

## STRONTIUM CERAMICS FOR CHEMICAL APPLICATIONS

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### Summary

Within this program more than 450 strontium containing perovskites and related compounds have been prepared and characterized by X-ray diffraction and electrical conduction. Many of these compounds exhibit conductivities approaching those of metals, even at room temperatures. These have considerable potential as electrochemical electrodes, while their high temperature stability under both oxidizing and reducing atmospheres suggests their applicability as MHD electrodes. Of particular interest are  $\text{La}_{0.55}\text{-Sr}_{0.15}\text{CoO}_3$ ,  $\text{La}_{0.8}\text{Sr}_{0.2}(\text{Co}_{0.8}\text{Ni}_{0.2})\text{O}_3$ ,  $\text{SrRuO}_3$ , all of which have resistivities below  $1 \text{ m}\Omega/\text{cm}$  at room temperature. At the other extreme are the insulating perovskites such as  $\text{SrTiO}_3$  and  $\text{SrZrO}_3$ . Since conductivities may vary by orders of magnitude for small variations in elemental composition or deviations from stoichiometry, the possibilities for tailoring these materials for specific requirements are legion. Add to this the high catalytic activity of a large percentage of the compounds and their interest and importance can readily be appreciated.

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### Introduction

Recently, considerable attention has been addressed to strontium containing compounds [1], particularly those exhibiting electrical conductivities approaching those of metals. Electrically-conductive ceramics largely based on strontium-containing perovskites and related structures commend themselves as potential electrodes in a wide range of electrochemical processes involving aqueous and molten electrolytes. Additionally, many of these same materials are highly active catalysts extending still further their range of interest.

As early as 1968 - 1969, Meadowcroft [2] advocated the use of lanthanum strontium chromite or cobaltite as oxygen electrode materials in fuel

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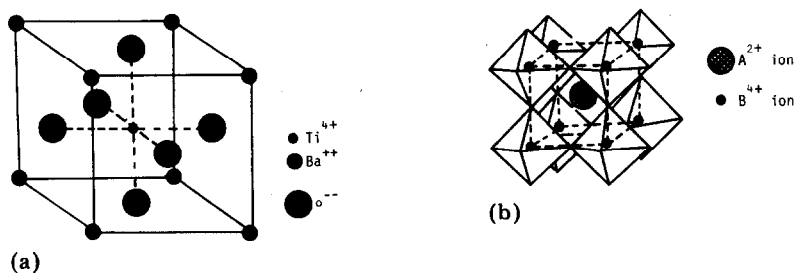


Fig. 1. (a) The perovskite crystal structure of barium titanate. The prototype crystal is calcium titanate (perovskite). The structure is cubic with Ba<sup>2+</sup> ions at the cube corners, O<sup>2-</sup> ions at the face corners and a Ti<sup>4+</sup> ion at the body centre. (b) Perovskite structure ABO<sub>3</sub> considered as a three-dimensional framework of BO<sub>6</sub> octahedra.

cells and also identified the chromite as a potential MHD electrode material having regard to its high temperature properties. Previously, the importance of strontium additions to lanthanum chromite and cobaltite had been established by Jonker [3]. Recently, Takahashi [4] and others have investigated oxygen ion conduction in nonstoichiometric perovskites adding yet another area of interest.

### Crystal structure

Generically, perovskites are structurally related to the mineral perovskite, CaTiO<sub>3</sub>, originally believed to be a cubic structure ABO<sub>3</sub>. However, Megaw [5] has established that the mineral is actually orthorhombic whereas SrTiO<sub>3</sub> possesses the ideal cubic "perovskite" structure. The structure is illustrated in Fig. 1 in which each A cation is coordinated with twelve oxygen ions and each B cation with six. A prerequisite to stability is the existence of a stable BO<sub>3</sub> skeletal structure which obtains when  $r_B > 0.51 \text{ \AA}$  for oxides with  $r_A > 0.90 \text{ \AA}$ . The criteria for a stable perovskite structure can best be defined on the basis of size limitations after Goldschmidt [6] by a tolerance factor,  $T$ , defined as:

$$T = (r_A + r_O) / \sqrt{2}(r_B + r_O)$$

where  $r_A$ ,  $r_B$  and  $r_O$  are the appropriate ionic radii, respectively. For stability  $T$  must lie in the range  $1 > T > 0.5$ . Within these limitations, and providing the net ionic charge balance is maintained, a very wide range of compositions can be accommodated within the perovskite structure, particularly when it is appreciated that both A and B ion sites can accommodate a number of different ions simultaneously and also that the structure will tolerate considerable deviation from stoichiometry.

In reviewing the many perovskites, it is convenient to classify them in very broad groups as A<sup>+</sup>B<sup>5+</sup>O<sub>3</sub>, A<sup>2+</sup>B<sup>4+</sup>O<sub>3</sub>, A<sup>3+</sup>B<sup>3+</sup>O<sub>3</sub> and the complex

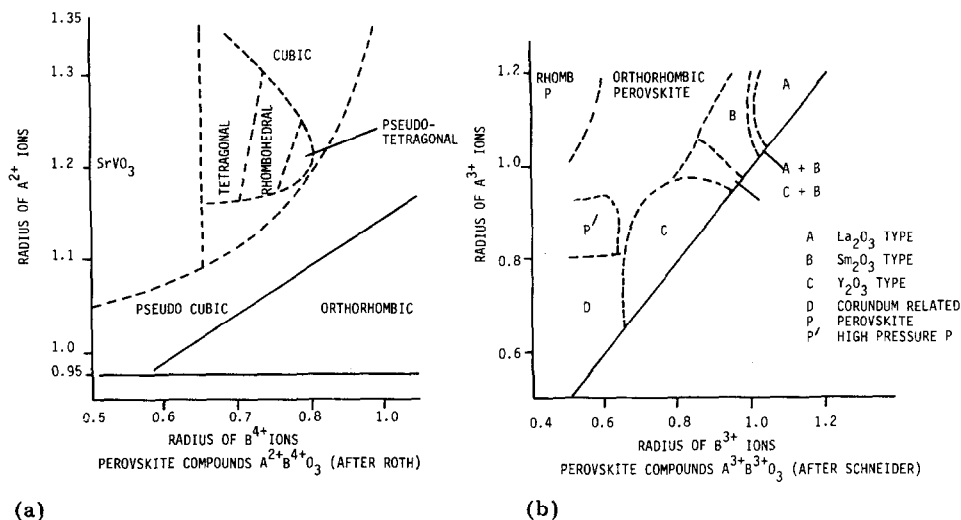


Fig. 2. Crystal habit of perovskite compounds  $A^{2+}B^{4+}O_3$  after Roth [7], and of perovskite compounds  $A^{3+}B^{3+}O_3$  after Schneider [8].

perovskites and related compounds. The first group, typical of which are the alkali metal niobates and tantalates (e.g.,  $KNbO_3$  and  $KTaO_3$ ), can also be construed to include the "tungsten bronze" structures  $Na_xWO_3$  or, more generally, the nonstoichiometric oxides  $A_xB^{6+}O_3$  where  $x$  can vary over the range 0.33 - 0.95.

While the crystal habit of  $A^{2+}B^{4+}O_3$  and  $A^{3+}B^{3+}O_3$  have been described in Fig. 2(a) and (b), after Roth [7] and Schneider [8], respectively, many exceptions are observed and the former (Fig. 2(a)) has very limited applicability owing to ferroelectric distortions and to the development of complex structures with variable layer sequences.

Providing the net charge and size criteria are met, there are also a wide range of complex perovskites with multiple layer sequences where the A and B sites are occupied by two or more different ions. These are of particular significance in the context of electrode and electrocatalytic materials, since great attention has been accorded to the rare earth-strontium transition metal oxide systems, typical of which are the  $La_{0.85}Sr_{0.15}CoO_3$  fuel cell oxygen electrodes.

A partial listing of strontium-containing perovskites is given in Appendix 1, although it should be emphasized that the great tolerance of the perovskite structure to deviations from stoichiometry, which materially affects both the electrical and catalytic properties, provides room for a very large number of compounds, indeed.

## Preparation of strontium containing perovskites

The techniques for the preparation of strontium containing perovskites can be roughly divided into two groups, depending on the means of homogenization. The first group comprises the classical ceramic methods of mechanical mixing of the ingredients, wet or dry ball milling, and progressive thermal treatment. The second group is characterized by chemical processes from solution to yield homogeneous products or their calcinable precursors. These techniques include precipitation, spray or freeze drying, and flame hydrolysis, all used to a greater or lesser extent in the electronic ceramics industry. Frequently, combinations of these approaches are used, such as mixing and ball milling the appropriate precipitated precursors.

A shortcoming of mechanical processing is the relatively poor homogeneity and the necessity of regrinding the partially converted material to ensure complete conversion. The high temperatures encountered also lead to undesirable grain growth. Nevertheless, the process is simple and yields product of the desired composition and overall stoichiometry at low cost. Oxides and carbonates are the normal raw materials but their reactivity is relatively low. A preferred precursor would be an oxalate which yields a more homogeneous product at lower temperatures.

Precipitation and co-precipitation are widely employed techniques when a fine particle size reactive product is required. The former is generally employed when a single phase product is desired, while the latter is more appropriate when two or more phases may be present in the precipitate. Caution must be observed in these techniques to avoid deviation from stoichiometry which frequently occurs due to partial solubility of one component either directly or by formation of a complex with the precipitant. This is frequently encountered in the use of ammonia when transition metal ions are present. In the case of strontium compounds, the considerable solubility of strontium hydroxide, particularly at elevated temperatures, must be avoided. The preferred coprecipitation technique for moderate to large quantities initiated by Gray [9] is illustrated in Fig. 3. Complex formation is avoided by operating at an elevated temperature and by immediate dilution and washing of the precipitate formed from the converging jets of mixed solution and precipitant dispersed by a rotating propeller. For larger quantities the jets can be directly immersed in hot, distilled water rapidly circulating through a continuous vacuum filtration system. Compositional accuracy of better than 0.1% can readily be achieved by this apparatus. While hydrous oxides are normally used to produce very fine particle size, catalytically active co-precipitates, these must be avoided in the case of strontium compounds owing to the high solubility of  $\text{Sr}(\text{OH})_2$  in hot solutions.

Flame hydrolysis can frequently be used for the direct preparation of strontium containing perovskites without the necessity for firing the precursors. The technique involves the combustion of alcoholic or alternative solutions of the components in an oxygen-inert gas flame, preferably using a vortex type burner with cyclone, and electrostatic collection of the micron

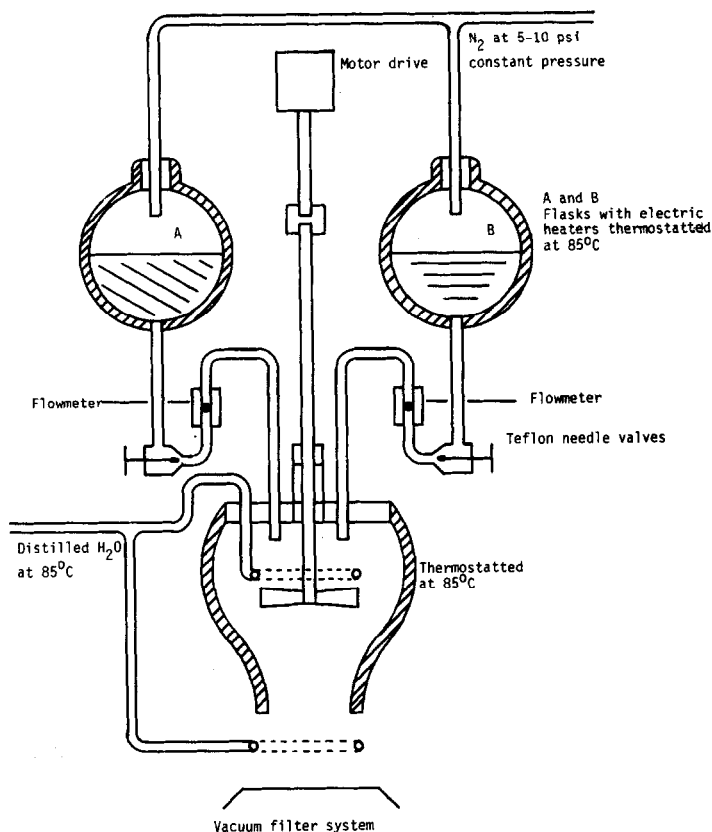


Fig. 3. Apparatus for the coprecipitation method of preparation of strontium containing perovskites.

and submicron product. Spray drying, freeze drying, and related techniques are all applicable with a preference for nitrates as the starting materials. These techniques are, again, most appropriate for ultra fine grain size.

### Calcination and fabrication

In many instances, particularly when preparing electrocatalytic specimens, a low firing temperature is desirable, thereby precluding the use of mechanical preparative techniques involving oxides, carbonates, and similar components requiring high dissociation and reaction temperatures. With these compounds, temperatures of  $850 - 1200^\circ C$  are generally required for complete conversion to the perovskite, as indicated by periodic X-ray analyses. Oxalates represent a suitable choice for low temperature conversion.

Fabrication to electrodes is preferably by isostatic pressing, although plasticized film techniques are equally applicable for longer, flat electrodes.

Porous electrodes can readily be prepared by the open-pore foam saturation technique followed by carefully controlled firing schedules. In the case of electrodes for high stability at elevated temperatures such as  $\text{La}_{0.8}\text{Sr}_{0.2}\text{CrO}_3$ , prefiring of the isostatically pressed specimen at 1000 °C, followed by electrolytic acid leach to remove any surface transition metal oxide excess before firing to high temperature, ensures optimum stability by eliminating degradation by loss of  $\text{CrO}_3$ .

It should be noted that in certain instances the "active" phase for electrocatalysis, tentatively identified as a  $\text{K}_2\text{NiF}_4$  structure, only develops to a significant extent after relatively high temperature sintering of the non-stoichiometric perovskite. This structure has been described by Rüdorff [10] and is closely related to the perovskite structure. Ruddlesden and Popper [11] have described isostructural compounds including  $\text{Sr}_2\text{TiO}_4$  and  $(\text{Sr}, \text{La})\text{AlO}_4$ .

### Lanthanum strontium cobaltite

One of the most interesting of the potential electrode materials for chemical applications is lanthanum strontium cobaltite, the subject of a patent by Meadowcroft [2] as a fuel cell oxygen electrode. The earlier work of Jonker [3] had established the advantage to electrical conductivity from the introduction of strontium into lanthanum cobaltite. Raccach and Goodenough [12] had described the properties of  $\text{La}_{1-x}\text{Sr}_x\text{CoO}_3$  in terms of the coexistence of itinerant and localized electrons in the same crystallographic phase. However, based on Mössbauer measurements in conjunction with conductivity and thermal e.m.f. measurements, Mott [13] has reinterpreted the data, drawing attention to the implication from experimental data that the hopping mechanism at low values of  $x$  for which the material is a semiconductor starts to change for  $x = 0.125$ . At this composition, the hopping time from hole to hole is of the same order of magnitude as the lifetime of the nuclear excited state,  $10^{-7}$  s. For the composition  $x = 0.2$  and greater, the hopping time has decreased significantly and conduction is metallic.

Lattice parameters for  $\text{La}_{1-x}\text{Sr}_x\text{CoO}_3$  are given in Table 1. Increasing substitution of lanthanum by strontium decreases the rhombohedral angle, noticeable by the increase in the hexagonal axis ratio,  $c/a$ .

Substitution of up to 25% Ni in replacement of Co has little effect on the resistivity, whereas the introduction of Cr or Mo increases resistivity by more than an order of magnitude.

It is interesting at this juncture to compare the effect of substitution of other alkaline earth elements, illustrated in Table 2. Meadowcroft [2] in his investigation of  $\text{La}_{1-x}\text{Sr}_x\text{CoO}_3$  as an oxygen electrode established that there was an abrupt increase in activity and concurrent resistivity for a cobalt deficiency down to  $\text{Co}_{0.9}$  with the appearance of a second phase. This has been identified by Gray *et al.* [9] as a phase with the  $\text{K}_2\text{NiF}_4$  structure.

TABLE 1

Nominal composition	Phases	Lattice parameters of perovskite phase	Remarks
LaCoO <sub>3</sub>	Rhombohedral perovskite	$a = 5.439, c = 13.100$ $c/a = \sqrt{5.805}$	Semiconductor $r_{20^\circ\text{C}} = 4.9 \times 10^{-2}$ $\Omega/\text{cm}$
La <sub>0.85</sub> Sr <sub>0.15</sub> CoO <sub>3</sub>	Rhombohedral perovskite	$a = 5.436, c = 13.125$ $c/a = \sqrt{5.83}$	Semiconductor $r_{20^\circ\text{C}} = 1.4 \times 10^{-3}$ $\Omega/\text{cm}$
La <sub>0.80</sub> Sr <sub>0.20</sub> CoO <sub>3</sub> and La <sub>0.75</sub> Sr <sub>0.25</sub> CoO <sub>3</sub>	Rhombohedral perovskite	Decreased rhombohedral distortion and $220_c < 404\text{rh}$ splitting 440rh No longer measurable	Metallic
La <sub>0.5</sub> Sr <sub>0.5</sub> CoO <sub>3</sub>	Rhombohedral	—	Metallic $r_{20^\circ\text{C}} = 8.4 \times 10^{-4}$ $\Omega/\text{cm}$
La <sub>0.33</sub> Sr <sub>0.67</sub> CoO <sub>3</sub>	Rhombohedral	—	Semiconductor $r_{20^\circ\text{C}} = 2 \times 10^{-3}$ $\Omega/\text{cm}$
La <sub>0.16</sub> Sr <sub>0.84</sub> CoO <sub>3</sub>	Rhombohedral	—	Semiconductor $r_{20^\circ\text{C}} = 1.2 \times 10^{-3}$ $\Omega/\text{cm}$
SrCoO <sub>3</sub>	Cubic	7.74	Semiconductor $r_{20^\circ\text{C}} = 3 \times 10^{-1}$ $\Omega/\text{cm}$

TABLE 2

Nominal composition	$c/a$ ratio (hexagonal indexing)	Relative resistivity at room temperature
LaCoO <sub>3</sub>	$\sqrt{5.805}$	12.0
La <sub>0.8</sub> Ca <sub>0.2</sub> CoO <sub>3</sub>	$\sqrt{5.906}$	6.20
La <sub>0.8</sub> Ca <sub>0.1</sub> Sr <sub>0.1</sub> CoO <sub>3</sub>	—	3.88
La <sub>0.8</sub> Sr <sub>0.2</sub> CoO <sub>3</sub>	$\sqrt{5.868}$	1.00
La <sub>0.8</sub> Sr <sub>0.1</sub> Ba <sub>0.1</sub> CoO <sub>3</sub>	—	1.44
La <sub>0.8</sub> Ba <sub>0.2</sub> CoO <sub>3</sub>	$\sqrt{5.925}$	1.92

### K<sub>2</sub>NiF<sub>4</sub> structures containing strontium

While primary emphasis has been accorded strontium containing perovskites. it has already been observed that, at least in the case of lanthanum

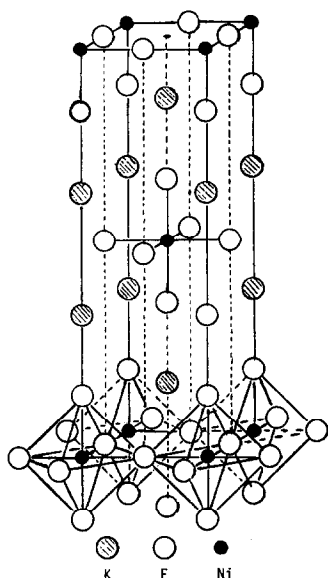


Fig. 4. The  $K_2NiF_4$  structure after Balz and Plieth [14].

TABLE 3

Strontium containing compounds with the  $K_2NiF_4$  structure

Compound	<i>a</i>	<i>c</i>	Comments and reference
$Sr_2ZrO_4$	4.112	12.58	R. Scholder, D. Rade and H. Schwarz, <i>Z. Anorg. Allg. Chem.</i> , 362 (1968) 149.
$Sr_2HfO_4$	4.089	12.52	<i>Ibid</i>
$Sr_2MoO_4$	3.92	12.84	D. Balz and K. Plieth, <i>Z. Elektrochem.</i> , 59 (1955) 545.
$Sr_2TiO_4$	3.88	12.60	<i>Ibid</i>
$Sr_2MnO_4$	3.79	12.43	<i>Ibid</i>
$Sr_2IrO_4$	3.89	12.92	J. J. Randall, L. Katz and R. Ward, <i>J. Am. Chem. Soc.</i> , 79 (1957) 266; 81 (1959) 2629.
$Sr_2RuO_4$	3.87	12.74	<i>Ibid</i>
$Sr_2RhO_4$	3.85	12.90	<i>Ibid</i>
$Sr_2SnO_4$	4.037	12.53	R. Weiss and R. Faivre, <i>C. R. Acad. Sci.</i> , 248 (1959) 106.
$Sr_2FeO_{3.7}$	3.864	12.390	Oxygen deficient phase, P. K. Gallagher, J. B. MacChesney and D. N. E. Buchannan, <i>J. Chem. Phys.</i> , 45 (1966) 2466. M. Shimada and M. Koizumi, <i>Mater. Res. Bull.</i> , 11 (1976) 1237.
$SrLaFeO_4$	3.880	12.687	} J. C. Joubert, A. Collomba, D. Elmalah, G. LeFlem, A. Douadi and G. Ollivier, <i>J. Solid State Chem.</i> , 2 (1970) 343.
$SrPrFeO_4$	3.861	12.554	
$SrNdFeO_4$	3.855	12.535	
$SrSmFeO_4$	3.851	12.458	
$SrEuFeO_4$	3.849	12.444	
$SrGdFeO_4$	3.848	12.438	



TABLE 4

Strontium containing  $K_2NiF_4$  related structures

Sr <sub>3</sub> Ti <sub>2</sub> O <sub>7</sub> type			Sr <sub>4</sub> Ti <sub>3</sub> O <sub>10</sub> type		
Composition	a	c	Composition	a	c
Sr <sub>3</sub> Ti <sub>2</sub> O <sub>7</sub>	3.90	20.38	Sr <sub>4</sub> Ti <sub>3</sub> O <sub>10</sub>	3.90	28.1
Sr <sub>3</sub> Ir <sub>2</sub> O <sub>7</sub>	3.90	20.90	Sr <sub>4</sub> Ir <sub>3</sub> O <sub>10</sub>	3.93	28.4
Sr <sub>3</sub> Zr <sub>2</sub> O <sub>7</sub>	a = 5.798	20.94	Sr <sub>4</sub> Zr <sub>3</sub> O <sub>10</sub>	a = 5.795	29.34
(ortho-R distortion)	b = 5.808		(ortho-R distortion)	b = 5.814	
Sr <sub>3</sub> Cr <sub>2</sub> O <sub>7</sub>	3.82	20.1			
Sr <sub>3</sub> Fe <sub>2</sub> O <sub>6,9</sub>	3.853	20.149			
Sr <sub>3</sub> Fe <sub>2</sub> O <sub>6</sub>	3.892	20.054			

strontium cobaltite, the electrocatalytic activity can be correlated with the coexistence of a  $K_2NiF_4$  phase. This structure is tetragonal and closely related to the perovskite structure with empirical constitutions such as  $A_2^+B^{6+}O_4$ ,  $A_2^{2+}B^{4+}O_4$ ,  $A^{2+}A^{3+}B^{3+}O_4$  and other combinations with the same ionic charge balance. The structure after Balz and Plieth [14] is illustrated in Fig. 4. Table 3 lists a few of the more interesting compounds which readily form during the preparation of the corresponding perovskite.

Several related structures have also been described as orthorhombically deformed  $K_2NiF_4$  structures. Typical of these are Sr<sub>2</sub>CuO<sub>3</sub> [15] and Sr<sub>2</sub>PdO<sub>3</sub> [16], while the tetragonal titanates, Sr<sub>3</sub>Ti<sub>2</sub>O<sub>7</sub> and Sr<sub>4</sub>Ti<sub>3</sub>O<sub>10</sub>, have been considered by Ruddlesden and Popper [11] as being intermediate between the perovskite SrTiO<sub>3</sub> and  $K_2NiF_4(Sr_2TiO_4)$  structures.

Some strontium containing compounds exhibiting these structures are given in Table 4.

### Acknowledgements

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## Appendix I

### Strontium containing perovskites

(c = cubic; Rh = rhombohedral; O = orthorhombic; Tet = tetragonal; M = monoclinic; Hex = Hexagonal.)

Compound	Type	a	b	c	Comments and references
SrCeO <sub>3</sub>	O	6.011	6.156	8.588	A. J. Smith and A. J. E. Welch, <i>Acta Crystallogr.</i> , 13 (1960) 653; A. Hoffman, <i>Z. Phys. Chem.</i> , 28 (1935) 65.
SrCoO <sub>3-x</sub>	C	7.725	—	—	H. L. Yakel, <i>Acta Crystallogr.</i> , 8 (1955) 394; Solid solution with La: H. Watanabe, <i>J. Phys. Soc. Jpn.</i> , 12 (1957) 515.
SrCrO <sub>3</sub>	C	3.818	—	—	B. L. Chamberland, <i>Solid State Commun.</i> , 5 (1967) 663. Sr <sub>x</sub> La <sub>1-x</sub> CrO <sub>3</sub> ; Rh for x > 0.2 Pseudocubic a = 3.87. Sr <sub>0.5</sub> La <sub>0.5</sub> CrO <sub>3-x</sub> — cubic 7.754 — H. Yakel, <i>Acta Crystallogr.</i> , 8 (1955) 394.
SrFeO <sub>2.84</sub>	Tet	3.851	—	3.867	J. B. MacChesney, R. C. Sherwood and J. F. Potter, <i>J. Chem. Phys.</i> , 43 (1965) 1907.
SrFeO <sub>2.5</sub>	O	5.671	15.59	5.528	H. J. Watanabe, <i>J. Phys. Soc. Jpn.</i> , 12 (1957) 515; H. L. Yakel, <i>Acta Crystallogr.</i> , 8 (1955) 394; P. K. Gallagher, J. B. MacChesney and D. N. E. Buchanan, <i>J. Chem. Phys.</i> , 41 (1964) 2429; G. Shirane, D. E. Cox and S. L. Ruby, <i>Phys. Rev.</i> , 125 (1962) 1158; Solid solutions with La: P. K. Gallagher and J. B. MacChesney, <i>Symp. Faraday Soc.</i> , 1 (1967) 40; J. S. Waugh, <i>Tech. Rept., MIT Labs for Insulation Res.</i> , 1960; SS with Bi: J. B. MacChesney, J. J. Jetzt, J. F. Potter, H. J. Williams and R. C. Sherwood, <i>J. Am. Ceram. Soc.</i> , 49 (1966) 64; SS with Ti: T. R. Clevenger, <i>J. Am. Ceram. Soc.</i> , 46 (1963) 207; L. H. Brixner, <i>Mater. Res. Bull.</i> , 3 (1968) 299; J. B. MacChesney, <i>Mater. Res. Bull.</i> , 3 (1968) 299.
SrFeO <sub>2.5</sub>	O	5.671	15.59	5.528	J. B. MacChesney, <i>Mater. Res. Bull.</i> , 3 (1968) 299; P. Batti, <i>Ann. Chim. (Rome)</i> , 52 (1962) 941.
SrHfO <sub>3</sub>	C	4.069	—	—	A. Hoffman, <i>Z. Phys. Chem.</i> , 28 (1935) 65; I. Naray-Szabo, <i>Publ. Tech. Univ. Budapest</i> , 1 (1947) 30; Solid solution with Zr: A. S. Berezhnoi, V. Ya Belik, A. M. Gavriush and N. V. Gulko, <i>Izv. Akad. Nauk SSSR, Neorg. Mater.</i> , 4 (1968) 1605.

Compound	Type	a	b	c	Comments and references
SrIrO <sub>3</sub>	M	5.60	9.62	14.17	( $\beta = 93^{\circ}16'$ ) J. M. Longo, J. A. Kafalas and R. J. Arnett, <i>J. Solid State Chem.</i> , 3 (2) (1971) 174. High pressure phase.
SrMnO <sub>3</sub>	Hex	5.449	—	9.085	High pressure phase, Y. Syono, S. Akimoto and K. Kohn, <i>Tech. Rep. Inst. Solid State Phys., Univ. Tokyo</i> , A 337 (1968). Also solid solutions with (Bi, Ba, La) MnO <sub>3</sub> , V. V. Ivonova and Yu. N. Venevstev, <i>Izv. Akad. Nauk SSSR, Ser. Fiz.</i> , 31 (1967) 1803.
SrMoO <sub>3</sub>	C	3.98	—	—	R. Scholder and W. Klemm, <i>Angew. Chem.</i> , 66 (1954) 461; R. Scholder and L. Brixner, <i>Z. Naturforsch.</i> , 10b (1955) 178; G. M. Bouchard and M. J. Sienko, <i>Inorg. Chem.</i> , 7 (1968) 441; Solid solutions with Ti and Zr, L. H. Brixner, <i>J. Inorg. Nucl. Chem.</i> , 15 (1960) 356.
SrPbO <sub>3</sub>	O	5.864	5.949	8.336	R. Weiss, <i>C. R. Acad. Sci.</i> , 246 (1958) 3073.
SrPuO <sub>3</sub>	C	4.28	—	—	C. Kelley, <i>Nukleonik</i> , 4 (1962) 271.
SrRuO <sub>3</sub>	O	5.53	5.57	7.85	J. J. Randall and R. Ward, <i>J. Am. Ceram. Soc.</i> , 81 (1959) 2629; A. Callaghan, C. W. Moeller and R. Ward, <i>Inorg. Chem.</i> , 5 (1966) 1572.
SrRu <sub>0.5</sub> Ir <sub>0.5</sub> O <sub>3</sub>	O	5.55	5.58	7.84	D. D. Khanolkor, <i>Current Sci.</i> , 3 (1961) 52; J. M. Longo, P. M. Raccoh and J. B. Goodenough, <i>J. Appl. Phys.</i> , 39 (1968) 1327.
SrSnO <sub>3</sub>	C	8.070	—	—	A. J. Smith and A. J. E. Welch, <i>Acta Crystallogr.</i> , 13 (1960) 653; A. Hoffman, <i>Z. Phys. Chem.</i> , 28 (1935) 65; H. D. Megaw, <i>Proc. Phys. Soc. (London)</i> , 58 (1946) 133; W. W. Coffeen, <i>J. Am. Ceram. Soc.</i> , 36 (1953) 207.
SrTeO <sub>3</sub>	C	3.95	—	—	O. Muller, W. B. White and R. Ray, <i>J. Inorg. Nucl. Chem.</i> , 26 (1964) 2075; C. Keller and M. Wossilopoulos, <i>Radiochem. Acta</i> , 5 (1966) 87.
SrThO <sub>3</sub>	C	8.84	—	—	St. V. Noray-Szako, <i>Publ. Tech. Univ. Budapest</i> , 1 (1947) 30; Solid solution with Ba: A. S. Bereznoi and V. Ya. Belik, <i>Dopov. Akad. Nauk Ukr. SSSR</i> , 38 (1967) 708.

Compound	Type	a	b	c	Comments and references
SrTiO <sub>3</sub>	C	3.905			>110 K, H. D. Megaw, <i>Proc. Phys. Soc. (London)</i> , <b>A189</b> (1946) 261; 65 - 110 K, F. W. Lytle, <i>J. Appl. Phys.</i> , <b>35</b> (1964) 2212.
	Tet	3.8972		3.8991	and <i>Adv. X-ray Anal.</i> , Vol. 7, Plenum Press, New York, 1964. <i>a:b:c</i> 0.9998: 1:1.0002 (35 - 65 K) Orthorhombic. At 10 K Rhombohedral.
SrTiS <sub>3</sub>	Hex	6.730		5.829	H. Hahn and W. Mutschke, <i>Z. Anorg. Allg. Chem.</i> , <b>288</b> (1956) 269. Also orthorhombic and tetragonal modifications.
SrUO <sub>3</sub>	O	6.01	6.17	8.60	S. M. Lang, <i>NBS Circ.</i> 568, 1956.
SrVO <sub>3</sub>	C	3.838			M. Kesligian, J. G. Dickinson and R. Ward, <i>J. Am. Chem. Soc.</i> , <b>79</b> (1957) 5598.
SrVO <sub>2.5</sub>	C	3.848			M. Wollnik, <i>M. Thesis, Tech. Univ. Berlin</i> , 1965.
SrZrO <sub>3</sub>	O	5.792	5.818	8.189	Y. Perez, M. Jorba, G. Tilloca and R. Collanges, <i>C. R. Acad. Sci.</i> , <b>260</b> (1965) 170; A. Hoffman, <i>Z. Phys. Chem.</i> , <b>28</b> (1935) 65; H. D. Megaw, <i>Proc.</i> <i>Phys. Soc. (London)</i> , <b>58</b> (1946) 133; A. J. Smith and A. J. E. Welch, <i>Acta</i> <i>Crystallogr.</i> , <b>13</b> (1960) 653; R. Scholder, D. Rade and H. Schwarz, <i>Z.</i> <i>Anorg. Allg. Chem.</i> , <b>362</b> (1968) 149. Solid solution with Hf, A. S. Berezhnoi, V. Ya. Belik, A. M. Gavrish and N. N. Gulkov, <i>Izv. Akad. Nauk</i> <i>SSSR, Neorg. Mater.</i> , <b>4</b> (1968) 1605.
SrZrS <sub>3</sub>	O	13.49	9.79	14.23	A. Clearfield, <i>Acta Crystallogr.</i> , <b>16</b> (1963) 134; A. U. Novoselova and L. A. Aslanov, <i>Dokl. Akad. Nauk SSSR, Phys. Chem.</i> , <b>172</b> (1967) 357.

(Appendix II overleaf)

## Appendix II

Strontium containing perovskites — type  $\text{Sr}_2\text{B}'\text{B}'\text{O}_6$ 

Compound	Type	a	b	c	Comments and references
$\text{Sr}_2\text{AlNbO}_6$	C	7.784			V. S. Filipev and E. G. Fesenko, <i>Kristallografiya</i> , 10 (1965) 626.
$\text{Sr}_2\text{CaNbO}_{5.5}$	C	8.20			F. Galasso, L. Katz and R. Ward, <i>J. Am. Chem. Soc.</i> , 81 (1959) 820.
$\text{Sr}_2\text{CoNbO}_6$	C	3.93			G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.
$\text{Sr}_2\text{CrNbO}_6$	C	7.87			G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993. L. H. Brixner, <i>J. Phys. Chem.</i> , 64 (1960) 165.
$\text{Sr}_2\text{MnNbO}_6$	Rh	3.97			$\alpha \approx 90^\circ$ . E. E. Havinga, <i>Philips Res. Rpts.</i> , 21 (1966) 432; M. F. Kupriyanov and V. S. Filipev, <i>Kristallografiya</i> , 8 (1963) 356.
$\text{Sr}_2\text{FeNbO}_6$	Tet C	3.960 3.968		3.980	M. F. Kupriyanov and E. G. Fesenko, <i>Kristallografiya</i> , 6 (1967) 794; Phase change $250^\circ\text{C}$ , cubic above. F. Galasso, L. Katz and R. Ward, <i>J. Am. Chem. Soc.</i> , 87 (1959) 820.
$\text{Sr}_2\text{GaNbO}_6$	C	3.9477			L. H. Brixner, <i>J. Phys. Chem.</i> , 64 (1960) 165.
$\text{Sr}_2\text{YNbO}_6$	Rh	5.184			$\alpha = 59^\circ 51'$ cubic above $630^\circ\text{C}$ ; M. F. Kupriyanov and V. S. Filipev, <i>Kristallografiya</i> , 8 (1963) 356.
$\text{Sr}_2\text{InNbO}_6$	C	8.106			V. S. Filipev and E. G. Fesenko, <i>Kristallografiya</i> , 10 (1965) 626; L. H. Brixner, <i>J. Phys. Chem.</i> , 64 (1960) 165.
$\text{Sr}_2\text{PrNbO}_6$	Tet	5.822		8.431	M. F. Kupriyanov and V. S. Filipev, <i>Kristallografiya</i> , 8 (1963) 356.
$\text{Sr}_2\text{NdNbO}_6$	Tet	5.780		8.367	M. F. Kupriyanov and V. S. Filipev, <i>Kristallografiya</i> , 8 (1963) 356.
$\text{Sr}_2\text{SmNbO}_6$	M	5.85	5.94	8.30	$\beta = 90^\circ 12'$ V. S. Filipev and E. G. Fesenko, <i>Kristallografiya</i> , 10 (1965) 626.
$\text{Sr}_2\text{SmNbO}_6$	M	5.84	5.91	8.30	$\beta = 90^\circ 12'$
$\text{Sr}_2\text{GdNbO}_6$	M	5.83	5.90	8.28	$\beta = 90^\circ 15'$
$\text{Sr}_2\text{TbNbO}_6$	M	5.82	5.88	8.27	$\beta = 90^\circ 8'$
$\text{Sr}_2\text{DyNbO}_6$	M	5.81	5.87	8.26	$\beta = 90^\circ 9'$ V. S. Filipev and E. G. Fesenko, <i>Kristallografiya</i> , 10 (1965) 626.
$\text{Sr}_2\text{ErNbO}_6$	M	5.81	5.86	8.28	$\beta = 90^\circ 6'$

Compound	Type	a	b	c	Comments and references
Sr <sub>2</sub> TmNbO <sub>6</sub>	C	8.20	—	—	Slight distortion
Sr <sub>2</sub> VNbO <sub>6</sub>	C	3.965	—	—	C. Chauvel, J. C. Bernier and A. Michel, <i>C. R. Acad. Sci.</i> , 263 (1966) 1536.
Sr <sub>2</sub> YbNbO <sub>6</sub>	C	8.196	—	—	M. F. Kupriyanov and V. S. Filipev, <i>Kristallografiya</i> , 8 (1963) 356.
Sr <sub>2</sub> LaNbO <sub>6</sub>	C	8.19	—	—	
SrLaCoNbO <sub>6</sub>	C	7.99	—	—	
SrLaNiNbO <sub>6</sub>	C	7.95	—	—	G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.
SrLaCuNbO <sub>6</sub>	Tet	7.80	—	8.25	
Sr <sub>2</sub> CrSbO <sub>6</sub>	C	7.87	—	—	
Sr <sub>2</sub> MnSbO <sub>6</sub>	Tet	7.86	—	8.08	G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.
Sr <sub>2</sub> FeSbO <sub>6</sub>	C	7.86	—	—	
Sr <sub>2</sub> CoSbO <sub>6</sub>	C	7.88	—	—	G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.
Sr <sub>2</sub> NdSbO <sub>6</sub>	Tet	—	—	—	
Sr <sub>2</sub> GaSbO <sub>6</sub>	Tet	7.84	—	7.91	
Sr <sub>2</sub> RhSbO <sub>6</sub>	O	5.55	5.77	7.99	
SrLaCoSbO <sub>6</sub>	C	7.99	—	—	
SrLaNiSbO <sub>6</sub>	C	7.93	—	—	
SrLaCuSbO <sub>6</sub>	Tet	7.80	—	8.35	
Sr <sub>2</sub> AlTaO <sub>6</sub>	C	7.786	—	—	V. S. Filipev and E. G. Fesenko, <i>Kristallografiya</i> , 10 (1965) 626; A. W. Sleight, <i>Thesis Diss. Abstr.</i> , Univ. Connecticut 1963, 24 (1964) 64.
Sr <sub>2</sub> VTaO <sub>6</sub>	C	3.967	—	—	C. Chauvel, J. C. Bernier and A. Michel, <i>C. R. Acad. Sci.</i> , 263 (1966) 1536;
Sr <sub>2</sub> CrTaO <sub>6</sub>	C	3.94	—	—	T. Nakagawa and S. Nomura, <i>J. Phys. Soc. Jpn.</i> , 21 (1966) 1468; R. Roy, <i>J. Am. Ceram. Soc.</i> , 37 (1954) 581.
Sr <sub>2</sub> MnTaO <sub>6</sub>	C	3.994	—	—	
Sr <sub>2</sub> FeTaO <sub>6</sub>	Tet	3.960	—	3.981	M. F. Kupriyanov and V. S. Filipev, <i>Kristallografiya</i> , 8 (1963) 356.

Compound	Type	a	b	c	Comments and references
Sr <sub>2</sub> GaTaO <sub>6</sub>	C	7.892			A. W. Sleight, <i>Thesis Diss. Abstr.</i> , 24 (1964) 64, Univ. Connecticut, 1963.
Sr <sub>3</sub> TaO <sub>6</sub>	C	8.34			F. Galasso, L. Katz and R. Ward, <i>J. Am. Chem. Soc.</i> , 81 (1959) 820. L. H. Brixner, <i>J. Am. Chem. Soc.</i> , 80 (1958) 3214.
Sr <sub>2</sub> YTaO <sub>6</sub>	Rh	5.837			$\alpha = 59^{\circ}46'$ M. F. Kupriyanov and V. S. Filipev, <i>Kristallografiya</i> , 8 (1963) 356.
Sr <sub>2</sub> RhTaO <sub>6</sub>	C	7.936			A. W. Sleight, <i>Thesis Diss. Abstr.</i> , 24 (1964) 64, Univ. Connecticut, 1963.
Sr <sub>2</sub> InTaO <sub>6</sub>	C	8.110			
Sr <sub>2</sub> LaTaO <sub>6</sub>	Tet	5.853		8.387	
Sr <sub>2</sub> PrTaO <sub>6</sub>	M	5.87	5.98	8.35	$\beta = 90^{\circ}9'$ V. S. Filipev and E. G. Fesenko,
Sr <sub>2</sub> NdTaO <sub>6</sub>	M	5.86	5.96	8.34	$\beta = 90^{\circ}9'$ <i>Kristallografiya</i> , 10 (1965) 626.
Sr <sub>2</sub> SmTaO <sub>6</sub>	M	5.85	5.93	8.31	$\beta = 90^{\circ}11'$
Sr <sub>2</sub> EuTaO <sub>6</sub>	M	5.84	5.91	8.30	$\beta = 90^{\circ}12'$
Sr <sub>2</sub> GdTaO <sub>6</sub>	M	5.83	5.90	8.29	$\beta = 90^{\circ}13'$
Sr <sub>2</sub> TbTaO <sub>6</sub>	M	5.82	5.88	8.28	$\beta = 90^{\circ}9'$
Sr <sub>2</sub> DyTaO <sub>6</sub>	M	5.82	5.87	8.26	$\beta = 90^{\circ}8'$
Sr <sub>2</sub> HoTaO <sub>6</sub>	M	5.81	5.85	8.23	$\beta = 90^{\circ}8'$ V. S. Filipev and E. G. Fesenko,
Sr <sub>2</sub> ErTaO <sub>6</sub>	M	5.80	5.84	8.23	$\beta = 90^{\circ}4'$ <i>Kristallografiya</i> , 10 (1965) 626.
Sr <sub>2</sub> TmTaO <sub>6</sub>	C	8.20			
Sr <sub>2</sub> YbTaO <sub>6</sub>	C	8.196			
Sr <sub>2</sub> LaTaO <sub>6</sub>	C	8.18			
SrLaCoTaO <sub>6</sub>	C	7.99			
SrLaCoTaO <sub>6</sub>	C	7.99			G. Blasse,



Compound	Type	a	b	c	Comments and references
SrLaNiTaO <sub>6</sub>	C	7.95			<i>J. Inorg. Nucl. Chem.</i> , 26 (1965) 993.
SrLaCuTaO <sub>6</sub>	Tet	7.80			
Sr <sub>2</sub> CrMoO <sub>6</sub>	C	3.91			L. M. Brixner, <i>J. Phys. Chem.</i> , 64 (1960) 165.
Sr <sub>2</sub> MnMoO <sub>6</sub>	C	7.98			
Sr <sub>2</sub> FeMoO <sub>6</sub>	Tet	7.888		7.909	F. Galasso, F. C. Douglas and R. J. Kasper, <i>J. Chem. Phys.</i> , 44 (1966) 1672; F. K. Patterson, C. W. Moeller and R. Ward, <i>Inorg. Chem.</i> , 2 (1963) 196.
Sr <sub>2</sub> CoMoO <sub>6</sub>	Tet	5.581	7.940		Solid solutions with Ca and Ba To cubic at 320 °C, M. F. Kupryianov and E. G. Fesenko, <i>Kristallografiya</i> , 7 (1962) 451.
	C	7.981			
Sr <sub>2</sub> NiMoO <sub>6</sub>	Tet	5.560	7.886		To cubic at 230 °C
	C	7.878			SS with Ba Cubic above 22% Ba
Sr <sub>2</sub> ZnMoO <sub>6</sub>	Tet	5.561	7.966		To cubic at 420 °C
	C	7.954			
Sr <sub>2</sub> MgTeO <sub>6</sub>	C	7.94			G. Bayer, <i>J. Am. Ceram. Soc.</i> , 46 (1963) 604.
SrPbMgTeO <sub>6</sub>	C	7.955			
Sr <sub>2</sub> NiTeO <sub>6</sub>	C	3.95			D. Reinen, <i>Theoret. Chim. Acta</i> , 5 (1966) 312; <i>Z. Naturforsch.</i> , 23A (1968) 521.
Sr <sub>2</sub> CuTeO <sub>6</sub>	Tet	7.680		8.465	
Sr <sub>2</sub> BaPaO <sub>5.5</sub>	C	8.784			C. Keller, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 321.
SrBaMgWO <sub>6</sub>	C	8.02			I. N. Belyaev, V. S. Filipev and E. G. Fesenko, <i>Zh. Strukt. Khim.</i> , 4 (1963) 719.
SrBa <sub>2</sub> WO <sub>6</sub>	C	8.53			E. G. Steward and H. P. Rooksby, <i>Acta Crystallogr.</i> , 4 (1951) 503.
SrBaCaWO <sub>6</sub>	C	8.29			
SrBaZnWO <sub>6</sub>	C	8.07			
Sr <sub>2</sub> MgWO <sub>6</sub>	C	7.8			
Sr <sub>2</sub> CaWO <sub>6</sub>	C	8.2			
Sr <sub>2</sub> CrWO <sub>6</sub>	C	7.82			F. K. Patterson, L. W. Moeller and R. Ward, <i>Inorg. Chem.</i> , 2 (1963) 196.
Sr <sub>2</sub> MnWO <sub>6</sub>	C	8.07			G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.

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Compound	Type	a	b	c	Comments and references
$\text{Sr}_2\text{FeWO}_6$	C	7.96			
$\text{Sr}_2\text{CoWO}_6$	Tet	7.89		7.98	Cubic above 400 °C E. J. Fresia, L. Katz and R. Ward, <i>J. Am. Chem. Soc.</i> , 81 (1959) 4783.
	C	7.904			
$\text{Sr}_2\text{NiWO}_6$	Tet	7.86		7.91	Cubic above 300 °C
	C	7.908			
$\text{Sr}_2\text{CuWO}_6$	Tet	7.66		8.40	G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993; A. G. Kapyshv, V. V. Ivanova and Yu N. Venevtsev, <i>Dokl. Akad. Nauk SSSR</i> , 167 (1966) 564.
$\text{Sr}_2\text{ZnWO}_6$	Tet	7.92		8.01	E. J. Fresia, L. Katz and R. Ward, <i>J. Am. Chem. Soc.</i> , 81 (1959) 4783. Solid solution with Ba; cubic above 40% Ba.
	C	7.956			Cubic above 430 °C.
$\text{Sr}_3\text{WO}_6$	C	8.3			I. N. Belyaev, V. S. Filipev and E. G. Fesenko, <i>Zh. Strukt. Khim.</i> , 4 (1963) 719.
$\text{SrCaMgWO}_6$	C	7.87			E. G. Steward and H. P. Rooksby, <i>Acta Crystallogr.</i> , 4 (1951) 503.
$\text{SrCa}_2\text{WO}_6$					
$\text{SrBa}_2\text{ReO}_6$	Tet	8.6		8.43	A. W. Sleight, J. Longo and R. Ward, <i>Inorg. Chem.</i> , 1 (1962) 245.
$\text{Sr}_2\text{MgReO}_6$	Tet	7.88		7.94	
$\text{Sr}_2\text{CaReO}_6$	O	5.76	5.85	8.21	
$\text{Sr}_2\text{ScReO}_6$	C	8.02			
$\text{Sr}_2\text{CrReO}_6$	C	7.82			
$\text{Sr}_2\text{MnReO}_6$	C	8.07			
$\text{Sr}_2\text{FeReO}_6$	Tet	7.86		7.89	
$\text{Sr}_2\text{CoReO}_6$	Tet	7.88		7.98	
$\text{Sr}_2\text{WReO}_6$	Tet	7.85		7.92	A. W. Sleight, J. Longo and R. Ward, <i>Inorg. Chem.</i> , 1 (1962) 245.
$\text{Sr}_2\text{ZnReO}_6$	Tet	7.89		8.07	J. Longo and R. Ward, <i>J. Am. Chem. Soc.</i> , 83 (1961) 2816.
$\text{Sr}_2\text{GaReO}_6$	C	7.843			R. Scholder and P. P. Pfeiffer, <i>Angew. Chem., Int. Ed. Engl.</i> , 2 (1963) 265.

Compound	Type	a	b	c	Comments and references
Sr <sub>3</sub> ReO <sub>6</sub>	Tet	8.41	8.13		
Sr <sub>2</sub> YReO <sub>6</sub>	C	8.197			
Sr <sub>2</sub> CdReO <sub>6</sub>	O	5.73	5.81	8.16	
Sr <sub>2</sub> InReO <sub>6</sub>	C	8.071			
Sr <sub>2</sub> TbReO <sub>6</sub>	C	8.223			
Sr <sub>2</sub> DyReO <sub>6</sub>	C	8.210			G. Bond and M. Cap-ston, <i>C. R. Acad. Sci.</i> , 266 (1968) 314.
Sr <sub>2</sub> ErReO <sub>6</sub>	C	8.181			
Sr <sub>2</sub> TmReO <sub>6</sub>	C	8.167			
Sr <sub>2</sub> YbReO <sub>6</sub>	C	8.155			
SrBa <sub>2</sub> OsO <sub>6</sub>	Tet	8.43		8.72	A. W. Sleight, J. Longo and R. Ward, <i>Inorg. Chem.</i> , 1 (1962) 245.
Sr <sub>2</sub> MgOsO <sub>6</sub>	Tet	7.86		7.92	
Sr <sub>2</sub> CaOsO <sub>6</sub>	C	8.21			
Sr <sub>2</sub> ScOsO <sub>6</sub>	C	8.02			
Sr <sub>2</sub> CrOsO <sub>6</sub>	C	7.84			
Sr <sub>2</sub> FeOsO <sub>6</sub>	C	7.85			
Sr <sub>2</sub> CoOsO <sub>6</sub>	Tet	7.86		7.92	
Sr <sub>2</sub> GaOsO <sub>6</sub>	C	7.82			A. W. Sleight, J. Longo and R. Ward, <i>J. Inorg. Nucl. Chem.</i> , 26 (1965) 993.
Sr <sub>3</sub> OsO <sub>6</sub>	Tet	8.32		8.12	
Sr <sub>2</sub> InOsO <sub>6</sub>	C	8.06			
Sr <sub>2</sub> Ba <sub>2</sub> UO <sub>6</sub>	C	8.84			A. W. Sleight and R. Ward, <i>Inorg. Chem.</i> , 1 (1962) 790.
Sr <sub>2</sub> BaUO <sub>6</sub>	C	8.66			W. Rüdorff and F. P. Fitzer, <i>Z. Naturforsch.</i> , 96 (1954) 568.
Sr <sub>2</sub> MgUO <sub>6</sub>	C	8.19			
Sr <sub>2</sub> CaUO <sub>6</sub>	O	5.93	6.06	8.46	
Sr <sub>2</sub> CrUO <sub>6</sub>	C	8.09			
Sr <sub>2</sub> MnUO <sub>6</sub>	C	8.28			
Sr <sub>2</sub> FeUO <sub>6</sub>	C	8.11			A. W. Sleight and R. Ward, <i>Inorg. Chem.</i> , 1 (1962) 790.
Sr <sub>2</sub> CoUO <sub>6</sub>	C	8.19			

(continued overleaf)

Compound	Type	a	b	c	Comments and references
$\text{Sr}_2\text{NiUO}_6$	C	8.15			
$\text{Sr}_3\text{UO}_6$	M	5.959	6.179	8.553	$\beta = 90^\circ 11'$ (complete structure estab.)
$\text{Sr}_2\text{CdUO}_6$	O	5.91	6.03	8.42	
$\text{Sr}_2\text{InUO}_6$	C	8.33			
$\text{SrCa}_2\text{UO}_6$	O	5.83	6.07	8.36	
$\text{SrBa}_2\text{NpO}_6$	C	8.799			
$\text{Sr}_2\text{BaNpO}_6$	C	8.735			C. Keller, <i>Nukleonik</i> , 4 (1962) 271.
$\text{Sr}_2\text{BaPuO}_6$	C	8.717			
$\text{Sr}_2\text{LiTcO}_6$	C	7.84			Wassilopoulos, <i>USAEC-KFK 341</i> , 1965.
$\text{Sr}_2\text{NaTcO}_6$	Tet	8.09		8.14	C. Keller and Wassilopoulos, <i>Radiochim. Acta</i> , 5 (1966) 87.
$\text{Sr}_2\text{LiReO}_6$	C	7.81			A. W. Sleight, J. Longo and R. Ward, <i>Inorg. Chem.</i> , 1 (1962) 245.
$\text{Sr}_2\text{LiOsO}_6$	C	7.86			
$\text{Sr}_2\text{NaOsO}_6$	C	8.13			

### Appendix III

#### Strontium containing perovskites — type $\text{Sr}_3\text{B}'\text{B}'\text{O}_9$

Compound	Type	a	b	c	Comments and references
$\text{Sr}_3\text{MgNb}_2\text{O}_9$	Hex	5.66		6.98	F. Galasso and J. Pyle, <i>J. Phys. Chem.</i> , 67 (1963) 1561.
$\text{Sr}_3\text{CaNb}_2\text{O}_9$	Hex	5.76		7.16	F. Galasso and J. Pyle, <i>J. Phys. Chem.</i> , 67 (1963) 1561.
$\text{Sr}_3\text{FeNb}_2\text{O}_9$	Tet	3.997		4.018	F. Galasso and J. Pyle, <i>J. Phys. Chem.</i> , 67 (1963) 1561.
$\text{Sr}_3\text{CoNb}_2\text{O}_9$	C	8.07			G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.
$\text{Sr}_3\text{NiNb}_2\text{O}_9$	Hex			6.90	F. Galasso and J. Pyle, <i>J. Phys. Chem.</i> , 67 (1963) 1561.
$\text{Sr}_3\text{CuNb}_2\text{O}_9$	Tet	7.888		8.148	A. G. Kapyshnev, V. V. Ivonova and Ya W. Veneutsev, <i>Dokl. Akad. Nauk SSSR</i> , 167 (1966) 564.
$\text{Sr}_3\text{ZnNb}_2\text{O}_9$	Hex	5.66		6.95	F. Galasso and J. Pyle, <i>J. Phys. Chem.</i> , 67 (1963) 1561.
$\text{Sr}_3\text{CdNb}_2\text{O}_9$	C	4.089			F. Galasso and J. Pyle, <i>J. Phys. Chem.</i> , 67 (1963) 1561.
$\text{Ba}_3\text{SrSb}_2\text{O}_9$	Hex	6.15		15.6	
$\text{Sr}_3\text{MgSb}_2\text{O}_9$	C	7.96			
$\text{Sr}_3\text{CaSb}_2\text{O}_9$	C	8.17			
$\text{Sr}_3\text{CoSb}_2\text{O}_9$	C	7.99			G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.
$\text{Sr}_3\text{NiSb}_2\text{O}_9$	C	3.98			
$\text{Sr}_3\text{CaSb}_2\text{O}_9$	Tet	7.84		8.19	
$\text{Sr}_4\text{Sb}_2\text{O}_9$	O	5.78	5.80	8.34	
$\text{Sr}_3\text{La}_{0.5}\text{Sb}_2\text{O}_9$	O	5.62	5.68	8.00	
$\text{Sr}_3\text{MgTa}_2\text{O}_9$	Hex	5.652		6.951	
$\text{Sr}_3\text{CaTa}_2\text{O}_9$	Hex	5.764		7.096	
$\text{Sr}_3\text{CoTa}_2\text{O}_9$	Hex	5.630		6.937	F. Galasso and J. Pyle,

(continued overleaf)

Compound	Type	a	b	c	Comments and references
$\text{Sr}_3\text{CuTa}_2\text{O}_9$	Tet	7.860		8.248	<i>Inorg. Chem.</i> , 2 (1963) 482.
$\text{Sr}_3\text{ZnTa}_2\text{O}_9$	Hex	5.664		6.951	
$\text{Sr}_3\text{NiTa}_2\text{O}_9$	Hex	5.607		6.923	
$\text{Sr}_3\text{Fe}_2\text{WO}_9$	Tet	3.945		3.951	F. Galasso, G. K. Layden and D. E. Flinchbaum, <i>J. Chem. Phys.</i> , 44 (1966) 2703. G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.
$\text{SrLa}_2\text{Mg}_2\text{WO}_9$	C	7.91			G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.
$\text{SrLa}_2\text{Co}_2\text{WO}_9$	C	7.90			G. Blasse, <i>J. Inorg. Nucl. Chem.</i> , 27 (1965) 993.
$\text{Sr}_3\text{Cr}_2\text{ReO}_9$	C	8.015			A. W. Sleight, J. Longo and R. Ward, <i>J. Inorg. Nucl. Chem.</i> , 11 (1962) 245.
$\text{Sr}_3\text{Fe}_2\text{ReO}_9$	C	7.890			
$\text{Sr}_3\text{In}_2\text{ReO}_9$	C	8.297			
$\text{Sr}_3\text{Cr}_2\text{UO}_9$	C	8.00			
$\text{Sr}_3\text{Fe}_2\text{UO}_9$	C	8.066			
$\text{Sr}(\text{Zn}_{0.2}\text{Fe}_{0.2}\text{Ta}_{0.6})\text{O}_3$	C	4.07			F. Galasso, L. Katz and R. Ward, <i>J. Am. Chem. Soc.</i> , 81 (1959) 820.
$\text{Sr}(\text{Na}_{0.25}\text{Ta}_{0.75})\text{O}_3$	C	4.055			
$\text{Sr}(\text{Fe}_{0.7}\text{Nb}_{0.3})\text{O}_3$	C	3.96			
$\text{Sr}(\text{La}_{0.3}\text{Ta}_{4.7})\text{O}_3$	C	4.00			