Case Study 9
Ferronickel production

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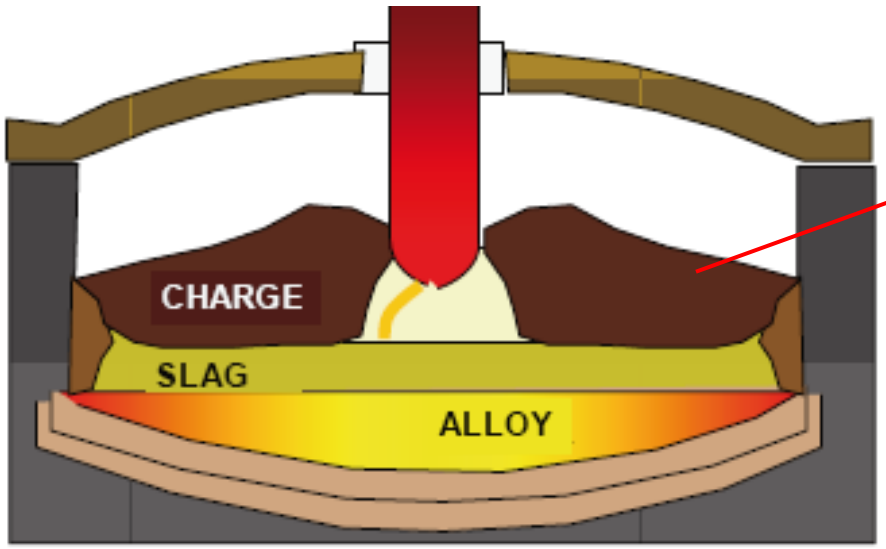
Ferronickel production



Calcined Laterite	wt%	Char	wt%
FeO	8.1	Al_2O_3	4.8
Fe_2O_3	20.9	SiO_2	14
SiO_2	43.8	C	81.2
Al_2O_3	6.4		
MgO	16.8		
NiO	2.3		
CaO	0.1		
CoO	0.1		
Cr_2O_3	0.8		
MnO_2	0.6		
Na_2O	0.3		

After removal of moisture from the laterite, char is added to react with calcined laterite.

Productions are Slag and Alloys(Fe-Ni).

After the calcination, the temperature of laterite is assumed as 500^{o}C Char is assumed to be added at 100^{o}C in the EAF and react at 1600^{o}C

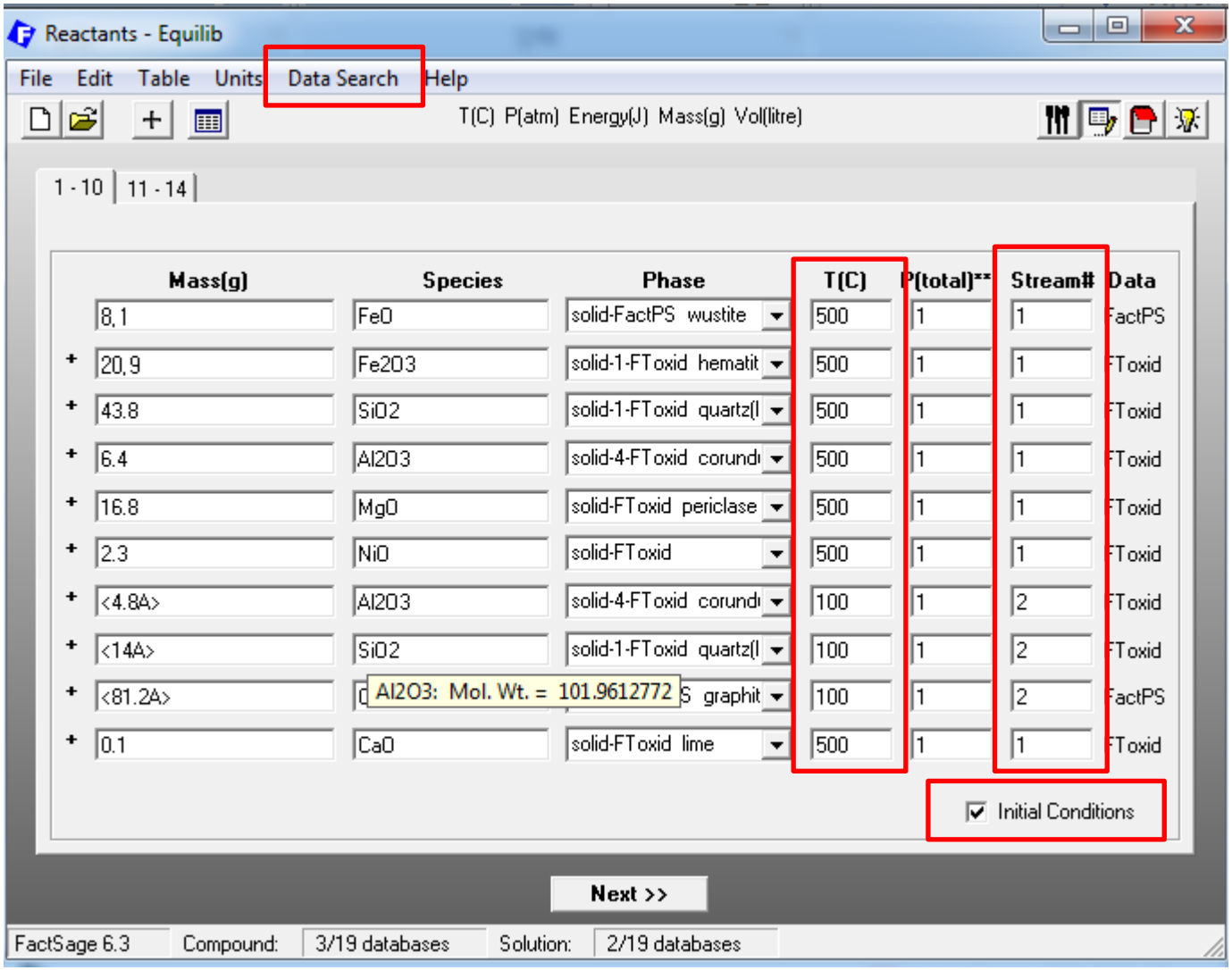
We are considering gas, slag and Fe-alloys in this case study.

Determine the amount of reductant needed to produce Fe-Ni with 25% nickel

Composition Target

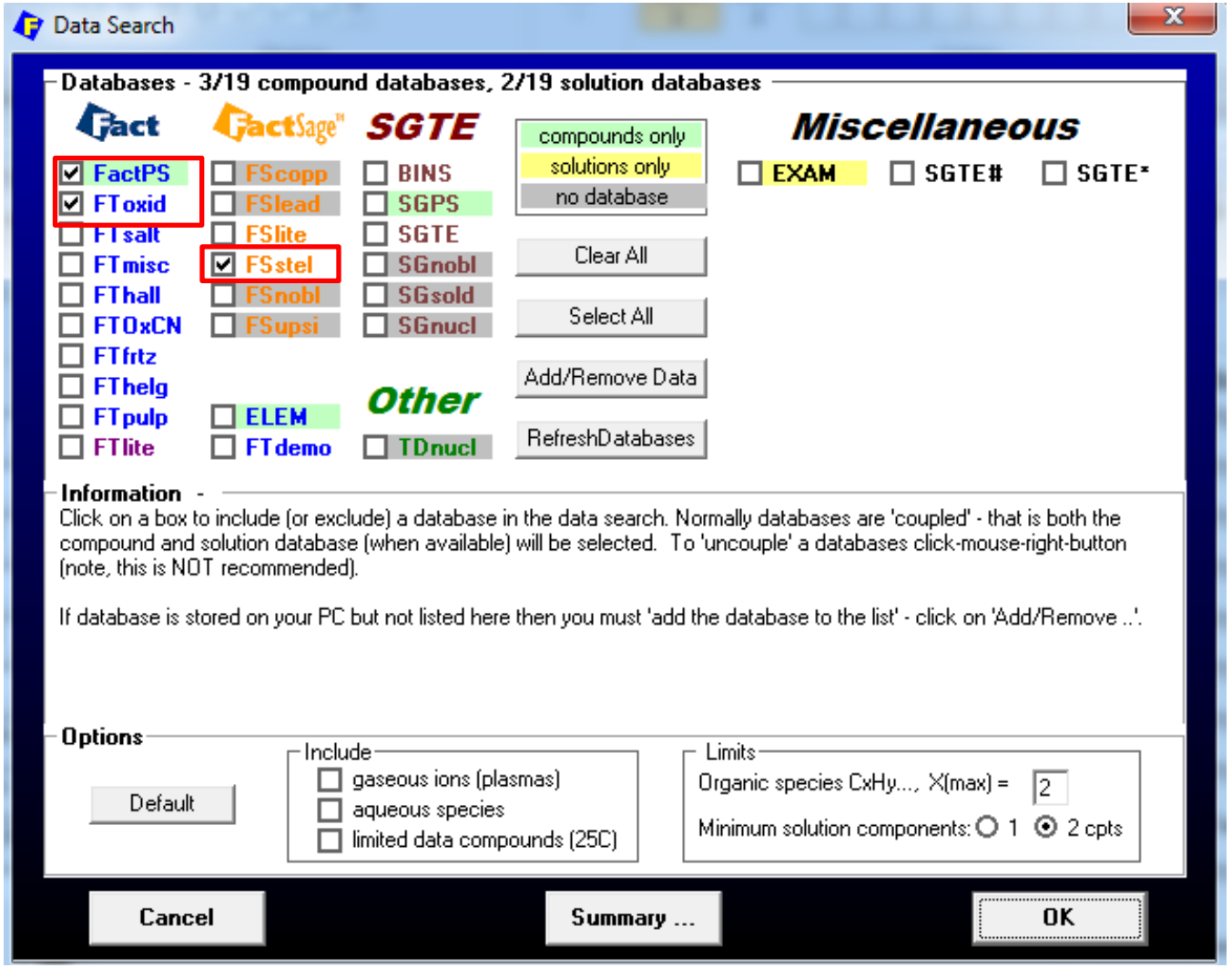
Reactants Window - Laterite + Char

Reactants Window

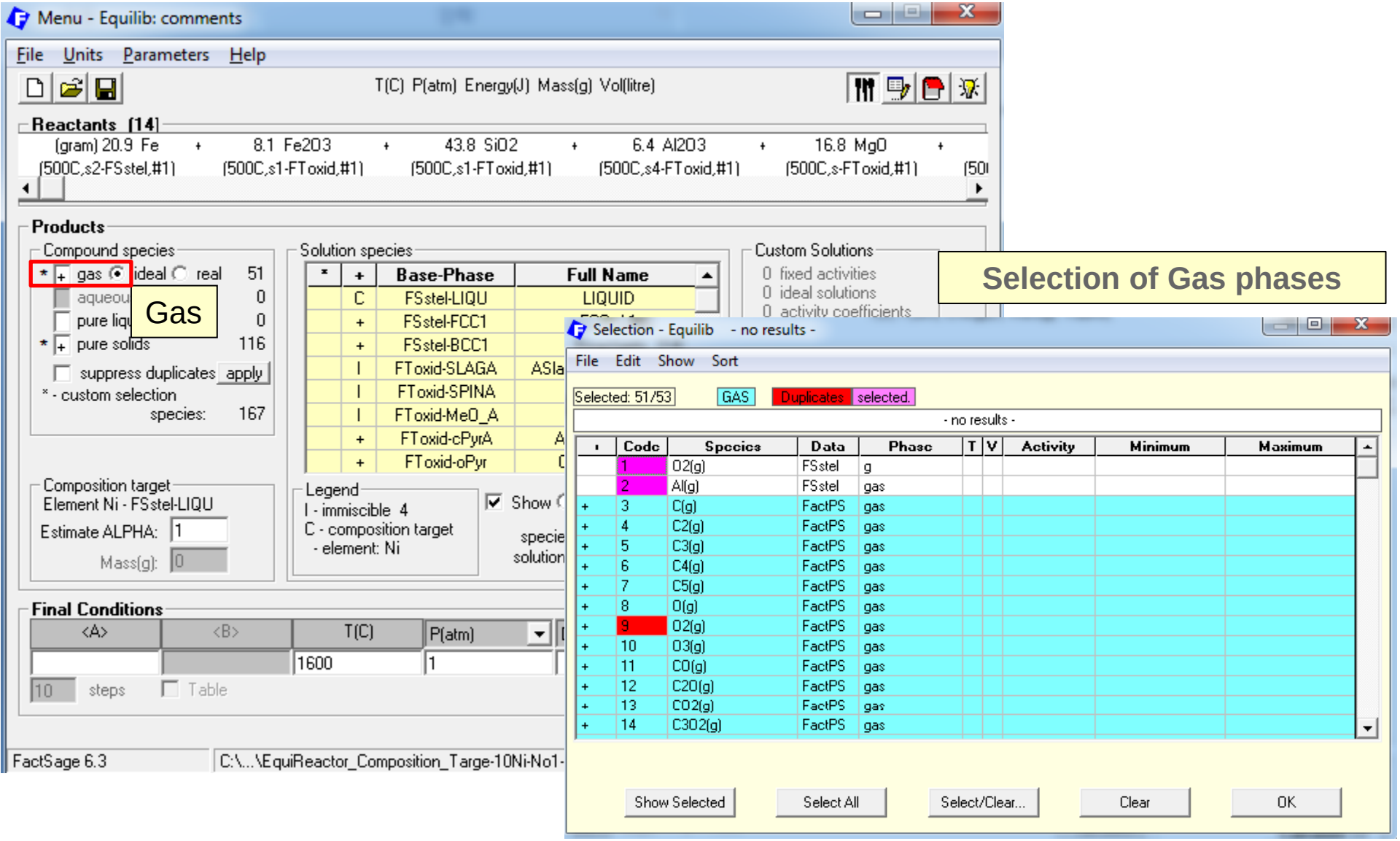


Reactants Window - Laterite + Char at 1600°C

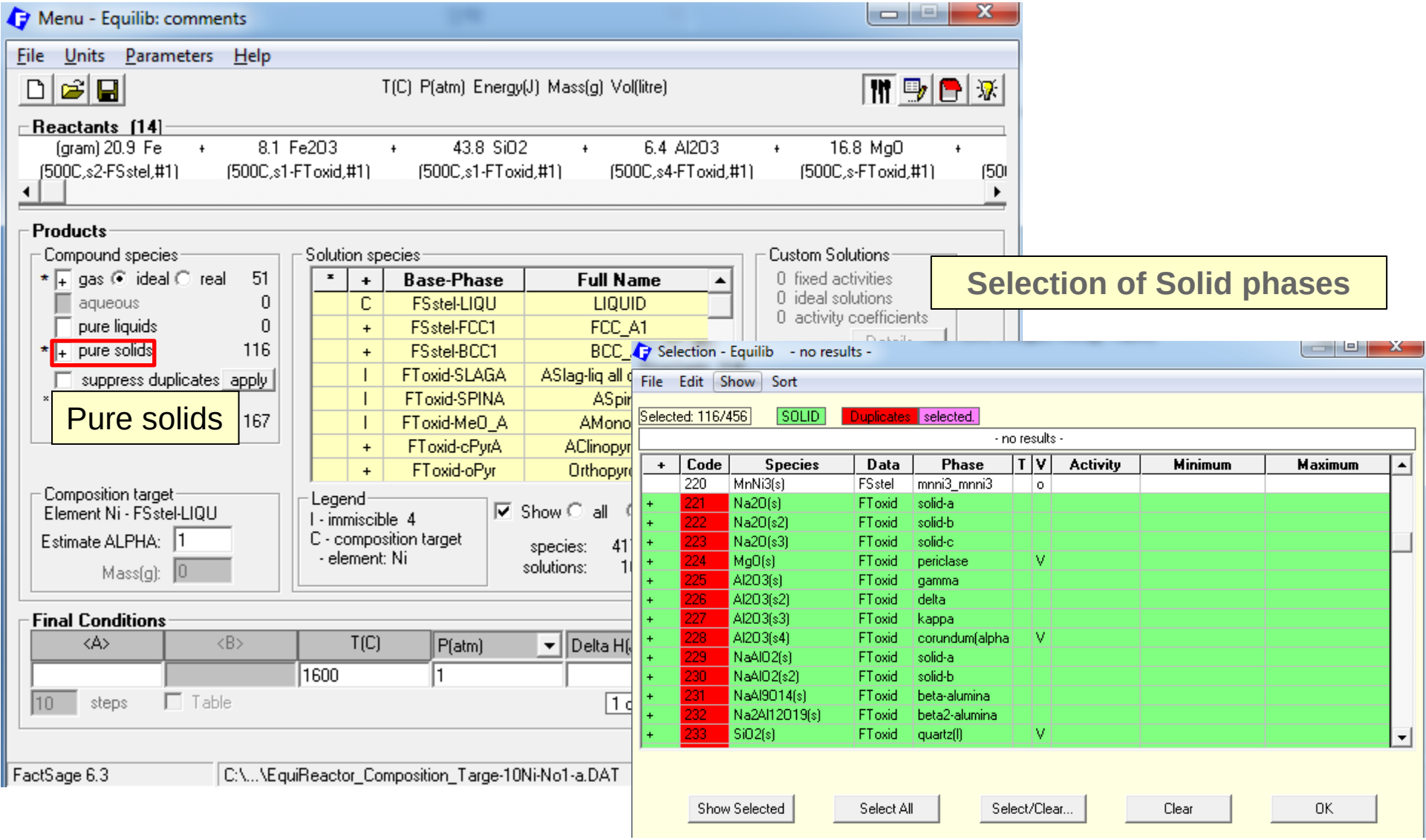
Data Search



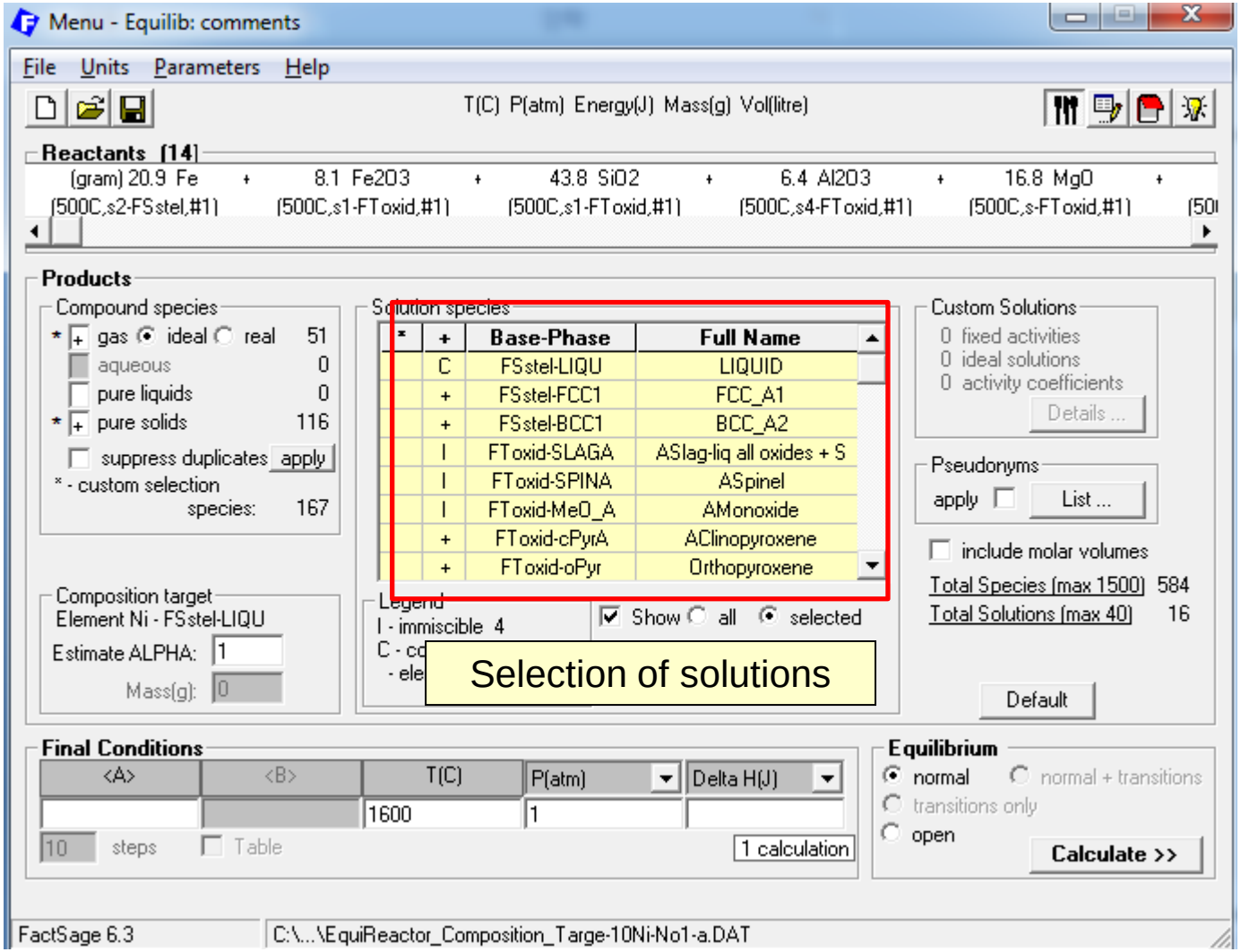
Menu Window - Laterite + Char at 1600°C



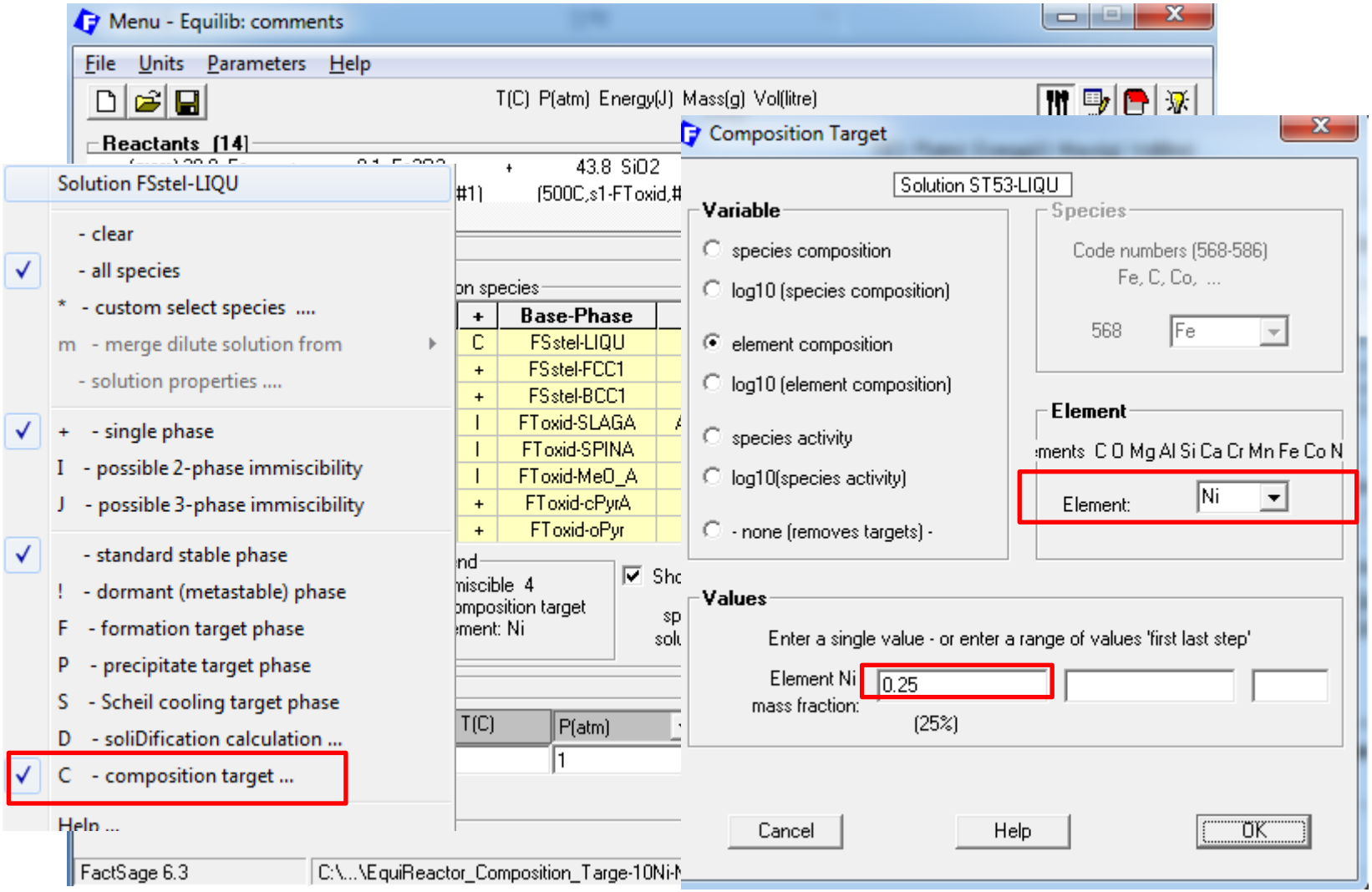
Menu Window - Laterite + Char at 1600°C



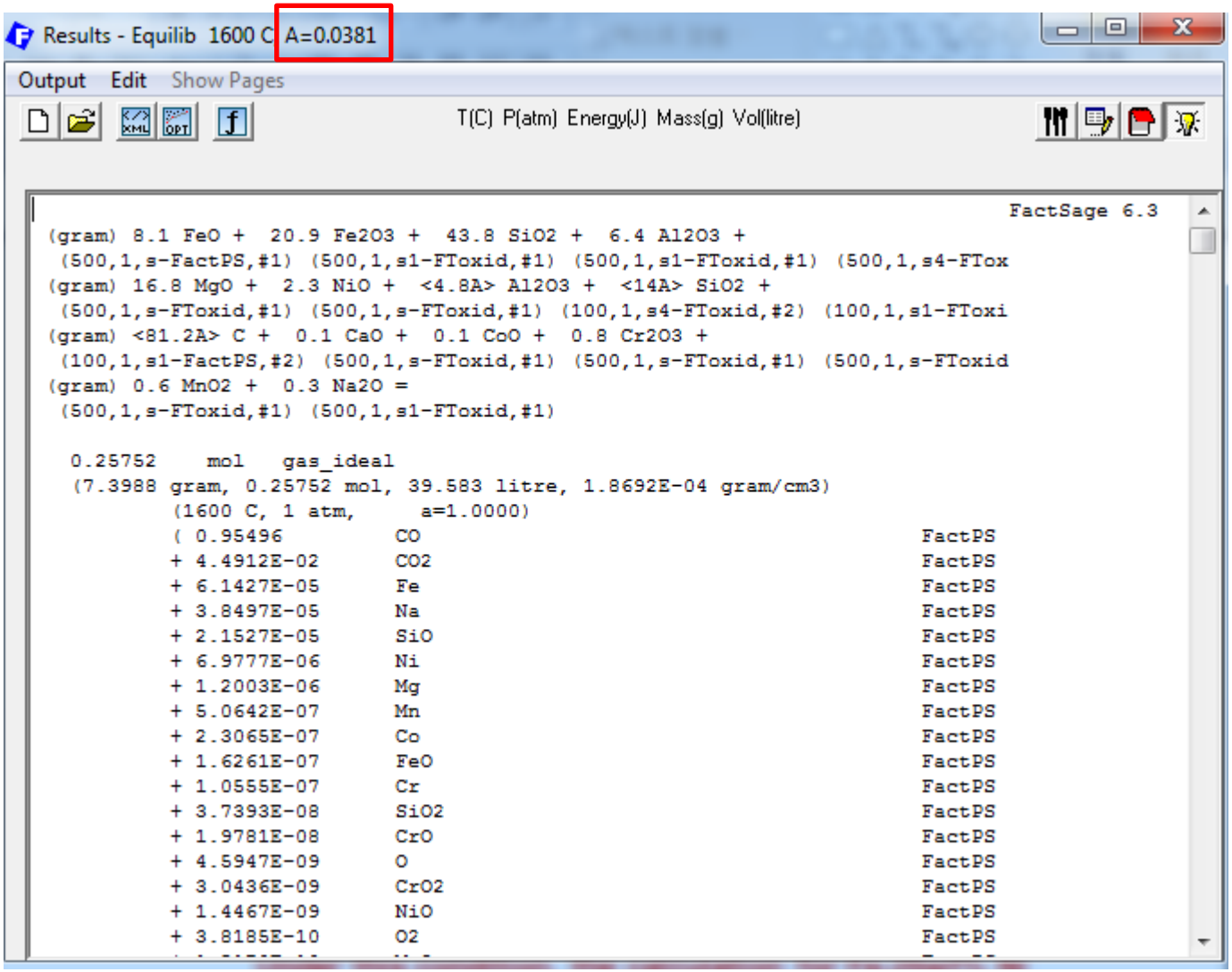
Menu Window - Laterite + Char at 1600°C



Menu Window – Composition Target

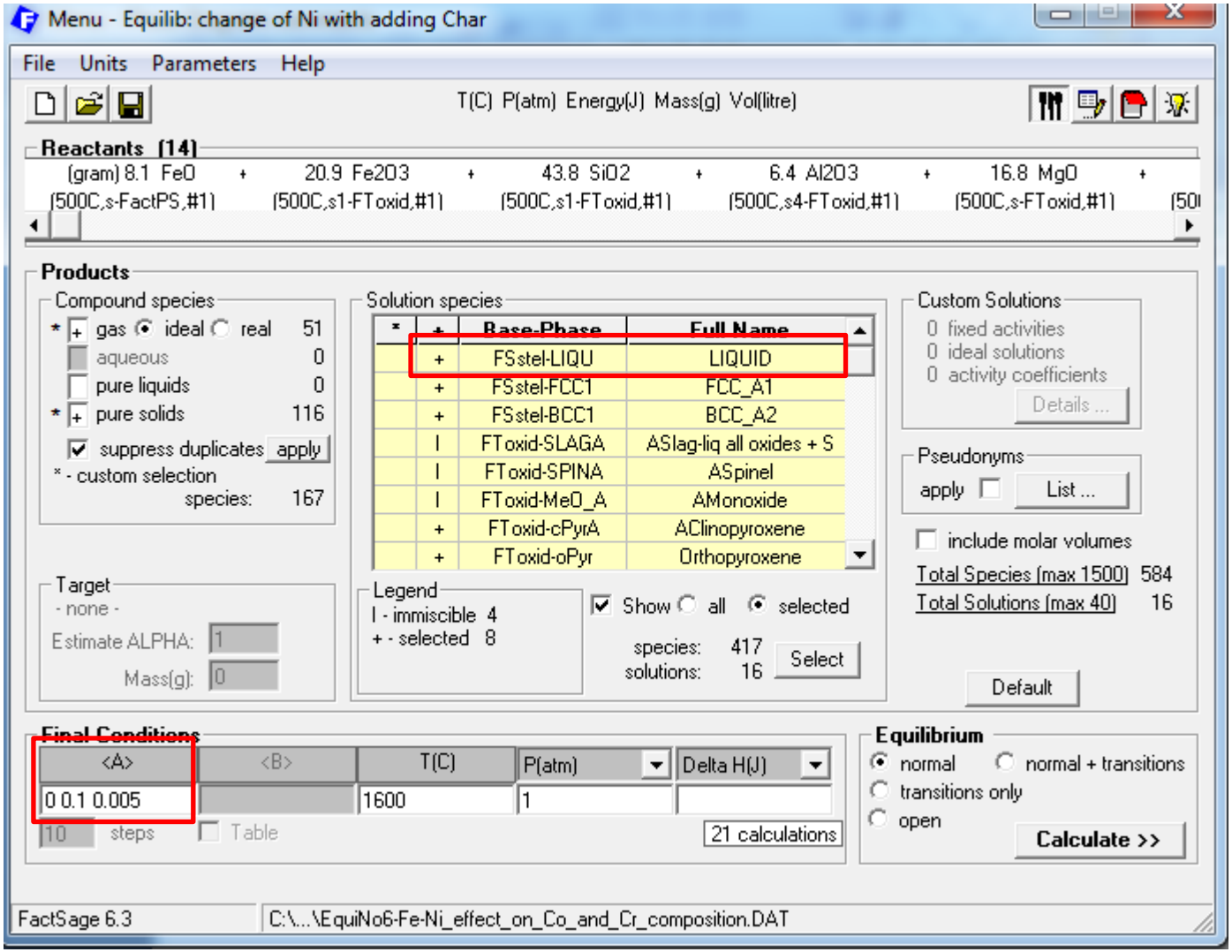


Results Window - Laterite + Char at 1600°C



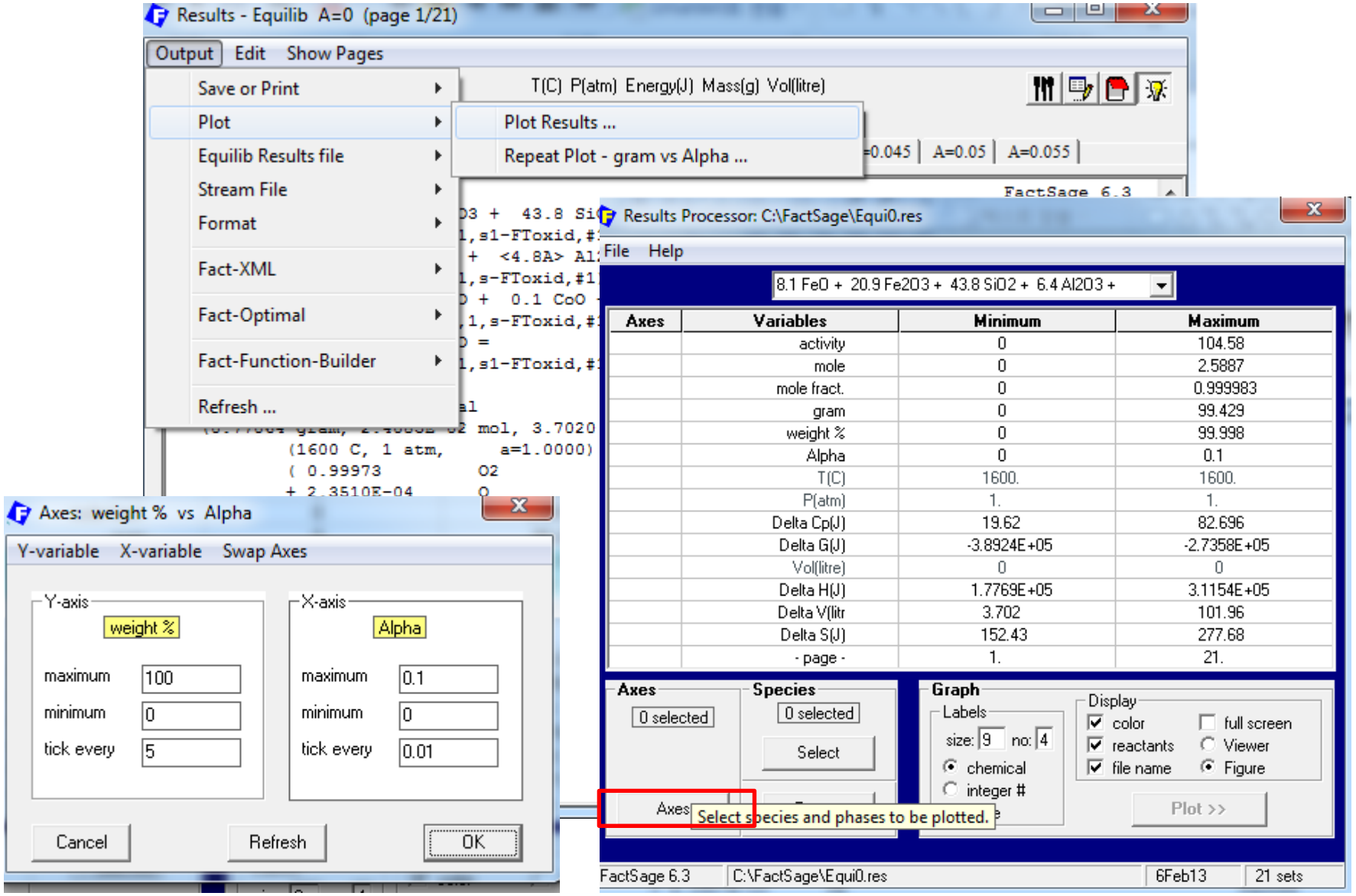
Laterite 100 g vs Char 0.0381 g
Laterite 1 ton vs Char 0.381 kg

Effect of change of Char - Laterite + Char at 1600°C

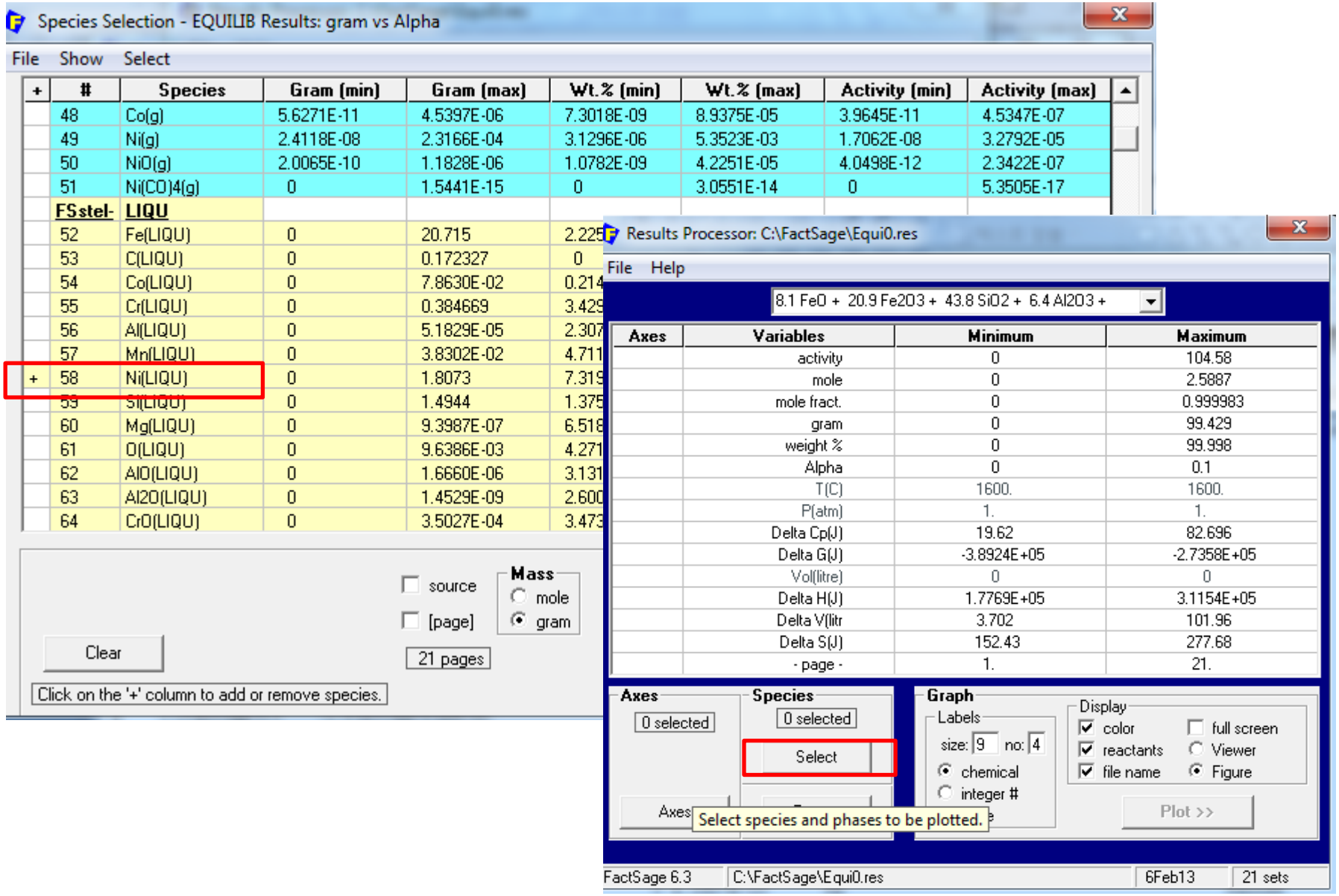


Change of Char from 0 to 0.1g based on 100g Laterite
Laterite 1 ton vs change of Char from 0 to 1 kg

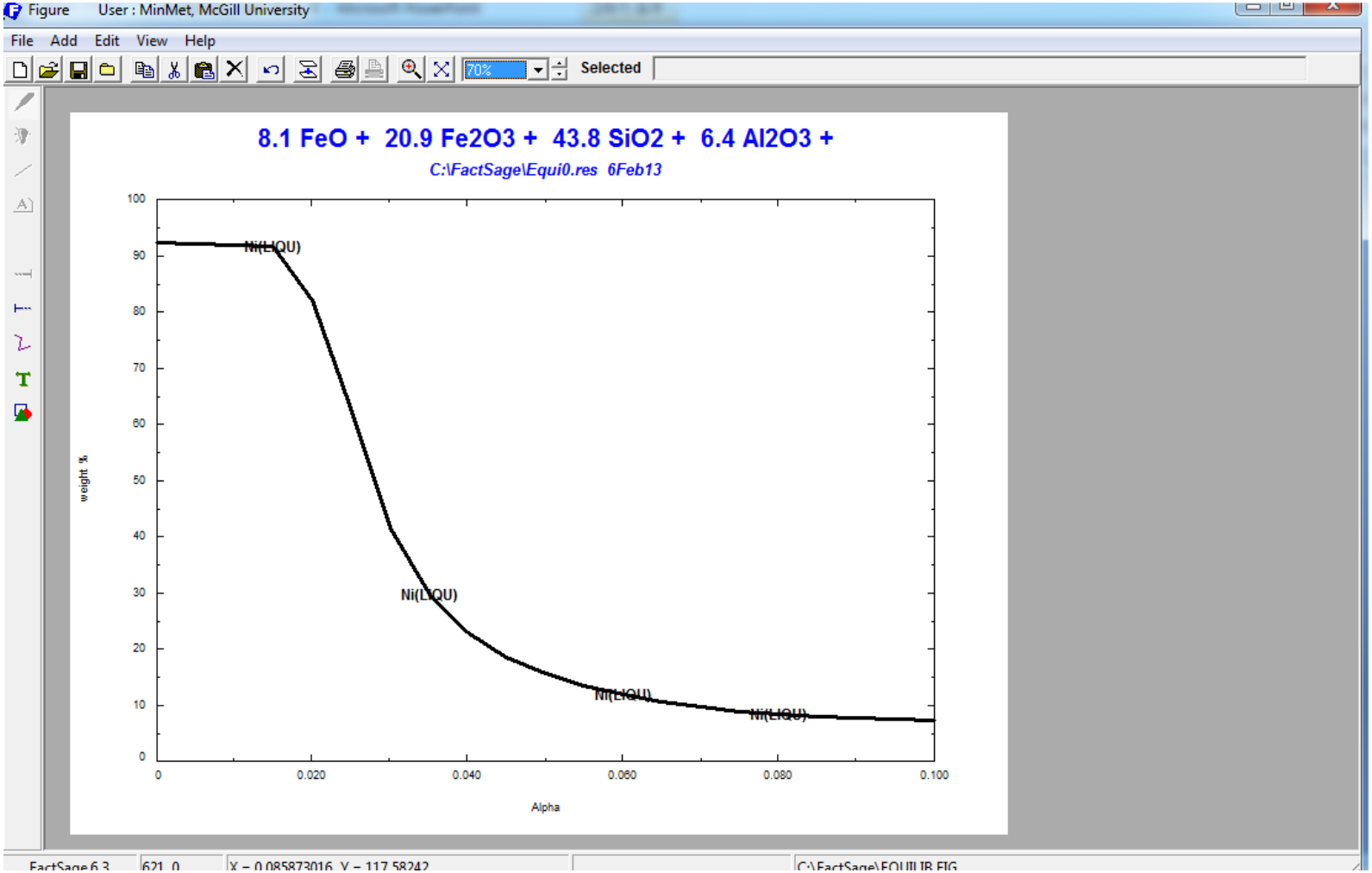
Effect of change of Char - Laterite + Char at 1600°C



Effect of change of Char - Laterite + Char at 1600°C

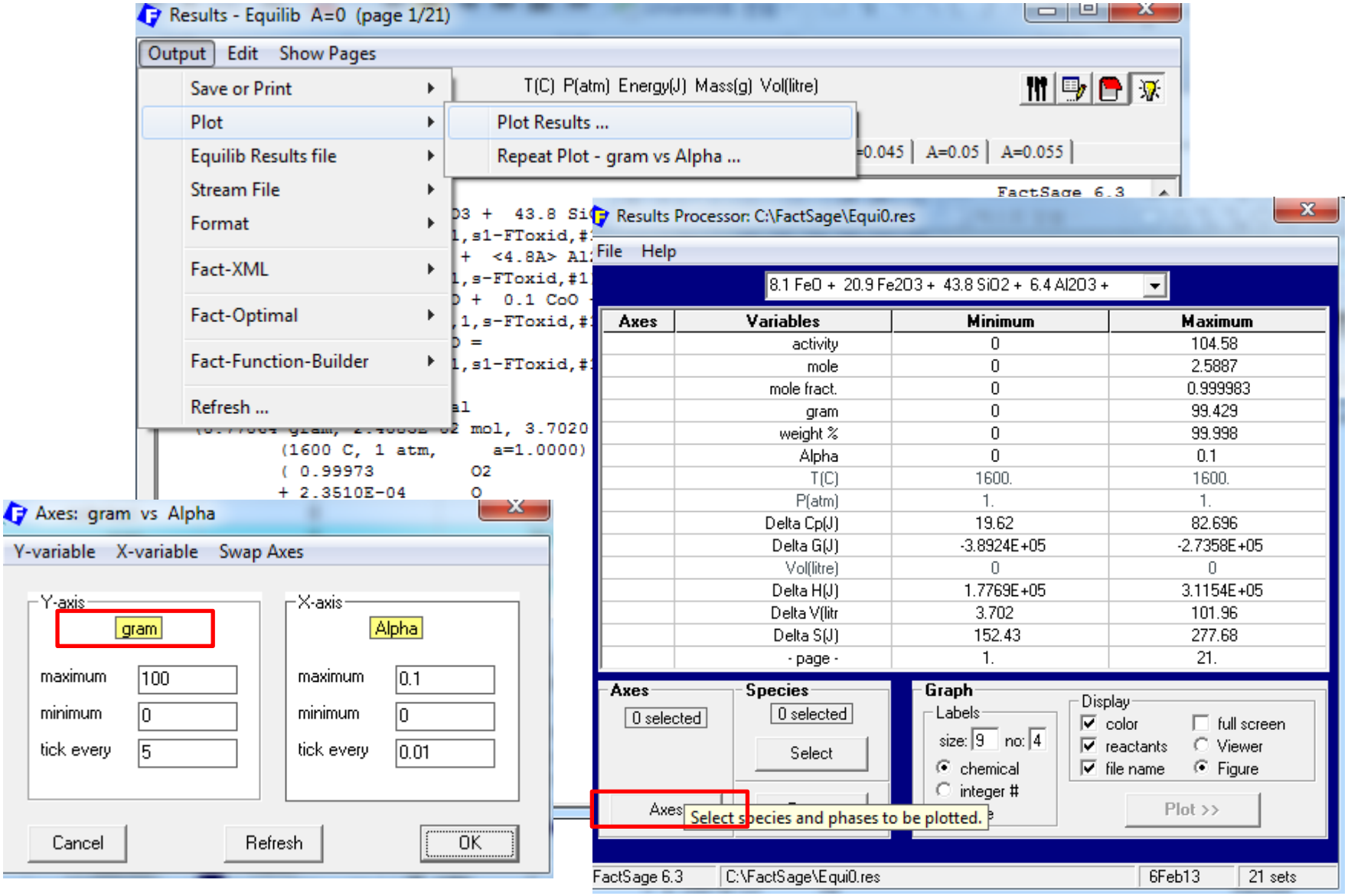


Effect of change of Char - Laterite + Char at 1600°C

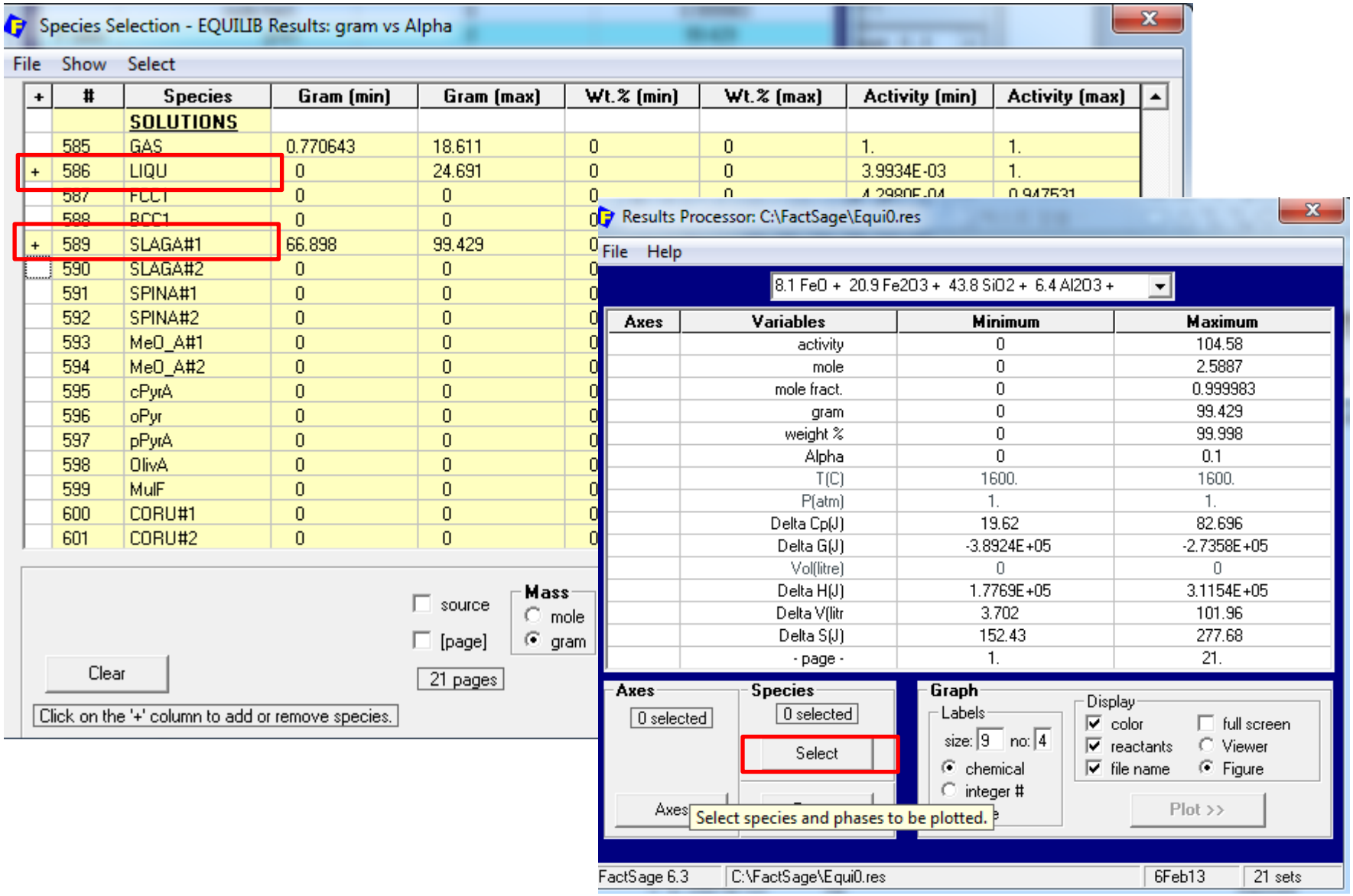


With addition of Change the contents of Ni dissolved in liquid iron decrease. If then, what are amounts of Fe-Ni and Slag after each process?

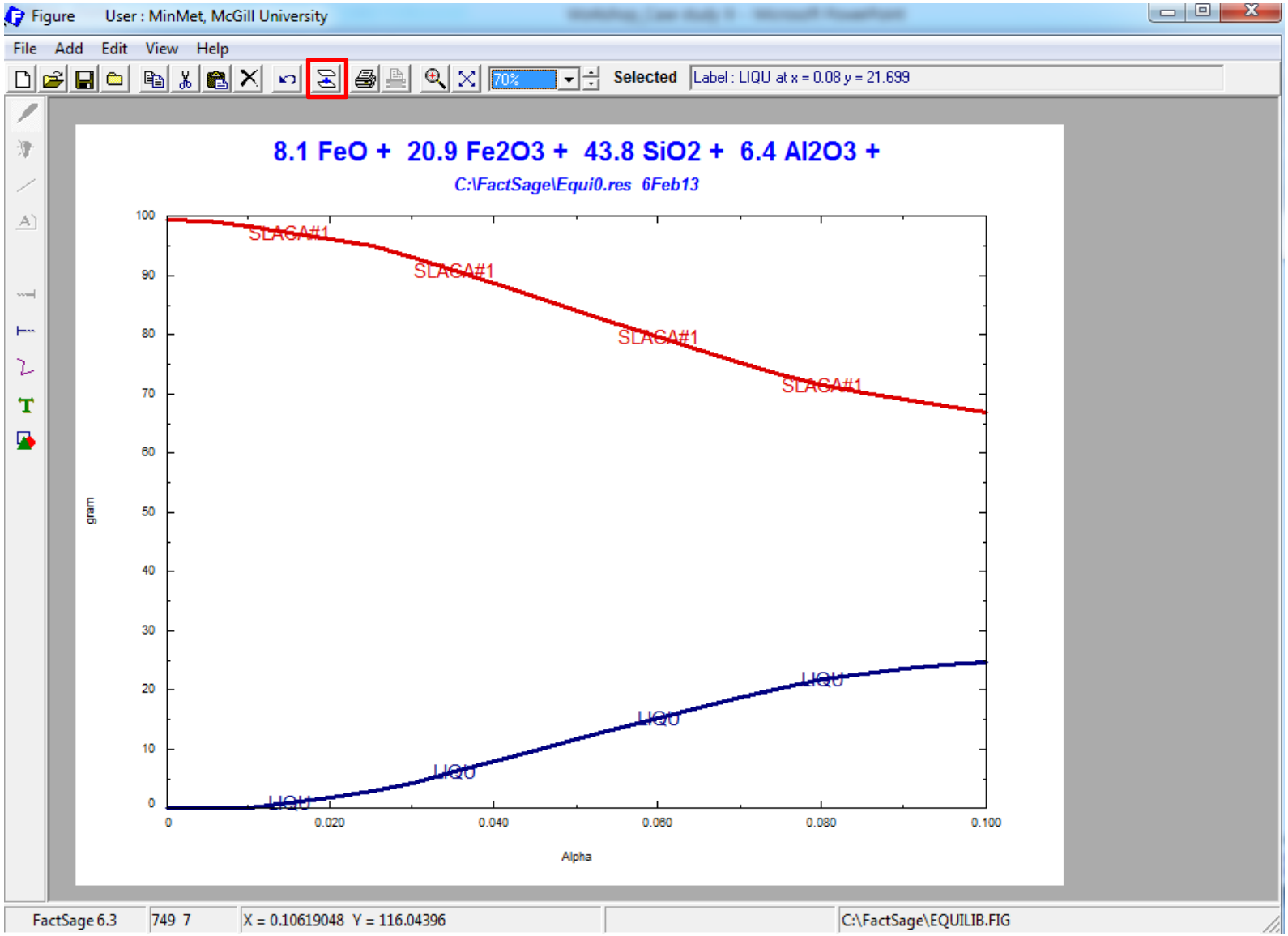
Effect of change of Char - Laterite + Char at 1600°C



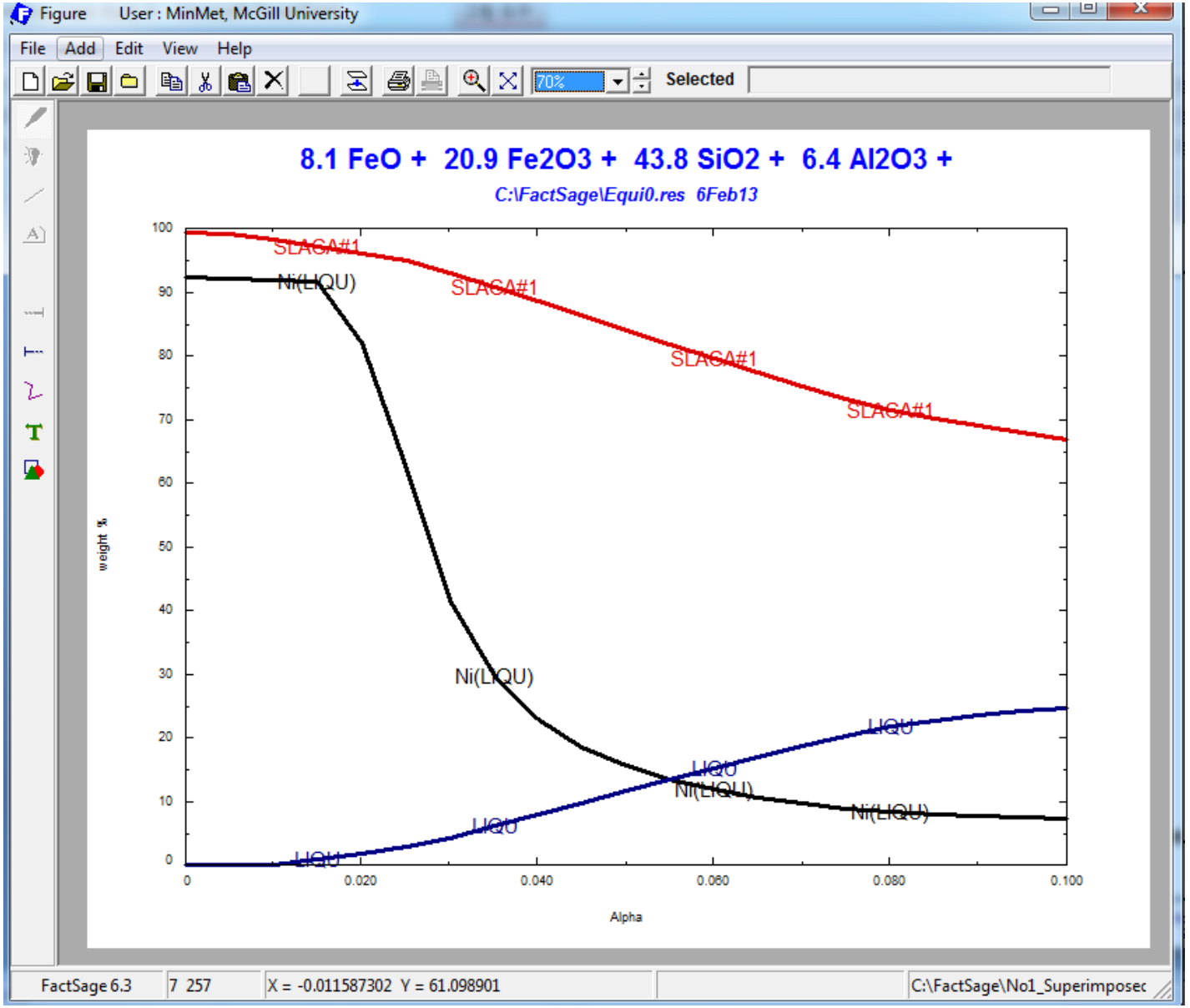
Effect of change of Char - Laterite + Char at 1600°C



Effect of change of Char - Laterite + Char at 1600°C



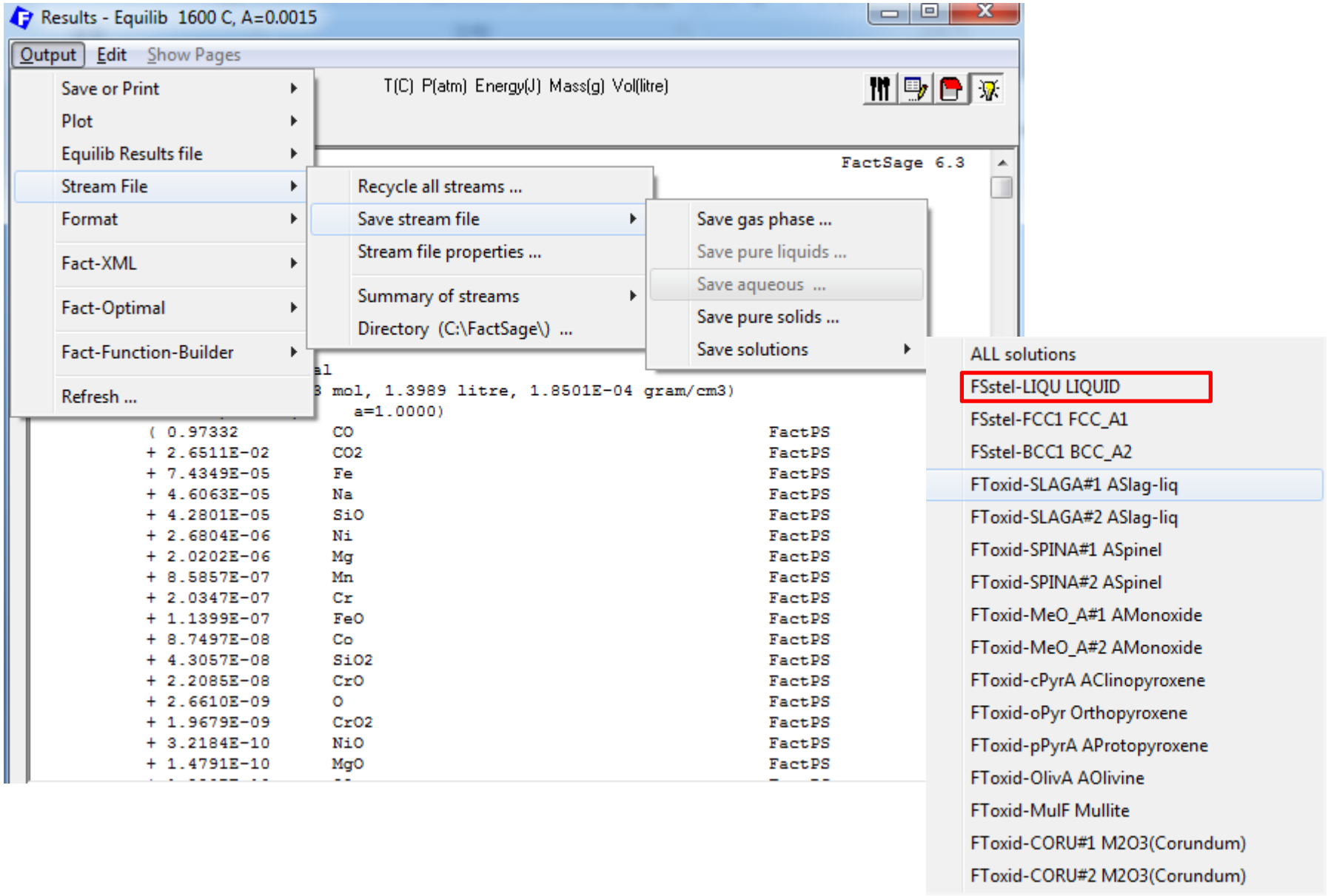
Effect of change of Char - Laterite + Char at 1600°C



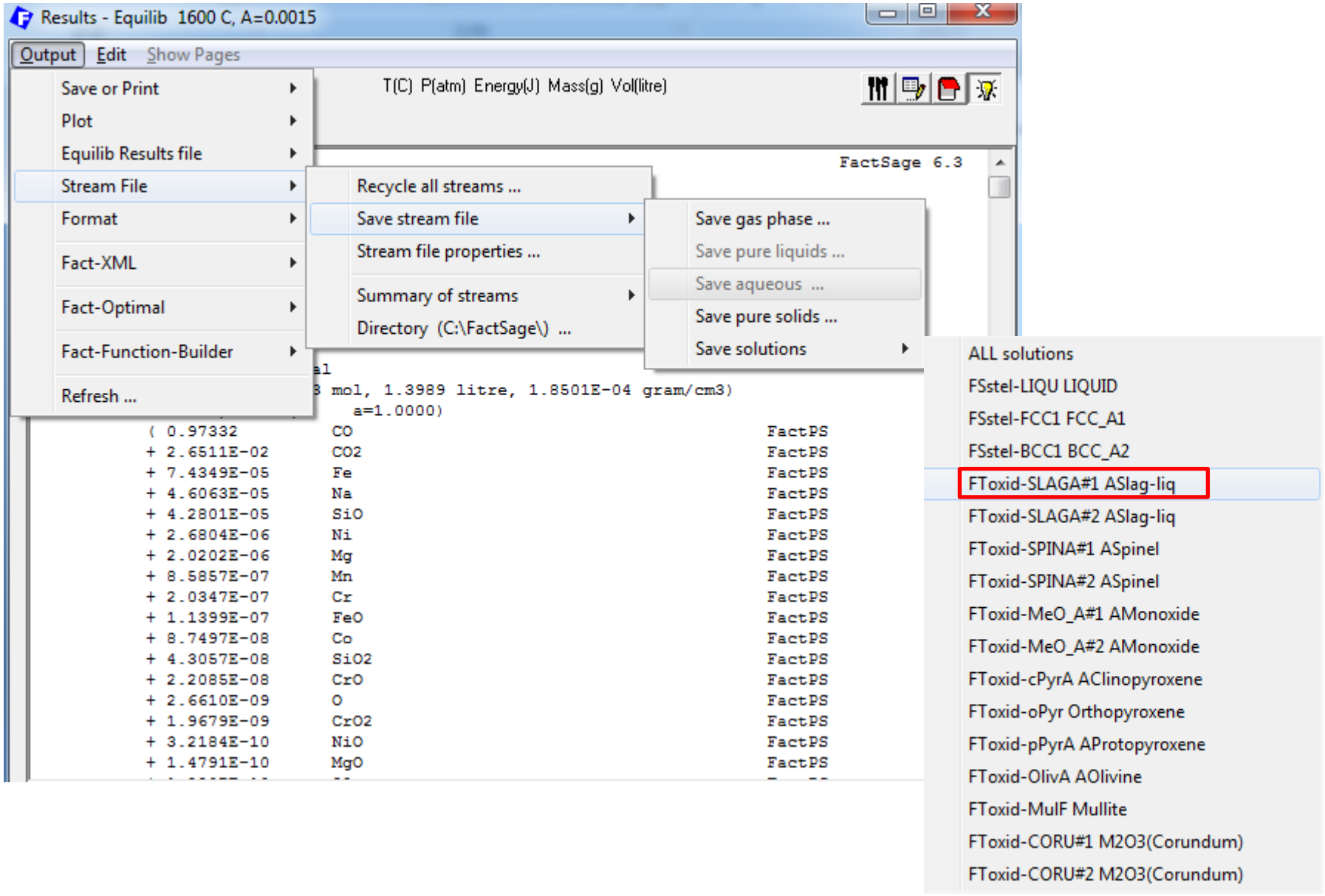
Determine the liquidus temperatures of slag and alloy (Fe-25wt% Ni)

Stream / Precipitate Target

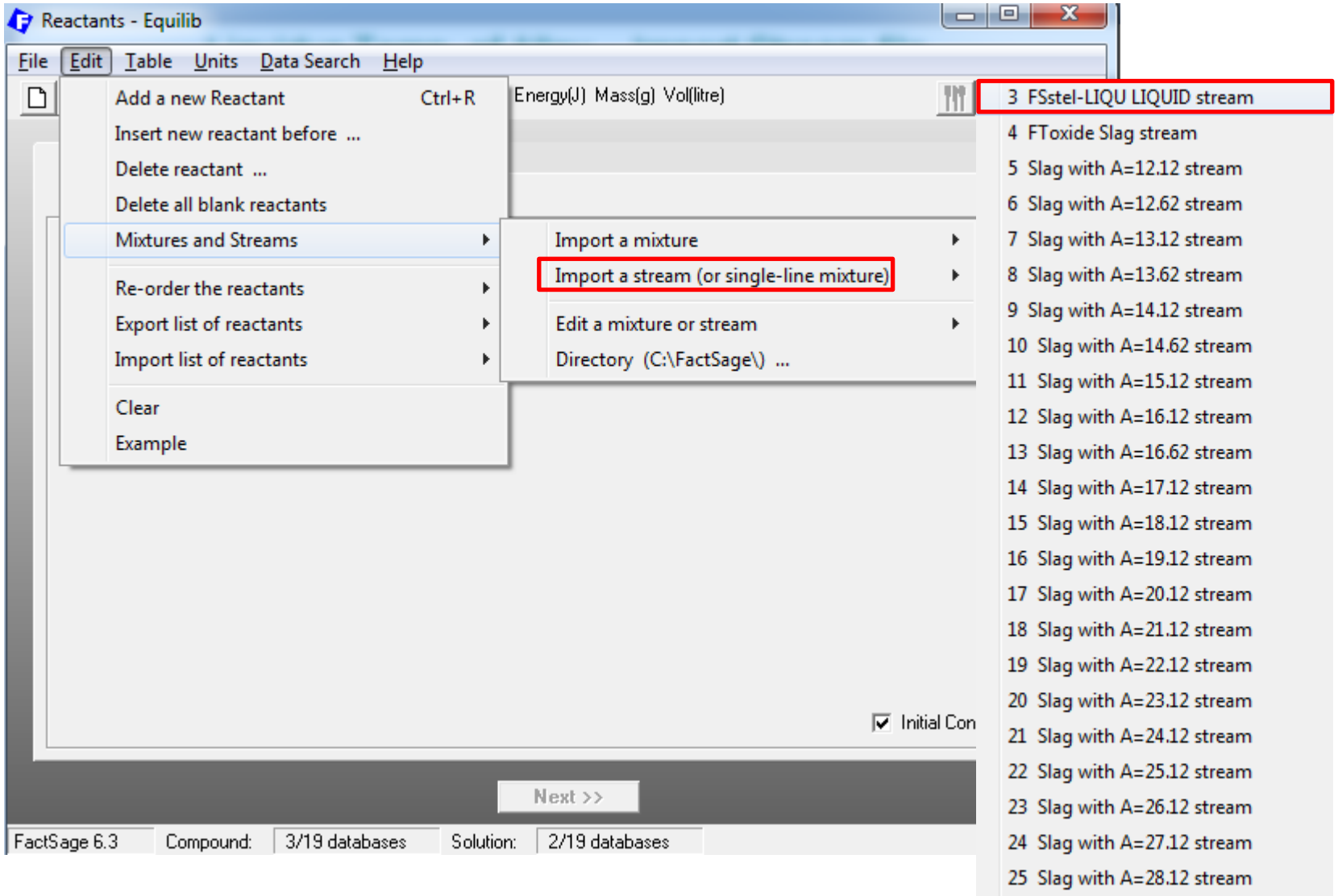
Liquidus Temp. of Alloy – Creating Stream file



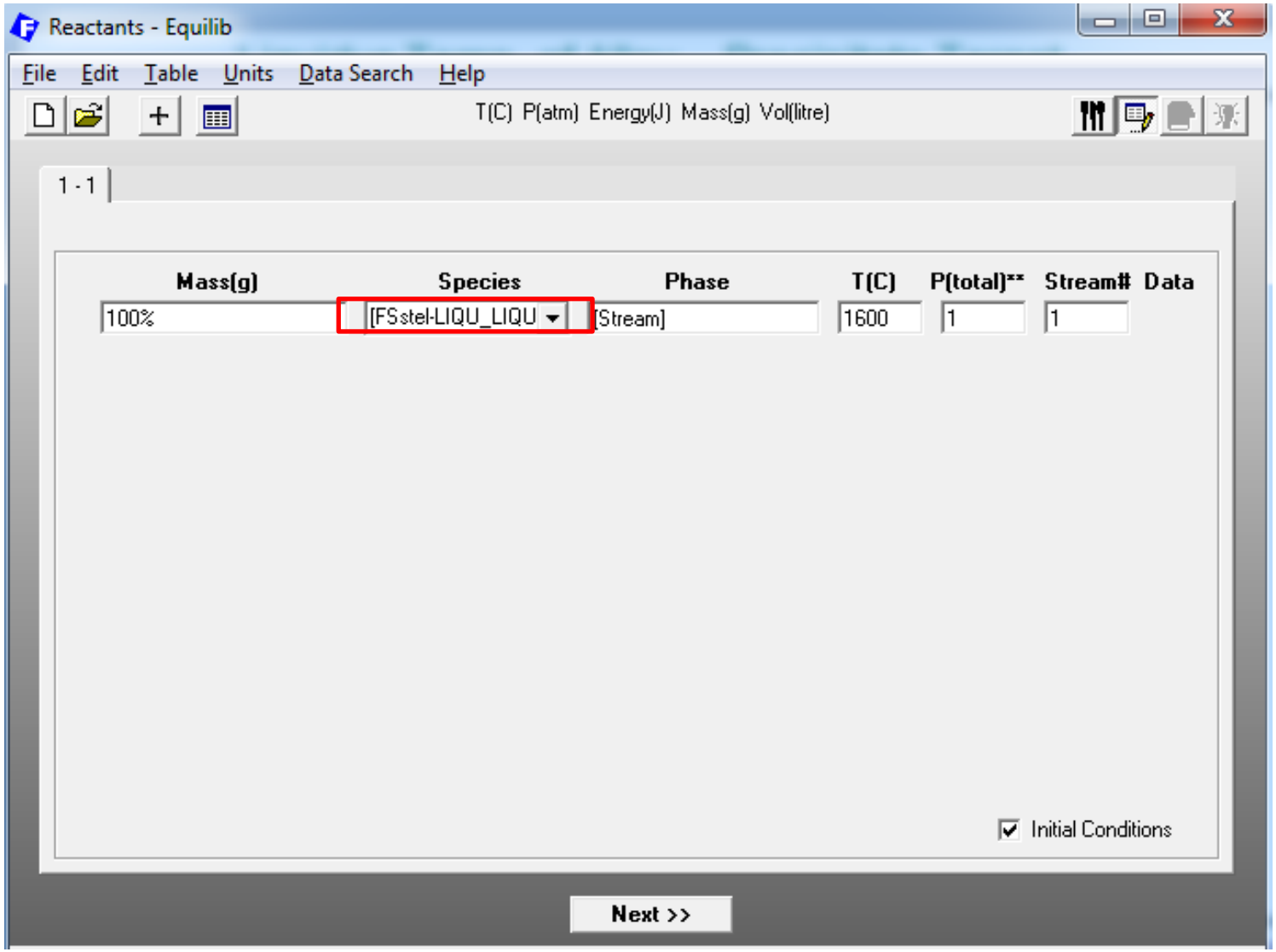
Liquidus Temp. of Slag – Creating Stream file



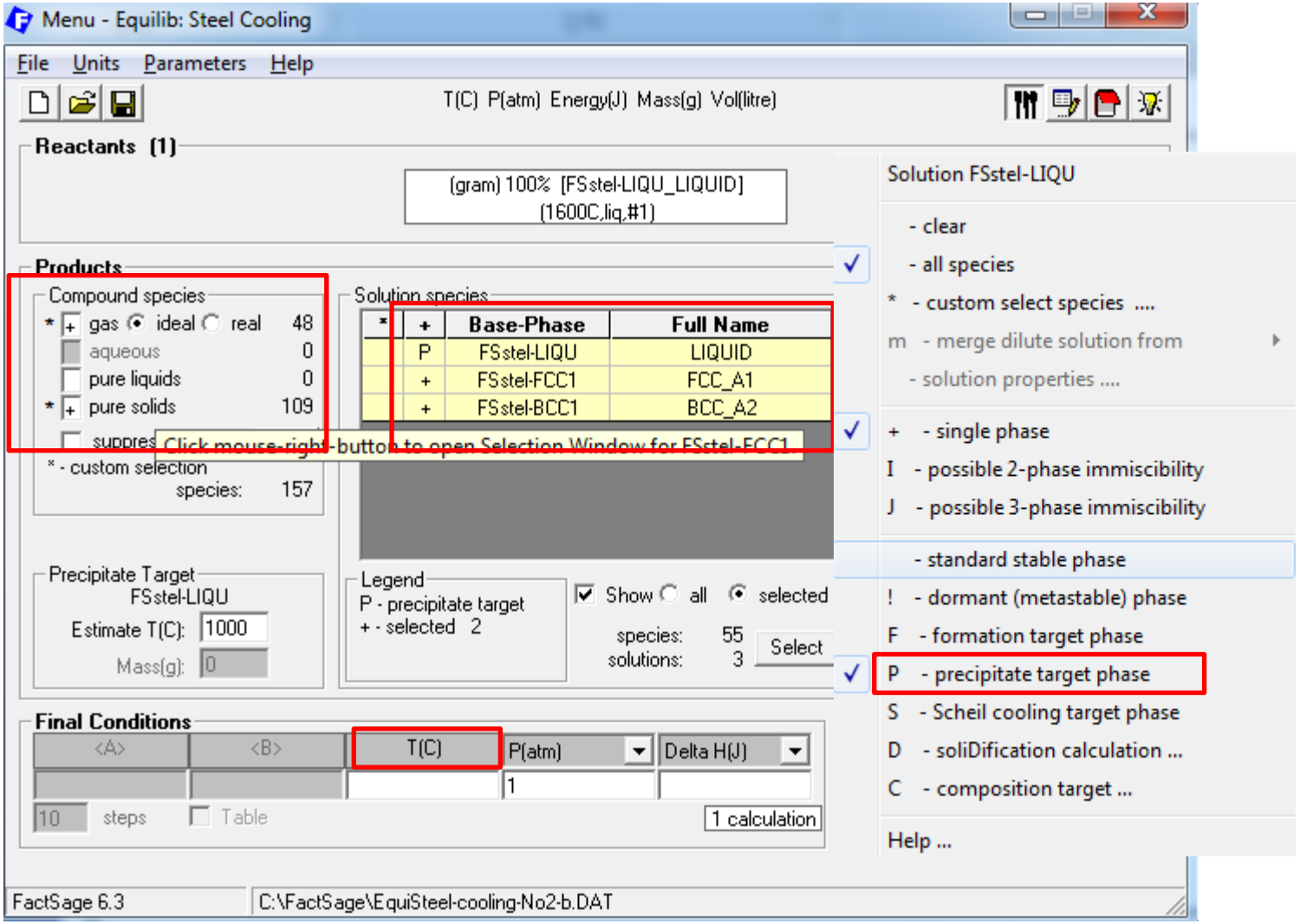
Liquidus Temp. of Alloy – Import Stream file



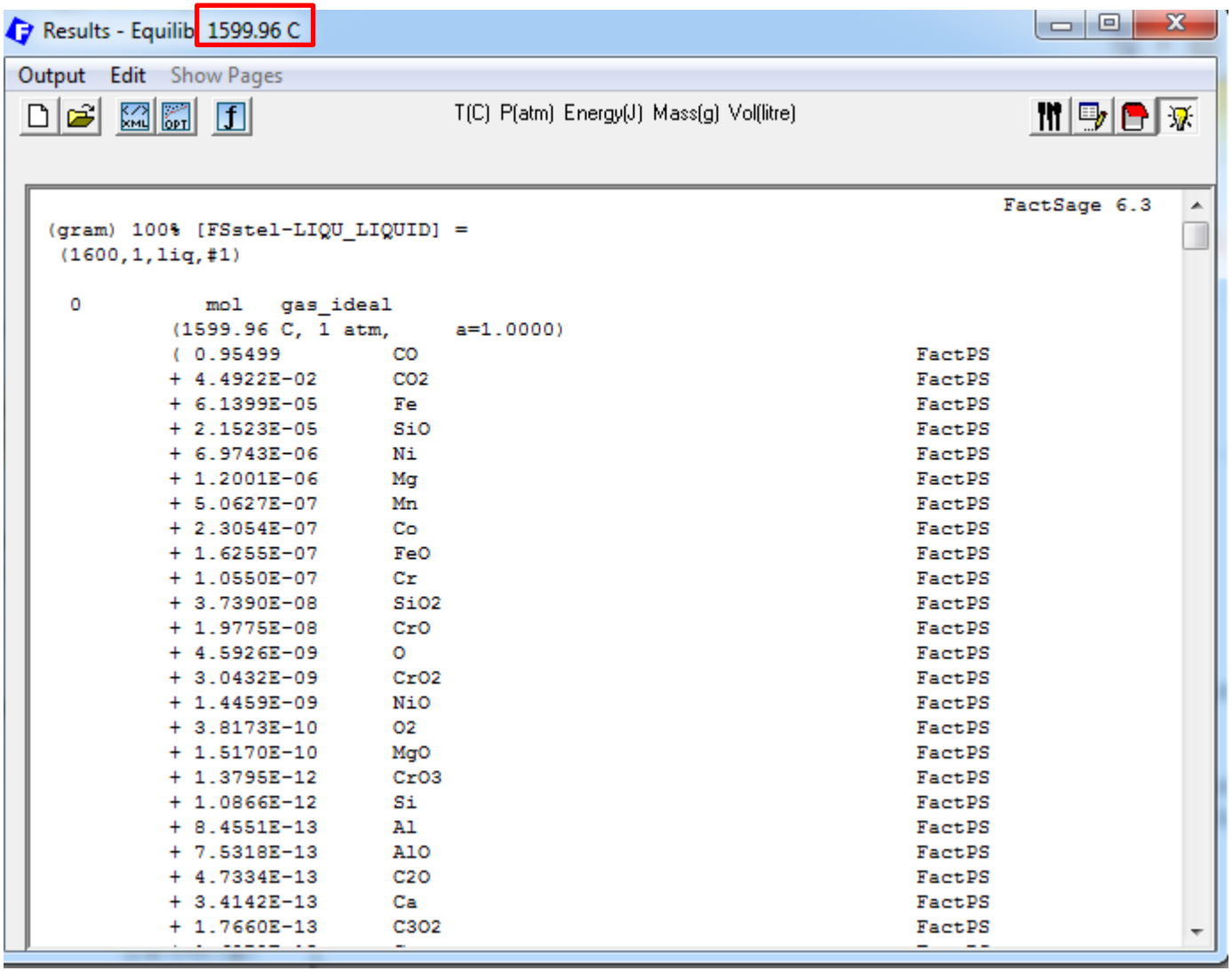
Liquidus Temp. of Alloy – Precipitate Target



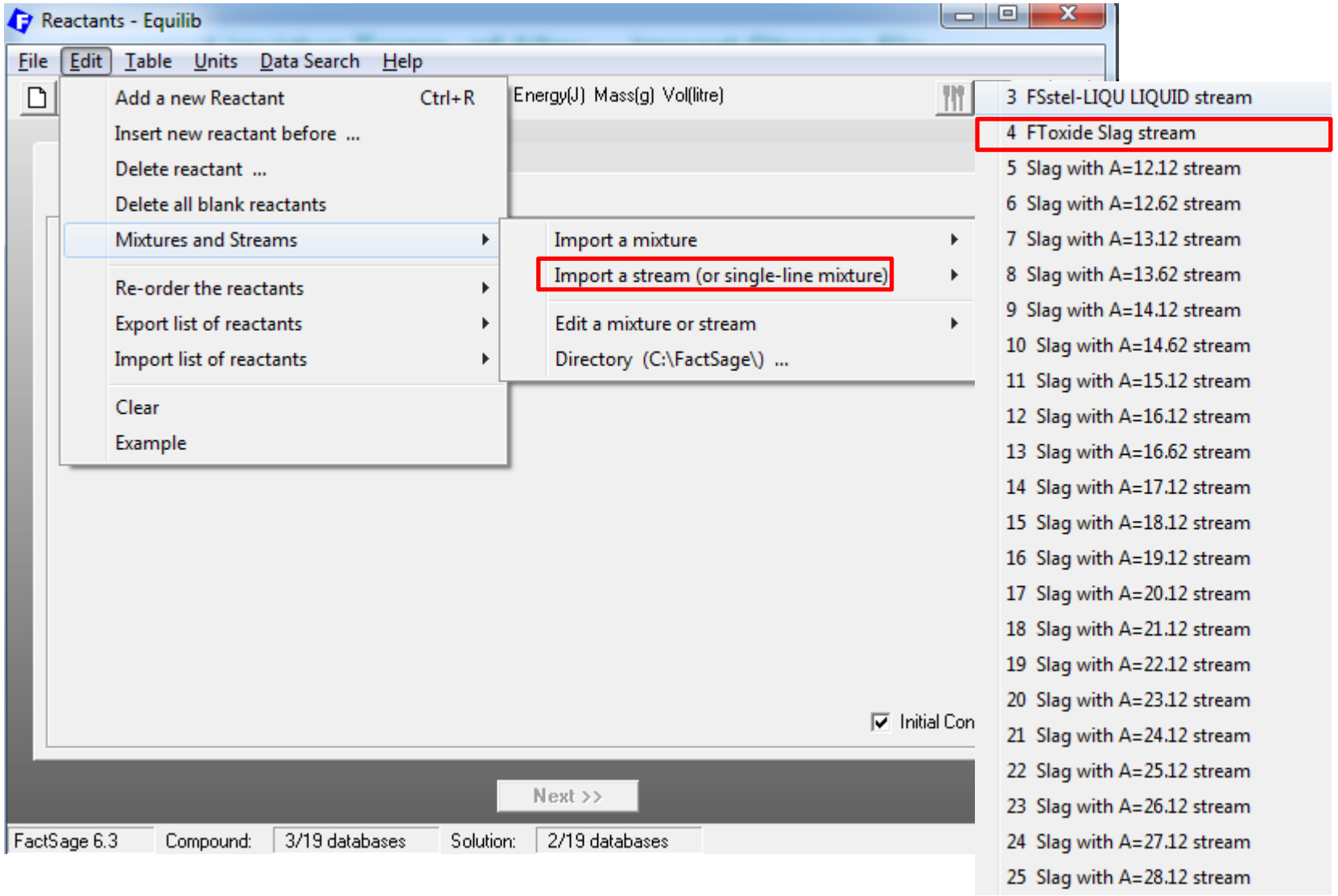
Liquidus Temp. of Alloy – Precipitate Target



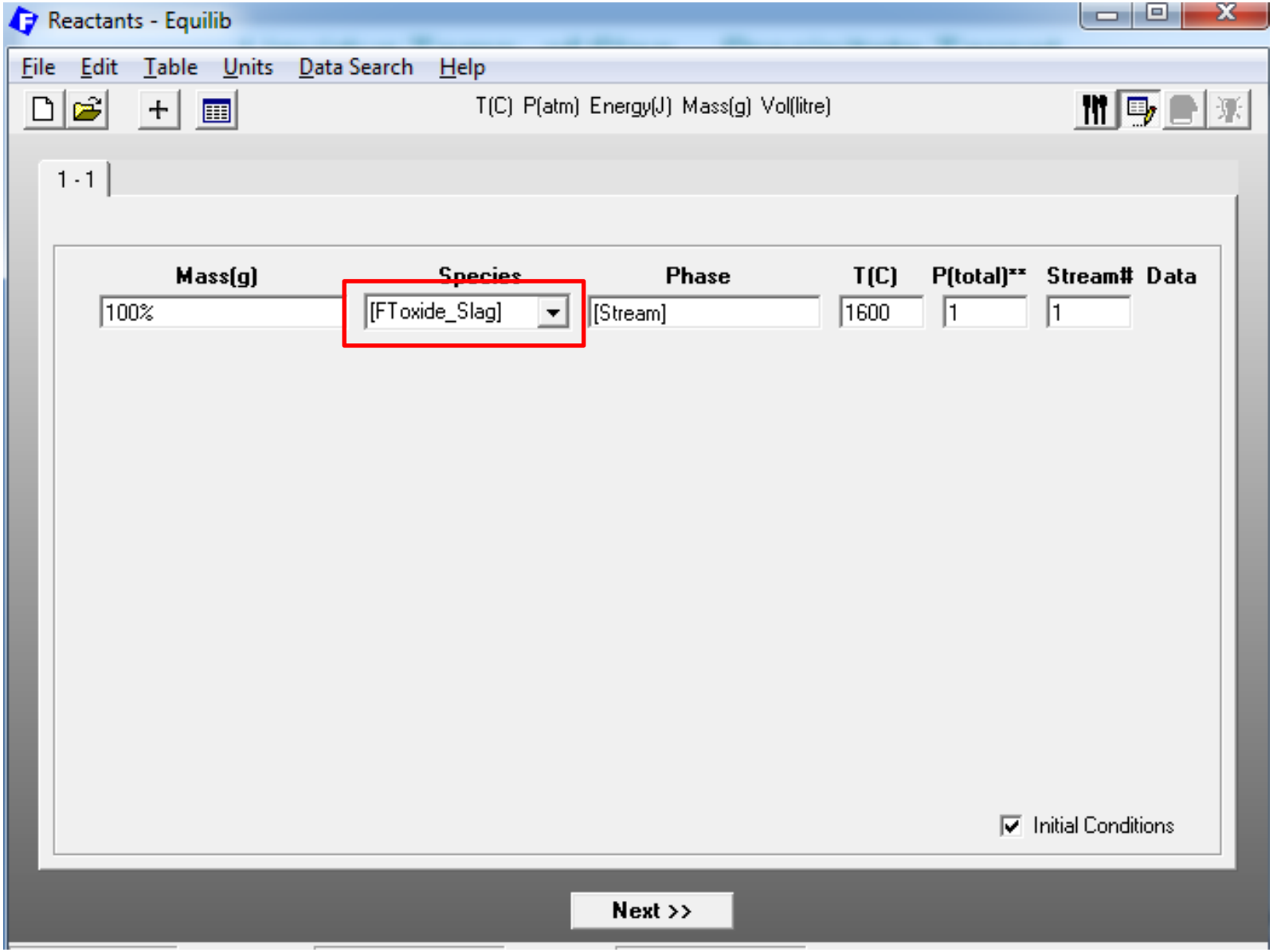
Liquidus Temp. of Alloy – Precipitate Target



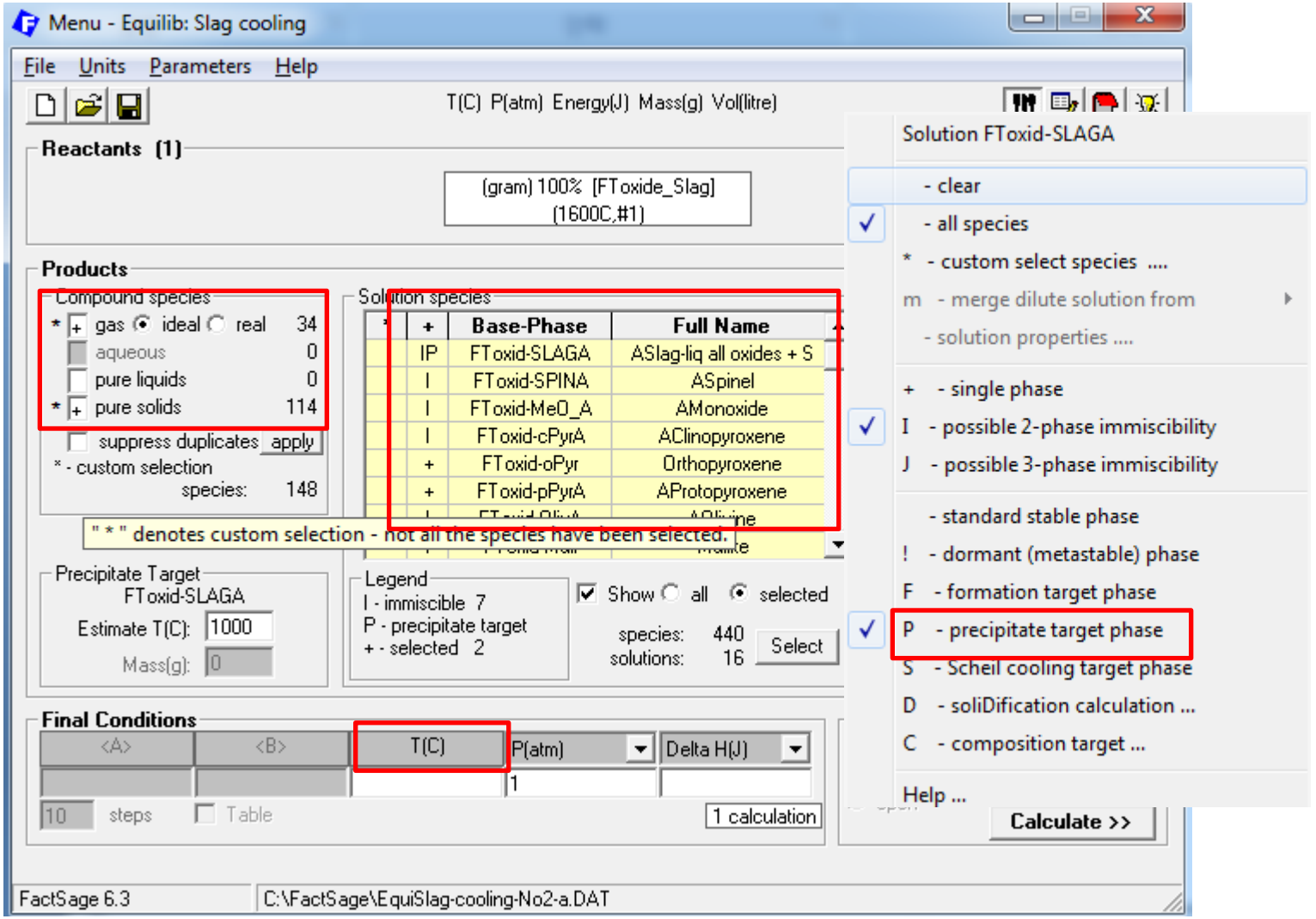
Liquidus Temp. of Slag – Import Stream file



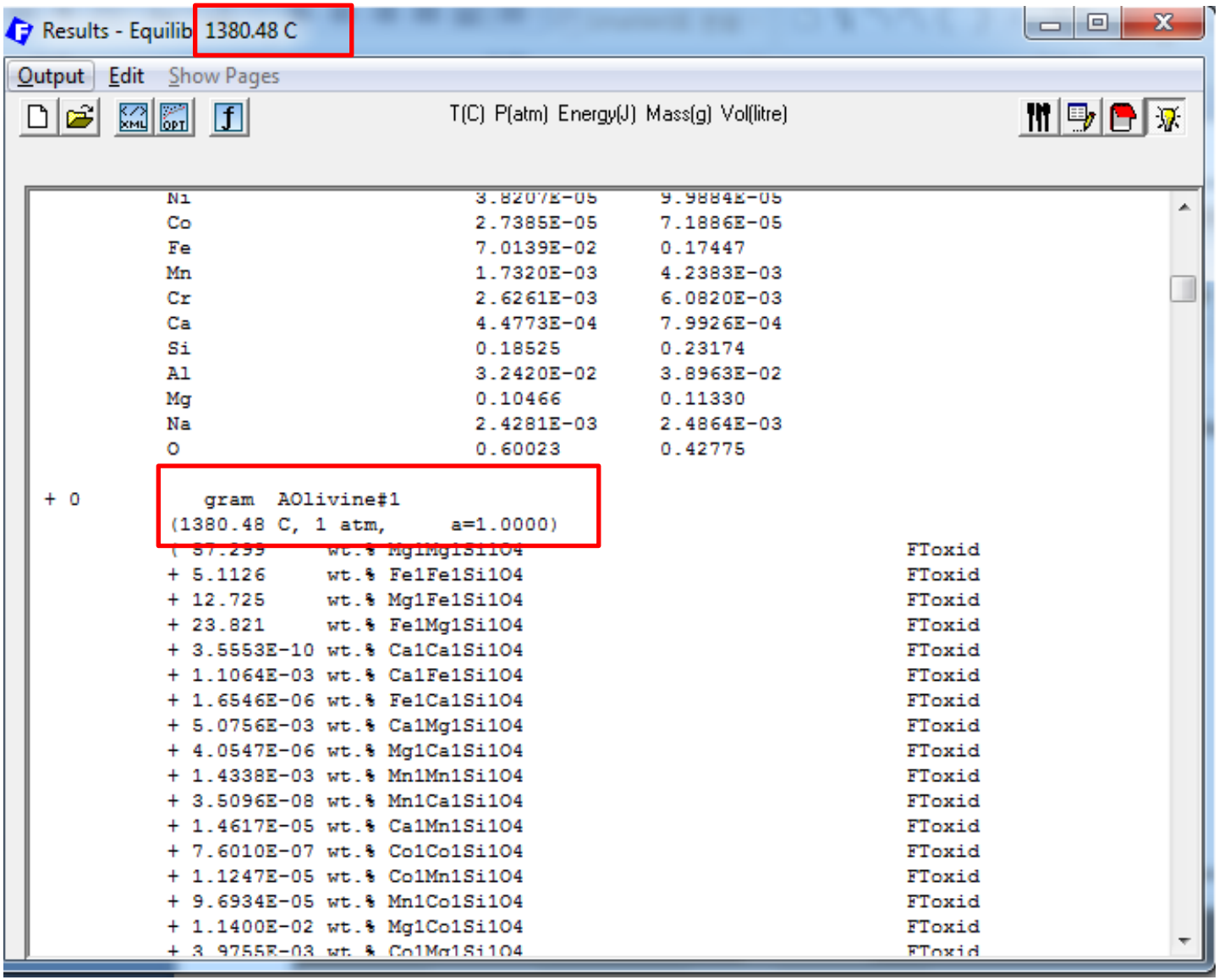
Liquidus Temp. of Slag – Precipitate Target



Liquidus Temp. of Slag – Precipitate Target



Liquidus Temp. of Slag – Precipitate Target

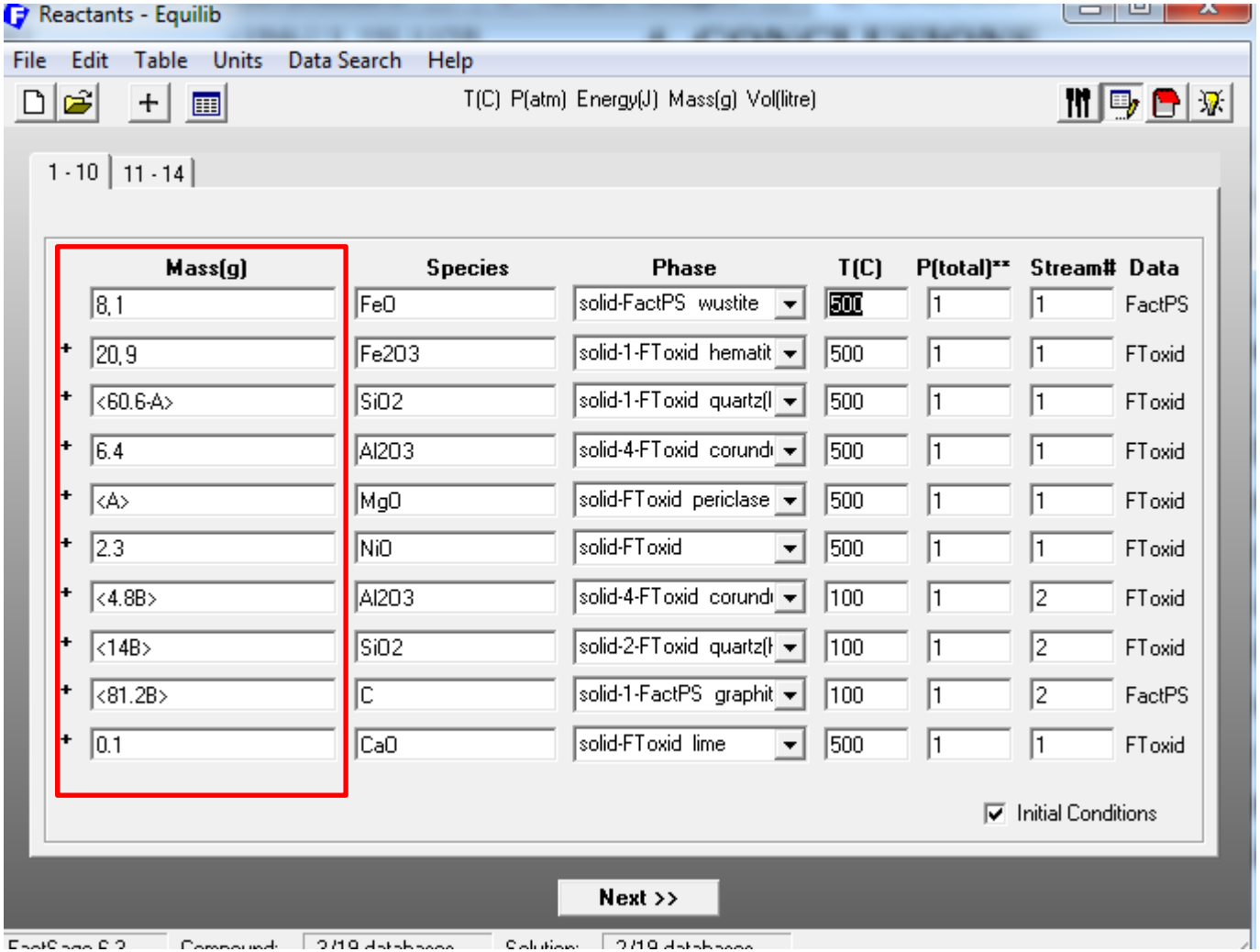


Show the impact of the SiO_2/MgO (in the range of 1 to 4) ratio on the liquidus temperature of the slag (Primary crystallization phase)

Stream / Precipitate Target

Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag

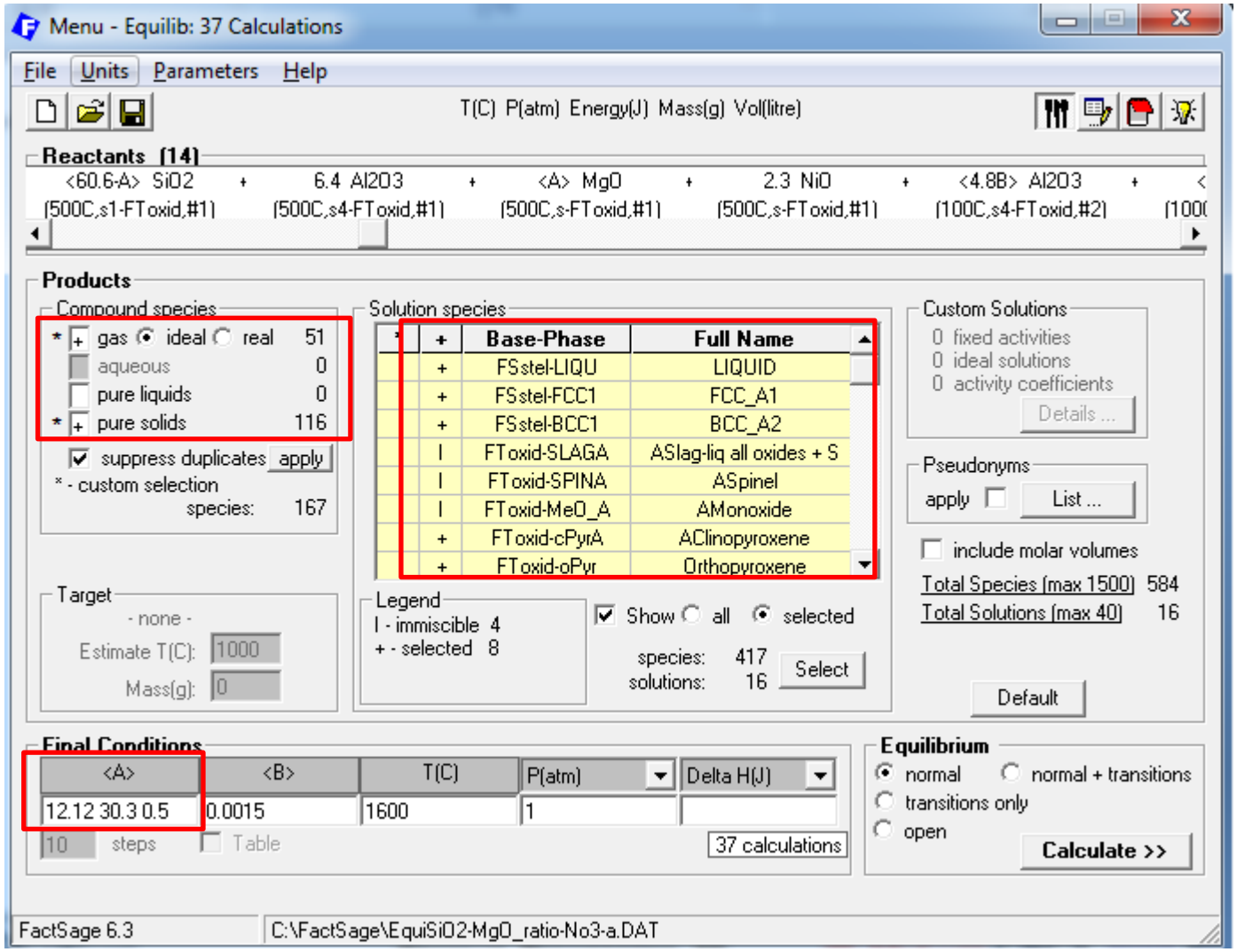
Addition of 0.381 kg of Char
with 1 tone of Laterite
SiO_2+MgO = 60.6 wt%



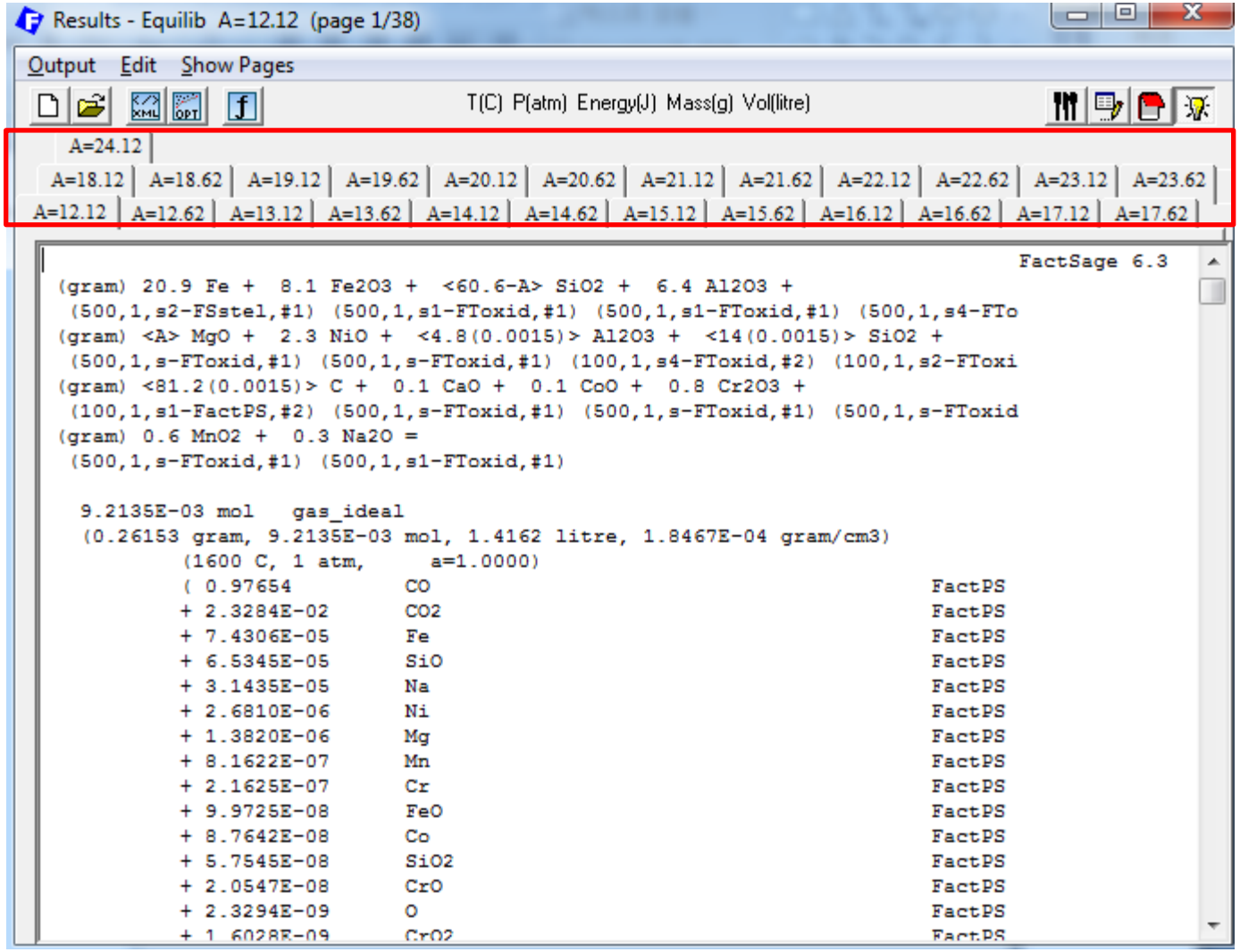
Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag

MgO = 12.12 to 30.3 wt%

SiO_2/MgO = 1 to 4 ratio

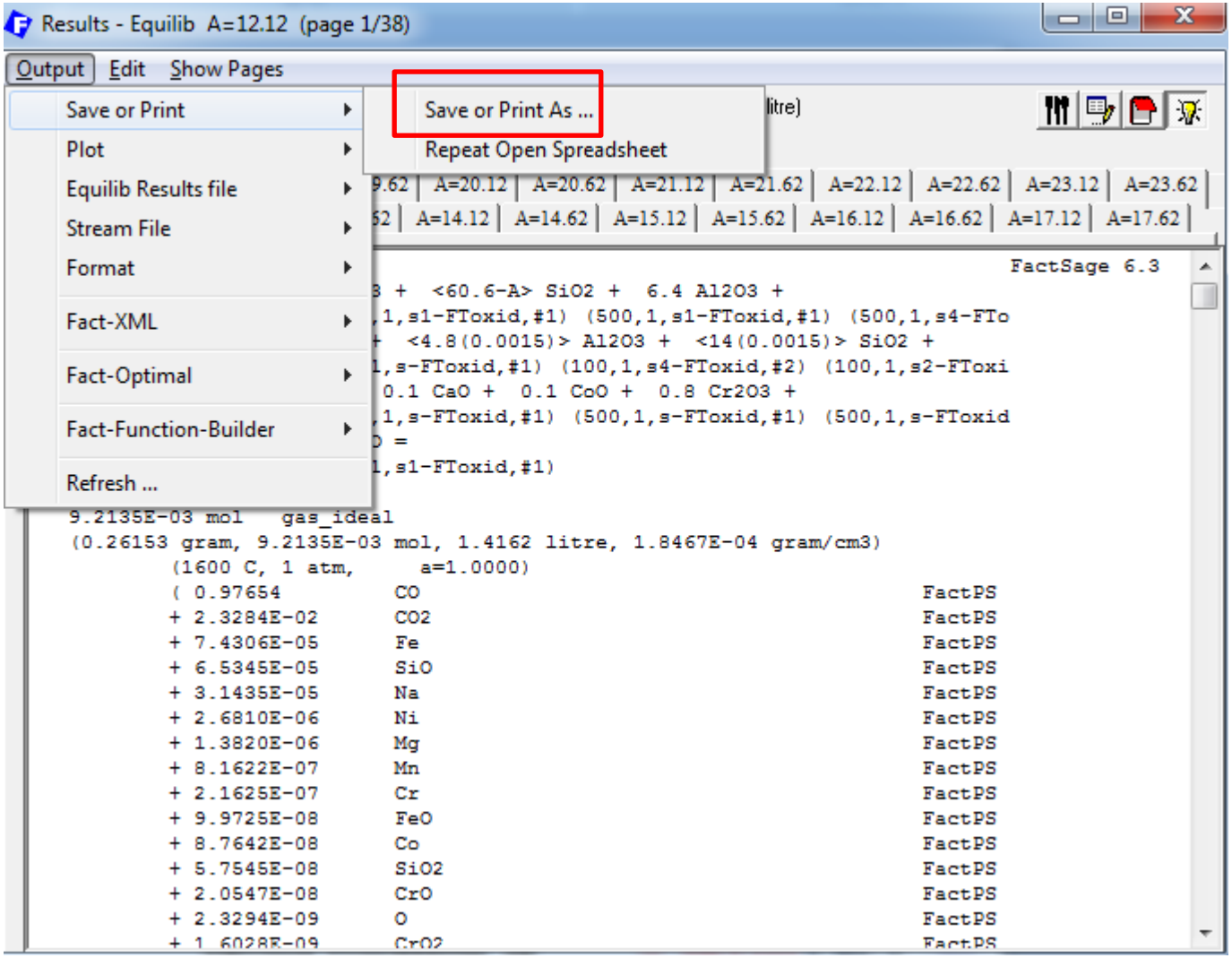


Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag



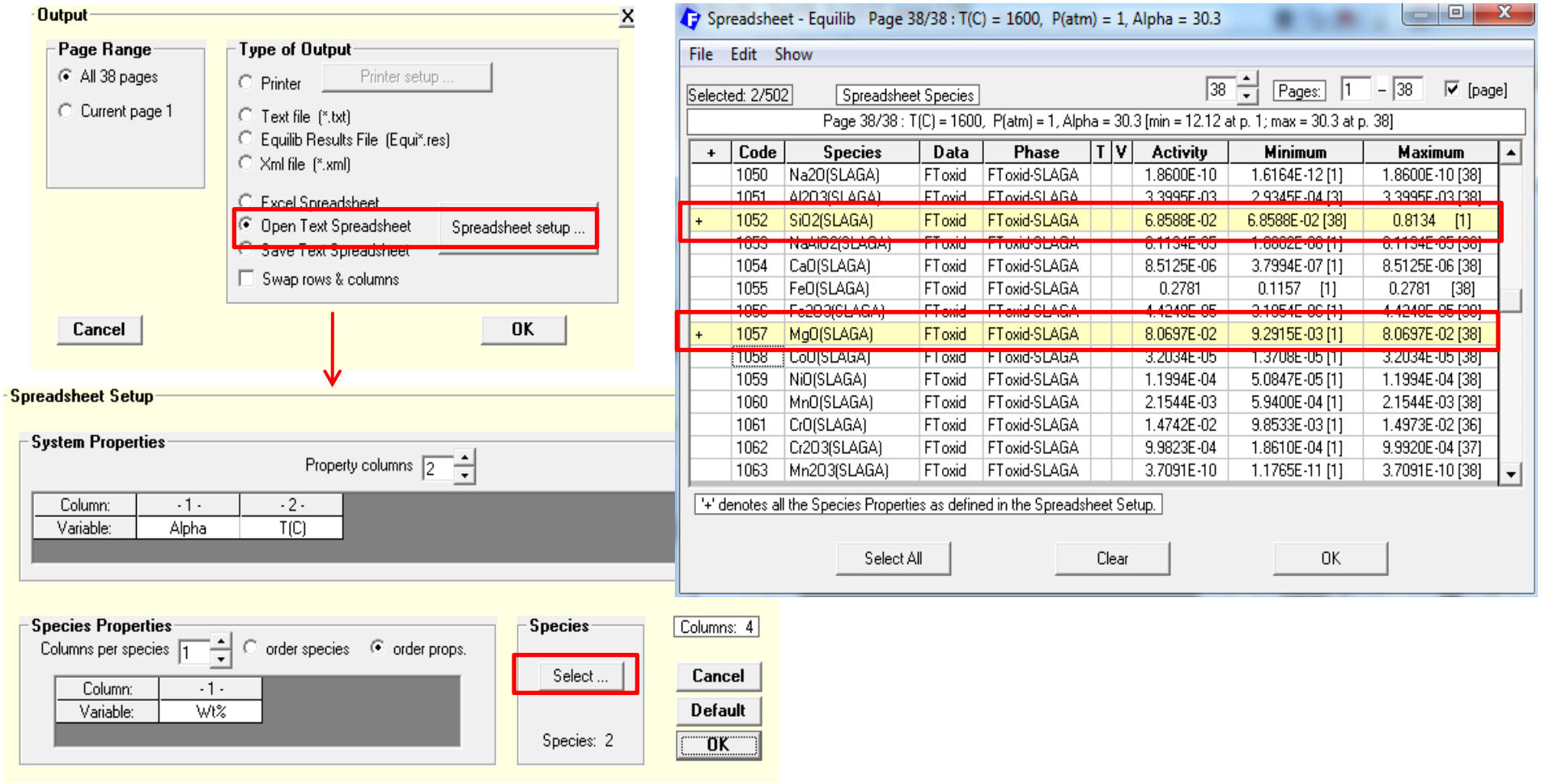
37 different Slags and Alloys are formed with change of SiO_2/MgO at 1600°C.

Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag



To export wt% of SiO_2 and MgO in Slag phase

Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag



Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag

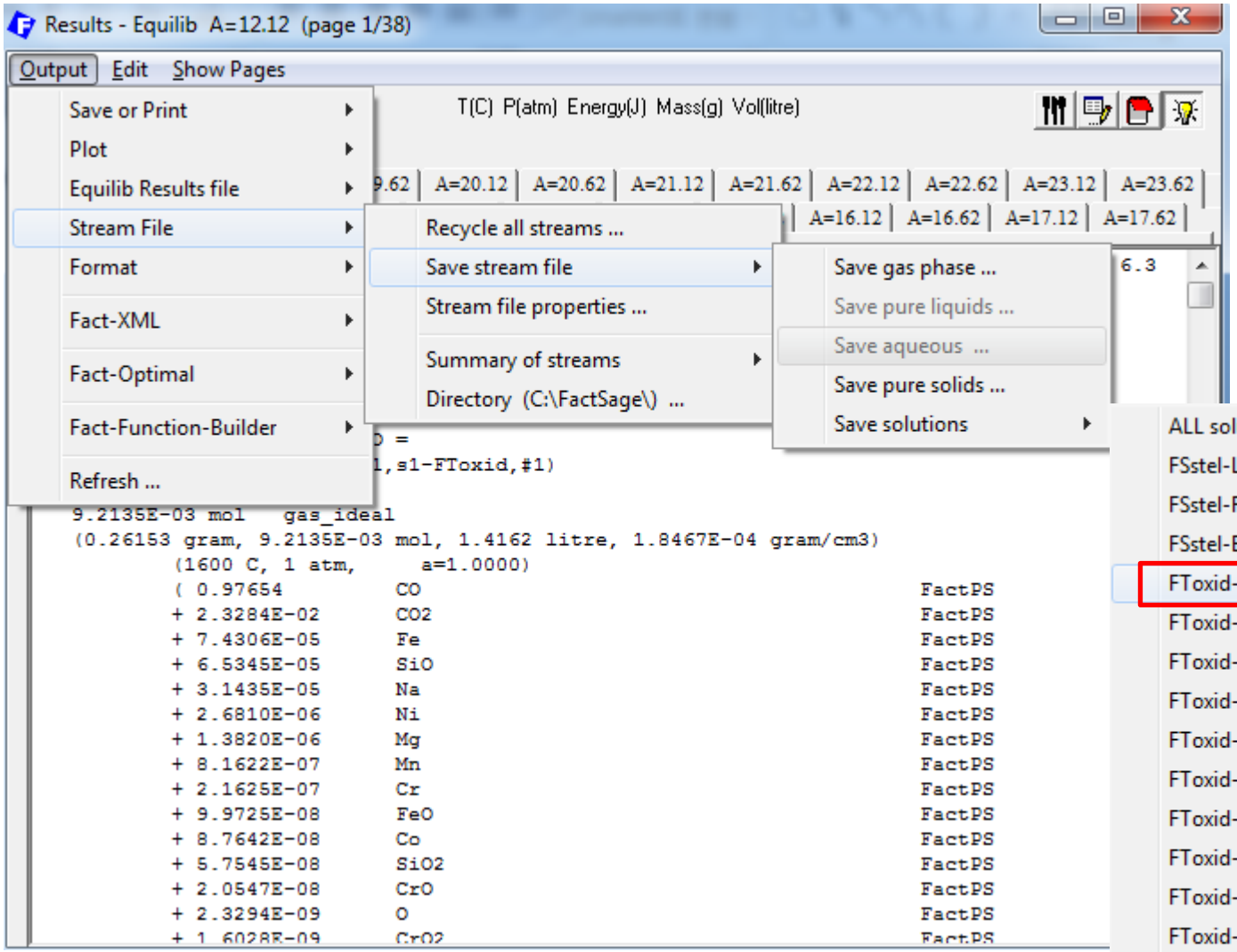
Equilib Results

File Edit Swap rows and columns

Alpha	T(C)	Wt%-SiO2(SLAGA#1)	Wt%-MgO(SLAGA#1)	Wt%-SiO2(SLAGA#2)	Wt%-MgO(SLAGA#2)
1.2120000E+01	1.6000000E+03	5.9104840E+01	1.4772695E+01	5.9104840E+01	1.4772695E+01
1.2620000E+01	1.6000000E+03	5.8497349E+01	1.5382513E+01	5.8497349E+01	1.5382513E+01
1.3120000E+01	1.6000000E+03	5.7889996E+01	1.5992402E+01	5.7889996E+01	1.5992402E+01
1.3620000E+01	1.6000000E+03	5.7282768E+01	1.6602366E+01	5.7282768E+01	1.6602366E+01
1.4120000E+01	1.6000000E+03	5.6675654E+01	1.7212408E+01	5.6675654E+01	1.7212408E+01
1.4620000E+01	1.6000000E+03	5.6068642E+01	1.7822534E+01	5.6068642E+01	1.7822534E+01
1.5120000E+01	1.6000000E+03	5.5461721E+01	1.8432746E+01	5.5461721E+01	1.8432746E+01
1.5620000E+01	1.6000000E+03	5.4854884E+01	1.9043049E+01	5.4854884E+01	1.9043049E+01
1.6120000E+01	1.6000000E+03	5.4248124E+01	1.9653448E+01	5.4248124E+01	1.9653448E+01
1.6620000E+01	1.6000000E+03	5.3641436E+01	2.0263948E+01	5.3641436E+01	2.0263948E+01
1.7120000E+01	1.6000000E+03	5.3034815E+01	2.0874555E+01	5.3034815E+01	2.0874555E+01
1.7620000E+01	1.6000000E+03	5.2428259E+01	2.1485276E+01	5.2428259E+01	2.1485276E+01
1.8120000E+01	1.6000000E+03	5.1821769E+01	2.2096119E+01	5.1821769E+01	2.2096119E+01
1.8620000E+01	1.6000000E+03	5.1215345E+01	2.2707092E+01	5.1215345E+01	2.2707092E+01
1.9120000E+01	1.6000000E+03	5.0608990E+01	2.3318205E+01	5.0608990E+01	2.3318205E+01
1.9620000E+01	1.6000000E+03	5.0002708E+01	2.3929470E+01	5.0002708E+01	2.3929470E+01
2.0120000E+01	1.6000000E+03	4.9396507E+01	2.4540898E+01	4.9396507E+01	2.4540898E+01
2.0620000E+01	1.6000000E+03	4.8790393E+01	2.5152504E+01	4.8790393E+01	2.5152504E+01
2.1120000E+01	1.6000000E+03	4.8184375E+01	2.5764304E+01	4.8184375E+01	2.5764304E+01
2.1620000E+01	1.6000000E+03	4.7578465E+01	2.6376315E+01	4.7578465E+01	2.6376315E+01
2.2120000E+01	1.6000000E+03	4.6972673E+01	2.6988559E+01	4.6972673E+01	2.6988559E+01
2.2620000E+01	1.6000000E+03	4.6367012E+01	2.7601056E+01	4.6367012E+01	2.7601056E+01
2.3120000E+01	1.6000000E+03	4.5761495E+01	2.8213831E+01	4.5761495E+01	2.8213831E+01
2.3620000E+01	1.6000000E+03	4.5156135E+01	2.8826909E+01	4.5156135E+01	2.8826909E+01
2.4120000E+01	1.6000000E+03	4.4550942E+01	2.9440317E+01	4.4550942E+01	2.9440317E+01

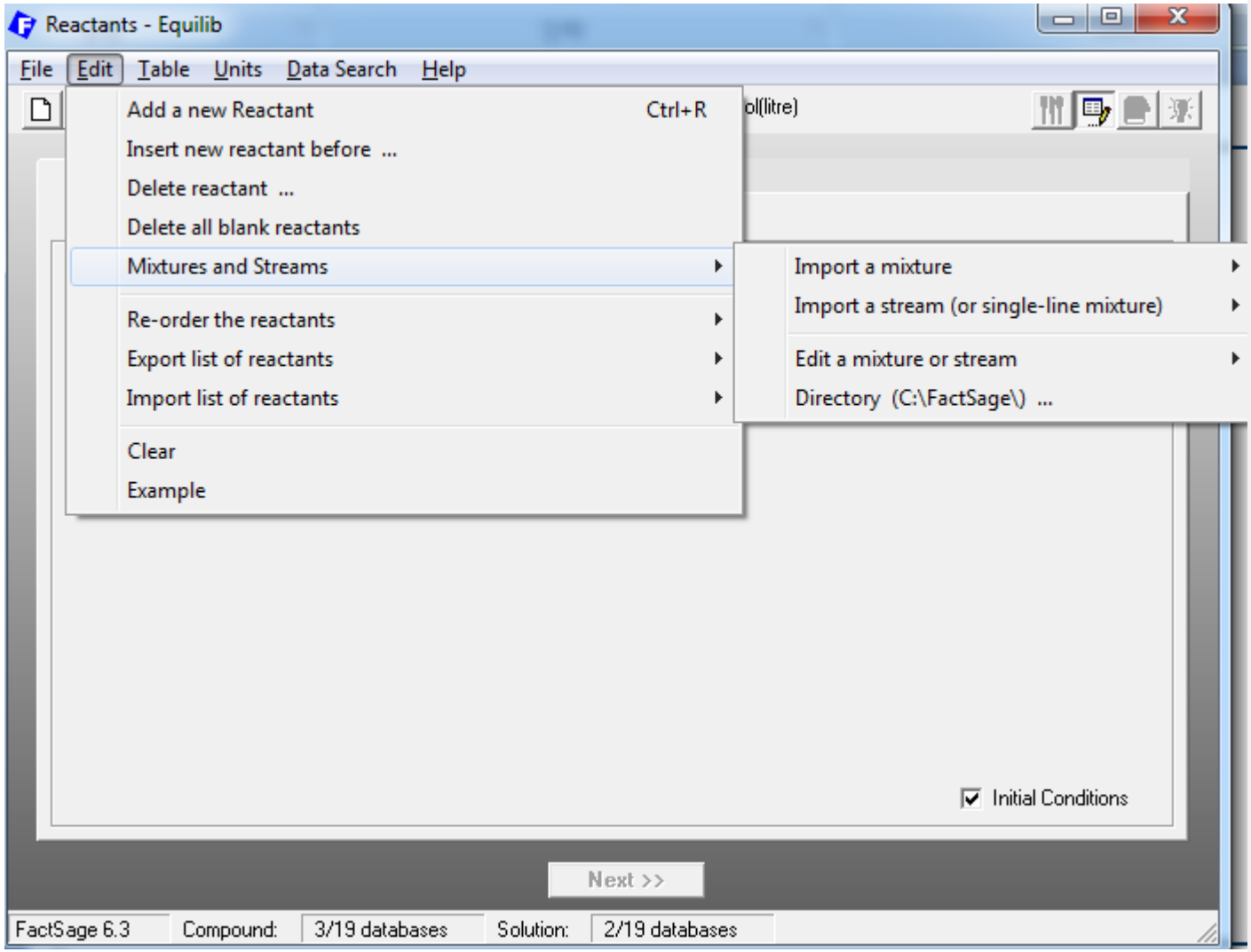
Copy and paste in Excel file and then, you can calculate the ratio of SiO_2/MgO in Slag
Impossible to draw as a function of SiO_2/MgO in FactSage

Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag



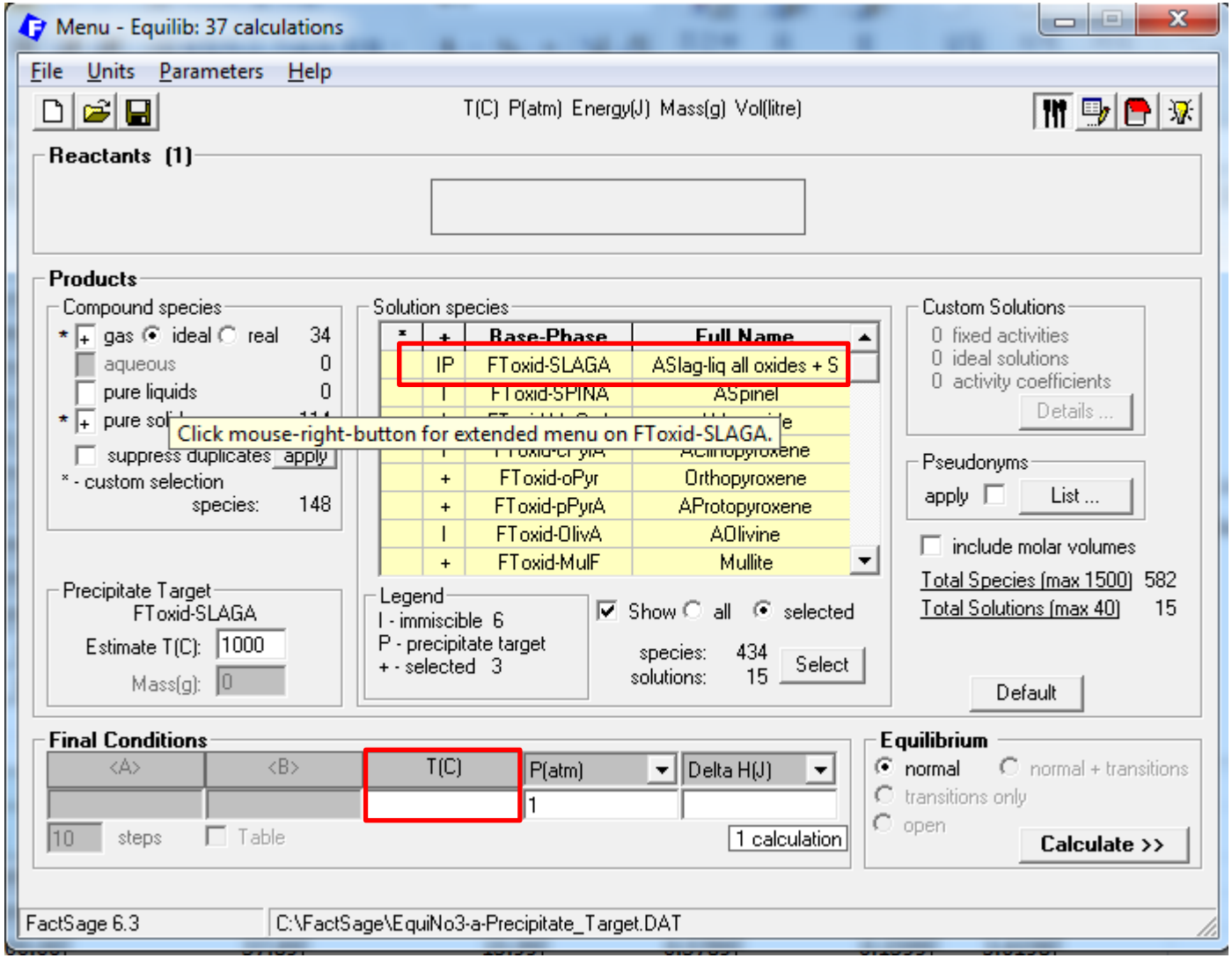
Create 37 stream files for Slag phases

Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag

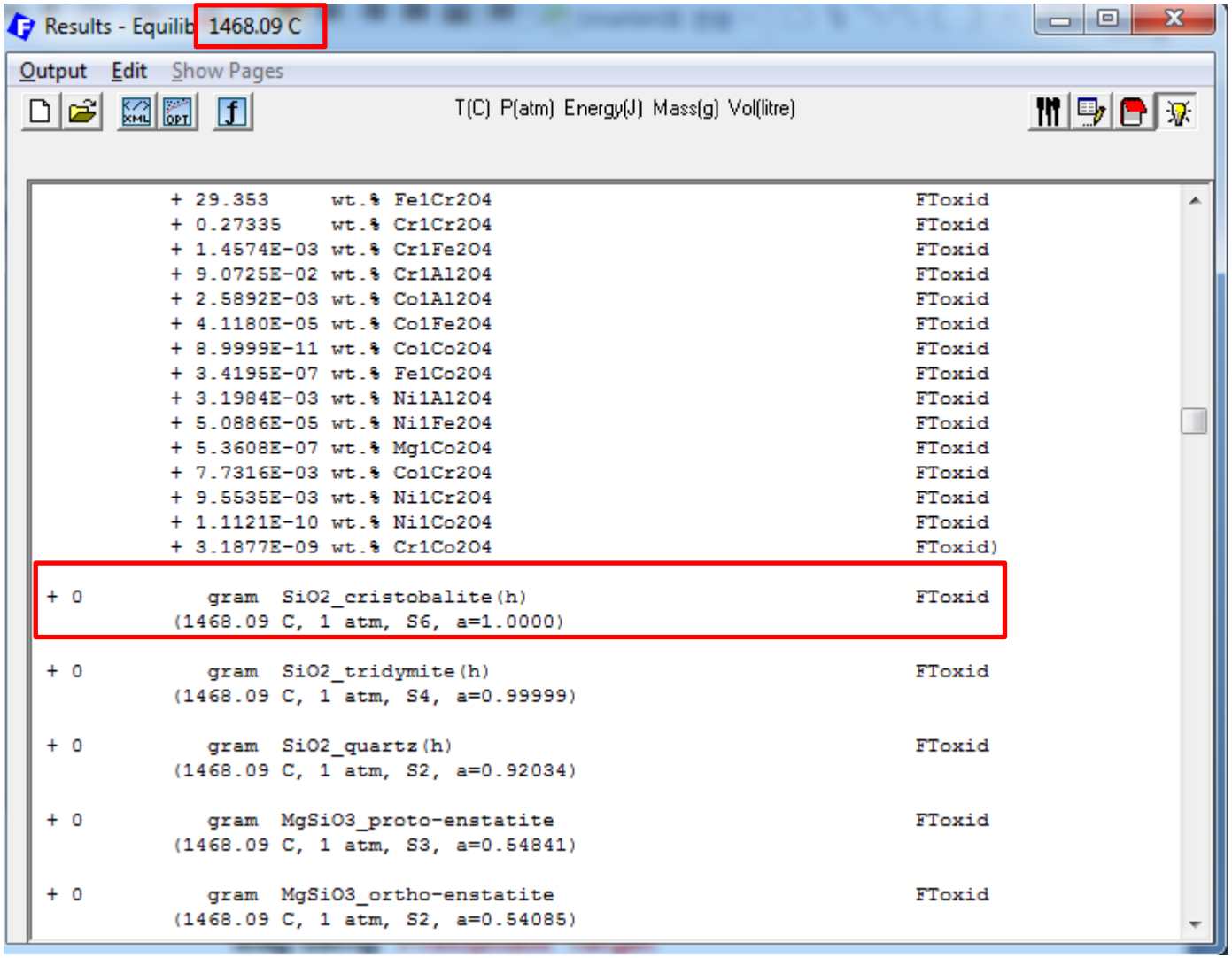


Select each stream and calculate liquidus temp. using '<u>Precipitate Target</u>'

Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag



Effect of SiO_2/MgO ratio of Laterite on Liqudus Temp. of Slag



Primary crystallization phase is SiO_2 (cristobalite)

Using Macro function, this kind of calculation can be carried out automatically.

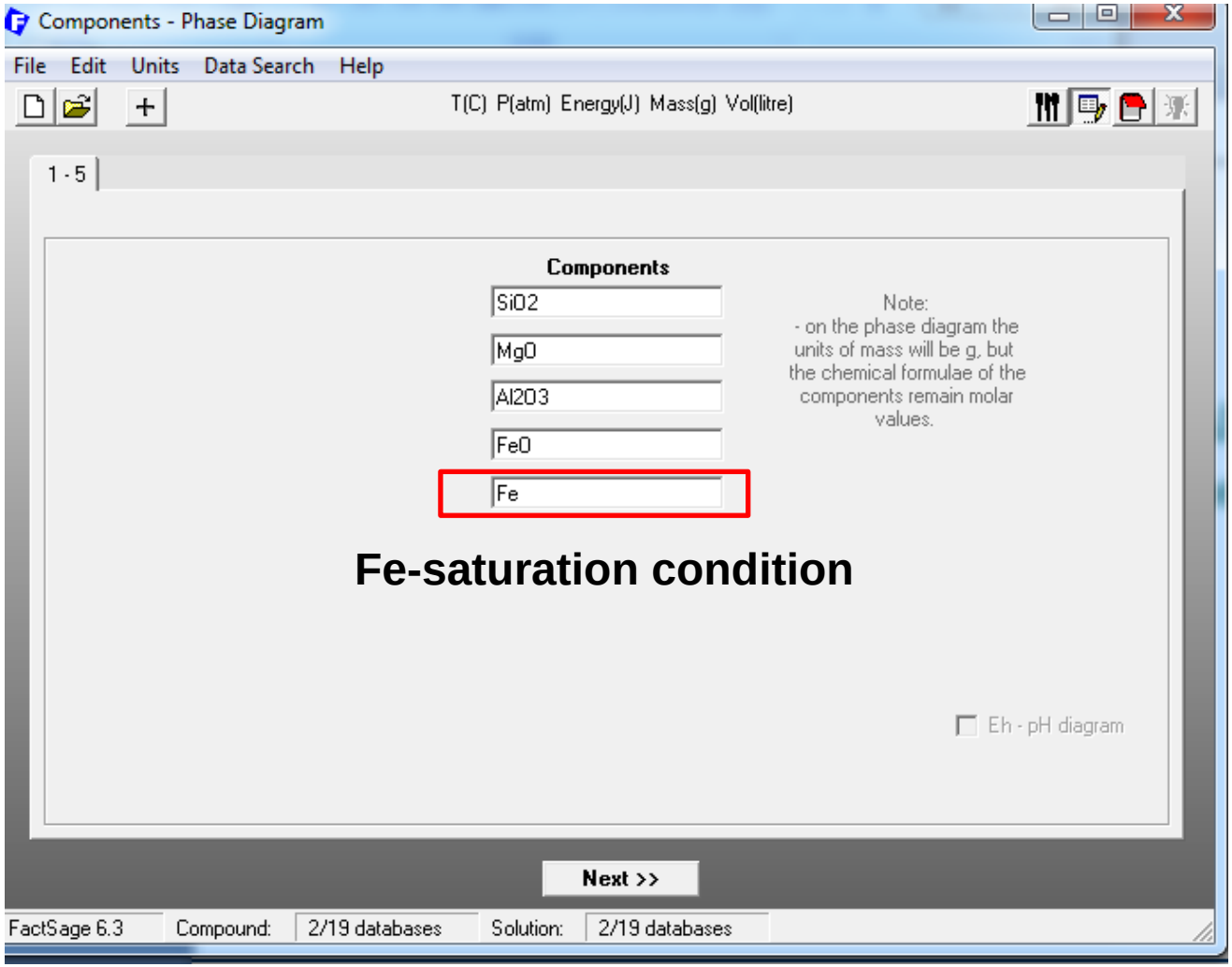
Repeat to calculate the liquidus temp of each slag using 'Precipitate Target'

The effect of SiO_2/MgO and FeO and Al_2O_3 in Slag on the liquidus temperature of the Slag

Phase Diagram / Equilib

Phase diagram of SiO_2-MgO-Al_2O_3-FeO-Fe

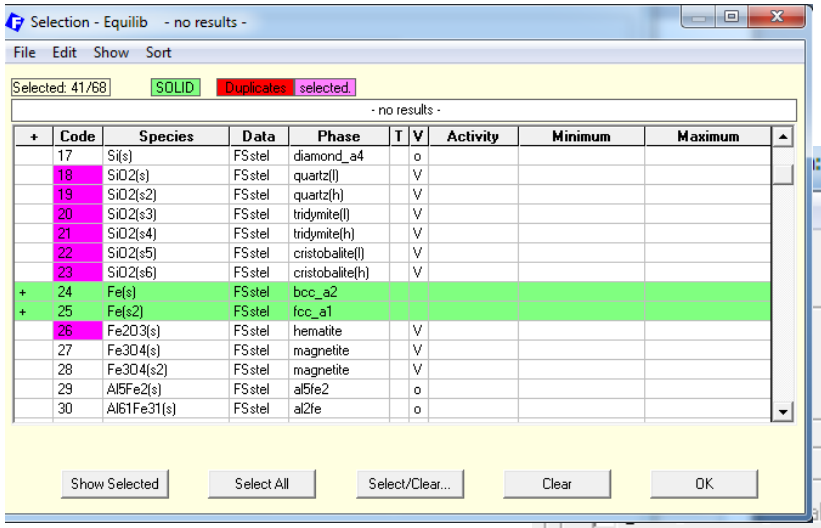
Actually, SiO_2/MgO of Laterite is almost same as that of the produced Slag
The main system of Slag is virtually SiO_2-MgO-Al_2O_3-FeO

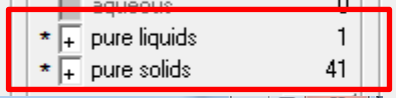


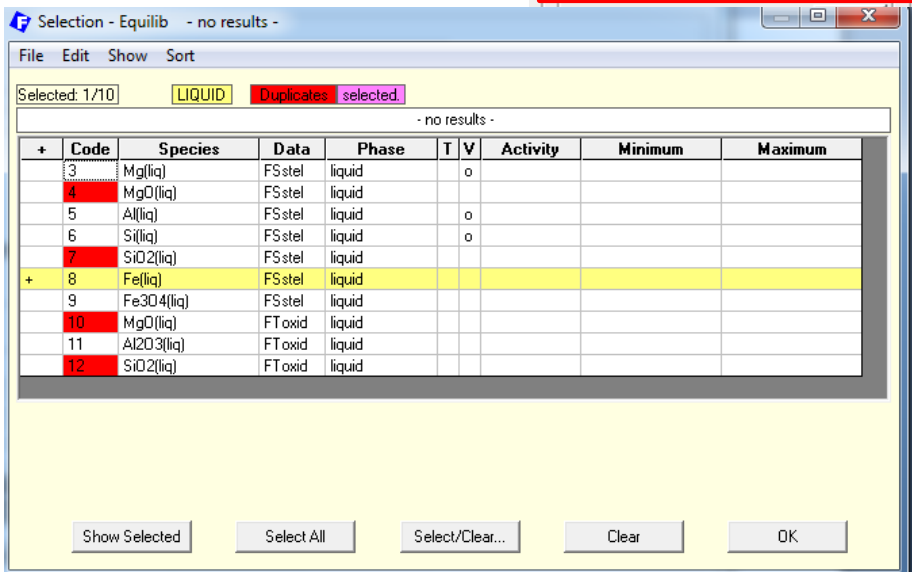
Fe-saturation condition

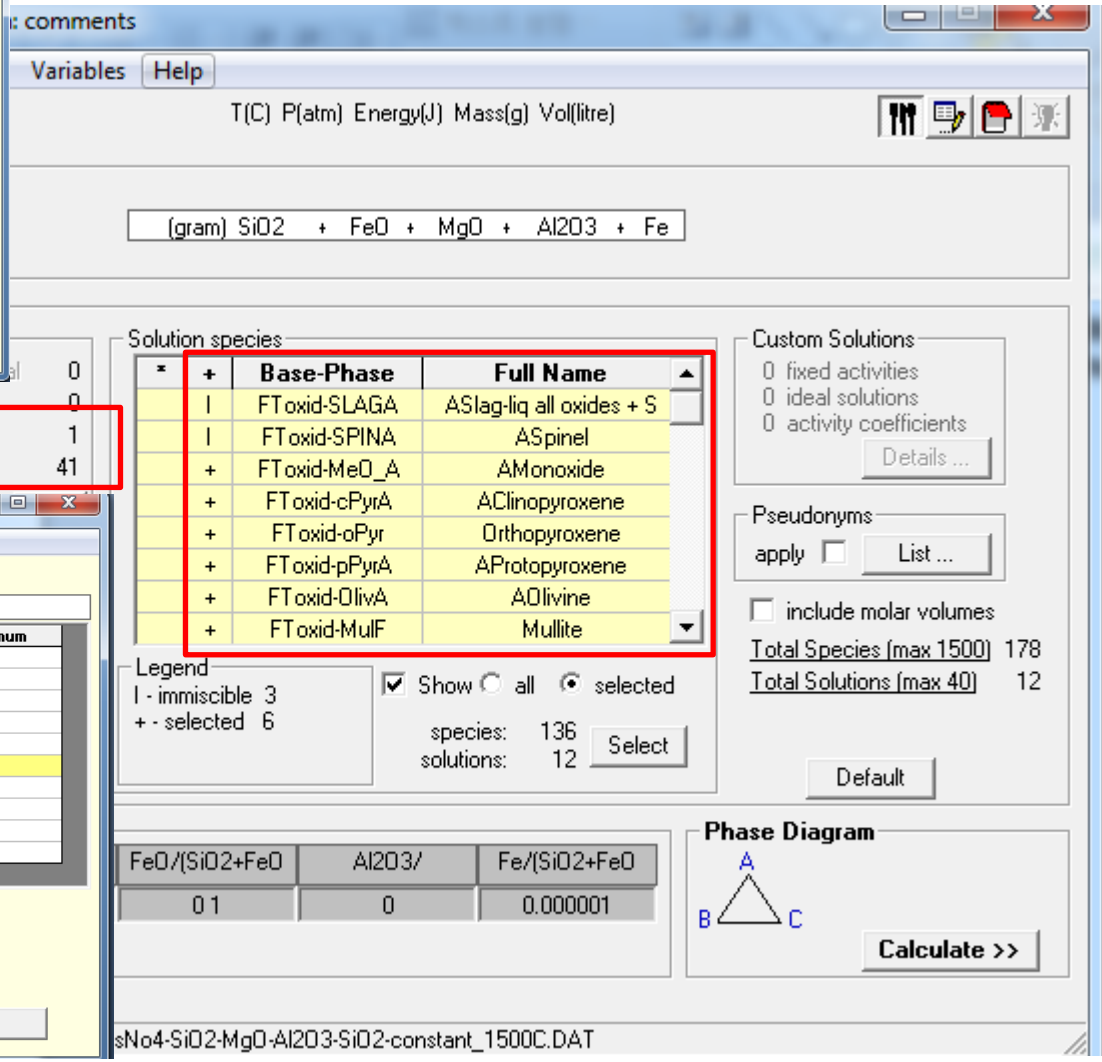
Phase diagram of SiO_2-MgO-Al_2O_3-FeO-Fe

Select pure solid and liquid of Fe for Fe-saturation condition

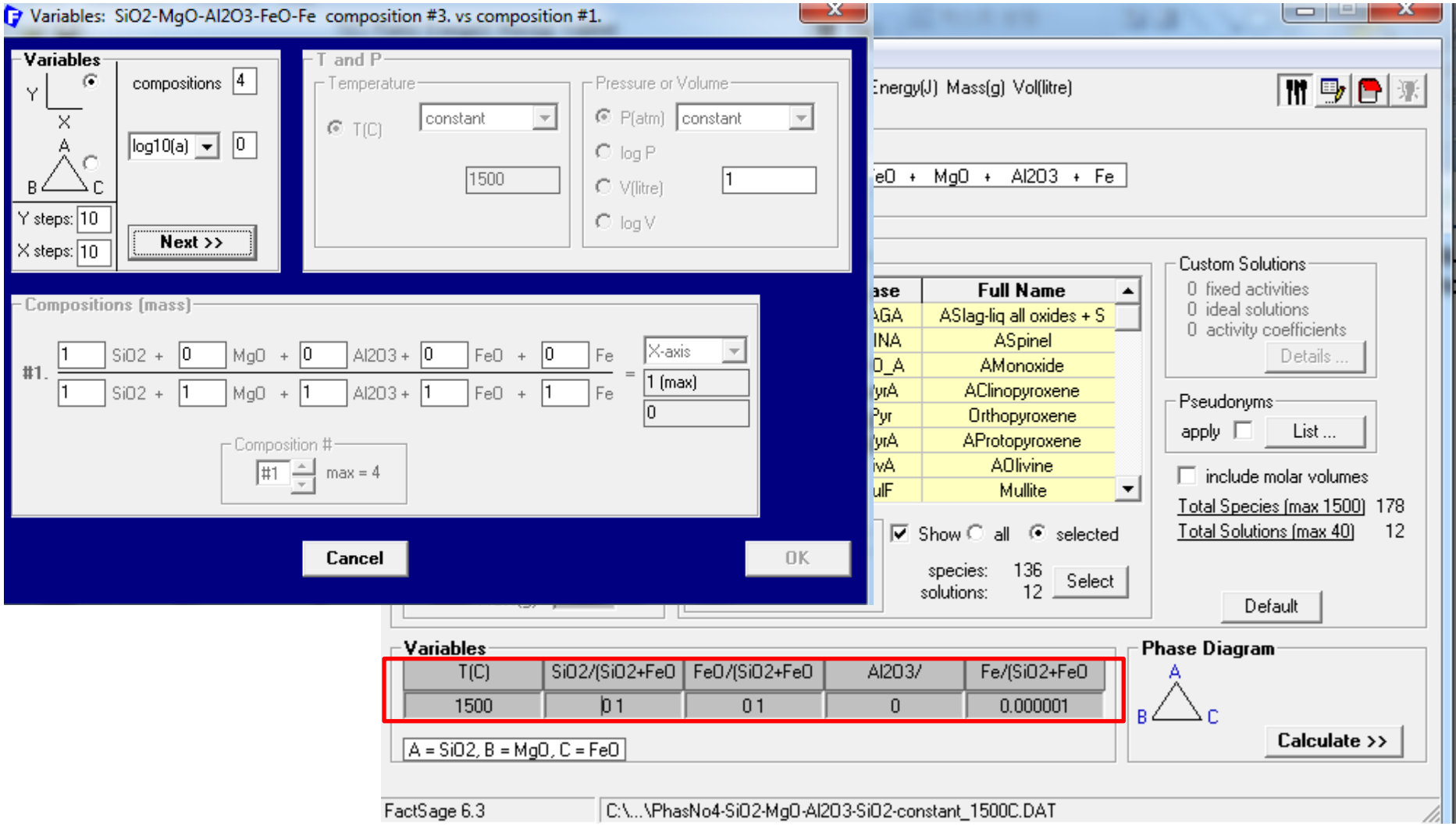




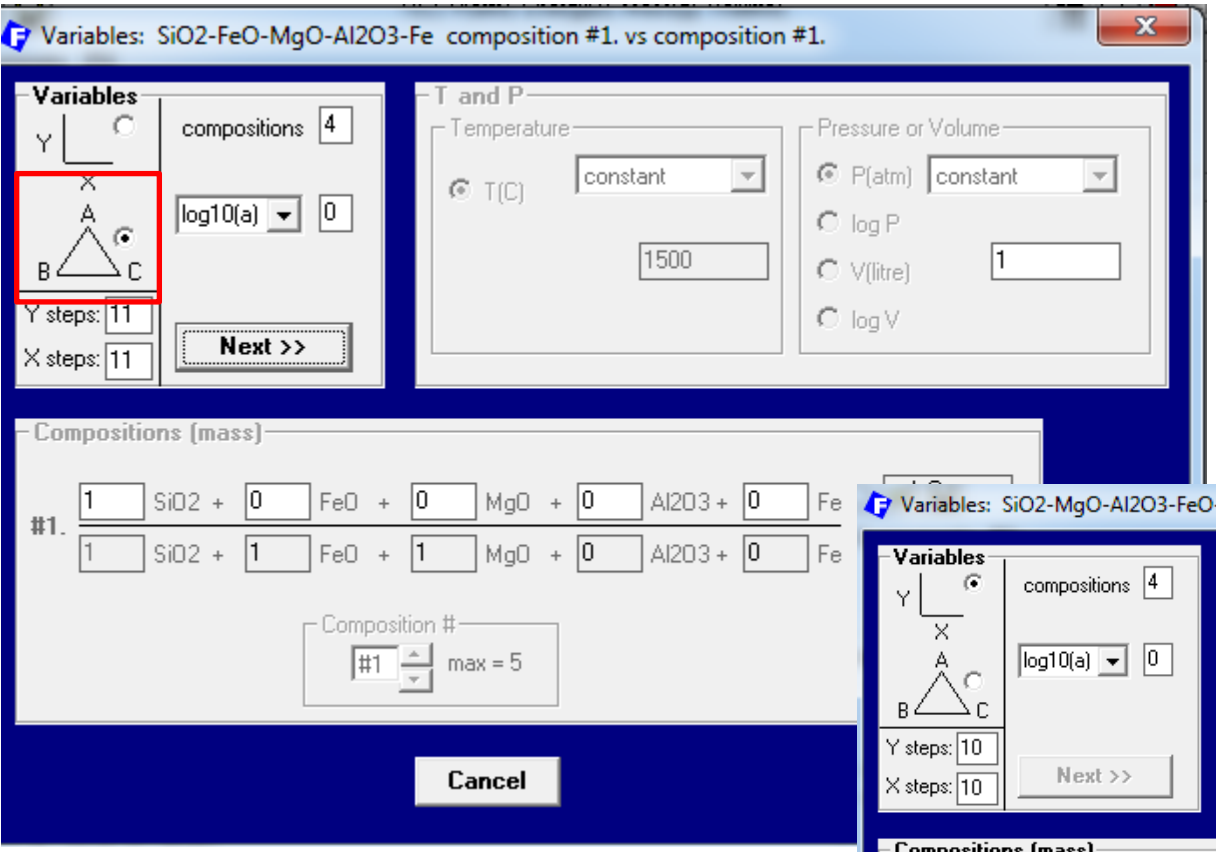


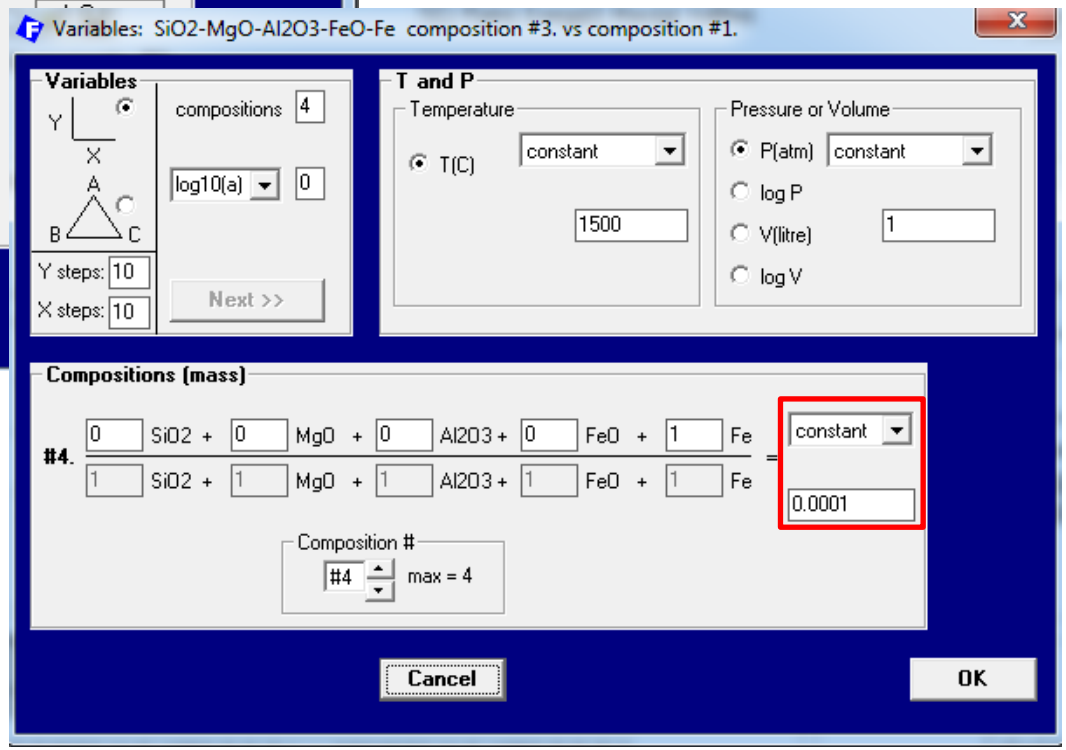


Phase diagram of SiO_2-MgO-Al_2O_3-FeO-Fe



Phase diagram of SiO_2-MgO-Al_2O_3-FeO-Fe



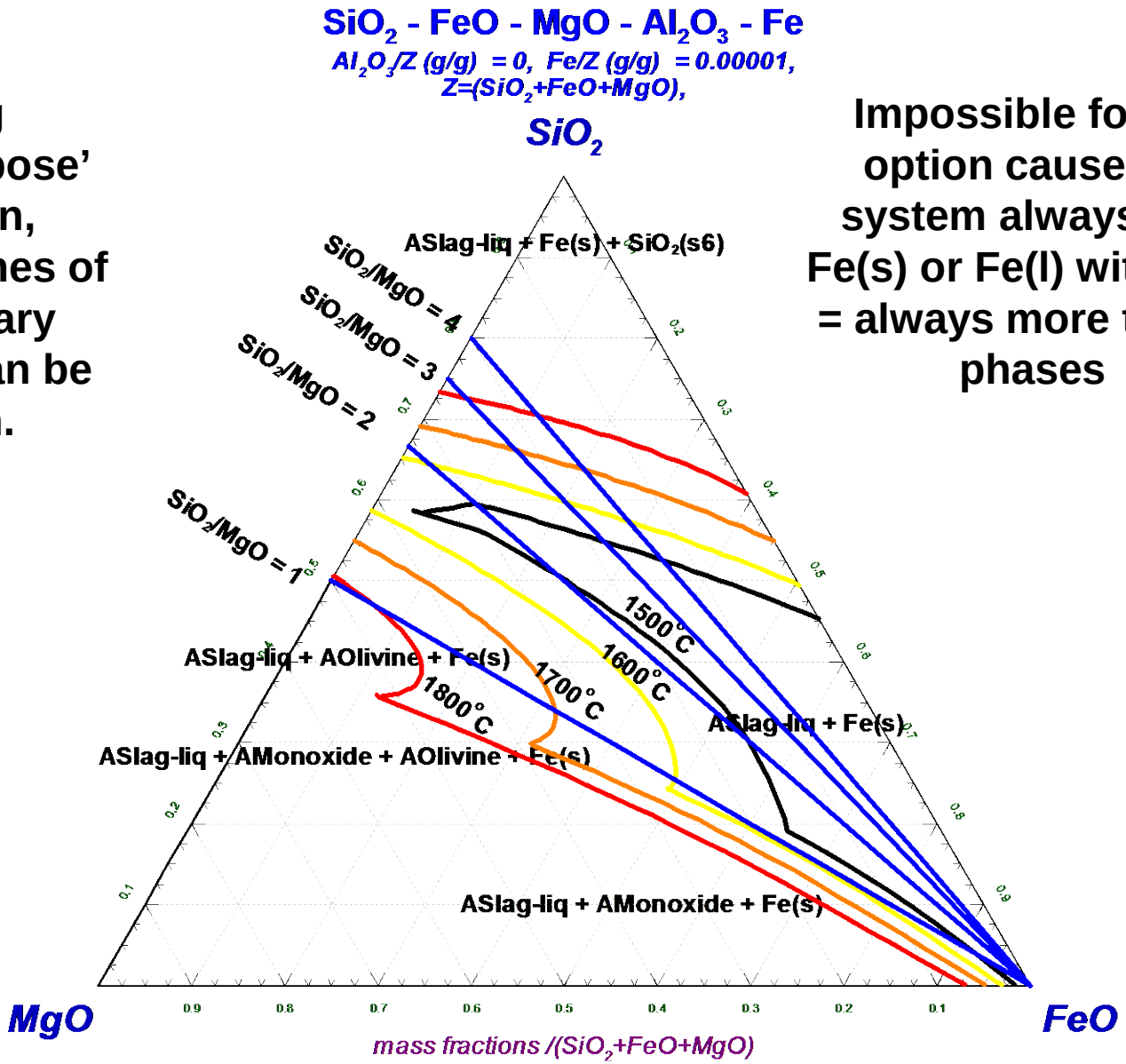


Ternary phase diagram of FeO-MgO-SiO_2 at constant Al_2O_3 with Fe-saturation

Add small amount of Fe

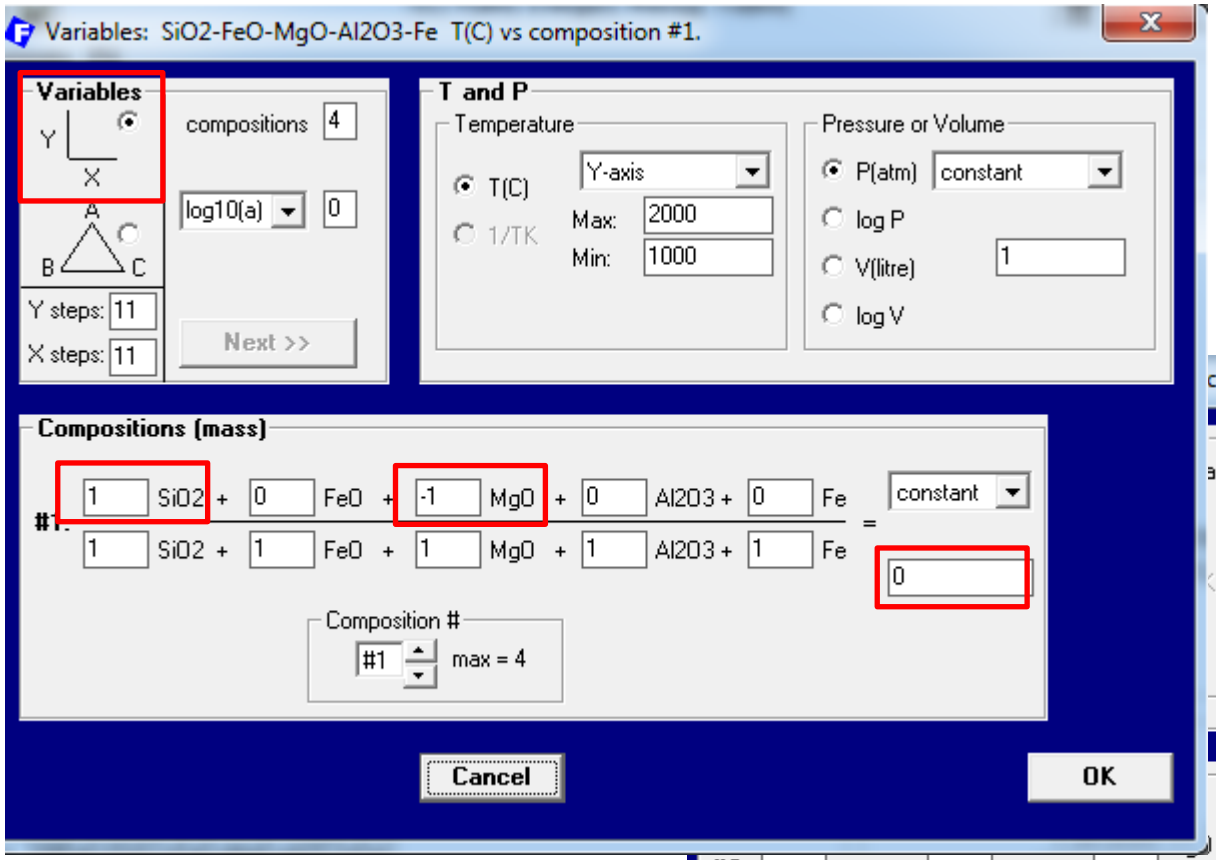
Phase diagram of SiO_2-MgO-Al_2O_3-FeO-Fe

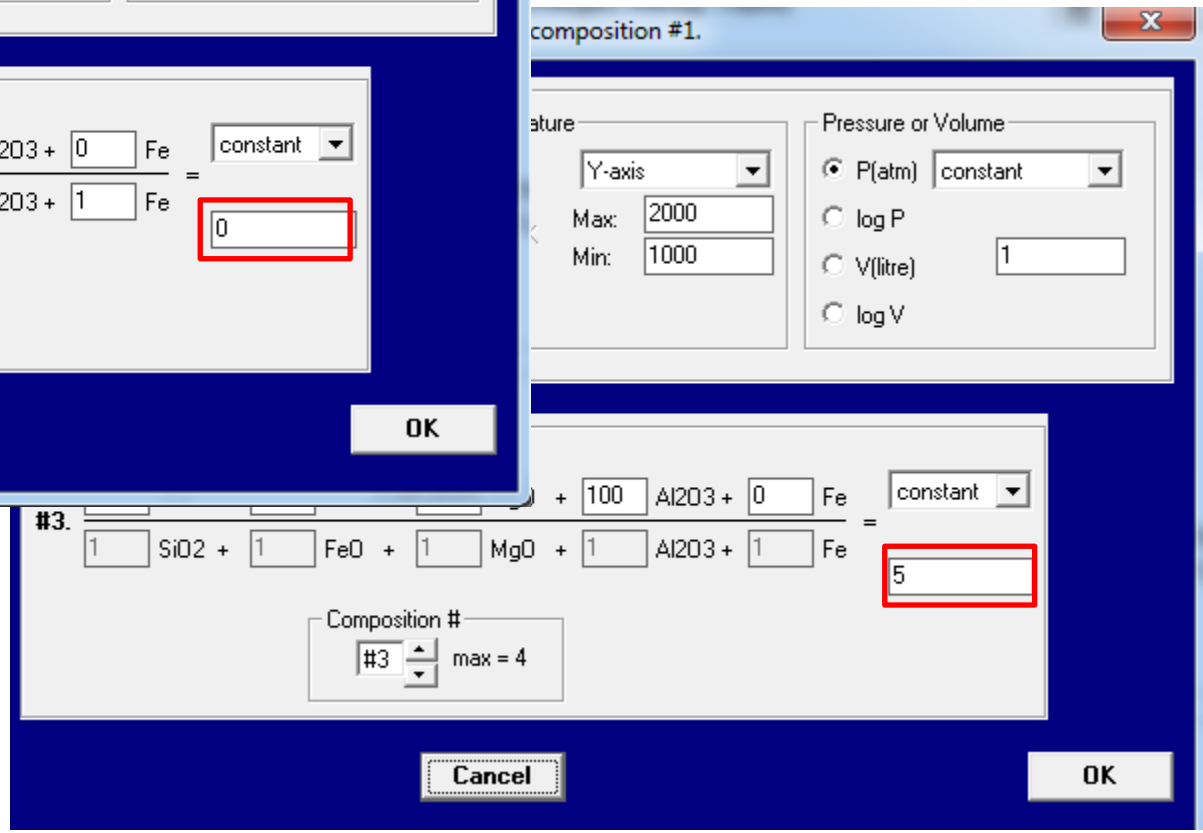
Using 'superimpose' function, liquidus lines of the ternary system can be drawn.



Impossible for 'O' option cause the system always has Fe(s) or Fe(l) with slag = always more than 2 phases

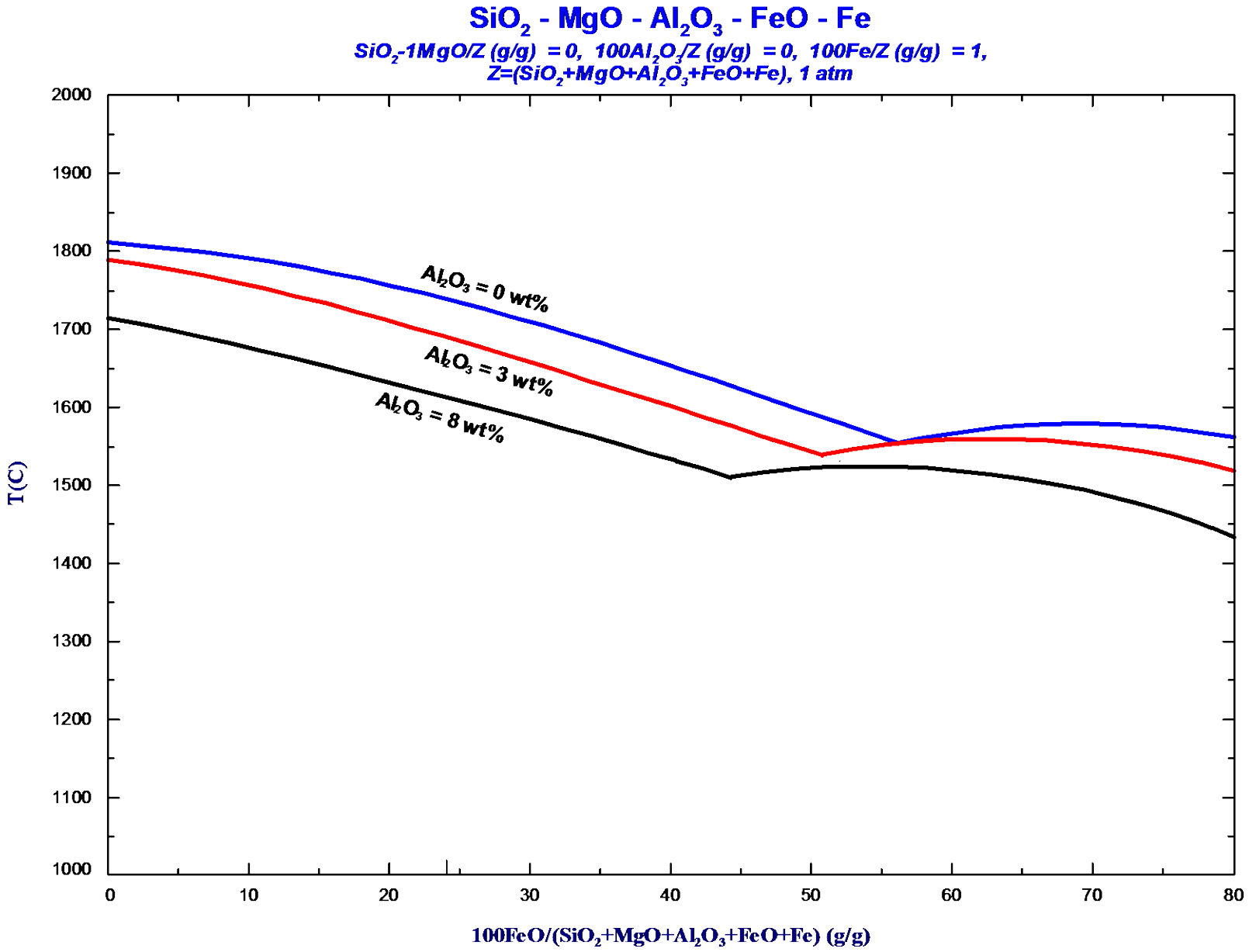
Phase diagram of SiO_2-MgO-Al_2O_3-FeO-Fe





With change 0 to 8 wt% of Al_2O_3 at constant SiO_2/MgO=1 under Fe-saturation

Phase diagram of SiO_2-MgO-Al_2O_3-FeO-Fe

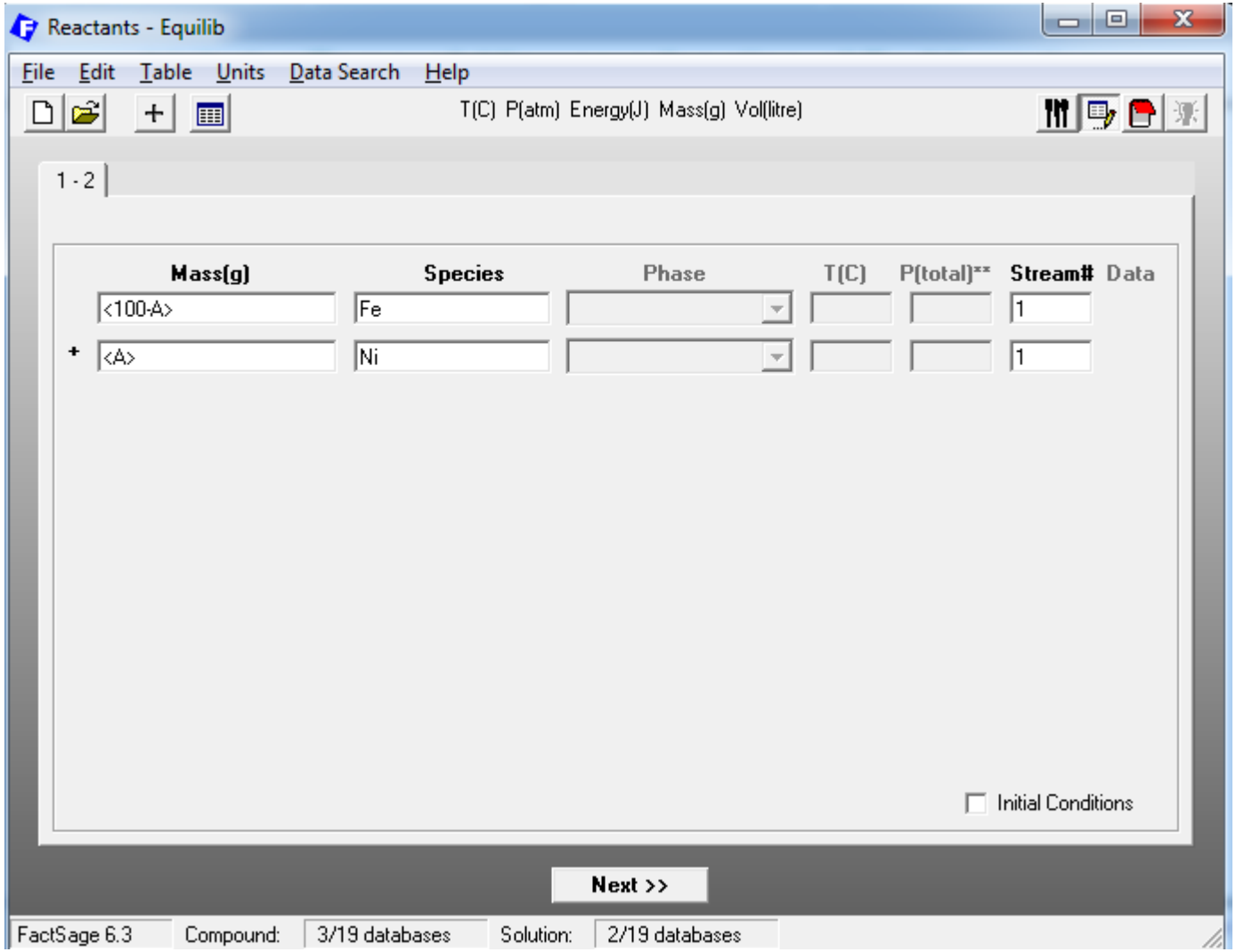


Show the liquidus temperature of the alloy as a function of Fe-Ni grades

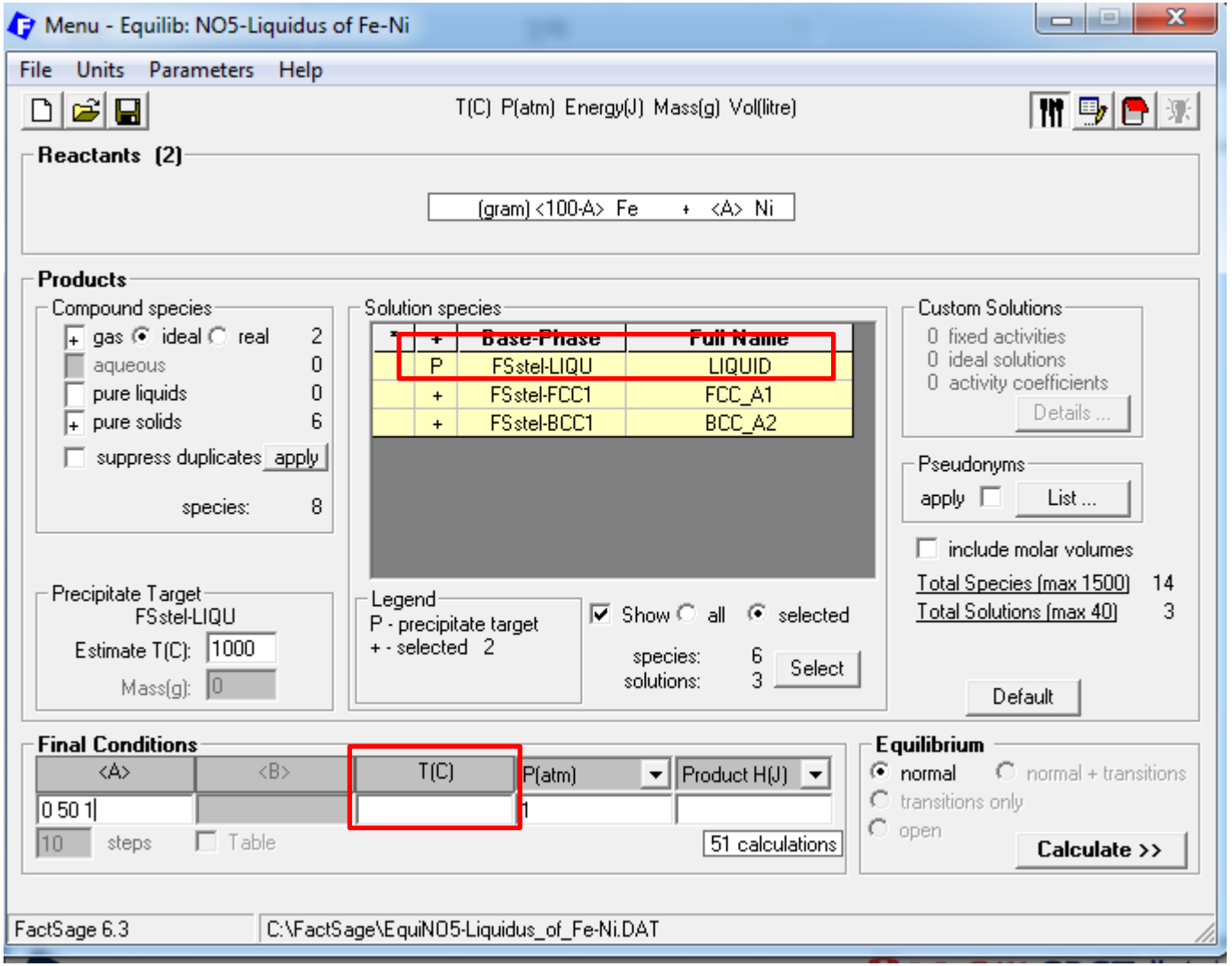
Precipitate target / Phase diagram

Liqiudus Temp of Alloy as a function of Fe-Ni grades

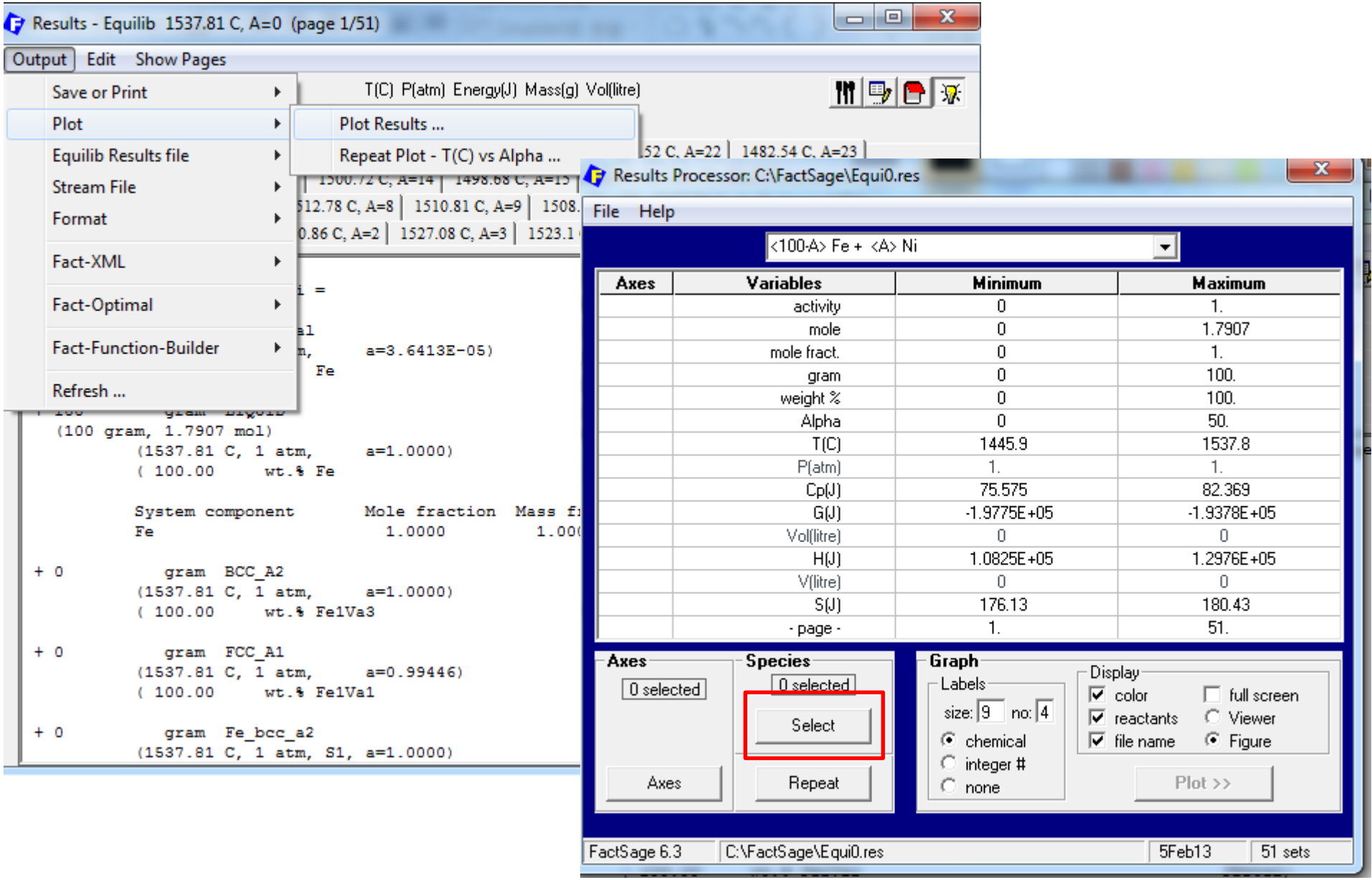
The alloy mainly contains Fe and Ni with small amounts of Co or Cr
Virtually, it is a binary Fe-Ni system



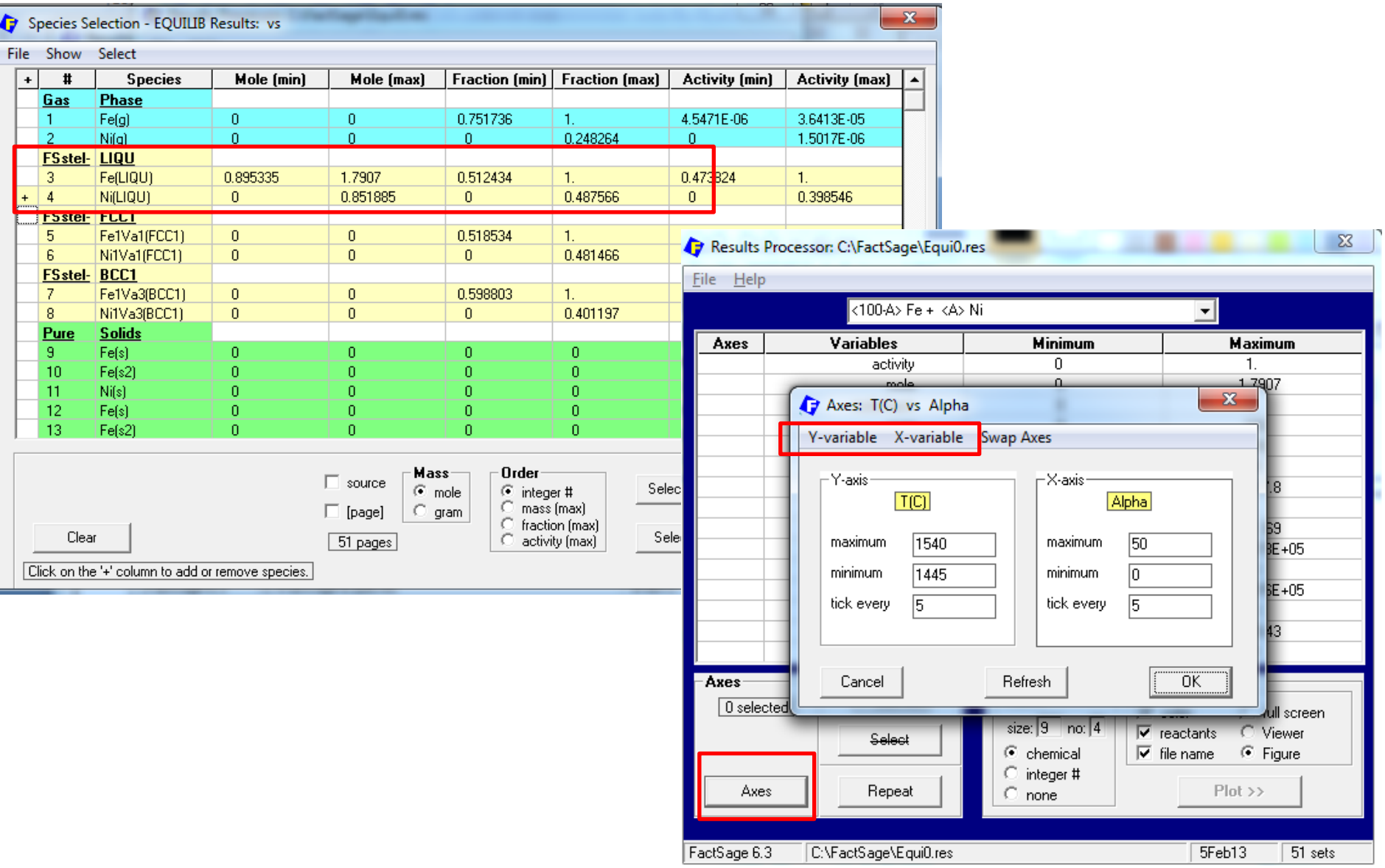
Liqiudus Temp of Alloy as a function of Fe-Ni grades



Liqiudus Temp of Alloy as a function of Fe-Ni grades



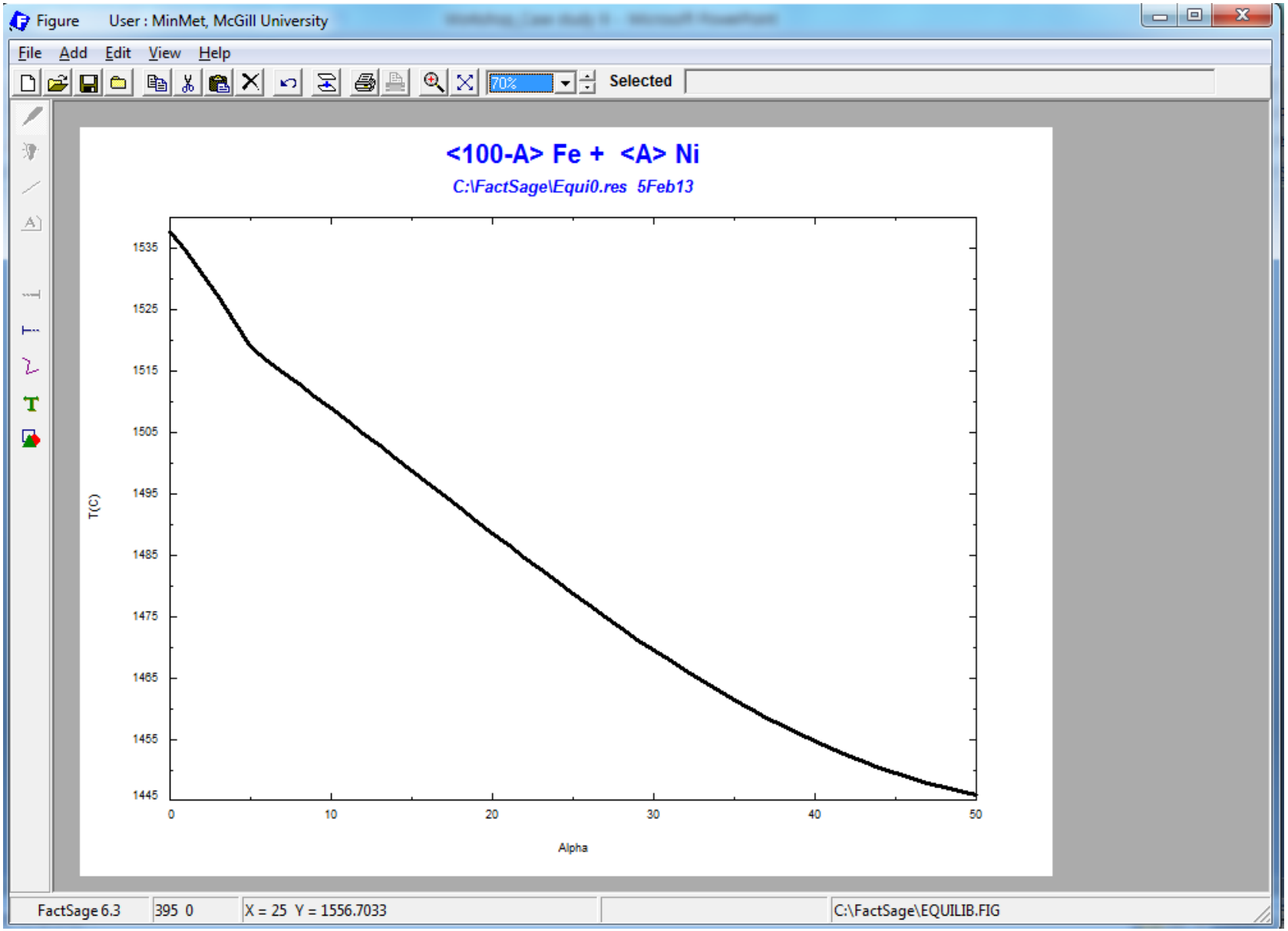
Liqiudus Temp of Alloy as a function of Fe-Ni grades



+	#	Species	Mole (min)	Mole (max)	Fraction (min)	Fraction (max)	Activity (min)	Activity (max)
	Gas	Phase						
	1	Fe(g)	0	0	0.751736	1.	4.5471E-06	3.6413E-05
	2	Ni(g)	0	0	0	0.248264	0	1.5017E-06
	FSstel-	LIQU						
	3	Fe(LIQU)	0.895335	1.7907	0.512434	1.	0.473824	1.
+	4	Ni(LIQU)	0	0.851885	0	0.487566	0	0.398546
	FSstel-	FCC1						
	5	Fe1Va1(FCC1)	0	0	0.518534	1.		
	6	Ni1Va1(FCC1)	0	0	0	0.481466		
	FSstel-	BCC1						
	7	Fe1Va3(BCC1)	0	0	0.598803	1.		
	8	Ni1Va3(BCC1)	0	0	0	0.401197		
	Pure	Solids						
	9	Fe(s)	0	0	0	0		
	10	Fe(s2)	0	0	0	0		
	11	Ni(s)	0	0	0	0		
	12	Fe(s)	0	0	0	0		
	13	Fe(s2)	0	0	0	0		

Axes	Variables	Minimum	Maximum
	activity	0	1.
	mole	0	1.7907

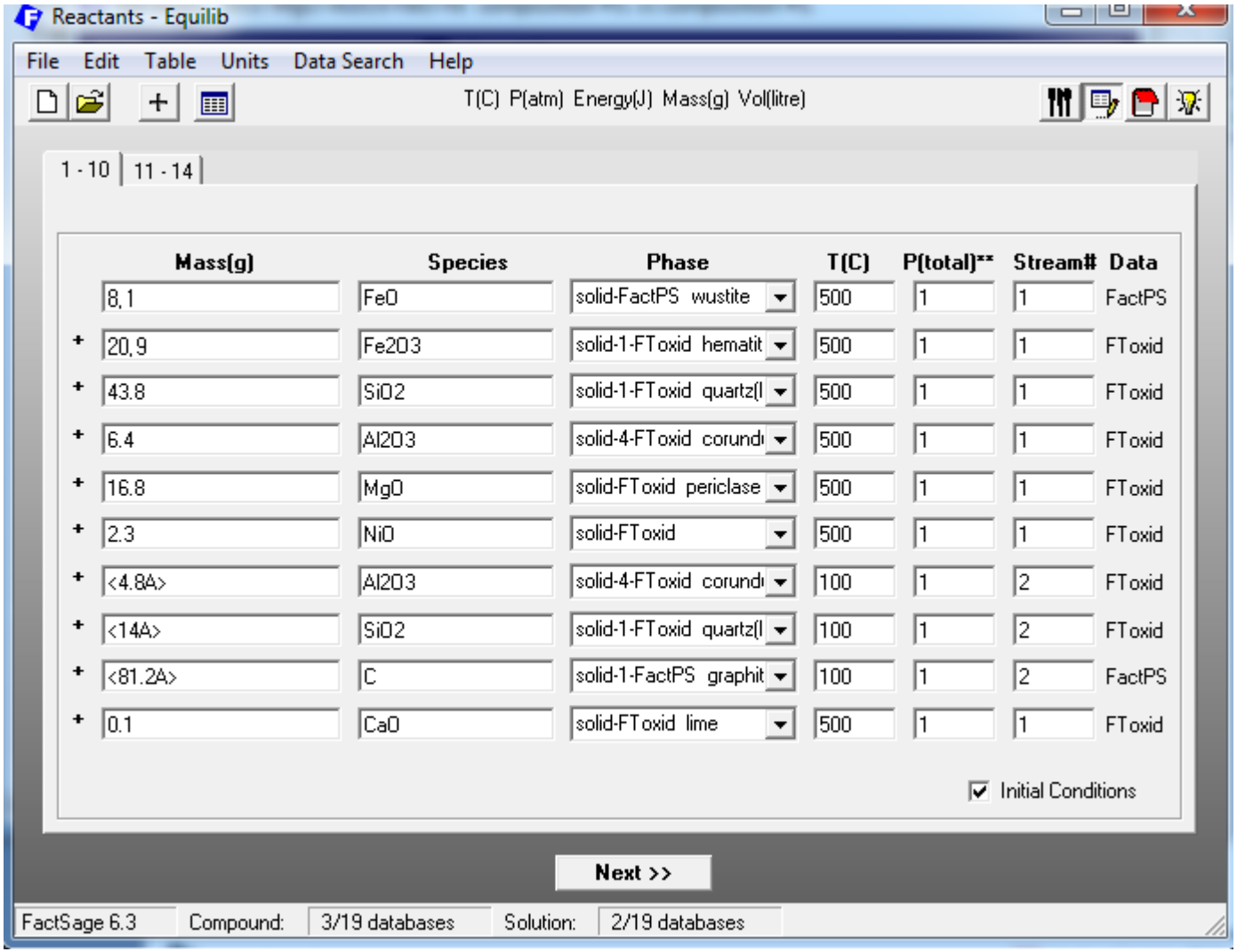
Liqiudus Temp of Alloy as a function of Fe-Ni grades



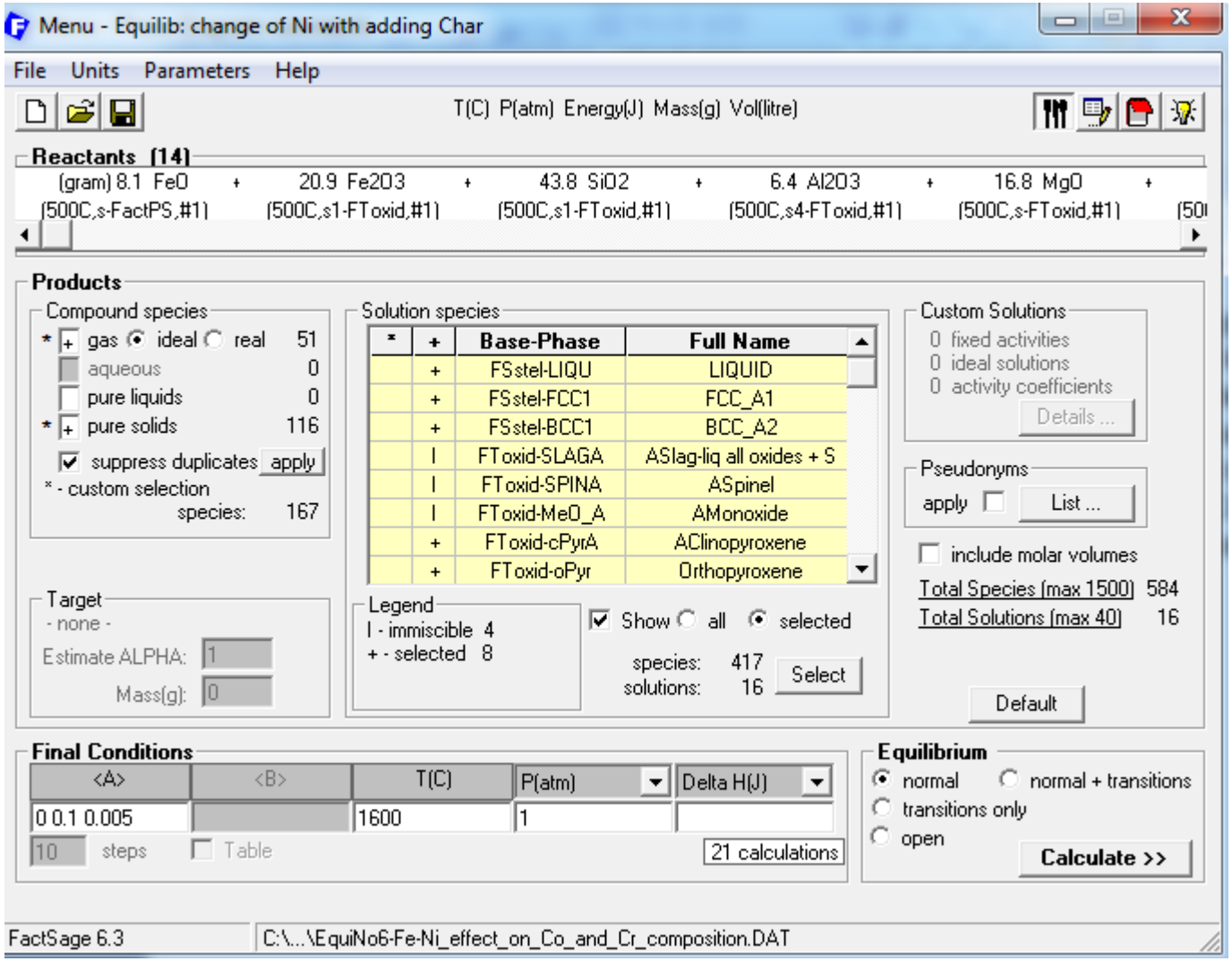
The effect of Fe-Ni grades on the concentration of Co and Cr in the liquid alloy

Equilib Calculation

The effect of Fe-Ni grades on the solubility of Co and Cr

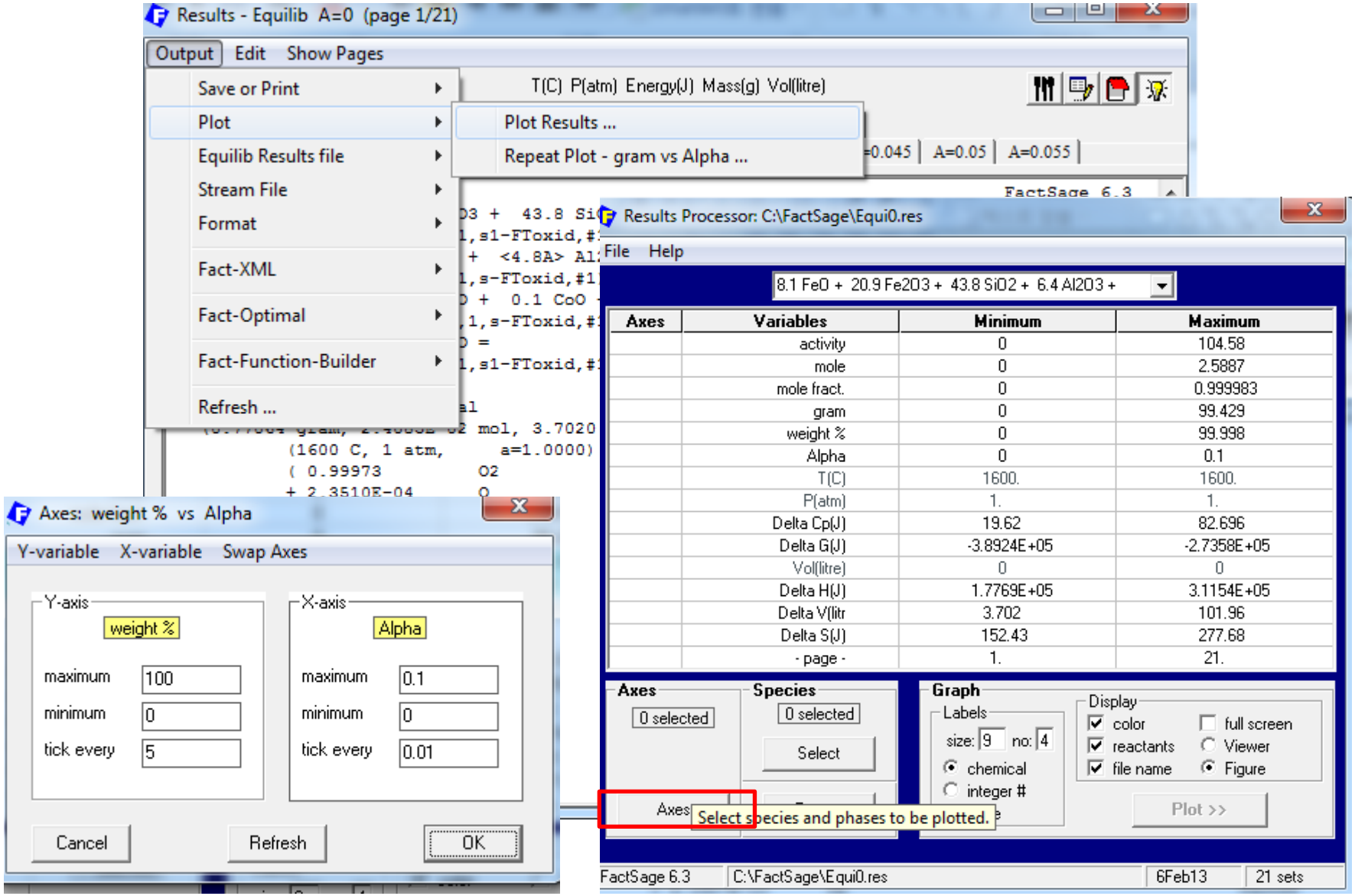


The effect of Fe-Ni grades on the solubility of Co and Cr



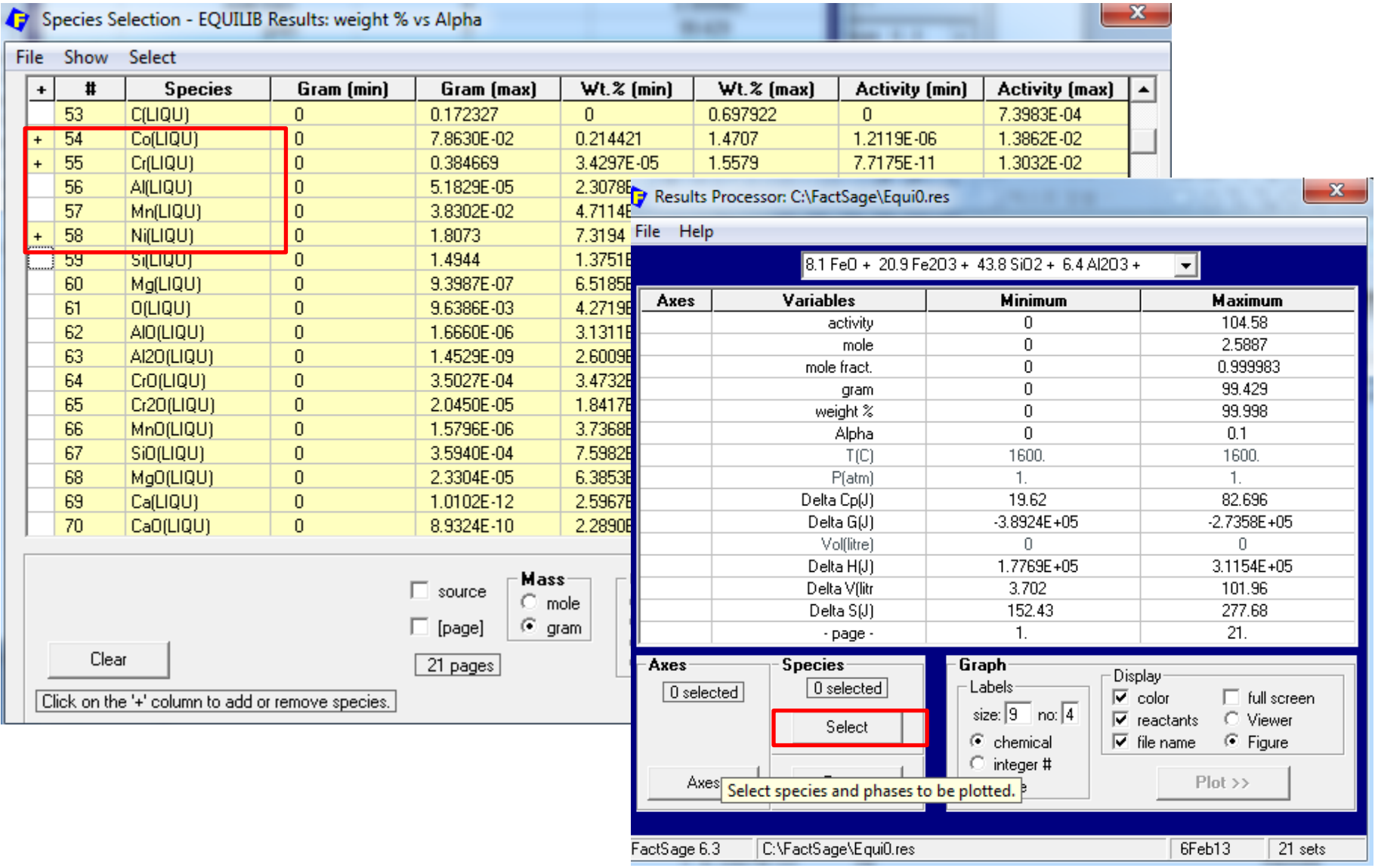
With change of Char, Fe-Ni grade will be changed.
The effect of Fe-Ni grades on the solubility of Co and Cr can be calculated with change of Char.

The effect of Fe-Ni grades on the solubility of Co and Cr

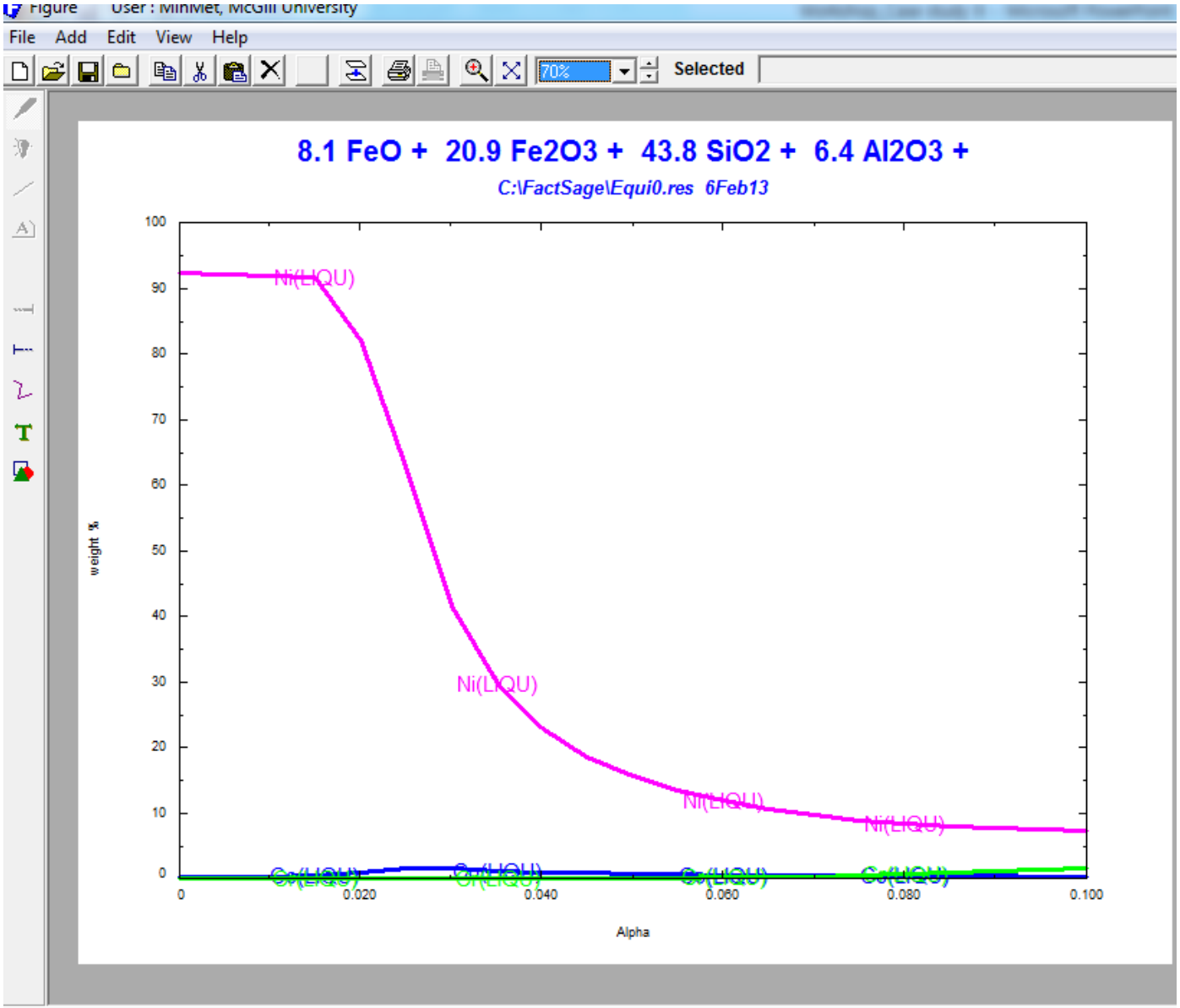


Axes	Variables	Minimum	Maximum
	activity	0	104.58
	mole	0	2.5887
	mole fract.	0	0.999983
	gram	0	99.429
	weight %	0	99.998
	Alpha	0	0.1
	T(C)	1600.	1600.
	P(atm)	1.	1.
	Delta Cp(J)	19.62	82.696
	Delta G(J)	-3.8924E+05	-2.7358E+05
	Vol(litre)	0	0
	Delta H(J)	1.7769E+05	3.1154E+05
	Delta V(litr	3.702	101.96
	Delta S(J)	152.43	277.68
	- page -	1.	21.

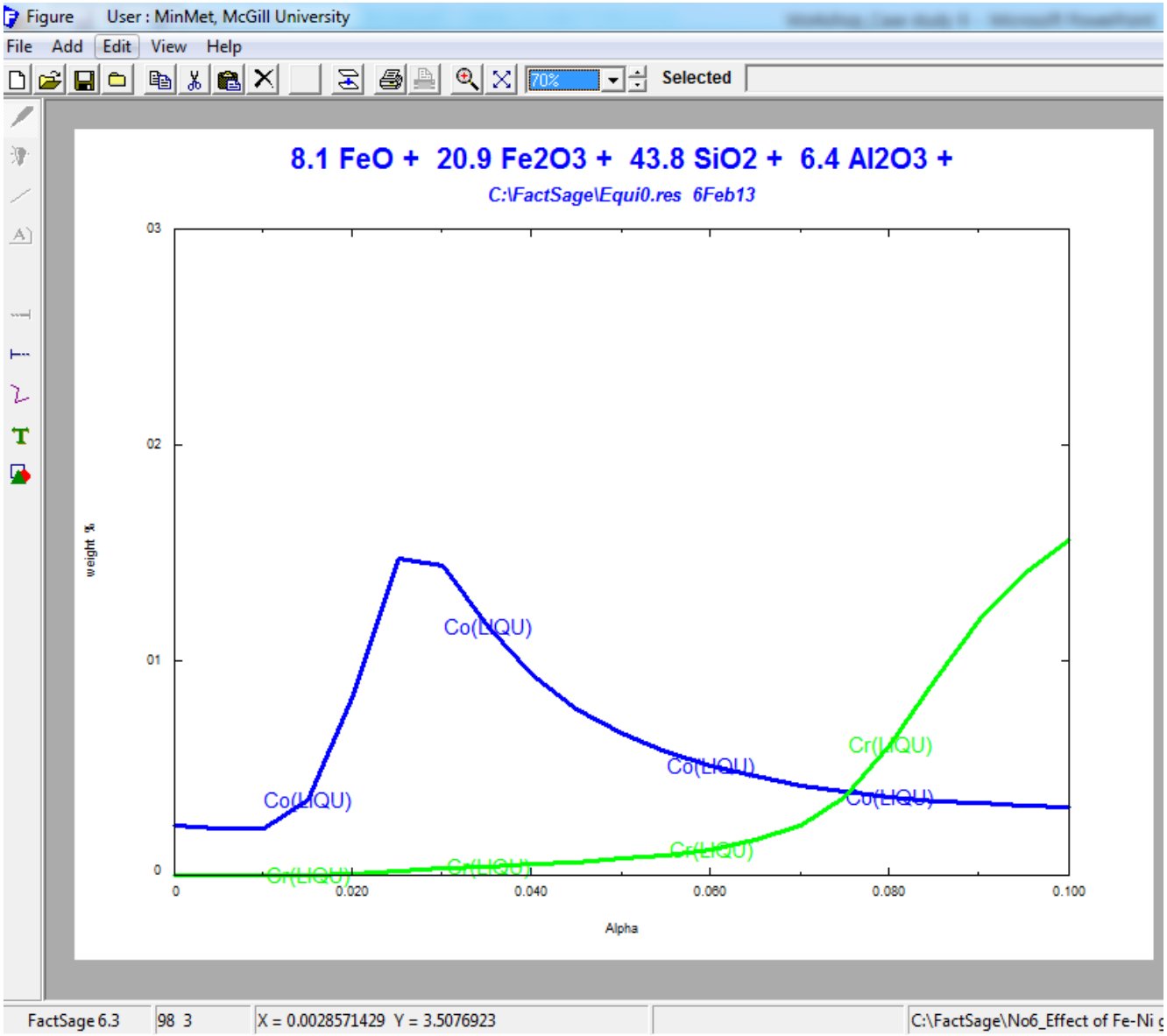
The effect of Fe-Ni grades on the solubility of Co and Cr



The effect of Fe-Ni grades on the solubility of Co and Cr



The effect of Fe-Ni grades on the solubility of Co and Cr



Blow-up Scale of the solubility of Co and Cr with change of Char and Fe-Ni grade.