Table 5 Thermodynamic Properties of the Au-Mo Alloys

$G^0(\text{Mo, fcc}) - G^0(\text{Mo, bcc}) = (1190 + 3.6T)R$
$-(G^0(\text{Mo, bcc}) - \Delta H^0_{298})/RT = 1.933 - 3.30 \times 10^{-5}T + 3.15 \times 10^{-8}T^2 - 1.068 \times 10^{-11}T^3 (\Delta H/R = 4\,298$ K at the melting point, $\Delta H/R = 5\,326$ K at 627 °C)

$G^{ex}_{Au} = 11\,000RX^2_{Mo}$ (infinitely dilute solute standard state of Mo in fcc Au)

$G^{ex}_{Mo} = 2450RX^2_{Au}$ (infinitely dilute solute standard state of Au in liquid Mo)

From [80Bre].
Note: R is the gas constant 8.314 J/mol · K.

parameters, but are reported as simplified or approximated by [80Bre]. These boundaries are accepted in Fig. 1 as a good representation of the equilibrium diagram. Further experimental studies on both thermodynamic properties and phase boundaries are needed for confirmation.

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24Dre: Dreibholz, "Investigation of Binary and Ternary Molybdenum Alloys," *Z. Phys. Chem.*, *108*, 1-50 (1924) in German. (Equi Diagram; Experimental)

***53Gea:** G.A. Geach and E. Summers-Smith, "The Constitution of Gold-Molybdenum Alloys, with Particular Reference to the Solubility of Molybdenum in Gold," *J. Inst. Met.*, *82*, 471-474 (1953). (Equi Diagram, Crys Structure; Experimental)

***60Rau:** E. Raub, "The Alloys of Gold with Chromium, Molybdenum, and Tungsten," *Z. Metallkd.*, *51*(5), 290-291 (1960) in German. (Equi Diagram; Experimental)

74Pil: G. Pilkington, G. Antwi-Boateng, and G. Meyrick, "Phase Transformations in Vapor-Quenched Molybdenum and Molybdenum Gold Alloys," U.S. Nat. Tech. Inform. Serv., AD Rep., No. 776970/6GA, 73 p (1974). (Meta Phases; Experimental)

***80Bre:** L. Brewer, Ed., *Molybdenum: Physico-Chemical Properties of its Compounds and Alloys*, Atomic Energy Reviews, Special Issue No. 7 (1980). (Equi Diagram, Thermo; Theory; #)

*Indicates key paper.
#Indicates presence of a phase diagram.

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The Au-Sr (Gold-Strontium) System

196.9665 87.62

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Equilibrium Diagram

The assessed phase diagram for the Au-Sr system (Fig. 1) is essentially the same as that of [Elliott], which is based on the work of Feller-Kniepmeier and Heumann [60Fel]. The equilibrium phases are: (1) the liquid, L; (2) the terminal fcc solid solution, (Au), with very small solubility of Sr; (3) the terminal bcc solid solution, (βSr)—designated (γSr) in [Pearson2]—with unknown solubility of Au; (4) the terminal fcc solid solution, (αSr), with very small solubility of Au and stable below 547 °C; and (5) several intermetallic phases—Au_5Sr, Au_2Sr, $AuSr_3$, $AuSr_9$, (AuSr)—and phases denoted by [60Fel] as β and γ.

Alloys were prepared by [60Fel] in corundum crucibles in an argon atmosphere (up to 20 atm for high-Sr alloys) from 99.99% Au and Sr that was redistilled several times (Sr initially contained 1.2% Ca). The compositions of the alloys were determined by chemical analysis. The phase boundaries were studied mainly by thermal analysis. Other methods were also used—density measurements (for six alloys), specific resistance (<31 at.% Sr), microhardness (15 to 19.5 at.% Sr), microstructure observation, and X-ray analysis.

Special points in the assessed phase diagram are summarized in Table 1. Additional information on each phase follows.

(Au) Terminal Solid Solution. The melting point of pure Au is 1064.43 °C [Melt]. The liquidus from the position of the melting point of Au in the diagram of [60Fel] goes down to the eutectic point (890 °C and 7 at.% Sr) almost as a straight line with a slope of about −25 °C/at.%. Assuming immiscibility of Sr in (Au) and using 13 000 J/mol for the heat of fusion of Au [83Cha], the initial slope of the liquidus is −11.7 °C/at.%.

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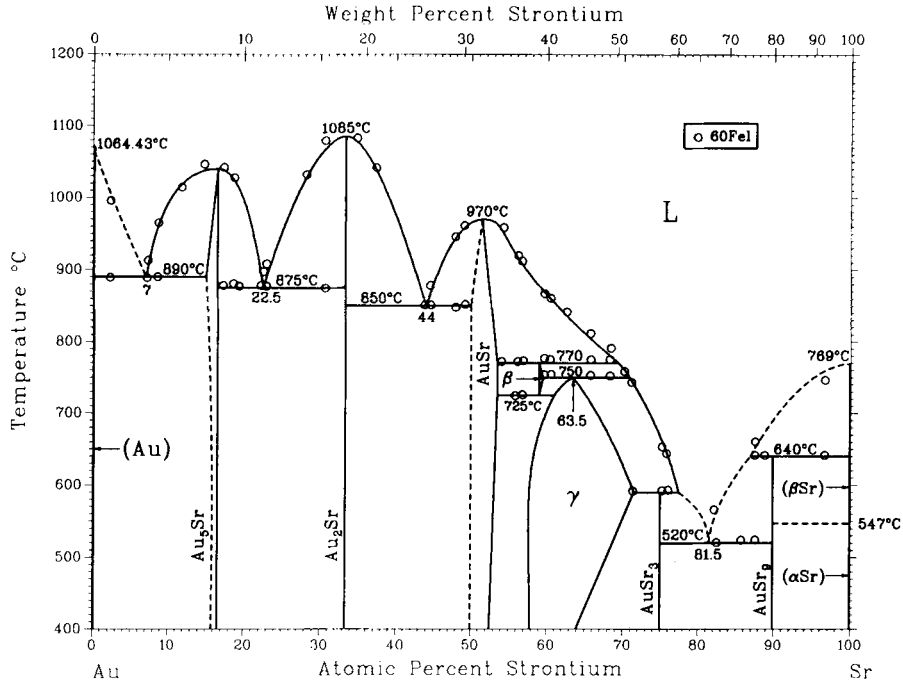
Fig. 1 Assessed Au-Sr Phase Diagram



C.B. Alcock, V.P. Itkin, H. Okamoto, and T.B. Massalski, 1986.

Table 1 Special Points in the Au-Sr Phase Diagram

Reaction	Compositions of the respective phases, at.% Sr		Temperature, °C	Reaction type
$L \rightleftarrows (Au)$	0		1064.43(a)	Freezing
$L \rightleftarrows (Au) + Au_5Sr$ 7	0	15.7	890	Eutectic
$L \rightleftarrows Au_5Sr$	16.7		1040	Congruent
$L \rightleftarrows Au_5Sr + Au_2Sr$ 22.5	16.7	33.3	875	Eutectic
$L \rightleftarrows Au_2Sr$	33.3		1085	Congruent
$L \rightleftarrows Au_2Sr + (AuSr)$ 44.0	33.3	51.5	850	Eutectic
$L \rightleftarrows (AuSr)$	51.5		970	Congruent
$L + (AuSr) \rightleftarrows \beta$ 69	54	59	770	Peritectic
$L + \beta \rightleftarrows \gamma$ 71	60	63.5	750	Peritectic
$\beta \rightleftarrows (AuSr) + \gamma$ 59	53.5	61	725	Eutectoid
$L + \gamma \rightleftarrows AuSr_3$ 78	71.5	75	590	Peritectic
$L \rightleftarrows AuSr_3 + AuSr_9$ 81.5	75	90	520	Eutectic
$L + (\beta Sr) \rightleftarrows AuSr_9$ 87	100	90	640	Peritectic
$L \rightleftarrows (\beta Sr)$	100		769(a)	Freezing
$(\beta Sr) \rightleftarrows (\alpha Sr)$	100		547(b)	Allotropic

(a) From [Melt]. (b) From [83Cha].

The considerable difference between the measured and estimated values indicates that the shape of the liquidus between Au and the eutectic point in the diagram of [60Fel] may be wrong. Therefore, this part of the diagram is shown by a dashed line in Fig. 1.

(AuSr), β, and γ Phases. [60Fel] reported a phase with approximately equiatomic composition, which was denoted α. [60Fel] stated that the results of thermal analysis for alloys with more than 55 at.% Sr were poor because of the smaller thermal effect. As a result, the Sr-rich portion of the phase diagram is more uncertain than the Au-rich side. Therefore, the phase boundaries of α, β, and γ were studied additionally by qualitative microanalysis and X-ray analysis.

Fornasini [85For] synthesized AuSr and studied it by single crystal and powder methods (Tables 2 and 3). Based on this information, the α phase has been renamed "(AuSr)", and its Au-rich boundary has been moved to the left to the more probable position shown by the dashed line.

$L \rightleftarrows AuSr_3 + AuSr_9$ Eutectic Reaction. The data point at ~82.5 at.% Sr and 560 °C is shown as hypoeutectic in the original phase diagram of [60Fel], which brings about a

Table 2 Au-Sr Crystal Structure Data

Phase	Homogeneity, at.% Sr	Pearson symbol	Space group	Strukturbericht designation	Prototype	Reference
(Au)	0	*cF4*	*Fm3m*	*A1*	Cu	[King1]
Au_5Sr	15.7 to 16.7	*hP6*	*P6/mmm*	$D2_d$	$CaCu_5$	[60Fel]
Au_2Sr	33.3	*oI12*	*Imma*	···	$CeCu_2$	[70Bru, 82Bru]
(AuSr)	50 to 54	*mP40*	$P2_1/m$	···	(a)	[85For]
(βSr)	100	*cI2*	*Im3m*	*A2*	W	[King2]
(αSr)	100	*cF4*	*Fm3m*	*A1*	Cu	[King1]

(a) New stacking variant of the FeB-CrB type with Jagodzinski notation hch_2ch_2chc.

Table 3 Au-Sr Lattice Parameter Data

Phase	Composition, at.% Sr	Lattice parameters, nm *a*	*b*	*c*	Comment	Reference
(Au)	0	0.40784	···	···	(a)	[King 1]
Au_5Sr	15.7 to 16.7	0.563	···	0.462	···	[60Fel]
Au_2Sr	33.3	0.4700	0.7489	0.8234	···	[70Bru]
(AuSr)	50 to 54	4.013	0.4697	0.6192	β = 94.21° (b)	[85For]
(βSr)	100	0.487	···	···	(a)	[King2]
(αSr)	100	0.6084	···	···	(a)	[King1]

(a) Lattice parameters as measured for the pure elements. (b) Lattice parameters as measured for the composition 50 at.% Sr.

thermodynamically improbable L/[L + $AuSr_9$] liquidus form. Therefore, this point is regarded as hypereutectic in Fig. 1. Consequently, the L ⇄ $AuSr_3$ + $AuSr_9$ eutectic composition is estimated to be 81.5 at.% Sr, instead of ~83.5 at.% Sr in [60Fel].

(βSr) Terminal Solid Solution. The melting point of βSr and the βSr ⇄ αSr transition temperature are 769 °C [Melt] and 547 °C [83Cha], respectively. [60Fel] observed the melting point of their distilled Sr at 758 °C, which indicates the presence of impurities and/or supercooling during thermal measurements of this highly volatile metal. The initial slope of the liquidus is −2.8 °C/at.% according to the diagram of [60Fel], whereas a thermodynamic estimate is −12.1 °C/at.%, using 7431 J/mol [83Cha] for the heat of fusion of Sr. This difference in values of initial slope indicates some solubility of Au in (βSr).

Crystal Structures and Lattice Parameters

Crystal structure and lattice parameter data of the Au-Sr system are listed in Tables 2 and 3, respectively.

Thermodynamics

The initial slopes of the L/[L + (Au)] and L/[L + (βSr)] liquidus boundaries are discussed in the "Equilibrium Diagram" section. Butler and Alcock [85But] investigated the Au-Sr alloy containing 20 at.% Sr by Knudsen cell mass spectrometry. The ratio of the activity coefficients γ_{Sr}/γ_{Au} increases with temperature from 2.1×10^{-5} at 1600 K to 6.6×10^{-5} at 1700 K.

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*60Fel: M. Feller-Kniepmeier and T. Heumann, "The Constitution Diagram Gold-Strontium," *Z. Metallkd.*, *51*, 404-408 (1960) in German. (Equi Diagram; Experimental; #)

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83Cha: M.W. Chase, "Heats of Transformation of the Elements," *Bull. Alloy Phase Diagrams*, *4*(1), 123-124 (1983). (Equi Diagram; Compilation)

*85But: J. Butler and C.B. Alcock, private communication (1985).

*85For: M.L. Fornasini, "New Alkaline Earth Equiatomic Phases: SrAu and BaAu," *J. Solid State Chem.*, *59*, 60-64 (1985). (Crys Structure; Experimental)

*Indicates key paper.
#Indicates presence of a phase diagram.

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