

Addition of SrO to the HotVeGas and GTOX Oxide databases

GTT-Technologies

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Tatjana Jantzen, Klaus Hack, Stephan Petersen



Addition of Strontium

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Binary systems

- ❖ Sr-O , Fe-Sr
- ❖ $\text{Al}_2\text{O}_3-\text{SrO}$
- ❖ $\text{CaO}-\text{SrO}$
- ❖ $\text{FeO}-\text{SrO}$
- ❖ $\text{Fe}_2\text{O}_3-\text{SrO}$
- ❖ $\text{MgO}-\text{SrO}$
- ❖ $\text{NiO}-\text{SrO}$
- ❖ $\text{P}_2\text{O}_5-\text{SrO}$
- ❖ SiO_2-SrO
- ❖ $\text{SrO-V}_2\text{O}_5$
- ❖ SrO-ZnO

Ternary systems

- ❖ Fe-O-Sr
- ❖ $\text{FeO-Fe}_2\text{O}_3-\text{SrO}$
- ❖ SrO-MgO-SiO_2

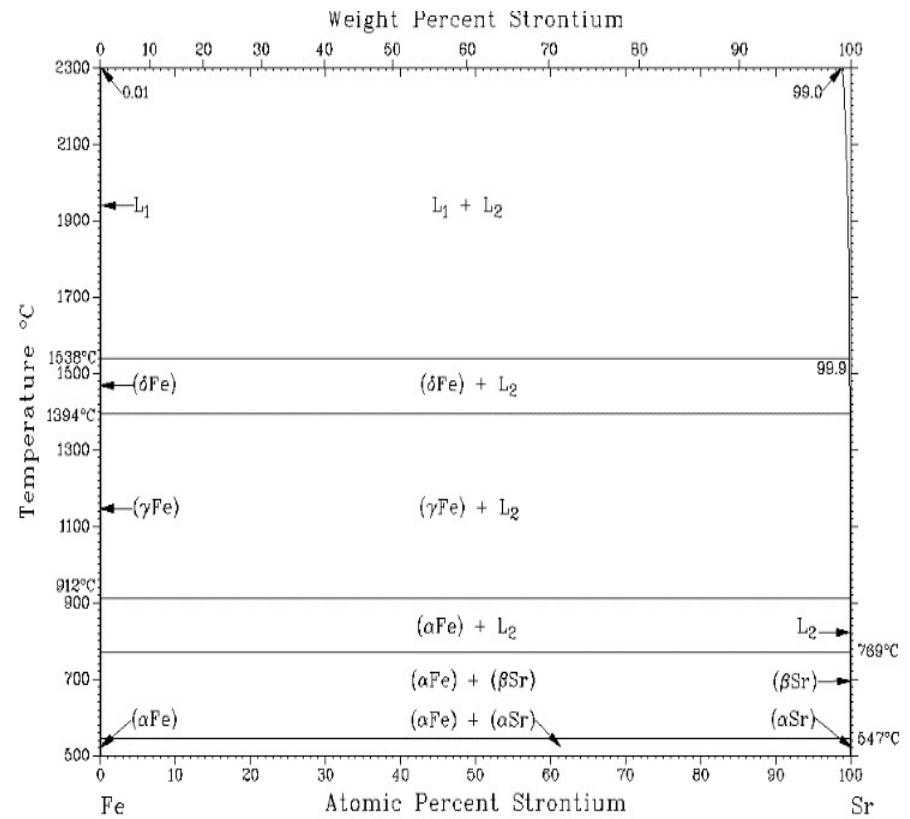
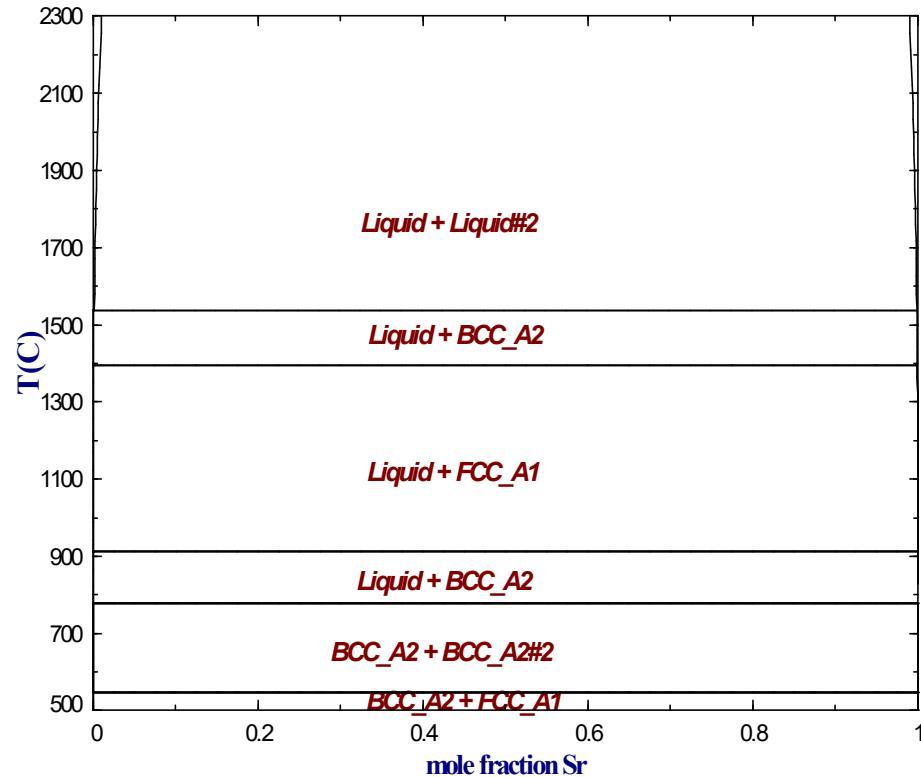
System	Associate species	Used data
Sr-O	Sr , SrO	SGPS
$\text{Al}_2\text{O}_3-\text{SrO}$	Al_2SrO_4	GTT
$\text{SrO-Fe}_2\text{O}_3$	$\text{Sr}_2\text{Fe}_2\text{O}_5$	GTT
$\text{SrO-P}_2\text{O}_5$	SrP_2O_6 , $\text{Sr}_2\text{P}_2\text{O}_7$, $\text{Sr}_3\text{P}_2\text{O}_8$	GTT
SrO-SiO_2	SrSiO_3 , Sr_2SiO_4 , Sr_3SiO_5	GTT

The associate species containing SrO were added in order to describe the liquid phase. The composition of the liquid oxide species are as introduced by Spear taking two moles of cations per associate. Species for similar systems are modelled in the same way, i.e. using the same stoichiometry. The Sr-species were added according to Mg and Ca.



Binary Fe-Sr phase diagram

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T.B. Massalski, *Binary Alloy Phase Diagrams.*, ASM, 1990.



Binary Sr-O phase diagram

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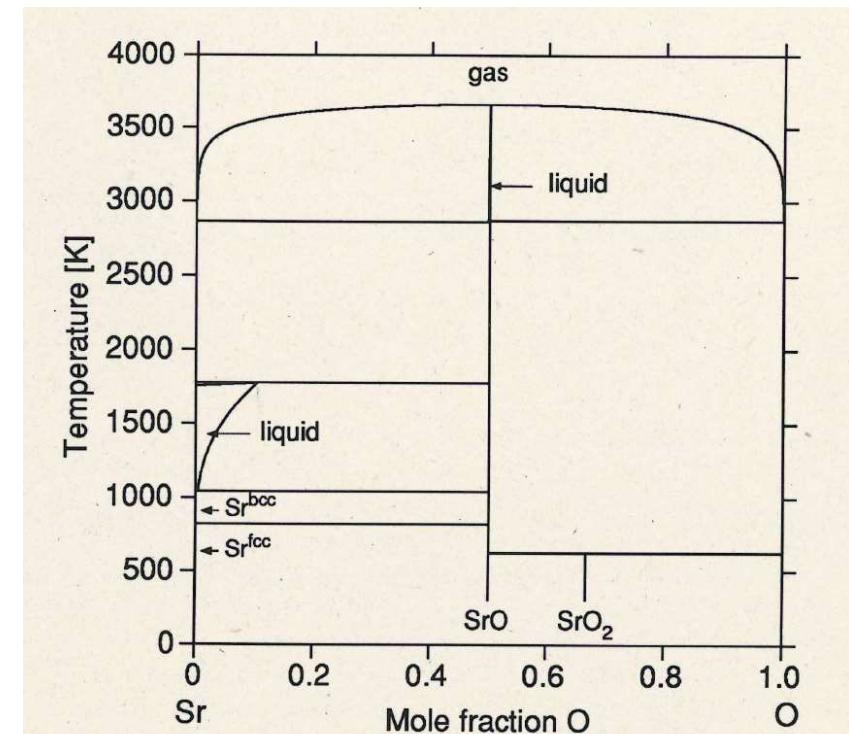
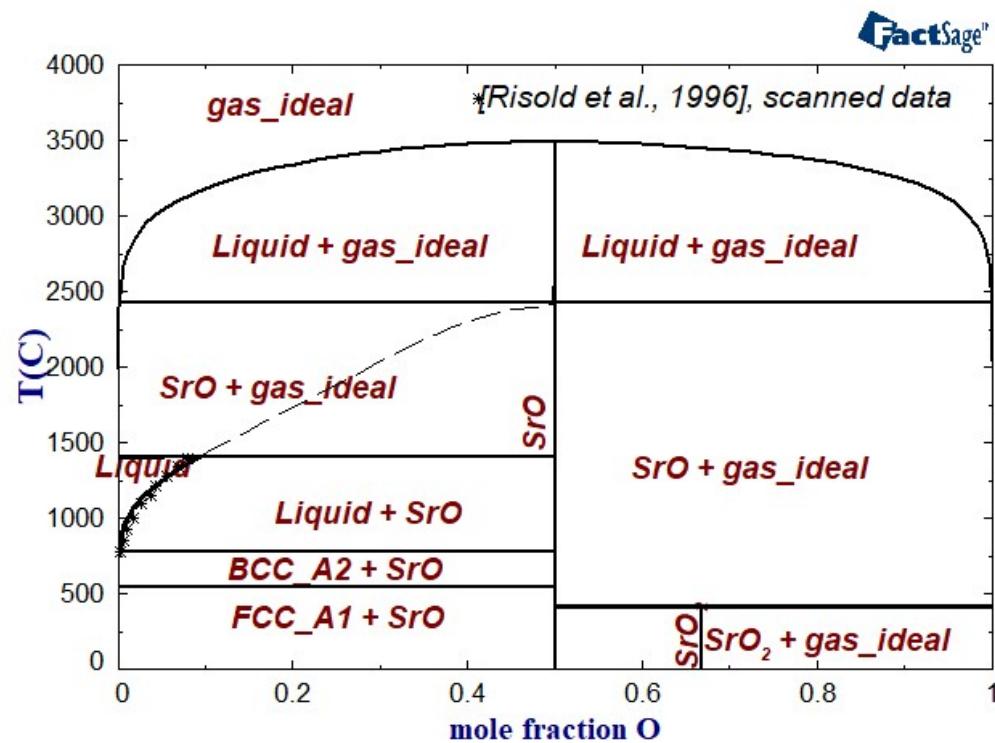


Figure 6: Sr-O phase diagram at 1 bar total pressure

D. Risold, B. Hallstedt, L.J. Gauckler,
CALPHAD, Vol. 20, Issue 3, (1996), pp. 353-361.

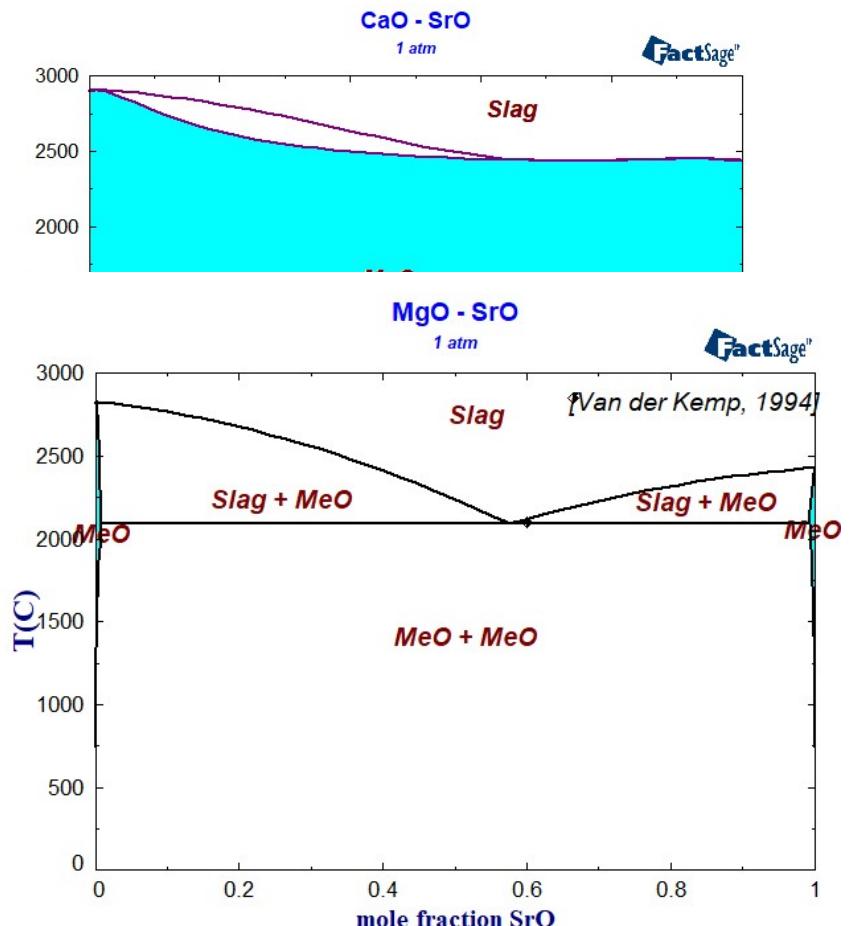
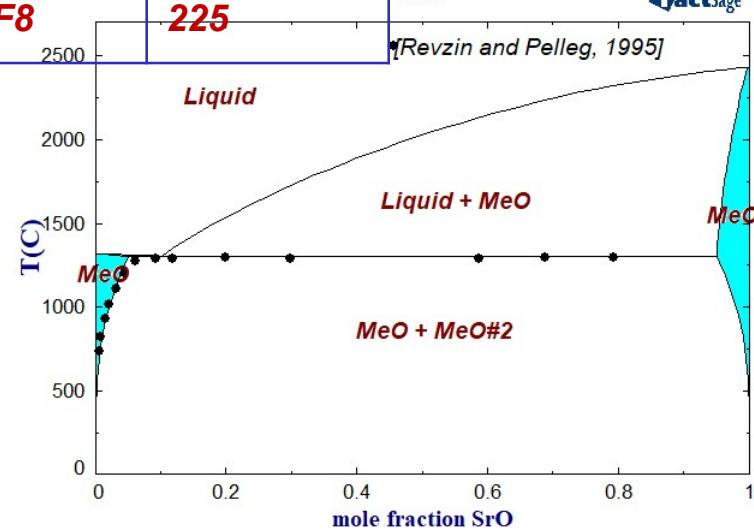


Strontium oxide

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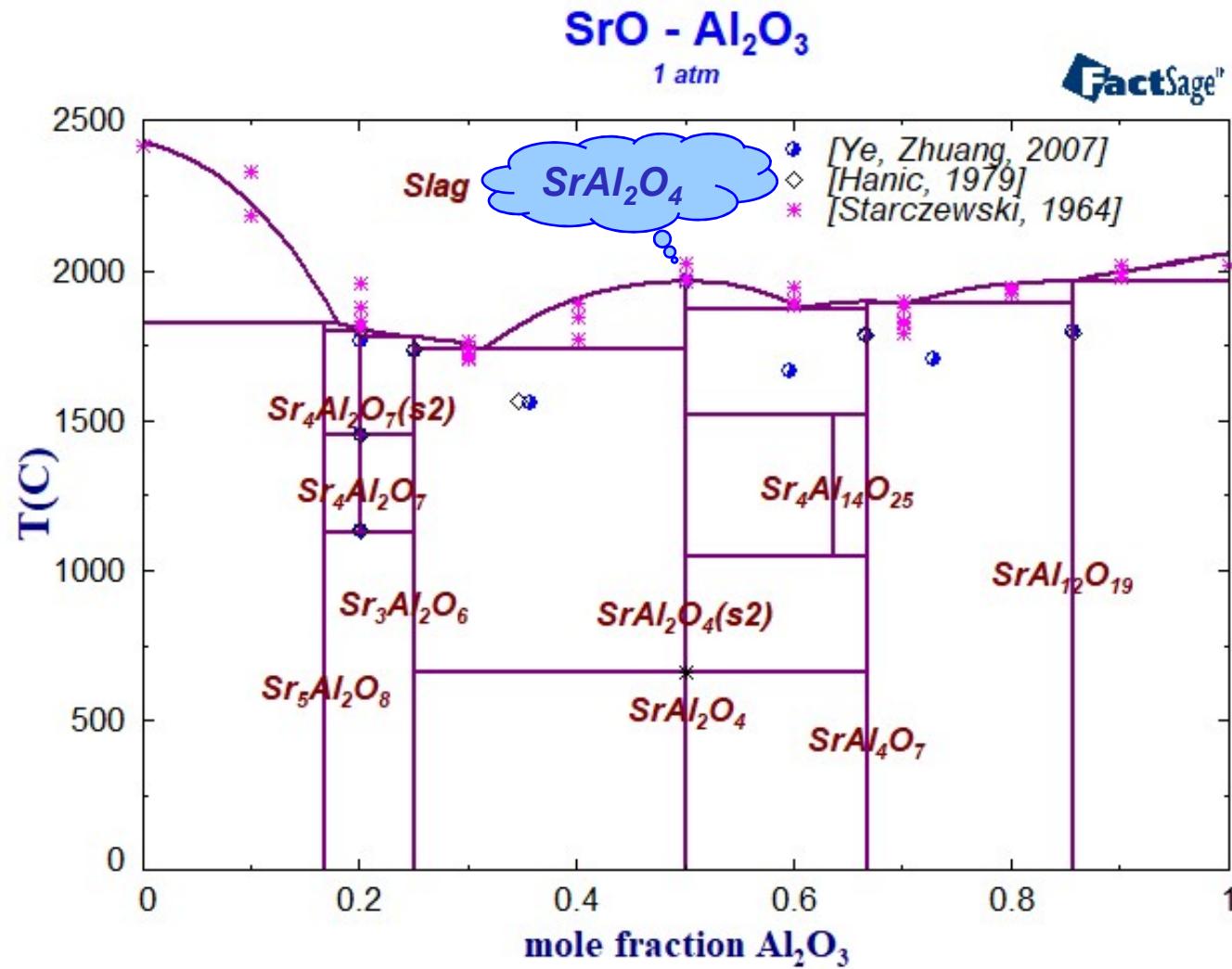
MeO ($Al^{+3}, Ca^{+2}, Cr^{+3}, Fe^{+2}, Fe^{+3}, Mg^{+2}, Mn^{+2}, Mn^{+3}, Ni^{+2}, Sr^{+2}, Ti^{+4}, Ti^{+3}, Zn^{+2}$) (O^{-2})

MeO	Pearson symbol	Space group
CaO	cF8	225
FeO	cF8	225
MgO	cF8	225
MnO	cF8	225
NiO	cF8	225
SrO	cF8	225



Al_2O_3 -SrO phase diagram

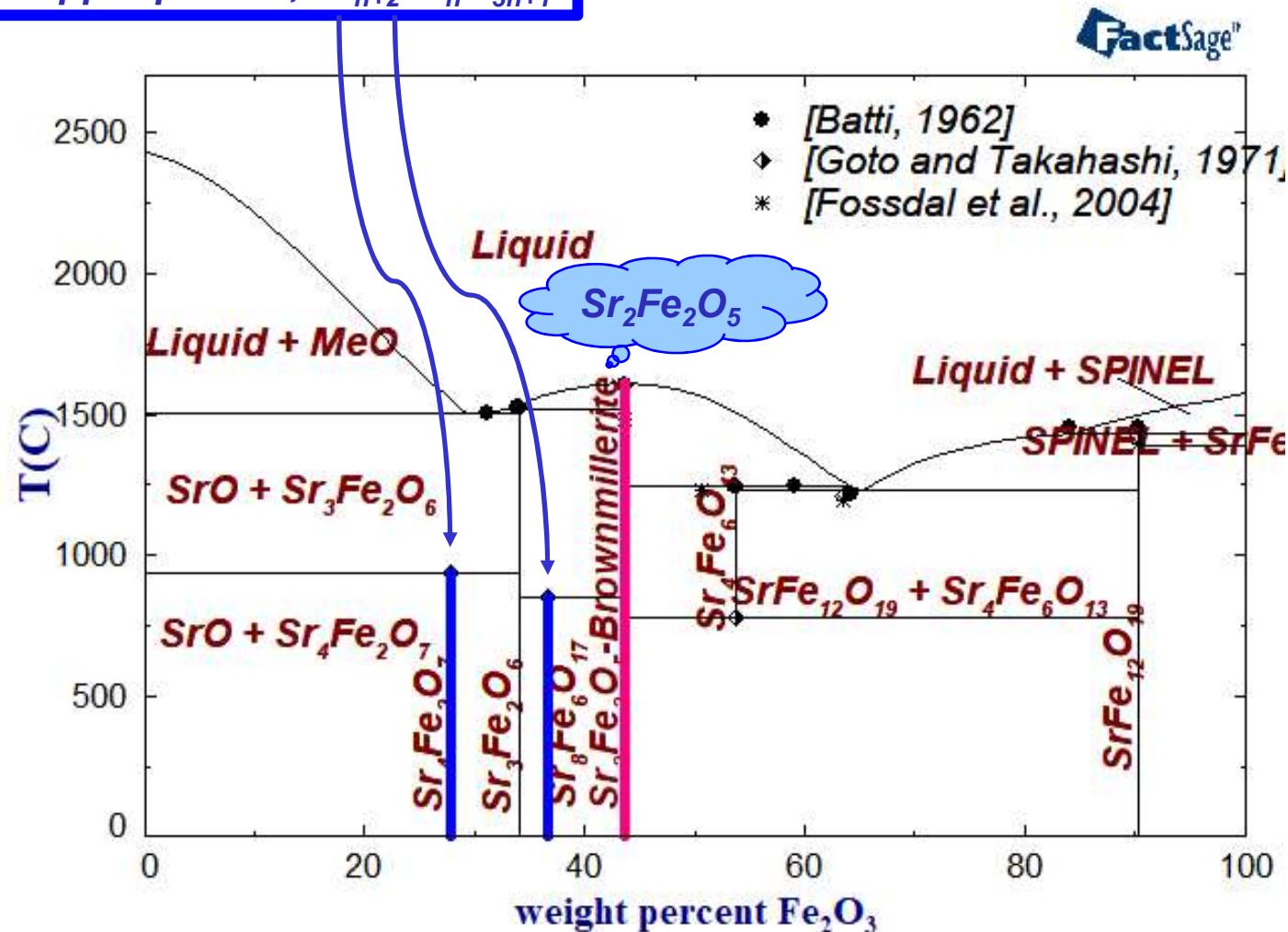
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SrO- Fe_2O_3 phase diagram in air

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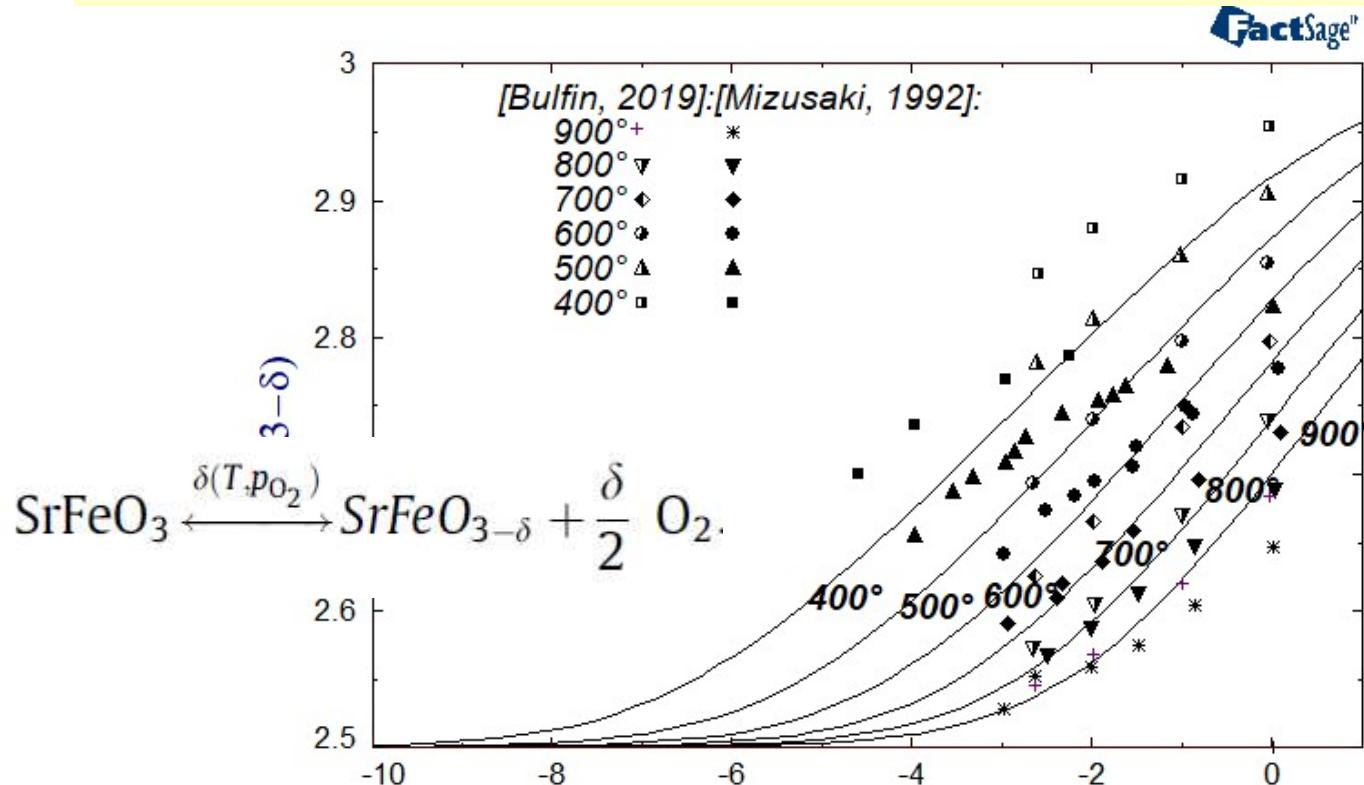
Ruddlesden-Popper phases, $\text{Sr}_{n+2}\text{Fe}_n\text{O}_{3n+1}$



Oxygen nonstoichiometry of $\text{SrFeO}_{2.5}$ - SrFeO_3 system

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Perovskite $\text{SrFe}_{3-\delta}$ is modelled as $(\text{Sr})_2(\text{Fe})_2(\text{O}, \text{Va})\text{O}_5$ with two end-members Brownmillerite $\text{Sr}_2\text{Fe}_2\text{O}_5$ and $\text{Sr}_2\text{Fe}_2\text{O}_6$



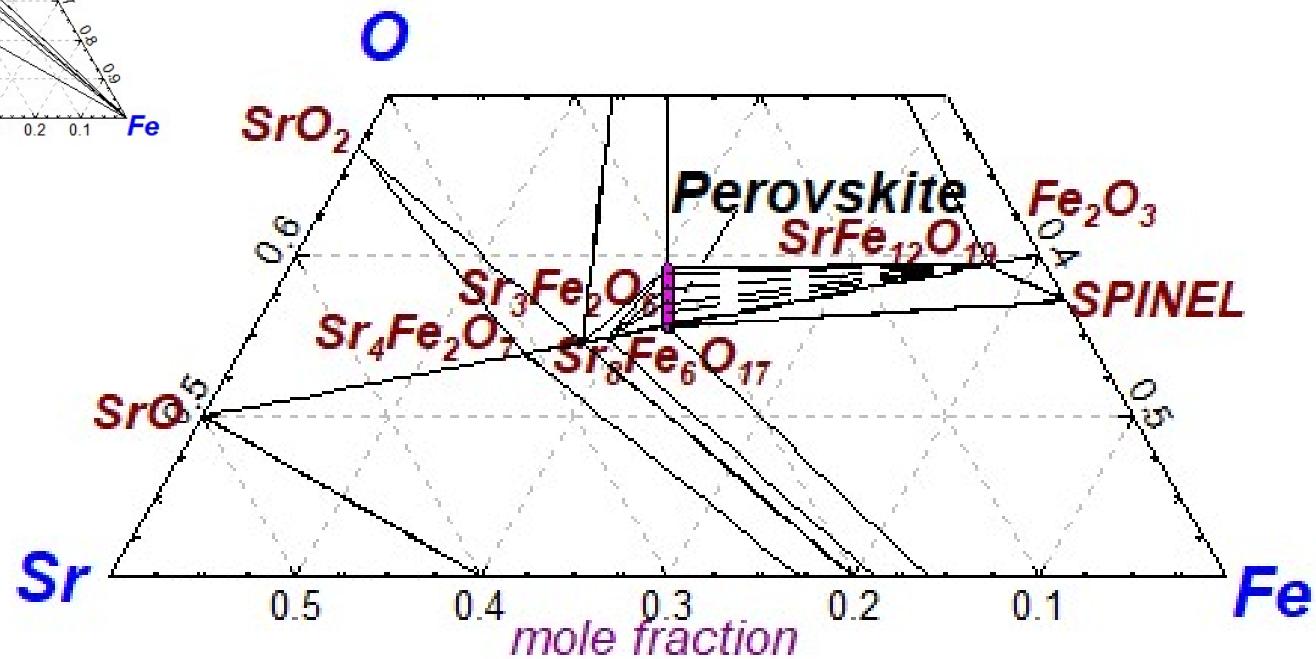
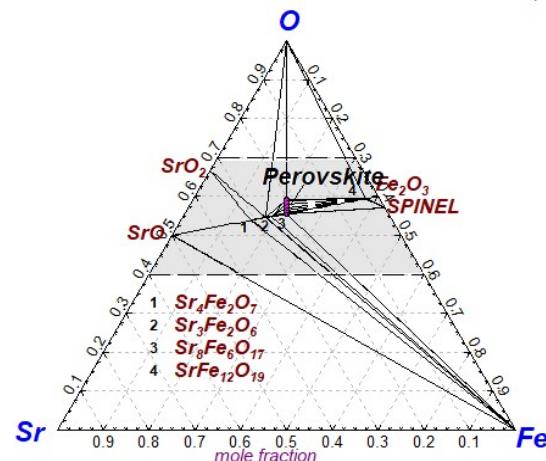
Perovskite $\text{SrFe}_{3-\delta}$ can absorb oxygen gas at a relatively low partial pressure and release it at a higher partial pressure, which amounts to oxygen pumping.



The Sr-Fe-O phase diagram at 400°C

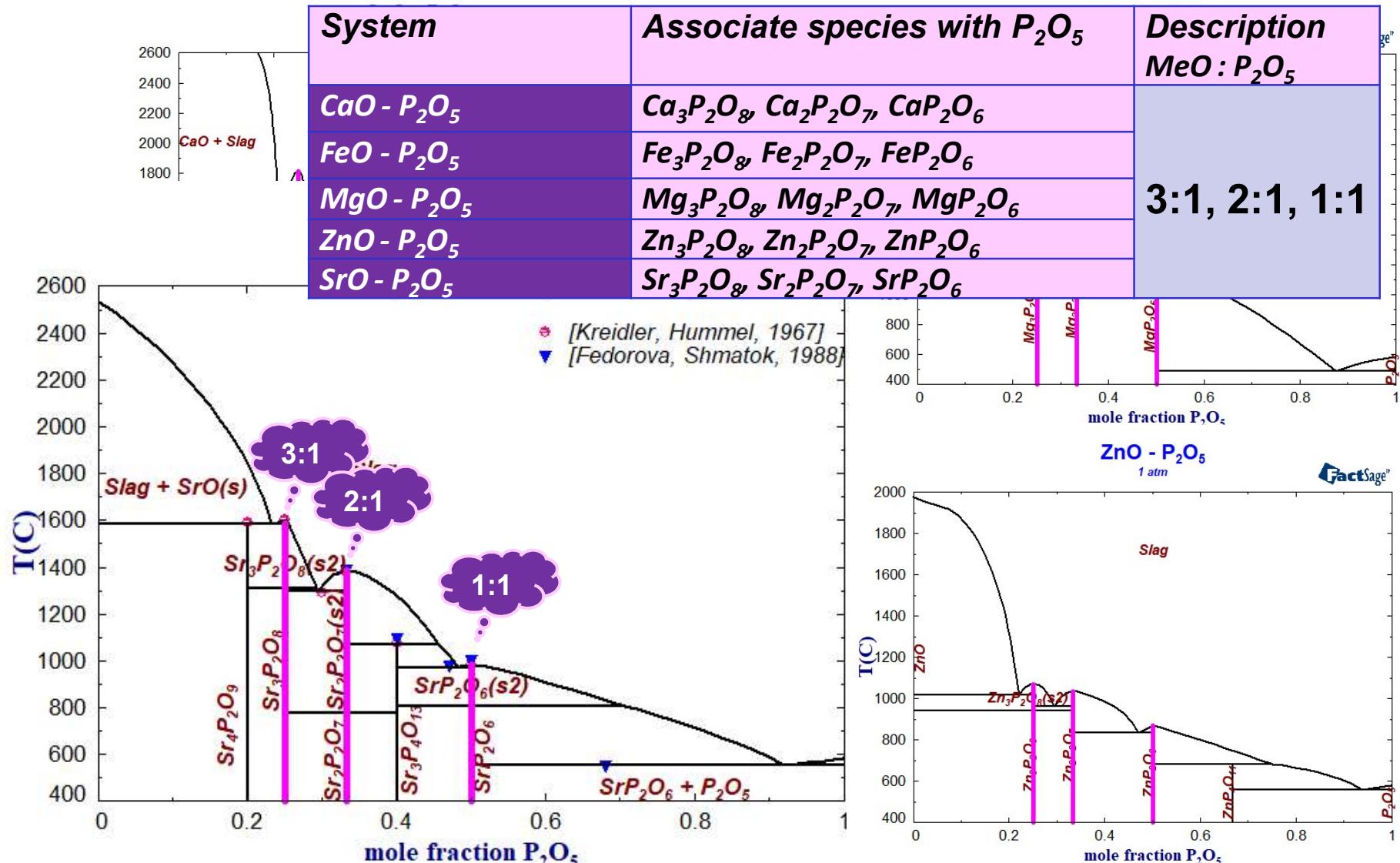
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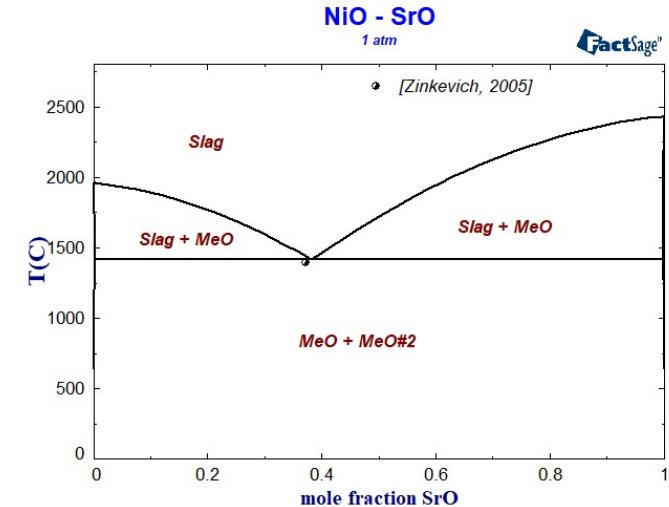
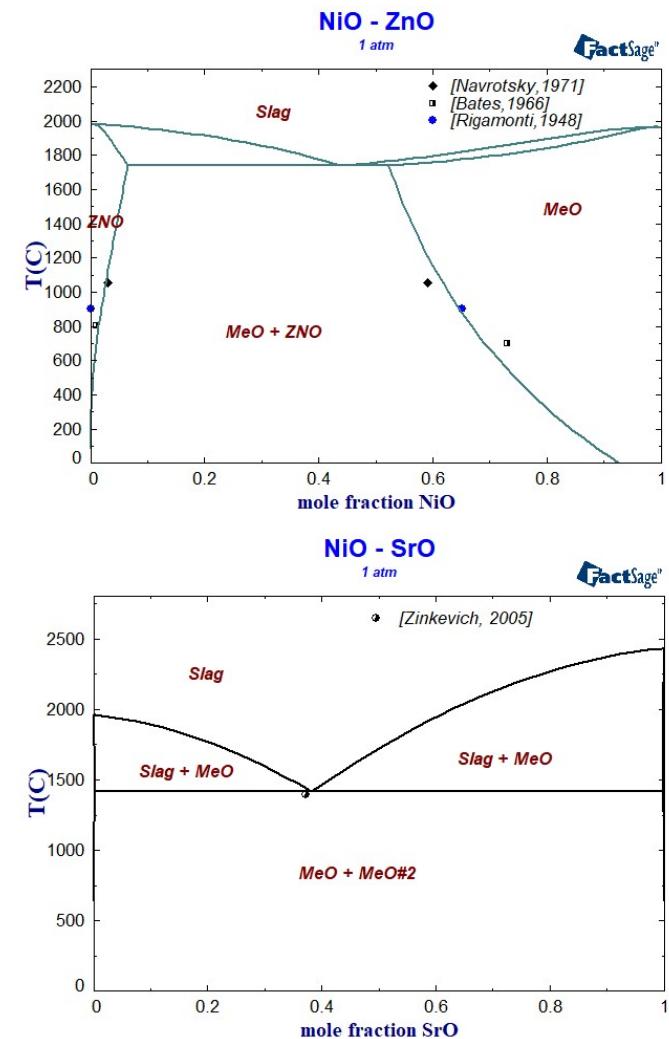
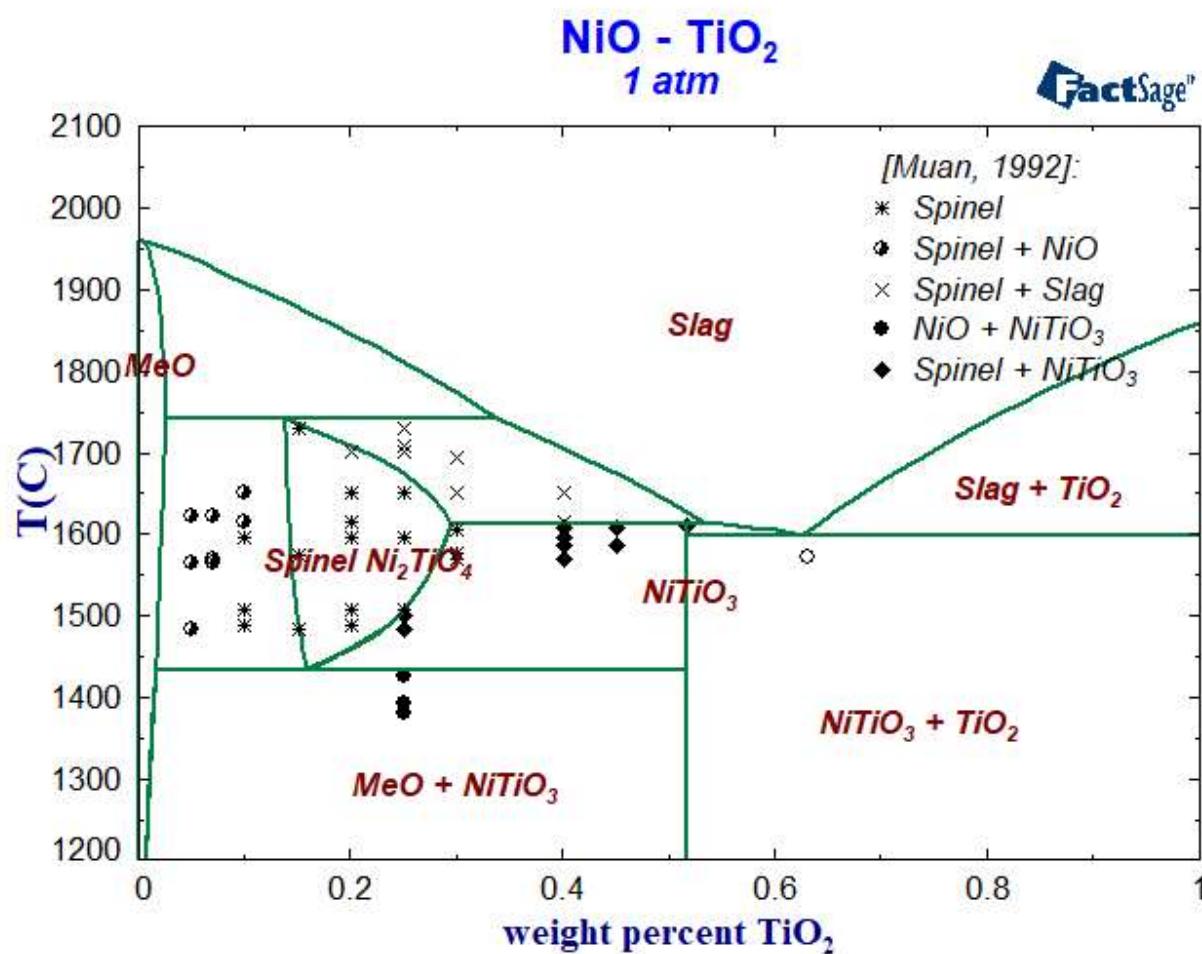
SrO–P₂O₅ phase diagram

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New systems with NiO

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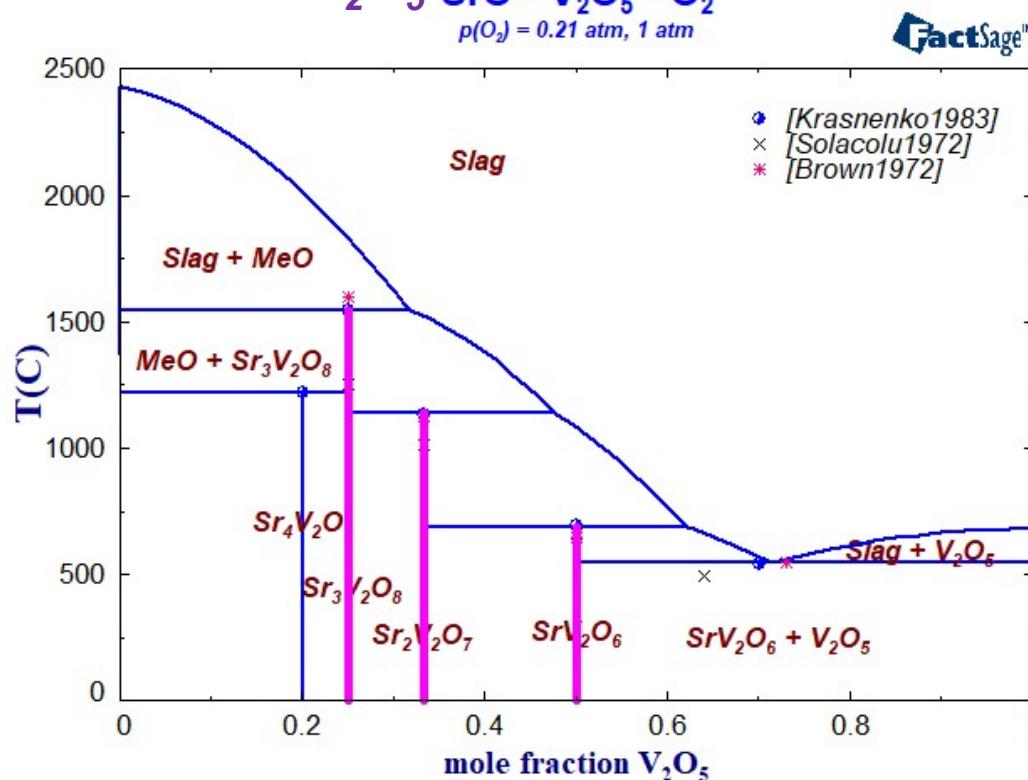


New systems with V_2O_3 and V_2O_5

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Binary systems

- $Al_2O_3-V_2O_3$
- $CaO-V_2O_3$
- $SrO-V_2O_5$
- $ZnO-V_2O_5$



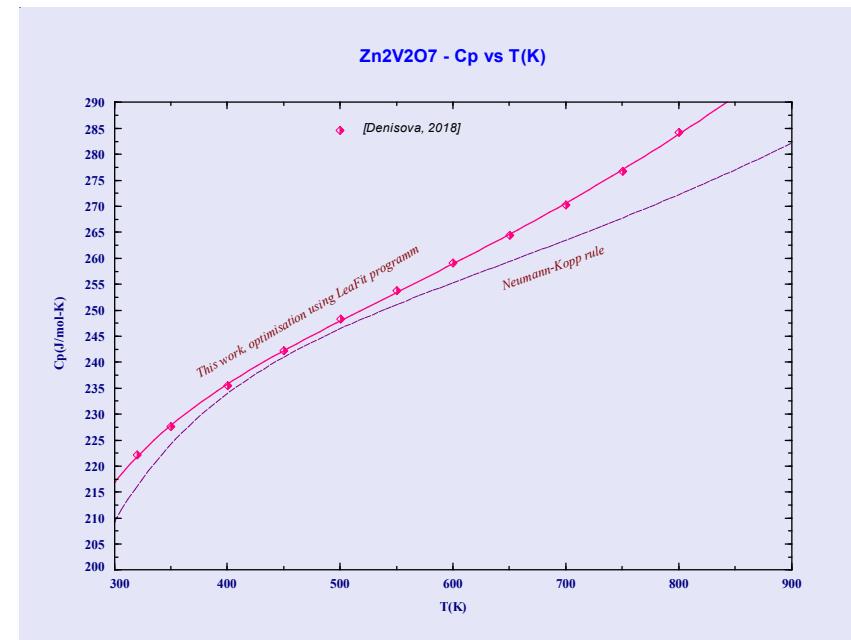
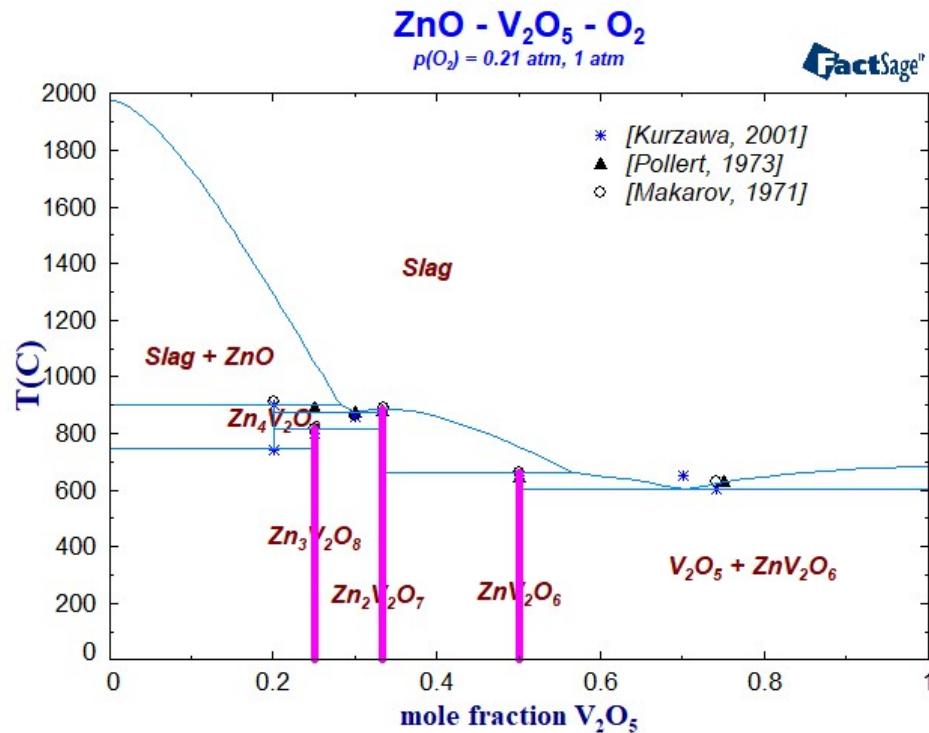
Ternary systems

- $Al_2O_3-Na_2O-V_2O_5$
- $CaO-Fe_2O_3-V_2O_3$
- $CaO-MgO-V_2O_5$
- $CaO-SiO_2-V_2O_3$
- $FeO-Fe_2O_3-V_2O_3$
- $Fe_2O_3-Na_2O-V_2O_5$
- $FeO-SiO_2-V_2O_3$
- $MgO-SiO_2-V_2O_5$
- $MgO-SiO_2-V_2O_3$
- $NiO-V_2O_5-ZnO$



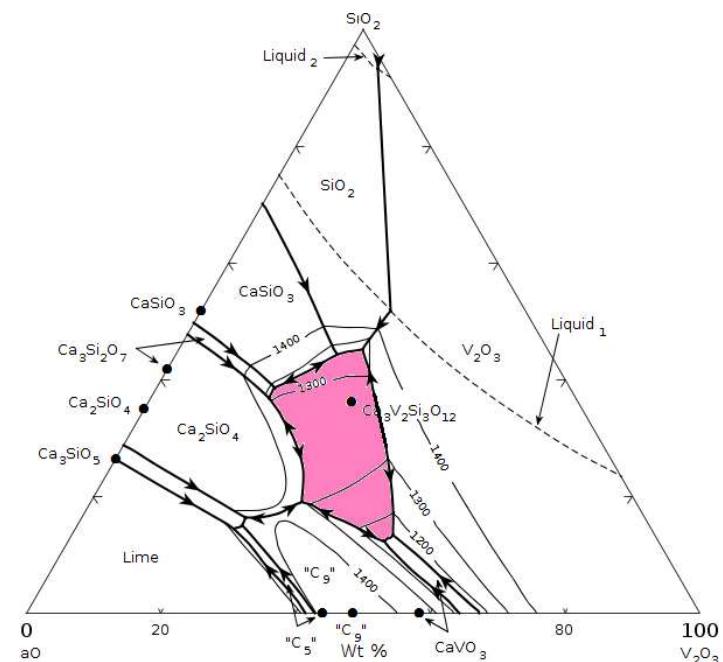
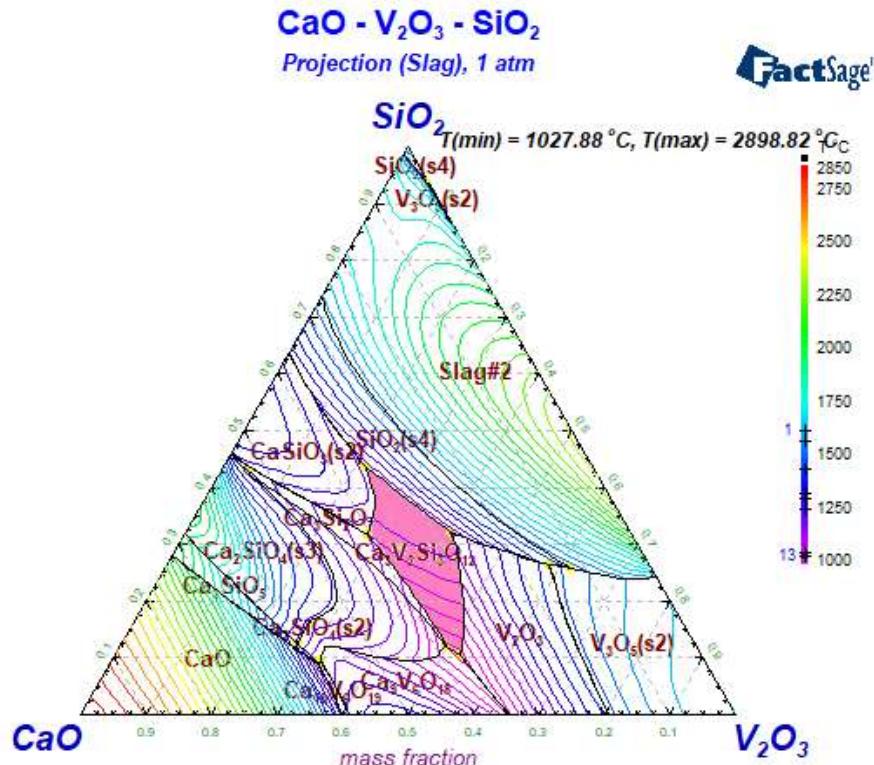
ZnO–V₂O₅ phase diagram in air

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Liquidus surface in CaO-SiO₂-V₂O₃

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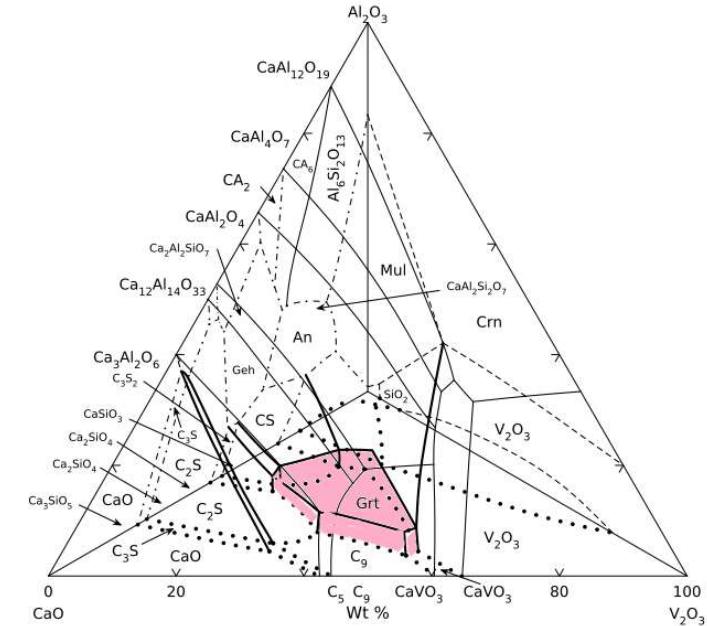
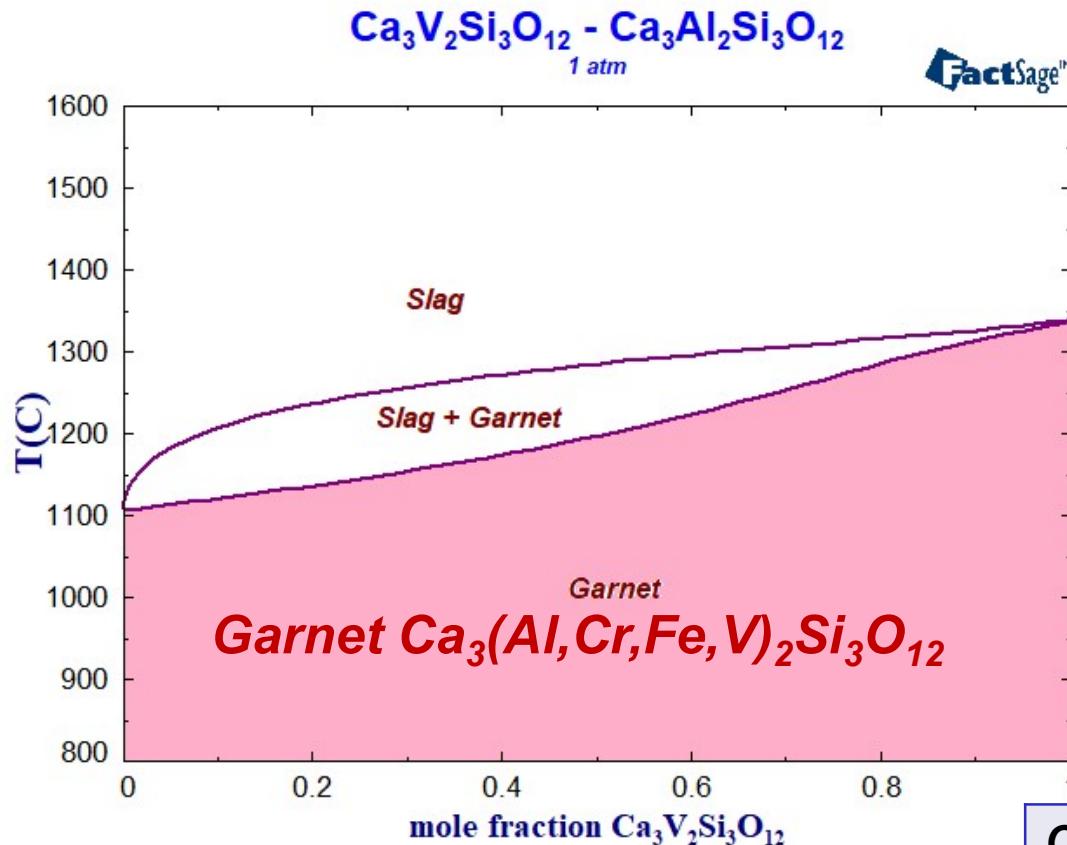
M. S. Najjar and A. Muan,
"Vanadium garnet materials", US
Patent 4,980,320, December 25, 1990

**Ca₃V₂Si₃O₁₂- Vanadium Garnet or
Goldmanite, calculated T_m=1339°C**



The phase Garnet $\text{Ca}_3(\text{Al,Cr,Fe,V})_2\text{Si}_3\text{O}_{12}$

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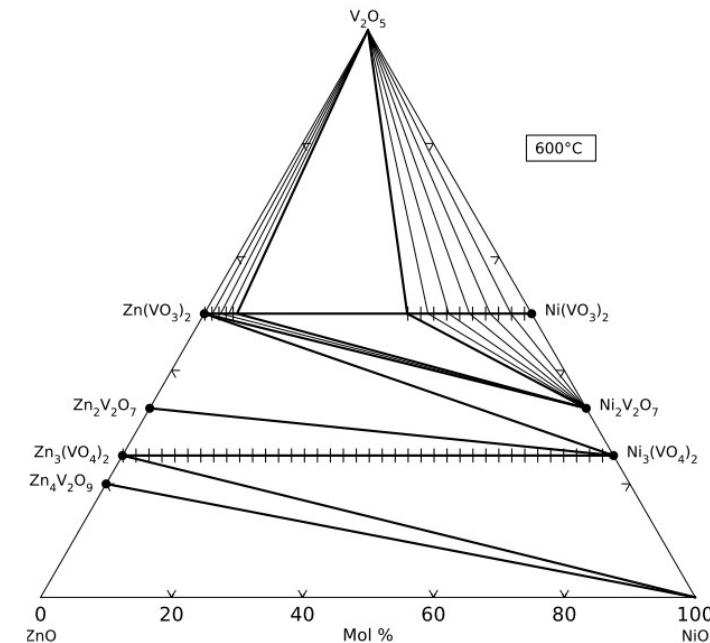
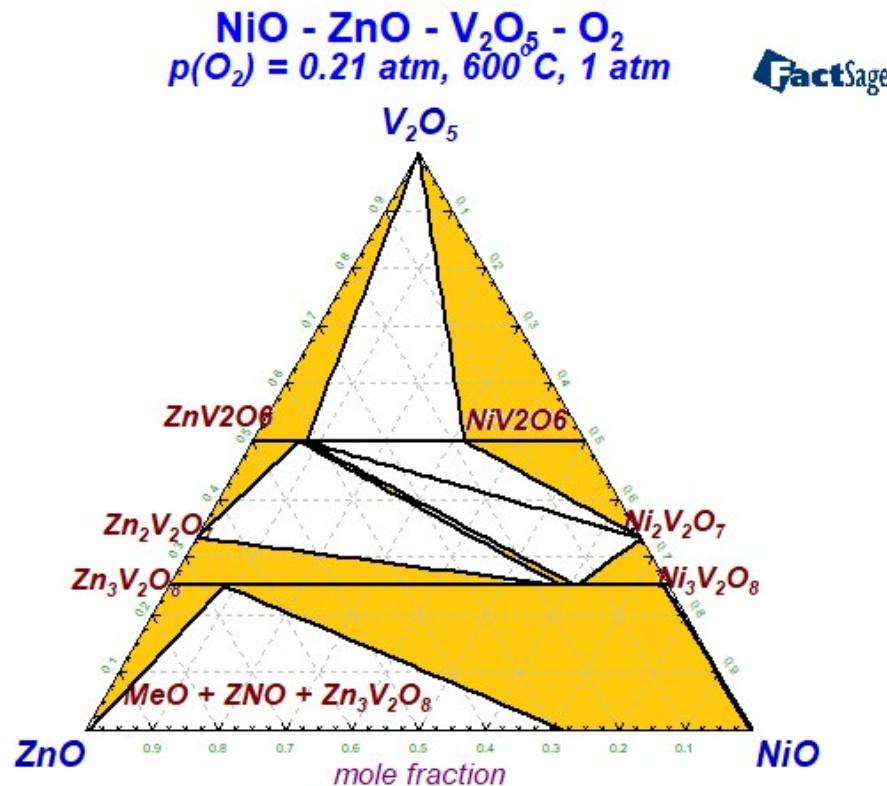
M. S. Najjar, Texaco Inc., White Plains, New York; private communication, 1992.

$\text{Ca}_3\text{Al}_2\text{Si}_3\text{O}_{12}$	Grossularite	Garnet
$\text{Ca}_3\text{Cr}_2\text{Si}_3\text{O}_{12}$	Uvarovite	
$\text{Ca}_3\text{Fe}_2\text{Si}_3\text{O}_{12}$	Andradite	
$\text{Ca}_3\text{V}_2\text{Si}_3\text{O}_{12}$	Goldmanite	



Isothermal section at 600°C in NiO-V₂O₅-ZnO

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L. L. Surat, V. D. Zhuravlev, A. A. Fotiev, Yu. A. Velikodnyi, Zh. Neorg. Khim., 41 [8] 1370-1372 (1996).



Vanadium recovery from LD converter slag

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Trans. Nonferrous Met. Soc. China 24(2014) 2687–2694

Transactions of
Nonferrous Metals
Society of China

www.tnmsc.cn

Extraction of vanadium from molten vanadium bearing slag by oxidation with pure oxygen in the presence of CaO



Wen-chen SONG^{1,2}, Hong LI^{1,2}, Fu-xing ZHU³, Kun LI^{1,2}, Quan ZHENG^{1,2}

1. State Key Laboratory of Advanced Metallurgy, University of Science and Technology Beijing, Beijing 100083, China;

2. School of Metallurgical and Ecological Engineering, University of Science and Technology Beijing, Beijing 100083, China;

3. State Key Laboratory for Comprehensive Utilization of Vanadium and Titanium Resources, Pangang Group Research Institute Co., Ltd, Panzhihua 617000, China

Table 1 Chemical composition of vanadium slag (mass fraction, %)

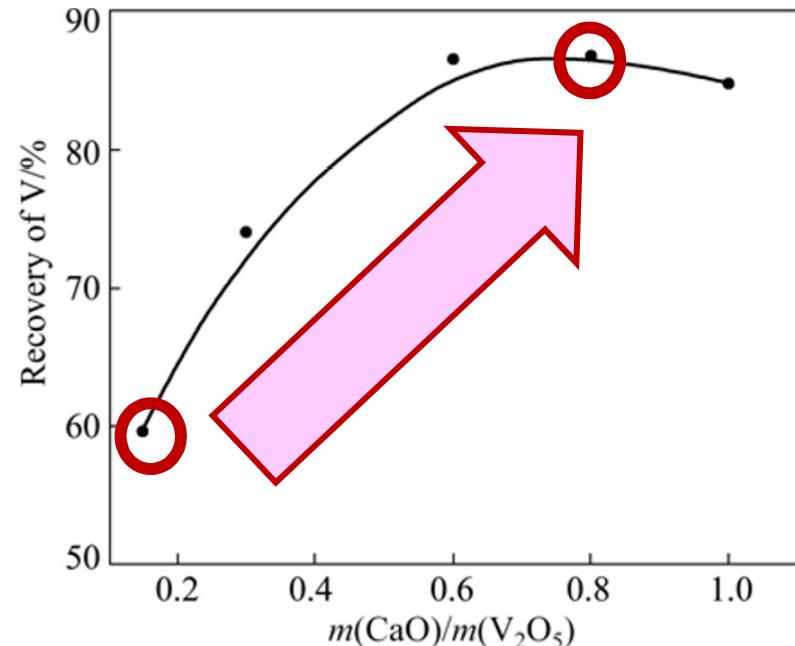
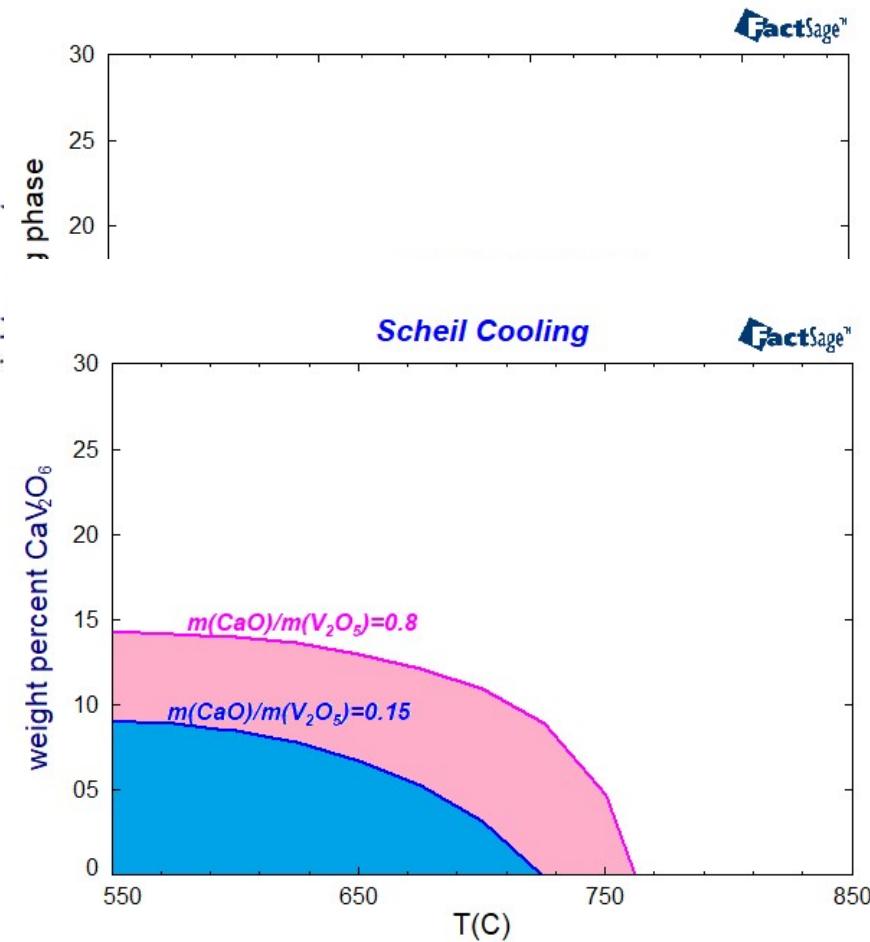
FeO	SiO ₂	V ₂ O ₃	TiO ₂	MnO
32.3	21.1	14.2	12.0	8.7
MgO	Al ₂ O ₃	CaO	P ₂ O ₅	
4.6	4.2	2.6	0.2	

$m(\text{CaO})/m(\text{V}_2\text{O}_5) = 0.15 \text{ to } 1$
Oxygen blown at T = 1450°C



Vanadium recovery from LD converter slag

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As the content of CaO increases, vanadium oxide will intensely interact with CaO to form more Ca–V-rich phases.

W.-C. Song, H. Li, F.-X. Zhu, K. Li, Q. Zheng, Trans. Nonferrous Met. Soc. China, 24 (2019), pp. 2687-2694.



Conclusions

- The liquid phase in all subsystems was evaluated using associate species model (two cations per species).
- All systems were assessed using experimental phase diagram information.
- **NiO**: 3 binary and 1 ternary systems were described.
- **SrO**: 10 binary and 2 ternary systems were described.
- **V₂O₃ and V₂O₅**: 4 binary and 10 ternary systems were described.



Thanks for your attention

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