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The Crystal Structure of $Na_4Sn_2Ge_4O_{12}(OH)_4$

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The crystal structure of $Na_4Sn_2Ge_4O_{12}(OH)_4$ was determined from three-dimensional Fourier functions and was refined to a conventional R-value of 5.4 %. The space group is $P\bar{1}$, with $a=5.77_8$ Å, $b=11.61_5$ Å, $c=5.54_0$ Å, $\alpha=107.62°$, $\beta=75.75°$, $\gamma=94.75°$. The cell contains one formula unit. Germanium atoms were tetrahedrally coordinated with oxygen atoms and tin atoms are octahedrally coordinated with oxygen atoms. GeO_4-tetrahedra form strings along [001], by sharing corners. The strings are bonded together by SnO_6-octahedra.

Hydrothermal synthesis with mixtures of germanium(IV) oxide and tin(IV) oxide in a sodium hydroxide solution can yield the phases $Na_4Ge_9O_{20}$, $Na_8Sn_4Ge_{10}O_{30}(OH)_4$, and $Na_4Sn_2Ge_4O_{12}(OH)_4$. The crystal structure of the first mentioned compound was determined by Ingri and Lundgren.[1] The structure of the second compound was reported by Larsen, Christensen and Rasmussen,[2] and the crystal structure of $Na_4Sn_2Ge_4O_{12}(OH)_4$ is given below.

EXPERIMENTAL

Chemistry. The compound $Na_4Sn_2Ge_4O_{12}(OH)_4$ was prepared hydrothermally in 20 ml pressure bombs lined with pure silver. In a typical experiment a mixture of 250 mg GeO_2 and 25 mg SnO_2 was treated with 5 ml of a 1 M NaOH solution at 450°C and 500 atm for 60 h. Microscopical investigation of the product proved it to consist of two phases. No chemical analysis was made.

X-Ray technique. The powder pattern of the product was obtained with a Guinier-de Wolff camera using Cu$K\alpha$-radiation ($\lambda=1.5418$ Å). One of the phases in the product was identified as $Na_8Sn_4Ge_{10}O_{30}(OH)_4$ and the other as $Na_4Sn_2Ge_4O_{12}(OH)_4$. A crystal of dimensions $0.17\times0.17\times0.04$ mm^3 was investigated by Weissenberg and precession methods using Cu$K\alpha$-radiation. Weissenberg photographs were taken of $hk0$ and $hk1$, and precession photographs were taken of $h0l$ and $0kl$. 1194 independent reflections with $I>3\ \sigma(I)$ were measured on a single crystal diffractometer with a scintillation counter using monochromatic Mo$K\alpha$-radiation ($\lambda=0.7107$ Å). The monochromator was a lithium fluoride crystal and the pulse height analyzer was set to include 99 % of the Mo$K\alpha$-peak thus excluding harmonics in the beam. The diffractometer was of equiinclination Weissenberg type manufactured by Supper and Pace.

Lorentz-polarisation corrections were applied and absorption correction was made.

STRUCTURE DETERMINATION

The space group $P1$ or $P\bar{1}$ of the triclinic crystal was indicated from Weissenberg and precession photographs. The space group $P\bar{1}$ was assumed. One of the tin atoms was given the special position (0,0,0). A three-dimensional Fourier map based on this assumption showed the positions of all the heavy atoms. A new Fourier map based on structure factor signs calculated with all the heavy atoms gave the position of all sodium and oxygen atoms.

The refinement proceeded by the method of least squares, (Hazell),[3] giving an R-value of 5.4 % at the end of the refinement. Anisotropic temperature factor coefficients were used. A final difference Fourier map showed the positions of the hydrogen atoms. With the hydrogen atoms inserted an R-value of 5.4 % was obtained.

CRYSTAL DATA

The formula of the compound is $Na_4Sn_2Ge_4O_{12}(OH)_4$ and the unit cell contains one formula unit. The crystal system is triclinic with $a = 5.77_8$ Å, $b = 11.61_5$ Å, $c = 5.54_0$ Å, $\alpha = 107.62°$, $\beta = 75.75°$, $\lambda = 94.75°$. The calculated density is 4.20 g/cm^3 and the absorption coefficient for Mo-radiation is 130 cm^{-1} ($\lambda = 0.7107$ Å). The structure factors were calculated using the atomic scattering factors from Vol. III of *International Tables of X-ray Crystallography* approximated by Bassi polynomials.[4] The atomic scattering factors for germanium and tin were corrected for dispersion, using the real part of the correction only.

Final atomic coordinates and temperature factor parameters are given in Table 1, and interatomic distances and bond angles in Table 2. Table 3 is a list of observed and calculated structure factors. Fig. 1 is a projection of a part of the structure along [100].

Table 1. Atomic coordinates and temperature factor coefficients. Diffractometer data, 1194 reflections, anisotropic refinement, $R = 5.4$ %.

Atom	x	σx	y	σy	z	σz
O_1	0.1681	(17)	0.0535	(9)	0.3031	(19)
O_2	0.6798	(15)	0.0364	(9)	0.2522	(19)
O_3	0.4919	(16)	0.2098	(9)	0.0740	(21)
O_4	0.4415	(15)	0.2321	(8)	0.6024	(19)
O_5	0.0241	(17)	0.1687	(8)	0.9668	(20)
O_6	0.2440	(17)	0.4028	(9)	0.0626	(18)
O_7	0.7365	(16)	0.4398	(9)	0.2449	(20)
O_8	0.9381	(18)	0.3612	(9)	0.6925	(23)
Na_1	0.5830	(10)	0.4375	(5)	0.6710	(11)
Na_2	0.8251	(10)	0.1509	(6)	0.6435	(12)
Ge_1	0.2808	(2)	0.2501	(1)	0.9317	(3)
Ge_2	0.4378	(2)	0.1251	(1)	0.3009	(3)
Sn_1	0		0		0	
Sn_2	0		0.5		0	
H_1	0.697	(40)	0.360	(23)	0.191	(49)
H_2	0.316	(32)	0.271	(18)	0.658	(39)

Table 1. Continued.

Temperature factor coefficients with standard deviations ($\times 10^5$).

Atom	u_{11}	σu_{11}	u_{22}	σu_{22}	u_{33}	σu_{33}	u_{12}	σu_{12}	u_{13}	σu_{13}	u_{23}	σu_{23}
O_1	1246	439	997	414	668	459	−743	332	3	349	−74	387
O_2	151	386	1316	434	1062	442	−41	311	−360	326	335	397
O_3	672	418	1071	428	1415	487	247	325	−10	354	429	409
O_4	410	392	922	403	940	456	−3	311	−224	330	−255	387
O_5	1552	477	456	381	1317	480	−63	328	−380	382	360	384
O_6	1567	459	1257	427	0 [a]	395	41	342	−673	334	552	379
O_7	559	423	1593	464	1388	488	−185	342	−749	357	168	421
O_8	1174	457	1087	428	2374	577	−287	343	−459	403	521	443
Na_1	1593	281	1601	269	953	268	−555	212	−597	217	527	245
Na_2	1358	271	1573	264	1398	284	620	209	−437	216	234	246
Ge_1	774	60	459	53	913	66	−54	45	−72	51	96	54
Ge_2	739	60	529	55	825	65	57	44	61	49	108	54
Sn_1	617	53	404	47	863	59	29	39	−9	44	165	48
Sn_2	823	56	569	50	1240	63	112	41	−107	47	148	51
H_1	1	5 [b]										
H_2	0 [c]	4										

[a] The value was −83 in the final refinement.
[b] Isotropic temperature factor coefficient B (Å^2) and σB (Å^2).
[c] The value was −0.9 in the final refinement.

Table 2. Interatomic distances in Å and bond angles in degrees in $Na_4Sn_2Ge_4O_{12}(OH)_4$. Standard deviations in parantheses.

Ge_1-O_3'	1.767 (12)	$O_4-Ge_1-O_5$	115.11 (46)
Ge_1-O_4	1.789 (9)	$O_4-Ge_1-O_3'$	103.30 (50)
Ge_1-O_5	1.694 (9)	$O_4-Ge_1-O_6'$	104.11 (43)
Ge_1-O_6'	1.710 (9)	$O_5-Ge_1-O_3'$	112.64 (46)
		$O_5-Ge_1-O_6'$	114.28 (46)
Ge_2-O_3	1.774 (12)	$O_3'-Ge_1-O_6'$	106.33 (44)
Ge_2-O_4	1.758 (9)		
Ge_2-O_1	1.703 (9)	$O_1-Ge_2-O_2$	116.64 (47)
Ge_2-O_2	1.725 (10)	$O_1-Ge_2-O_3$	109.54 (52)
		$O_1-Ge_2-O_4$	111.73 (40)
Sn_1-O_1	2.055 (11)	$O_2-Ge_2-O_3$	110.85 (46)
Sn_1-O_2	2.013 (8)	$O_2-Ge_2-O_4$	102.32 (47)
Sn_1-O_5'	2.013 (10)	$O_3-Ge_2-O_4$	104.99 (47)
Sn_2-O_6	2.031 (11)	$O_5-Sn_1-O_1'$	90.97 (35)
Sn_2-O_7'	2.007 (10)	$O_5-Sn_1-O_2'$	90.91 (35)
Sn_2-O_8'	2.042 (10)	$O_1'-Sn_1-O_2'$	90.50 (35)
Na_1-O_4	2.405 (11)	$O_6-Sn_2-O_7'$	90.97 (35)
Na_1-O_6''	2.320 (11)	$O_6-Sn_2-O_8'$	92.15 (35)
Na_1-O_6'	2.648 (11)	$O_7'-Sn_2-O_8'$	90.61 (35)
Na_1-O_7'	2.316 (13)		
Na_1-O_7''	2.295 (12)		
Na_1-O_8	2.343 (13)		

Table 2. Continued.

Na_2-O_1''	2.483	(13)
Na_2-O_2	2.478	(12)
Na_2-O_3'	2.614	(10)
Na_2-O_4	2.565	(12)
Na_2-O_5'	2.307	(14)
Na_2-O_8	2.428	(12)
O_7-H_1	0.9	(2)
O_4-H_2	0.8	(2)

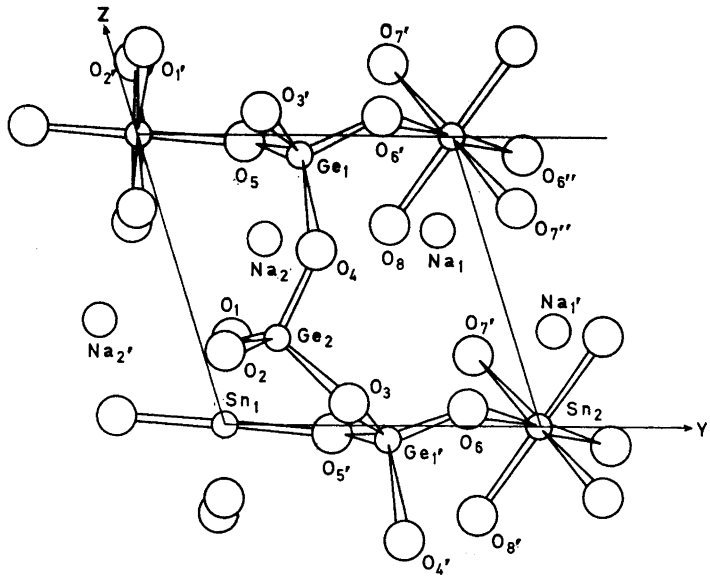

Fig. 1. Projection of a part of the structure along [100].

DISCUSSION

The X-ray structure analysis gave the chemical composition of the compound. The germanium atoms are tetrahedrally coordinated with oxygen atoms. The tetrahedra share corners and strings of germanium tetrahedra run along [001]. The tin atoms are octahedrally coordinated with oxygen atoms and corner sharing is used in connecting germanium tetrahedra with tin octahedra.

In the two germanium tetrahedra eight Ge – O distances were calculated. The mean distance was 1.730 Å, $\sigma = 0.003$ Å in fair agreement with the average Ge – O distance of 1.737 Å, $\sigma = 0.003$ Å, found by Smith and Isaacs [5] in the quartz modification of GeO_2, and the average Ge – O distance of 1.741 Å, $\sigma = 0.002$ Å, reported by Ingri and Lundgren [1] for the tetrahedrally coordinated germanium atoms in the $Na_4Ge_9O_{20}$ structure. The distances from Ge_1 to

Table 3. Observed and calculated structure factors.

h	k	l	Fo	Fc	h	k	l	Fo	Fc	h	k	l	Fo	Fc	h	k	l	Fo	Fc	h	k	l	Fo	Fc
1	-15	0	399	-402	3	7	0	170	-161	-1	-6	1	1119	1177	0	5	1	414	440	1	-10	2	174	163
2	-15	0	125	155	5	7	0	571	533	0	-6	1	133	82	1	5	1	817	-844	2	-10	2	636	649
1	-14	0	199	209	6	7	0	511	-505	1	-6	1	723	781	2	5	1	435	436	3	-10	2	289	285
2	-14	0	675	697	7	7	0	186	187	2	-6	1	744	737	3	5	1	413	405	4	-10	2	431	460
1	-13	0	432	429	0	8	0	1124	1187	3	-6	1	783	768	4	5	1	183	-181	5	-10	2	141	172
3	-13	0	307	-304	1	8	0	256	258	4	-6	1	116	117	-5	6	1	883	833	-6	-9	2	356	365
4	-13	0	299	307	2	8	0	400	399	5	-6	1	634	659	-4	6	1	410	377	-4	-9	2	446	-443
1	-12	0	553	584	3	8	0	560	556	-7	-5	1	201	-190	-3	6	1	269	264	-2	-9	2	136	130
3	-12	0	559	576	4	8	0	565	548	-6	-5	1	648	628	-2	6	1	1282	1308	-1	-9	2	237	244
4	-12	0	530	509	5	8	0	165	154	-5	-5	1	353	-361	-1	6	1	547	586	0	-9	2	600	-636
1	-11	0	144	131	0	9	0	243	242	-2	-5	1	397	376	0	6	1	483	507	1	-9	2	623	649
3	-11	0	524	541	1	9	0	762	-793	-1	-5	1	112	71	1	6	1	164	170	2	-9	2	158	-145
4	-11	0	398	-383	2	9	0	644	661	1	-5	1	993	1035	2	6	1	1426	1447	3	-9	2	310	-311
1	-10	0	538	555	4	9	0	120	89	2	-5	1	833	-819	3	6	1	499	479	6	-9	2	117	231
2	-10	0	571	601	5	9	0	256	-252	3	-5	1	108	-120	4	6	1	261	233	-6	-8	2	513	536
3	-10	0	554	577	6	9	0	120	115	5	-5	1	374	349	5	6	1	533	510	-4	-8	2	366	373
5	-10	0	698	689	1	10	0	420	427	-7	-4	1	486	477	6	6	1	266	315	-3	-8	2	724	748
6	-10	0	216	223	2	10	0	888	925	-6	-4	1	612	613	-5	7	1	248	247	-1	-8	2	363	380
1	-9	0	139	-138	4	10	0	569	534	-4	-4	1	722	698	-4	7	1	649	-629	0	-8	2	557	600
2	-9	0	111	-101	5	10	0	232	241	-3	-4	1	389	380	-3	7	1	615	579	1	-8	2	1136	1186
3	-9	0	127	-105	6	10	0	532	505	-2	-4	1	819	802	-2	7	1	118	94	2	-8	2	389	-378
5	-9	0	345	329	0	11	0	277	-274	-1	-4	1	107	80	-1	7	1	196	-215	3	-8	2	513	501
6	-9	0	500	-491	1	11	0	376	400	1	-4	1	908	949	1	7	1	184	197	4	-8	2	668	650
1	-8	0	180	179	3	11	0	181	-201	3	-4	1	927	898	2	7	1	516	522	5	-8	2	429	472
2	-8	0	516	521	4	11	0	425	404	4	-4	1	417	389	3	7	1	749	-760	-5	-7	2	288	-287
3	-8	0	507	510	5	11	0	108	-90	5	-4	1	712	710	4	7	1	568	545	-4	-7	2	586	573
4	-8	0	736	714	0	12	0	399	399	-7	-3	1	213	221	5	7	1	142	129	-3	-7	2	357	-370
5	-8	0	337	350	1	12	0	753	755	-6	-3	1	289	-276	-6	8	1	280	274	0	-7	2	124	131
6	-8	0	143	163	2	12	0	103	-86	-4	-3	1	636	615	-5	8	1	448	412	1	-7	2	197	189
1	-7	0	888	-936	3	12	0	667	663	-3	-3	1	630	-611	-4	8	1	304	276	2	-7	2	609	-621
2	-7	0	497	493	4	12	0	491	479	-2	-3	1	171	-152	-3	8	1	858	827	3	-7	2	870	836
5	-7	0	152	-161	5	12	0	234	233	-1	-3	1	410	-405	-1	8	1	605	650	4	-7	2	444	-448
6	-7	0	220	226	0	13	0	177	-151	0	-3	1	757	806	0	8	1	636	670	-6	-6	2	256	253
1	-6	0	1020	1055	2	13	0	109	-84	1	-3	1	684	-678	1	8	1	457	469	-5	-6	2	423	407
2	-6	0	1362	1361	3	13	0	316	313	2	-3	1	639	-581	2	8	1	176	167	-4	-6	2	724	703
4	-6	0	346	326	4	13	0	290	-278	3	-3	1	410	407	3	8	1	349	316	-2	-6	2	1149	1159
5	-6	0	452	445	0	14	0	198	192	4	-3	1	494	-469	4	8	1	867	799	-1	-6	2	529	514
6	-6	0	746	722	1	14	0	553	541	-7	-2	1	268	268	6	8	1	258	325	0	-6	2	656	672
1	-5	0	563	580	2	14	0	463	467	-5	-2	1	1051	1009	-4	9	1	189	178	2	-6	2	1158	1198
2	-5	0	239	231	3	14	0	282	289	-3	-2	1	458	461	-2	9	1	584	-576	3	-6	2	954	932
3	-5	0	471	-450	1	15	0	157	159	-2	-2	1	1263	1252	-1	9	1	571	574	4	-6	2	162	121
4	-5	0	501	446	0	-16	1	415	422	-1	-2	1	685	682	0	9	1	156	-148	5	-6	2	673	710
5	-5	0	192	-183	1	-16	1	410	391	1	-2	1	111	84	5	9	1	382	-352	-5	-5	2	152	151
7	-5	0	131	-148	-2	-15	1	347	-322	2	-2	1	1866	1956	6	9	1	291	327	-4	-5	2	178	-180
1	-4	0	883	931	-1	-15	1	298	282	3	-2	1	236	210	-5	10	1	477	463	-3	-5	2	103	95
2	-4	0	117	92	1	-15	1	183	-177	4	-2	1	425	401	-4	10	1	408	401	-2	-5	2	1162	1154
3	-4	0	1062	1012	3	-15	1	199	199	5	-2	1	579	551	-2	10	1	409	416	-1	-5	2	908	-917
4	-4	0	573	570	-3	-14	1	240	229	6	-2	1	289	421	-1	10	1	688	714	2	-5	2	465	449
6	-4	0	508	477	-2	-14	1	361	349	-5	-1	1	141	110	1	10	1	612	616	3	-5	2	407	-421
7	-4	0	307	320	-1	-14	1	672	669	-4	-1	1	707	-689	2	10	1	576	589	4	-5	2	105	107
1	-3	0	120	-142	0	-14	1	216	-214	-3	-1	1	469	468	3	10	1	529	506	5	-5	2	431	458
2	-3	0	168	-172	1	-14	1	450	456	-2	-1	1	478	443	5	10	1	464	495	-6	-4	2	222	203
3	-3	0	740	709	2	-14	1	411	415	-1	-1	1	720	-721	-4	11	1	122	53	-5	-4	2	410	398
4	-3	0	558	-546	3	-14	1	462	450	1	-1	1	104	86	-1	11	1	200	-179	-4	-4	2	114	104
5	-3	0	247	-241	-2	-13	1	306	286	2	-1	1	506	504	0	11	1	322	-303	-3	-4	2	1181	1192
6	-3	0	252	251	-1	-13	1	161	-144	3	-1	1	576	-558	1	11	1	591	588	-2	-4	2	721	746
1	-2	0	1132	1185	0	-13	1	220	-225	4	-1	1	706	663	2	11	1	171	-167	-1	-4	2	519	506
2	-2	0	433	433	1	-13	1	435	444	-7	0	1	524	499	4	11	1	176	-144	2	-4	2	781	781
3	-2	0	1232	1213	2	-13	1	132	-165	-6	0	1	387	380	5	11	1	282	272	3	-4	2	163	149
4	-2	0	119	-92	4	-13	1	150	-131	-5	0	1	322	285	-4	12	1	584	591	4	-4	2	1392	1304
5	-2	0	1239	1175	-4	-12	1	705	695	-4	0	1	324	305	-3	12	1	419	419	5	-4	2	171	174
6	-2	0	292	273	-3	-12	1	269	281	-1	0	1	1046	1056	-2	12	1	417	399	-7	-3	2	266	282
7	-2	0	262	242	-2	-12	1	373	384	1	0	1	896	935	-1	12	1	153	159	-6	-3	2	456	-464
1	-1	0	402	412	-1	-12	1	207	197	2	0	1	238	228	0	12	1	735	729	-5	-3	2	182	192
2	-1	0	317	-324	0	-12	1	753	779	3	0	1	335	318	1	12	1	512	531	-4	-3	2	147	-161
3	-1	0	281	-279	1	-12	1	528	544	4	0	1	1758	1750	2	12	1	132	151	-3	-3	2	293	288
4	-1	0	96	-94	3	-12	1	752	792	6	0	1	285	383	3	12	1	569	562	-2	-3	2	698	-715
5	-1	0	577	549	4	-12	1	365	378	-6	1	1	129	-148	4	12	1	316	303	-1	-3	2	231	231
6	-1	0	332	-293	-4	-11	1	362	348	-5	1	1	158	114	-3	13	1	330	-311	2	-3	2	284	-276
7	-1	0	174	158	-3	-11	1	222	-215	-1	1	1	1198	1181	0	13	1	285	274	4	-3	2	559	518
2	0	0	707	681	0	-11	1	520	549	0	1	1	90	-127	1	13	1	397	-376	5	-3	2	330	-308
3	0	0	649	619	1	-11	1	473	-515	1	1	1	310	-324	3	13	1	346	324	-6	-2	2	286	310
4	0	0	1001	953	2	-11	1	215	214	2	1	1	158	-185	-2	14	1	620	621	-5	-2	2	822	832
5	0	0	455	408	3	-11	1	152	139	3	1	1	740	723	-1	14	1	295	300	-4	-2	2	273	269
6	0	0	129	133	4	-11	1	296	-275	5	1	1	356	-369	0	14	1	391	382	-3	-2	2	279	271
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Table 3. Continued.

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1	12	2	293	272	0	-1	3	388	-416	-4	-10	4	664	604	0	5	4	331	331	-2	1	6	112	113
2	12	2	316	316	3	-1	3	239	-252	-3	-10	4	134	-84	2	5	4	348	-336	-1	1	6	363	-352
4	12	2	637	635	4	-1	3	468	-421	-2	-10	4	488	490	3	5	4	371	339	0	1	6	367	361
0	13	2	309	292	5	-1	3	567	632	-1	-10	4	447	432	-4	6	4	553	556	1	1	6	142	177
1	13	2	272	-283	-6	0	3	420	424	0	-10	4	764	778	-2	6	4	623	602	2	1	6	150	-155
2	13	2	143	153	-5	0	3	204	205	2	-10	4	722	710	-1	6	4	301	316	-2	2	6	184	198
0	-16	3	583	584	-4	0	3	464	479	3	-10	4	663	637	0	6	4	588	567	-1	2	6	234	225
1	-16	3	329	347	-3	0	3	264	256	5	-10	4	348	313	2	6	4	643	598	0	2	6	846	832
2	-16	3	278	284	-2	0	3	981	969	-4	-9	4	222	-194	3	6	4	804	778	2	2	6	522	528
0	-15	3	412	396	2	0	3	573	542	-2	-9	4	120	84	4	6	4	144	69	3	2	6	258	217
1	-15	3	328	-339	3	0	3	571	535	0	-9	4	148	-133	5	6	4	203	308	4	2	6	356	362
-2	-14	3	294	319	4	0	3	595	503	1	-9	4	248	-231	-2	7	4	270	284	-1	3	6	178	176
-1	-14	3	568	559	5	0	3	853	921	2	-9	4	646	676	1	7	4	291	279	1	3	6	239	-238
0	-14	3	427	407	-6	1	3	184	-205	3	-9	4	506	-480	2	7	4	586	533	2	3	6	475	439
2	-14	3	695	677	-4	1	3	238	242	4	-9	4	166	-176	3	7	4	238	-235	5	3	6	147	-164
3	-14	3	253	236	-2	1	3	307	-324	-5	-8	4	426	418	-3	8	4	595	597	-1	4	6	374	356
4	-14	3	341	311	-1	1	3	228	-239	-3	-8	4	782	713	-2	8	4	470	473	1	4	6	423	405
0	-13	3	254	-239	0	1	3	885	879	-2	-8	4	410	363	-1	8	4	154	118	2	4	6	511	451
1	-13	3	169	161	1	1	3	242	-285	-1	-8	4	153	130	0	8	4	348	341	4	4	6	421	407
3	-13	3	318	-319	4	1	3	119	103	0	-8	4	410	419	1	8	4	404	395	1	5	6	270	222
-3	-12	3	765	766	-5	2	3	896	921	1	-8	4	706	679	2	8	4	547	512	2	5	6	276	232
-2	-12	3	240	235	-4	2	3	332	329	2	-8	4	663	634	4	8	4	645	584					
-1	-12	3	430	438	-3	2	3	450	435	4	-8	4	660	567	5	8	4	152	225					
0	-12	3	276	286	-2	2	3	245	218	5	-8	4	343	345	-2	9	4	439	-428					
1	-12	3	799	798	-1	2	3	965	960	-3	-7	4	408	381	-1	9	4	194	137					

O_3' and O_4 have a mean value of 1.776 Å, $\sigma = 0.007$ Å, and the distances from Ge_1 to O_5 and O_6' have a mean value of 1.702 Å, $\sigma = 0.006$ Å. The distances from Ge_2 to O_3 and O_4 have a mean value of 1.763 Å, $\sigma = 0.007$ Å, and the distances from Ge_2 to O_1 and O_2 have a mean value of 1.712 Å, $\sigma = 0.007$ Å. This gives a mean value for the short Ge – O distances of 1.706 Å, $\sigma = 0.005$ Å, and a mean value for the longer Ge – O distances of 1.774 Å, $\sigma = 0.005$ Å. These distances are compared with the mean Ge – O distances in $Na_8Sn_4Ge_{10}O_{30}(OH)_4$ given by Larsen, Christensen and Rasmussen,[2] a short Ge – O distance of 1.722 Å, $\sigma = 0.005$ Å, a Ge – O distance of 1.754 Å, $\sigma = 0.004$ Å, and a longer Ge – OH distance of 1.791 Å, $\sigma = 0.006$ Å.

The oxygen atom O_3 is only bonded to two germanium atoms, and the oxygen atom O_4 is bonded to two germanium and two sodium atoms. From consideration of those distances it is assumed that O_3 and O_4 are oxygen atoms in OH^- ions. Before the last refinement cycle the hydrogen atoms H_1 and H_2 were inserted so that the distances were 1 Å to O_3 and O_4, respectively. However, the hydrogen atom H_1 moved close to O_7 in the last cycle of refinement.

The Sn – O distances from Sn_1 to O_1, O_2, and O_5' can be divided in two groups. $Sn_1 - O_1$ is 2.055 Å, $\sigma = 0.011$ Å, and the mean value of the two other distances is 2.013 Å, $\sigma = 0.007$ Å. The hypothesis that the two sets of Sn – O distances are equal can be rejected at the 5 % significance level.

The Sn – O distances from Sn_2 to O_6, O_7' and O_8' can be divided in two groups. $Sn_2 - O_7'$ is 2.007 Å, $\sigma = 0.010$ Å, and the mean value of the two other distances is 2.037 Å, $\sigma = 0.007$ Å. The hypothesis that the two sets of Sn – O distances are equal can be rejected at the 5 % significance level. Distorted SnO_6-octahedra were also found in the $Na_8Sn_4Ge_{10}O_{30}(OH)_4$-structure,[2] where Sn – O distances of 2.020 Å, $\sigma = 0.006$ Å, and 2.049 Å, $\sigma = 0.004$ Å, can be calculated. The oxygen atoms O_1, O_2, O_5, and O_6 are bonded to sodium, germanium, and tin atoms, and the oxygen atoms O_7 and O_8 are only bonded to sodium and tin atoms.

The two sodium ions in the structure, Na_1 and Na_2, are both coordinated with six oxygen atoms.

The crystal structure of $Na_4Sn_2Ge_4O_{12}(OH)_4$ has points of resemblance with that of $Na_8Sn_4Ge_{10}O_{30}(OH)_4$. Both have GeO_3-chains held together by sodium and tin atoms.

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