase reach equilibrium with both the graphite and the carbon in solution in the metal, the foils dissolve the equilibrium amount of carbon concomitant with the annealing temperature. Equilibrations at a given temperature were carried out for various times until no further increase in the dissolved carbon content could be achieved. For all the solvent metals equilibration times of a week were found sufficient to produce saturation at the lowest temperature. A few of the ampoules were packed tightly with finely-divided graphite powder and no residual air was purposefully retained. The carburization mechanism in these equilibrations is possibly direct diffusion instead of vapor transport but the saturation solubility found from these equilibrations was consistent with that found in the vapor transport technique.

The very small solid solubilities, ranging from an atom fraction C of about 1.0×10^{-4} to 7.0×10^{-4} , were found by analyzing the equilibrated foils for carbon with a Leco low carbon combustion apparatus capable of determining carbon concentrations of 10 ppm. on a 1 gm. sample.

The variation of equilibrium carbon concentration with temperature is given in Figure 1. These plots of $\ln$ wt.% carbon vs $1/T$ are linear. This is taken to indicate that the interstitial solid solutions are Henrian so that the saturation solubility C with respect to graphite is given by (3)

$$\frac{C}{1-2C} = \exp \left\{ -\frac{\Delta \bar{H}_C}{kT} \right\} \exp \left\{ \frac{\Delta \bar{S}_C}{k} \right\}, \quad (1)$$

where $\Delta \bar{H}_C = \bar{H}_C - H_{gr}^O$ is the relative partial enthalpy of a carbon atom in solution and $\Delta \bar{S}_C = \bar{S}_C^v - S_{gr}^O$ is the relative partial excess entropy.

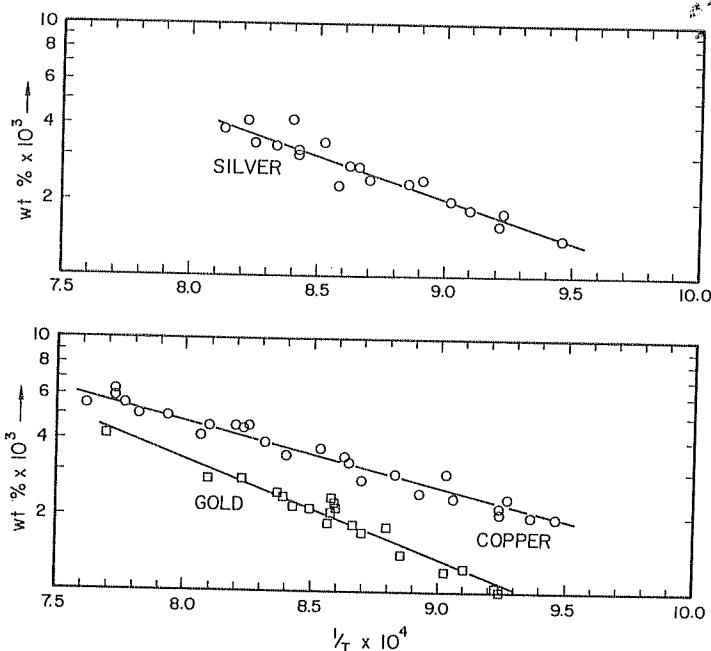


FIG. 1

Variation of Carbon Solubility with Temperature.

The measured solubility data were fitted to Eq. 1 by a least squares regression and the best values of $\Delta \bar{H}_C$ and $\Delta \bar{S}_C/k$ are given in Table 1. The values of the partial enthalpy $\bar{H}_C$ and the partial excess entropy $\bar{S}_C^v/k$ are also given. These were calculated from the relative partial quantities using the thermodynamic data for graphite (4) and computing H_{gr}^O and S_{gr}^O for the mean temperature in the T-range of the measurements.

TABLE 1

Thermodynamic Parameters of the Solid Solutions

Solvent	T-range °C	$\Delta \bar{H}_C$ k.cal/mole	$\frac{\Delta \bar{S}_C}{k}$	$\bar{H}_C$ k.cal/mole	$\bar{S}_C^v/k$
Au	810-1027	20.16 ± 0.81	-0.146 ± 0.36	-147.71	3.20
Cu	785-1041	12.40 ± 0.71	-3.28 ± 0.35	-155.47	0.07
Ag	785-957	15.17 ± 0.92	-1.73 ± 0.42	-152.95	1.57

Within the uncertainty determined by the adequacy of the data, the interstitial solid solutions of carbon in solid gold, copper, and silver are Henrian. This is to be expected for such dilute solutions. As the partial energy of solution increases from Au $\rightarrow$ Ag $\rightarrow$ Cu, the partial excess entropy decreases in a regular manner as would be expected of an oscillator in an increasingly stiff force field.

References

1. W. W. Dunn, R. B. McLellan, and W. A. Oates, Trans. AIME, 242, 2129, (1968).
2. R. H. Siller, W. A. Oates, and R. B. McLellan, J. Less Common Metals, 16, 71, (1968).
3. R. B. McLellan, Phase Stability in Metals and Alloys, Ed. by P. S. Rudman et al., McGraw-Hill, New York, (1967) p. 393.
4. F. D. Rossini, D. D. Wagman, W. H. Evans, S. Levine, and I. Jaffee, Nat. Bur. Std. (U.S.), Circ. No. 500, pt. 1, (1961).