Cu smelting process

Case- 8 Copper extraction

Chemical assay of the copper concentrate:

Comp	Cu	Fe	S	SiO_2	Al_2O_3	CaO	MgO	Sb	Pb	Cr	Zn	P	Ti	Mn
Wt-%	32	24	28	9	2	1	1	0.8	0.5	0.3	1	0.1	0.1	0.2

The flux is (98%SiO_2 + 1%CaO + 1%Al_2O_3).

Oxygen enriched air (35% oxygen) is used.

The operational temperature is ~1250°C. Nitrogen is used for temperature control.

The desired matte grade (Cu% in matte) is 60%.

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FTmisc for non-ferrous smelting process

(2) The matte smelting system (S-Cu-Fe-Ni-Co-Pb-Zn-As)

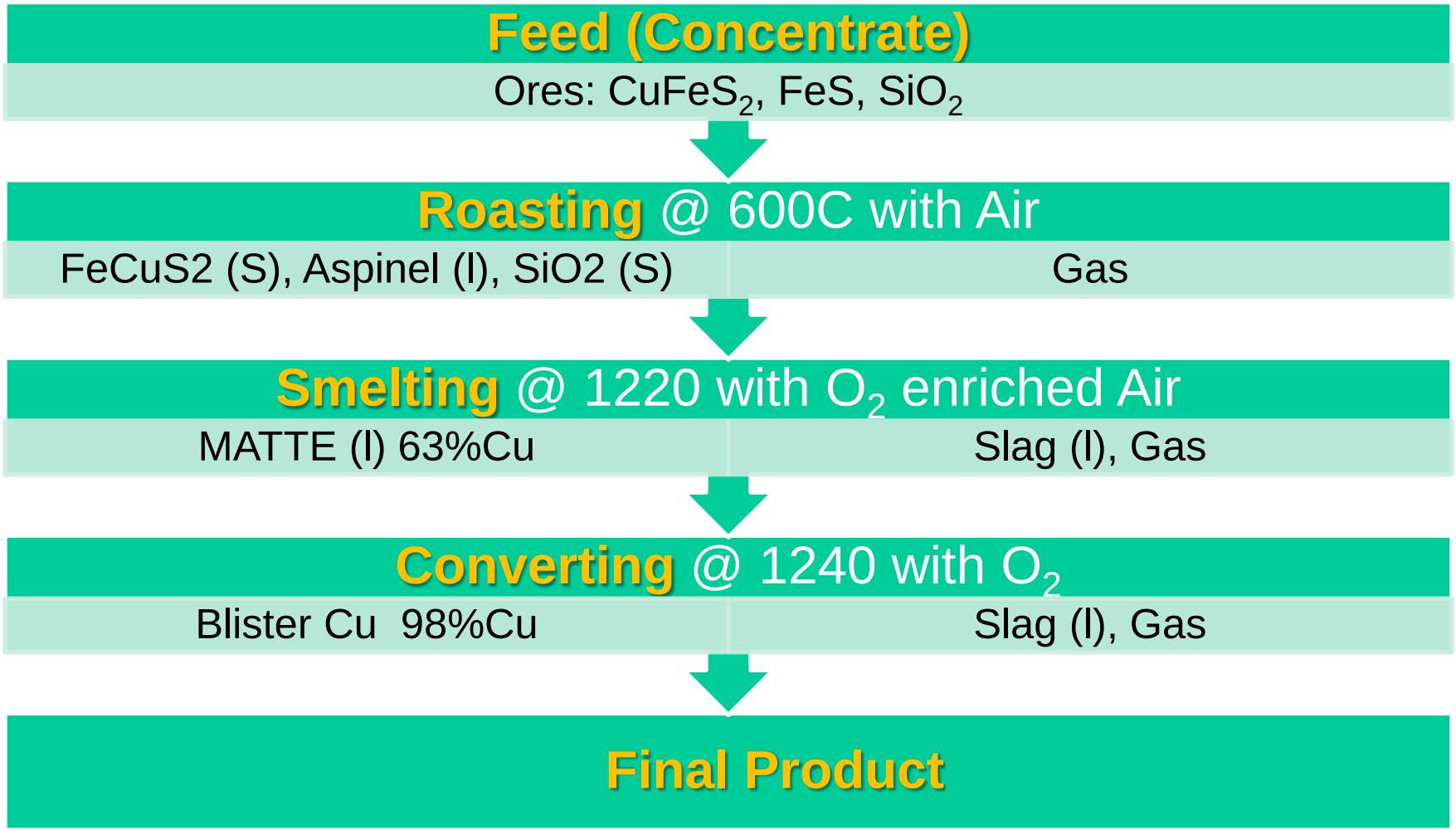
This system has been evaluated and optimized [4006, 4007, 4008, 4009, 4010, 6019] mainly for matte/slag/metal/speiss equilibrium calculations involved in Cu-, Pb- and Zn-smelting and processing.

- The following solutions and compounds form a thermodynamically self-consistent set of phases which are designed to be used together (and with FToxid-SLAG and the gas phase from the FACT53 database.) Users are urged to read the descriptions of each of these phases under “Description of solutions.”
  - Liquid matte [FTmisc-MATT] – S-Cu-Fe-Ni-Co-Pb-Zn-As
  - Liquid copper or speiss [FTmisc-CuLQ] – Cu-Pb-Zn-As-Fe-Ni-Au-S-O
  - Fe-Cu [FTmisc-FeCu] – fcc solution
  - Sphalerite [FTmisc-SPHA] – Solid ZnS with FeS in solution
  - Wurtzite [FTmisc-WURT] – Solid ZnS with FeS in solution
  - Cu_2S-PbS-ZnS [FTmisc-Cu2S] – solid solution
  - Liquid Pb [FTmisc-PbLQ] – Liquid Pb with 12 alloying elements

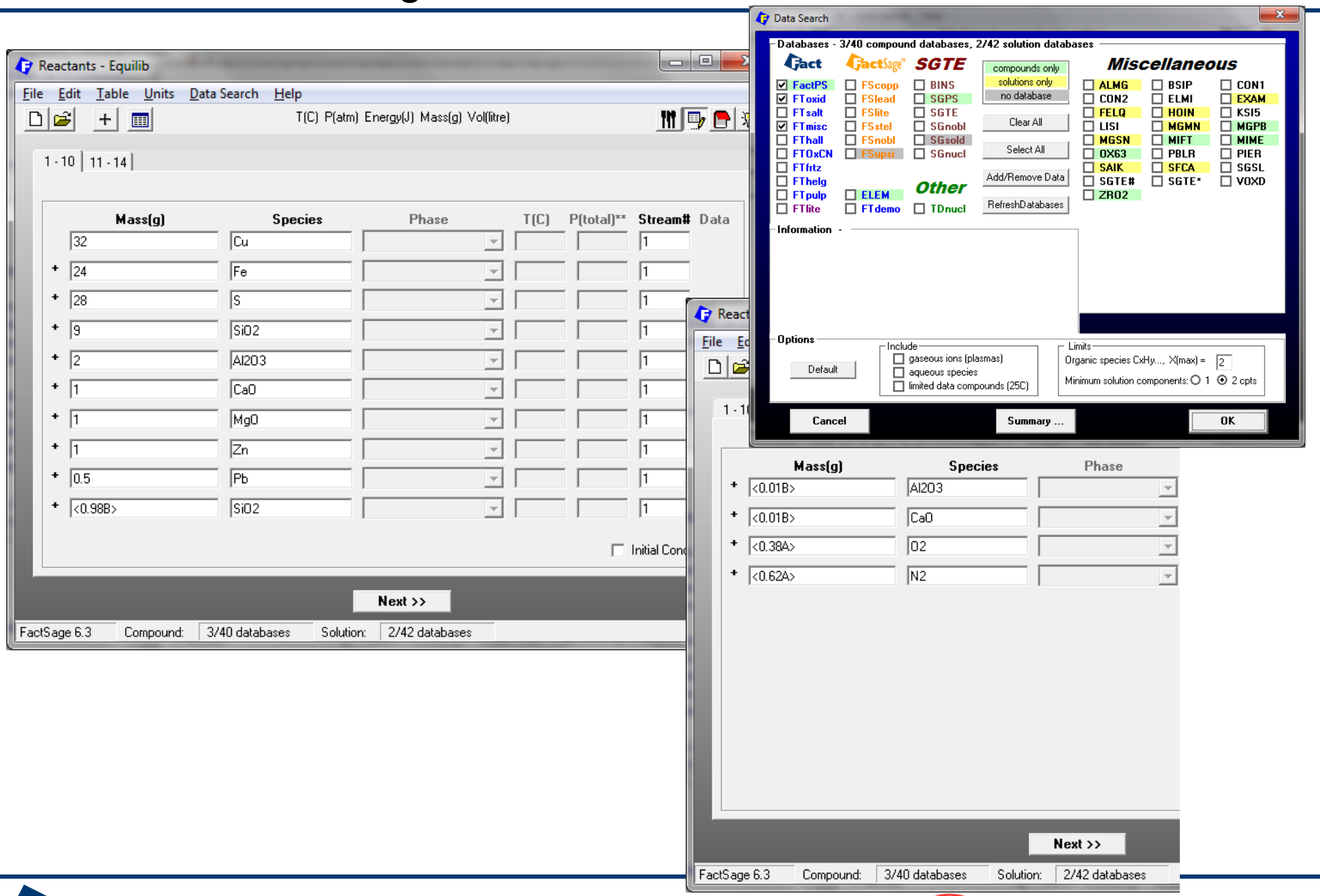
Cu smelting and converting processes

- Roasting
  - Dry and heat the furnace charge
  - Increase Cu_2S : FeS
- Smelting
  - Produce copper rich matte
  - Separate matter and slag
  - $2CuFeS_2 + 5/2O_2 + SiO_2 = Cu_2S\text{-}\ FeS + FeO.SiO_2 + 2\ SO_2$
- Converting
  - Remove Fe and S from matte and produce blister copper
  - $Cu\text{-}Fe\text{-}S + O_2 + SiO_2 = Cu_{impure} + 2\ FeO.SiO_2 - Fe_3O_4 + SO_2$

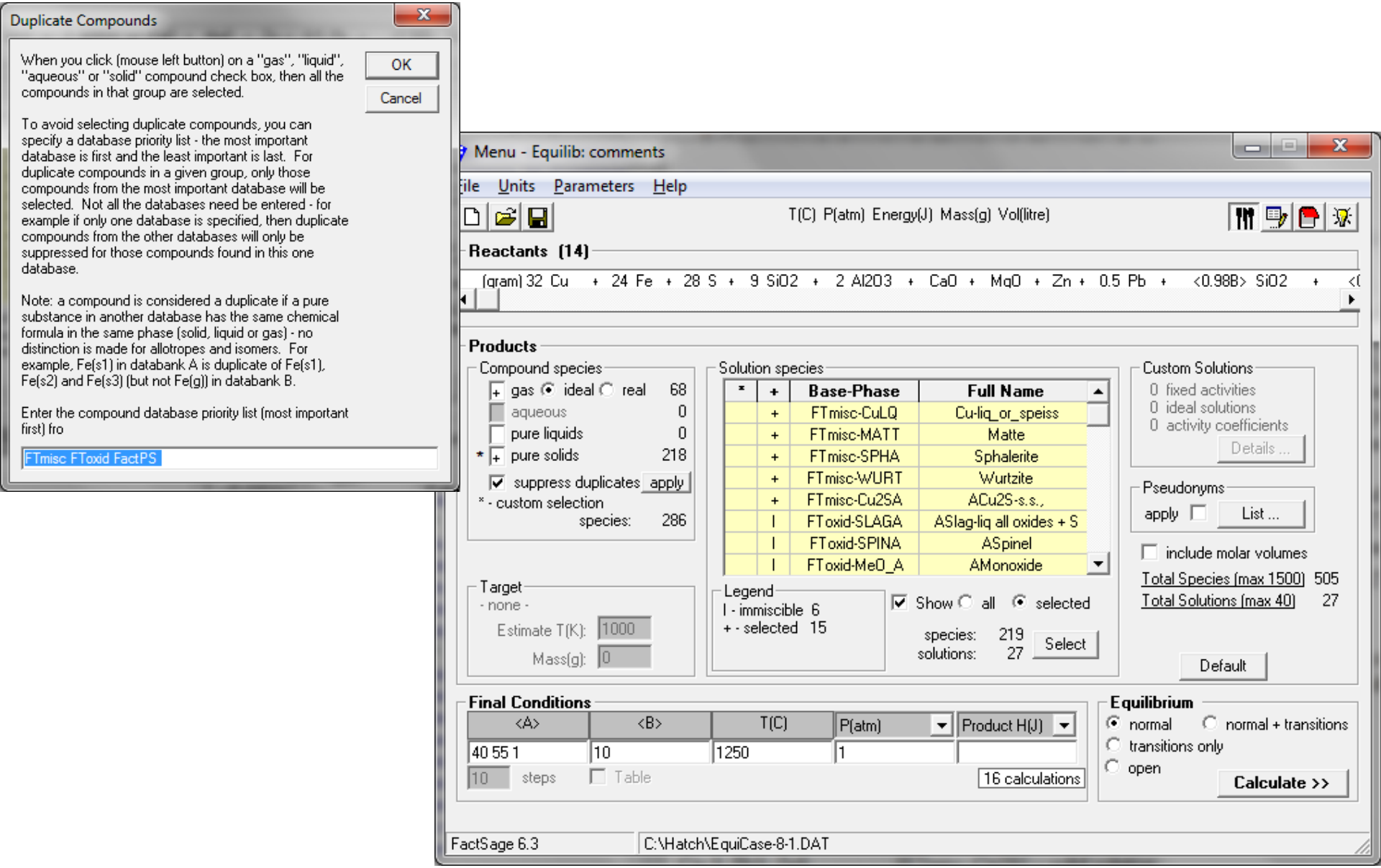
Flow Chart


Feed (Concentrate)
Ores: $CuFeS_2$, FeS, SiO_2
Roasting @ 600C with Air
FeCuS2 (S), Aspinel (l), SiO2 (S)
Gas
Smelting @ 1220 with O_2 enriched Air
MATTE (l) 63%Cu
Slag (l), Gas
Converting @ 1240 with O_2
Blister Cu 98%Cu
Slag (l), Gas
Final Product

Smelting: Database Selection / Reactants



Smelting: Selection of phases



Results

Results - Equilib A=47 (page 8/16)

Output Edit Show Pages

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

A=54 | A=55

A=40 | A=41 | A=42 | A=43 | A=44 | A=45 | A=46 | - A=47 - | A=48 | A=49 | A=50 | A=51 | A=52 | A=53

```
(gram) 32 Cu +  24 Fe +  28 S +  9 SiO2 +

(gram) 2 Al2O3 +  CaO +  MgO +  Zn +

(gram) 0.5 Pb +  <0.98(10)> SiO2 +  <0.01(10)> Al2O3 +  <0.01(10)> CaO +

(gram) <0.38A> O2 +  <0.62A> N2 =

 1.4728     mol   gas_ideal
 (56.975 gram, 1.4728 mol, 184.08 litre, 3.0951E-04 gram/cm3)
         (1250 C, 1 atm,     a=1.0000)
         ( 0.70628         N2                                    FactPS
         + 0.28017         SO2                                   FactPS
         + 1.0117E-02      S2                                    FactPS
         + 1.6758E-03      SO                                    FactPS
         + 8.5659E-04      SS                                    FactPS
         + 5.1513E-04      Pb                                    FactPS
         + 3.3973E-04      Zn                                    FactPS
         + 2.4775E-05      Pb                                    FactPS
         + 1.0105E-05      S3                                    FactPS
         + 5.3496E-06      S                                     FactPS
         + 2.1274E-06      PbO                                   FactPS
         + 1.8948E-06      CuS                                   FactPS
         + 1.0461E-06      Cu                                    FactPS
         + 7.9114E-07      SO3                                   FactPS
         + 5.9805E-07      ZnS                                   FactPS
         + 2.5735E-07      NO                                    FactPS
         + 5.8996E-08      NS                                    FactPS
         + 3.1239E-08      S4                                    FactPS
         + 7.0877E-09      O2                                    FactPS
         + 3.5371E-09      FeS                                   FactPS
         + 2.0047E-09      Fe                                    FactPS
         + 4.6243E-10      O                                     FactPS
         + 2.6605E-10      FeO                                   FactPS
         + 7.8804E-11      SiO                                   FactPS
         + 4.1632E-11      Cu2                                   FactPS
         + 1.7218E-11      CuO                                   FactPS
         + 1.4608E-11      S5                                    FactPS
         + 1.4431E-11      SiO2                                  FactPS
         + 1.3126E-11      N2O                                   FactPS
         + 9.8412E-12      Pb2                                   FactPS
         + 1.6347E-12      SiS                                   FactPS
```

Gas composition

In order to change this matte grade, we can change the amounts of flux <B> and gas (oxygen) <A>

Matte composition

```
+ 54.314     gram  Matte
  (54.314 gram, 1.0766 mol)
         (1250 C, 1 atm,     a=1.0000)
         ( 24.650     wt.% S                                  C FTmisc
         + 15.418     wt.% Fe                                   FTmisc
         + 58.710     wt.% Cu                                   FTmisc
         + 0.72112    wt.% Zn                                   FTmisc
         + 0.50117    wt.% Pb                                   FTmisc)

         System component       Mole fraction  Mass fraction
         Pb                       1.2203E-03     5.0117E-03
         Zn                       5.5644E-03     7.2112E-03
         Cu                       0.46610        0.58710
         Fe                       0.13928        0.15418
         S                        0.38783        0.24650
```

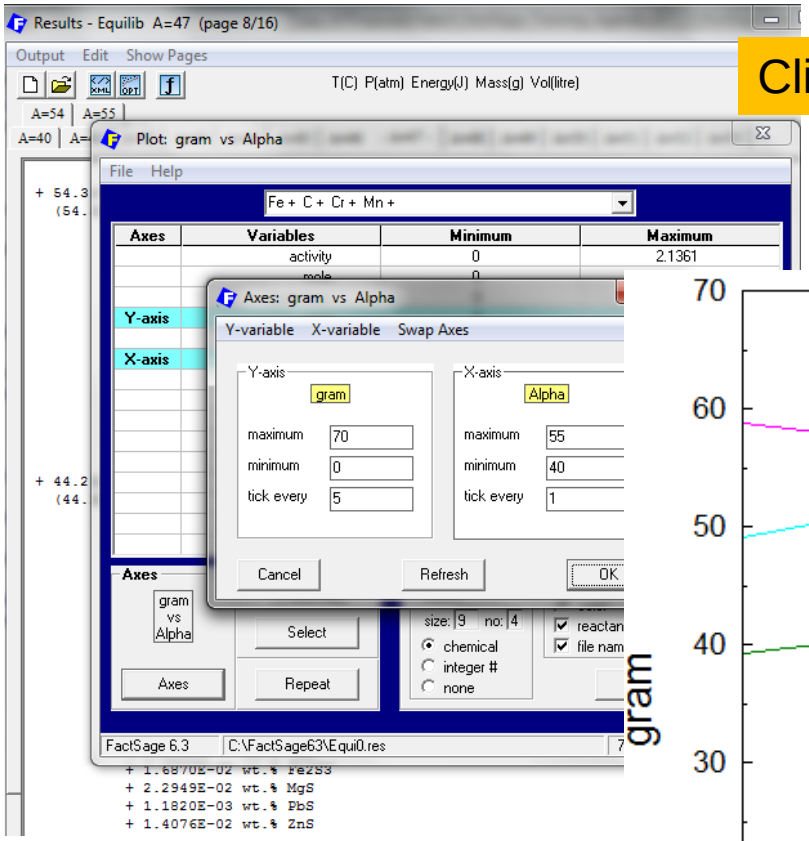
Slag composition

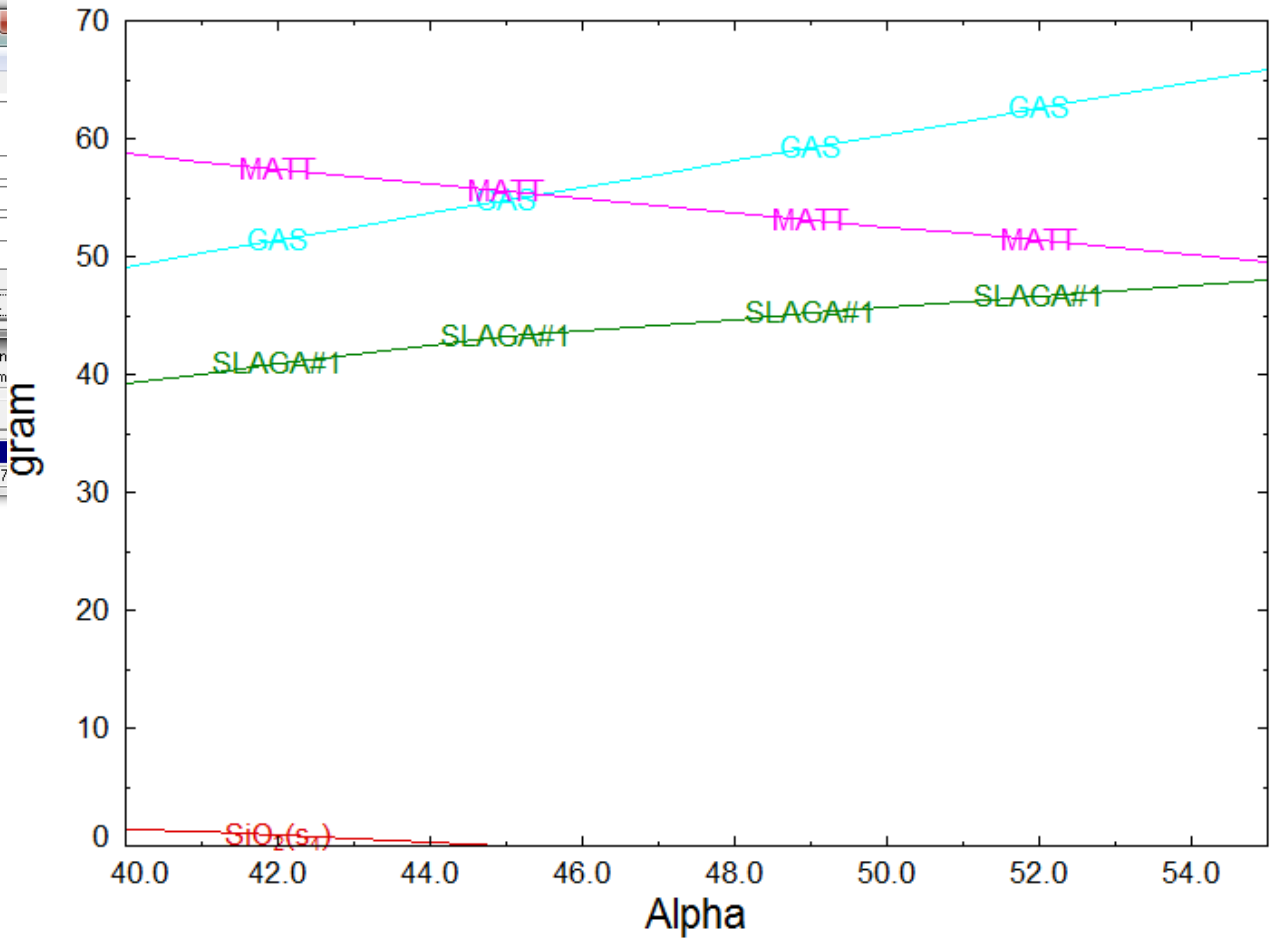
```
+ 44.211     gram  ASlag-liq#1
  (44.211 gram, 0.66276 mol)
         (1250 C, 1 atm,     a=1.0000)
         ( 4.7155     wt.% Al2O3                                FToxid
         + 42.215     wt.% SiO2                                 FToxid
         + 2.4700     wt.% CaO                                  FToxid
         + 43.544     wt.% FeO                                  FToxid
         + 1.7734     wt.% Fe2O3                                FToxid
         + 2.2455     wt.% MgO                                  FToxid
         + 0.15090    wt.% PbO                                  FToxid
         + 1.6087     wt.% ZnO                                  FToxid
         + 0.28257    wt.% Cu2O                                 FToxid
         + 5.0745E-02 wt.% Al2S3                                FToxid
         + 0.47344    wt.% SiS2                                 FToxid
         + 2.3220E-02 wt.% CaS                                  FToxid
         + 0.38934    wt.% FeS                                  FToxid
         + 1.6870E-02 wt.% Fe2S3                                FToxid
         + 2.2949E-02 wt.% MgS                                  FToxid
         + 1.1820E-03 wt.% PbS                                  FToxid
         + 1.4076E-02 wt.% ZnS                                  FToxid
         + 2.2967E-03 wt.% Cu2S                                 FToxid)

         Site fraction of sublattice constituents:
         Al                       5.9769E-02
         Si                       0.45401
```

Results: Overview of products

Click: Output → Plot → Plot Results →





Results: Cu matte grade

Species Selection - EQUILIB Results: weight % vs Alpha

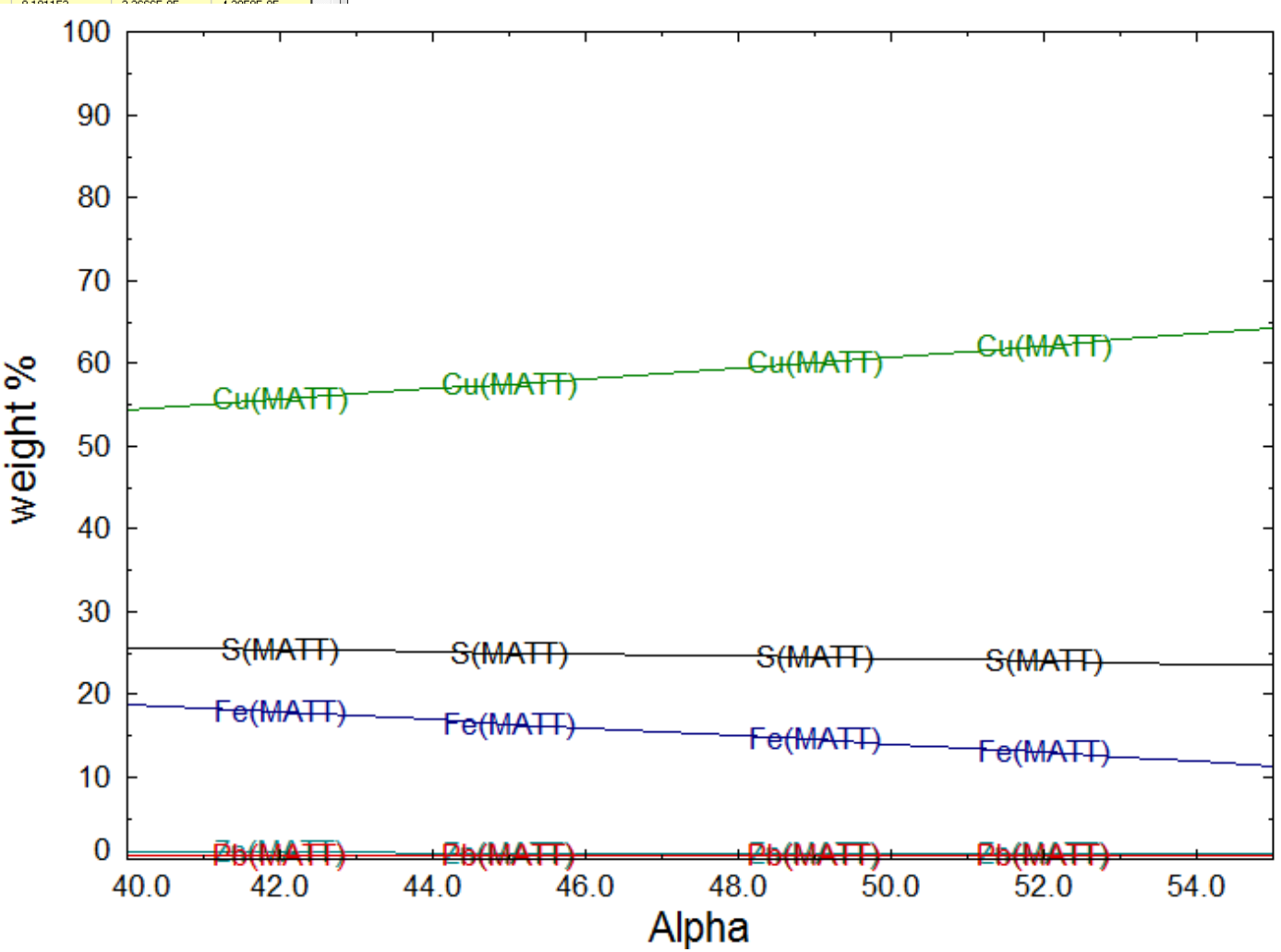
File Show Select

+	#	Species	Gram (min)	Gram (max)	Wt.% (min)	Wt.% (max)	Activity (min)	Activity (max)
	FTmisc	CuLQ						
	69	Pb(CuLQ)	0	0	2.1755E-03	2.8492E-03	7.0045E-04	1.0472E-03
	70	Cu(CuLQ)	0	0	75.75	79.764	7.4191E-02	0.111982
	71	Fe(CuLQ)	0	0	4.175	7.4521	6.1199E-03	6.3985E-03
	72	S(CuLQ)	0	0	15.9	16.6	4.4232E-03	7.2394E-03
	73	Zn(CuLQ)	0	0	2.3149E-03	3.9770E-03	2.4706E-05	2.7017E-05
	74	O(CuLQ)	0	0	0.156503			
	FTmisc	MATT						
+	75	S(MATT)	11.633	15.02	23.464			
+	76	Fe(MATT)	5.5697	10.995	11.235			
+	77	Cu(MATT)	31.844	31.916	54.35			
+	78	Zn(MATT)	0.289828	0.491775	0.584611			
+	79	Pb(MATT)	0.240215	0.30112	0.484536			
	FTmisc	SPHA						
	80	ZnS(SPHA)	0	0	14.322			
	81	FeS(SPHA)	0	0	83.869			
	FTmisc	WURT						
	82	ZnS(WURT)	0	0	20.902			
	83	FeS(WURT)	0	0	76.696			
	FTmisc	Cu2S						
	84	PbS(Cu2SA)	0	0	8.3055E-02			
	85	Cu2S(Cu2SA)	0	0	97.435			
	86	ZnS(Cu2SA)	0	0	1.4404			
	FToxid	SLAG						
	87	Al2O3(SLAGA#1)	2.0832	2.087	4.3449			
	88	SiO2(SLAGA#1)	17.201	18.684	38.897			
	89	CaO(SLAGA#1)	1.0912	1.0932	2.2759			

source [page] Mass: mole gram Order

Clear 16 pages

Click on the '+' column to add or remove species.



Results: Slag composition

Species Selection - EQUILIB Results: weight % vs Alpha

File Show Select

+	#	Species	Gram (min)	Gram (max)	Wt.% (min)	Wt.% (max)	Activity (min)	Activity (max)
	84	PbS(Cu2SA)	0	0	8.3055E-02	0.106657	2.1640E-04	2.3691E-04
	85	Cu2S(Cu2SA)	0	0	97.435	98.477	0.433446	0.603325
	86	ZnS(Cu2SA)	0	0	1.4404	2.4586	1.7165E-02	2.5737E-02
	FToxid-	SLAG						
+	87	Al2O3(SLAGA#1)	2.0832	2.087	4.3449	5.3148	4.2677E-04	5.6021E-04
+	88	SiO2(SLAGA#1)	17.201	18.684	38.897	43.886	0.675601	0.835017
+	89	CaO(SLAGA#1)	1.0912	1.0932	2.2759	2.7839	1.7084E-06	2.3986E-06
+	90	FeO(SLAGA#1)	16.106	22.436	41.091			
+	91	Fe2O3(SLAGA#1)	0.546017	1.2529	1.393			
+	92	MgO(SLAGA#1)	0.991983	0.993809	2.069			
+	93	PbO(SLAGA#1)	5.6579E-02	7.9408E-02	0.144349			
+	94	ZnO(SLAGA#1)	0.593498	0.828118	1.5142			
+	95	Cu2O(SLAGA#1)	9.3128E-02	0.174412	0.237597			
+	96	Al2S3(SLAGA#1)	1.9146E-02	2.4793E-02	3.9860E-02			
+	97	SiS2(SLAGA#1)	0.178627	0.214487	0.371884			
+	98	CaS(SLAGA#1)	8.7608E-03	1.1345E-02	1.8239E-02			
+	99	FeS(SLAGA#1)	0.159268	0.176202	0.356041			
+	100	Fe2S3(SLAGA#1)	5.7445E-03	1.0161E-02	1.4656E-02			
+	101	MgS(SLAGA#1)	8.6585E-03	1.1212E-02	1.8026E-02			
+	102	PbS(SLAGA#1)	4.9016E-04	5.3044E-04	1.1040E-03			
+	103	ZnS(SLAGA#1)	5.7433E-03	6.3514E-03	1.2860E-02			
+	104	Cu2S(SLAGA#1)	8.3712E-04	1.2085E-03	2.1357E-03			
	FToxid-	SLAG						
	105	Al2O3(SLAGA#2)	0	0	3.2378E-11			
	106	SiO2(SLAGA#2)	0	0	8.2401E-13			
	107	CaO(SLAGA#2)	0	0	1.1583E-06			
	108	FeO(SLAGA#2)	0	0	2.0170E-03			

source [page] Mass: mole gram Order: inte mas fract acti

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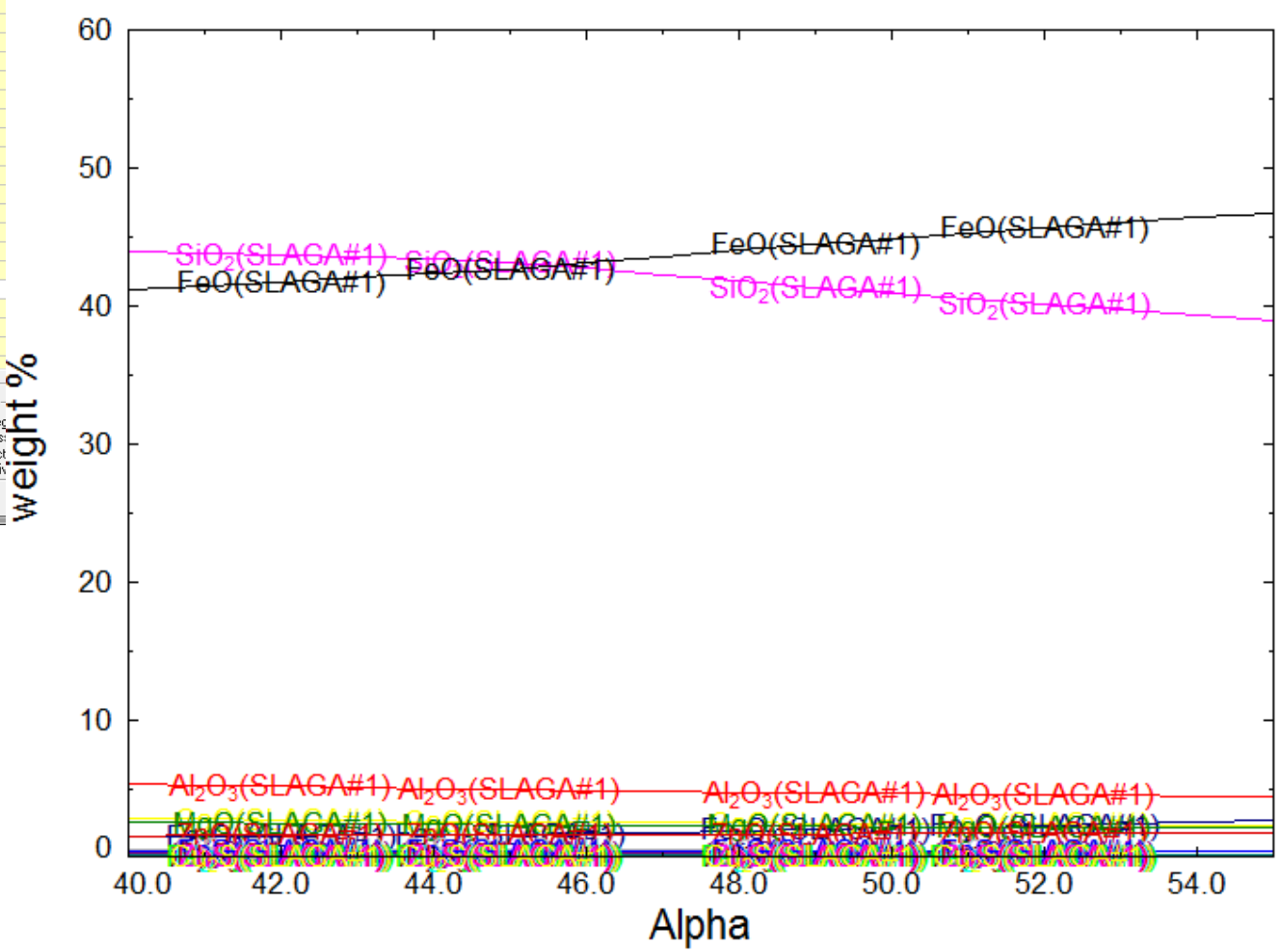
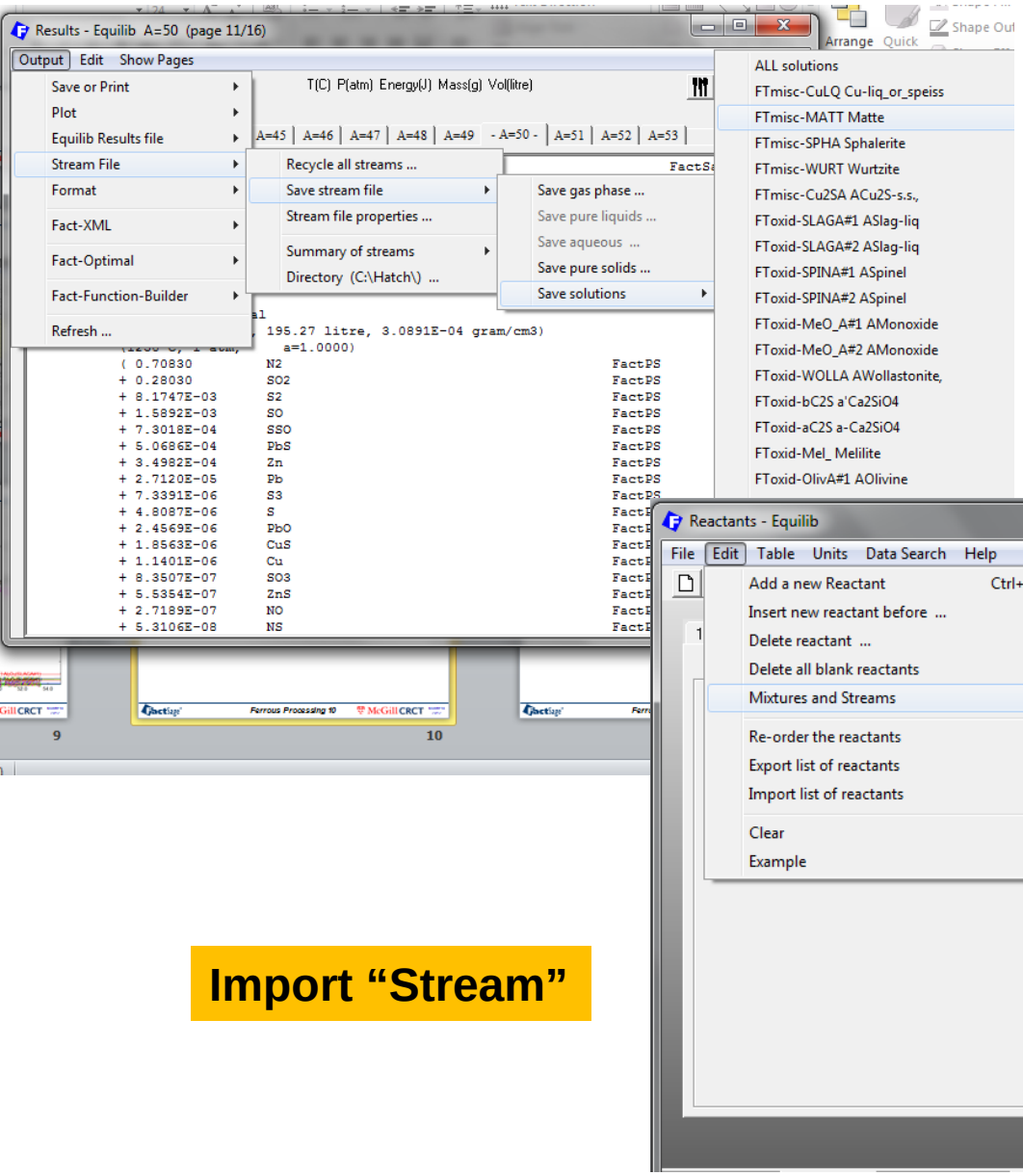
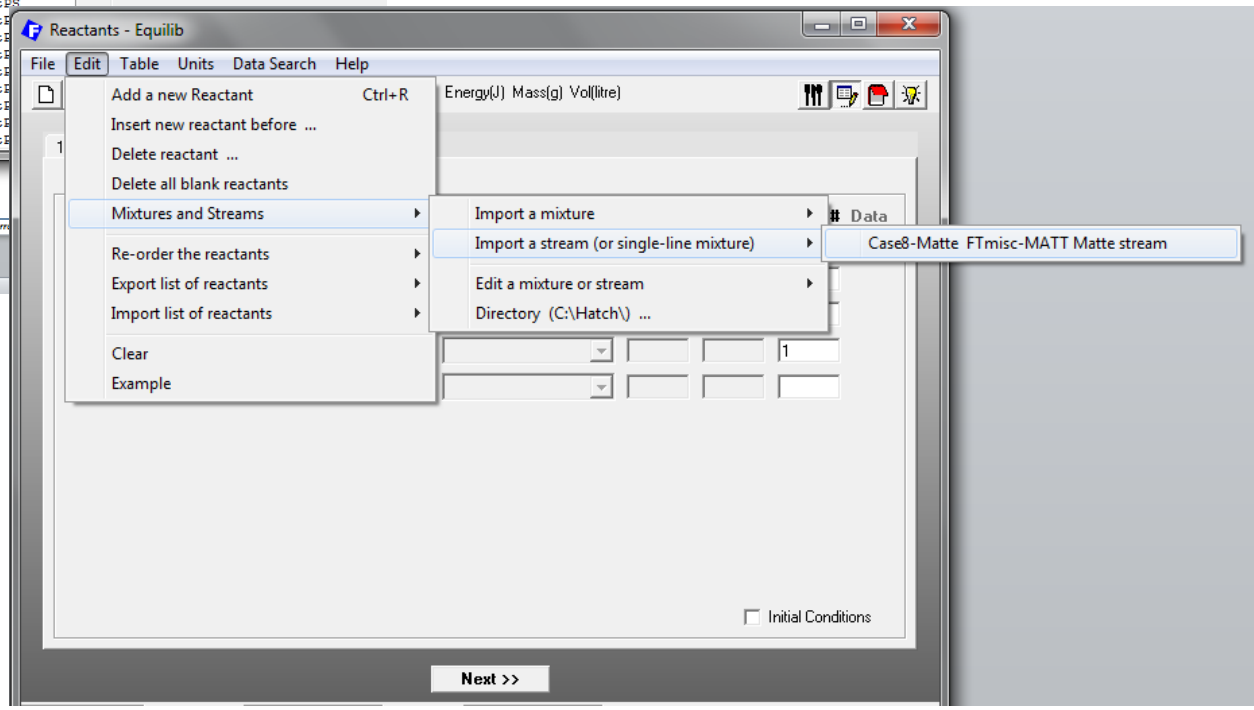
Click on the '+' column to add or remove species.



Save/Import matte for converting process

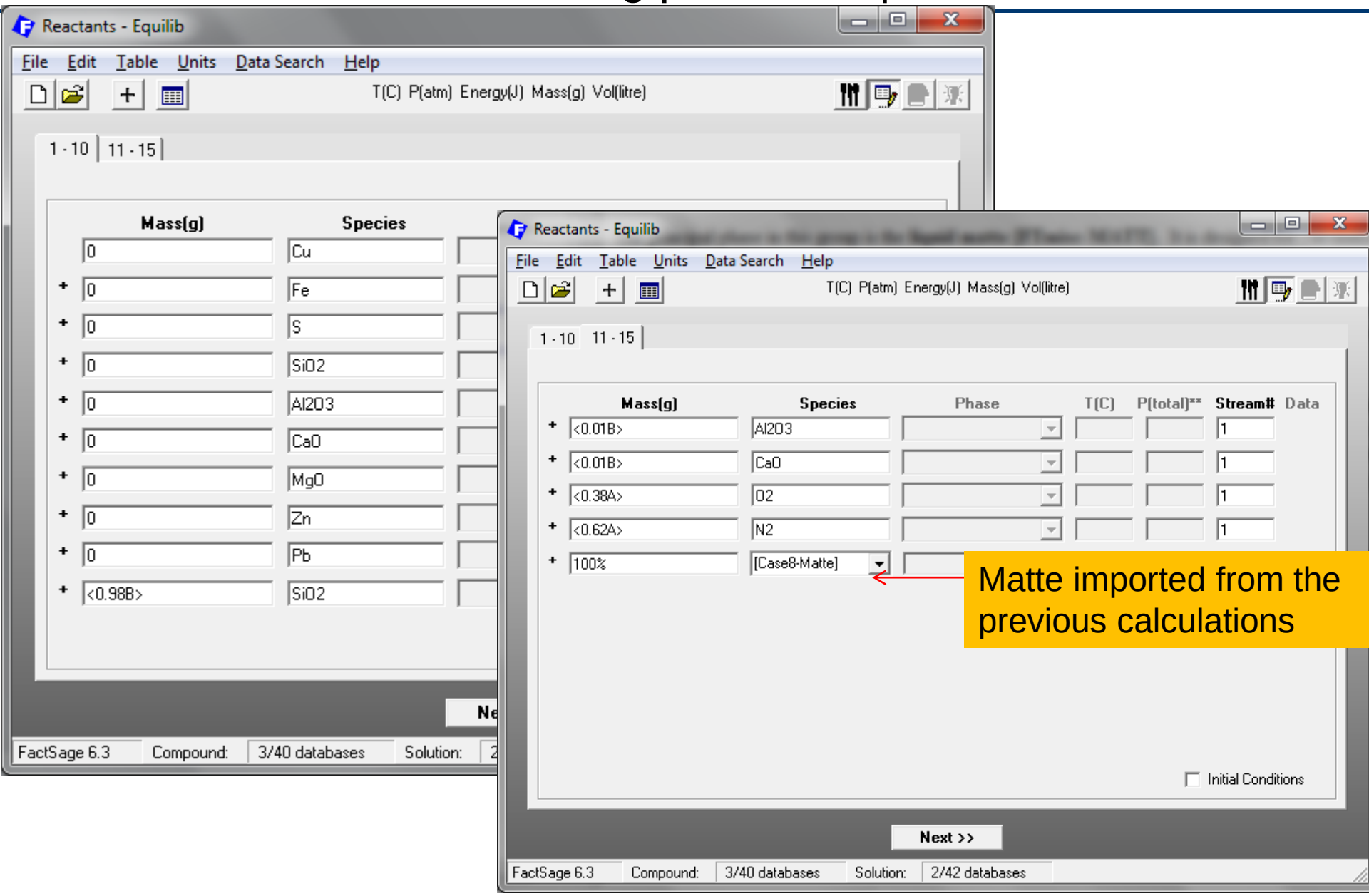


Save "Stream"



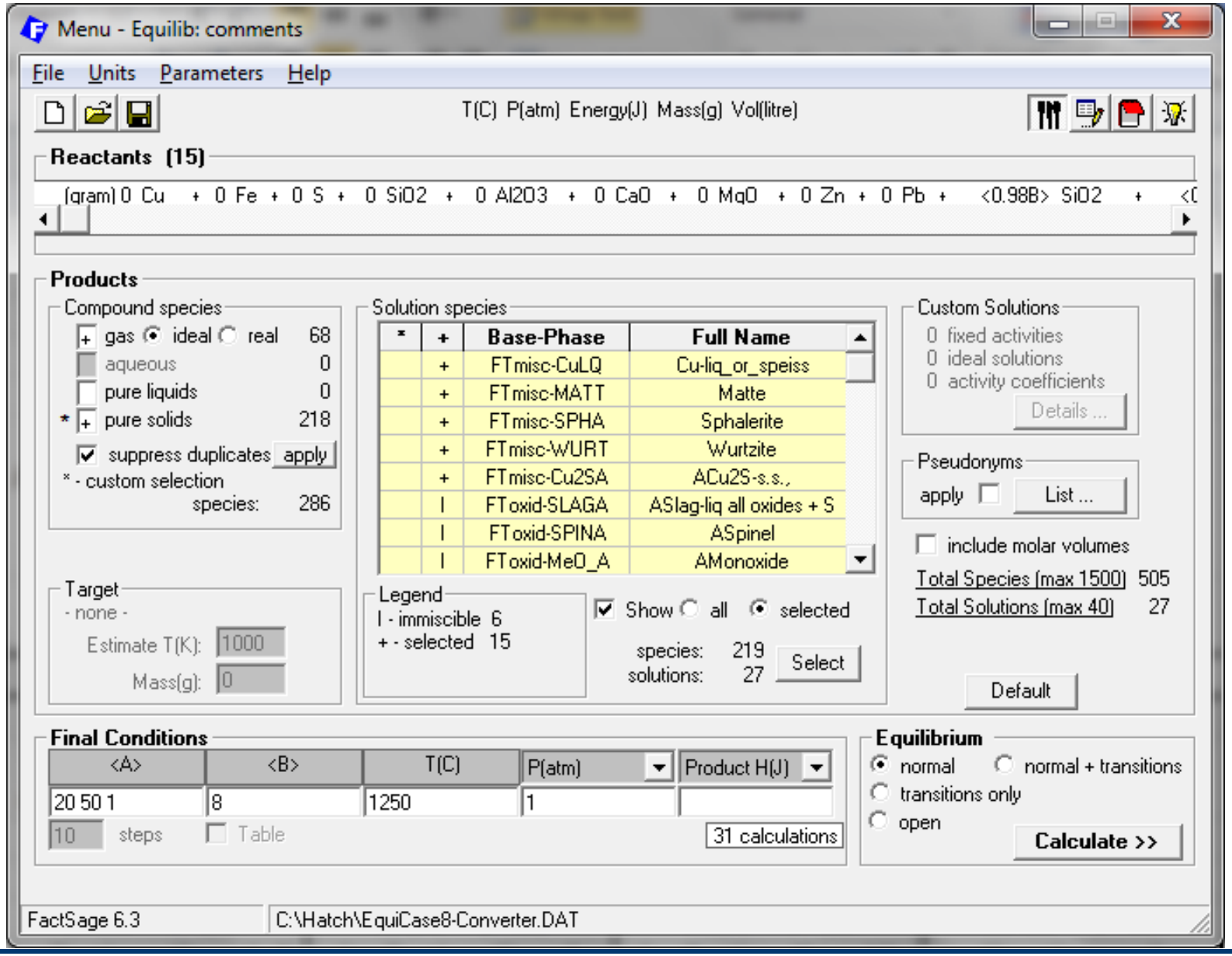
Import "Stream"

Converting process: input

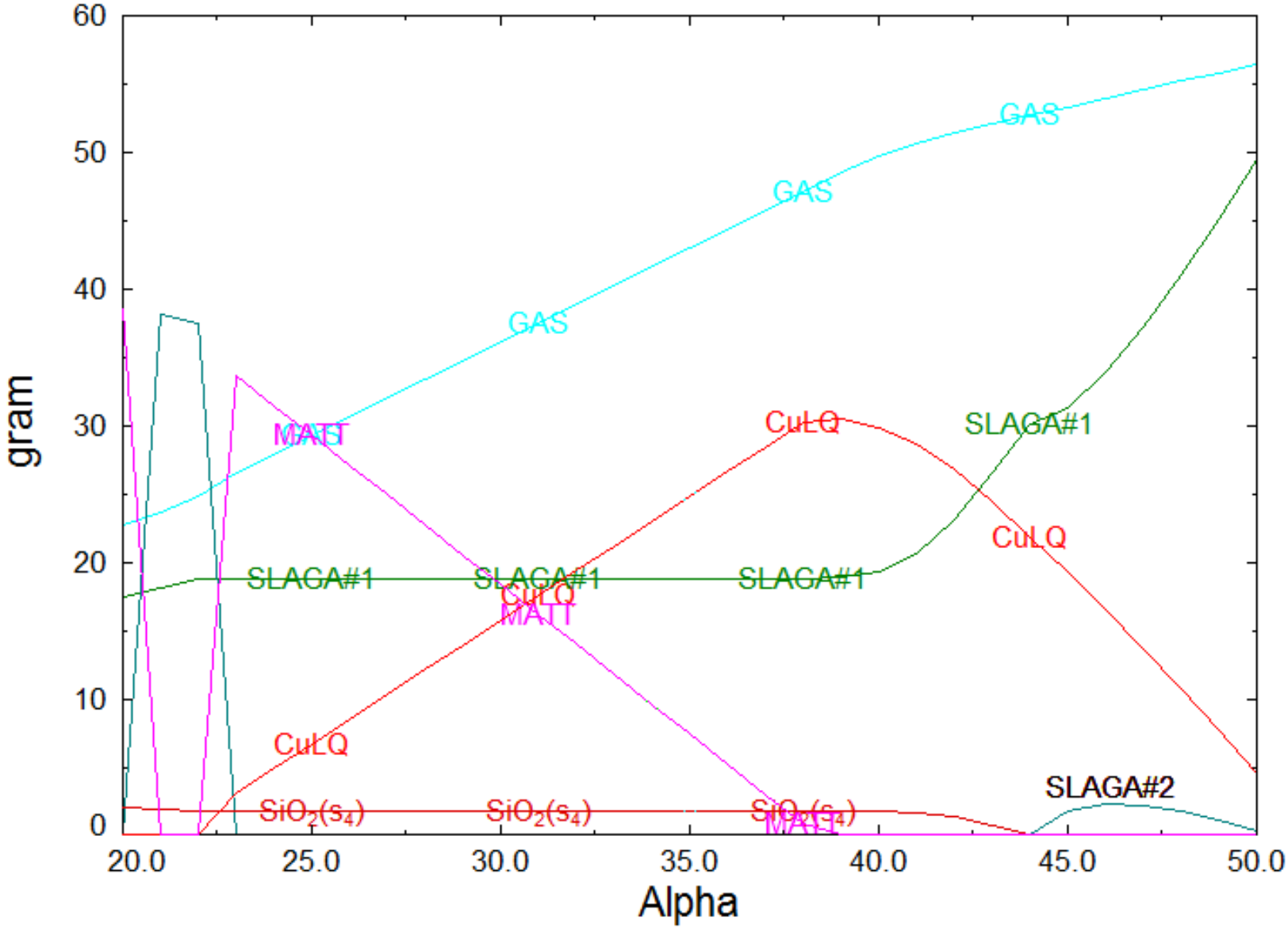


Matte imported from the previous calculations

Converting process: phase selection



Results: Overview of products



Results: Cu-liquid