BOF process

Case-6 Oxygen steel making

- Based on the following HM and flux chemistry chemistry , we would like to calculate the equilibrium composition of HM and Slag at 1600 deg C.
- We would also like to calculate the slag viscosity of the equilibrium slag at its liquidus temperature.
- We can assume excess oxygen in the system.

HM Chemistry (wt%)

CARBON	4.6844
CHROMIUM	0.028
COPPER	0.0035
MANGANESE	0.6975
NICKEL	0.0075
PHOSPHORUS	0.0612
SILICON	0.4935
SULPHUR	0.0027
TITANIUM	0.0404
VANADIUM	0.0097

Scrap Chemistry (wt%)

Si	0.02%
Mn	0.05%

Flux Chemistry (Wt%)

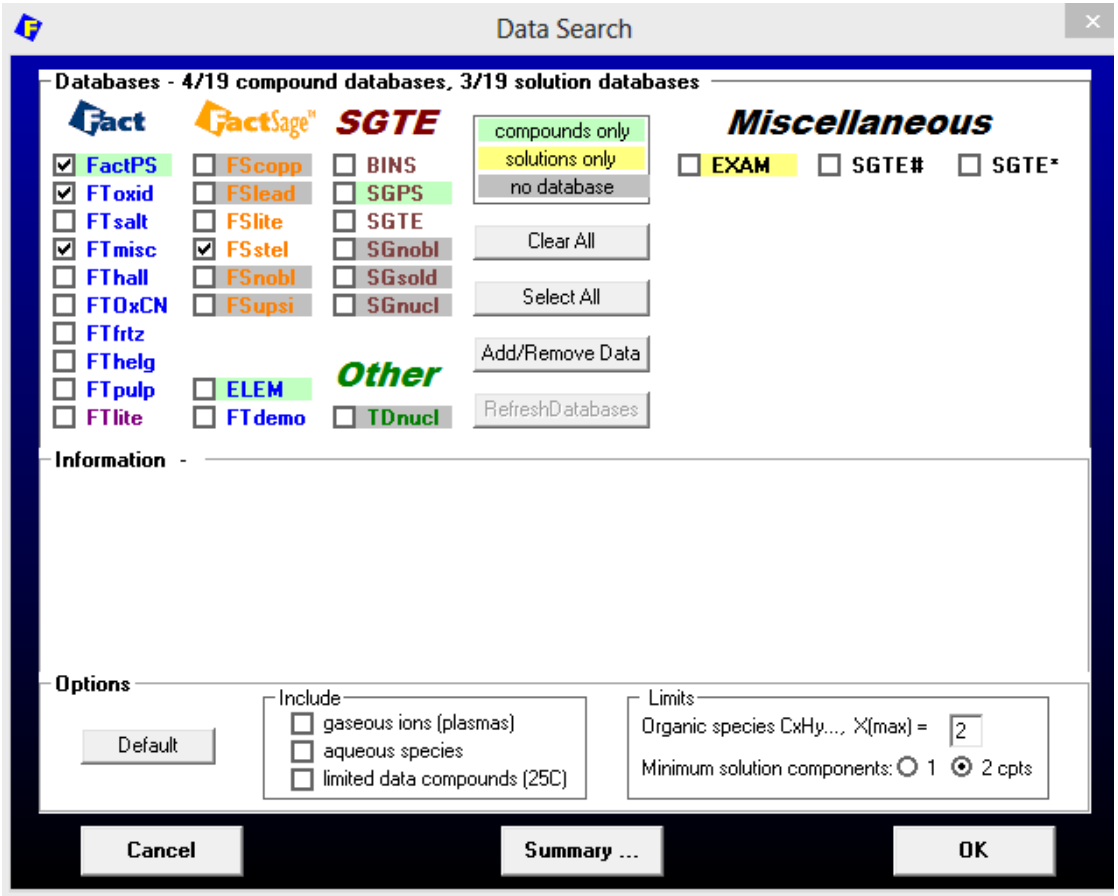
Burnt Lime	95% CaO
Dolo Lime	55% CaO

Amounts charged (tons)

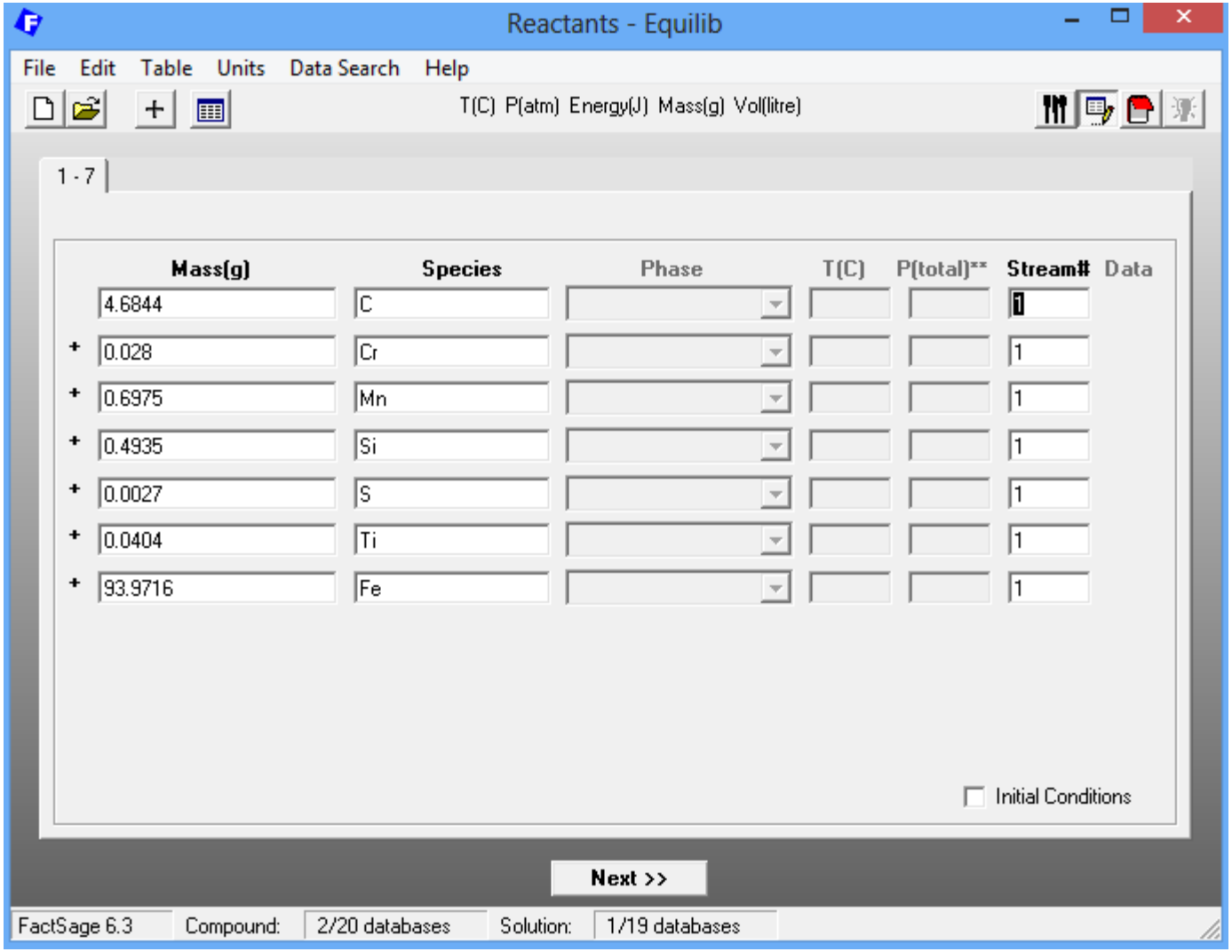
Type	Wt Charged
HM	213
Scrap	60
Dolo	5
Burnt	7

Databases

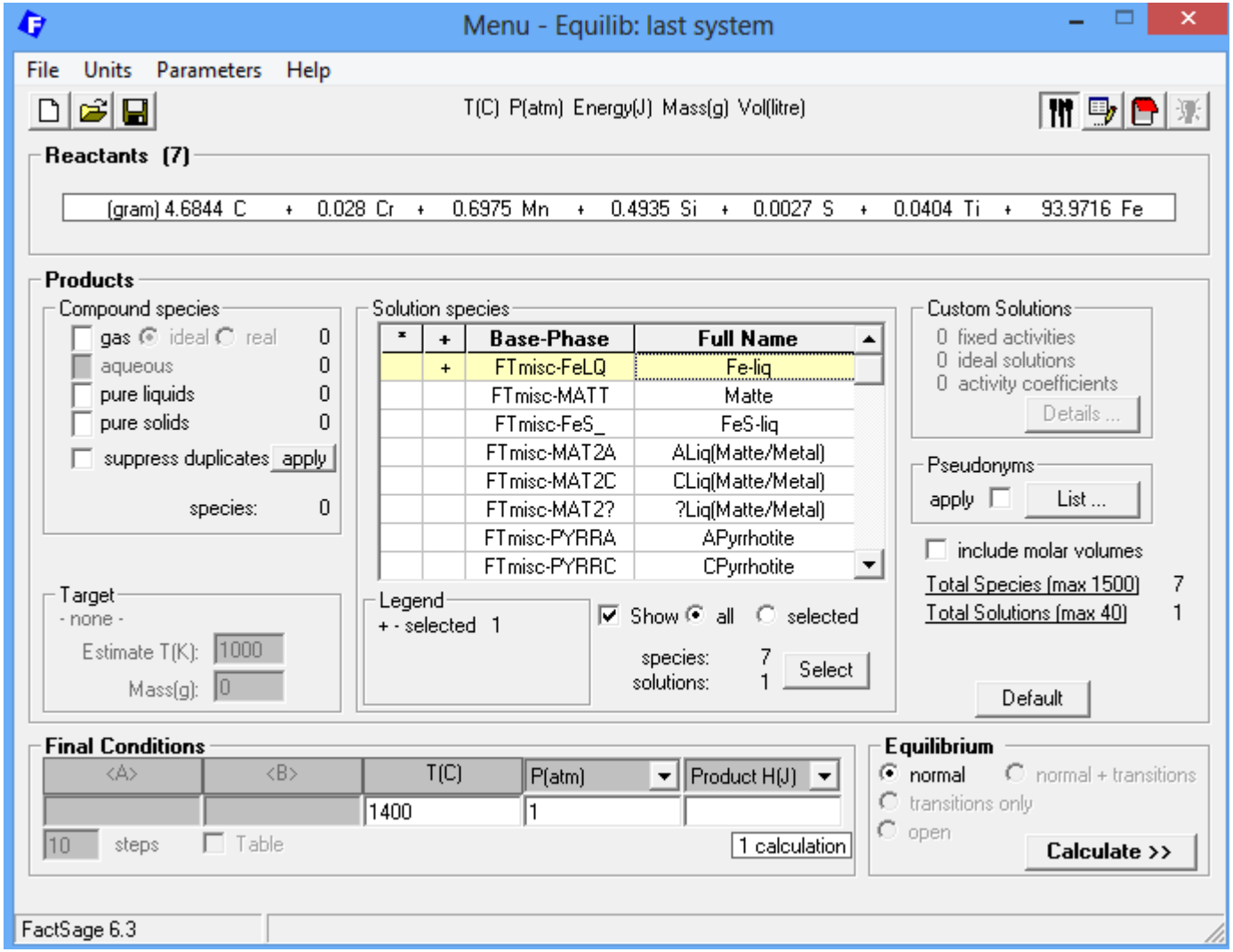
- FToxid: slag
- FTmisc: molten steel
- FSstel: scrap



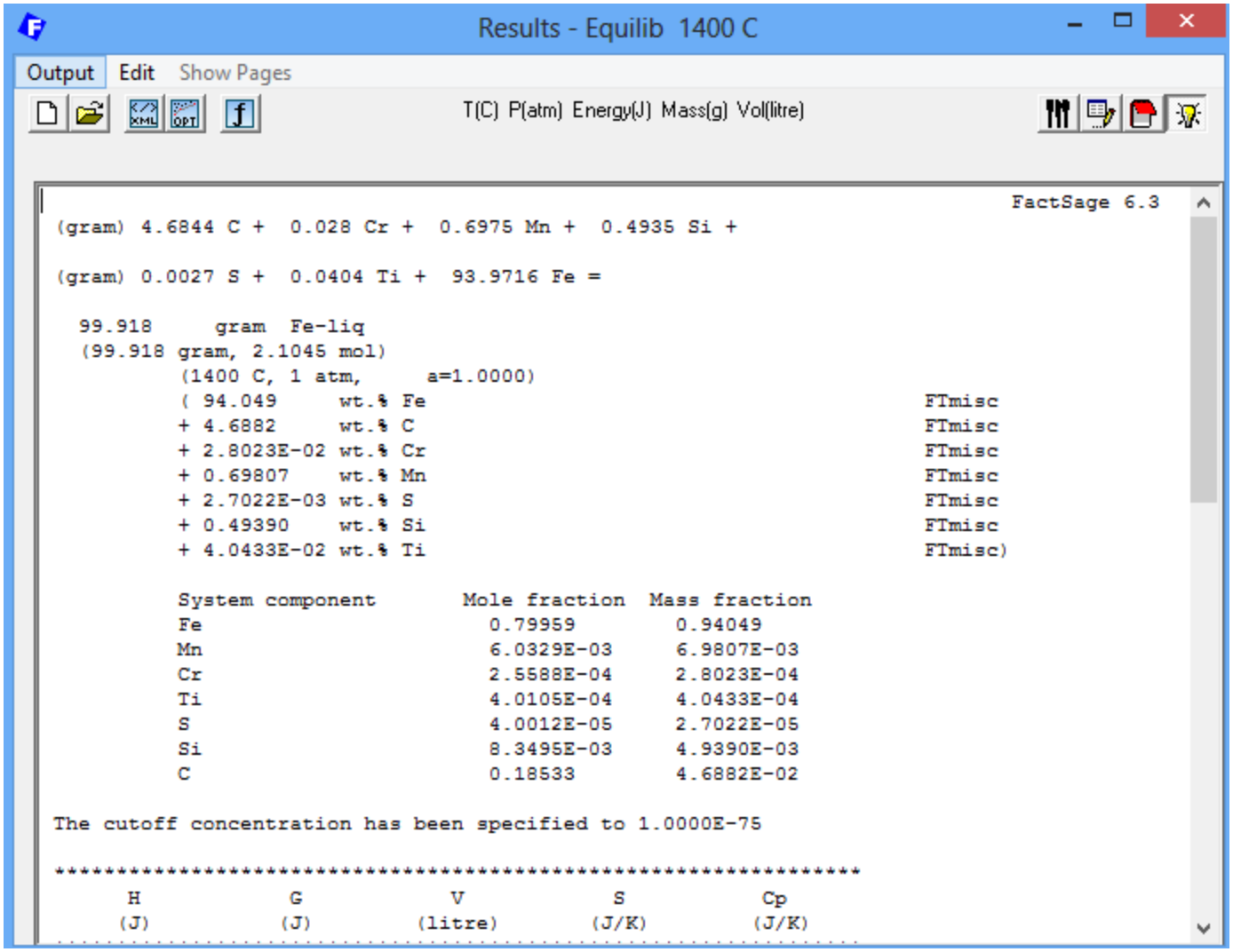
Using Streams



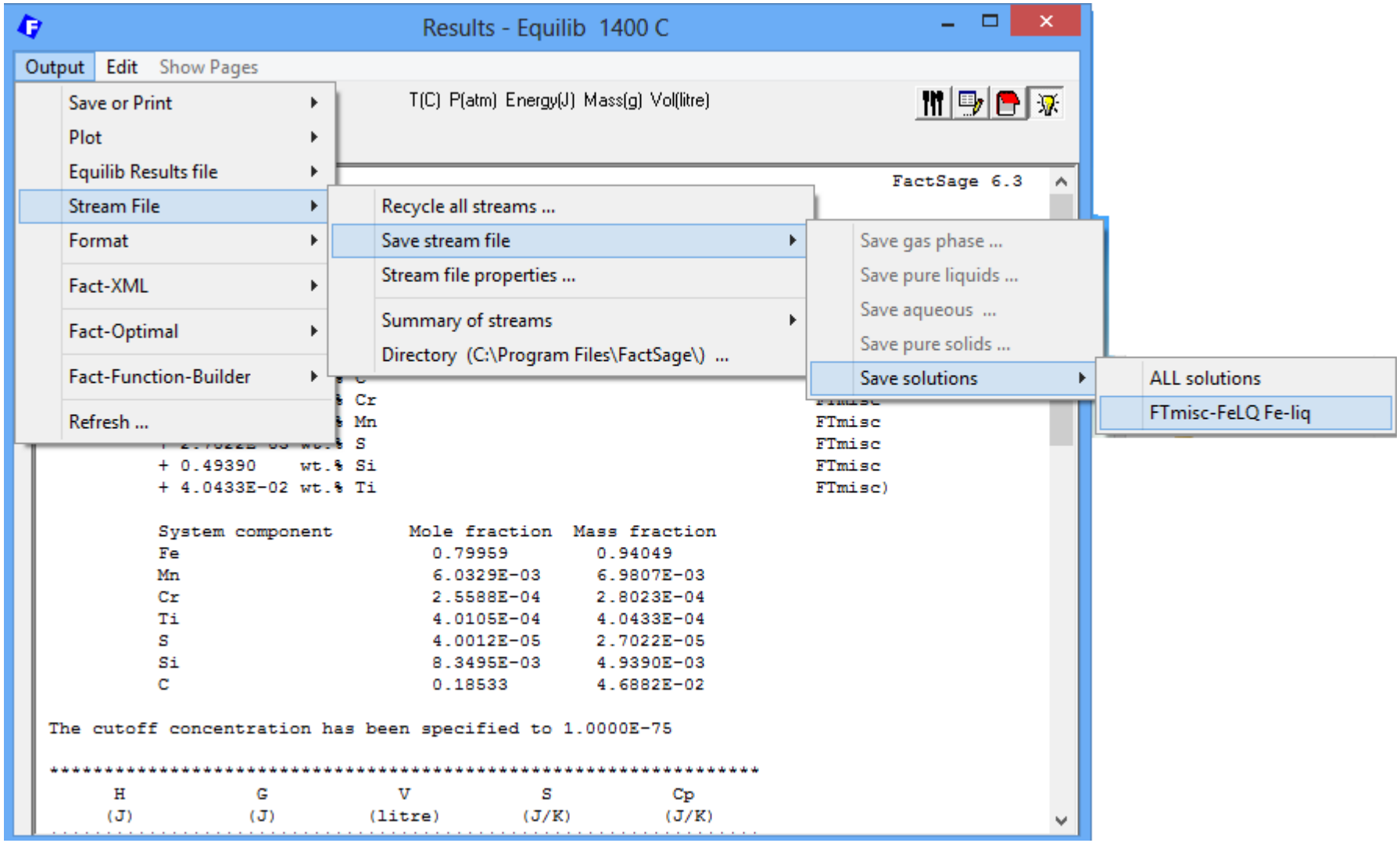
Selecting Solution and Temperature



Check Results

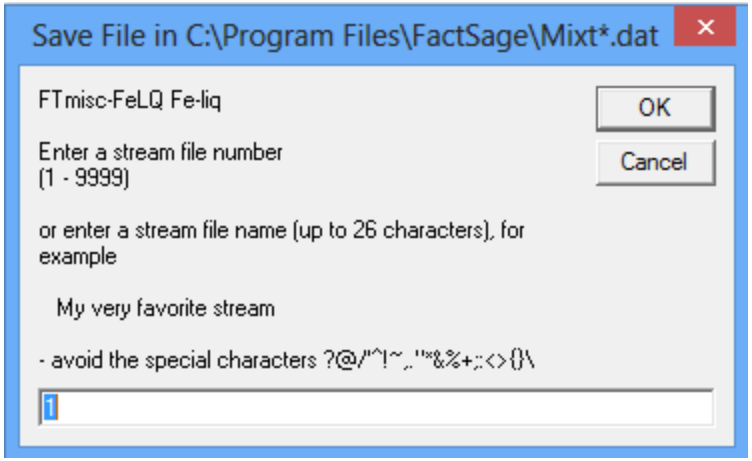


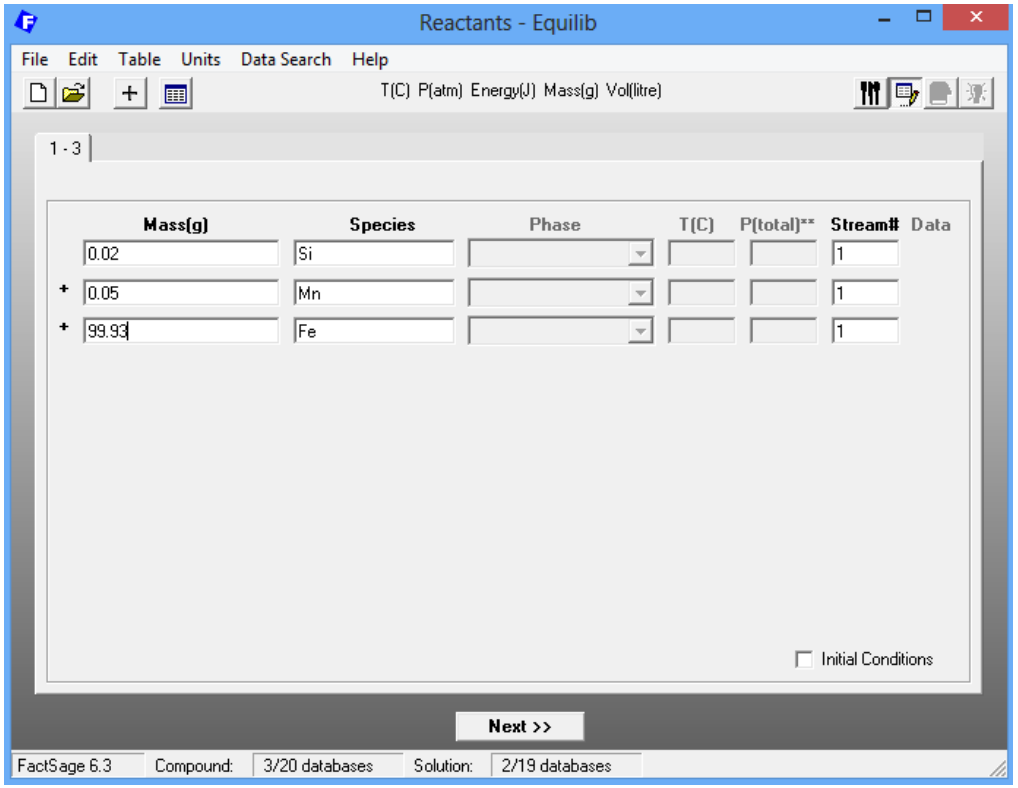
Save Stream


Results - Equilib 1400 C
Output
Edit
Show Pages
T(C) P(atm) Energy(J) Mass(g) Vol(litre)
Save or Print
Plot
Equilib Results file
Stream File
Format
Fact-XML
Fact-Optimal
Fact-Function-Builder
Refresh ...
Recycle all streams ...
Save stream file
Stream file properties ...
Summary of streams
Directory (C:\Program Files\FactSage\) ...
Save gas phase ...
Save pure liquids ...
Save aqueous ...
Save pure solids ...
Save solutions
ALL solutions
FTmisc-FeLQ Fe-liq
FactSage 6.3
+ 0.49390 wt.% Si
+ 4.0433E-02 wt.% Ti
System component Mole fraction Mass fraction
Fe 0.79959 0.94049
Mn 6.0329E-03 6.9807E-03
Cr 2.5588E-04 2.8023E-04
Ti 4.0105E-04 4.0433E-04
S 4.0012E-05 2.7022E-05
Si 8.3495E-03 4.9390E-03
C 0.18533 4.6882E-02
The cutoff concentration has been specified to 1.0000E-75
H (J)
G (J)
V (litre)
S (J/K)
Cp (J/K)

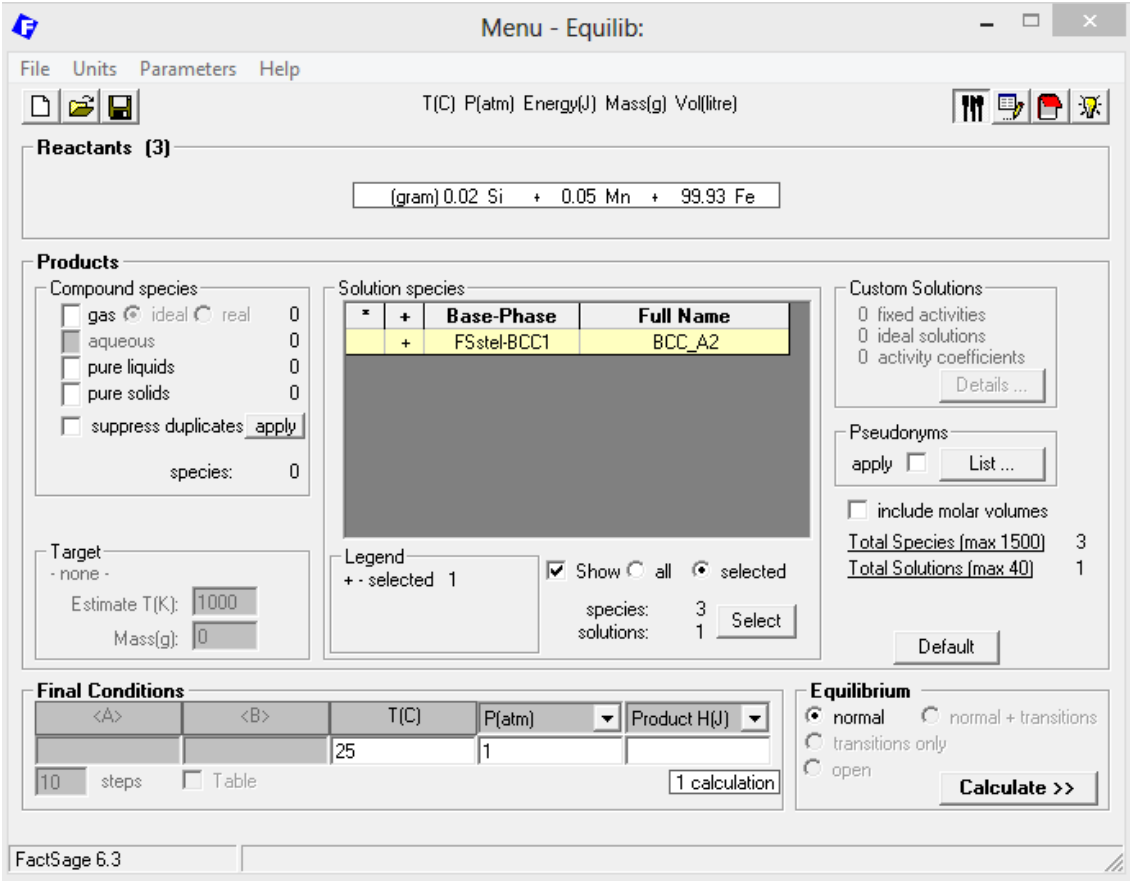
Save Stream

- Save this as a stream (I named it HMChem)
- Perform similar actions for remaining streams



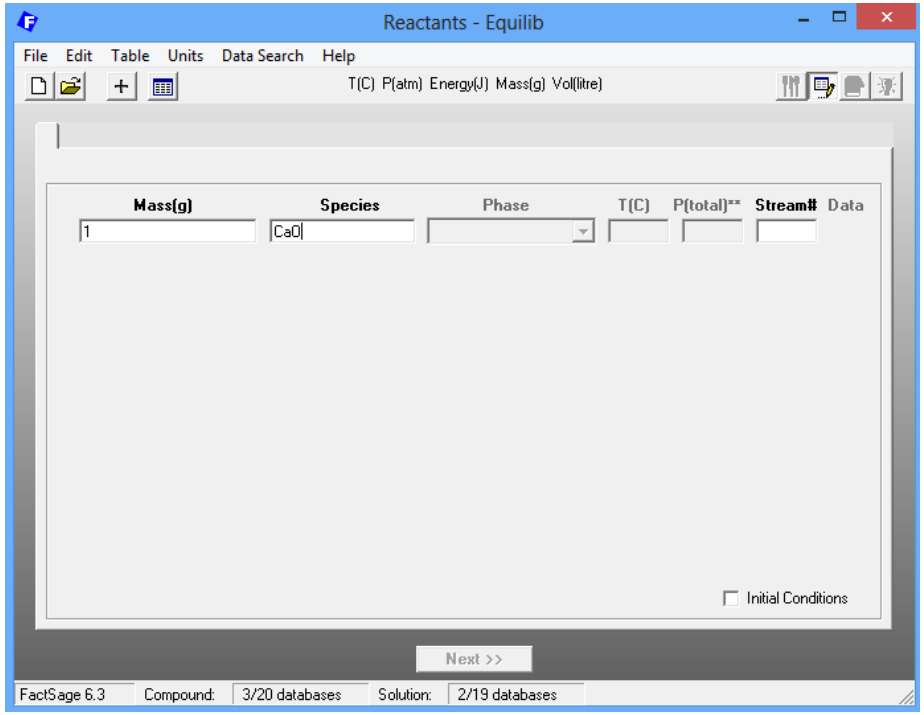


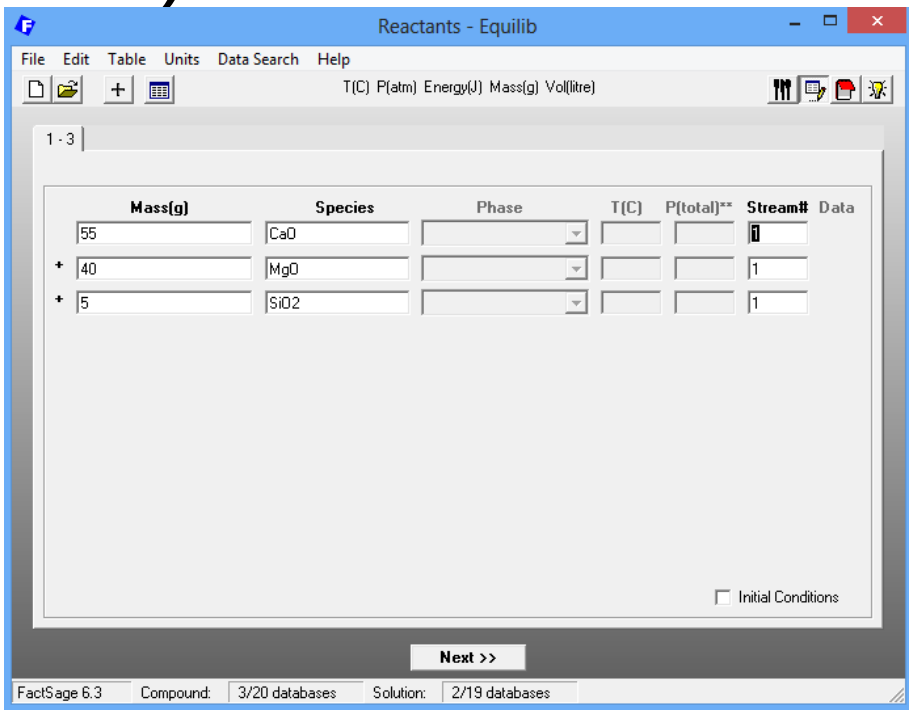
- This time 25C was chosen
- Along with BCC from FSstel



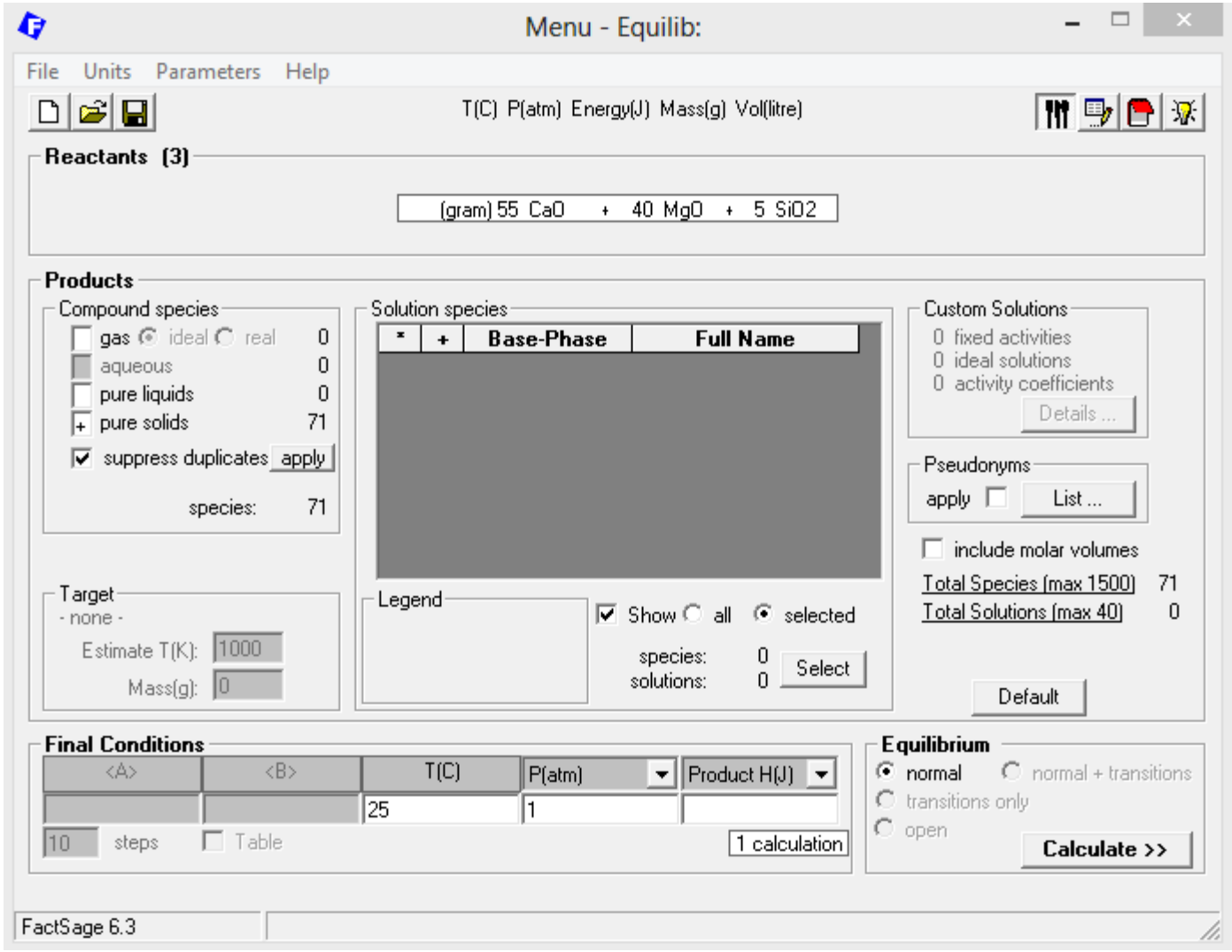
Adding Lime

- You now have two streams (I've named them HMChem and Scrap)
- Now we need two more streams (1 for dolo lime and one for burnt lime)

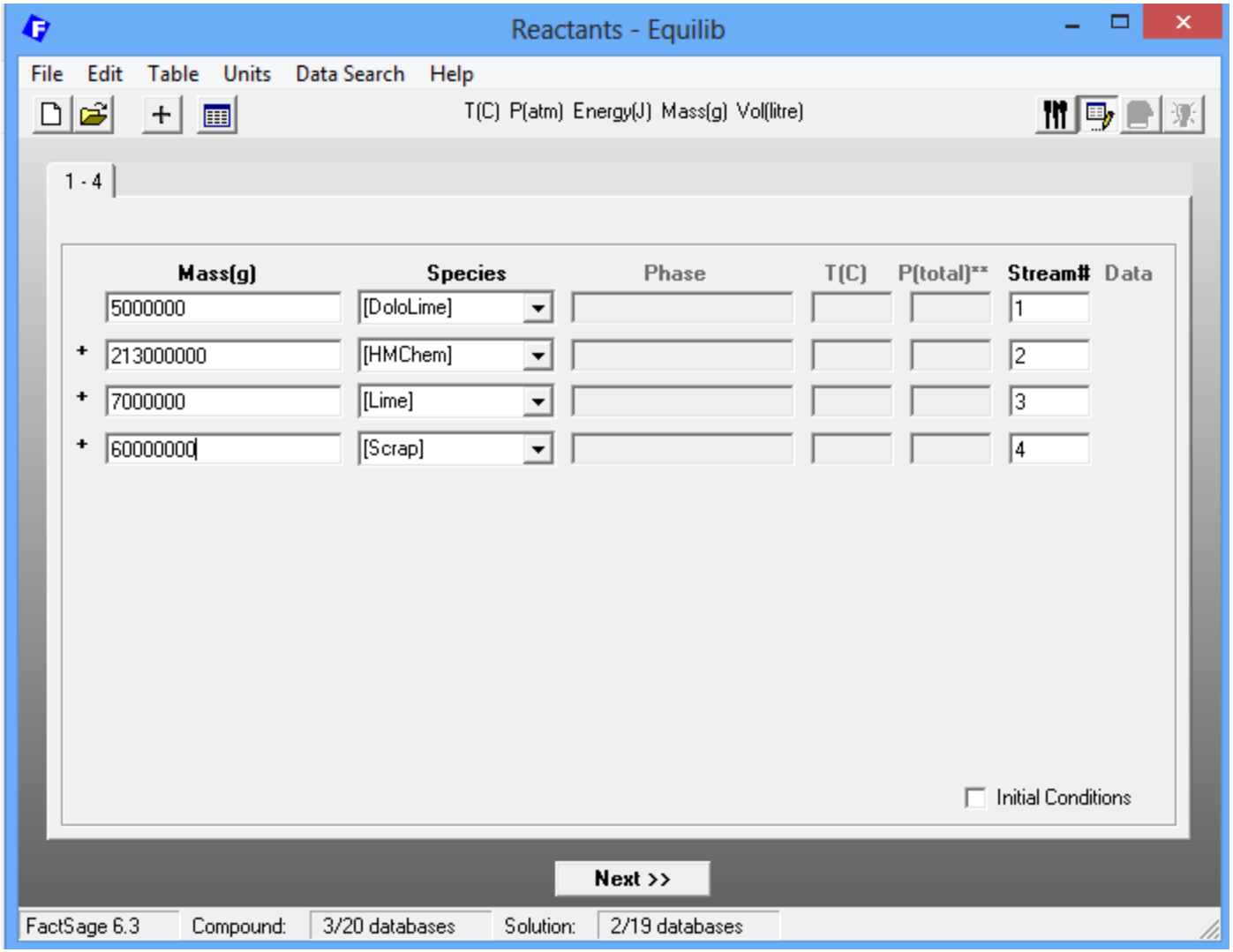




Pure Solids


Menu - Equilib:
File Units Parameters Help
T(C) P(atm) Energy(J) Mass(g) Vol(litre)
Reactants (3)
(gram) 55 CaO + 40 MgO + 5 SiO2
Products
Compound species
gas ideal real 0
aqueous 0
pure liquids 0
pure solids 71
suppress duplicates apply
species: 71
Solution species
* + Base-Phase Full Name
Custom Solutions
0 fixed activities
0 ideal solutions
0 activity coefficients
Details ...
Pseudonyms
apply List ...
include molar volumes
Total Species (max 1500) 71
Total Solutions (max 40) 0
Target
- none -
Estimate T(K): 1000
Mass(g): 0
Legend
Show all selected
species: 0
solutions: 0
Select
Default
Final Conditions
<A> <B> T(C) P(atm) Product H(J)
25 1
10 steps Table
1 calculation
Equilibrium
normal normal + transitions
transitions only
open
Calculate >>
FactSage 6.3

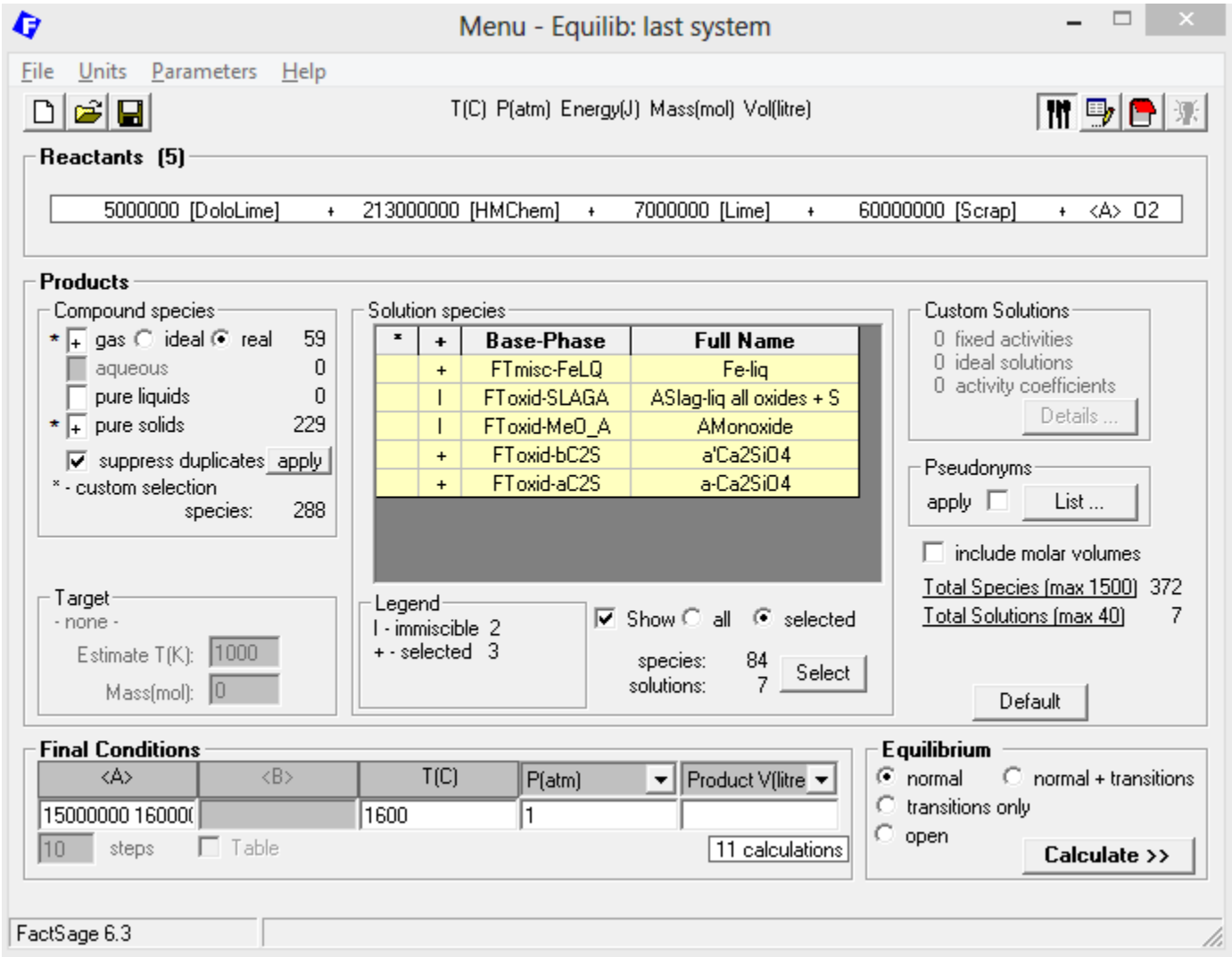
Combine Mixtures with Weights



Add Variable Oxygen

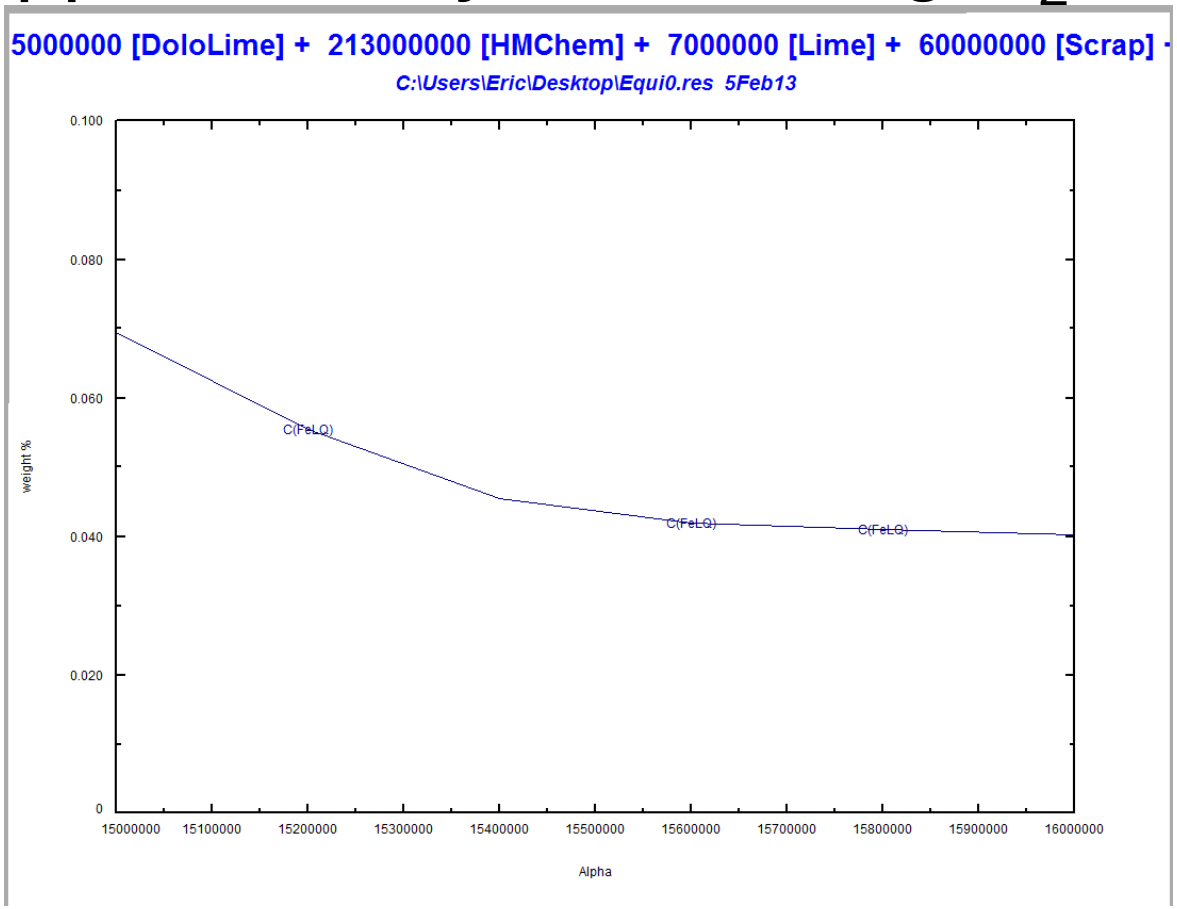
Adding variable oxygen
Solutions chosen
-Iron liquid
-Liquid slag
-Calcium Silicate
-Monoxides

Amount of oxygen
-Educated guess



Limit of Oxygen Blowing

- Aiming for 500ppm (or 0.05 wt% C in FeLQ)
- Occurs at approximately 15300000g O_2



Products

- Gas
- Fe liquid
- a-Ca2SiO4
- Amonoxide#1
- Amonoxide#2

```
+ 2.6063E+08 gram  Fe-liq
  (2.6063E+08 gram, 4.6801E+06 mol)
        (1600 C, 1 atm,      a=1.0000)
        ( 99.675      wt.% Fe
        + 4.9950E-02 wt.% C
        + 2.5290E-09 wt.% Ca
        + 1.6186E-02 wt.% Cr
        + 0.21547     wt.% Mn
        + 3.7013E-02 wt.% O
        + 2.1753E-03 wt.% S
        + 1.2811E-06 wt.% Si
        + 6.7243E-08 wt.% Ti
        + 4.0606E-07 wt.% Mg
        + 1.0582E-03 wt.% MgO
        + 1.4818E-03 wt.% CaO
        + 5.0430E-08 wt.% TiO
        + 3.2375E-04 wt.% CrO
        + 2.6259E-09 wt.% SiO
        + 1.3664E-03 wt.% MnO
        + 4.5965E-07 wt.% Cr2O
        + 1.2129E-15 wt.% Ti2O
```

```
+ 9.0432E+05 gram  ASlag-liq#1
  (9.0432E+05 gram, 15123. mol)
        (1600 C, 1 atm,      a=1.0000)
        ( 17.638      wt.% SiO2
        + 54.355      wt.% CaO
        + 6.2383      wt.% FeO
        + 0.15336     wt.% Fe2O3
        + 4.0114      wt.% MgO
        + 1.6328      wt.% MnO
        + 2.2442E-02 wt.% CrO
        + 5.8106E-02 wt.% Cr2O3
        + 9.6847E-02 wt.% Ti2O3
        + 15.773      wt.% TiO2
        + 2.9364E-03 wt.% Mn2O3
        + 3.4781E-03 wt.% SiS2
        + 8.9846E-03 wt.% CaS
        + 9.8076E-04 wt.% FeS
        + 2.5652E-05 wt.% Fe2S3
        + 7.2084E-04 wt.% MgS
        + 2.5731E-04 wt.% MnS
        + 3.5647E-06 wt.% CrS
        + 9.8331E-06 wt.% Cr2S3
        + 1.6616E-05 wt.% Ti2S3
        + 2.8419E-03 wt.% TiS2
        + 4.9246E-07 wt.% Mn2S3
```

Solids are forming already (at 1600C)
Slag in a BOF typically >100C hotter than melt

```
+ 2.3745E+06 gram  AMonoxide#2
  (2.3745E+06 gram, 50553. mol)
        (1600 C, 1 atm,      a=1.0000)
        ( 13.341      wt.% FeO
        + 0.11941     wt.% Fe2O3
        + 1.9438      wt.% CaO
        + 67.136      wt.% MgO
        + 16.927      wt.% MnO
        + 0.53103     wt.% Cr2O3
        + 9.7763E-04 wt.% TiO2
```

```
+ 6.2565E+06 gram  AMonoxide#1
  (6.2565E+06 gram, 1.0951E+05 mol)
        (1600 C, 1 atm,      a=1.0000)
        ( 3.8730      wt.% FeO
        + 0.12320     wt.% Fe2O3
        + 78.398      wt.% CaO
        + 4.7469      wt.% MgO
        + 12.679      wt.% MnO
        + 0.18018     wt.% Cr2O3
        + 6.6229E-04 wt.% TiO2
```

```
FToxid
FToxid
FToxid
FToxid
FToxid
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FToxid)
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FToxid
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FToxid
FToxid)
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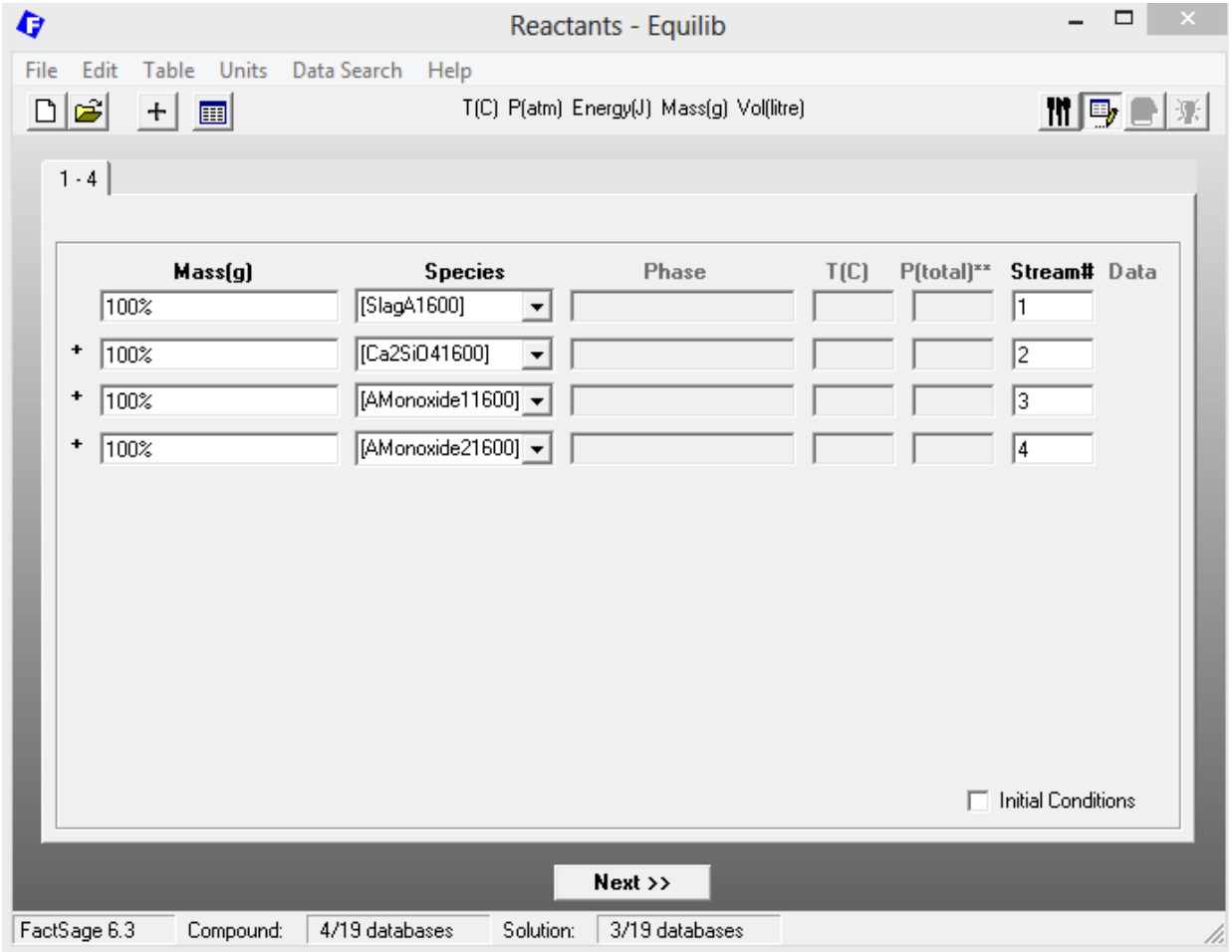
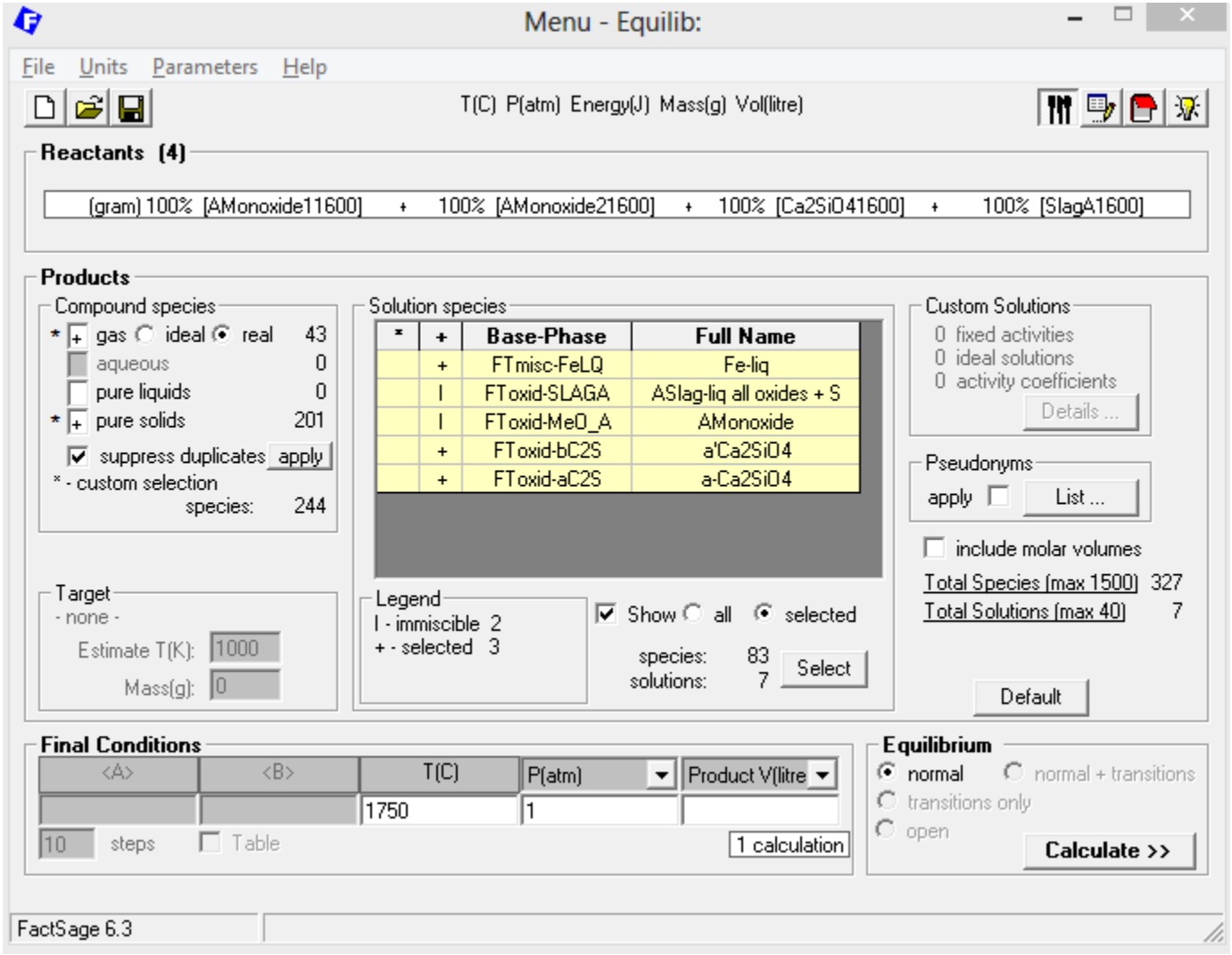
```
+ 6.7623E+06 gram  a-Ca2SiO4
  (6.7623E+06 gram, 39391. mol)
        (1600 C, 1 atm,      a=1.0000)
        ( 1.7890      wt.% Mg2SiO4
        + 97.731      wt.% Ca2SiO4
        + 0.28042     wt.% Mn2SiO4
        + 0.19931     wt.% Fe2SiO4
```

- Save all oxide products as streams



Calculate at 1750C



Examining Products

```
+ 5.9733E+06 gram  AMonoxide#1
  (5.9733E+06 gram, 1.0588E+05 mol)
          (1750 C, 1 atm,      a=1.0000)
          ( 2.1965      wt.% FeO                FToxid
          + 4.5933E-02  wt.% Fe2O3              FToxid
          + 76.999      wt.% CaO                FToxid
          + 7.1776      wt.% MgO                FToxid
          + 13.455      wt.% MnO                FToxid
          + 0.12513     wt.% Cr2O3              FToxid
          + 4.6990E-04  wt.% TiO2               FToxid)

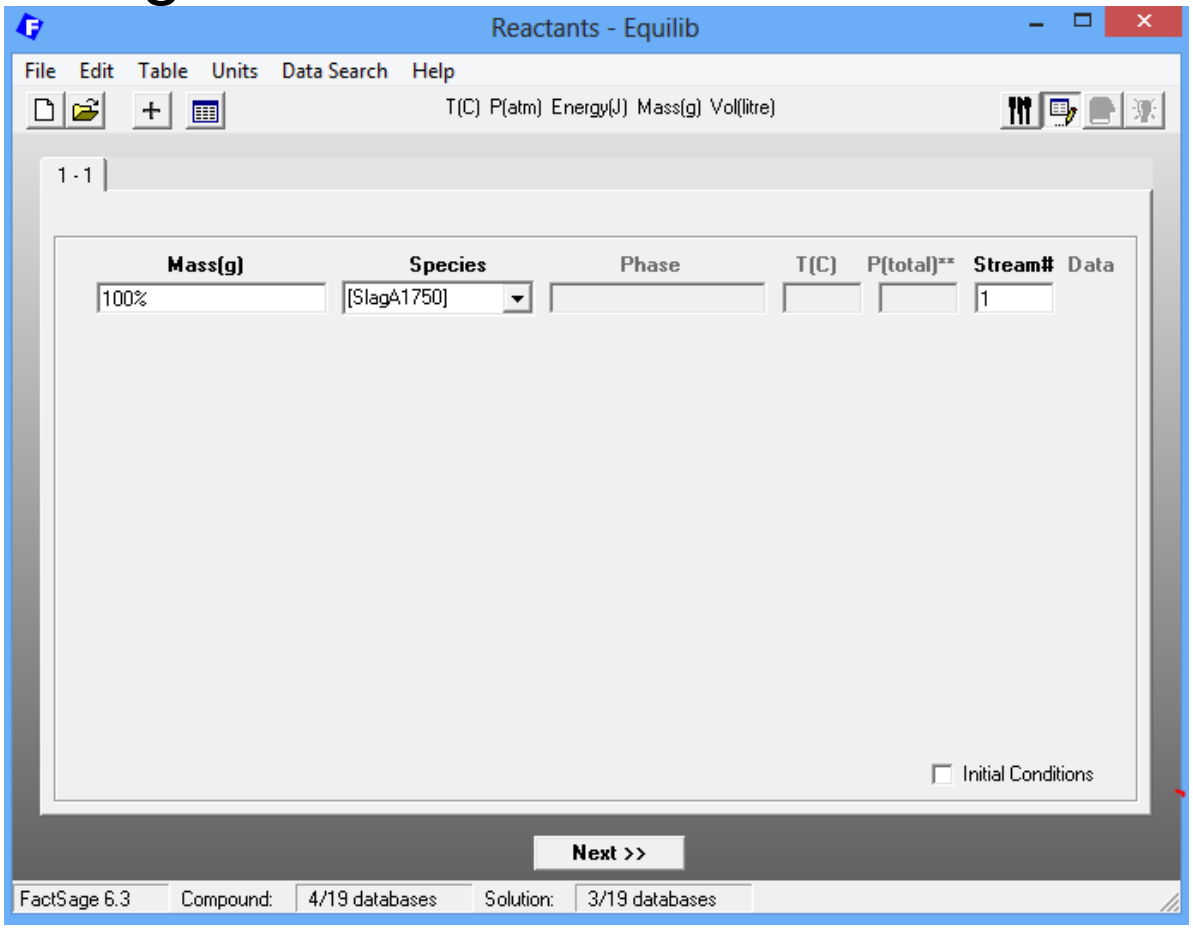
+ 1.7833E+06 gram  AMonoxide#2
  (1.7833E+06 gram, 39352. mol)
          (1750 C, 1 atm,      a=1.0000)
          ( 6.7838      wt.% FeO                FToxid
          + 4.2044E-02  wt.% Fe2O3              FToxid
          + 2.5646      wt.% CaO                FToxid
          + 73.913      wt.% MgO                FToxid
          + 16.301      wt.% MnO                FToxid
          + 0.39407     wt.% Cr2O3              FToxid
          + 5.5205E-04  wt.% TiO2               FToxid)

+ 4.2816E+06 gram  a-Ca2SiO4
  (4.2816E+06 gram, 24958. mol)
          (1750 C, 1 atm,      a=1.0000)
          ( 2.0871      wt.% Mg2SiO4            FToxid
          + 97.460      wt.% Ca2SiO4            FToxid
          + 0.30432     wt.% Mn2SiO4            FToxid
          + 0.14828     wt.% Fe2SiO4            FToxid)

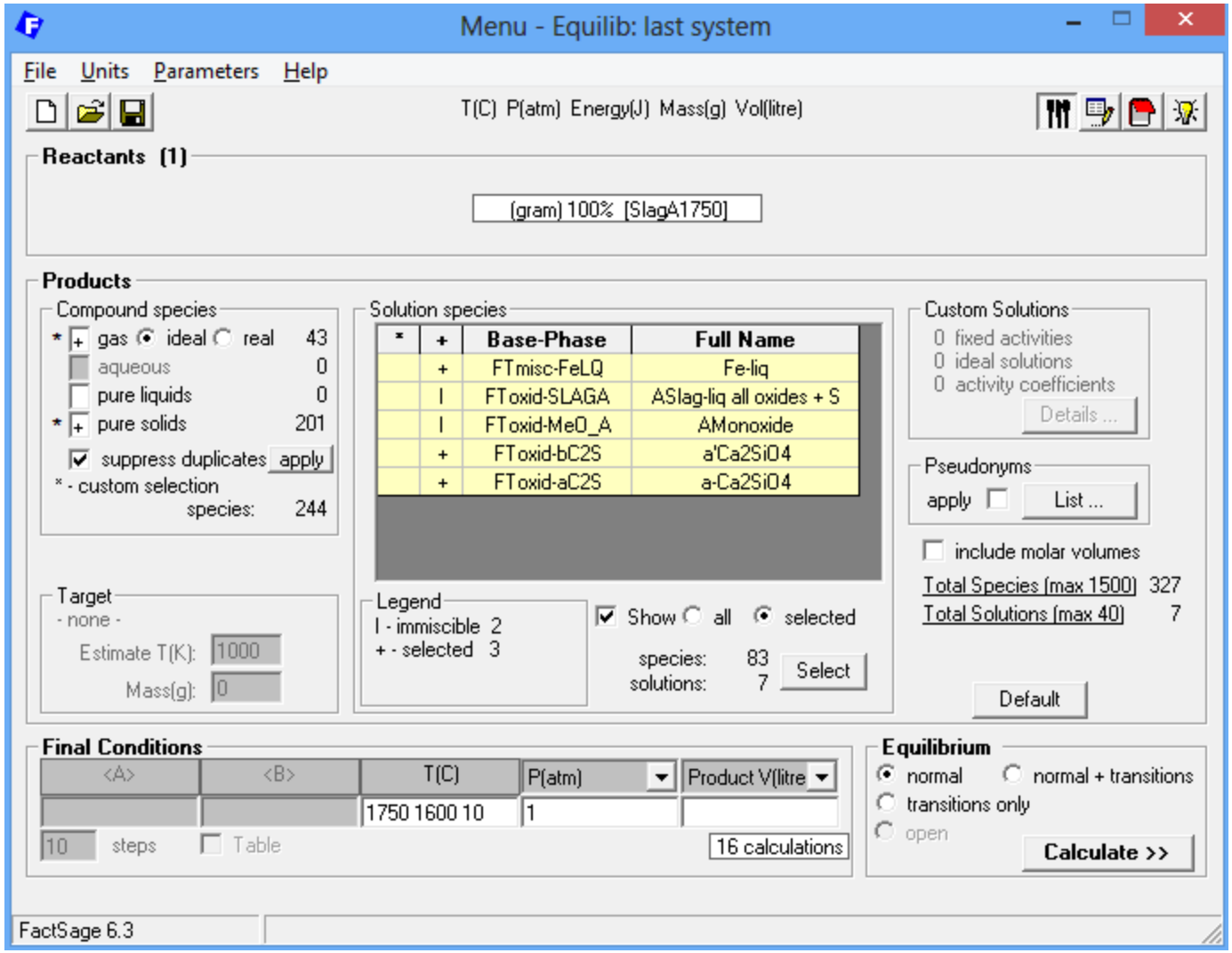
+ 4.2593E+06 gram  ASlag-liq#1
  (4.2593E+06 gram, 73209. mol)
          (1750 C, 1 atm,      a=1.0000)
          ( 24.104      wt.% SiO2
          + 55.966      wt.% CaO
          + 8.5096      wt.% FeO
          + 0.34639     wt.% Fe2O3
          + 4.6657      wt.% MgO
          + 2.7993      wt.% MnO
          + 6.5583E-02  wt.% CrO
          + 0.16459     wt.% Cr2O3
          + 8.9577E-02  wt.% Ti2O3
          + 3.2731      wt.% TiO2
          + 1.1991E-02  wt.% Mn2O3
          + 1.0084E-03  wt.% SiS2
          + 1.9626E-03  wt.% CaS
          + 2.8383E-04  wt.% FeS
          + 1.2292E-05  wt.% Fe2S3
          + 1.7788E-04  wt.% MgS
          + 9.3587E-05  wt.% MnS
          + 2.2101E-06  wt.% CrS
          + 5.9091E-06  wt.% Cr2S3
          + 3.2605E-06  wt.% Ti2S3
          + 1.2512E-04  wt.% TiS2
          + 4.2666E-07  wt.% Mn2S3
```

- Still a large amount of solid oxide
- Over-saturation of MgO and CaO

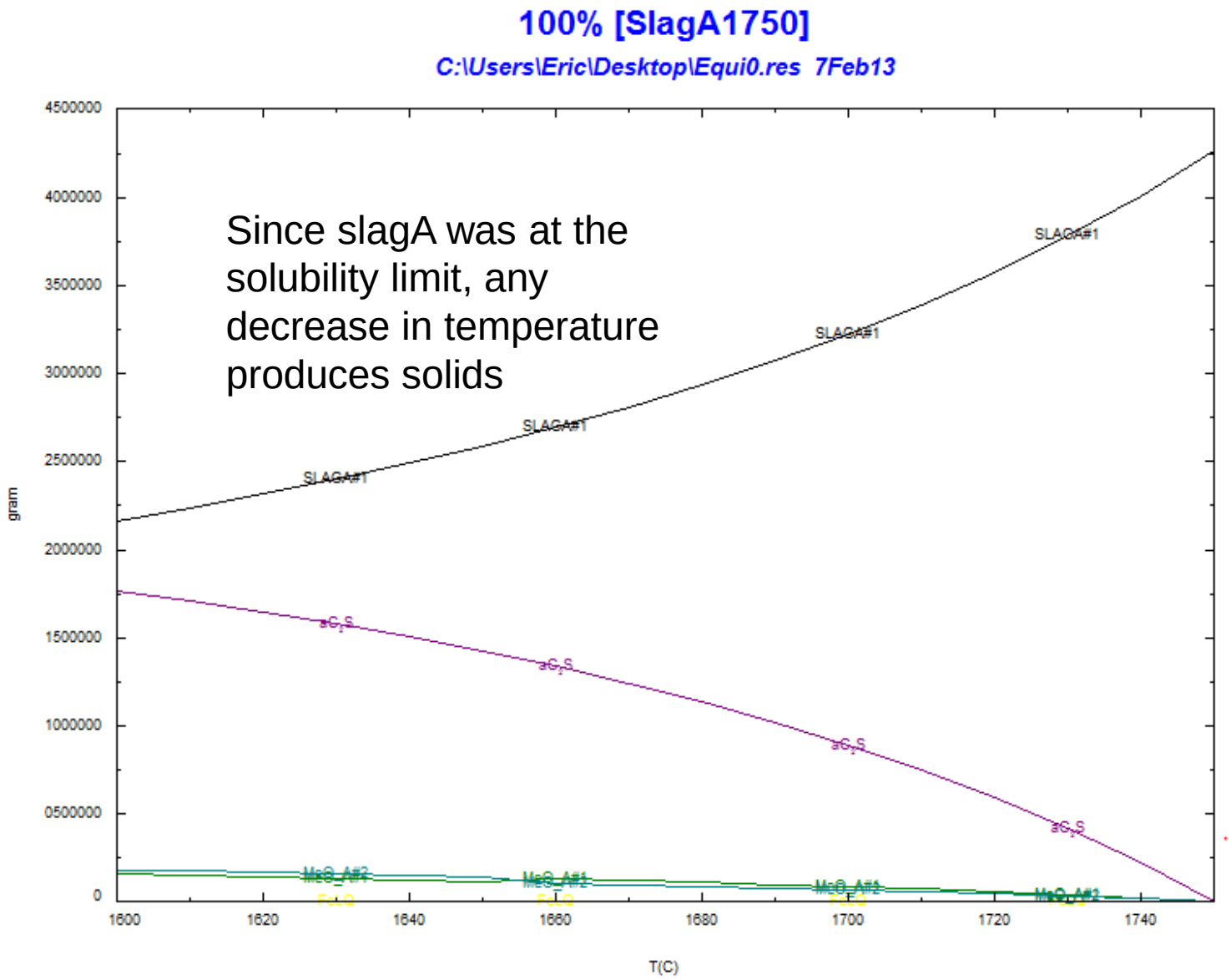
- Ignore the current solid products
  - Take SlagA as a stream and determine melting T



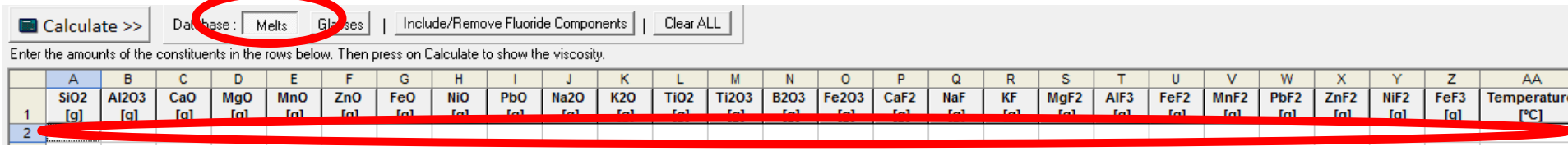
Multiple Temperatures



Plot Results of Solids Formed



Based on Criteria Select Temperature



- Enter slag composition and temperature
  - Obtain viscosity