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Crystallography of the Silver-Rich Rare-Earth–Silver Intermetallic Compounds

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The crystal structures of the silver-rich compounds in the rare-earth-silver systems were determined by means of X-ray powder diffraction methods. Metallographic methods were used to confirm the stoichiometries. The low temperature form of LaAg₅ crystallizes in a 'substituted' MgZn₂ (C14) type Laves-phase structure. The high temperature polymorph of LaAg₅ and the phases CeAg₅, PrAg₅ and YbAg₅ were found to be isotypic but the crystal structure was not established. EuAg₅ crystallizes in the CaCu₅ (D2a) type structure; LuAg₄ and ScAg₄ of the MoNi₄ (D1a) type were found. $R_{14}Ag_{51}$ phases of the Gd₁₄Ag₅₁ type exist for R = Y, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho and Er. Yb₂Ag₇ crystallizes in the Ca2Ag₇ type structure. TmAg₃ was found to exist in both the AuCu₃ (L1₂) type and the TiCu₃ (D0a) type structures. The crystallographic data for these phases are given and their structural relationships are discussed.

Introduction

During an investigation of the solubility limits of the rare earths in silver, it became necessary to determine the stoichiometry of the first silver-rich compound in the rare-earth-silver systems (Gschneidner, McMasters, Alexander & Venteicher, 1970). Since most of these compounds are new, their structural properties and crystallographic data were determined and are the subject of this paper.

All of the rare earths except europium form the RAg compound with the cubic CsCl (B2) type structure. These phases have been studied by several investigators and most of their results are given in Pearson (1967) and McMasters & Gschneidner (1964). For YbAg and YAg the data are given by Moriarty, Humphreys, Gordon & Baenziger (1966). Iandelli & Palenzona (1969) have shown that YbAg crystallizes in both the CsCl and FeB type structures. Köster & Meixner (1965) reported that EuAg exists but the structure was not established.

For R = La, Ce, Pr, Nd, Eu and Yb the phase RAg_2 crystallizes in the orthorhombic CeCu₂ (KHg₂) type structure according to Iandelli & Palenzona (1968) and Köster & Meixner (1965) in the case of EuAg₂. For R = Gd, Tb, Dy, Ho, Er, Tm, Lu, Sc and Y the RAg_2 phase of the tetragonal $MoSi_2$ ($C11_b$) type structure has been reported by several investigators: Baenziger & Moriarty (1961), Moriarty, Gordon & Humphreys (1965), Dwight, Downey & Conner (1967), Kusma & Laube (1965), Ferro, Capelli, Borsese & Delfino (1967), Iandelli & Palenzona (1968), and Steeb, Godel & Lohr (1968). Different structures have been reported for SmAg₂ by Iandelli & Palenzona (1968), for YbAg₂ by Moriarty, Humphreys, Gordon & Baenziger (1966), and for YAg₂ by Gebhardt, von Erdberg & Lütz (1964).

The structure data for the RAg_3 phases reported by Steeb, Godel & Lohr (1968) and Donalato & Steeb (1969) will be discussed later in connection with the results of our investigation.

Lattice parameters and structure types for Yb₅Ag₃ (Cr₅B₃ type) and Yb₃Ag₂ (U₃Si₂ type) were determined by Iandelli & Palenzona (1969). Palenzona (1967) and Köster & Meixner (1965) reported EuAg₅ as being of the hexagonal CaCu₅ ($D2_d$) type structure. The latter also reported that the phases EuAg₄ and Eu₅Ag₃ exist but did not determine the structures.

Experimental procedures

The purity of the metals used in this investigation and alloy preparation procedures are described by Gschneidner *et al.* (1970). Samples, weighing 5-8 g, of the stoichiometries RAg_6 , RAg_5 , RAg_4 , R_2Ag_7 , and RAg_3 were prepared for most of the *R*-Ag systems by arcmelting techniques. For R=Eu and Yb the samples were prepared by induction heating the constituents in sealed tantalum crucibles. Weight losses were found to be negligible and heat treatments were carried out with the alloys sealed in tantalum crucibles. All samples were examined by metallographic and X-ray powder techniques. The metallographic results were used to confirm the compound stoichiometries and are given in detail by Gschneidner *et al.* (1970). The powder specimens were prepared under an inert gas atmosphere and were sealed in Pyrex capillaries for use in the X-ray analysis.

A computer program written by Yvon, Jeitschko & Parthé (1969) was used to interpret the powder patterns. The extrapolated lattice parameters were determined by a least-squares fit of the back-reflection powder pattern data and the Nelson-Riley function by means of a computer program written by Vogel & Kempter (1961). The calculated $\sin^2\theta$ values listed in the text are based on the extrapolated lattice parameters for the compounds and are therefore less than the observed $\sin^2\theta$ values since the latter contain the sample absorption error. The magnitude of the differences $(\sin^2\theta_c -$ $\sin^2\theta_0$) is reflected in the slope of the straight line obtained by the extrapolation program. The accuracy of the lattice parameters (reported σ_s) corresponds to the standard deviation calculated for the observed reflection data in reference to the fitted straight line. Both Cr K α , $\lambda = 2.29092$ Å ($\lambda_1 = 2.28962$ and $\lambda_2 = 2.29351$ Å) and Cu $K\alpha, \lambda = 1.54178$ Å($\lambda_1 = 1.54050$ and $\lambda_2 = 1.54434$ Å) were used in conjunction with a 114.6 mm Debye-Scherrer camera.

Results

Lattice parameters and structure types of the new rareearth-silver compounds studied in this investigation are listed in Table 1. RAg₅, 83·3 at.% Ag

The compounds LaAg₅, CeAg₅, PrAg₅, YbAg₅, and EuAg₅ were found to exist. The powder pattern data for the low temperature modification of LaAg₅ are given in Table 2. The sample which yielded this pattern had been heat treated at 500 °C for 2 weeks. The powder pattern was indexed on the basis of the MgZn₂ (C14) type Laves-phase structure and the agreement between the observed and calculated intensity and $\sin^2\theta$ data is excellent. This agreement is retained when the AB_2 stoichiometry is shifted to AB_5 by randomly substituting two Ag atoms for two La atoms per unit cell. It was therefore concluded that LaAg₅ crystallizes in a 'substituted' $MgZn_2$ (C14) type structure. The calculated pattern based on the LuMn₅ (prototype to C14) structure reported by Wang & Gilfrich (1966) accounts for the more intense reflections of the LaAg pattern; however, several discrepancies between the calculated and observed less intense reflections occur. For this reason the LuMn₅ (C14) prototype structure was eliminated as a possible solution for this structure.

The powder pattern of the LaAg₅ sample that had been heat treated at 780 °C for 2 days contained several more reflections than that of the low temperature form but was not extremely complex. Attempts to index the pattern were unsuccessful, but it was determined that the structure is closely related to the low temperature form. This became apparent during the comparison of the observed $\sin^2\theta$ values with those calculated for the known Laves and Laves-related structures. The *b* and *c* type variations of the CaCu₅ type structure reported by Bronger (1967) for some *R*Pt₅ phases could not be compared since the structural data are incomplete.

The CeAg₅, PrAg₅, and YbAg₅ phases are isostructural with the high temperature LaAg₅ phase as evidenced by the similarity in their powder patterns. Various heat treatments failed to produce these three RAg_5 compounds in the low temperature LaAg₅ crystalline form. The powder patterns of PrAg₅ and YbAg₅ are nearly identical and they probably have nearly the

Table 1. Structure data for some rare-earth-silver binary intermetallic compounds

		5		•	-	
	Crystal	Space	Structure	L	attice constants	6
Compound	system	group	type	a_0	b_0	c ₀
LaAg ₅ (low	hexagonal	P6 ₃ /mmc	'substituted' MgZn ₂ ($C14$)	5∙5690±0∙0003 Å	· —	9·0775±0·0005Å
EuAgs	hexagonal	P6/mmm	$CaCu_s(D2_d)$	5.6201 ± 0.0008		4·6439 ± 0·0008
LuAg	tetragonal	I4/m	$MoNi_4(D1_a)$	6.6696 ± 0.0002		4.1581 ± 0.0002
ScAg ₄	tetragonal	I4/m	$MoNi_4(D1_a)$	6.5740 ± 0.0002	—	4.0686 ± 0.0008
La14Ag51	hexagonal	P6/m	Gd ₁₄ Ag ₅₁	12.955 ± 0.005		9.525 ± 0.007
Ce14Ag51	hexagonal	P6/m	Gd ₁₄ Ag ₅₁	12.883 ± 0.005		9·455 ± 0·008
Pr ₁₄ Ag ₅₁	hexagonal	P6/m	Gd ₁₄ Ag ₅₁	12.846 ± 0.003		9.446 ± 0.005
Nd14Ag51	hexagonal	P6/m	Gd ₁₄ Ag ₅₁	12·814 <u>+</u> 0·002		9·432±0·006
Sm14Ag51	hexagonal	P6/m	$Gd_{14}Ag_{51}$	12.750 ± 0.003	<u> </u>	9.381 ± 0.002
Gd14Ag51	hexagonal	P6/m	Gd ₁₄ Ag ₅₁	12·681 ± 0·003		9·289 ± 0·004
Tb14Ag51	hexagonal	P6/m	$Gd_{14}Ag_{51}$	12.650 ± 0.005		9.280 ± 0.003
$Dy_{14}Ag_{51}$	hexagonal	P6/m	Gd14Ag51	12.635 ± 0.003		9·271 ± 0·002
Ho14Ag51	hexagonal	P6/m	$Gd_{14}Ag_{51}$	12.609 ± 0.006	_	9.257 ± 0.002
Er ₁₄ Ag ₅₁	hexagonal	P6/m	$Gd_{14}Ag_{51}$	12.596 ± 0.002		9.236 ± 0.001
Y14Ag51	hexagonal	P6/m	$Gd_{14}Ag_{51}$	12·637 <u>+</u> 0·003	_	9·300 <u>+</u> 0·002
Yb ₂ Ag ₇	hexagonal	P6322	Ca_2Ag_7	5·463 ± 0·001		14.084 ± 0.005
TmAg ₃	cubic	Pm3m	$AuCu_3(L1_2)$	4·2117 ± 0·0005		—
TmAg ₃	orthorhombic	Pmmn	$TiCu_3(D0_a)$	6.075 ± 0.005	4·948 ± 0·002	5.163 ± 0.003

Table 2. Calculated and observed powder pattern data for LaAgs, low temperature form

Table 2 (cont.)

for LaAgs, low temperature form								$\sin^2 \theta_o$	Io	h	k	1	$\sin^2 \theta_c$	Ic
Cu Ka r	adiation. Aton	nic sca	tter	ing	facto	rs for at	oms in the	0.5670	· S	∫4	1	2	0.5654	156
4(f)(1, 2, z; etc.) DOS	sitions	are	an	avera	ge of $f_{1.0}$	and $f_{A''}$.			12	2	6	0.5662	76
.07.0	LaA	$g_{s}(C)$	4) N	/leZ	n ₂ tyr	е	und Jagi	0.5908	ms	4	0	5	0.5891	114
ain? A	1	63(0-1 L	., L	1	-2 •J F	ain? A	T	0.6418	m	2	1	8	0.6404	88
51112 00	10	"	ĸ	1		SIII- De	10	0.6704	mw	4	0	6	0.6684	61
0.0780	ms	1	1	0		0.0767	307	0.7048	w	5	0	3	0.7036	35
0.0919	5	1	0	3		0.0902	703	0.7204	m	3	3	2	0.7187	75
0.1035	w	2	0	0		0.1022	107	0.7240	m	4	2	1	0.7226	129
0.1070	vs	1	1	2		0.1055	1000	0.7459	mw	ſ4	2	2	0.7442	34
0.1108	vs	2	0	1		0.1094	816			13	2	6	0.7451	30
0.1169	mw	0	0	4		0.1154	184	0.7437	w	2	ī	9	0.7630	27
0.1327	mw	2	0	2		0.1310	162	0.7951	m	3	ĩ	8	0.7937	86
0.1430	mw	-1	0	4		0.1409	100	0.8244	mw	2	Ô	10	0.8234	77
0.2327	w	3	0	0		0.2299	57	0.8385	w	3	2	7	0.8388	49
0.2454	ms	2	1	3		0.2438	274	0.8578	ms	5	1	ż	0.8569	102
0.2606	ms	3	0	2		0.2288	244	0.8964	S	4	2	5	0.8957	347
0.2843	ms	2	0	5		0.2825	313	0.9078	mw	5	ī	4	0.9074	50
0.2962	W	2	1	4		0.2942	80	0.9170	mw	3	î	ġ	0.9163	51
0.3086	ms	2	2	0		0.3066	274	0.9205	ms	6	Ô	ó	0.9198	200
0.3634	m	- 2	0	6		0.3618	116	0.9474	mw	Å,	ž	Ř	0.9470	140
0∙3990	m	3	1	3		0.3970	133	0.9752	5	٢ž	õ	11	0.9748	357
0.4174	m	4	0	1		0.4160	95	0 7 102	5	١ã	ž	6	0.9750	401
0.4235	m	2	2	4		0.4220	136				-		0 9 1 0 0	401
0.4399	mw	∫2	1	6		0.4385	21	* Obse	rved value co	nsists	of .	$K\alpha_1$	and $K\alpha_2$ converted	d to $K\alpha$
		ો 4	0	2		0.4376	23	(mean) da	ata in order	to sim	pli	fy tl	ne listing. This ho	olds for
0.4494	w	3	1	4		0.4475	31		values from	m aster	isk	to e	end of Table.	
0.4577	w	2	0	7		0.4556	25							
0.4882	w	1	0	8		0.4871	45	came lat	tica narama	tor vo	hue		which anorate th	hat tha
0.5392	w	∫4	1	0		0.5365	32		, parame		·uc	, v	villen suggests ti	iai ine
		<u></u> 11	1	8		0.5382	32	r b in th	is compoun	ia is d	108	llen	t.	
0.5527*	m	3	2	3		0.5503	99	It is	conceivable	that	th	e s	toichiometry of	these

Table 3. Calculated and observed patterns of the tetragonal $MoNi_4$ (D1a) type structures of LuAg₄ and ScAg₄

Cu $K\alpha$ (mean) radiation.

LuA	$g_4 a_0 = 6.6$	696, $c_0 = 4.1581$	Å			$ScAg_4 a_0 = 6.5740, c_0 = 4.0686 \text{ Å}$						
$\sin^2 \theta_o$	Io	$\sin^2 \theta_c$	Ic	h	k	l	$\sin^2 \theta_o$	Io	$\sin^2 \theta_c$	Ic		
		0.0267	26	1	1	0	0.0275	w	0.0275	49		
0.0487	vw	0.0477	27	1	Ō	1	0.0504	w	0.0497	49		
0.0527	vw	0.0534	12	2	Ó	Õ	0.0553	w	0.0550	21		
0.1015	vs	0.1012	1000	1	2	1	0.1057	vvs	0.1047	1000		
0.1334	5	0.1336	331	3	1	Ö	0.1385	vs	0.1375	331		
0.1379	S	0.1375	158	0	0	2	0.1452	S	0.1436	154		
_		0.1546	6	3	0	1	0.1603	w	0.1597	10		
	_	0.1642	5	1	1	2	0.1733	vw	0.1711	9		
0.1915	UW	0.1909	4	2	0	2	0.2005	vw	0.1986	7		
0.2082	vw	0.2080	7	3	2	1	0.2157	w	0.2147	13		
		0.2444	3	2	2	2	0.2549	UW	0.2536	5		
0.2664	ms	0.2672	110	2	4	0	0.2769	S	0.2750	108		
0.2707	\$	0.2711	215	3	1	2	0.2832	vs	0.2811	209		
0.3681	5	0.3684	256	5	0	1	0.3816	vs	0.3797	248		
0·3752	5	0.3761	124	1	2	3	0.3935	vs	0.3919	118		
0.4037	5	0.4047	111	2	4	2	0.4205	vs	0.4186	106		
		0.4218	2	2	5	1	0.4365	vw	0.4347	5		
		0.4830	2	2	3	3	0.5022	w	0.5019	4		
0.5380	w	0.5344	39	6	2	0	0.5510	m	0.5500	38		
0.5521	w	0.5499	19	0	0	4	0.5743	mw	0.5744	18		
		0.5917	1	5	3	2	0.6121	w	0.6111	4		
0.6384*	m	0.6355	71	3	6	1	0.6560	m	0.6547	72		
0.6453	ms	0.6433	142	5	0	3	0.6684	5	0.6669	144		
0.6705	m	0.6680	72	5	5	0	0.6900	5	0.6875	72		
0.6743	m	0.6719	71	6	2	2	0.6946	S	0.6936	73		
0.6860	m	0.6835	71	3	1	4	0.7130	5	0.7119	75		
0.8071	5	0.8055	166	5	5	2	0.8321	vs	0.8311	176		
0·8184	5	0.8171	86	2	4	4	0.8500	vs	0.8494	93		
0.9035	S	0.9027	234	7	4	1	0.9300	vs	0.9297	274		
0.9114	S	0.9105	122	3	6	3	0.9423	vs	0.9419	151		
0.9267	\$	0.9260	134	1	2	5	0.9664	vs	0.9663	199		

* See footnote for Table 2.

compounds is not exactly RAg_5 since metallographic evidence was used to establish it. A complete crystal structure determination should establish the true stoichiometry for this phase.

EuAg₅ crystallizes in the CaCu₅ $(D2_d)$ type Lavesrelated structure. The lattice parameters listed in Table 1 are in reasonable agreement with reported values.

RAg₄, 80.0 at.% Ag

The silver-richest compound in the Lu-Ag and Sc-Ag systems was found to be of the RAg_4 stoichiometry. Both LuAg₄ and ScAg₄ crystallize in the MoNi₄ (D1_a) type structure. Since these are new compounds, their powder pattern data are given in Table 3 for comparative purposes. The agreement between the observed and calculated data is good. The atomic positional parameters established by Harker (1944) for the 8(h) set (x=0.200, y=0.400, z=0.0) were used in these calculations.

$R_{14}Ag_{51}, 78.5 at.\% Ag$

The $R_{14}Ag_{51}$ phase is the silver-richest compound in the Nd-, Sm-, Gd-, Tb-, Dy-, Y-, Ho-, and Er-Ag systems. This phase crystallizes in the new Gd₁₄Ag₅₁ type structure. Single-crystal X-ray diffraction methods have been used by Bailey & Kline (1970) to complete the structure determination of this compound. The atom position data listed in Table 4 were supplied by them and were used to calculate the powder patterns of these $R_{14}Ag_{51}$ phases. Their observed and calculated intensities yield an R index of 4.5. Metallographically the alloys in these systems are two phase at 75 at.% Ag and single phase between 77.8 and 80.0 at.% Ag, in agreement with the structure determination of Bailey & Kline (1970). The powder patterns of these phases could be properly indexed on the basis of these structural data and the measured values for $Tb_{14}Ag_{51}$ listed in Table 5 are in good agreement with the calculated data.

Table 4. Crystallographic data for the Gd₁₄Ag₅₁ type structure

The refined data will be given by Bailey & Kline (1970) in their report on the complete structure determination. Gd₁₄Ag₅₁ stoichiometry with disordered set.*

Hexagonal – space group $P6/m-C_{6h}^1$.

	Wyckoff notation	x	у	Z
Ag	2(c)	0.333	0.667	0.0
Ag	4(h)	0.333	0.667	0.298
Ag	6(k)	0.239	0.059	0.2
Ag	12(l)	0.115	0.494	0.153
Ag	12(l)	0.266	0.192	0.237
Ag	12(1)	0.440	0.104	0.331
Gd	2(e)	0.0	0.0	0.307
Gd	6(<i>j</i>)	0.389	0.114	0.0
Gd	6(k)	0.141	0.469	0.5
3Ag*	6(<i>j</i>)	0.112	0.135	0.0

Table 5. Calculated and observed powder patterns for Tb₁₄Ag₅₁ with the Gd₁₄Ag₅₁ type structure

Cr $K\alpha$ (mean) radiation.

sin2 A.	L	h	k	1	sin2 A.	1.
5111-00	10		~	1	511-02	10
0.1440	vw	3	1	0	0.1421	12
		2	2	1	0.1464	53
0.1606	UW	3	0	2	0.1593	25
0.1769	W	4	0	0	0.1749	87
0.1939	w	₹4	0	1	0.1902	34
		l 2	2	2	0.1921	56
0.2020	S	∫ 1	3	2	0.2031	589
		13	1	2	0.2031	113
0.2096	m	2	3	0	0.2077	84
0.2150	vs	∫2	1	3	0.2137	1000
		<u></u> 11	2	3	0.2137	294
0.2251	т	ſ 3	2	1	0.2230	48
		ો 2	3	1	0.2230	94
0.2317	vs	[4	1	0	0.2296	118
		11	4	0	0.2296	827
0.2369	m	3	0	3	0.2355	269
		0 l	0	4	0.2438	111
0.2470	S	4	1	1	0.2448	349
0 = 170		li	4	1	0.2448	41
0.2557	w	î	ó	4	0.2547	81
0.2711	m	12	ž	2	0.2683	67
02/11		15	2	2	0.2687	217
0.2750	W/	5	ő	á	0.2733	85
0.2730	m	2	1	2	0.2733	160
0.2800	//l	2	1	3	0.2792	100
0.2890	mw	(1	0	4	0.2075	107
0.2931	mw	- 1	4	2	0.2903	97
0.2405	***	(4	1	2	0.2903	20
0.3405	mw	{ ?	I	0	0.3389	21
0.04.00		ι	2	0	0.3389	31
0.3459	m	3	2	3	0.3448	114
0.3685	W	11	4	3	0.366/	14
		(4	2	2	0.36/1	27
0.4067	w	4	3	0	0.4045	25
0.4438	m	4	2	3	0.4432	64
0.4669	vw	4	3	2	0.4654	25
0.4764	vw	1	4	4	0.4734	28
0.5427	m	4	3	3	0.5416	58
0.5484	m	0	0	6	0.5485	95
0.5652	m_W	5	2	3	0.5635	63
0.6108	S	4	1	5	0.6105	207
0.6252	w	2	1	6	0.6250	45
0.6312	S	6	2	2	0.6294	198
0.6490	m	3	4	4	0.6483	138
0.6633	ms	4	4	3	0.6619	151
0.6706	ms	5	2	4	0.6701	120
0.6847	m_W	∫4	5	1	0.6821	54
		ί7	1	2	0.6841	41
		[6	3	0	0.6887	85
0.6910	S	3	6	0	0.6887	52
		1	3	6	0.6906	89
		L3	1	6	0.6906	71
0.7064	\$	[2	6	3	0.7056	133
		<u>ا</u> 6	2	3	0.7056	28
0.7144	s	f 1	6	4	0.7139	105
	-	18	0	1	0.7149	82
0.7231	mw	4	Ō	6	0.7234	76
0.7340	mw	7	2	ŏ	0.7325	69
0.7623*	s	í	7	ž	0.7603	183
0.7779	5	4	í	6	0.7781	240
0.7956	5 m	2	7	2	0.7934	95
0.8221	m	4	ó	6	0.8218	60
0.8270	774	5	5	1	0.8357	81
0.8556	M2 141		2	1 6	0.8546	66
0.8664	11/	4 (2	47	0	0.2627	121
0.0004	3		, 7	1	0.8660	40
0.8700		2	<i>'</i>	4	0.0002	104
0.00/90	mw	5	6	1	0.0255	204
0.9900	m	{ }	1	0	0.0022	100
		()	1	ю	0.00/4	120

		Table	5	(cont	.)		for the $R_{14}A$	g ₅₁ stoichior	neti
$\sin^2 \theta_o$	Io	h	k	ì	$\sin^2 \theta_c$	Ic	slight solubil Yb ₂ Ag ₇ ci	ity ranges ex vstallizes in	istiı the
0.9026	mw	٤ آ	0	1	0.9008	55	102.18/ 01		
0,0020		14	4	5	0.9057	45	Table 6 Ca	Invlated and	ahe
0.9202	w	8	2	0	0.9183	90	Table 6. Ca		00s
0.9260	ms	7	3	2	0.9246	436	Y b ₂ A	Ag_7 with the	Ca_{2}
0.9329	ms	3	6	4	0.9325	291			rad
0.9511	m	2	6	5	0.9494	118	,	-i-20	
0.9535	S	∫4	3	6	0.9530	123	Io	SIN ² Ø ₀	
		ો 2	3	7	0.9543	170	W	0.0483	
		ſO	0	8	0.9751	129	m	0.0359	
0.9770	5	{1	4	7	0.9761	229	S	0.0204	
		[7	2	4	0.9762	447	m	0.0832	
	* 0	6	4	. .	Table 2		3	0.0021	
	+ 5	ee 1000	note	e 101	Table 2.		<i></i>	0.1022	
							5 110	0.1073	ſ
Steeb,	Godel &	Lohr (196	58) re	eported lattice p	oaram-	03	0 1075	{
eters for	some RA	g. (R=	= La	ı. Ce	Sm. Gd. Dy.	Ho, Y	m	0.1186	
and Er)	compound	le Foi	R	- Pr	Nd Th and T	m the	m	0.1278	
	tion moment			- 1 1	orted by Done	lato &	m	0.1328	
RAg ₃ lat	nce paran	leters	wei	erel	Doned by Dona		m	0.1361	
Steeb (1	969). The	eir latt	tice	par	ameters are cl	ose to	m	0.1880	
those of	the $R_{14}A_{14}$	g ₅₁ pha	ases	s fou	nd in this study	y. It is	w	0.1935	
believed	that their	RAg.	latt	ice n	arameters are a	ctually	m	0.2150	
Deneveu	that mon			P		J			

ry with the possibility of ng for these phases.

e hexagonal Ca₂Ag₇ type

Table	6.	Calcula	ted	and	observed	powder	patterns	for
	Ŋ	b_2Ag_7	with	the	$Ca_2Ag_7 t_3$	vpe struc	cture	

	Cu Ka	radiat	ion.		
In	$\sin^2 \theta_o$	h	k	l	$\sin^2 \theta_c$
w	0.0483	0	0	4	0.0479
m	0.0539	1	0	3	0.0535
s	0.0755	1	0	4	0.0745
m	0.0804	1	1	0	0.0797
s	0.0832	1	1	1	0.0827
m	0.0921	1	1	2	0.0916
s	0.1022	. 1	0	5	0.1015
vs	0.1073	2 آ	0	0	0.1062
		1	1	3	0.1066
m	0.1186	2	0	2	0.1182
m	0.1278	1	1	4	0.1276
m	0.1328	2	0	3	0.1332
m	0.1361	1	0	6	0.1344
m	0.1880	1	1	6	0.1875
w	0.1935	0	0	8	0.1917
т	0.2150	2	0	6	0.2141

Table 7. Calculated and observed powder patterns for $TmAg_3$ which exists in both the cubic AuCu₃ (L1₂) and the orthorhombic $TiCu_3$ (D0_a) type structures

					Cu $K\alpha$ (mean) r TmAg ₃ observed	adiation.						
	AuCu ₂ type				pattern 75 at.º	/ Ag					TiCu ₃ type	
I.	$\sin^2 \theta_c$	h	k	1	$\sin^2 \theta_o$	I.	h	!	k	l	$\sin^2 \theta_c$	Ic
-0			••	-	0.0885	m	2	2	0	1	0.0867	330
					0.0910	w	ō)	Õ	2	0.0892	67
					0.0982	m	C)	2	0	0.0971	445
1000	0.1005	1	1	1	0.1024	vs						
1000	0 1005	-	•	-	0.1072	UW	1		0	2	0.1053	10
					0.1124	S	2	2	1	1	0.1110	1000
					0.1154	ms	. ()	1	2	0.1134	607
489	0.1340	2	0	0	0.1356	S	•					
102	0 10 10	-	Ŭ	•	0.1855	mw	2	2	2	1	0.1838	213
					0.2605	w	2	1	0	0	0.2576	97
322	0.2680	2	2	0	0.2705	vs	2	2	0	3	0.2651	174
		_	-	-	0.3076	m	î2	2	3	1	0.3052	200
							10)	3	2	0.3076	124
					0.3565	w	، ک	1	2	0	0.3547	114
							l)	0	4	0.3567	30
					0.3641	mw		2	2	3	0.3621	209
381	0.3685	3	1	1	0.3704	vs	4	4	1	2	0.3711	183
111	0.4020	2	2	2	0.4039	ms						
					0.4458	UW	4	4	2	2	0.4439	22
					0.4745	vw		2	4	1	0.4751	47
58	0.5360	4	0	0	0.5375*	m						
213	0.6365	3	3	1	0.6390	S		4	1	4	0.6386	57
214	0.6700	4	2	0	0.6721	m		_	_		0.000	
					0.6939	mw		2	5	1	0.6935	84
					0.7022	w		6	2	1	0.6991	39
					0.7137	mw		4	2	- 4	0.7114	67
					0.7366	w		4	4	2	0.7352	17
					0.7832	mw		6	0	3	0.7803	20
253	0.8040	4	2	2	0.8055	5		0	0	6	0.8020	104
					0.8223	ms		6	3	1	0.8204	104
					0.8343	т		4	3	-4	0.0320	14
					0.8416	m		2	5	S	0.0402	100
					0.8730	w		Ú,	0	2	0.0730	178
				-	0.8797	5		6	2	3	0.8007	170
488	0.9046	3	3	3	0.9053	S		0	2	0	0.0537	202
					0.9525	ms		4	2	2	0.9530	110
					0.9615	mw		2	0	1	0.2003	119

* See footnote for Table 2.

 Table 8. Intermetallic compound formation in the rare-earth-silver systems

Sequence		2				0				
number	Rare earth	R_5Ag_3	R_3Ag_2	RAg	RAg ₂	RAg ₃	R_2Ag_7	$R_{14}Ag_{51}$	RAg ₄	RAg ₅
1	La, Ce, Pr			×	× *			×		׆
2	Nd			×	× *			×		•
3	Sm			×	׆			×		
4	Eu	׆		׆	× *				׆	×
5	Gd, Tb, Dy, Ho, Er, Y			×	ׇ			×		
6	Tm			×	ׇ	×				
7	Yb	×	×	×	×*		×			׆
8	Lu, Sc			×	ׇ				×	
		* Ce	Cu ₂ , KHg	₂ type.						

† Structure type unknown.

‡ MoSi₂ type.

structure reported in Pearson (1958). The atomic parameters needed to calculate the powder pattern intensities are not known so the observed and calculated $\sin^2\theta$ values listed for comparison in Table 6 are given as evidence for this structure.

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