Application 4: **Killing of steel in the ladle**

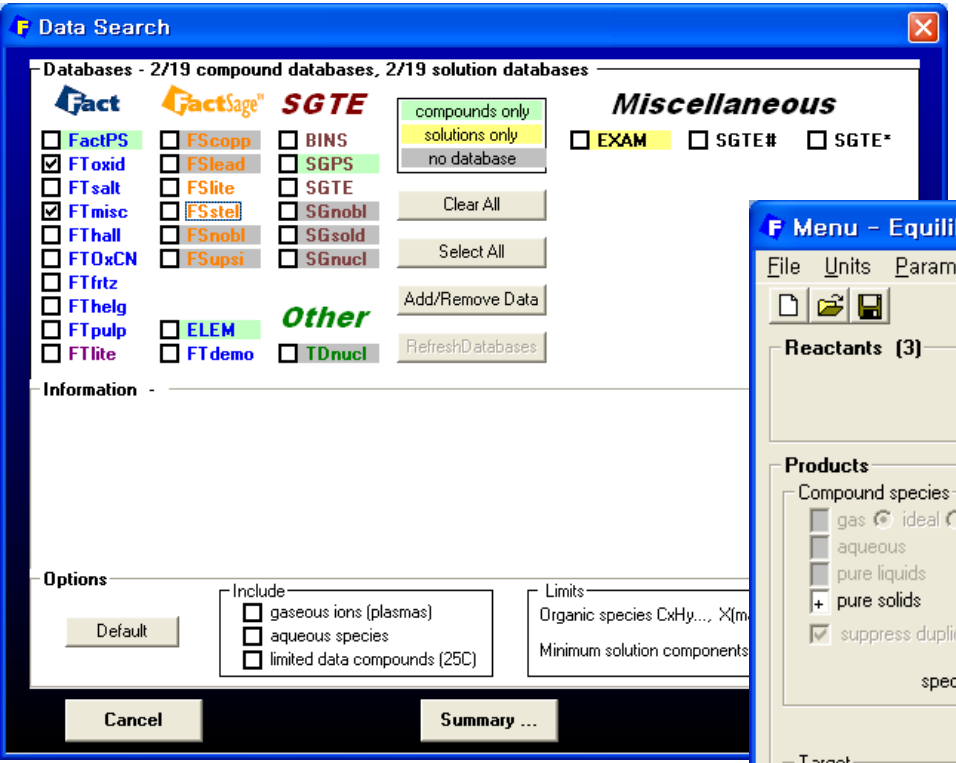
Deoxidation of steel
Inclusion formation / composition in molten steels
: Mn/Si/Ti steel
Inclusion stability diagram (phase diagram): Al/Ti steel

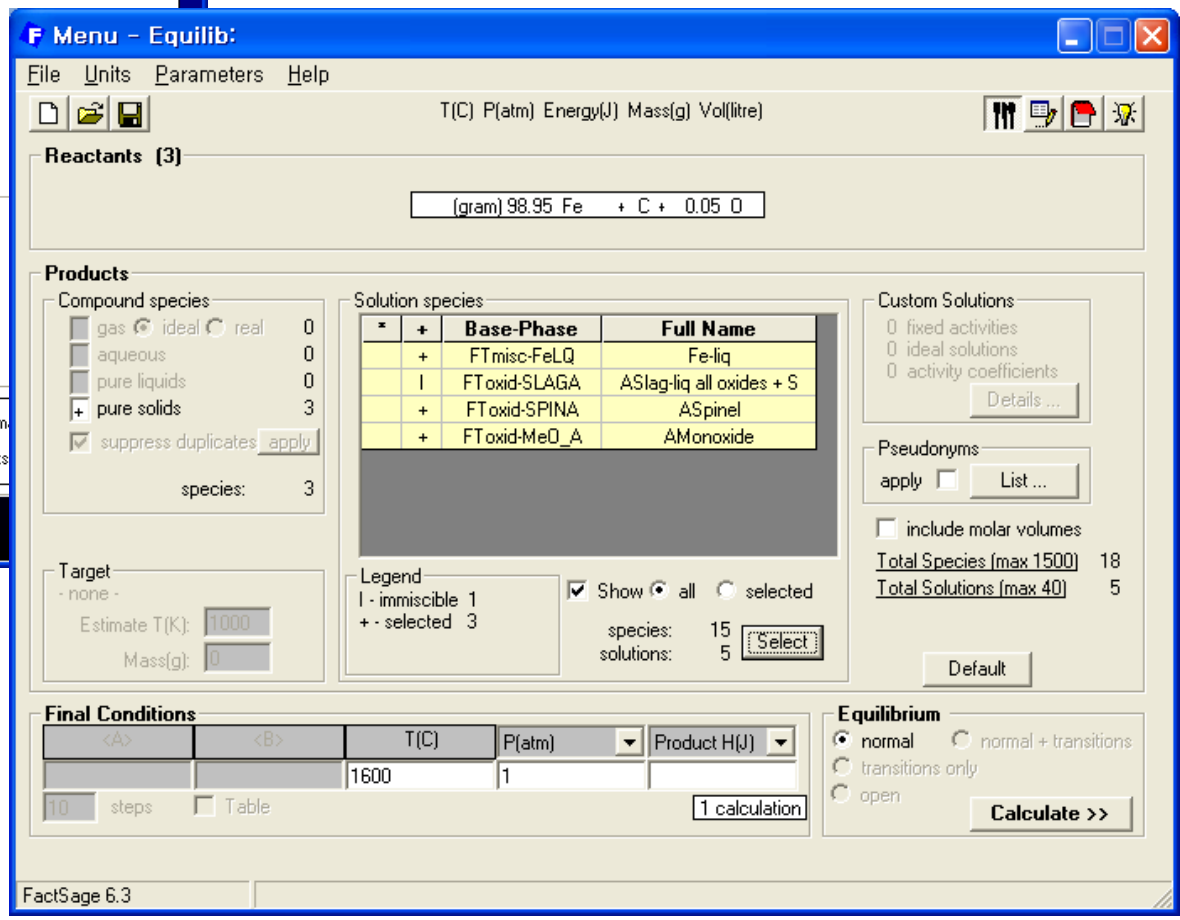
Ex3-1. Deoxidation of steel (Ferromanganese)

Liquid Fe-1wt.%C-500 ppm O at 1600°C

← Ftoxid: oxide inclusions

← Ftmisc: FeLq





Ex3-1. Deoxidation of steel (Ferromanganese)

Results - Equilib 1600 C

Output Edit Show Pages

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

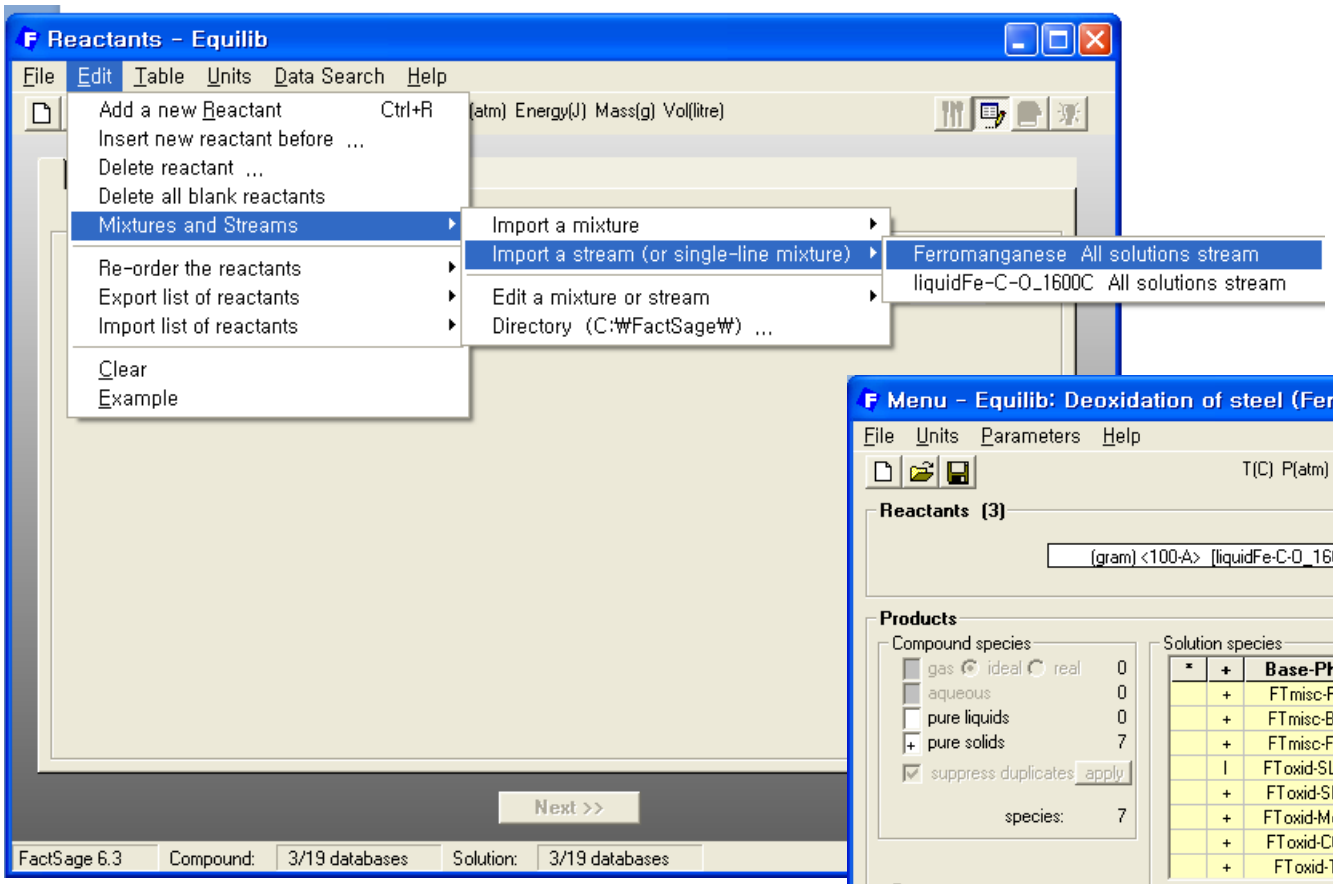
- Save or Print
- Plot
- Equilib Results file
- Stream File
  - Recycle all streams ...
  - Save stream file
    - Save gas phase ...
    - Save pure liquids ...
    - Save aqueous ...
    - Save pure solids ...
    - Save solutions
      - ALL solutions
      - FTmisc-FeLQ Fe-liq
      - FToxid-SLAGA#1 ASlag-liq
      - FToxid-SLAGA#2 ASlag-liq
      - FToxid-SPINA ASpinel
      - FToxid-MeO_A AMonoxide
  - Stream file properties ...
  - Summary of streams
  - Directory (C:₩FactSage₩) ...
- Format
- Fact-XML
- Fact-Optimal
- Fact-Function-Builder
- Refresh ...

```
FactSage 6.3

2 wt.% O                                                    FTm

System component        Mole fraction  Mass fraction
Fe                        0.95351        0.98950
O                         1.6818E-03     5.0000E-04
C                         4.4805E-02     1.0000E-02

+ 0        gram  AMonoxide
(1600 C, 1 atm,      a=0.15453)
( 95.355     wt.% FeO                                       FTo
+ 4.6453     wt.% Fe2O3                                     FTo

+ 0        gram  ASlag-liq#1
(1600 C, 1 atm,      a=0.10522)
( 92.358     wt.% FeO
+ 7.6419     wt.% Fe2O3

+ 0        gram  ASlag-liq#2
(1600 C, 1 atm,      a=0.10522)
( 92.358     wt.% FeO
+ 7.6419     wt.% Fe2O3
```

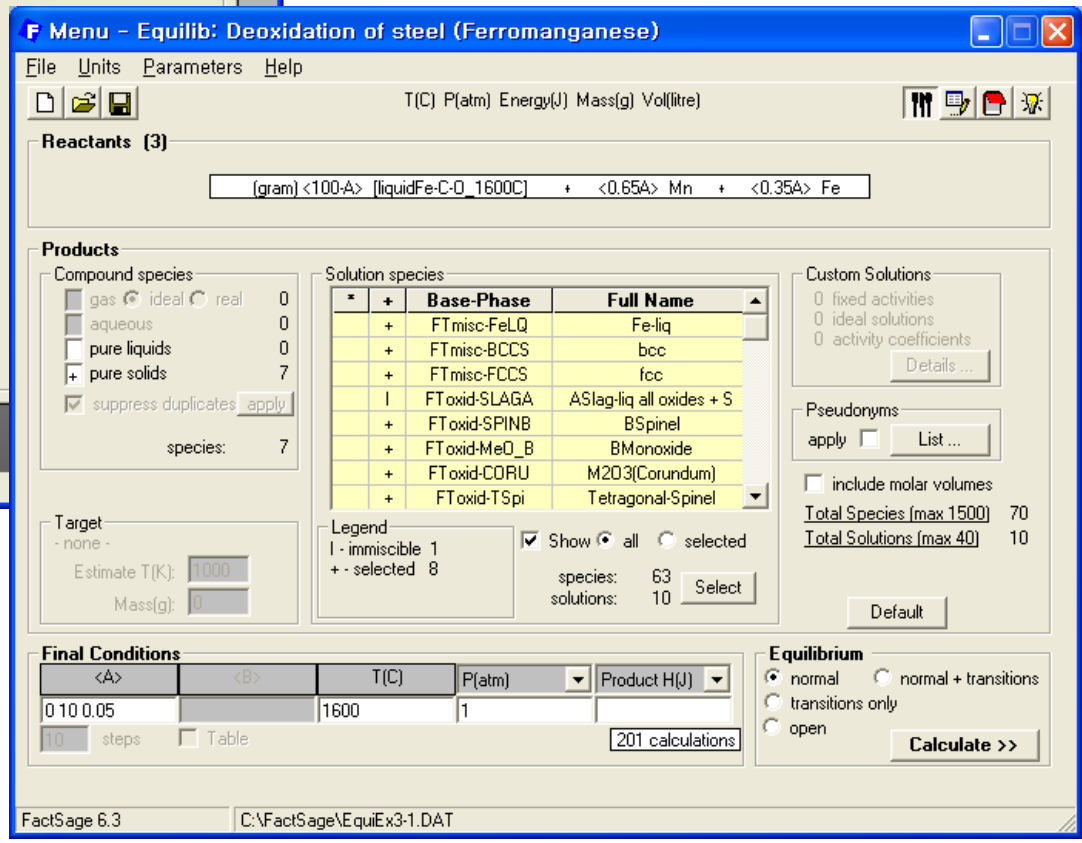
Save as stream

```
100.00      gram  Fe-liq
(100.00 gram, 1.8583 mol)
        (1600 C, 1 atm,      a=1.0000)
        ( 98.950     wt.% Fe                                FTmisc
        + 1.0000     wt.% C                                 FTmisc
        + 5.0000E-02 wt.% O                                 FTmisc)

        System component        Mole fraction  Mass fraction
        Fe                        0.95351        0.98950
        O                         1.6818E-03     5.0000E-04
        C                         4.4805E-02     1.0000E-02
```

Ex3-1. Deoxidation of steel (Ferromanganese)



65% Mn + 35% Fe



Ex3-1. Deoxidation of steel (Ferromanganese)

Results - Equilib A=0 (page 1/201)

Output Edit Show Pages

Save or Print
Plot
Equilib Results file
Stream File
Format
Fact-XML
Fact-Optimal
Fact-Function-Builder
Refresh ...

Plot Results ...
Repeat Plot - log10(gram) vs Alpha ...

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

A=1.1 | A=1.15 | A=1.2 | A=0.45 | A=0.5 | A=0.55

-C-O_1600C] + <A> [Ferromanganese] =

-liq
3 mol)
atm, a=1.0000)
wt.% Fe
wt.% C
2 wt.% O

System component Mole fraction Ma
Fe 0.95351
O 1.6818E-03
C 4.4805E-02

+ O gram BCC_A2
(1600 C, 1 atm, a=0.92889)
(0.69434 wt.% FelC3
+ 99.306 wt.% FelVa3

+ O gram FCC_A1
(1600 C, 1 atm, a=0.92679)
(2.1931 wt.% FelC1
+ 97.807 wt.% FelVal

+ O gram CUB_A13
(1600 C, 1 atm, a=0.71912)
(0.20013 wt.% FeC

Plot: log10(gram) vs

File Help

100% [liquid

Axes	Variables
	activity
	mole
	mole fract.
Y-axis	gram
	weight %
X-axis	Alpha
	T(C)
	P(atm)
	Cp(J)
	G(J)
	Vol(litre)
	H(J)
	V(litre)
	S(J)
	- page -

1. 201.

Axes: log10(gram) vs Alpha

Y-variable X-variable Swap Axes

Y-axis: log10(gram)
maximum -1.3
minimum -3
tick every 0.1

X-axis: Alpha
maximum 10
minimum 0
tick every 1

Cancel Refresh OK

Axes: log10(gram) vs Alpha
Axes

Species: 1 selected
Select
Repeat

Graph
Labels: size: 9 no: 4
chemical
integer #
none

Display
color
reactants
file name
full screen
Viewer
Figure

Plot >>

FactSage 6.3 C:\FactSage\Equi0.res 6Feb13 201 sets

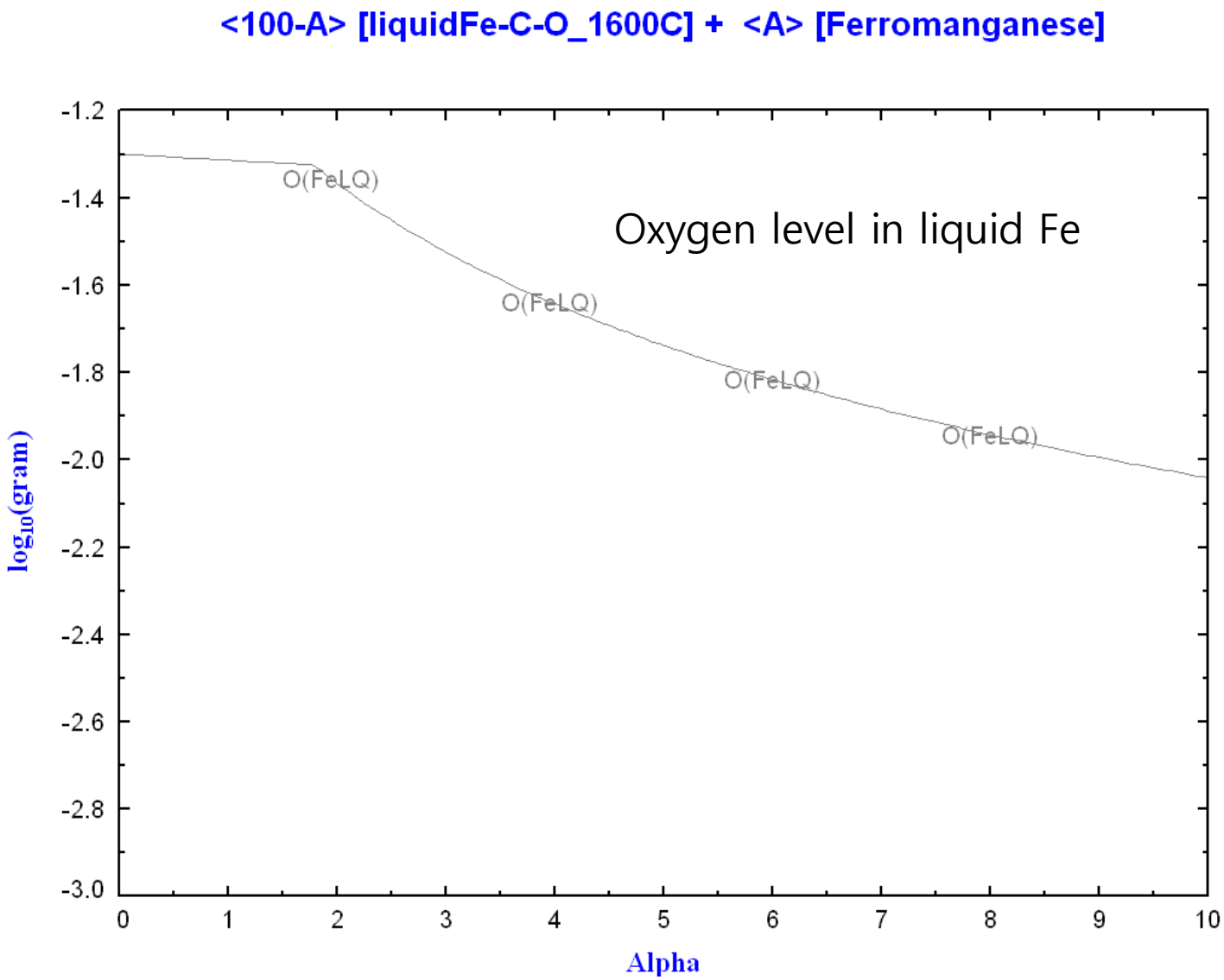
Species Selection - EQUILIB Results: log10(gram) vs Alpha

File Show Select

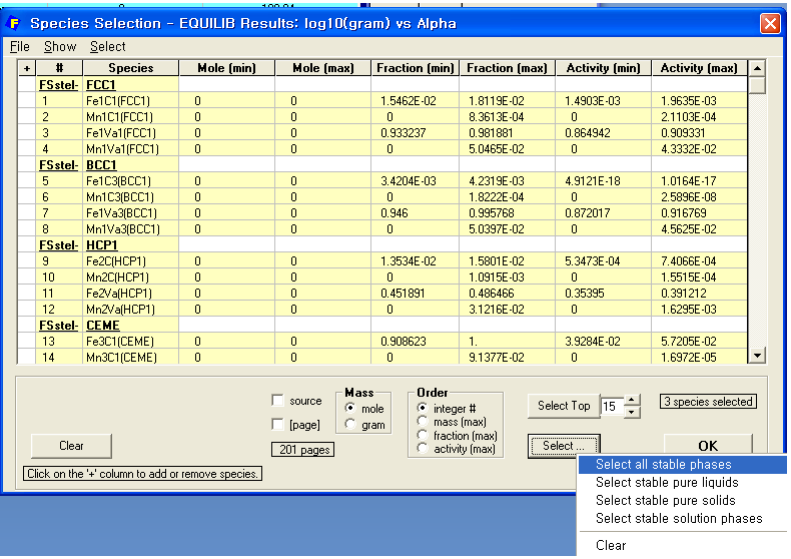
+	#	Species	Mole (min)	Mole (max)	Fraction (min)	Fraction (max)	Activity (min)	Activity (max)
	33	FeO(MONO)	0	7.3571E-05	2.0296E-02	1.	2.9605E-02	0.154038
	34	MnO(MONO)	0	2.2465E-03	0	0.979704	0	0.979858
	FTmisc	FeLQ						
	35	Fe(FeLQ)	1.7719	1.8345	0.901692	0.953513	0.899227	0.945375
	36	C(FeLQ)	8.3259E-02	8.3259E-02	4.0924E-02	4.4805E-02	3.6592E-02	4.5856E-02
	37	Mn(FeLQ)	0	0.115923	0	5.6978E-02	0	5.2637E-02
+	38	O(FeLQ)	6.8732E-04	3.1251E-03	3.3783E-04	1.6818E-03	3.1977E-06	1.5826E-05
	39	MnO(FeLQ)	0	1.3862E-04	0	6.8132E-05	0	6.7946E-05
	FToxid-	SLAG						
	40	FeO(SLAGA#1)	0	0	5.4309E-02	0.96411	3.7818E-02	0.19677
	41	Fe2O3(SLAGA#1)	0	0	3.0027E-04	3.5890E-02	1.1103E-07	1.4877E-05
	42	MnO(SLAGA#1)	0	0	0	0.943529	0	0.657311
	43	Mn2O3(SLAGA#1)	0	0	0	3.1769E-03	0	1.8248E-05
	FToxid-	SLAG						
	44	FeO(SLAGA#2)	0	0	5.4309E-02	0.96411	3.7818E-02	0.19677
	45	Fe2O3(SLAGA#2)	0	0	3.0027E-04	3.5890E-02	1.1103E-07	1.4877E-05
	46	MnO(SLAGA#2)	0	0	0	0.943529	0	0.657311
	47	Mn2O3(SLAGA#2)	0	0	0	3.1769E-03	0	1.8248E-05

source
[page]
201 pages
Mass: mole / gram
Order: integer # / mass (max) / fraction (max) / activity (max)
Select Top 15
1 species selected
Select ...
OK
Clear
Click on the '+' column to add or remove species.

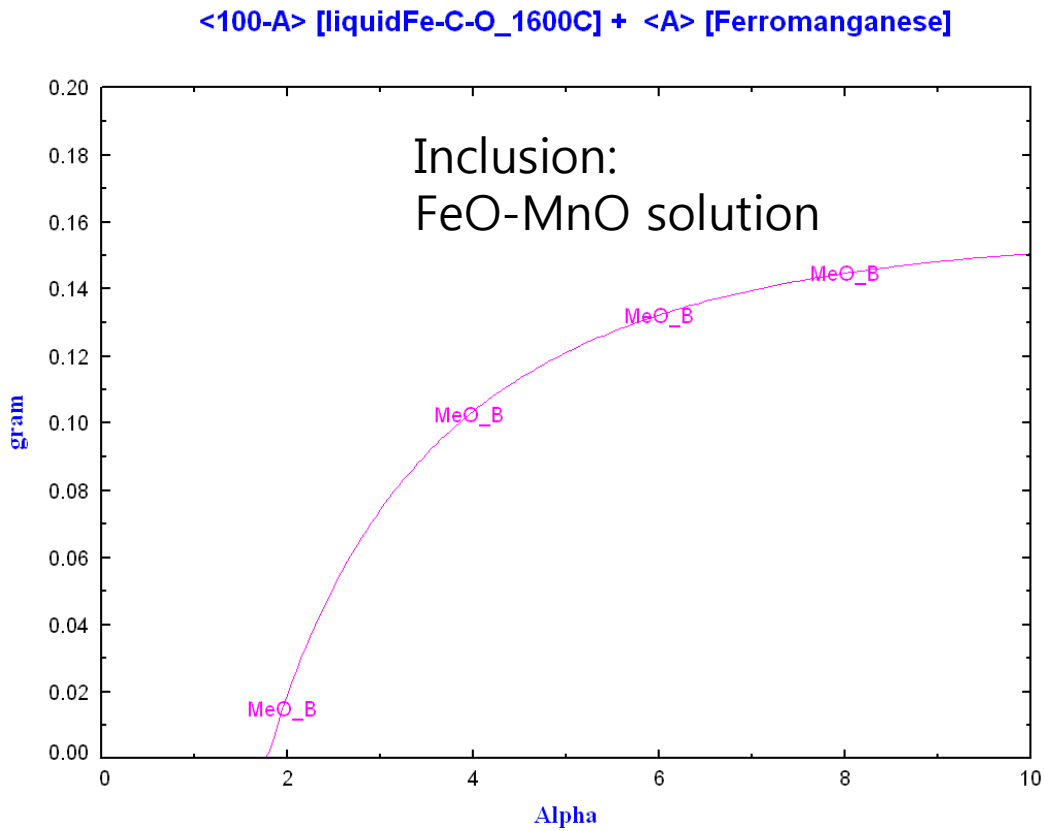
Ex3-1. Deoxidation of steel (Ferromanganese)



Ex3-1. Deoxidation of steel (Ferromanganese)



+	#	Species	Mole (min)	Mole (max)	Fraction (min)	Fraction (max)	Activity (min)	Activity (max)
	FSstel-	FCC1						
	1	Fe1C1(FCC1)	0	0	1.5462E-02	1.8119E-02	1.4903E-03	1.9635E-03
	2	Mn1C1(FCC1)	0	0	0	8.3613E-04	0	2.1103E-04
	3	Fe1Va1(FCC1)	0	0	0.933237	0.981881	0.864942	0.909331
	4	Mn1Va1(FCC1)	0	0	0	5.0465E-02	0	4.3332E-02
	FSstel-	BCC1						
	5	Fe1C3(BCC1)	0	0	3.4204E-03	4.2319E-03	4.9121E-18	1.0164E-17
	6	Mn1C3(BCC1)	0	0	0	1.8222E-04	0	2.5896E-08
	7	Fe1Va3(BCC1)	0	0	0.946	0.995768	0.872017	0.916769
	8	Mn1Va3(BCC1)	0	0	0	5.0397E-02	0	4.5625E-02
	FSstel-	HCP1						
	9	Fe2C(HCP1)	0	0	1.3534E-02	1.5801E-02	5.3473E-04	7.4066E-04
	10	Mn2C(HCP1)	0	0	0	1.0915E-03	0	1.5515E-04
	11	Fe2Va(HCP1)	0	0	0.451891	0.486466	0.35395	0.391212
	12	Mn2Va(HCP1)	0	0	0	3.1216E-02	0	1.6295E-03
	FSstel-	CEME						
	13	Fe3C1(CEME)	0	0	0.908623	1.	3.9284E-02	5.7205E-02
	14	Mn3C1(CEME)	0	0	0	9.1377E-02	0	1.6972E-05



Ex3-2. Deoxidation of steel (Ferrosilicon)

65%Si-35%Fe

Menu - Equilib: Deoxidation of steel (Ferrosilicon)

File Units Parameters Help

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

Reactants (3)

(gram) <100-A> [liquidFe-C-O_1600C] + <0.65A> Si + <0.35A> Fe

Products

Compound species: gas ideal real 0; aqueous 0; pure liquids 0; pure solids 17; suppress duplicates apply; species: 17

Solution species

*	+	Base-Phase	Full Name
	+	FTmisc-FeLQ	Fe-liq
	I	FToxid-SLAGA	ASlag-liq all oxides + S
		FToxid-SLAGG	GSlag-liq with C/N/CN
		FToxid-SLAG?	?Slag-liq
	+	FToxid-SPINA	ASpinel
	+	FToxid-MeO_A	AMonoxide
	+	FToxid-cPyrA	AClinopyroxene

Custom Solutions

Target - none - Estimate T(K): 1000 Mass(g): 0

Legend: I - immiscible 1; + - selected 4

Show all selected; species: 23; solutions: 6; Select

Final Conditions

<A>	<B>	T(C)	P(atm)	Product H(J)
0 10 0.05		1600	1	

10 steps Table 201 calculations

Equilibrium: normal; transition; open

FactSage 6.3 C:\FactSage\EquiEx3-2.DAT

Results - Equilib A=0 (page 1/201)

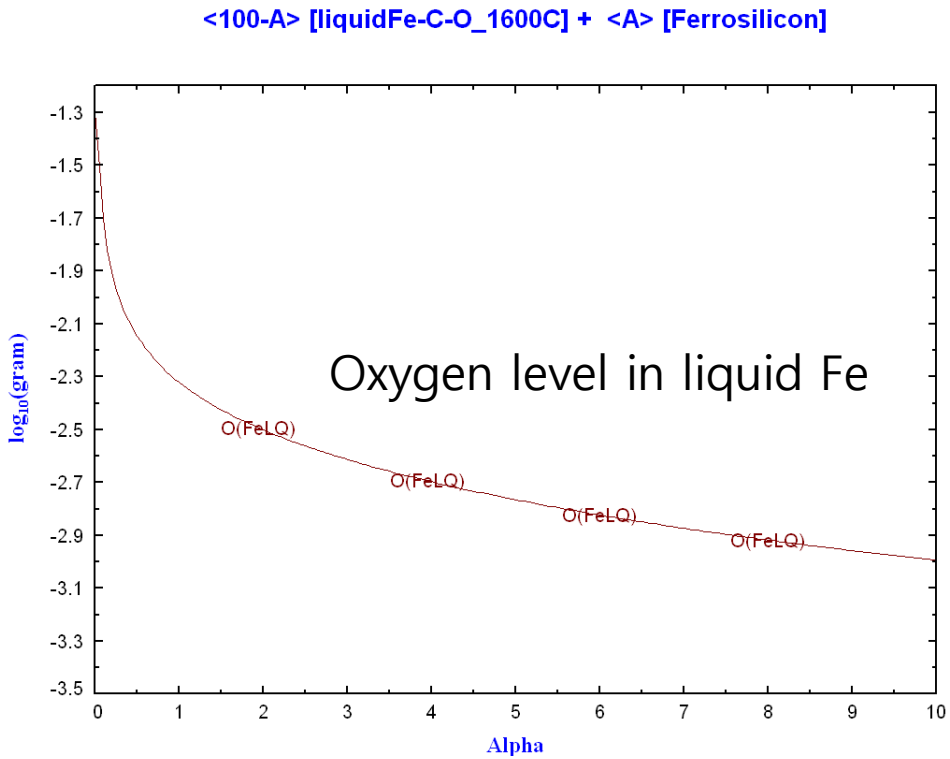
Output Edit Show Pages

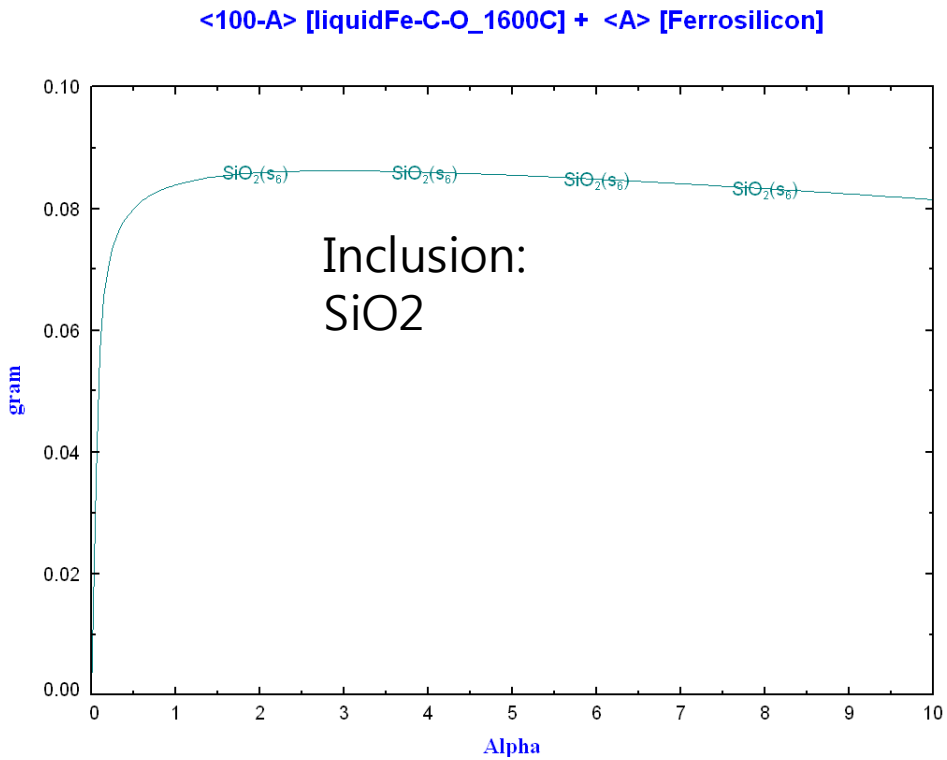
T(C) P(atm) Energy(J) Mass(g) Vol(litre)

A=0.65 | A=0.7 | A=0.75 | A=0.8 | A=0.85 | A=0.9 | A=0.95 | A=1 | A=1.05 | A=1.1 | A=1.15 | A=1.2 | A=0 | A=0.05 | A=0.1 | A=0.15 | A=0.2 | A=0.25 | A=0.3 | A=0.35 | A=0.4 | A=0.45 | A=0.5 | A=0.55 | A=0.6

```
                                                                    FactSage 6.3
(gram) <100-A> [liquidFe-C-O_1600C] +  <0.65A> Si +  <0.35A> Fe =

  100.00      gram  Fe-liq
  (100.00 gram, 1.8583 mol)
          (1600 C, 1 atm,      a=1.0000)
          ( 98.950      wt.% Fe                                      FTmisc
          + 1.0000      wt.% C                                       FTmisc
          + 5.0000E-02 wt.% O                                        FTmisc)

          System component        Mole fraction  Mass fraction
          Fe                        0.95351        0.98950
          O                         1.6818E-03     5.0000E-04
          C                         4.4805E-02     1.0000E-02

+ 0          gram  AMonoxide
          (1600 C, 1 atm,      a=0.15453)
          ( 95.355      wt.% FeO                                     FToxid
          + 4.6453      wt.% Fe2O3                                   FToxid)

+ 0          gram  ASlag-liq#1
          (1600 C, 1 atm,      a=0.10522)
          ( 92.358      wt.% FeO                                     FToxid
          + 7.6419      wt.% Fe2O3                                   FToxid)

+ 0          gram  ASlag-liq#2
          (1600 C, 1 atm,      a=0.10522)
          ( 92.358      wt.% FeO                                     FToxid
          + 7.6419      wt.% Fe2O3                                   FToxid)
```

Ex3-2. Deoxidation of steel (Ferrosilicon)





Ex3-3. Deoxidation of steel (Mn-Si)

50%Mn-50%Si

Menu - Equilib: Deoxidation of steel (Ferrosilicon)

File Units Parameters Help

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

Reactants (3)

(gram) <100-A> [liquidFe-C-O_1600C] + <0.5A> Mn + <0.5A> Si

Products

Compound species

gas ideal real	0
aqueous	0
pure liquids	0
pure solids	23
suppress duplicates apply	
species:	23

Solution species

*	+	Base-Phase	Full Name
	+	FTmisc-FeLQ	Fe-liq
	+	FTmisc-BCCS	bcc
	+	FTmisc-FCCS	fcc
	I	FToxid-SLAGA	ASlag-liq all oxides + S
		FToxid-SLAGG	GSlag-liq with C/N/CN
		FToxid-SLAG?	?Slag-liq
	+	FToxid-SPINB	BSpinel
	+	FToxid-MeO_B	BMonoxide

Custom Solutions

0 fixed activities

Target

- none -

Estimate T(K): 1000

Mass(g): 0

Legend

I - immiscible 1

+ - selected 12

Show all selected

species: 79

solutions: 14

Select

Final Conditions

<A>	<B>	T(C)	P(atm)	Product H(J)
0 10 0.05		1600	1	

10 steps Table 201 calculations

Equilibriu

normal

transition

open

FactSage 6.3 C:\FactSage\EquiEx3-2.DAT

Results - Equilib A=0 (page 1/201)

Output Edit Show Pages

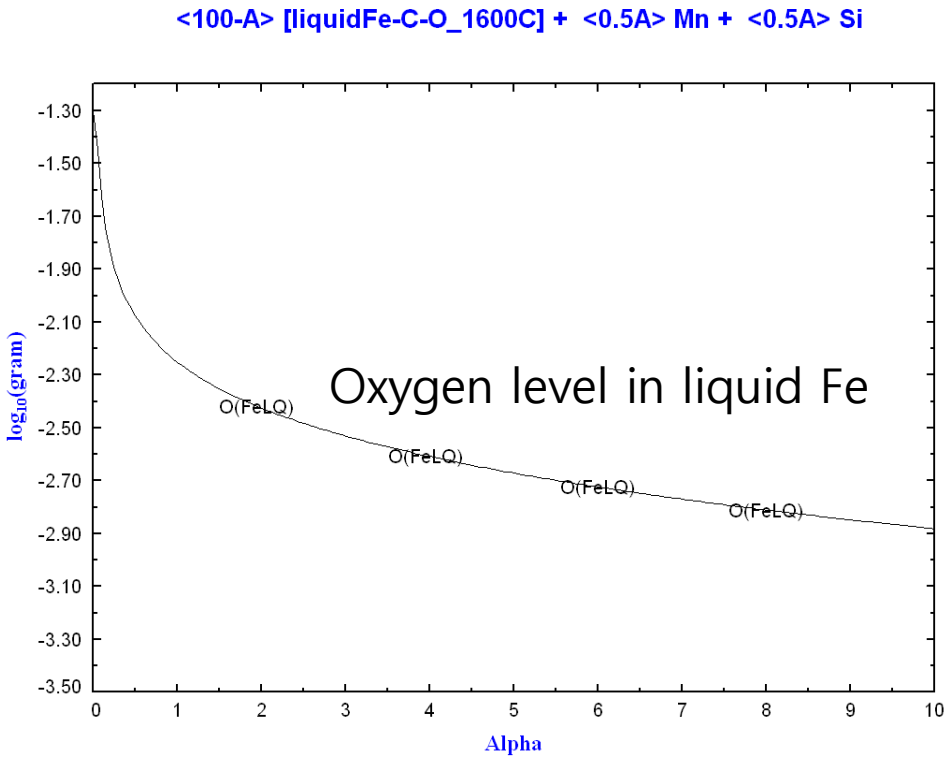
T(C) P(atm) Energy(J) Mass(g) Vol(litre)

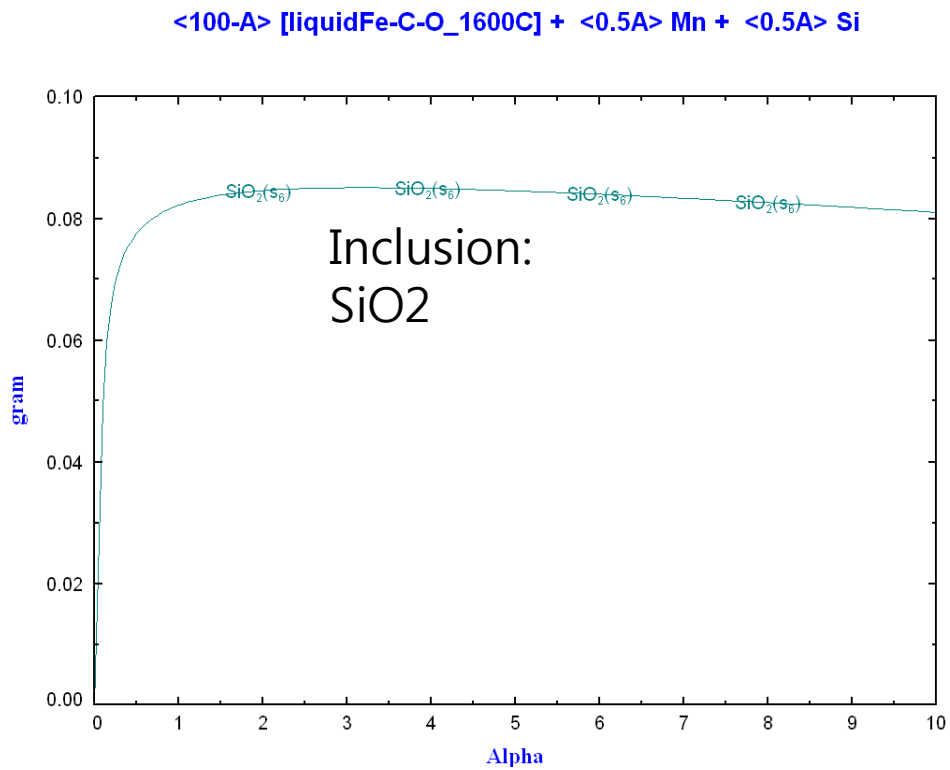
A=0.65 | A=0.7 | A=0.75 | A=0.8 | A=0.85 | A=0.9 | A=0.95 | A=1 | A=1.05 | A=1.1 | A=1.15 | A=1.2

A=0 | A=0.05 | A=0.1 | A=0.15 | A=0.2 | A=0.25 | A=0.3 | A=0.35 | A=0.4 | A=0.45 | A=0.5 | A=0.55 | A=0.6

```
                                                                    FactSage 6.3
(gram) <100-A> [liquidFe-C-O_1600C] +  <0.5A> Mn +  <0.5A> Si =

  100.00      gram  Fe-liq
  (100.00 gram, 1.8583 mol)
          (1600 C, 1 atm,      a=1.0000)
          ( 98.950      wt.% Fe                                    FTmisc
          + 1.0000      wt.% C                                     FTmisc
          + 5.0000E-02 wt.% O                                      FTmisc)

          System component        Mole fraction  Mass fraction
          Fe                        0.95351        0.98950
          O                         1.6818E-03     5.0000E-04
          C                         4.4805E-02     1.0000E-02

+ 0          gram  bcc
          (1600 C, 1 atm,      a=0.91677)
          ( 100.00      wt.% Fe:Va                                 FTmisc)

+ 0          gram  fcc
          (1600 C, 1 atm,      a=0.90933)
          ( 100.00      wt.% Fe:Va                                 FTmisc)

+ 0          gram  BMonoxide
          (1600 C, 1 atm,      a=0.15453)
          ( 95.355      wt.% FeO                                   FToxid
          + 4.6453      wt.% Fe2O3                                 FToxid)

+ 0          gram  ASlag-liq#1
```

Ex3-3. Deoxidation of steel (Mn-Si)





Ex3-4. Deoxidation of steel (Mn-Si-Al)

33.333%Mn-33.333%Si-33.333%Al

Menu - Equilib:

File Units Parameters Help

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

Reactants (4)

(gram) <100-A> [liquidFe-C-O_1600C] + <0.33333A> Mn + <0.33333A> Si + <0.33333A> Al

Products

Compound species

gas ideal real	0
aqueous	0
pure liquids	0
pure solids	35
suppress duplicates apply	
species:	35

Solution species

*	+	Base-Phase	Full Name
	+	FTmisc-FeLQ	Fe-liq
	+	FTmisc-BCCS	bcc
	+	FTmisc-FCCS	fcc
	I	FToxid-SLAGA	ASlag-liq all oxides + S
		FToxid-SLAGG	GSlag-liq with C/N/CN
		FToxid-SLAG?	?Slag-liq
	I	FToxid-SPINA	ASpinel
		FToxid-SPINB	BSpinel

Legend
I - immiscible 4
+ - selected 12

Show all selected
species: 113
solutions: 20
Select

Custom Solutions

Target
- none -
Estimate T(K): 1000
Mass(g): 0

Final Conditions

<A>	<B>	T(C)	P(atm)	Product H(J)
0 1 0 0.05		1600	1	

10 steps Table 201 calculations

Equilibrium
normal
transition
open

FactSage 6.3

Results - Equilib A=0 (page 1/201)

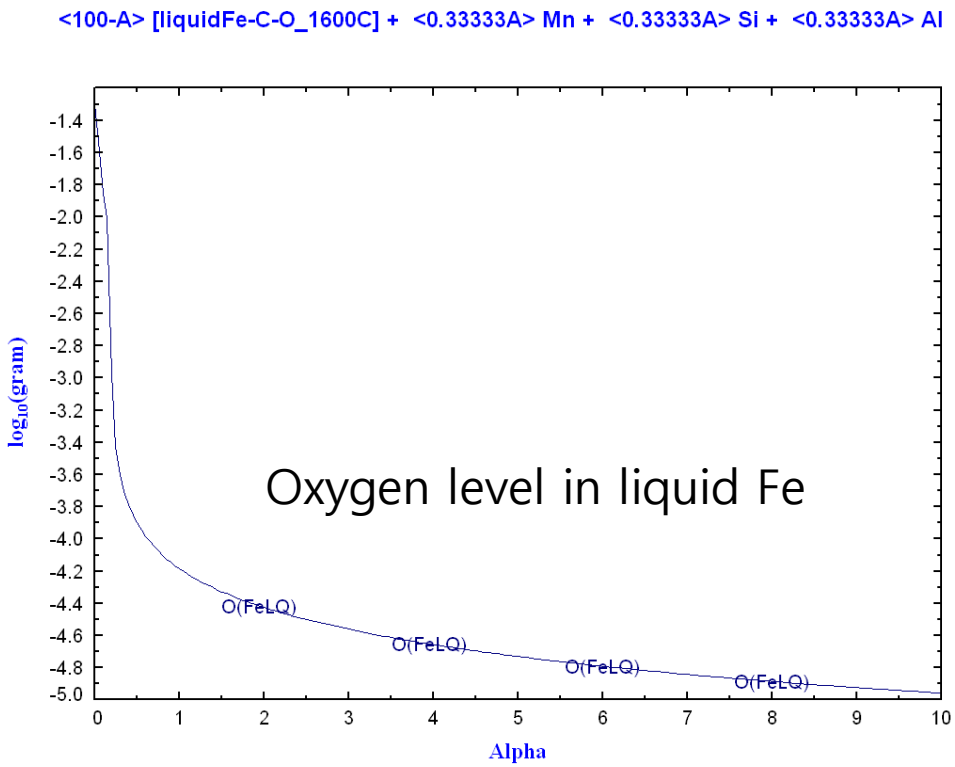
Output Edit Show Pages

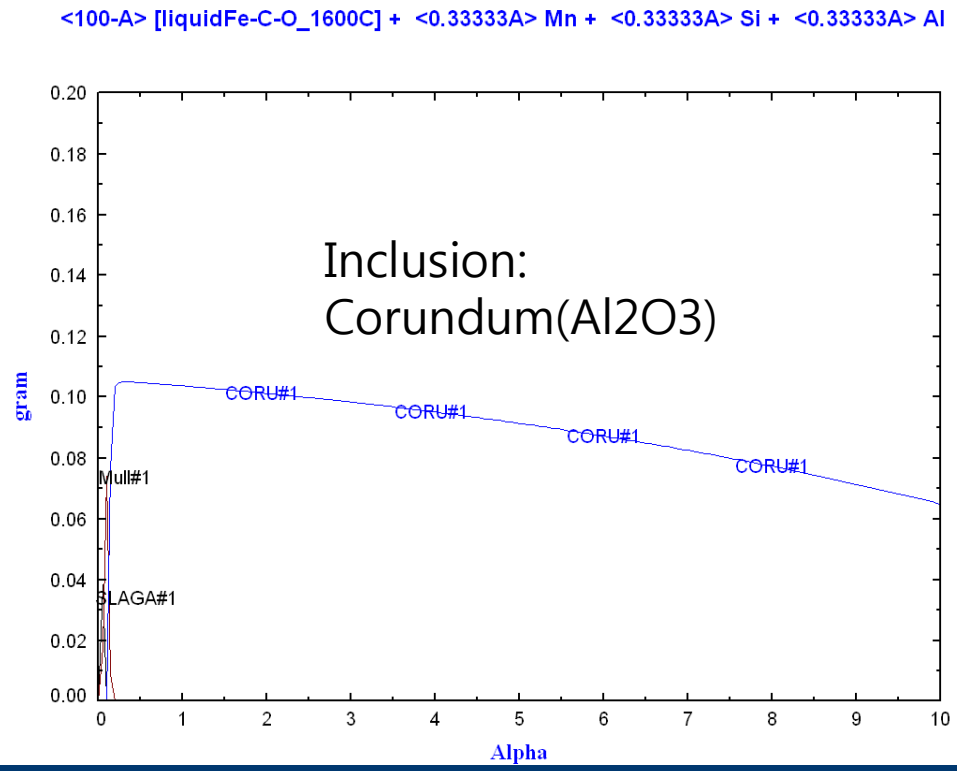
T(C) P(atm) Energy(J) Mass(g) Vol(litre)

A=0.65 | A=0.7 | A=0.75 | A=0.8 | A=0.85 | A=0.9 | A=0.95 | A=1 | A=1.05 | A=1.1 | A=1.15 | A=1.2
A=0 | A=0.05 | A=0.1 | A=0.15 | A=0.2 | A=0.25 | A=0.3 | A=0.35 | A=0.4 | A=0.45 | A=0.5 | A=0.55 | A=0.6

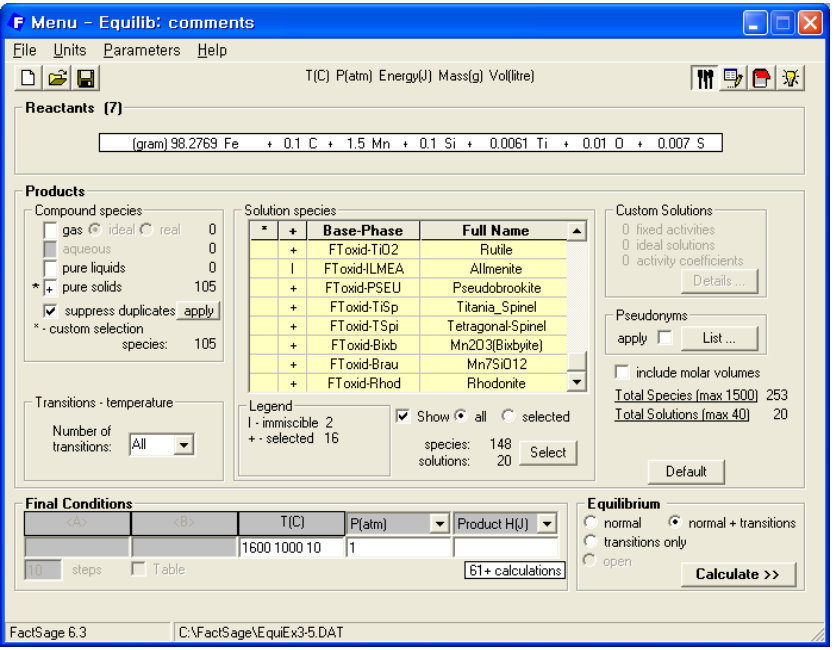
```
                                                                    FactSage 6.3
(gram) <100-A> [liquidFe-C-O_1600C] + <0.33333A> Mn + <0.33333A> Si + <0.3...

  100.00      gram  Fe-liq
  (100.00 gram, 1.8583 mol)
          (1600 C, 1 atm,      a=1.0000)
          ( 98.950      wt.% Fe                                     FTmisc
          + 1.0000      wt.% C                                      FTmisc
          + 5.0000E-02 wt.% O                                       FTmisc)

          System component        Mole fraction  Mass fraction
          Fe                        0.95351        0.98950
          O                         1.6818E-03     5.0000E-04
          C                         4.4805E-02     1.0000E-02

+ 0          gram  bcc
          (1600 C, 1 atm,      a=0.91677)
          ( 100.00      wt.% Fe:Va                                  FTmisc)

+ 0          gram  fcc
          (1600 C, 1 atm,      a=0.90933)
          ( 100.00      wt.% Fe:Va                                  FTmisc)

+ 0          gram  AMonoxide
          (1600 C, 1 atm,      a=0.15453)
          ( 95.355      wt.% FeO                                    FToxid
          + 4.6453      wt.% Fe2O3                                  FToxid)

+ 0          gram  ASlag-liq#1
```

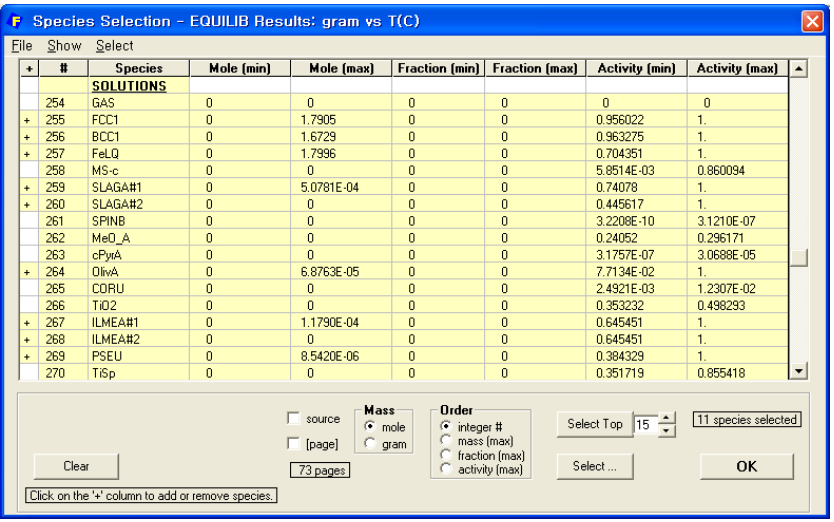
Ex3-4. Deoxidation of steel (Mn-Si-Al)





Ex3-5. Inclusion evolution with temperature: Mn/Si/Ti steel

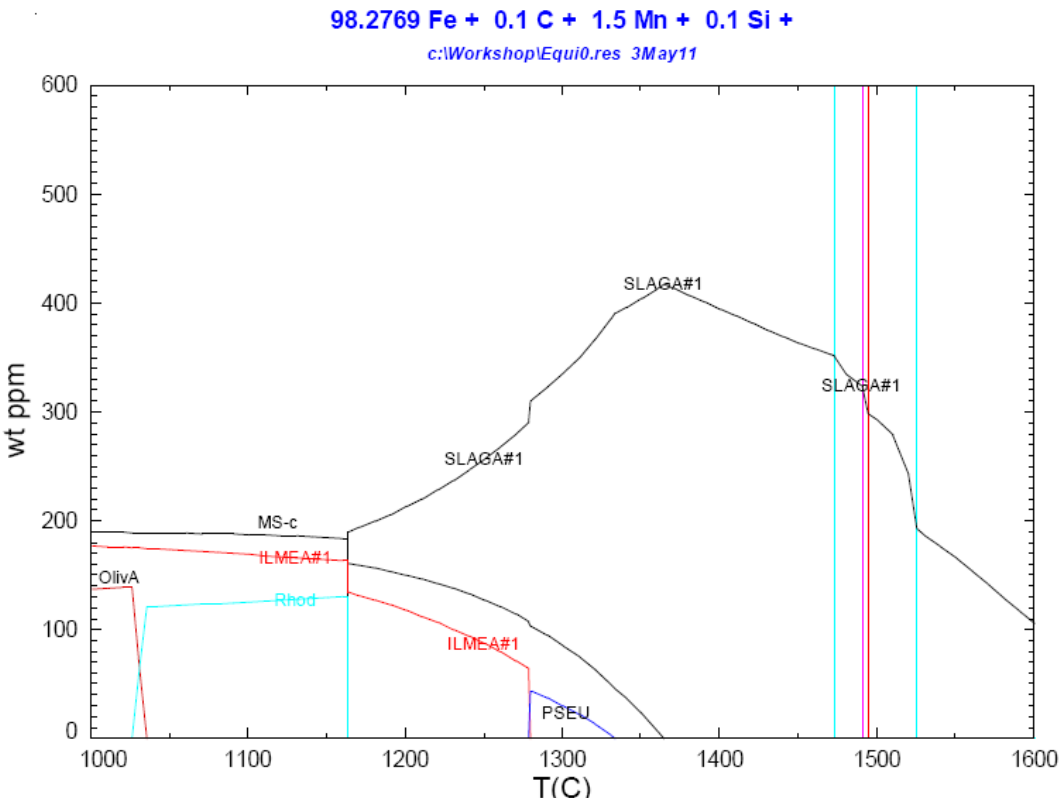




← FToxid : oxide inclusions

← FTmisc: FeLq, MnS solid (MS_c)

← FSStel: solid steel phases (fcc, bcc)

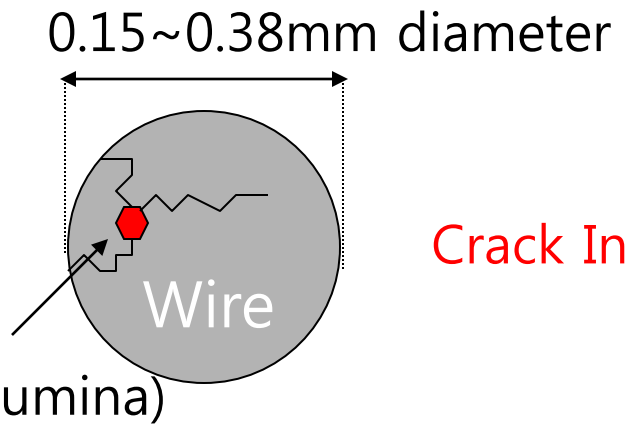


← Select all phases (pure solids and solutions) with amount > 0

Or simply select all stable phases

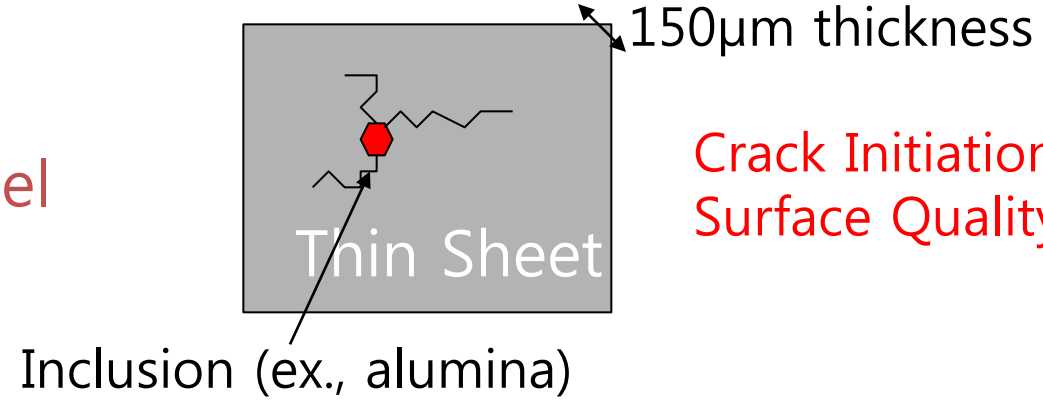
Application to Tire-Cord Steel (Mn/Si deoxidation)

Tire-Cord Steel



Crack Initiation

Fe-36%Ni Invar Steel

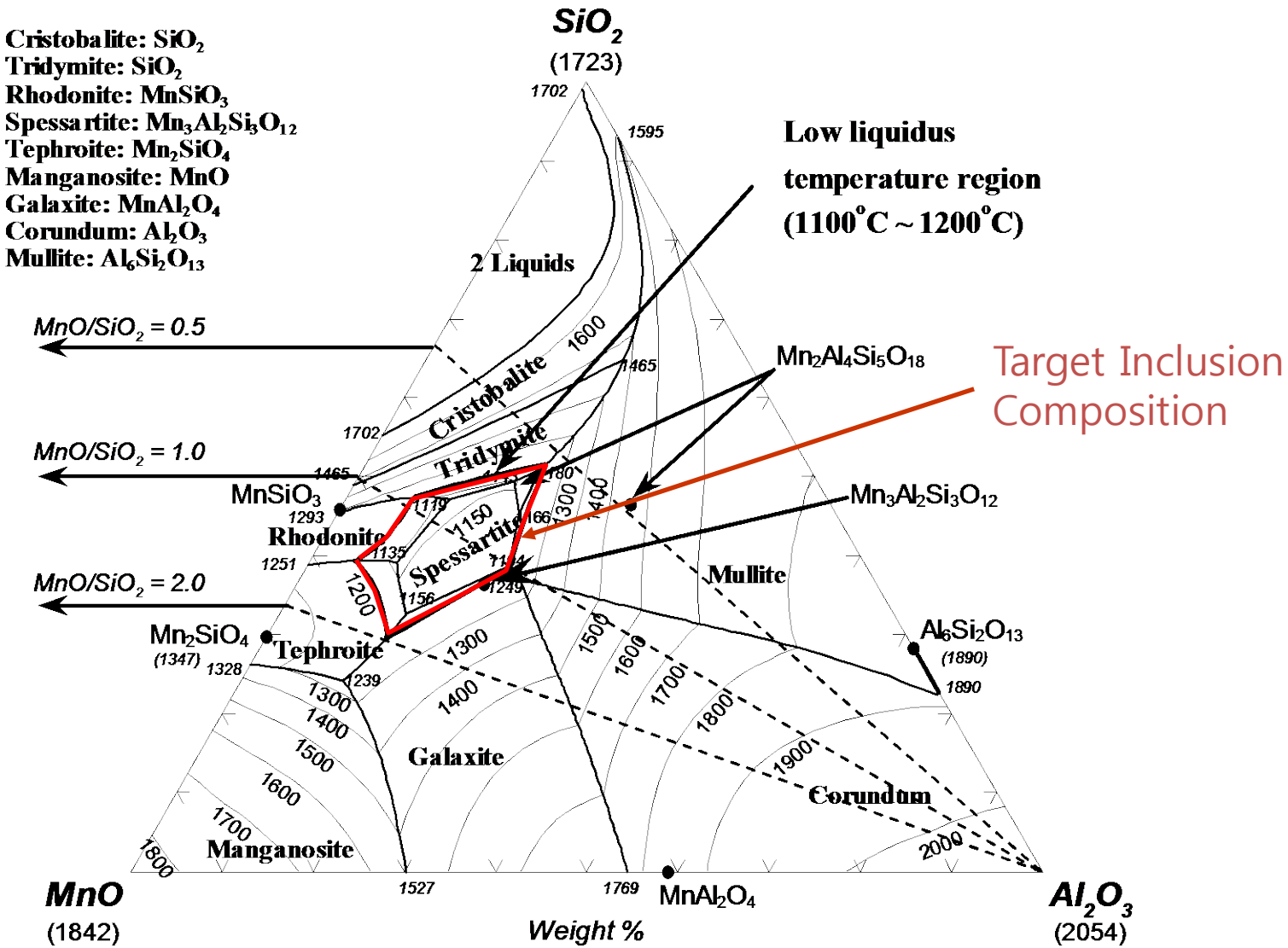


Crack Initiation
Surface Quality

- Undeformable Inclusion should be removed
- Liquid phase is desirable at process temperature (~1200°C)

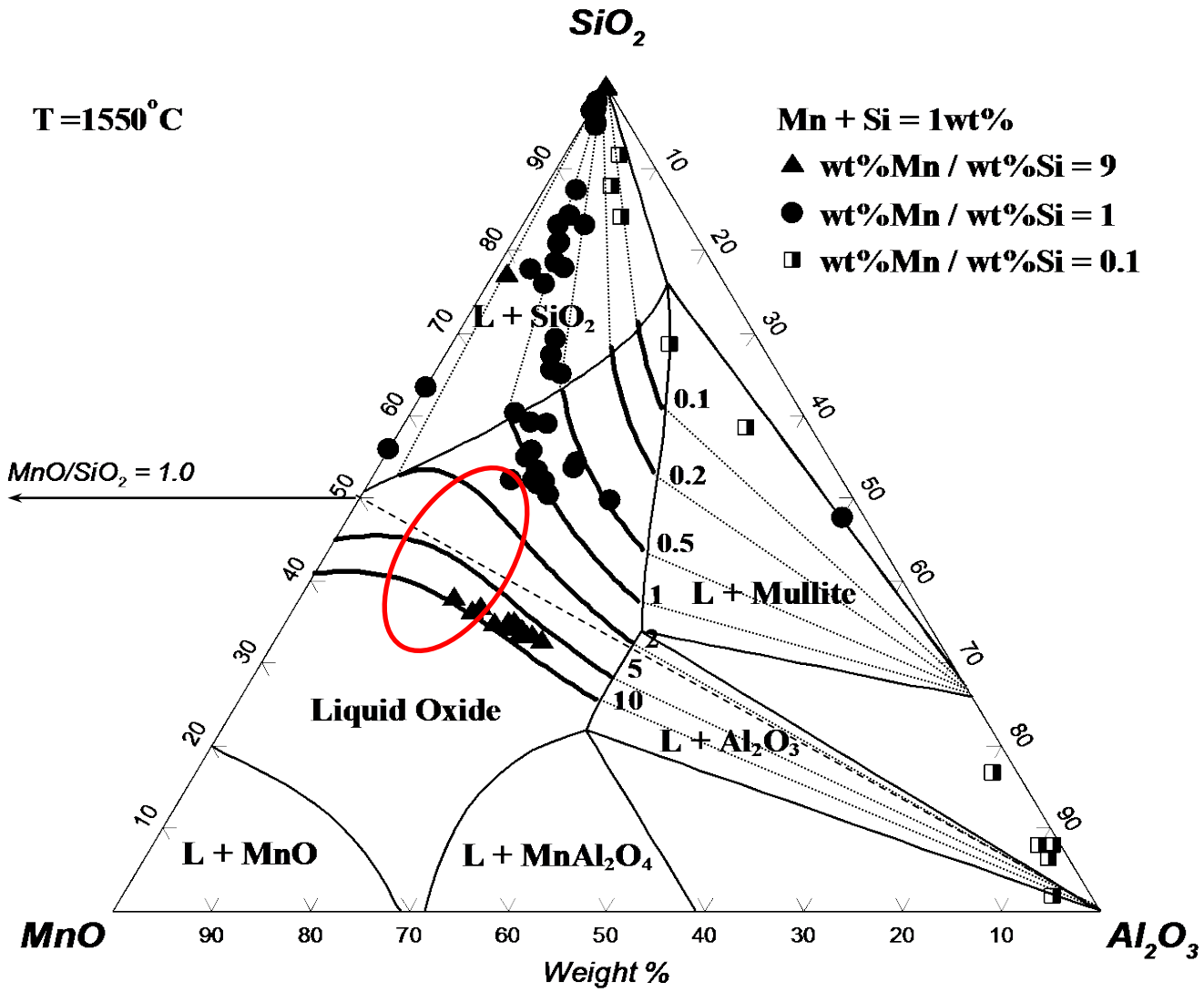
→ **Mn/Si Deoxidation**

$MnO-Al_2O_3-SiO_2$ Phase Diagram



Jung et al., Metall. Mater. Trans. B, 2004, vol. 35B, pp. 259-268

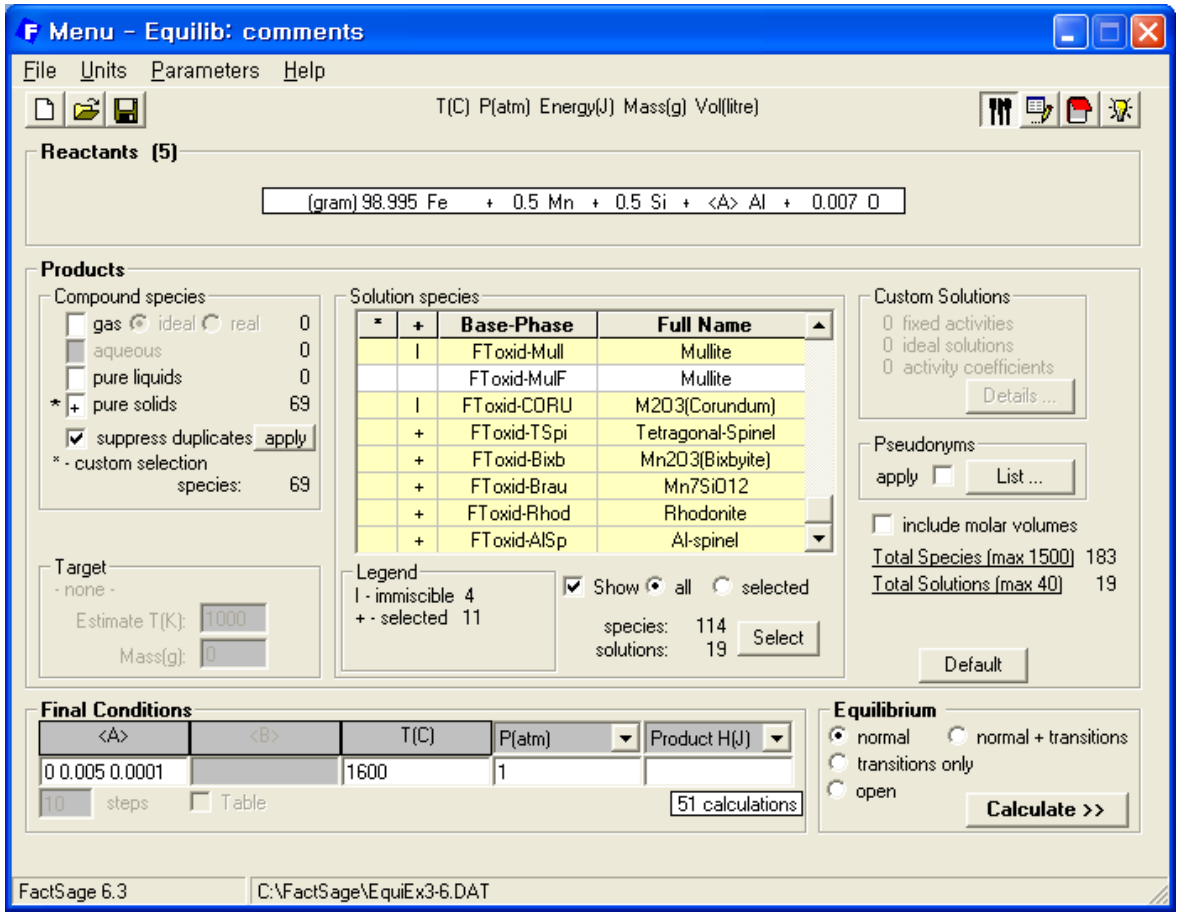
Inclusion composition with steel composition



Jung et al., Metall. Mater. Trans. B, 2004, vol. 35B, pp. 259-268
Kang and Lee, ISIJ Inter., 2004.

Ex3-6. Inclusion calculation in Mn/Si deoxidation

Calculation of the inclusion trajectory using Equilib



The compositions of Mn and Si are set based on the target Mn/Si ratio and Mn+Si content
Oxygen content should be controlled reasonably. If O is too high, Mn and Si will be largely changed from original target composition after rxn with oxygen.

Ex3-6. Inclusion calculation in Mn/Si deoxidation

Results - Equilib A=0.001 (page 11/51)

Output Edit Show Pages

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

A=0 | A=1.00E-04 | A=0.0002 | A=0.0003 | A=0.0004 | A=0.0005 | A=0.0006 | A=0.0007 | A=0.0008 | A=0.0018 | A=0.0019 | A=0.002 | A=0.0021 | A=0.0022 | A=0.0023 | A=0.0024 | A=0.0009 | - A=0.001 - | A=0.0011 | A=0.0012 | A=0.0013 | A=0.0014 | A=0.0015 | A=0.0016 | A=0.0017

```
(gram) 98.995 Fe +  0.5 Mn +  0.5 Si +  <A> Al +

(gram) 0.007 O =

 99.998     gram  Fe-liq
 (99.998 gram, 1.7998 mol)
        (1600.00 C, 1 atm,     a=1.0000)
        ( 98.997     wt.% Fe                                  FTmisc
        + 2.3649E-04 wt.% Al                                  FTmisc
        + 0.49861    wt.% Mn                                  FTmisc
        + 4.5663E-03 wt.% O                                   FTmisc
        + 0.49882    wt.% Si                                  FTmisc
        + 6.8340E-05 wt.% AlO                                 FTmisc
        + 1.3779E-04 wt.% SiO                                 FTmisc
        + 3.7851E-04 wt.% MnO                                 FTmisc
        + 5.6476E-08 wt.% Al2O                                FTmisc)

        System component       Mole fraction  Mass fraction
        Fe                       0.98492        0.98997
        Mn                       5.0455E-03     4.9890E-03
        Si                       9.8696E-03     4.9891E-03
        Al                       5.7541E-06     2.7944E-06
        O                        1.6415E-04     4.7271E-05

+ 5.3906E-03 gram  ASlag-liq#1
 (5.3906E-03 gram, 7.6111E-05 mol)
        (1600.00 C, 1 atm,     a=1.0000)
        ( 25.257     wt.% Al2O3                               FToxid
        + 43.746     wt.% SiO2                                FToxid
        + 4.4146     wt.% FeO                                 FToxid
        + 1.2224E-03 wt.% Fe2O3                               FToxid
        + 26.576     wt.% MnO                                 FToxid
        + 5.1664E-03 wt.% Mn2O3                               FToxid)

        Site fraction of sublattice constituents:
        Al                       0.29850
        Si                       0.43869
        Fe2+                     3.7023E-02
        Fe3+                     9.2243E-06
        Mn2+                     0.22573
        Mn3+                     3.9435E-05
        ----------------------------------
        O                        1.0000
```

Mn + Si + Al + O → (Mn,Si,Al) oxide inclusion

After deoxidation, Mn ~ 0.5 and Si ~ 0.5

(Target steel composition: Mn/Si = 1 and Mn+Si = 1)

→ Extraction of slag composition

Spreadsheet - Equilib T(C) = 1600, P(atm) = 1, Alpha = 0...

File Edit Show

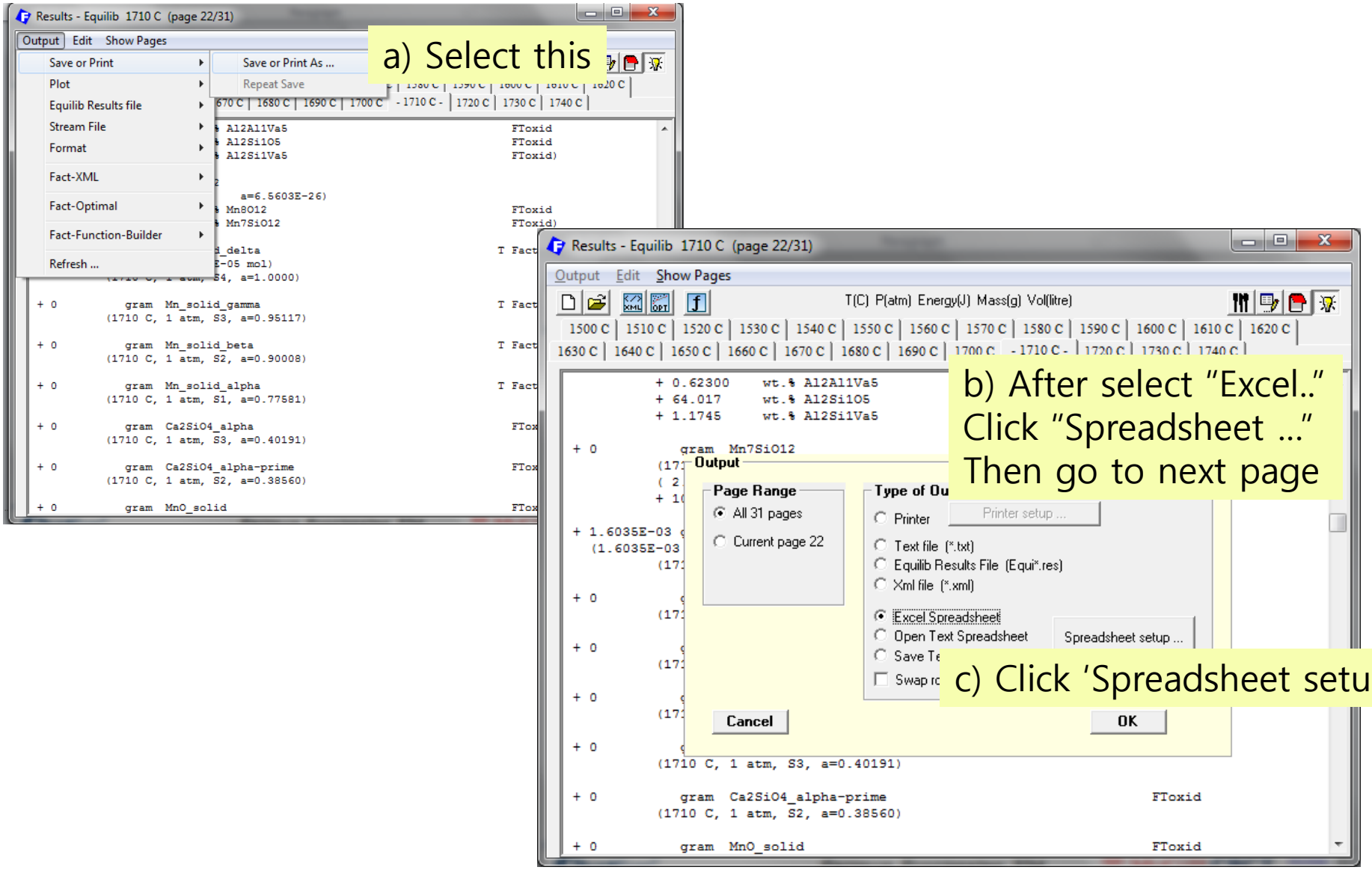
Selected: 6/76 | Spreadsheet Species | Page 51 | Refresh

+	Code	Species	Data	Phase	T	V	Activity
	44	AlO(FeLQ)	FTmisc	FTmisc-FeLQ			1.9788E-06
	45	SiO(FeLQ)	FTmisc	FTmisc-FeLQ			1.2069E-06
	46	MnO(FeLQ)	FTmisc	FTmisc-FeLQ			2.0599E-06
	47	Al2O(FeLQ)	FTmisc	FTmisc-FeLQ			3.2461E-09
+	63	Al2O3(SLAGA)	FToxid	FToxid-SLAGA			0.2308
+	64	SiO2(SLAGA)	FToxid	FToxid-SLAGA			0.2550
+	65	FeO(SLAGA)	FToxid	FToxid-SLAGA			1.3509E-02
+	66	Fe2O3(SLAGA)	FToxid	FToxid-SLAGA			4.6227E-09
+	67	MnO(SLAGA)	FToxid	FToxid-SLAGA			1.9928E-02
+	68	Mn2O3(SLAGA)	FToxid	FToxid-SLAGA			1.4048E-09
	123	FeO(MeO_A)	FToxid	FToxid-MeO_A			1.0181E-02
	124	Fe2O3(MeO_A)	FToxid	FToxid-MeO_A			2.3568E-10
	125	Al2O3(MeO_A)	FToxid	FToxid-MeO_A			6.9432E-03
	126	MnO(MeO_A)	FToxid	FToxid-MeO_A			2.9716E-02
	145	Fe1Fe1Si1O4(OlivA)	FToxid	FToxid-OlivA			5.4870E-05

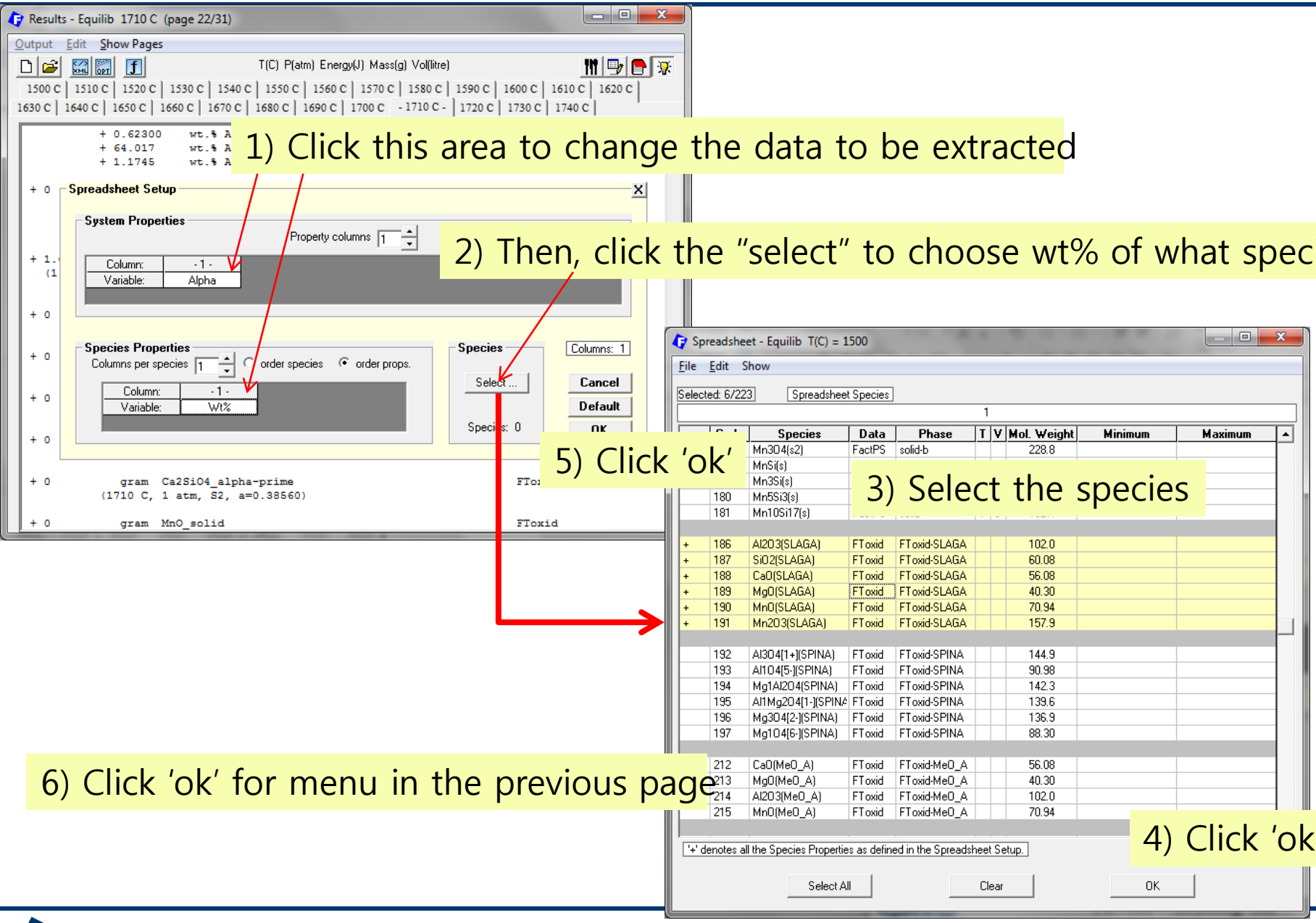
'+' denotes all the Species Properties as defined in the Spreadsheet Setup.

Select All | Clear | OK

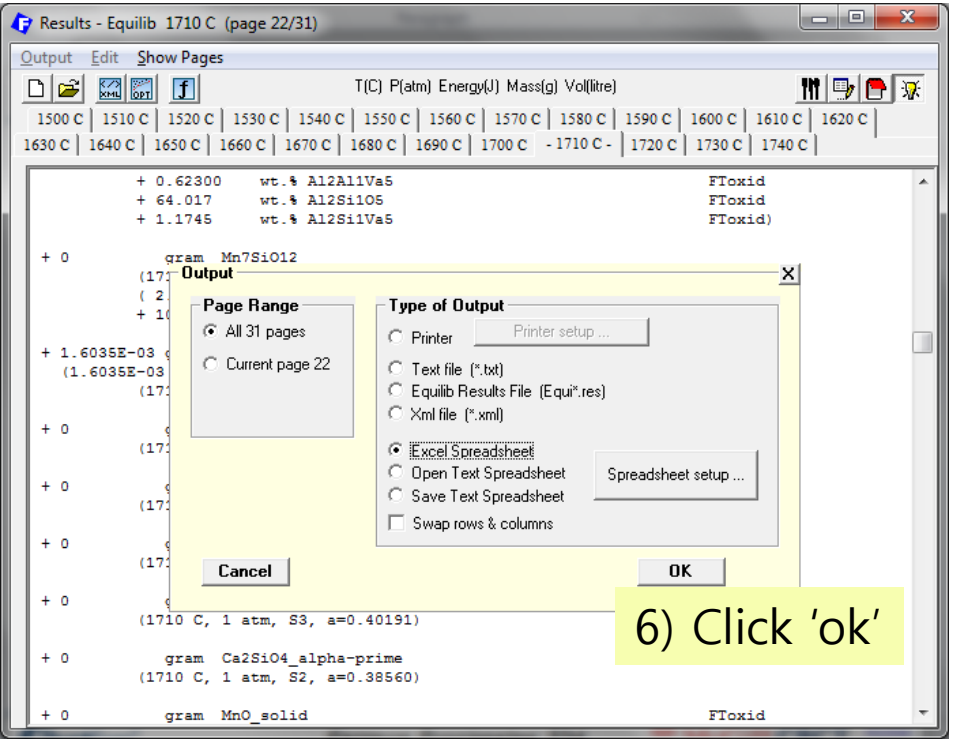
Ex3-6. Inclusion calculation in Mn/Si deoxidation



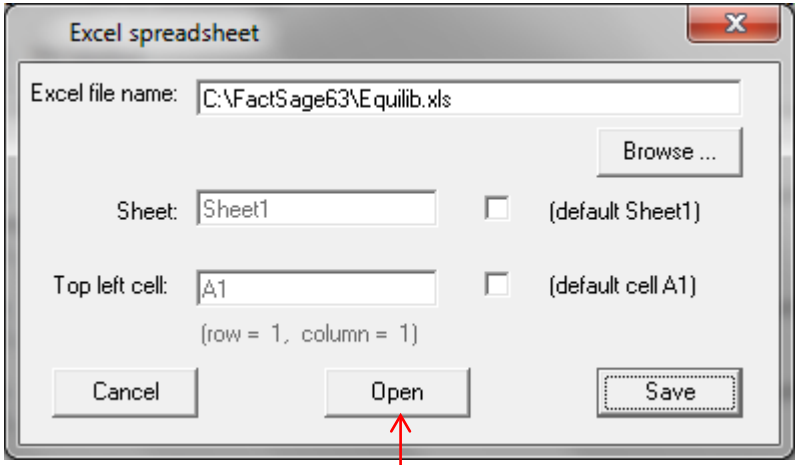
Ex3-6. Inclusion calculation in Mn/Si deoxidation



Ex3-6. Inclusion calculation in Mn/Si deoxidation



6) Click 'ok'



7) Click 'open' then you can see excel file containing all information.

Ex3-6. Inclusion calculation in Mn/Si deoxidation

c:\Workshop\Equilib.xls - Equilib.xls

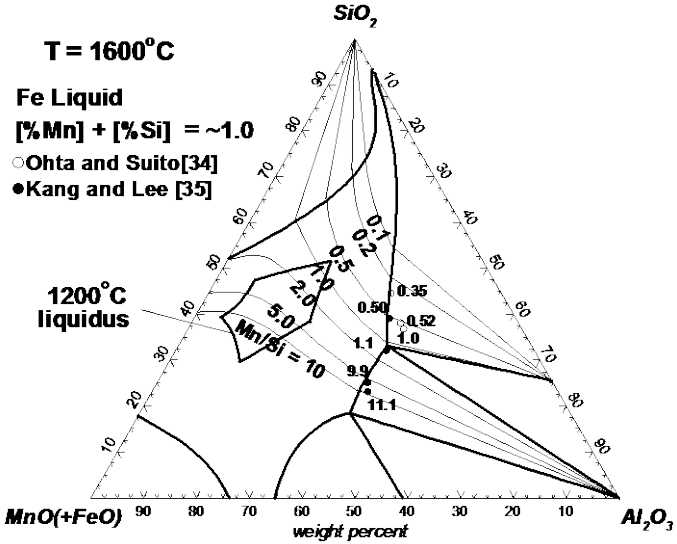
Alpha	t%-Al2O3(SLAGA#	t%-SiO2(SLAGA#	t%-FeO(SLAGA#	t%-Fe2O3(SLAGA#	t%-MnO(SLAGA#	%-Mn2O3(SLAGA	%-Al2O3(SLAGA	%-SiO2(SLAGA	t%-FeO(SLAGA#	t%-Fe2O3(SLAGA#	Wt%-MnO(SLAGA#2	t%-Mn2O3(SLAGA#	A corner	B corner	C corner
0	0	99.590634	0.1269274	9.38178E-05	0.28145943	0.000884935	0	62.570747	6.6540505	0.005014931	30.767009	0.00317861	0.995906	0.004094	0
0.0001	8.7711586	59.790882	5.5597671	0.001167373	25.873633	0.003391942	0.88364011	97.580289	0.48783513	4.63662E-05	1.0475307	0.000659026	0.597909	0.31438	0.087712
0.0002	11.759224	56.597871	5.3249481	0.001032808	26.31312	0.00380378	11.759224	56.597871	5.3249481	0.001032808	26.31312	0.00380378	0.565979	0.316429	0.117592
0.0003	14.066974	54.208548	5.151598	0.001005925	26.567742	0.004133219	14.066974	54.208548	5.151598	0.001005925	26.567742	0.004133219	0.542085	0.317245	0.14067
0.0004	16.049565	52.214521	5.0095657	0.001013321	26.720934	0.004400963	16.049565	52.214521	5.0095657	0.001013321	26.720934	0.004400963	0.522145	0.317359	0.160496
0.0005	17.835339	50.467437	4.8866687	0.001036335	26.804901	0.004618552	17.835339	50.467437	4.8866687	0.001036335	26.804901	0.004618552	0.504674	0.316972	0.178353
0.0006	19.486052	48.895636	4.7767601	0.001067679	26.835691	0.004793466	19.486052	48.895636	4.7767601	0.001067679	26.835691	0.004793466	0.488956	0.316183	0.194861
0.0007	21.036027	47.458868	4.6763608	0.001103733	26.82271	0.004931303	21.036027	47.458868	4.6763608	0.001103733	26.82271	0.004931303	0.474589	0.315051	0.21036
0.0008	22.506131	46.132115	4.583358	0.001142381	26.772216	0.005036713	22.506131	46.132115	4.583358	0.001142381	26.772216	0.005036713	0.461321	0.313618	0.225061
0.0009	23.909924	44.898539	4.4964022	0.001182243	26.688838	0.005113818	23.909924	44.898539	4.4964022	0.001182243	26.688838	0.005113818	0.448985	0.311915	0.239099
0.001	25.25674	43.745988	4.4145919	0.001222358	26.576291	0.005166381	25.25674	43.745988	4.4145919	0.001222358	26.576291	0.005166381	0.43746	0.309973	0.252567
0.0011	26.553373	42.665141	4.3372955	0.001262035	26.4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.426651	0.307815	0.265534
0.0012	27.805041	41.648467	4.2640469	0.001300776	26.2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.416485	0.305465	0.27805
0.0013	29.015965	40.689634	4.1944816	0.001338226	26.0[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.406896	0.302944	0.29016
0.0014	30.189703	39.783161	4.1282982	0.001374146	25.8[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.397832	0.300271	0.301897
0.0015	31.329359	38.924207	4.0652354	0.001408385	25.6[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.389242	0.297464	0.313294
0.0016	32.437708	38.108454	4.0050587	0.001440861	25.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.381085	0.294538	0.324377
0.0017	33.517264	37.332014	3.9475524	0.001471545	25.1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.37332	0.291507	0.335173
0.0018	34.570329	36.591383	3.8925152	0.001500449	24.9[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.365914	0.288383	0.345703
0.0019	35.599022	35.883392	3.8397581	0.001527614	24.6[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.358834	0.285176	0.35599
0.002	36.605295	35.205174	3.7891028	0.001553101	24.3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.352052	0.281895	0.366053
0.0021	37.590952	34.554135	3.7403815	0.001576986	24.1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.345541	0.278549	0.37591
0.0022	38.557655	33.927927	3.6934358	0.001599353	23.814537	0.004844809	38.557655	33.927927	3.6934358	0.001599353	23.814537	0.004844809	0.339279	0.275144	0.385577
0.0023	38.958213	33.671179	3.6739139	0.0016082	23.690264	0.004821379	38.958213	33.671179	3.6739139	0.0016082	23.690264	0.004821379	0.336712	0.273706	0.389582
0.0024	38.959257	33.66924	3.673336	0.001608031	23.691737	0.004821757	38.959257	33.66924	3.673336	0.001608031	23.691737	0.004821757	0.336692	0.273715	0.389593
0.0025	38.9603	33.667301	3.6727582	0.001607862	23.693211	0.004822135	38.9603	33.667301	3.6727582	0.001607862	23.693211	0.004822135	0.336673	0.273724	0.389603
0.0026	38.961344	33.665362	3.6721805	0.001607693	23.694683	0.004822514	38.961344	33.665362	3.6721805	0.001607693	23.694683	0.004822514	0.336654	0.273733	0.389613
0.0027	38.962387	33.663423	3.6716029	0.001607524	23.696156	0.004822892	38.962387	33.663423	3.6716029	0.001607524	23.696156	0.004822892	0.336634	0.273742	0.389624
0.0028	38.963431	33.661484	3.6710254	0.001607355	23.697629	0.004823267	38.963431	33.661484	3.6710254	0.001607355	23.697629	0.004823267	0.336615	0.273751	0.389634
0.0029	38.964474	33.659545	3.6704479	0.001607187	23.699102	0.004823648	38.964474	33.659545	3.6704479	0.001607187	23.699102	0.004823648	0.336595	0.27376	0.389645
0.003	38.965518	33.657606	3.6698706	0.001607018	23.700574	0.004824027	38.965518	33.657606	3.6698706	0.001607018	23.700574	0.004824027	0.336576	0.273769	0.389655
0.0031	38.966562	33.655667	[illegible]	[illegible]	23.702046	0.004824405	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.336557	0.273778	0.389666
0.0032	38.967606	33.653728	[illegible]	[illegible]	23.703519	0.004824783	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	336537	0.273787	0.389676
0.0033	39.008877	33.626253	[illegible]	[illegible]	23.692193	0.004822743	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	336263	0.273649	0.390089
0.0034	39.790634	33.132693	[illegible]	[illegible]	23.441059	0.004775571	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	331327	0.270767	0.397906
0.0035	39.791347	33.132923	[illegible]	[illegible]	23.440259	0.004775134	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	331329	0.270757	0.397913
0.0036	39.79206	33.133152	[illegible]	[illegible]	23.439459	0.004774697	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	331332	0.270748	0.397921
0.0037	39.792773	33.133382	[illegible]	[illegible]	23.438658	0.004774261	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	331334	0.270738	0.397928
0.0038	39.793486	33.133611	3.6286471	0.001623686	23.437858	0.004773824	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	331336	0.270729	0.397935
0.0039	39.794199	33.133841	3.6285055	0.001623531	23.437058	0.004773388	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	331338	0.27072	0.397942
0.004	39.794911	33.13407	3.6283639	0.001623376	23.436258	0.004772952	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	331341	0.27071	0.397949
0.0041	39.795624	33.1343	3.6282223	0.001623221	23.435459	0.004772515	39.795624	33.1343	3.6282223	0.001623221	23.435459	0.004772515	0.331343	0.270701	0.397956
0.0042	39.796336	33.134529	3.6280808	0.001623066	23.434659	0.004772079	39.796336	33.134529	3.6280808	0.001623066	23.434659	0.004772079	0.331345	0.270691	0.397963
0.0043	39.797049	33.134758	3.6279392	0.00162291	23.433859	0.004771643	39.797049	33.134758	3.6279392	0.00162291	23.433859	0.004771643	0.331348	0.270682	0.39797
0.0044	39.797761	33.134988	3.6277977	0.001622755	23.43306	0.004771207	39.797761	33.134988	3.6277977	0.001622755	23.43306	0.004771207	0.33135	0.270673	0.397978
0.0045	40.292688	32.826409	3.604599	0.001633061	23.26993	0.004740786	40.292688	32.826409	3.604599	0.001633061	23.26993	0.004740786	0.328264	0.268809	0.402927
0.0046	40.834298	32.491949	3.5794444	0.001644042	23.087958	0.004707142	40.834298	32.491949	3.5794444	0.001644042	23.087958	0.004707142	0.324919	0.266738	0.408343

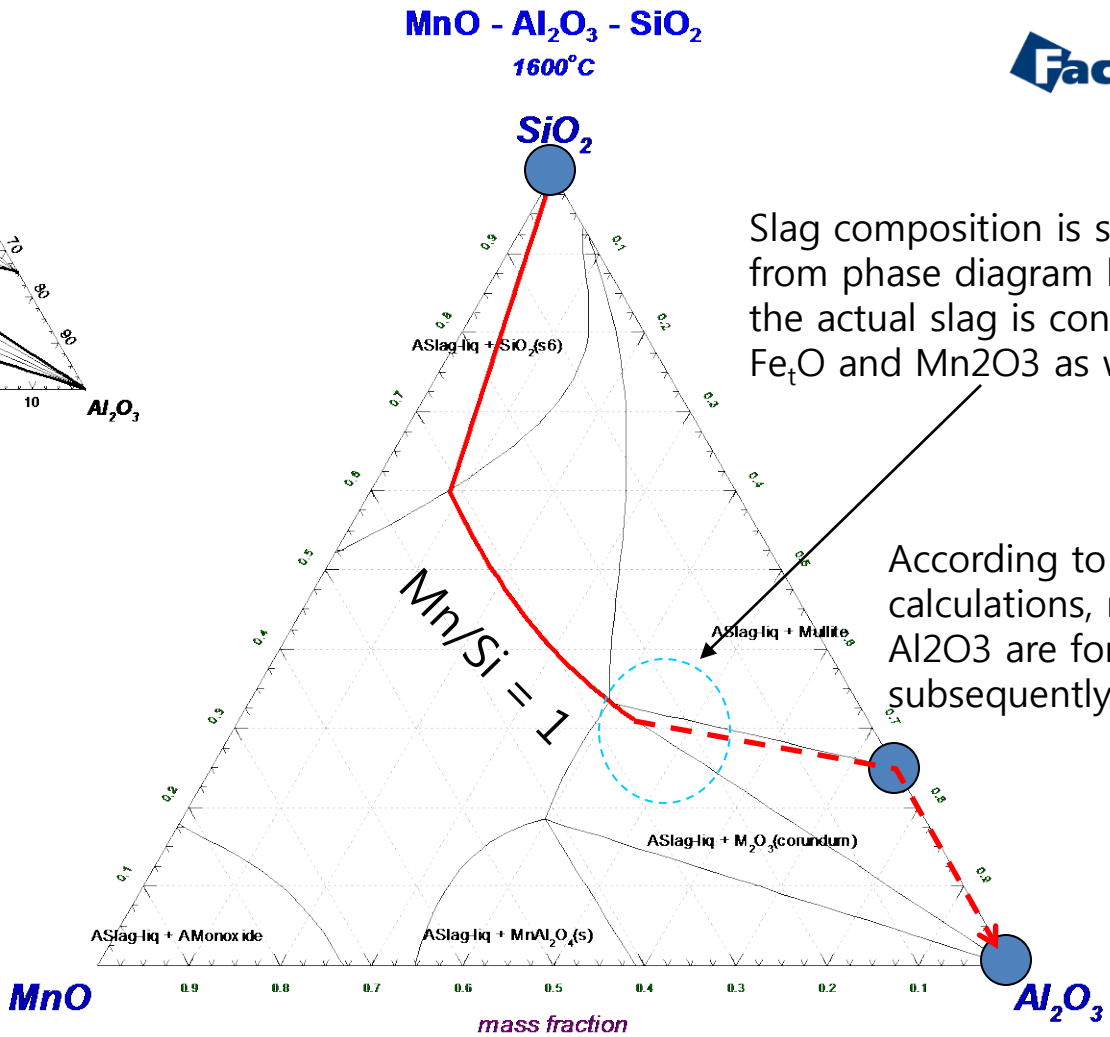
Composition from Slag #1
A corner = wt%SiO2/100
B corner = (wt%MnO+Mn2O3+FeO+Fe2O3)/100
C corner = wt%Al2O3/100

Slag #1
(stable slag)

Slag #2
(metastable or same as #1
except in case of stable miscibility gap)

Ex3-6. Inclusion calculation in Mn/Si deoxidation

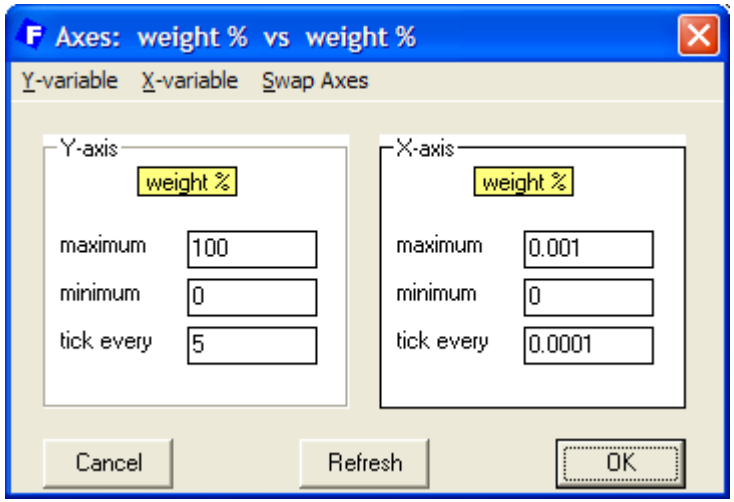


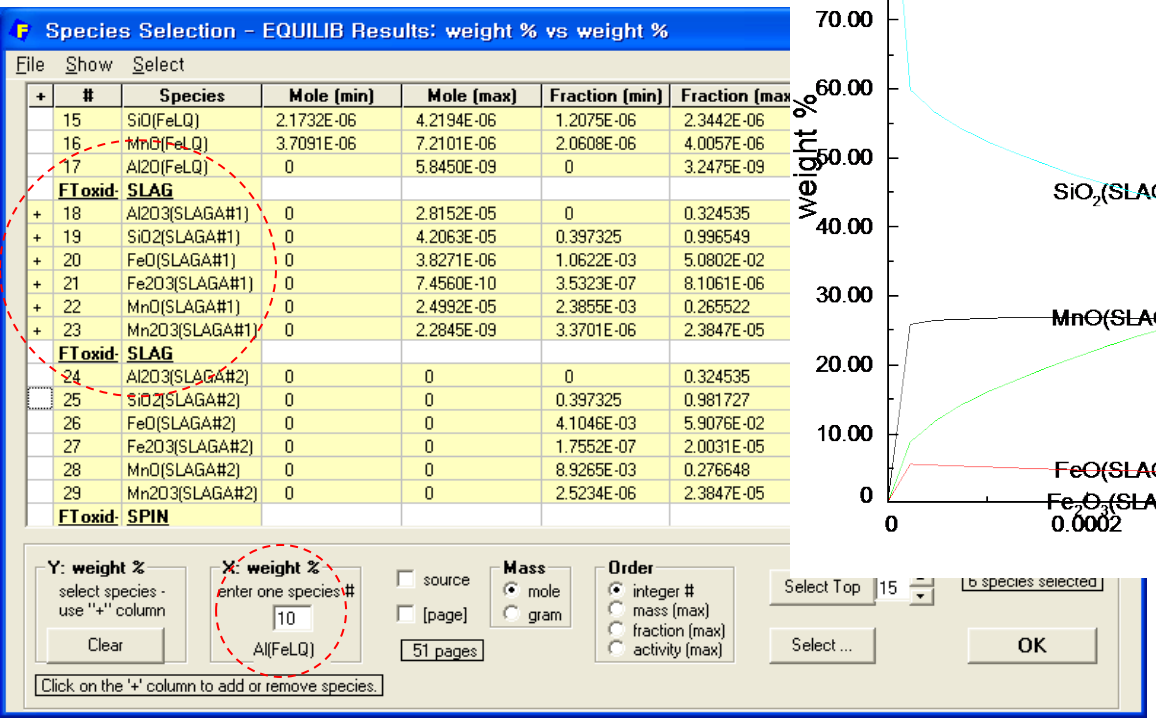


Slag composition is slightly off from phase diagram because the actual slag is containing Fe_tO and Mn2O3 as well.

According to calculations, mullite and Al2O3 are forming subsequently after slag

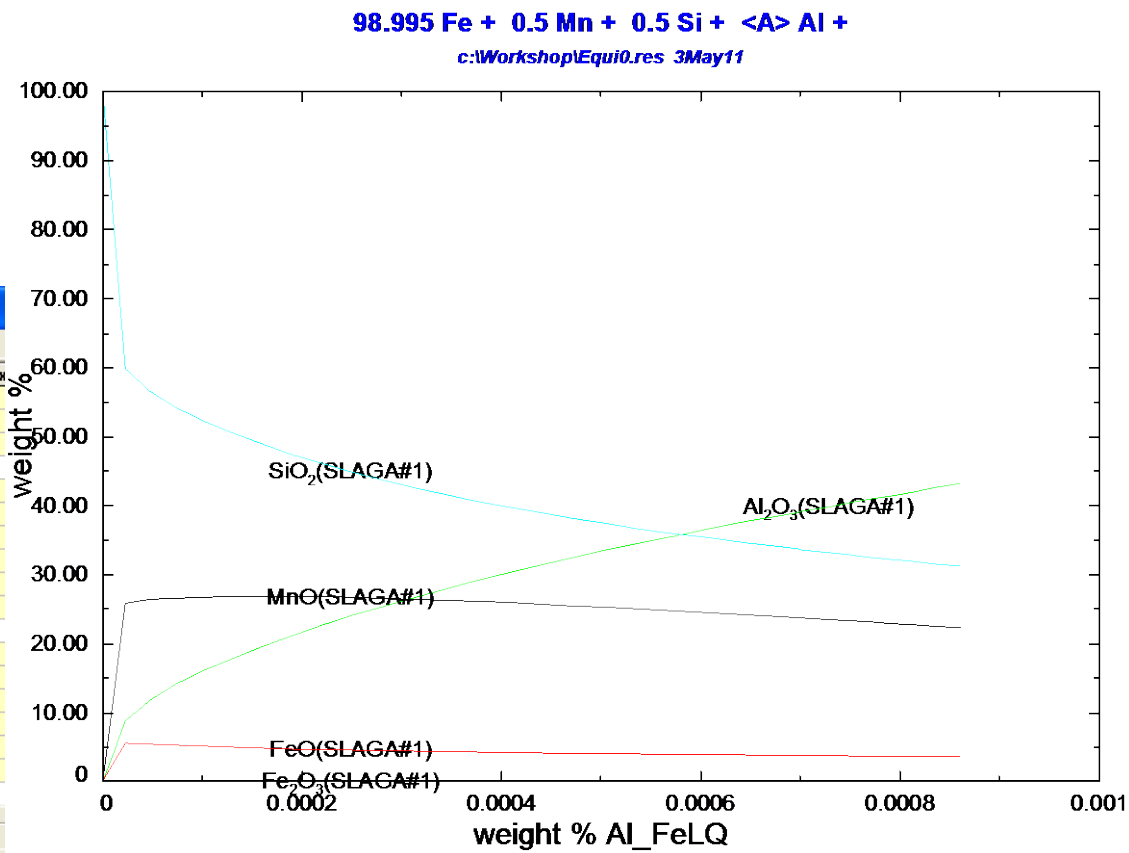
Ex3-6. Inclusion calculation in Mn/Si deoxidation





+	#	Species	Mole (min)	Mole (max)	Fraction (min)	Fraction (max
	15	SiO(FeLQ)	2.1732E-06	4.2194E-06	1.2075E-06	2.3442E-06
	16	MnO(FeLQ)	3.7091E-06	7.2101E-06	2.0608E-06	4.0057E-06
	17	Al2O(FeLQ)	0	5.8450E-09	0	3.2475E-09
	FToxid-	SLAG				
+	18	Al2O3(SLAGA#1)	0	2.8152E-05	0	0.324535
+	19	SiO2(SLAGA#1)	0	4.2063E-05	0.397325	0.996549
+	20	FeO(SLAGA#1)	0	3.8271E-06	1.0622E-03	5.0802E-02
+	21	Fe2O3(SLAGA#1)	0	7.4560E-10	3.5323E-07	8.1061E-06
+	22	MnO(SLAGA#1)	0	2.4992E-05	2.3855E-03	0.265522
+	23	Mn2O3(SLAGA#1)	0	2.2845E-09	3.3701E-06	2.3847E-05
	FToxid-	SLAG				
	24	Al2O3(SLAGA#2)	0	0	0	0.324535
	25	SiO2(SLAGA#2)	0	0	0.397325	0.981727
	26	FeO(SLAGA#2)	0	0	4.1046E-03	5.9076E-02
	27	Fe2O3(SLAGA#2)	0	0	1.7552E-07	2.0031E-05
	28	MnO(SLAGA#2)	0	0	8.9265E-03	0.276648
	29	Mn2O3(SLAGA#2)	0	0	2.5234E-06	2.3847E-05
	FToxid-	SPIN				

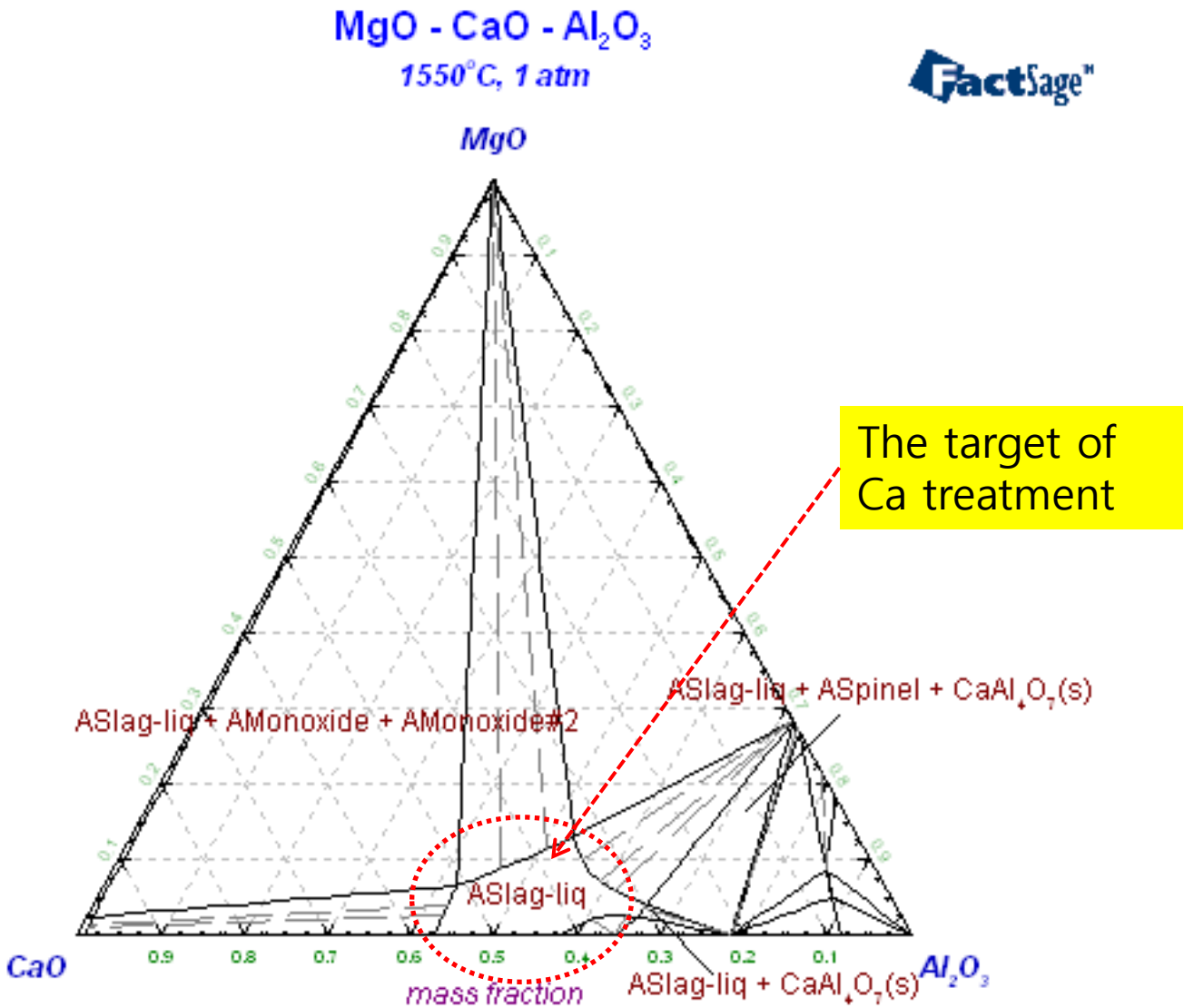
Soluble Al vs. Inclusion composition



Application 5: **Re-oxidation and inclusion modification in the tundish – Ca treatment**

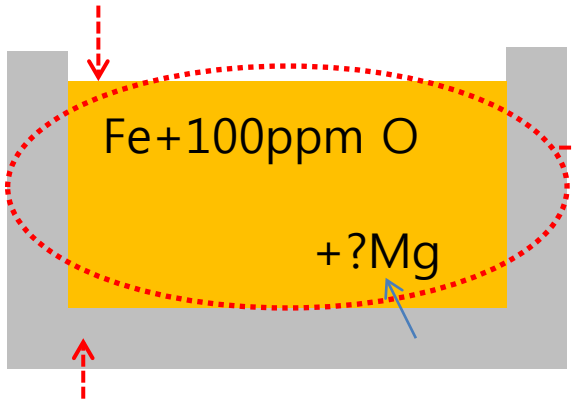
Junghwan Kim
Email: junghwan.kim@mail.mcgill.ca

Ex4-1. Reoxidation and inclusion modification in the tundish



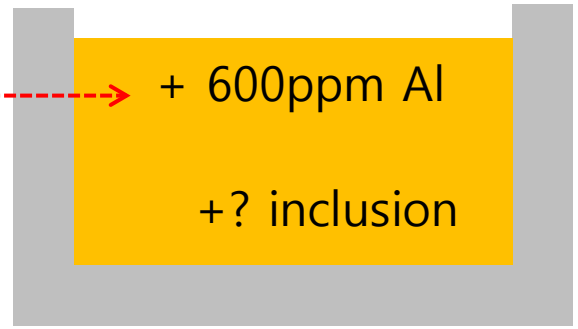
Ex4-1. Reoxidation and inclusion modification in the tundish

At 1550°C

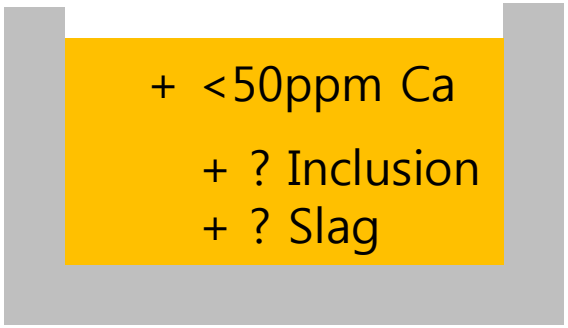


MgO based refractory

Al killed steel

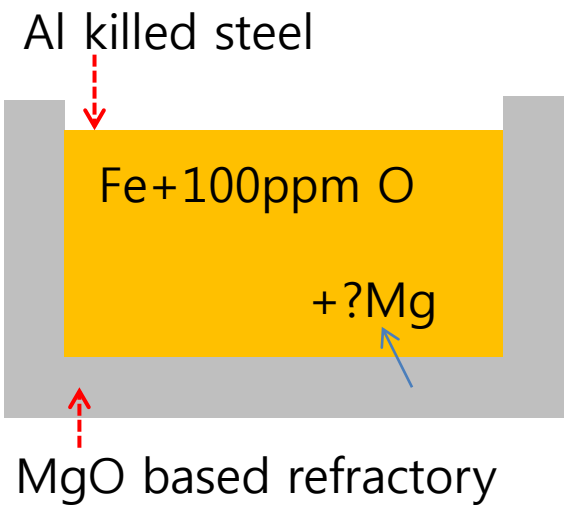


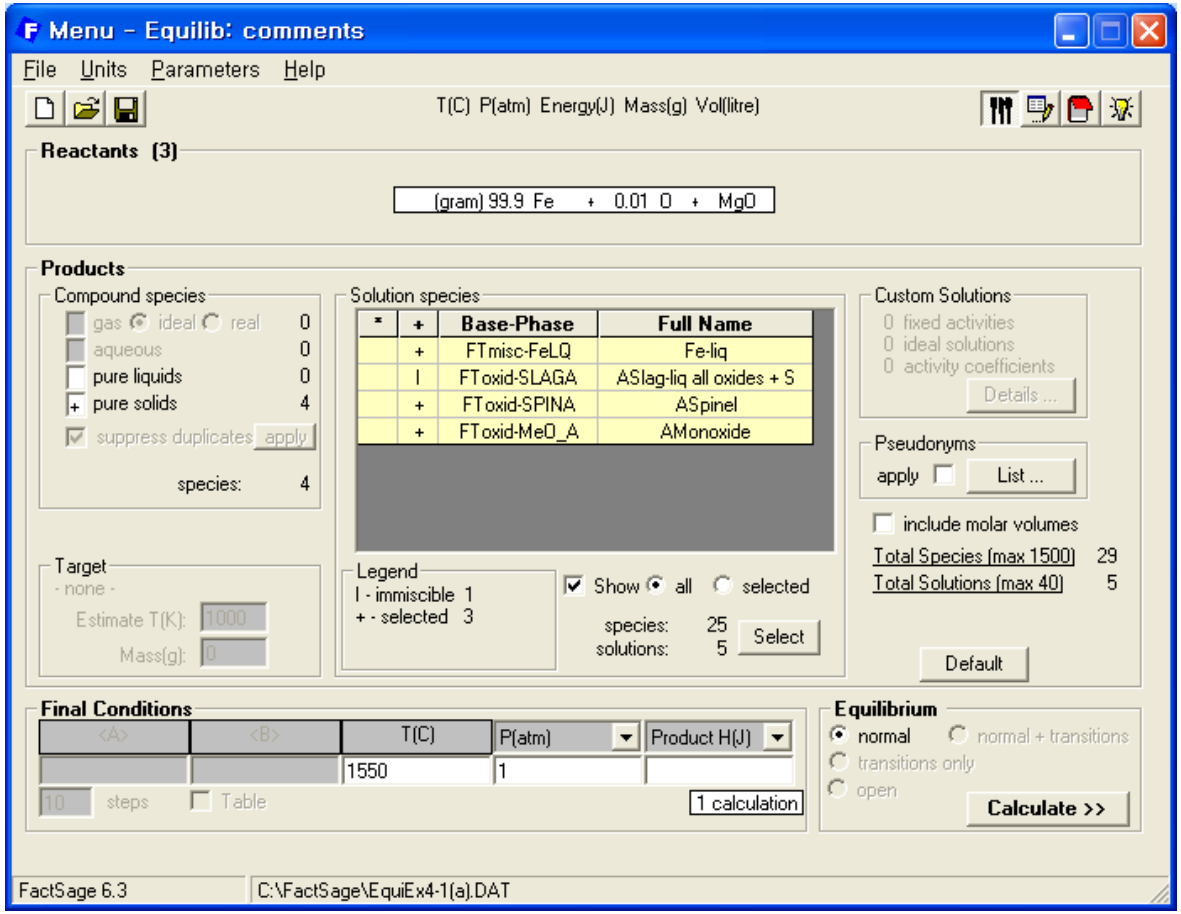
Ca treatment: liquid slag



Reoxidation: assuming mainly due to SiO2 based slag

Ex4-1. Reoxidation and inclusion modification in the tundish





Ex4-1. Reoxidation and inclusion modification in the tundish

Results - Equilib 1550 C

Output Edit Show Pages

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

```
                                                                    FactSage 6.3
(gram) 99.9 Fe +  0.01 O +  MgO =

  99.888      gram  Fe-liq
 (99.888 gram, 1.7889 mol)
          (1550 C, 1 atm,      a=1.0000)
          ( 99.994      wt.% Fe                                     FTmisc
          + 5.0050E-03 wt.% O                                       FTmisc
          + 1.0263E-06 wt.% Mg                                      FTmisc
          + 5.3290E-04 wt.% MgO                                     FTmisc)

          System component       Mole fraction  Mass fraction
          Fe                       0.99981        0.99994
          Mg                       7.4064E-06     3.2238E-06
          O                        1.8206E-04     5.2165E-05

+ 1.0219      gram  AMonoxide
 (1.0219 gram, 2.5110E-02 mol)
          (1550 C, 1 atm,      a=1.0000)
          ( 2.1884      wt.% FeO                                    FToxid
          + 6.8499E-03 wt.% Fe2O3                                   FToxid
          + 97.805      wt.% MgO                                    FToxid)

          System component       Mole fraction  Mass fraction
          Fe                       6.2157E-03     1.7059E-02
          Mg                       0.49378        0.58980
          O                        0.50000        0.39314

+ 0           gram  ASlag-liq#1
          (1550 C, 1 atm,      a=6.5420E-02)
```

Only save liquid Fe
as stream file for next step

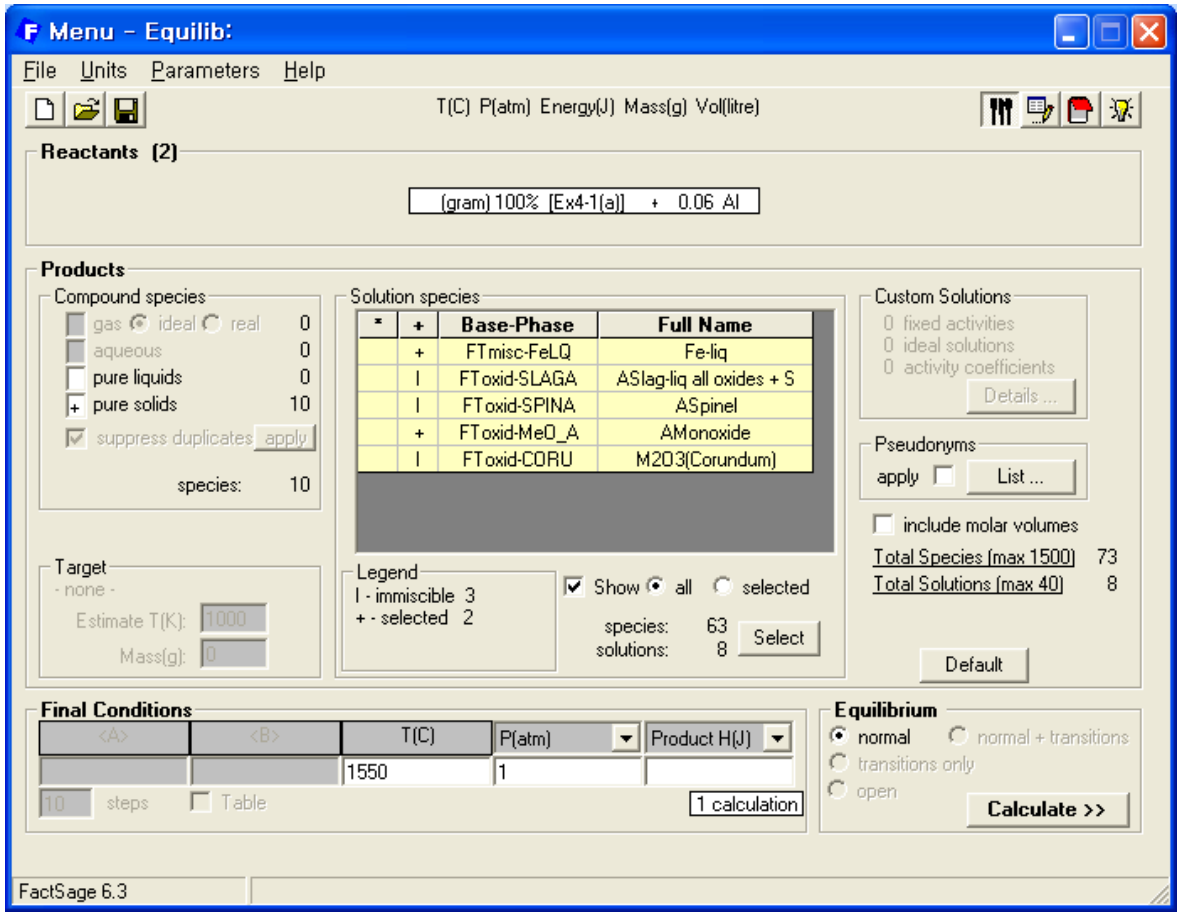
MgO based
refractory

Ex4-1. Reoxidation and inclusion modification in the tundish

Al killed steel

+ 600ppm Al

+? inclusion



Ex4-1. Reoxidation and inclusion modification in the tundish

Results - Equilib 1550 C

Output Edit Show Pages

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

```
(gram) 100% [Ex4-1(a)] +  0.06 Al =

  99.938      gram  Fe-liq
  (99.938 gram, 1.7906 mol)
          (1550 C, 1 atm,      a=1.0000)
          ( 99.945      wt.% Fe
          + 5.4402E-02 wt.% Al
          + 9.5917E-05 wt.% O
          + 2.6226E-06 wt.% Mg
          + 2.5691E-05 wt.% MgO
          + 3.7605E-04 wt.% AlO
          + 7.6232E-05 wt.% Al2O

          System component        Mole fraction  Mass fraction
          Fe                        0.99886        0.99945
          Al                        1.1314E-03     5.4697E-04
          Mg                        4.1599E-07     1.8115E-07
          O                         9.1930E-06     2.6353E-06

+ 7.8284E-03 gram  M2O3(Corundum)#1
  (7.8284E-03 gram, 7.6778E-05 mol)
          (1550 C, 1 atm,      a=1.0000)
          ( 100.00      wt.% Al2O3
          + 7.8267E-06 wt.% Fe2O3

          System component        Mole fraction  Mass fraction
          Fe                        1.9989E-08     5.4742E-08
          Al                        0.40000        0.52925
          O                         0.60000        0.47075
```

Alumina inclusion cause nozzle clogging

Results - Equilib 1550 C

Output Edit Show Pages

T(C) P(atm) E

```
+ 2.7607E-03 gram  ASpinel#1
  (2.7607E-03 gram, 1.9721E-05 mol)
          (1550 C, 1 atm,      a=1.0000)
          ( 9.2977E-09 wt.% Fe3O4
          + 1.1533E-09 wt.% Fe3O4[1-]
          + 1.1207E-12 wt.% Fe3O4[1+]
          + 9.5681E-06 wt.% Fe3O4[2-]
          + 3.9227E-07 wt.% Fe1O4[5-]
          + 3.2543E-03 wt.% Fe1O4[6-]
          + 6.4220E-02 wt.% Fe1Al2O4
          + 50.356      wt.% Al3O4[1+]
          + 7.8750E-03 wt.% Al1Fe2O4[1-]
          + 2.3230      wt.% Al1O4[5-]
          + 7.7410E-06 wt.% Fe1Al2O4[1+]
          + 7.6524E-06 wt.% Al1Fe2O4[1+]
          + 34.676      wt.% Mg1Al2O4
          + 6.5010      wt.% Al1Mg2O4[1-]
          + 4.4735      wt.% Mg3O4[2-]
          + 1.5818      wt.% Mg1O4[6-]
          + 5.2979E-06 wt.% Mg1Fe2O4
          + 1.0057E-06 wt.% Fe1Mg2O4[1-]
          + 8.3436E-03 wt.% Fe1Mg2O4[2-]
          + 5.4520E-03 wt.% Mg1Fe2O4[2-]
```

Formation of spinel phase

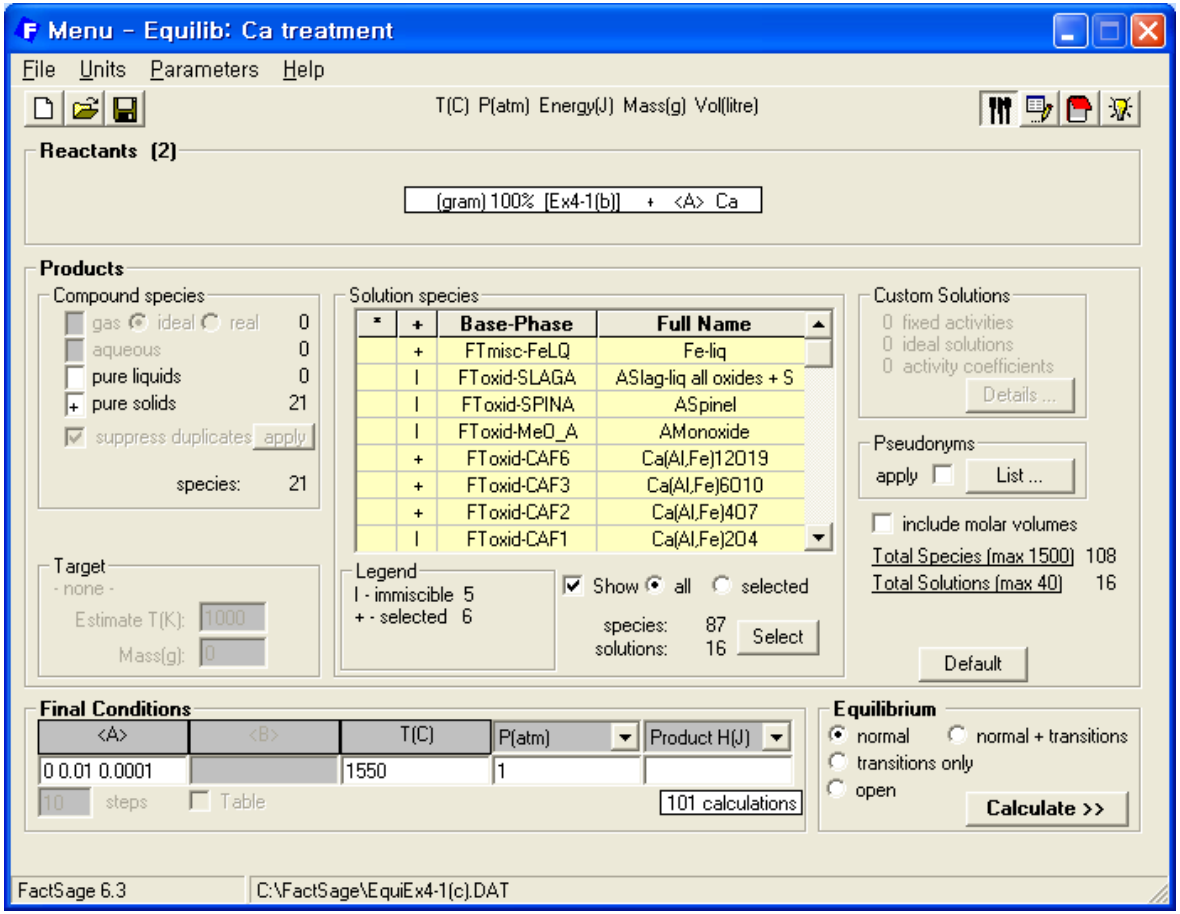
Save all phases as stream file for next step

Ex4-1. Reoxidation and inclusion modification in the tundish

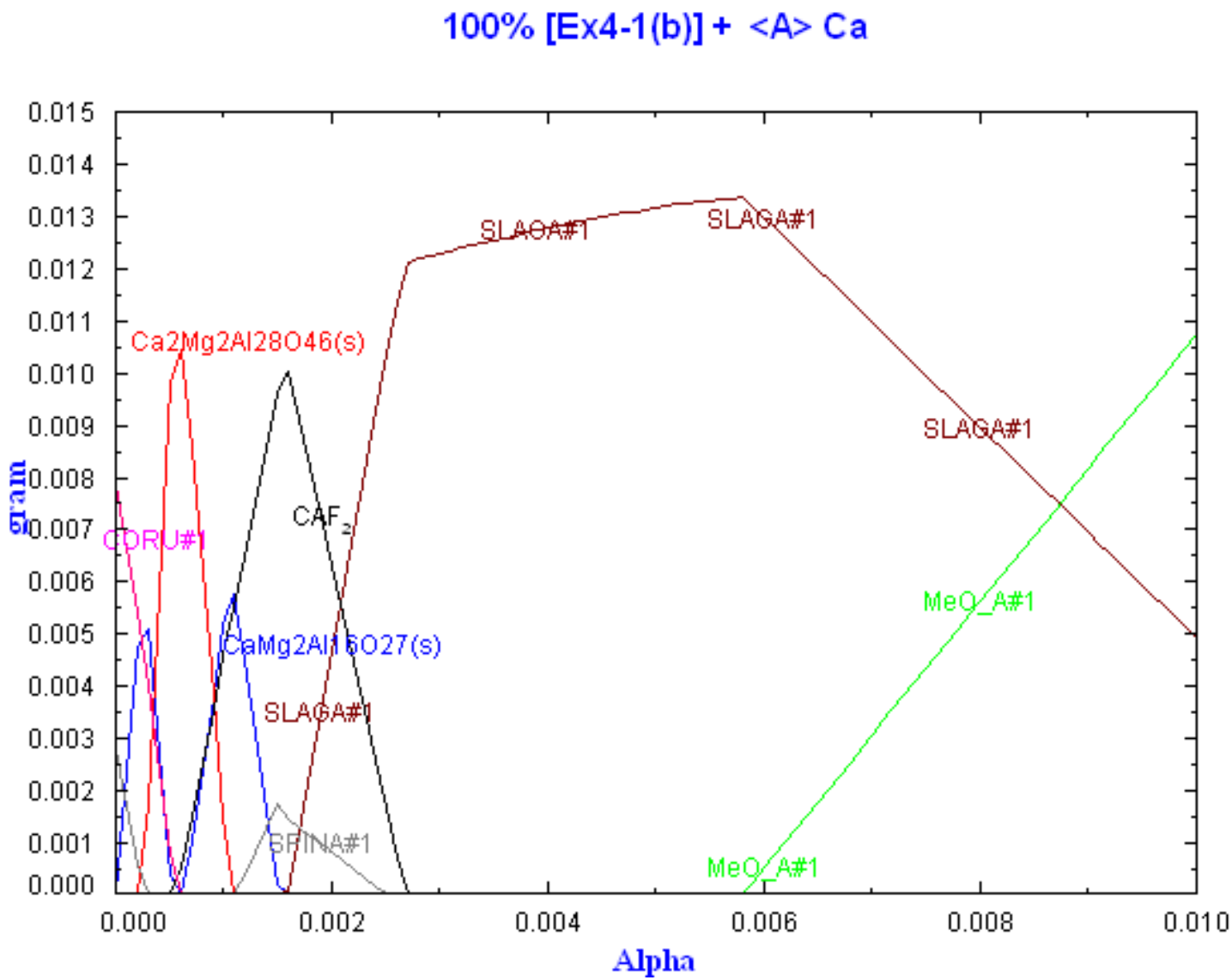
Ca treatment: liquid slag

+ <100ppm Ca

+ ? Inclusion
+ ? Slag

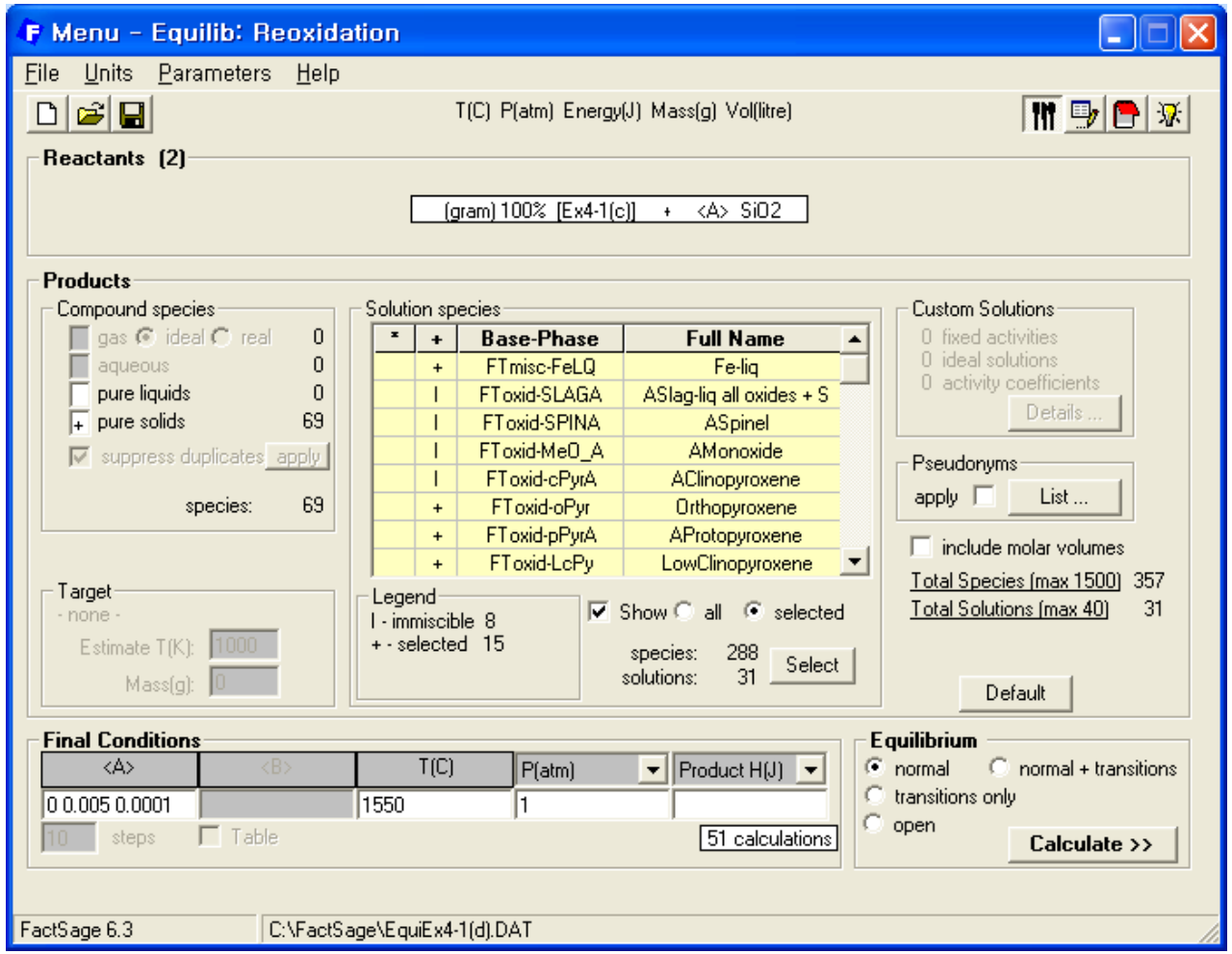


Ex4-1. Reoxidation and inclusion modification in the tundish

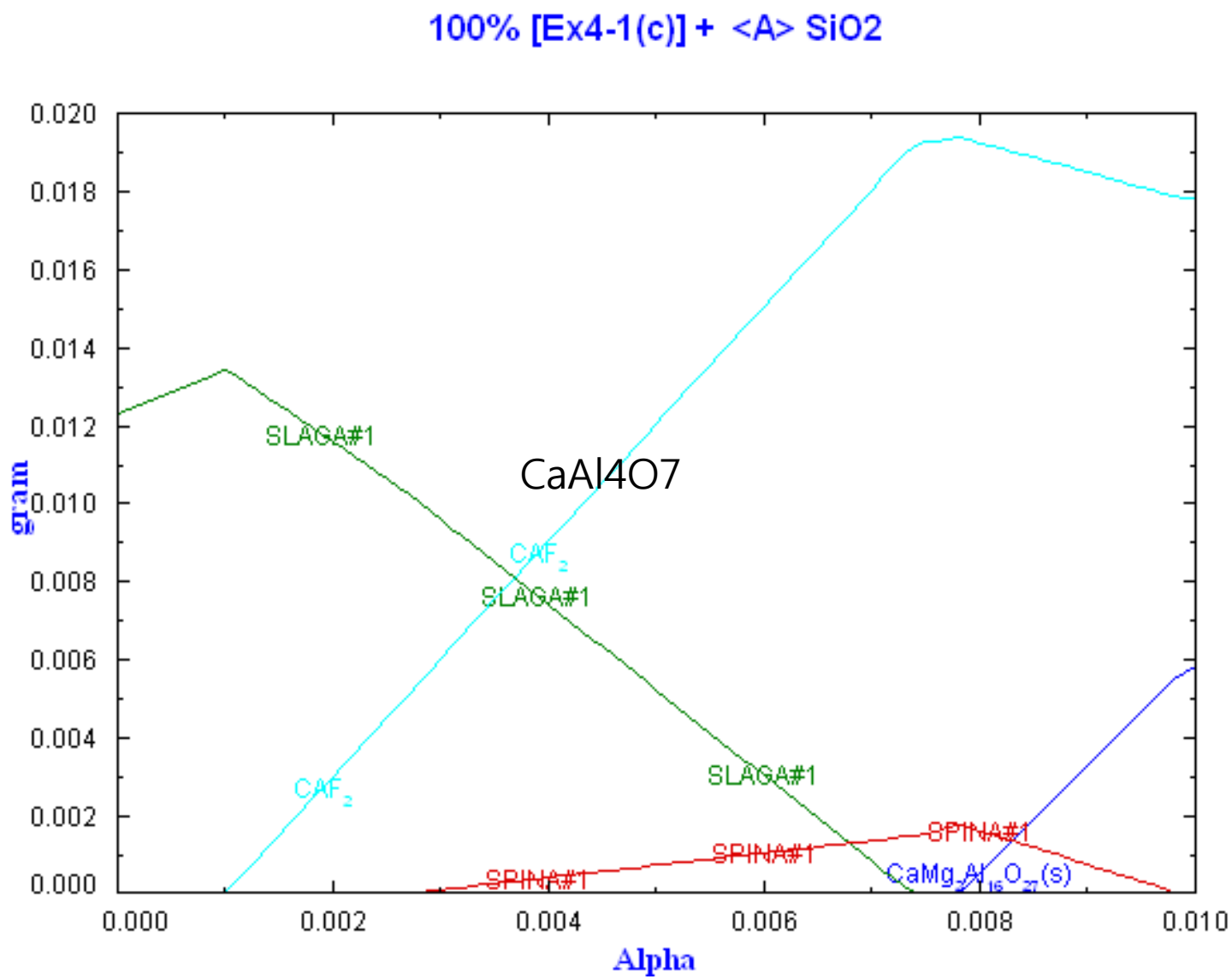


Ex4-1. Reoxidation and inclusion modification in the tundish

Reoxidation: assuming mainly due to SiO2 based slag



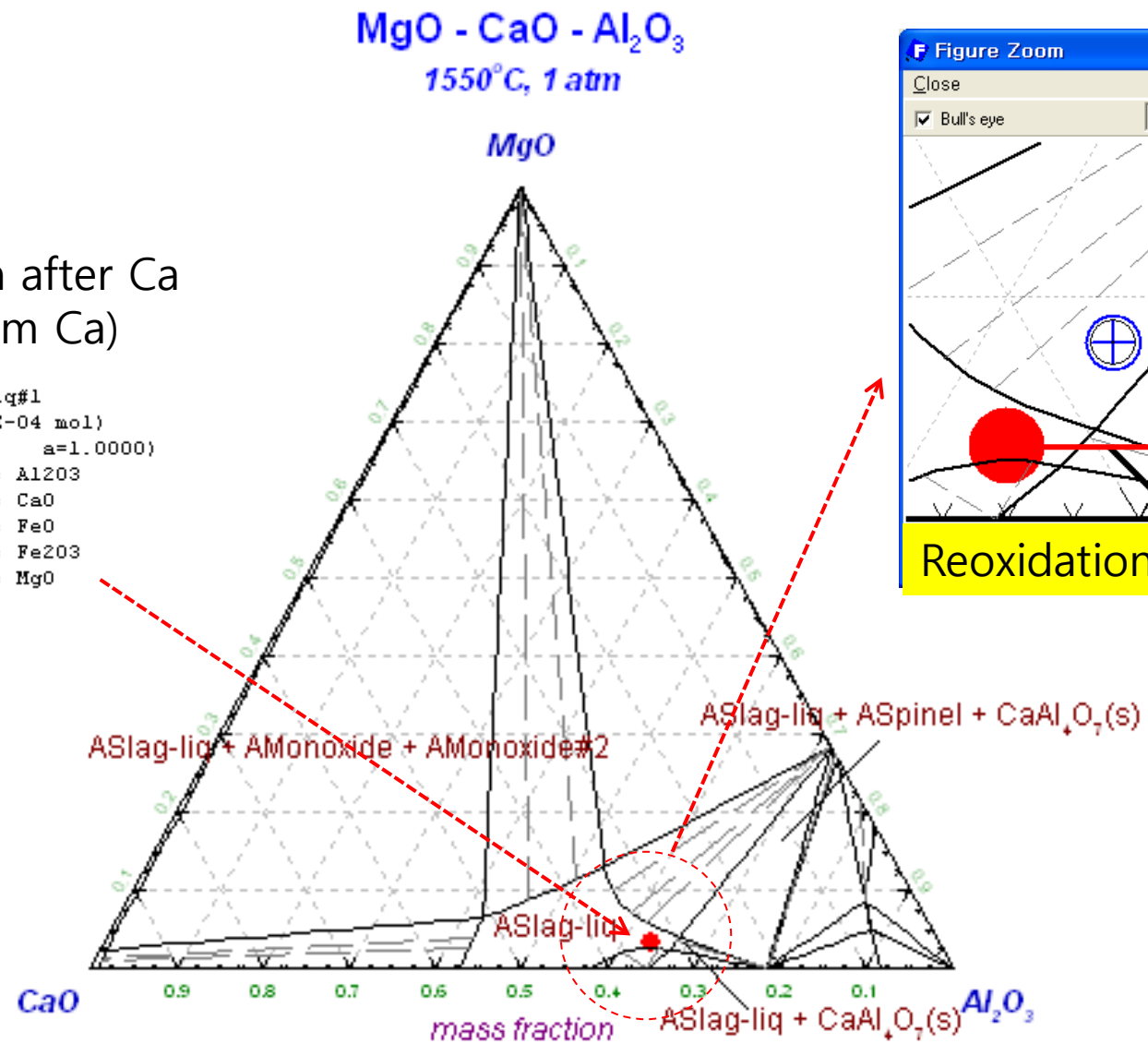
Ex4-1. Reoxidation and inclusion modification in the tundish

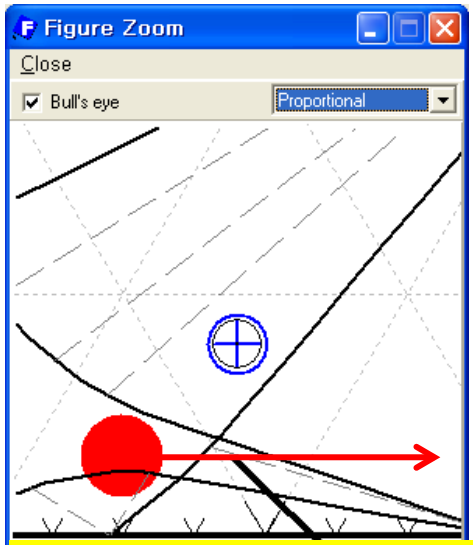


Ex4-1. Reoxidation and inclusion modification in the tundish

Slag composition after Ca treatment (30 ppm Ca)

```
+ 1.2284E-02 gram  ASlag-liq#1
  (1.2284E-02 gram, 1.5945E-04 mol)
          (1550 C, 1 atm,      a=1.0000)
          ( 63.328      wt.% Al2O3
          + 33.369      wt.% CaO
          + 6.3444E-03 wt.% FeO
          + 3.9494E-05 wt.% Fe2O3
          + 3.2969      wt.% MgO
```





Reoxidation direction

Ex4-2. Reoxidation of Al killed Ti bearing steel

Data Search

Databases - 3/37 compound databases, 2/38 solution databases

Fact: FactPS, FToxid, FTsalt, FTmisc, FThall, FTOxCN, FTfrtz, FThelg, FTpulp, FTlite

FactSage: FScopp, FSlead, FSlite, FSstel, FSnobl, FSupsi, ELEM, FTdemo

SGTE: BINS, SGPS, SGTE, SGnobl, SGsold, SGnucl, TDnucl

compounds only / solutions only / no databa

Miscellaneous: BSIP, CON1, CON2

Clear A / Select A / Add/Remov / RefreshData

Information -

Options: Default

Include: gaseous ions (plasmas), aqueous species, limited data compounds (25C)

Cancel / Summa

Menu - Equilib: last system

File Units Parameters Help

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

Reactants (8)

(gram) 98.9475 Fe + 0.7 Mn + 0.03 Al + 0.2 Si + 0.0025 O + 0.015 N + 0.005 C + 0.1 Ti

Products

Compound species: gas (ideal / real) 56; aqueous 0; pure liquids 0; * pure solids 123; suppress duplicates apply; * - custom selection; species: 179

Solution species

*	+	Base-Phase	Full Name
		FToxid-ILME?	?Ilmenite
	+	FToxid-PSEU	Pseudobrookite
	+	FToxid-TiSp	Titania_Spinel
	+	FToxid-TSpi	Tetragonal-Spinel
	+	FToxid-Bixb	Mn2O3(Bixbyite)
	+	FToxid-Brau	Mn7SiO12
	+	FToxid-Rhod	Rhodonite
	+	FToxid-AlSp	Al-spinel

Custom Solutions: 0 fixed activities; 0 ideal solutions; 0 activity coefficients; Details ...

Pseudonyms: apply; List ...

include molar volumes

Total Species (max 1500) 318

Total Solutions (max 40) 21

Target: - none -; Estimate T(C): 1600; Mass(g): 0

Legend: I - immiscible 5; + - selected 11

Show all / selected; species: 139; solutions: 21; Select

Default

Final Conditions

<A>	<B>	T(C)	P(atm)	Product H(J)
		1600	1	

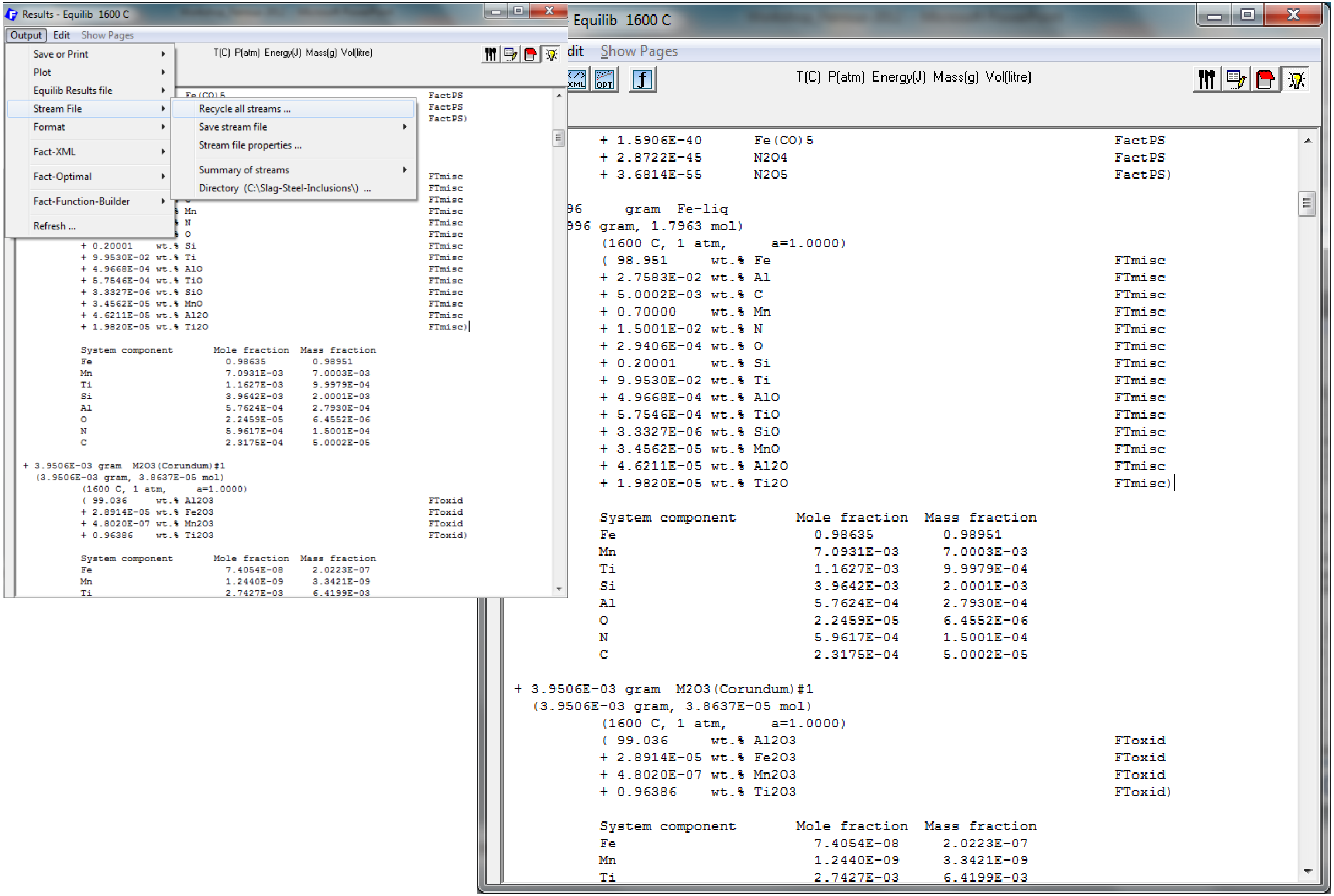
10 steps; Table; 1 calculation

Equilibrium: normal / normal + transitions / transitions only / open

Calculate >>

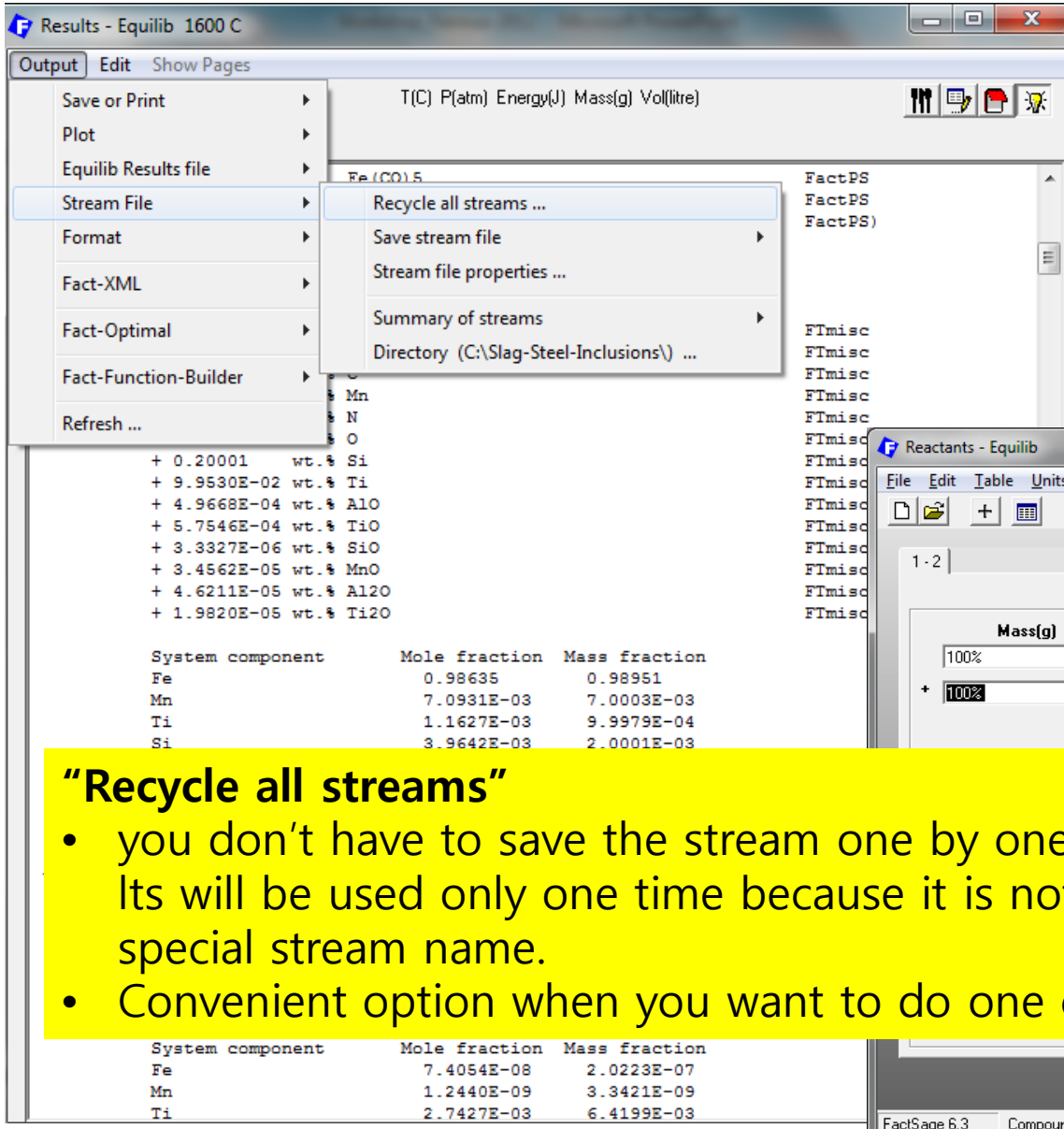
FactSage 6.3

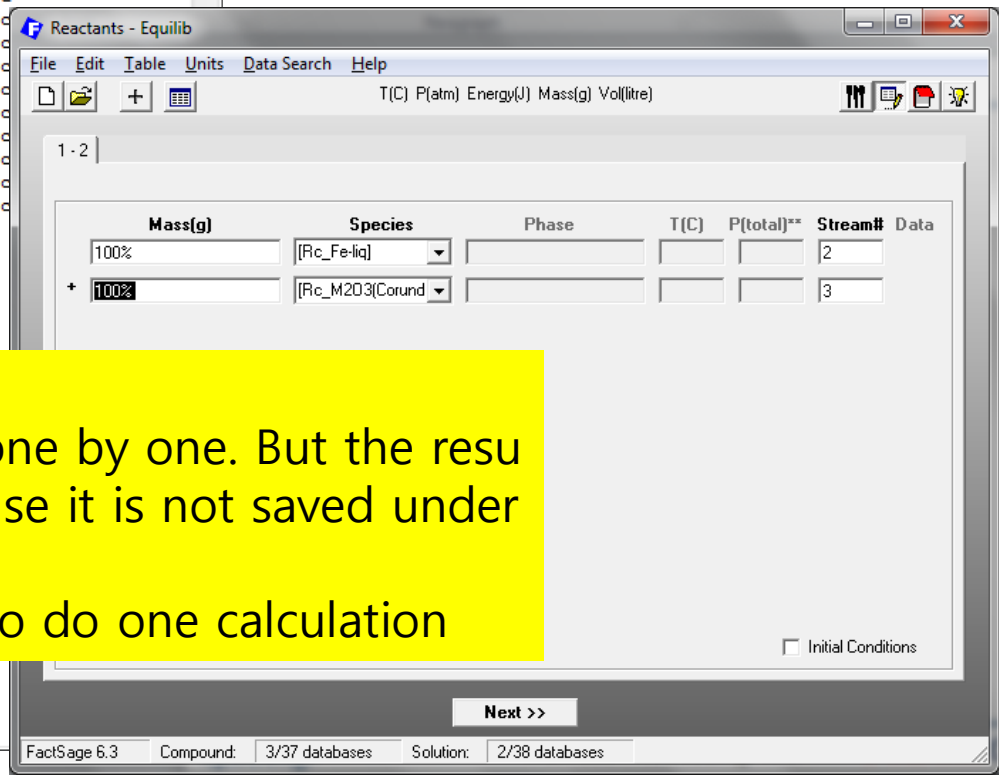
Ex4-2. Reoxidation of Al killed Ti bearing steel



```
 + 1.5906E-40      Fe(CO)5                                          FactPS
 + 2.8722E-45      N2O4                                             FactPS
 + 3.6814E-55      N2O5                                             FactPS)

96      gram  Fe-liq
996 gram, 1.7963 mol)
 (1600 C, 1 atm,      a=1.0000)
 ( 98.951       wt.% Fe                                             FTmisc
 + 2.7583E-02 wt.% Al                                               FTmisc
 + 5.0002E-03 wt.% C                                                FTmisc
 + 0.70000      wt.% Mn                                             FTmisc
 + 1.5001E-02 wt.% N                                                FTmisc
 + 2.9406E-04 wt.% O                                                FTmisc
 + 0.20001      wt.% Si                                             FTmisc
 + 9.9530E-02 wt.% Ti                                               FTmisc
 + 4.9668E-04 wt.% AlO                                              FTmisc
 + 5.7546E-04 wt.% TiO                                              FTmisc
 + 3.3327E-06 wt.% SiO                                              FTmisc
 + 3.4562E-05 wt.% MnO                                              FTmisc
 + 4.6211E-05 wt.% Al2O                                             FTmisc
 + 1.9820E-05 wt.% Ti2O                                             FTmisc)

 System component        Mole fraction   Mass fraction
 Fe                        0.98635         0.98951
 Mn                        7.0931E-03      7.0003E-03
 Ti                        1.1627E-03      9.9979E-04
 Si                        3.9642E-03      2.0001E-03
 Al                        5.7624E-04      2.7930E-04
 O                         2.2459E-05      6.4552E-06
 N                         5.9617E-04      1.5001E-04
 C                         2.3175E-04      5.0002E-05

+ 3.9506E-03 gram  M2O3(Corundum)#1
  (3.9506E-03 gram, 3.8637E-05 mol)
         (1600 C, 1 atm,      a=1.0000)
         ( 99.036       wt.% Al2O3                                  FToxid
         + 2.8914E-05 wt.% Fe2O3                                    FToxid
         + 4.8020E-07 wt.% Mn2O3                                    FToxid
         + 0.96386      wt.% Ti2O3                                  FToxid)

         System component        Mole fraction   Mass fraction
         Fe                        7.4054E-08      2.0223E-07
         Mn                        1.2440E-09      3.3421E-09
         Ti                        2.7427E-03      6.4199E-03
```

Ex4-2. Reoxidation of Al killed Ti bearing steel





"Recycle all streams"

- you don't have to save the stream one by one. But the resu lts will be used only one time because it is not saved under special stream name.
- Convenient option when you want to do one calculation

Ex4-2. Reoxidation of Al killed Ti bearing steel

Menu - Equilib: last system

File Units Parameters Help

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

Reactants (3)

(gram) 100% [Rc_Fe-liq] + 100% [Rc_M2O3(Corundum)] + <A> O2

Products

Compound species

+	gas ● ideal ○ real	56
	aqueous	0
	pure liquids	0
* +	pure solids	123

☑ suppress duplicates apply

* - custom selection

species: 179

Solution species

*	+	Base-Phase	Full Name
	+	FTmisc-FeLQ	Fe-liq
		FTmisc-BCCS	bcc
		FTmisc-FCCS	fcc
	I	FToxid-SLAGA	ASlag-liq all oxides + S
		FToxid-SLAGG	GSlag-liq with C/N/CN
		FToxid-SLAG?	?Slag-liq
	I	FToxid-SPINA	ASpinel
		FToxid-SPINB	BSpinel

Legend

I - immiscible 5

+ - selected 11

☑ Show ● all ○ selected

species: 139

solutions: 21

Select

☐ include molar volumes

Total Species (max 1500) 318

Total Solutions (max 40) 21

Default

Target

- none -

Estimate T(C): 1600

Mass(g): 0

Final Conditions

<A>	<B>	T(C)	P(atm)	Product H(J)
0 0.05 0.001		1600	1	

10 steps ☐ Table

51 calculations

Equilibrium

● normal ○ normal + transitions

○ transitions only

○ open

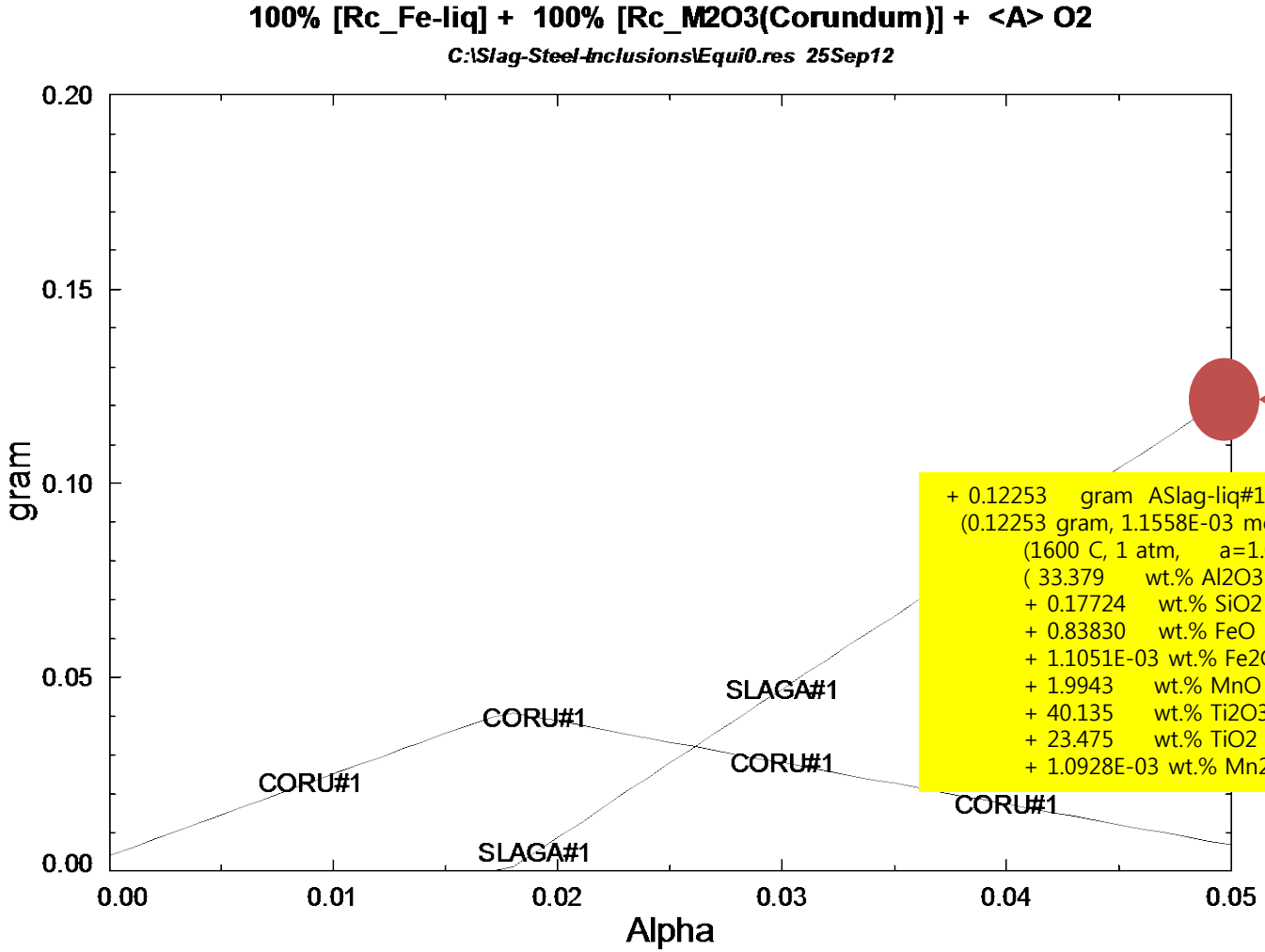
Calculate >>

FactSage 6.3

Addition of oxygen to simulation reoxidation phenomena.
Real source of oxygen could be high SiO_2 slag or refractories

Ex4-2. Reoxidation of Al killed Ti bearing steel

This calculation shows that mixed inclusion of Al2O3(s) and liquid (Al2O3-TiO2-Ti2O3) can be formed by the reoxidation of Al-killed Ti bearing steel.
→ Nozzle clogging.



+ 0.12253 gram ASlag-liq#1
(0.12253 gram, 1.1558E-03 mol)
(1600 C, 1 atm, a=1.0000)

(33.379	wt.% Al2O3	FToxid
+ 0.17724	wt.% SiO2	FToxid
+ 0.83830	wt.% FeO	FToxid
+ 1.1051E-03	wt.% Fe2O3	FToxid
+ 1.9943	wt.% MnO	FToxid
+ 40.135	wt.% Ti2O3	FToxid
+ 23.475	wt.% TiO2	FToxid
+ 1.0928E-03	wt.% Mn2O3	FToxid)