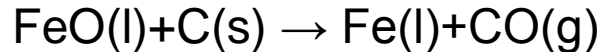


Case 3: Ilmenite (FeTiO_3) Smelting

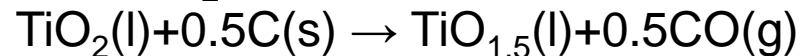
Ilmenite Smelting

Ilmenite is a mixture of FeO and TiO₂. Canada currently has one of the largest ilmenite deposits. This ilmenite is processed by Rio Tinto Iron and Titanium (QIT) in Sorel, Quebec.

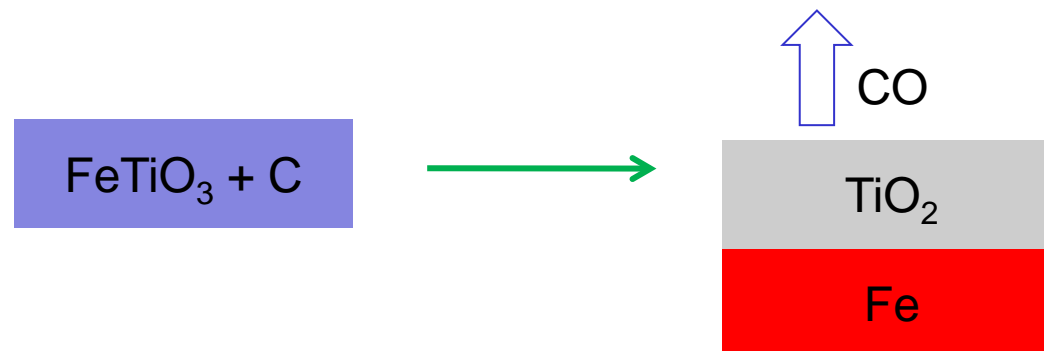
The main reactions occurring during ilmenite smelting is the reduction of FeO from slag to metal:



and the partial reduction of TiO₂ in the slag:



The ideal product would be a pure TiO₂ slag and pure Fe metal.



In the following slides, we will study this reaction and analyze the smelting products.

Ilmenite Smelting

1. We will assume that the ore is composed of pure ilmenite

2. We will make the amount of carbon variable

3. Select FTmisc for the liquid iron solution and FToxid for the slag

The screenshot shows two windows from the FactSage software. The 'Reactants - Equilib' window on the left has a table with two rows: one with '100' in the 'Mass(g)' column and 'FeTiO3' in the 'Species' column, and another with '<A>' in the 'Mass(g)' column and 'C' in the 'Species' column. The 'Data Search' window on the right shows a list of databases with checkboxes. 'FTmisc' and 'FToxid' are checked. The 'Miscellaneous' section has 'EXAM', 'SGTE#', and 'SGTE*' unchecked. The 'Options' section has 'Include' options for 'gaseous ions (plasmas)', 'aqueous species', and 'limited data compounds (25C)'. The 'Limits' section has 'Organic species CxHy... X(max) = 2' and 'Minimum solution components: 2 cpts' selected. The status bar at the bottom shows 'FactSage 6.3', 'Compound: 3/19 databases', and 'Solution'.

Ilmenite Smelting

1. Select all gas and pure solid phases (remember to suppress duplicates).

2. Select all possible solution phases (out of the slags, select only SlagA)

The screenshot shows the FactSage software interface. The 'Reactants' section contains '(gram) 100 FeTiO3 + <A> C'. The 'Products' section has 'gas' selected with 'ideal' and 'real' options, and 'pure solids' selected with 'suppress duplicates' checked. The 'Solution species' table is highlighted, showing various phases like FTmisc-FeLQ, FToxid-SLAGA, FToxid-SPINA, FToxid-MeO_A, FToxid-CORU, FToxid-TiO2, FToxid-ILMEA, and FToxid-PSEU. The 'Final Conditions' section shows a temperature of 1675 C. The 'Equilibrium' section has 'normal' selected.

| * | + | Base-Phase | Full Name |
|---|---|--------------|--------------------------|
| | + | FTmisc-FeLQ | Fe-liq |
| | l | FToxid-SLAGA | ASlag-liq all oxides + S |
| | + | FToxid-SPINA | ASpinel |
| | + | FToxid-MeO_A | AMonoxide |
| | + | FToxid-CORU | M2O3(Corundum) |
| | + | FToxid-TiO2 | Rutile |
| | + | FToxid-ILMEA | Ilmenite |
| | + | FToxid-PSEU | Pseudobrookite |

| <A> | | T(C) | P(atm) | Product H(J) |
|-----|-----|------|--------|--------------|
| 10 | | 1675 | 1 | |

3. We will select 10g carbon to start

4. The average temperature of an ilmenite smelter is 1650-1700C, so we will select 1675 as the final temperature.

Ilmenite Smelting

1. After calculation, it is found that solid pseudobrookite is precipitated.

2. It is necessary to select the right amount of carbon to avoid precipitation of pseudobrookite

3. This can be done using "Formation target"

F Results - Equilib 1675 C

Output Edit Show Pages

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

Site fraction of sublattice constituents:

| | |
|------|------------|
| Fe2+ | 7.4246E-02 |
| Fe3+ | 1.6055E-04 |
| Ti3+ | 0.56792 |
| Ti4+ | 0.35767 |

| | |
|---|--------|
| 0 | 1.0000 |
|---|--------|

System component Mole fraction Mass fraction

| | | |
|----|------------|------------|
| Fe | 2.8166E-02 | 5.5605E-02 |
| Ti | 0.35038 | 0.59290 |
| 0 | 0.62146 | 0.35150 |

+ 17.850 gram Pseudobrookite
(17.850 gram, 7.9747E-02 mol)
(1675 C, 1 atm, a=1.0000)
(1.4500 wt.% FeTi205[2-] FToxid
+ 49.907 wt.% Ti305[+] FToxid
+ 1.5362 wt.% FeTi205 FToxid
+ 47.107 wt.% Ti305[-] FToxid)

Site fraction of sublattice constituents:

| | |
|-----|------------|
| Fe | 2.8863E-02 |
| TI3 | 0.97114 |

| | |
|-----|---------|
| TI4 | 0.51443 |
| TI3 | 0.48557 |

System component Mole fraction Mass fraction

| | | |
|----|------------|------------|
| Fe | 3.6078E-03 | 7.2012E-03 |
|----|------------|------------|

Calculating the optimum amount of carbon addition: Pseudobrookite formation target

Ilmenite Smelting

1. Right-click on the pseudobrookite selection

2. Select "Formation target phase"

This example can be found in EquiCase3-1.dat

F Menu - Equilib: last system

File Units Parameters Help

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

Reactants (2)

(gram) 100 FeTiO3 + <10A> C

Products

Compound species

Solution species

| * | + | Base-Phase | Full Name |
|---|---|--------------|--------------------------|
| | | FTmisc-FeLQ | Fe-liq |
| | | FToxid-SLAGA | ASlag-liq all oxides + S |
| | | FToxid-SPINA | ASpinel |
| | | FToxid-MeO_A | AMonoxide |
| | | FToxid-CORU | M2O3(Corundum) |
| | | FToxid-TiO2 | Rutile |
| | | FToxid-ILMEA | Allmenite |
| F | | FToxid-PSEU | Pseudobrookite |

Legend

- I - immiscible 1
- F - formation target
- + - selected 7

Custom Solutions

- fixed activities
- ideal solutions
- activity coefficients

Pseudonyms

apply List ...

include molar volumes

Total Species (max 1500) 96

Total Solutions (max 40) 10

Equilibrium

- normal
- normal + transitions
- transitions only
- open

T(C) 1675 P(atm) 1 Product H(J)

1 calculation

Calculate >>

FactSage 6.3

Ilmenite Smelting

1. Leaving <A> blank, a solution will be found for the value of <A>, where the activity of pseudobrookite will be 1, but its amount will be 0.

2. Note that the amount of carbon was changed to <10A> to allow carbon amount to change from 0 to 10g during the calculation.

The screenshot shows the FactSage 6.3 software interface. The main window displays the following information:

- Reactants (2):** (gram) 100 FeTiO₃ + <10A> C
- Products:**
 - Compound species: gas (ideal), aqueous, pure liquids, pure solids (41), suppress duplicates (checked), custom selection (58 species).
 - Solution species table:

| * | + | Base-Phase | Full Name |
|---|---|--------------|--------------------------|
| | + | FTmisc-FeLQ | Fe-liq |
| | l | FToxid-SLAGA | ASlag-liq all oxides + S |
| | + | FToxid-SPINA | ASpinel |
| | + | FToxid-MeO_A | AMonoxide |
| | + | FToxid-CORU | M2O3(Corundum) |
| | + | FToxid-TiO2 | Rutile |
| | + | FToxid-ILMEA | Allmenite |
| | F | FToxid-PSEU | Pseudobrookite |
 - Legend: I - immiscible 1, F - formation target, + - selected 7. Show all selected (checked).
 - Custom Solutions: fixed activities, ideal solutions, activity coefficients (unchecked).
 - Pseudonyms: apply (unchecked), List ...
 - include molar volumes (unchecked).
 - Total Species (max 1500): 96
 - Total Solutions (max 40): 10
- Formation Target:** FToxid-PSEU, Estimate ALPHA: 0.5, Mass(g): 0 (highlighted by a red arrow).
- Final Conditions:** <A>, , T(C): 1675, P(atm): 1, Product H(J): 1 calculation.
- Equilibrium:** normal (selected), normal + transitions, transitions only, open.

Ilmenite Smelting

1. The solution is 9.741g carbon

2. Note that the amount of pseudobrookite is 0g, but its activity is 1. So it is ready to form as soon as we add just a little more carbon

F Results - Equilib 1675 C, A=0.9741

Output Edit Show Pages

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

```
+ 8.1261E-04 wt.% TiO      FTmisc
+ 1.6025E-06 wt.% Ti2O    FTmisc)

System component      Mole fraction      Mass fraction
Fe                    0.98924           0.99758
Ti                    9.6544E-05        8.3450E-05
O                     2.9180E-04        8.4306E-05
C                     1.0370E-02        2.2490E-03

+ 0      gram Pseudobrookite
(1675 C, 1 atm, a=1.0000)
( 1.4500 wt.% FeTi2O5[2-]
+ 49.907 wt.% Ti3O5[+]
+ 1.5362 wt.% FeTi2O5
+ 47.107 wt.% Ti3O5[-]
FToxid
FToxid
FToxid
FToxid

Site fraction of sublattice constituents:
Fe                    2.8863E-02
Ti3                   0.97114
-----
Ti4                   0.51443
Ti3                   0.48557

System component      Mole fraction      Mass fraction
Fe                    3.6078E-03        7.2012E-03
Ti                    0.37139           0.63540
O                     0.62500           0.35740

+ 0      gram Rutile
(1675 C, 1 atm, a=0.54369)
```

Ilmenite Smelting

1. Looking at the slag composition, it can be noted that the slag contains about 7% FeO

2. The iron phase, however, is composed of 99.8% Fe

3. It would be interesting to see how the slag and metal composition changes with carbon addition

F Results - Equilib 1675 C, A=0.9741

Output Edit Show Pages

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

| PHASE: | gram | MASS FRACTION | ACTIVITY |
|-----------------------|------------|---------------|------------|
| PHASE: ASlag-liq#1 | | | |
| FeO | 3.7983E+00 | 7.1382E-02 | 2.6445E-02 |
| Fe2O3 | 9.1279E-03 | 1.7154E-04 | 3.1829E-08 |
| Ti2O3 | 2.9063E+01 | 5.4618E-01 | 2.2613E-01 |
| TiO2 | 2.0341E+01 | 3.8227E-01 | 3.3919E-01 |
| TOTAL: | 5.3211E+01 | 1.0000E+00 | 1.0000E+00 |
| PHASE: ASlag-liq#2 | | | |
| FeO | 0.0000E+00 | 7.1382E-02 | 2.6445E-02 |
| Fe2O3 | 0.0000E+00 | 1.7154E-04 | 3.1829E-08 |
| Ti2O3 | 0.0000E+00 | 5.4618E-01 | 2.2613E-01 |
| TiO2 | 0.0000E+00 | 3.8227E-01 | 3.3919E-01 |
| TOTAL: | 0.0000E+00 | 1.0000E+00 | 1.0000E+00 |
| PHASE: Fe-liq | | | |
| Fe | 3.3842E+01 | 9.9758E-01 | 9.8884E-01 |
| C | 7.6297E-02 | 2.2490E-03 | 7.5501E-03 |
| O | 2.7909E-03 | 8.2268E-05 | 3.6983E-06 |
| Ti | 2.6239E-03 | 7.7345E-05 | 3.1673E-06 |
| TiO | 2.7567E-04 | 8.1261E-06 | 7.0432E-06 |
| Ti2O | 5.4362E-07 | 1.6025E-08 | 7.9390E-09 |
| TOTAL: | 3.3924E+01 | 1.0000E+00 | 1.0000E+00 |
| PHASE: Pseudobrookite | | | |
| FeTi2O5[2-] | 0.0000E+00 | 1.4500E-02 | 2.6757E-03 |
| Ti3O5[+] | 0.0000E+00 | 4.9907E-01 | 2.5036E-01 |
| FeTi2O5 | 0.0000E+00 | 1.5362E-02 | 1.8435E-02 |
| Ti3O5[-] | 0.0000E+00 | 4.7107E-01 | 2.3541E-01 |
| TOTAL: | 0.0000E+00 | 1.0000E+00 | 1.0000E+00 |
| PHASE: Rutile | | | |
| Ti2O3 | 0.0000E+00 | 1.8825E-01 | 3.7713E-01 |
| TiO2 | 0.0000E+00 | 8.1175E-01 | 4.3228E-01 |
| TOTAL: | 0.0000E+00 | 1.0000E+00 | 5.4369E-01 |

Visualizing the change in metal and slag composition with carbon addition

Ilmenite Smelting

A series of calculations at different carbon addition is performed to see how carbon content affects the composition of metal and slag.

F Menu - Equilib: last system

File Units Parameters Help

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

Reactants (2)

(gram) 100 FeTiO3 + <10A> C

Products

Compound species

- gas ideal real 17
- aqueous 0
- pure liquids 0
- * pure solids 41
- suppress duplicates apply
- * - custom selection species: 58

Solution species

| * | + | Base-Phase | Full Name |
|---|---|--------------|--------------------------|
| | l | FToxid-SLAGA | ASlag-liq all oxides + S |
| | + | FToxid-SPINA | ASpinel |
| | + | FToxid-MeO_A | AMonoxide |
| | + | FToxid-CORU | M2O3(Corundum) |
| | + | FToxid-TiO2 | Rutile |
| | + | FToxid-ILMEA | Allmenite |
| | + | FToxid-PSEU | Pseudobrookite |
| | + | FToxid-TiSp | Titania_Spinel |

Legend

- l - immiscible 1
- + - selected 8

Show all selected

species: 38
solutions: 10 Select

Custom Solutions

- fixed activities
- ideal solutions
- activity coefficients

Details ...

Pseudonyms

apply List ...

include molar volumes

Total Species (max 1500) 96
Total Solutions (max 40) 10

Default

Final Conditions

| <A> | | T(C) | P(atm) | Product H(J) |
|-----|-----|------|--------|--------------|
| 0 | 1 | 0.01 | 1675 | 1 |

10 steps Table 101 calculations

Equilibrium

- normal
- normal + transitions
- transitions only
- open

Calculate >>

FactSage 6.3

Ilmenite Smelting

1. For a graphical representation, we will plot the results

Plot: weight % vs Alpha

100 FeTiO₃ + <10A> C

| Axes | Variables | Minimum |
|---------------|-----------------|---------|
| | activity | 0 |
| | mole | 0 |
| | mole fract. | 0 |
| | gram | 0 |
| Y-axis | weight % | 0 |
| X-axis | Alpha | 0 |

Species Selection - EQUILIB Results: weight % vs Alpha

| # | Species | Mole (min) | Mole (max) | Fraction (min) |
|---------------------|----------------|------------|------------|----------------|
| 15 | Fe(g) | 0 | 1.7057E-04 | 7.9178E-06 |
| 16 | FeO(g) | 0 | 2.2425E-07 | 6.8808E-08 |
| 17 | Fe(CO)5(g) | 0 | 3.4462E-25 | 0 |
| FTmisc- FeLQ | | | | |
| 18 | Fe(FeLQ) | 0 | 0.622743 | 0.80506 |
| 19 | C(FeLQ) | 0 | 6.5279E-03 | 0 |
| 20 | O(FeLQ) | 0 | 6.7345E-04 | 2.8475E-04 |
| 21 | Ti(FeLQ) | 0 | 5.6330E-05 | 7.2890E-10 |
| 22 | TiO(FeLQ) | 0 | 4.4356E-06 | 3.5772E-07 |
| 23 | Ti2O(FeLQ) | 0 | 4.9998E-09 | 7.6410E-19 |
| FToxid- SLAG | | | | |
| 24 | FeO(SLAGA#1) | 3.3863E-02 | 0.649684 | 0.103701 |
| 25 | Fe2O3(SLAGA#1) | 3.6612E-05 | 2.8092E-02 | 1.1212E-04 |
| 26 | Ti2O3(SLAGA#1) | 2.8092E-02 | 0.201271 | 2.2258E-02 |
| 27 | TiO2(SLAGA#1) | 0.16313 | 0.602968 | 0.375718 |
| FToxid- SLAG | | | | |
| 28 | FeO(SLAGA#2) | 0 | 0 | 0.103701 |
| 29 | Fe2O3(SLAGA#2) | 0 | 0 | 1.1212E-04 |

2. Select wt% as the Y-axis and Alpha as the X-axis

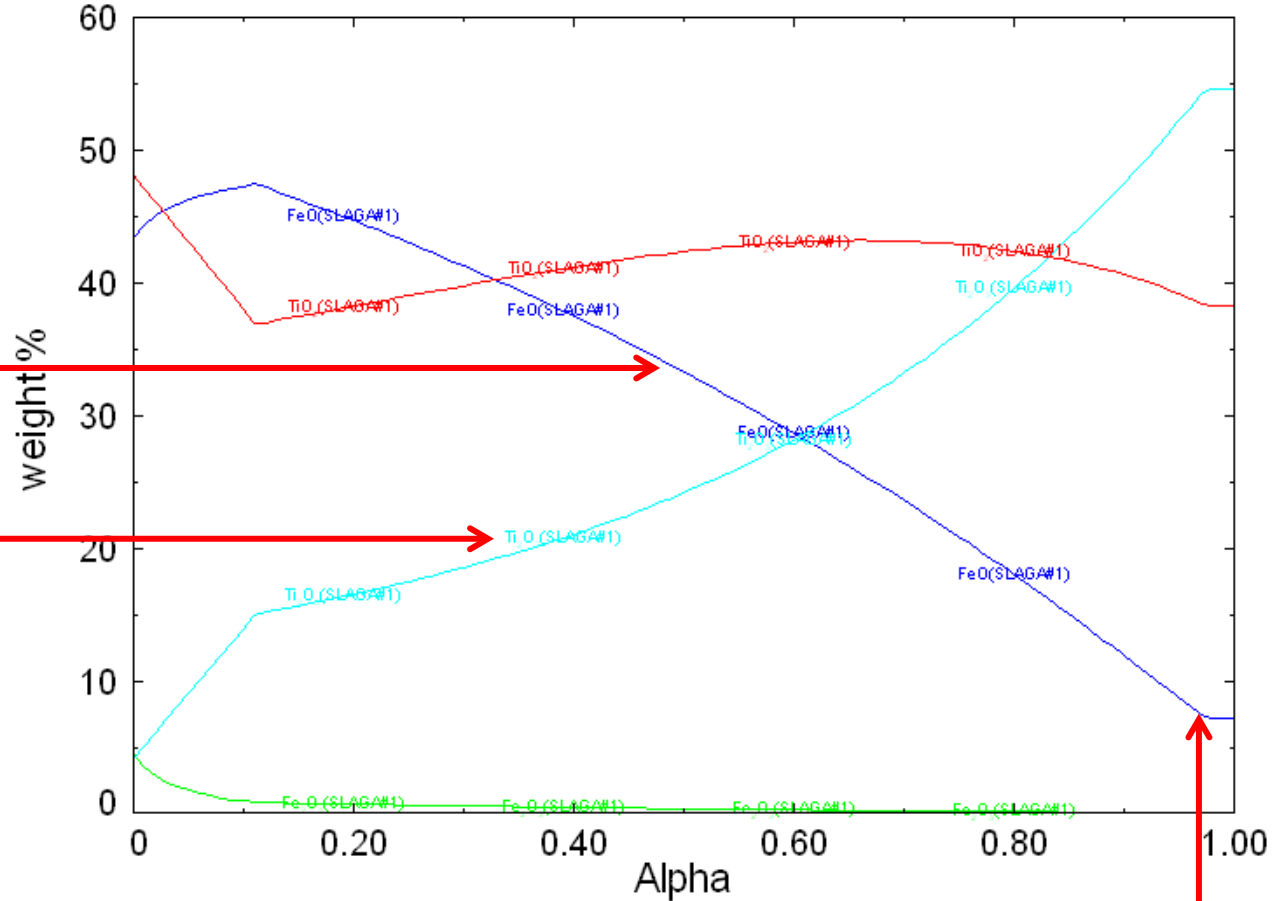
3. Select all SlagA components

Ilmenite Smelting

100 FeTiO₃ + <10A> C

C:\FactSage\Equi0.res 5Feb13

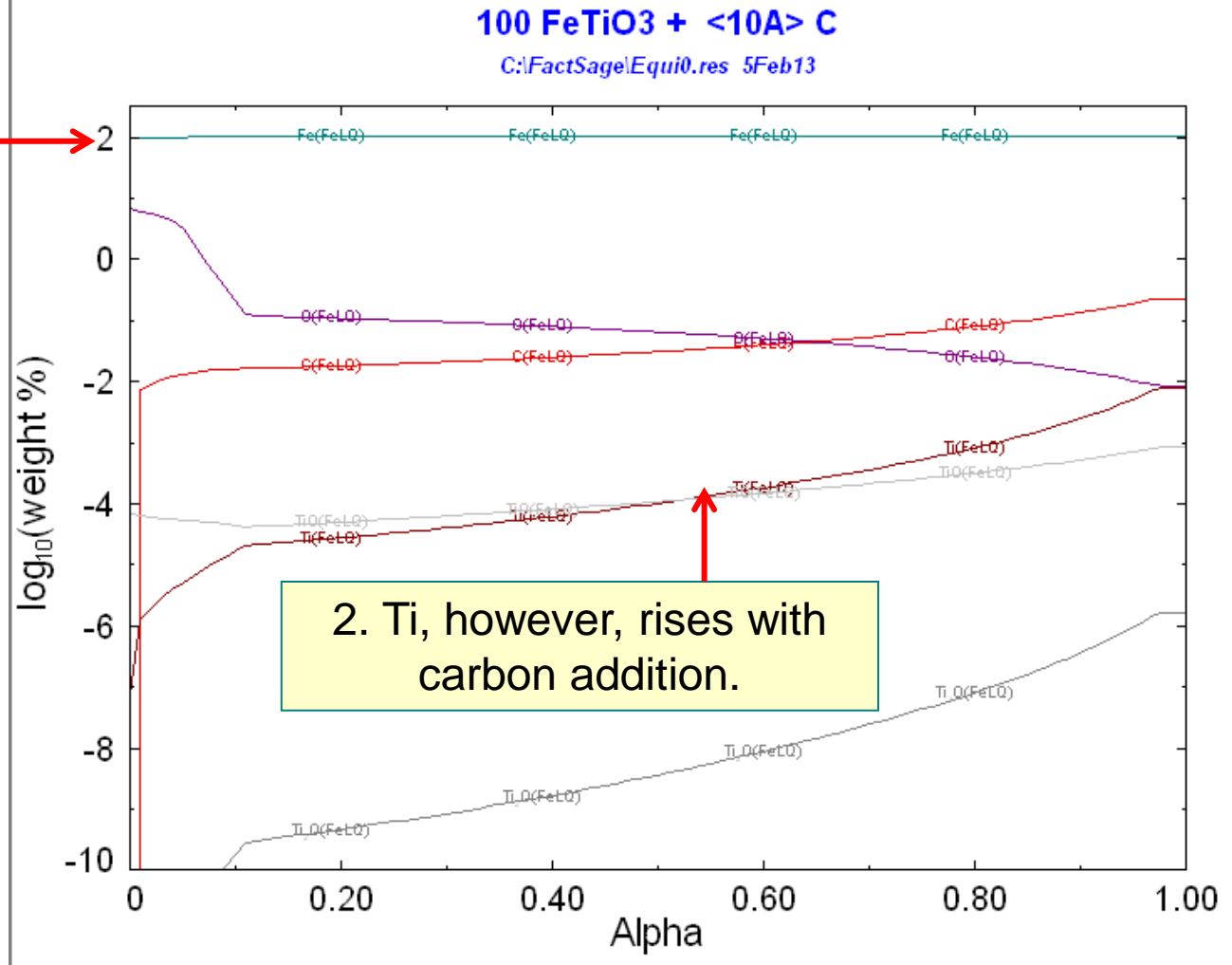
1. FeO content is decreased as carbon is added. Ti₂O₃ increases at almost the same rate.



2. The compositions remain constant after a certain point. This is when pseudobrookite precipitates.

Ilmenite Smelting

1. In the liquid metal, the percentage of iron remains close to 100%



3. Because TiO₂ slag is the more important product of ilmenite smelting, we will select the amount of carbon to be 9.7g to keep wt%FeO at a minimum

Visualizing the distribution of elements between phases: The “List” window

Ilmenite Smelting

1. A good way of seeing the distribution of the elements between phases is by clicking on the “List” button...

F List - Equilib T(C) = 1675, P(atm) = 1 (Page 1/101)

File Edit Help

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

| | Code | Data | Mole | Gram | Per Cent | Cumulate | T |
|----|------------|--------------|------------|---------|----------|----------|---|
| C | | | Totals | 0.0000 | 0.0000 | 0.0000 % | |
| | TOTAL C | | 0.0000 | 0.0000 | | | |
| | ELEMENT Fe | | Mole Fe | Gram Fe | Per Cent | Cumulate | |
| | GAS PHASE | | | | | | |
| | | | Totals | 0.0000 | 0.0000 % | | |
| | | | | | | | |
| | | | Totals | 0.0000 | 0.0000 % | | |
| | | | | | | | |
| | | | Totals | 0.0000 | 0.0000 % | | |
| Fe | 97 | FeO FToxid | 0.6030 | 33.67 | 91.48 % | 91.5 % | T |
| | 98 | Fe2O3 FToxid | 5.6184E-02 | 3.138 | 8.524 % | 100. % | T |
| | | | Totals | 0.6592 | 36.81 | 100.0 % | |
| | | | | | | | |
| | | | Totals | 0.0000 | 0.0000 % | | |
| | | | | | | | |
| | | | Totals | 0.0000 | 0.0000 % | | |

3. It is now possible to see that at $\langle A \rangle = 0 \dots$

4. ...100% of Fe is in the slag

2. ...and selecting “distribution”

Format: mole gram pound data distribution Post-Calculate activity

Order: code amount fraction activity

Page: 1 of 101 pages

OK

2. ...and selecting “distribution”

3. It is now possible to see that at $\langle A \rangle = 0 \dots$

4. ...100% of Fe is in the slag

Ilmenite Smelting

1. And this is the distribution at $\alpha=0.49$

F List - Equilib T(C) = 1675, P(atm) = 1, Alpha = 0.4899999999999999 (Page 50/101)

File Edit Help

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

| Code | Data | Mole | Gram | Per Cent | Cumulate | T |
|---------------------|------------|---------|------------|------------|--------------|-------------|
| ELEMENT Fe | | Mole Fe | Gram Fe | Per Cent | Cumulate | |
| GAS PHASE | | | | | | |
| 15 | Fe(g) | FactPS | 8.4795E-05 | 4.7354E-03 | 1.2864E-02 % | 1.286E-02 % |
| 16 | FeO(g) | FactPS | 2.2389E-07 | 1.2503E-05 | 3.3967E-05 % | 1.290E-02 % |
| 17 | Fe(CO)5(g) | FactPS | 1.4702E-25 | 8.2104E-24 | 2.2305E-23 % | 1.290E-02 % |
| Totals | | | 8.5019E-05 | 4.7479E-03 | 1.2898E-02 % | |
| FTmisc-FeLQ | | | | | | |
| 91 | Fe | FTmisc | 0.2968 | 16.57 | 45.02 % | 45.0 % T |
| Totals | | | 0.2968 | 16.57 | 45.02 % | |
| FToxid-SLAGA | | | | | | |
| 97 | FeO | FToxid | 0.3594 | 20.07 | 54.52 % | 99.6 % T |
| 98 | Fe2O3 | FToxid | 2.9178E-03 | 0.1629 | 0.4427 % | 100. % T |
| Totals | | | 0.3623 | 20.23 | 54.96 % | |
| FToxid-SLAGA | | | | | | |
| Totals | | | 0.0000 | 0.0000 | 0.0000 % | |
| FToxid-SPINA | | | | | | |
| Totals | | | 0.0000 | 0.0000 | 0.0000 % | |
| FToxid-MeO_A | | | | | | |

Fe

Show Species

- gas 17 duplicate
- liquid 0
- aqueous 0
- solid 41
- solution 38

selected 96

All/Clear

properties

Format

- mole
- gram
- pound
- data
- distribution

Order

- code
- amount
- fraction
- activity

Page 50 of 101 pages

Post-Calculate activity

OK

2. A convenient way to see the distribution of Fe for all values of α is to export the data into an Excel file

Ilmenite Smelting

F Results - Equilib A=0 (page 1/101)

Output Edit Show Pages

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

1. Press "Save or Print As..."

2. Select "Open Text Spreadsheet" and press "Spreadsheet setup"

Page Range

All 101 pages

Current page 1

Cancel

Type of Output

- Printer Printer setup ...
- Text file (*.txt)
- Equilib Results File (Equi*.res)
- Xml file (*.xml)
- Excel Spreadsheet
- Open Text Spreadsheet Spreadsheet setup ...
- Save Text Spreadsheet
- Swap rows & columns

Spreadsheet Setup

System Properties

Property columns 1

| | |
|-----------|-------|
| Column: | - 1 - |
| Variable: | Alpha |

4. Select the species

3. Select "Alpha" as the system property and "g" as the species property.

Species Properties

Columns per species 1

order species order props.

| | |
|-----------|-------|
| Column: | - 1 - |
| Variable: | g |

Species

Select ...

Species: 3

Columns: 4

Cancel

Default

OK

Ilmenite Smelting

1. Because Fe gets distributed in the gas, metal and slag phases, all elements from these phases must be selected.

Selected: 3/112 Spreadsheet Species 1 Pages: 1 - 101 [page]

Page 1/101 : T(C) = 1675, P(atm) = 1

| + Code | Species | Data | Phase | T | V | Activity | Minimum | Maximum |
|--------|--------------|------|---------------|---|---|----------|------------|---------|
| 160 | Solution | | FToxid-PSEU | | | 0.2905 | 0.2041 | 1.000 |
| 161 | Solution | | FToxid-TiSp | | | 0.1497 | 4.2514E-02 | 0.1787 |
| + 162 | All Elements | | GAS | | | | | |
| + 166 | All Elements | | FTmisc-FeLQ | | | | | |
| + 167 | All Elements | | FToxid-SLAGA# | | | | | |
| 170 | All Elements | | FToxid-SPINA | | | | | |
| 171 | All Elements | | FToxid-MeO_A | | | | | |
| 172 | All Elements | | FToxid-CORU | | | | | |
| 173 | All Elements | | FToxid-TiO2 | | | | | |
| 174 | All Elements | | FToxid-ILMEA | | | | | |
| 175 | All Elements | | FToxid-PSEU | | | | | |
| 176 | All Elements | | FToxid-TiO2 | | | | | |

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

Select All Clear OK

2. Press "OK" in all windows

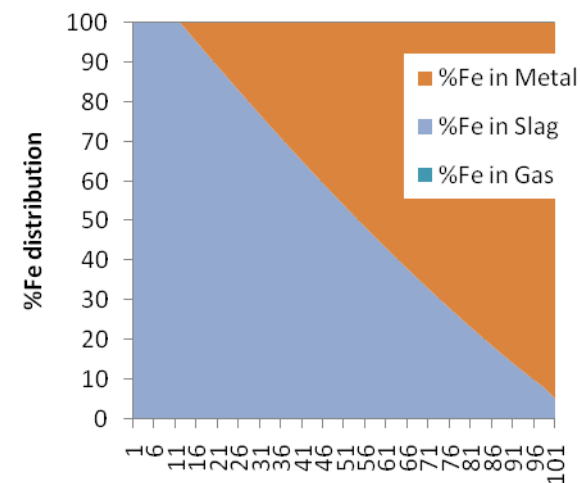
Ilmenite Smelting

1. The window with the amount of all elements in each phase will appear.

F Equilib Results

File Edit Swap rows and columns

| Alpha | g-Fe_GAS | g-Ti_GAS | g-O_GAS | g-C_GAS |
|---------------|---------------|---------------|---------------|---------------|
| 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 | 0.0000000E+00 |
| 1.0000000E-02 | 4.0964224E-06 | 2.4064555E-11 | 2.1365509E-01 | 1.0000000E-01 |
| 2.0000000E-02 | 1.2742725E-05 | 7.3638352E-11 | 3.9713850E-01 | 2.0000000E-01 |
| 3.0000000E-02 | 2.8197135E-05 | 1.5878802E-10 | 5.5682909E-01 | 3.0000000E-01 |
| 4.0000000E-02 | 5.3171052E-05 | 2.9045652E-10 | 7.0012011E-01 | 4.0000000E-01 |
| 5.0000000E-02 | 9.1190691E-05 | 4.8186466E-10 | 8.3272130E-01 | 5.0000000E-01 |
| 6.0000000E-02 | 1.4703239E-04 | 7.4978548E-10 | 9.5858400E-01 | 6.0000000E-01 |
| 7.0000000E-02 | 2.2727793E-04 | 1.1158442E-09 | 1.0803894E+00 | 7.0000000E-01 |



<A>*100

2. Copy all the values in Excel and keep only the columns with Fe

| | A | B | C | D | E | F | G |
|---|----------|----------|------------------|---------------------|--------------------------|--------------|-------------|
| 1 | Alpha | g-Fe_GAS | g-Fe_FTmisc-FelQ | g-Fe_FToxid-SLAGA#1 | %Fe in Gas | %Fe in Metal | %Fe in Slag |
| 2 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.68E+01 | 0.00E+00 | 0.00E+00 | 1.00E+02 |
| 3 | 1.00E-02 | 4.10E-06 | 0.00E+00 | 3.68E+01 | 1.11E-05 | 0.00E+00 | 1.00E+02 |
| 4 | 2.00E-02 | 1.27E-05 | 0.00E+00 | 3.68E+01 | 3.46E-05 | 0.00E+00 | 1.00E+02 |
| 5 | 3.00E-02 | 2.82E-05 | 0.00E+00 | 3.68E+01 | 7.66E-05 | 0.00E+00 | 1.00E+02 |
| 6 | 4.00E-02 | 5.32E-05 | 0.00E+00 | 3.68E+01 | =100*B6/(\$B6+\$C6+\$D6) | 0.00E+00 | 1.00E+02 |
| 7 | 5.00E-02 | 9.12E-05 | 0.00E+00 | 3.68E+01 | 2.48E-04 | 0.00E+00 | 1.00E+02 |

3. Add columns to calculate the %Fe in each phase

4. It is now convenient to plot the Fe distribution as an area plot. It can be seen that Fe in the slag is reduced as carbon is added

Calculating the liquidus of slag and metal: “Precipitate target” calculation

Ilmenite Smelting

1. As mentioned in slide 13, we will now calculate the equilibrium at 9.7g addition to reduce as much as possible the FeO content in the slag, but avoid pseudobrookite precipitation.

The screenshot shows the FactSage Equilib: comments window. The reactants are (gram) 100 FeTiO₃ + <10A> C. The products list includes gas, ideal, real, aqueous, pure liquids, and pure solids. The solution species table is as follows:

| * | + | Base-Phase | Full Name |
|---|---|--------------|--------------------------|
| | + | FTmisc-FeLQ | Fe-liq |
| | l | 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-CORU | M2O3(Corundum) |
| | + | FToxid-TiO2 | Rutile |

The final conditions are set to 0.97 for <A>, 1675 for T(C), and 1 for P(atm). The equilibrium calculation is set to normal. The status bar shows FactSage 6.3 and the file path C:\FactSage\EquiCase3-1.DAT.

Ilmenite Smelting

We would now like to see if our temperature is well chosen. For this, we want to see what is the liquidus temperature of the slag and the metal.

1. Press “Output” → “Stream File” → “Save solutions” and select the solution you would like to save. In this case, we want to save the metal and slag solutions.

2. In the pop-up window, enter the name of stream file

3. In the next window, enter any comments you might have.

4. In the same way, save the FToxid-SLAGA#1 solution

| T(C) | P(atm) | Energy(J) | Mass(g) | Vol(litre) |
|--------------|--------|-----------|---------|------------|
| E-03 | | | CO2 | |
| E-04 | | | Fe | |
| E-08 | | | FeO | |
| + 1.9084E-08 | | | TiO | |

+ 5

| | | |
|--------------|-------|-------|
| (7.3932 | wt. % | FeO |
| + 1.8146E-02 | wt. % | Fe2O3 |
| + 34.200 | wt. % | Ti2O3 |

Ilmenite Smelting

1. Set up a new reaction in the reactants window by pressing the “new reaction” button.

2. Press “Edit” → “Mixtures and Streams” → “Import a stream” and select the saved stream. Here we will start with liquid metal.

3. The “Liquid Metal” solution will be selected as one of the reactants.

4. Clicking on the arrow beside the name of the solution will show the composition of this solution.

The screenshot shows the 'Reactants - Equilib' window in FactSage. The 'Mixtures and Streams' menu is open, and 'Liquid_Metal' is selected. The 'Species' dropdown menu is also open, showing the composition of the selected solution.

| Mass(g) | Species |
|---------|--------------------|
| 100% | [Liquid Metal] |
| | [Liquid Metal] |
| | FTmisc-FeLQ_Fe-liq |
| | Weight %: |
| | 1.0000E+02 Total |
| | 9.9766E+01 Fe |
| | 2.1705E-01 C |
| | 8.5417E-03 O |
| | 7.1511E-03 Ti |

Ilmenite Smelting

1. In the “Menu” window, we will select the liquid metal solution and all the solids as possible products.

2. To make a “cooling” calculation, we will select 1675C as the starting temperature and 1000C as the final temperature.

3. We will calculate only the transitions.

F Menu - Equilib:

File Units Parameters Help

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

Reactants (1)

(gram) 100% [Liquid_Metal]

Products

Compound species

- gas ideal real 0
- aqueous 0
- pure liquids 0
- pure solids 41
- suppress duplicates
- * - custom selection species: 41

Transitions - temperature

Number of transitions: All

Final Conditions

| <A> | | T(C) | P(atm) | Product H(J) |
|-----|-----|------|--------|--------------|
| | | 1675 | 1000 | 1 |

10 steps Table

Solution species

| * | Base-Phase | Full Name |
|---|--------------|--------------------------|
| + | FTmisc-FeLQ | Fe-liq |
| | 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-CORU | M2O3(Corundum) |
| | FToxid-TiO2 | Rutile |

Legend

+ - selected 1

Show all selected

species: 6

solutions: 1

Equilibrium

normal normal + transitions

transitions only

open

Equilibrium Summary:

- fixed activities
- ideal solutions
- activity coefficients

Total Species [max 1500] 47

Total Solutions [max 40] 1

FactSage 6.3

Ilmenite Smelting

1. In the “Results” window, it is seen that Ti_3O_5 is ready to precipitate at 1674.17C (its activity is 1). So this is the liquidus temperature of our liquid metal.

F Results - Equilib 1674.17 C (page 1/27)

Output Edit Show Pages

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

1310.89 C | 1241.54 C | 1209.12 C |
1456.26 C | 1449.59 C | 1449.13 C | 1443.88 C | 1443.5 C | 1434.73 C | 1432.91 C | 1396.49 C | 1394.32 C | 1394.32 C | 1354.54 C |
-1674.17 C - | 1516.99 C | 1501.95 C | 1500.71 C | 1493.83 C | 1492.88 C | 1480.73 C | 1479.94 C | 1468.04 C | 1467.38 C | 1456.8

```
(gram) 100% [Liquid_Metal] =
33.806 gram Fe-liq
(33.806 gram, 0.61028 mol)
(1674.17 C, 1 atm, a=1.0000)
( 99.766 wt.% Fe FTmisc
+ 0.21705 wt.% C FTmisc
+ 8.5413E-03 wt.% O FTmisc
+ 7.1498E-03 wt.% Ti FTmisc
+ 7.9054E-04 wt.% TiO FTmisc
+ 1.4588E-06 wt.% Ti2O FTmisc)

System component Mole fraction Mass fraction
Fe 0.98960 0.99766
Ti 8.9611E-05 7.7435E-05
O 3.0258E-04 8.7395E-05
C 1.0010E-02 2.1705E-03

+ 0 gram Ti3O5_solid-b FToxid
(1674.17 C, 1 atm, S2, a=1.0000)
```

1310.89 C | 1241.54 C | 1209.12 C |
1456.26 C | 1449.59 C | 1449.13 C | 1443.88 C | 1443.5 C | 1434.73 C | 1432.91 C | 1396.49 C | 1394.32 C | 1394.32 C | 1354.54 C |
1674.17 C - | 1516.99 C - | 1501.95 C | 1500.71 C | 1493.83 C | 1492.88 C | 1480.73 C | 1479.94 C | 1468.04 C | 1467.38 C | 1456.8

```
+ 3.5331E-03 gram Ti3O5_solid-b FToxid
(3.5331E-03 gram, 1.5801E-05 mol)
(1516.99 C, 1 atm, S2, a=1.0000)

+ 0 gram Fe_bcc FactPS
(1516.99 C, 1 atm, S1, a=1.0000)
```

2. At 1516.99C, solid iron starts to precipitate.

Ilmenite Smelting

1. An easier way to find the liquidus of the liquid metal solution is by using the “Precipitate target” calculation.

2. Right-click on the Fe-liq selection and select “precipitate target phase”

3. Leave the temperature field blank. This calculation will find the temperature at which the first solid will precipitate from the Fe-liq solution

The screenshot shows the FactSage 6.3 Equilib software interface. The main window is titled "F Menu - Equilib:". The "Reactants (1)" field contains "(gram) 100% [Liquid_Metal]". A context menu is open over the "Fe-liq" selection in the "Solution species" table, with "P - precipitate target phase" selected. The "Legend" section shows "P - precipitate target" with a checked box. The "Equilibrium" section has "normal" selected. The "Calculate >>" button is visible at the bottom right.

| * | Base-Phase | Full Name |
|---|--------------|--------------------------|
| P | FTmisc-FeLQ | Fe-liq |
| | 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-CORU | M2O3(Corundum) |
| | FToxid-TiO2 | Rutile |

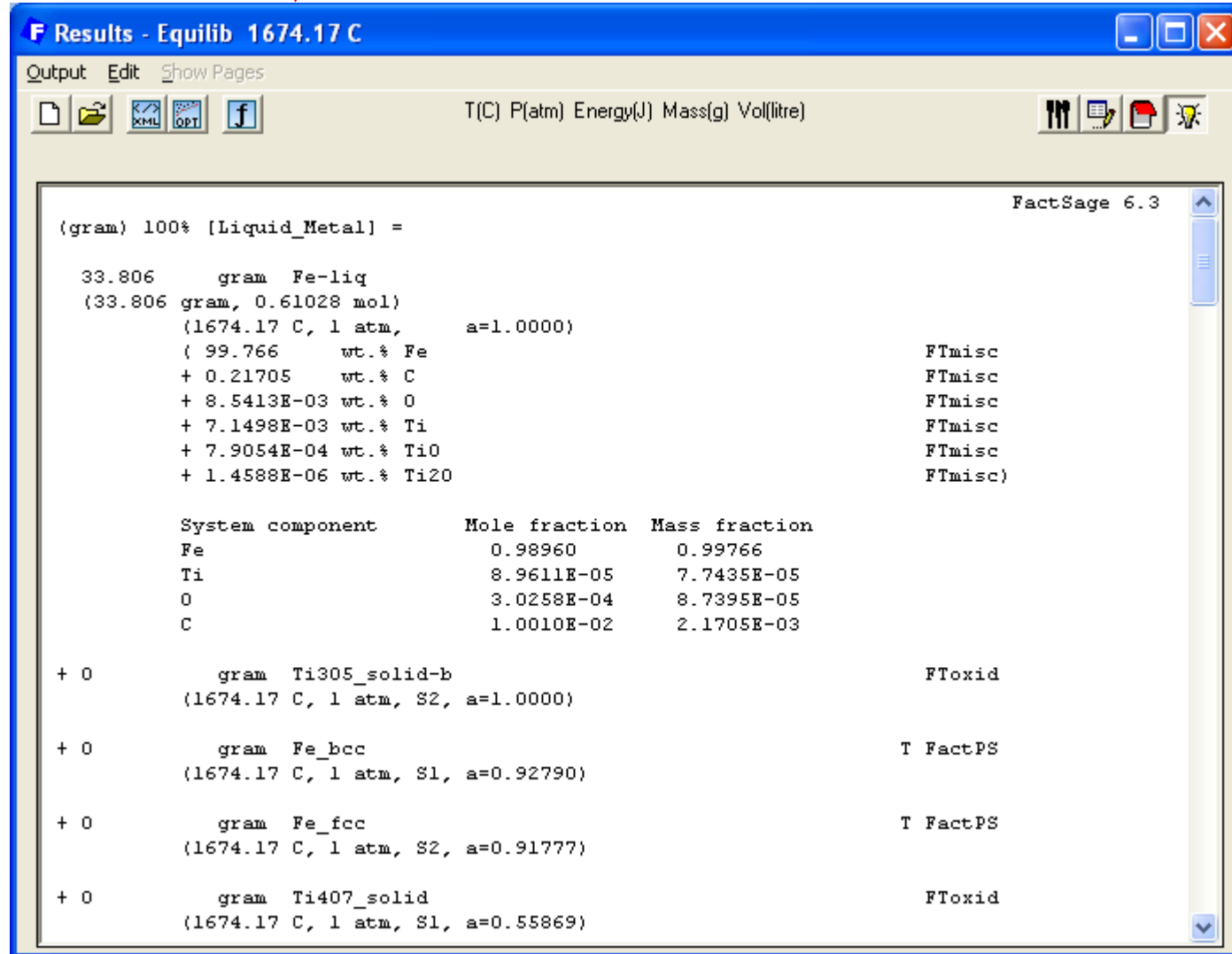
Legend
P - precipitate target

Equilibrium
 normal normal + transitions
 transitions only
 open

Calculate >>

Ilmenite Smelting

1. The liquidus temperature found is the same as in slide 23, but only one calculation had to be performed.



F Results - Equilib 1674.17 C

Output Edit Show Pages

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

FactSage 6.3

```
(gram) 100% [Liquid_Metal] =  
  
33.806      gram Fe-liq  
(33.806 gram, 0.61028 mol)  
  (1674.17 C, 1 atm,      a=1.0000)  
  ( 99.766      wt.% Fe      FTmisc  
  + 0.21705      wt.% C      FTmisc  
  + 8.5413E-03   wt.% O      FTmisc  
  + 7.1498E-03   wt.% Ti     FTmisc  
  + 7.9054E-04   wt.% TiO    FTmisc  
  + 1.4588E-06   wt.% Ti2O   FTmisc)  
  
System component      Mole fraction      Mass fraction  
Fe                     0.98960            0.99766  
Ti                     8.9611E-05         7.7435E-05  
O                      3.0258E-04         8.7395E-05  
C                      1.0010E-02         2.1705E-03  
  
+ 0      gram Ti305_solid-b      FToxid  
  (1674.17 C, 1 atm, S2, a=1.0000)  
  
+ 0      gram Fe_bcc            T FactPS  
  (1674.17 C, 1 atm, S1, a=0.92790)  
  
+ 0      gram Fe_fcc            T FactPS  
  (1674.17 C, 1 atm, S2, a=0.91777)  
  
+ 0      gram Ti407_solid       FToxid  
  (1674.17 C, 1 atm, S1, a=0.55869)
```

Ilmenite Smelting

1. The same calculation can be performed on the liquid slag to find its liquidus temperature.

2. Select all the solids and FToxid solutions, because they can all precipitate out of the slag phase

F Menu - Equilib:

File Units Parameters Help

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

Reactants (1)

(gram) 100% [Liquid_slag]

Products

Compound species

- gas ideal real 0
- aqueous 0
- pure liquids 0
- * pure solids 35
- suppress duplicates apply
- * - custom selection

species: 35

Solution species

| * | + | Base-Phase | Full Name |
|---|----|--------------|--------------------------|
| | IP | FToxid-SLAGA | ASlag-liq all oxides + S |
| | + | FToxid-SPINA | ASpinel |
| | + | FToxid-MeO_A | AMonoxide |
| | + | FToxid-CORU | M2O3(Corundum) |
| | + | FToxid-TiO2 | Rutile |
| | + | FToxid-ILMEA | Allmenite |
| | + | FToxid-PSEU | Pseudobrookite |
| | + | FToxid-TiSp | Titania_Spinel |

Legend

- I - immiscible 1
- P - precipitate target
- + - selected 7

species: 32 solutions: 9 Select

Custom Solutions

- fixed activities
- ideal solutions
- activity coefficients

Details ...

Pseudonyms

apply List ...

include molar volumes

Total Species (max 1500) 67

Total Solutions (max 40) 9

Default

Precipitate Target

FToxid-SLAGA

Estimate T(C): 1000

Mass(g): 0

Final Conditions

| <A> | | T(C) | P(atm) | Product H(J) |
|-----|-----|------|--------|--------------|
| | | | 1 | |

10 steps Table 1 calculation

Equilibrium

- normal normal + transitions
- transitions only
- open

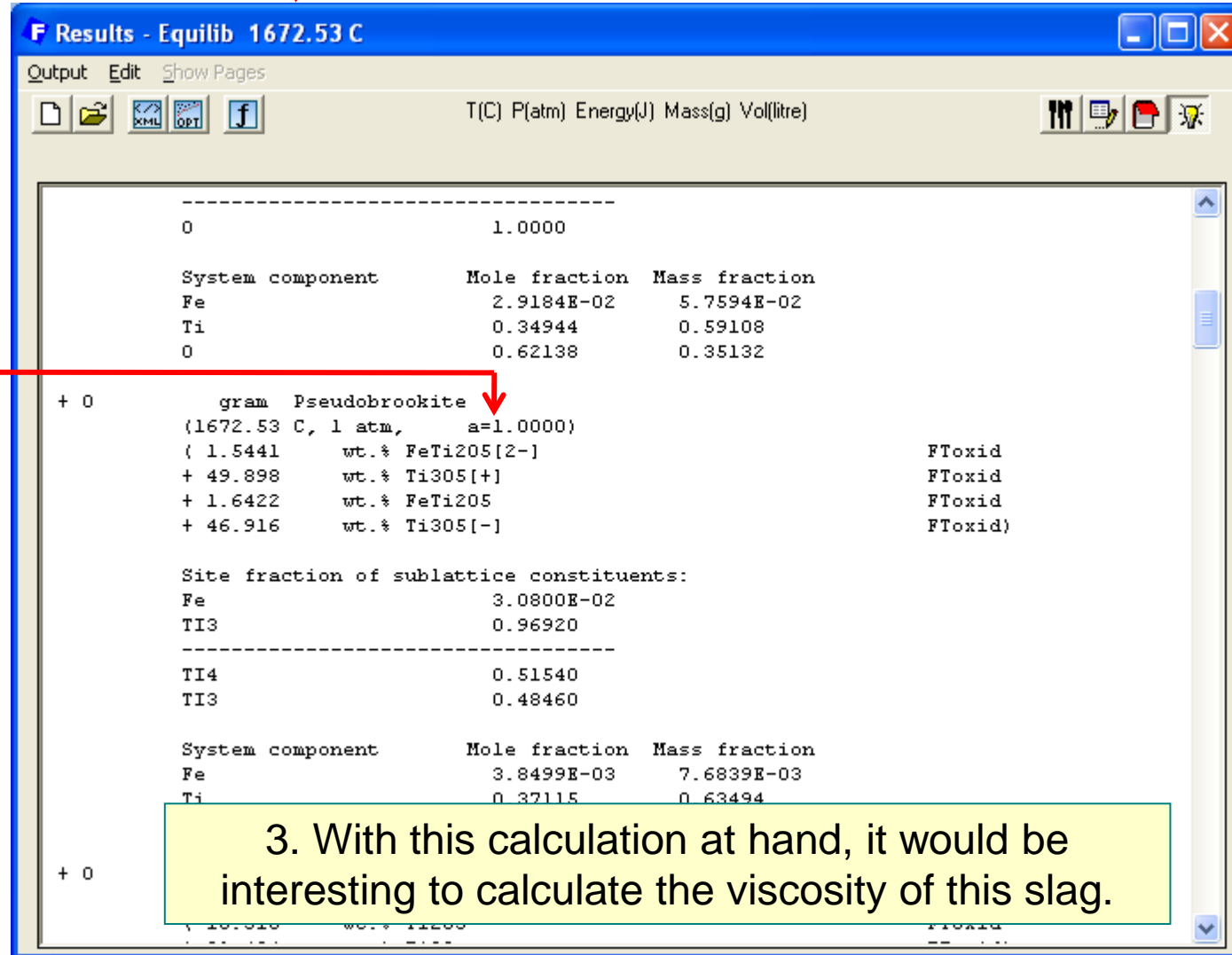
Calculate >>

FactSage 6.3

Ilmenite Smelting

1. The results show that pseudobrookite will precipitate out at 1672.53C

2. The last two results show that our smelting temperature is quite close to both the metal and the slag liquidus temperatures. It would thus be wise to increase the smelting temperature, to avoid precipitation of solid phases.



3. With this calculation at hand, it would be interesting to calculate the viscosity of this slag.

Calculating the viscosity of the slag: “Viscosity” calculation

Ilmenite Smelting

1. Open the "Viscosity" module.

2. The viscosity window will appear.

FactSage 6.3.1
Slide Show Programs Tools About

MinMet, McGill University

Info
General

Databases
Documentation
View Data
Compound
Solution

Calculate
Reaction
Predom
EpH
Equilib
Phase Diagram
OptiSage

Manipulate
Results
Mixture
Fact-XML
Figure
Viscosity

FactSage 6.3

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www.factsage.com

Viscosity of liquid oxides
File Edit Units Options Help

Calculate >> Database: Melts Glasses Include/Remove Fluoride Components Clear ALL

Enter the amounts of the constituents in the rows below. Then press on Calculate to show the viscosity.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|------------|-------------|-----------|-----------|-----------|-----------|-----------|-------------|-----------|--------------|-----------|------------|-------------|------------|-----------|
| 1 | SiO2 [mol] | Al2O3 [mol] | CaO [mol] | MgO [mol] | MnO [mol] | ZnO [mol] | FeO [mol] | IlIiO [mol] | PbO [mol] | IlIa2O [mol] | K2O [mol] | TiO2 [mol] | Ti2O3 [mol] | B2O3 [mol] | Fe2O [mo] |
| 2 | 1 | 1 | 1 | | | | | | | | | | | | |
| 3 | 1 | 2 | 1 | 1 | | 0 | 0 | | | | | | | | |
| 4 | | | | | | 1 | 1 | | | | | | | | |
| 5 | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | |

0% Selected database :

Ilmenite Smelting

F Results - Equilib 1672.53 C

Output Edit Show Pages

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

```

+ 53.375   gram  ASlag-liq#1
(53.375 gram, 0.51281 mol)
(1672.53 C, 1 atm,          a=1.0000)
( 7.3933   wt.% FeO          FToxid
+ 1.8030E-02 wt.% Fe2O3      FToxid
+ 54.200   wt.% Ti2O3        FToxid
+ 38.389   wt.% TiO2         FToxid)
    
```

1. In the Equilib results window, check the composition of the slag.

2. Select "grams" as the mass unit, "Celsius" as the temperature unit, and your favorite unit for viscosity.

F Viscosity of liquid oxides

File Edit Units Options Help

Temperature Viscosity Mass

Case: Melts Glasses Include/Remove Fluoride Components Clear ALL

Enter the amounts of the constituents in the rows below. Then press on Calculate to show the viscosity.

| | G | H | I | M | N | O | P | Q | R | S | T | U | V | W | X |
|---|---------|----------|---------|-----------|----------|-----------|----------|----------|--------|----------|----------|----------|----------|----------|----------|
| 1 | FeO [g] | liiO [g] | PbO [g] | Ti2O3 [g] | B2O3 [g] | Fe2O3 [g] | CaF2 [g] | liiF [g] | KF [g] | MgF2 [g] | AlF3 [g] | FeF2 [g] | MnF2 [g] | PbF2 [g] | ZnF2 [g] |
| 2 | 7.3933 | | | 38.389 | 54.2 | 0.0180 | | | | | | | | | |
| 3 | | | | | | 3 | | | | | | | | | |

3. Enter the slag composition.

4. On the far-right, select the desired temperature.

Calculate >> Database: Melts Glasses Include/Remove Fluoride Components Clear ALL

Enter the amounts of the constituents in the rows below. Then press on Calculate to show the viscosity.

| | O | P | Q | R | S | T | U | V | W | X | Y | Z | AA |
|---|-----------|----------|----------|--------|----------|----------|----------|----------|----------|----------|-----------|----------|-----------------|
| 1 | Fe2O3 [g] | CaF2 [g] | liiF [g] | KF [g] | MgF2 [g] | AlF3 [g] | FeF2 [g] | MnF2 [g] | PbF2 [g] | ZnF2 [g] | liiF2 [g] | FeF3 [g] | Temperature [c] |
| | | | | | | | | | | | | | 1672.53 |

5. Make sure the "Melts" database is selected, and press "Calculate"

Ilmenite Smelting

1. The result will be given on the far right.

File Edit Units Options Help

Calculate >> Database: Melts Glasses Include/Remove Fluoride Components Clear ALL

Enter the amounts of the constituents in the rows below. Then press on Calculate to show the viscosity.

| | U | V | W | X | Y | Z | AA | AB | AC | AD |
|---|----------|----------|----------|----------|----------|----------|------------------|-----------------|-------|----|
| 1 | FeF2 [g] | MnF2 [g] | PbF2 [g] | ZnF2 [g] | NiF2 [g] | FeF3 [g] | Temperature [eC] | vis[log(poise)] | | |
| 2 | | | | | | | 1672.53 | -0.182 | Melts | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |

2. To calculate the viscosity at different temperatures, enter the same composition several times and use a different temperature for each calculation.

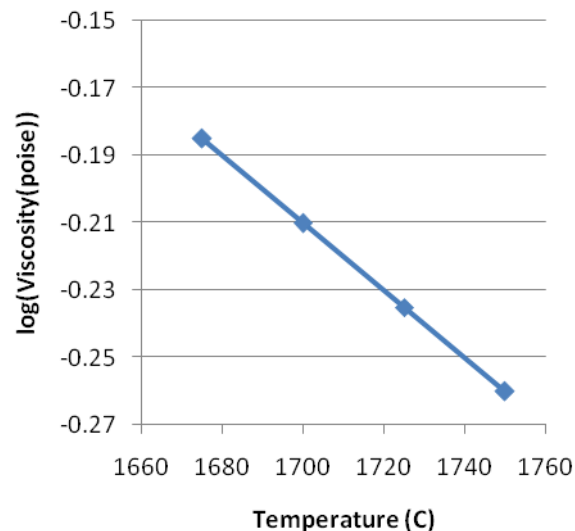
File Edit Units Options Help

Calculate >> Database: Melts Glasses Include/Remove Fluoride Components Clear ALL

Enter the amounts of the constituents in the rows below. Then press on Calculate to show the viscosity.

| | O | P | Q | R | S | T | U | V | W | X | Y | Z | AA | AB |
|---|-----------|----------|---|---|---|---|---|---|---|---|----------|----------|------------------|-----------------|
| 1 | Fe2O3 [g] | CaF2 [g] | | | | | | | | | NiF2 [g] | FeF3 [g] | Temperature [eC] | vis[log(poise)] |
| 3 | 0.01803 | | | | | | | | | | | | 1675.00 | -0.185 |
| 4 | 0.01803 | | | | | | | | | | | | 1700.00 | -0.210 |
| 5 | 0.01803 | | | | | | | | | | | | 1725.00 | -0.235 |
| 6 | 0.01803 | | | | | | | | | | | | 1750.00 | -0.260 |
| 7 | | | | | | | | | | | | | | |

3. Copying the results to Excel, it is possible to plot these results



4. As expected, the viscosity decreases with increasing temperature

Temperature-Pressure relationship at fixed slag
composition:
“Composition target” calculation

Ilmenite Smelting

Next, we would like to calculate the relationship between Temperature and partial pressure of oxygen at a constant slag composition.

Menu - Equilib: Ilmenite Smelting with variable carbon

File Units Parameters Help

T(C) P(atm) Energy

Reactants (2)

(gram) 100 FeTiO3

Products

Compound species

| | | | | | | |
|-------------------------------------|---------------------|----------------------------------|-------|-----------------------|-------|-------------|
| <input type="checkbox"/> | gas | <input checked="" type="radio"/> | ideal | <input type="radio"/> | real | 17 |
| <input type="checkbox"/> | aqueous | | | | | 0 |
| <input type="checkbox"/> | pure liquids | | | | | 0 |
| <input checked="" type="checkbox"/> | pure solids | | | | | 41 |
| <input checked="" type="checkbox"/> | suppress duplicates | | | | apply | |
| <input type="checkbox"/> | custom selection | | | | | species: 58 |

Solution species

| * | + | Base-Phase |
|---|---|--------------|
| | | FTmisc-FeLQ |
| | | FToxid-SLAGA |
| | | FToxid-SPINA |
| | | FToxid-MeO_A |
| | | FToxid-CORU |
| | | FToxid-TiO2 |
| | | FToxid-ILMEA |
| | | FToxid-PSEU |

Legend

- I - immiscible 1
- C - composition target
- species: FeO

Composition target

Species FeO - FToxid-SL

Estimate P(atm): 1.0

Mass(g): 0

Final Conditions

| <A> | | T(C) | P(atm) | Product H(J) |
|------|-----|-------------|--------|--------------|
| 0.97 | | 1675 1725 1 | | |

10 steps Table

51 calculations

FactSage 6.3 C:\FactSage\EquiCase3-1.DAT

Composition Target

Solution OX53-SLAGA

Variable

- species composition
- log10 (species composition)
- element composition
- log10 (element composition)
- species activity
- log10(species activity)
- none (removes targets) -

Species

Code numbers (97-100)
FeO, Fe2O3, Ti2O3.

97 FeO

Element

Elements 0 Ti Fe

Element: 0

Values

Enter a single value - or enter a range of values 'first last step'

Species FeO 0.1

mass fraction: (10%)

Cancel Help OK

normal normal + transitions
transitions only
open

Calculate >>

1. Select "composition target" for the slag phase.

2. We will select 10% FeO as our composition target.

3. Leave the Pressure field blank.

Ilmenite Smelting

F Results - Equilib 1675 C, 15.3 atm (page 1/51)

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 - weight % vs T(C) ...

1. We will plot O₂ activity versus the temperature.

Plot: log₁₀(activity) vs T(C)

100 FeTiO₃ + <10A> C

| Axes | Variables | Minimum | Maximum |
|--------|-------------|-------------|-------------|
| Y-axis | activity | 0 | 15.496 |
| | mole | 0 | 1.2043 |
| | mole fract. | 0 | 0.993139 |
| | gram | 0 | 55.108 |
| | weight % | 0 | 98.925 |
| | Alpha | 0.97 | 0.97 |
| X-axis | T(C) | 1675. | 1725. |
| | P(atm) | 15.324 | 15.603 |
| | Cp(J) | 135.96 | 138.05 |
| | G(J) | -1.2383E+06 | -1.2187E+06 |
| | Vol(litre) | 0 | 0 |
| | H(J) | -4.4970E+05 | -4.4291E+05 |
| | V(litre) | 8.0069 | 8.1143 |
| | S(J) | 394.72 | 398.05 |
| | - page - | 1. | 51. |

Species

log₁₀(activity) vs T(C)

1 selected

Select

Repeat

Graph

Labels

size: 9 no: 4

chemical
 integer #
 none

Display

color
 reactants
 file name

full screen
 Viewer
 Figure

Plot >>

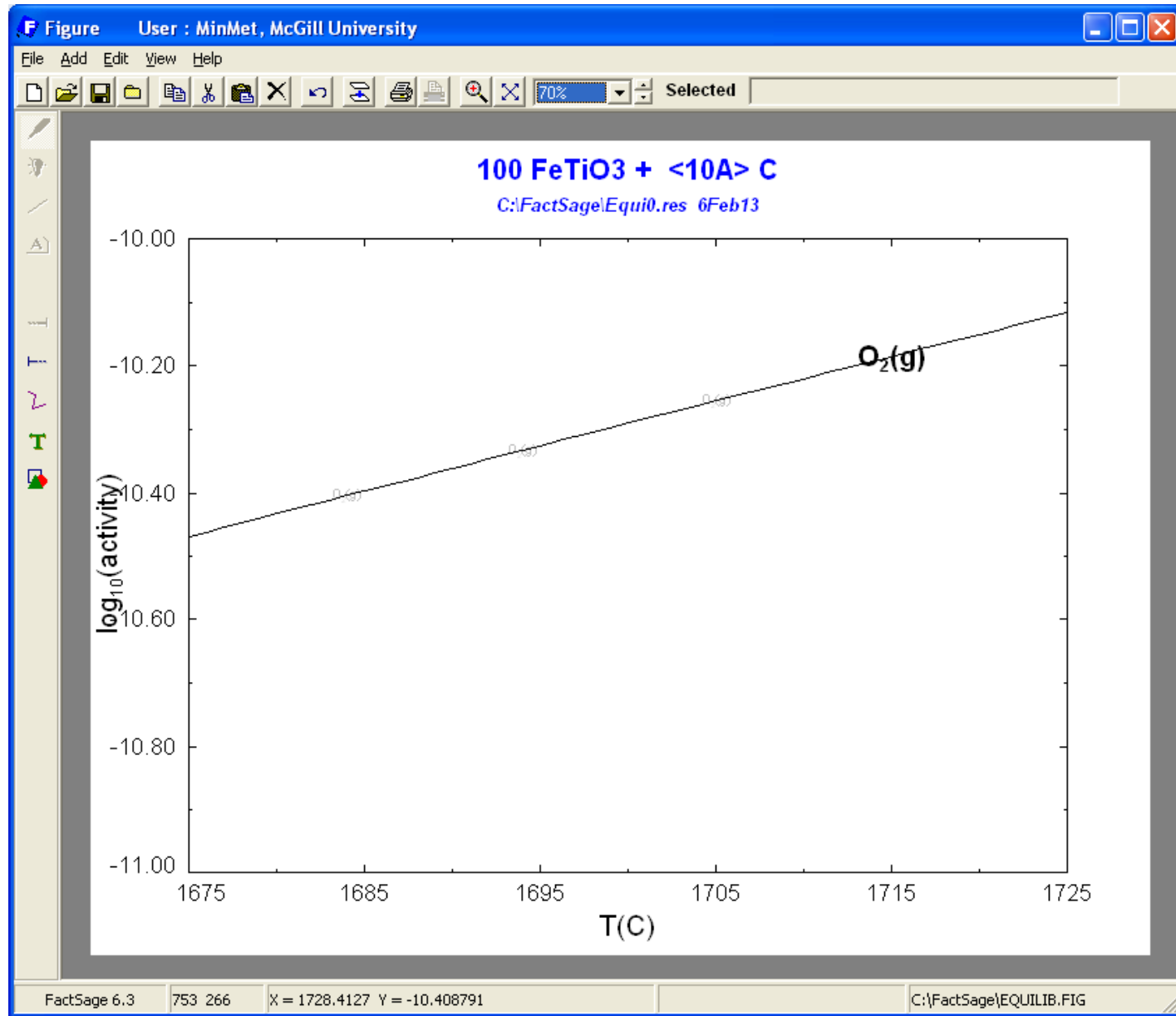
FactSage 6.3 C:\FactSage\Equi0.res 6Feb13 51 sets

```

(1675 C, 15.324
( 0.99300
+ 6.9874E-03
+ 1.2508E-05
+ 6.5063E-09
+ 9.0519E-10
+ 2.9778E-10
+ 1.6771E-10
+ 9.5294E-11
+ 2.2086E-12
+ 4.7483E-13
+ 4.6477E-14
+ 3.0038E-16
+ 1.4998E-16
+ 2.1111E-20
+ 1.0934E-21
+ 1.4294E-22
+ 5.2688E-25
+ 55.108 gram ASlag-1
    
```

Ilmenite Smelting

The graph shows that at lower temperatures, the oxygen pressure must be kept lower to keep the FeO content in the slag constant.



Ilmenite Smelting

Summarizing our findings:

9.7g C per 100g ilmenite seems to be ideal to reduce the amount of FeO in the slag while preventing the precipitation of pseudobrookite

The liquidus temperature of the resulting slag is 1672°C and the liquidus of the metal is 1674°C, so smelting at 1700°C would be better to avoid the precipitation of undesired phases