

08.2-2 CRYSTAL STRUCTURES OF AZIDES CONTAINING TWO DIFFERENT METAL ATOMS. By H. Krischner, Technical University Graz, AUSTRIA.

Azide compounds containing two different metal atoms can be prepared from aqueous solutions in various compositions and structure types. Crystal structure analyses of more than twenty azides demonstrate some general principles.

Elements with higher electronegativity have the greatest influence on the structures. They form finite or infinite metal-azide complexes. The coordination polyhedra are often similar to those in the simple azides. The apparent radii of the azide groups vary between 1.25 Å and 1.65 Å and can be taken as clue to the bonding strength. M-N-N-bond angles in finite complexes are about 120°.

Elements with lower electronegativity have various coordination numbers and are ionic bonded. M-N-N-bond angles vary between 80° and 180° and central nitrogen atoms of azide groups are sometimes located closer to the metal than terminal nitrogens. In potassium strontium azide hydrate both cations are distributed among identical lattice positions and form a series of solid solutions.

Azide groups are always coordinated with both terminal N-atoms to several metal atoms. The surroundings of the nitrogen atoms are irregular. N-N-bonds vary between 1.10 Å and 1.28 Å, the mean distance within azide groups amounts to 1.18 Å. The N-N-N-angles deviate somewhat from 180°.

Water is often situated beside azide groups within the coordination polyhedra.

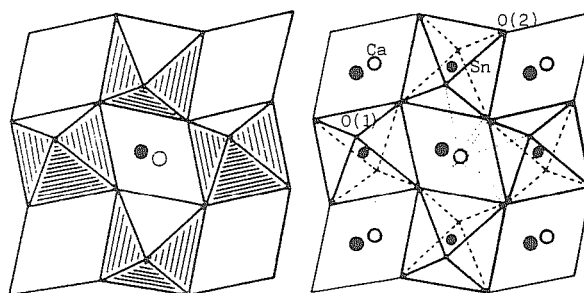


Fig.1

for octahedra lying in the *ab* plane (Fig.1) and 148.23(30)° for those linked parallel to the *c* axis, and corresponding to Sn...Sn distances of 3.963 and 3.953 Å, respectively (mean value 3.958 Å). From these distances, the "one-angle" radius for Sn can be evaluated as 1.98 Å. The Ca atoms appear eight-coordinated, at the center of an irregular bicapped trigonal prism, with Ca-O distances of 2x2.791(4), 2x2.640(4), 2.414(6), 2x2.364(4) and 2.344(6) Å. These bonds are represented as dotted lines in Figure 1.

The coordination numbers for anions are: four for O(1) (with two Sn at 2.063 Å and two Ca at distances of 2.344 and 2.414 Å) and five for O(2) (two Sn at 2.061 Å and three Ca at 2.364, 2.640 and 2.792 Å).

The SrSnO<sub>3</sub> crystals, whose orthorhombic unit cell dimensions would be approximately a = 5.702 b = 5.702 c = 8.064 Å, are receiving our attention.

08.2-3 THE CRYSTAL STRUCTURE OF CaSnO<sub>3</sub>. By A. Vegas, M.T. García-González\*, M. Vallet-Regí\*\* and J.M. González-Calbet\*\*, Instituto Elhuyar, CSIC, Madrid, \*Instituto de Edafología, CSIC, Madrid, \*\*Dpto. Química Inorgánica, Universidad Complutense, Madrid, Spain.

SrSnO<sub>3</sub> and CaSnO<sub>3</sub> have been reported to have a perovskite-like structure, the former being cubic, with  $a=2a_c$  ( $a_c$  is the cell parameter of the parent cubic perovskite E<sub>2</sub>) (Müller and Roy, The major ternary structural families, Springer Verlag, Berlin (1974)) and the last, orthorhombic, with cell dimensions  $a\sqrt{2}$ ,  $2a_c$ ,  $a\sqrt{2}$  (Coughanour, Roth and Fillmore, J. Research NBS (1954), 53, 201).

However, recent studies by electron diffraction and microscopy (Alario et al. (1983) unpublished results), suggest the existence of multitrinned crystals, in SrSnO<sub>3</sub>, leading to a cubic symmetry arising from the superposition of three orthorhombic (slightly distorted cubic) nets. Thus, the same cell-type of CaSnO<sub>3</sub> ( $a\sqrt{2}$ ,  $2a_c$ ,  $a\sqrt{2}$ ) must be assigned to SrSnO<sub>3</sub>. To elucidate the differences between both structures and to confirm the results obtained by electron microscopy, we have undertaken their crystal structure determination. The structure of CaSnO<sub>3</sub> is presented below.

CaSnO<sub>3</sub>, Pbnm,  $a=5.532(2)$   $b=5.681(2)$   $c=7.906(2)$  Å  $Z=4$ . The structure was solved from single crystal data, collected with Mo K $\alpha$  radiation and corrected for absorption. Anisotropic refinement using the high-order reflections ( $\sin \theta/\lambda > 0.40 \text{ \AA}^{-1}$ ) gave a final  $R=0.026$ .

The structure (Fig.1) is similar to that of CaTiO<sub>3</sub> and GdFeO<sub>3</sub>, and its relation with the parent cubic structure (E<sub>2</sub>) has been well established (O'Keefe and Hyde, Acta Cryst. (1977), B33, 3802). The SnO<sub>6</sub> octahedra are slightly compressed, with O-Sn-O angles from 87.65 to 92.35°, but with almost equal Sn-O bond-lengths (2.061-2.063(4) Å). The Sn-O-Sn angles are 146.65(30)°

08.2-4 STRUCTURAL ASPECTS OF THE PHASE TRANSITIONS IN TRICALCIUM SILICATE Ca<sub>3</sub>SiO<sub>5</sub> (=C<sub>3</sub>S)

Y. Takéuchi, F. Nishi, Mineralogical Institute, Faculty of Science, University of Tokyo, Hongo, Tokyo 113, and I. Maki, Department of Inorganic Materials, Nagoya Institute of Technology.

The crystal structure of the rhombohedral phase (Rh) of C<sub>3</sub>S, which is fundamental to those of the seven polymorphs of the material, has been determined based on a set of 371 diffraction intensities measured with a single-crystal diffractometer at 1200°C [ $a=7.135(6)$  Å,  $c=25.59(2)$  Å, R<sub>3m</sub>,  $Z=9 \times \text{Ca}_2.99\text{Al}_0.04\text{Si}_0.98\text{O}_5$ ,  $R=10\%$ ]. Although the structure is similar to the reported rhombohedral average structure (<M>) (Jeffery, Acta Cryst. (1952) 5, 56) of the monoclinic superstructure of the MI phase, it is highly characterized by orientational disorder of the silicate tetrahedra: (a) a fraction, by 70%, of one of the three independent tetrahedra on the threefold axis points the -*c*<sub>3</sub> direction (a D orientation), while the remaining fraction points the +*c*<sub>3</sub> direction (a U orientation), and (b) all tetrahedra are tilted in such a way that their apical bonds, otherwise on the threefold axis, slightly swing away from the threefold axis with Si's being kept in the axis.

The superstructure of MI has also been fully determined based on 3886 diffraction intensities [ $a=33.083(8)$  Å,  $b=7.027(2)$  Å,  $c=18.499$  Å,  $\beta=94.12(2)^\circ$ , Cm,  $Z=36 \times \text{Ca}_2.98\text{Mg}_{0.11}\text{SiO}_5$ ,  $R=9.9\%$ ]. Fig.1 shows the arrangement of the silicate tetrahedra in a plane corresponding to the mirror plane passing through the origin and parallel to (110) of Rh; the broken lines trace the cell of <MI>. In terms of the orientational characteristics with respect to the subcell axes, the silicate tetrahedra may be classified into three categories: (1) those having fixed orientations, (2) those showing disorder in the two orientations U and D (U-D disorder), and (3) those showing U-D-G disorder, where G (Fig.1) represents

a new type of orientation which is not found in the Rh structure. For each set of tetrahedra in the category (2), the fraction (%) of U is indicated in Fig.1, while for each set of tetrahedra in (3), those of U and D are indicated by a set of two numbers, the top indicating the fraction of U and the bottom that of D.

It is notable that the relative locations of Ca, Si, and the oxygen atoms, not bonded to Si, of MI are basically the same with those of Rh and TI (Golovastikov et al., Sov. Phys. Cryst. (1975) 20, 441). The series of phase transitions in C<sub>3</sub>S may hence be structurally characterized by the change in mode of orientational order-disorder of the silicate tetrahedra.

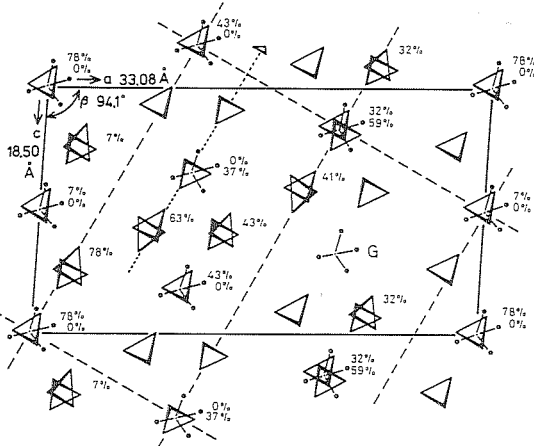


Fig.1 (one of the threefold axes of <MI> is indicated)

**08.2-5 NEW PRUSSIAN BLUE-RELATED CYANIDE CRYSTAL STRUCTURES: ONE-, TWO- AND THREEDIMENSIONAL LINKING OF HEXACYANO GROUPS BY HYDRATED CATIONS.** By M. Witzel and D. Babel, Sonderforschungsbereich 127 and Fachbereich Chemie der Philipps-Universität, Marburg, Germany

The cyanocomplexes listed in Table I were prepared and characterized by full single crystal structure determinations. The relations to the Fm3m structure types of elpasolites Cs<sub>2</sub>LiM(CN)<sub>6</sub> (B.I. Swanson and R.R. Ryan, Inorg. Chem. (1973) 12, 283) and prussian blue (A. Ludi et al., Inorg. Chem. (1970) 9, 2224; (1980) 19, 956) are discussed.

The alkali compounds are elpasolite variants, which contain Rb<sup>+</sup> or the hydrated ions (Na·H<sub>2</sub>O)<sup>+</sup> or (Li·2H<sub>2</sub>O)<sup>+</sup>, resp., in increasingly distorted octahedral N<sub>6</sub> cavities of six surrounding hexacyano groups. The resulting coordination is tetrahedral NaON<sub>3</sub> and LiO<sub>2</sub>N<sub>2</sub>, resp., for the smaller cations (M. Witzel and D. Babel, Z. Naturf. (1984) 39b, in press).

In the other compounds the M(II) ions Mn and Cd, resp., are octahedrally coordinated by 4H<sub>2</sub>O + 2N (trans) in the chain structure of the octahydrate (W. Kurtz and D. Babel, Solid State Commun. (1983) 48, 277) and by 4N + 2H<sub>2</sub>O (trans) in the layer structure of the tetrahydrate. In the "trihydrate" structure 1/5 of the M(II) ions have

only square pyramidal N<sub>5</sub>-coordination. These ions connect the square meshes of neighbouring layers in turn up and down in the third dimension, to produce a spacious framework. Additional uncoordinated water is hydrogen-bonded within the three structure types, which contrast by well defined and ordered MO<sub>n</sub>N<sub>6-n</sub> octahedra to the disordered species of the prussian blue structures.

Table I:

Compound (A=NMe <sub>4</sub> <sup>+</sup> )	S.G.	Z	a(pm)	b(pm)	c(pm)	β(°)
A <sub>2</sub> RbCo(CN) <sub>6</sub>	I4/m	2	884.7		1233.1	
A <sub>2</sub> RbFe(CN) <sub>6</sub>	R3m	3	886.7		2149.9	
A <sub>2</sub> NaFe(CN) <sub>6</sub> ·H <sub>2</sub> O	Pnma	4	1863.9	861.7	1317.2	
A <sub>2</sub> LiFe(CN) <sub>6</sub> ·2H <sub>2</sub> O	C2/c	4	1712.8	876.0	1625.4	119.3
ACdFe(CN) <sub>6</sub> ·3,2H <sub>2</sub> O	I4	10	1650.6		1725.7	
AMnMn(CN) <sub>6</sub> ·3,2H <sub>2</sub> O	I4	10	1653.2		1728.8	
AMnCr(CN) <sub>6</sub> ·4H <sub>2</sub> O	Pnma	4	1491.0	785.5	1723.5	
AMnCo(CN) <sub>6</sub> ·8H <sub>2</sub> O	P4/n	2	1062.2		1046.2	

**08.2-6 NEW METASTABLE TELLURIUM OXIDE PHASES WITH HIGHLY DISORDERED CaF<sub>2</sub> STRUCTURES**  
By M.Trömel, H.-G.Burckhardt, H.Heydarian, F.W. Hützler and E.Münch, Institut für Anorganische Chemie, D-6000 Frankfurt a.M. 50

By quenching SrO-TeO<sub>2</sub> melts, SrTe<sub>5</sub>O<sub>11</sub> is formed, in which the heavy atoms are distributed at random among the metal positions of a CaF<sub>2</sub> structure with incomplete oxygen packing (H.-G. Burckhardt, M.Trömel, Acta Cryst. (1983) C39, 1322). Extraordinarily high apparent temperature factors are due to large irregular displacements of all atoms. This kind of disorder (undefined short range order in spite of highly symmetrical long range order) results from tellurium being placed in a CaF<sub>2</sub>-type oxide which does not meet the geometrical requirements of the Te(IV) coordination. Similar phases are formed from TeO<sub>2</sub> and oxides of divalent and trivalent metals with ionic radii between 0.93 and 1.21 Å (Pb, Y, La, lanthanides). Their lattice constants (Å) and approximate formulae are:

SrTe <sub>5</sub> O <sub>11</sub>	5.655	Gd <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.611
PbTe <sub>3</sub> O <sub>7</sub>	5.647	Tb <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.600
Y <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.586	Dy <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.587
La <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.695	Ho <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.575
Pr <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.668	Er <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.567
Nd <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.655	Tm <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.551
Sm <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.638	Yb <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.537
Eu <sub>2</sub> Te <sub>6</sub> O <sub>15</sub>	5.617	Lu <sub>4</sub> Te <sub>7</sub> O <sub>20</sub>	5.491

CeTe<sub>6</sub>O<sub>(14-x)</sub> (a = 5.675 Å) is partly reduced when prepared from CeO<sub>2</sub> and TeO<sub>2</sub>. All phases decompose between 300 and 600°C, forming stable crystalline compounds.