


Cu smelting process

Case- 8 Copper extraction

Chemical assay of the copper concentrate:

Comp	Cu	Fe	S	SiO ₂	Al ₂ O 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%SiO₂ + 1%CaO + 1%Al₂O₃).

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%.



Safety • Quality • Sustainability • Innovation



01/2012

(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
 - Cu₂S-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 $\text{Cu}_2\text{S} : \text{FeS}$

- Smelting

- Produce copper rich matte
- Separate matter and slag
- $2\text{CuFeS}_2 + 5/2\text{O}_2 + \text{SiO}_2 = \text{Cu}_2\text{S} - \text{FeS} + \text{FeO} \cdot \text{SiO}_2 + 2 \text{SO}_2$

- Converting

- Remove Fe and S from matte and produce blister copper
- $\text{Cu-Fe-S} + \text{O}_2 + \text{SiO}_2 = \text{Cu}_{\text{impure}} + 2 \text{FeO} \cdot \text{SiO}_2 - \text{Fe}_3\text{O}_4 + \text{SO}_2$

Flow Chart

Feed (Concentrate)

Ores: CuFeS_2 , FeS , SiO_2

Roasting @ 600C with Air

FeCuS_2 (S), Aspinel (l), SiO_2 (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

Reactants - Equilib

File Edit Table Units Data Search Help

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

1 - 10 | 11 - 14

Mass(g)	Species	Phase	T(C)	P(total)**	Stream#	Data
32	Cu				1	
+ 24	Fe				1	
+ 28	S				1	
+ 9	SiO2				1	
+ 2	Al2O3				1	
+ 1	CaO				1	
+ 1	MgO				1	
+ 1	Zn				1	
+ 0.5	Pb				1	
+ <0.98B>	SiO2				1	

Initial Cond

Next >>

FactSage 6.3 Compound: 3/40 databases Solution: 2/42 databases

Data Search

Databases - 3/40 compound databases, 2/42 solution databases

Fact FactSage SGTE

FactPS
 FToxid
 FTsalt
 FTmisc
 FTthall
 FTOnCN
 FTfritz
 FThelg
 FTPulp
 FTlite

FSopp
 FSlead
 FSlite
 FSstel
 FSnobl
 FSupsi

BINS
 SGPS
 SGTE
 SGnobl
 SGsold
 SGnucl

ELEM
 FTdemo

TDnucl

ALMG
 CON2
 FELQ
 LISI
 MGSN
 OXG3
 SAIK
 SGTE#
 ZRO2

BSIP
 ELM1
 HOIN
 MGMN
 MIFR
 PBLR
 SFCA
 SGTE*

CON1
 EXAM
 KS15
 MGPN
 MIME
 PIER
 SGSL
 VOXD

compounds only
 solutions only
 no database

Clear All Select All Add/Remove Data RefreshDatabases

Information

Options

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

Limits
 Organic species CxHy... X(max) = 2
 Minimum solution components: 1 2 cpts

Cancel Summary ... OK

Reactants - Equilib

File Edit Table Units Data Search Help

1 - 10 | 11 - 14

Mass(g)	Species	Phase
+ <0.01B>	Al2O3	
+ <0.01B>	CaO	
+ <0.38A>	O2	
+ <0.62A>	N2	

Next >>

FactSage 6.3 Compound: 3/40 databases Solution: 2/42 databases

Smelting: Selection of phases

Duplicate Compounds

When you click (mouse left button) on a "gas", "liquid", "aqueous" or "solid" compound check box, then all the compounds in that group are selected.

To avoid selecting duplicate compounds, you can specify a database priority list - the most important database is first and the least important is last. For duplicate compounds in a given group, only those compounds from the most important database will be selected. Not all the databases need be entered - for example if only one database is specified, then duplicate compounds from the other databases will only be suppressed for those compounds found in this one database.

Note: a compound is considered a duplicate if a pure substance in another database has the same chemical formula in the same phase (solid, liquid or gas) - no distinction is made for allotropes and isomers. For example, Fe(s1) in databank A is duplicate of Fe(s1), Fe(s2) and Fe(s3) (but not Fe(g)) in databank B.

Enter the compound database priority list (most important first) fro

FTmisc FToxid FactPS

OK
Cancel

Menu - Equilib: comments

File Units Parameters Help

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

Reactants (14)

(gram) 32 Cu + 24 Fe + 28 S + 9 SiO2 + 2 Al2O3 + CaO + MgO + Zn + 0.5 Pb + <0.98B> SiO2 + <

Products

Compound species

gas ideal real 68

aqueous 0

pure liquids 0

* pure solids 218

suppress duplicates **apply**

* - custom selection
species: 286

Target

- none -

Estimate T(K): 1000

Mass(g): 0

Solution species

*	+	Base-Phase	Full Name
	+	FTmisc-CuLQ	Cu-liq_or_speiss
	+	FTmisc-MATT	Matte
	+	FTmisc-SPHA	Sphalerite
	+	FTmisc-WURT	Wurtzite
	+	FTmisc-Cu2SA	ACu2S-s.s.
		FToxid-SLAGA	ASlag-liq all oxides + S
		FToxid-SPINA	ASpinel
		FToxid-MeO_A	AMonoxide

Legend

| - immiscible 6

+ - selected 15

Show all selected

species: 219
solutions: 27 **Select**

Custom Solutions

fixed activities
 ideal solutions
 activity coefficients

Details ...

Pseudonyms

apply **List ...**

include molar volumes

Total Species (max 1500) 505
Total Solutions (max 40) 27

Default

Final Conditions

<A>		T(C)	P(atm)	Product H(J)
40	55	1	10	1250
10	steps	<input type="checkbox"/> Table		16 calculations

Equilibrium

normal normal + transitions
 transitions only
 open

Calculate >>

FactSage 6.3 C:\Hatch\EquiCase-8-1.DAT

Results

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

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)

Component	Amount	Phase
N2	0.70628	FactPS
SO2	0.28017	FactPS
S2	1.0117E-02	FactPS
SO	1.6758E-03	FactPS
SS	8.5659E-04	FactPS
Pb	5.1513E-04	FactPS
Zn	3.3973E-04	FactPS
Pb	2.4775E-05	FactPS
S3	1.0105E-05	FactPS
S	5.3496E-06	FactPS
PbO	2.1274E-06	FactPS
CuS	1.8948E-06	FactPS
Cu	1.0461E-06	FactPS
SO3	7.9114E-07	FactPS
ZnS	5.9805E-07	FactPS
NO	2.5735E-07	FactPS
NS	5.8996E-08	FactPS
S4	3.1239E-08	FactPS
O2	7.0877E-09	FactPS
FeS	3.5371E-09	FactPS
Fe	2.0047E-09	FactPS
O	4.6243E-10	FactPS
FeO	2.6605E-10	FactPS
SiO	7.8804E-11	FactPS
Cu2	4.1632E-11	FactPS
CuO	1.7218E-11	FactPS
S5	1.4608E-11	FactPS
SiO2	1.4431E-11	FactPS
N2O	1.3126E-11	FactPS
Pb2	9.8412E-12	FactPS
SiS	1.6347E-12	FactPS

Gas composition

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

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

Matte composition

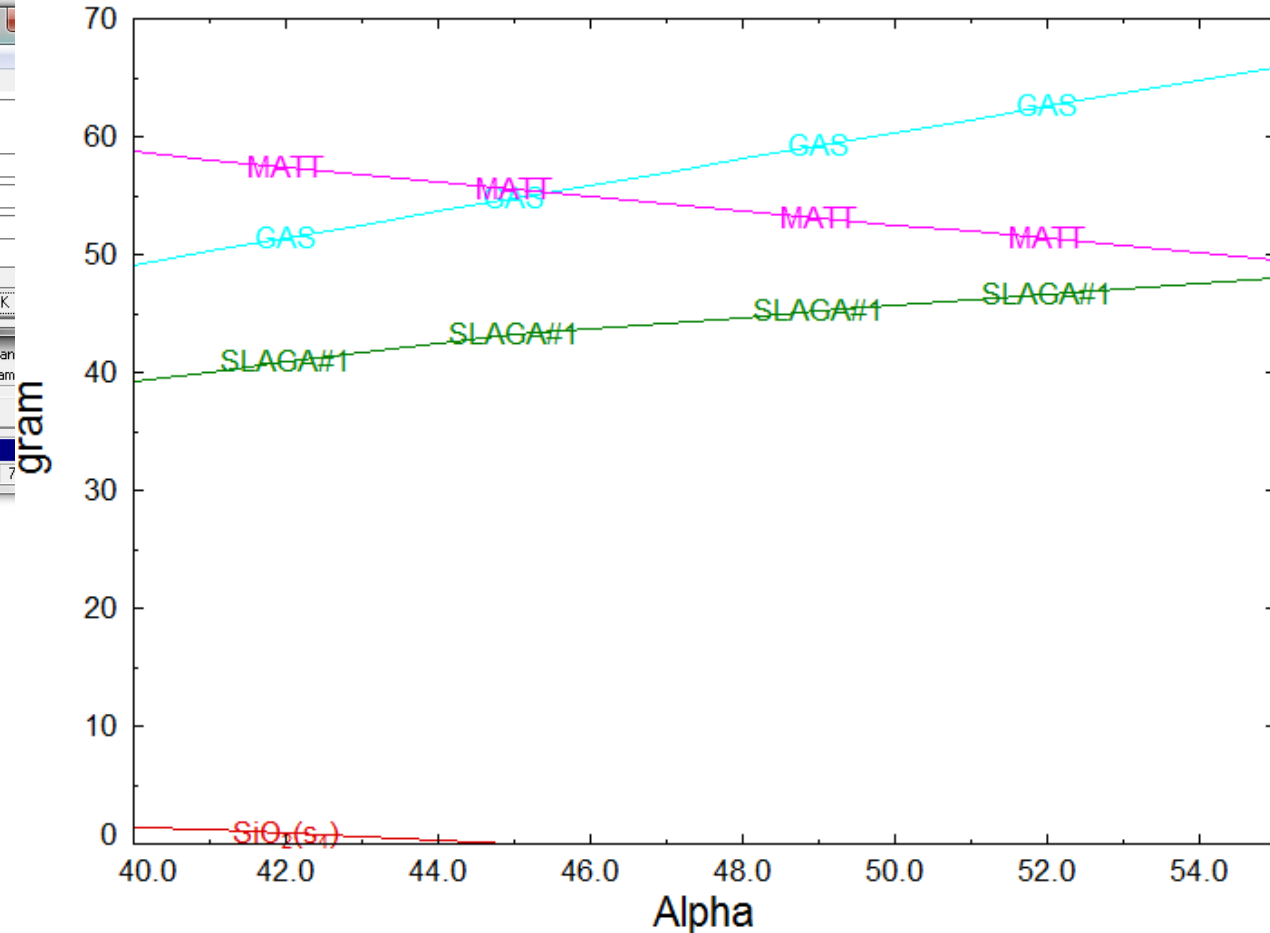
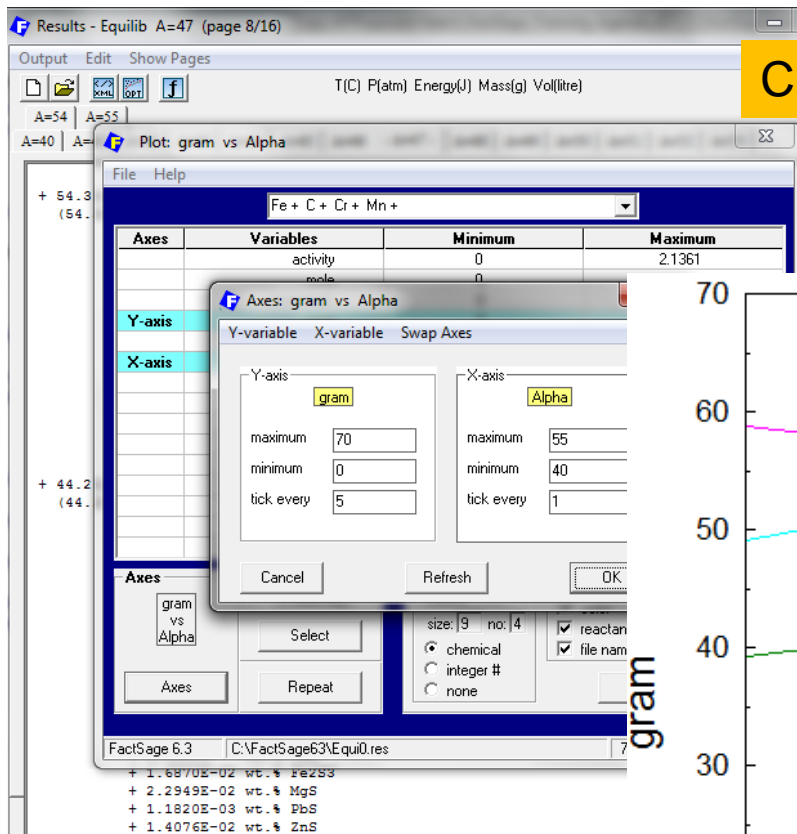
```
+ 44.211 gram ASlag-liq#1
(44.211 gram, 0.66276 mol)
(1250 C, 1 atm, a=1.0000)
( 4.7155 wt.% Al2O3
+ 42.215 wt.% SiO2
+ 2.4700 wt.% CaO
+ 43.544 wt.% FeO
+ 1.7734 wt.% Fe2O3
+ 2.2455 wt.% MgO
+ 0.15090 wt.% PbO
+ 1.6087 wt.% ZnO
+ 0.28257 wt.% Cu2O
+ 5.0745E-02 wt.% Al2S3
+ 0.47344 wt.% SiS2
+ 2.3220E-02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

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

Slag composition

Results: Overview of products

Click: Output → Plot → Plot Results →



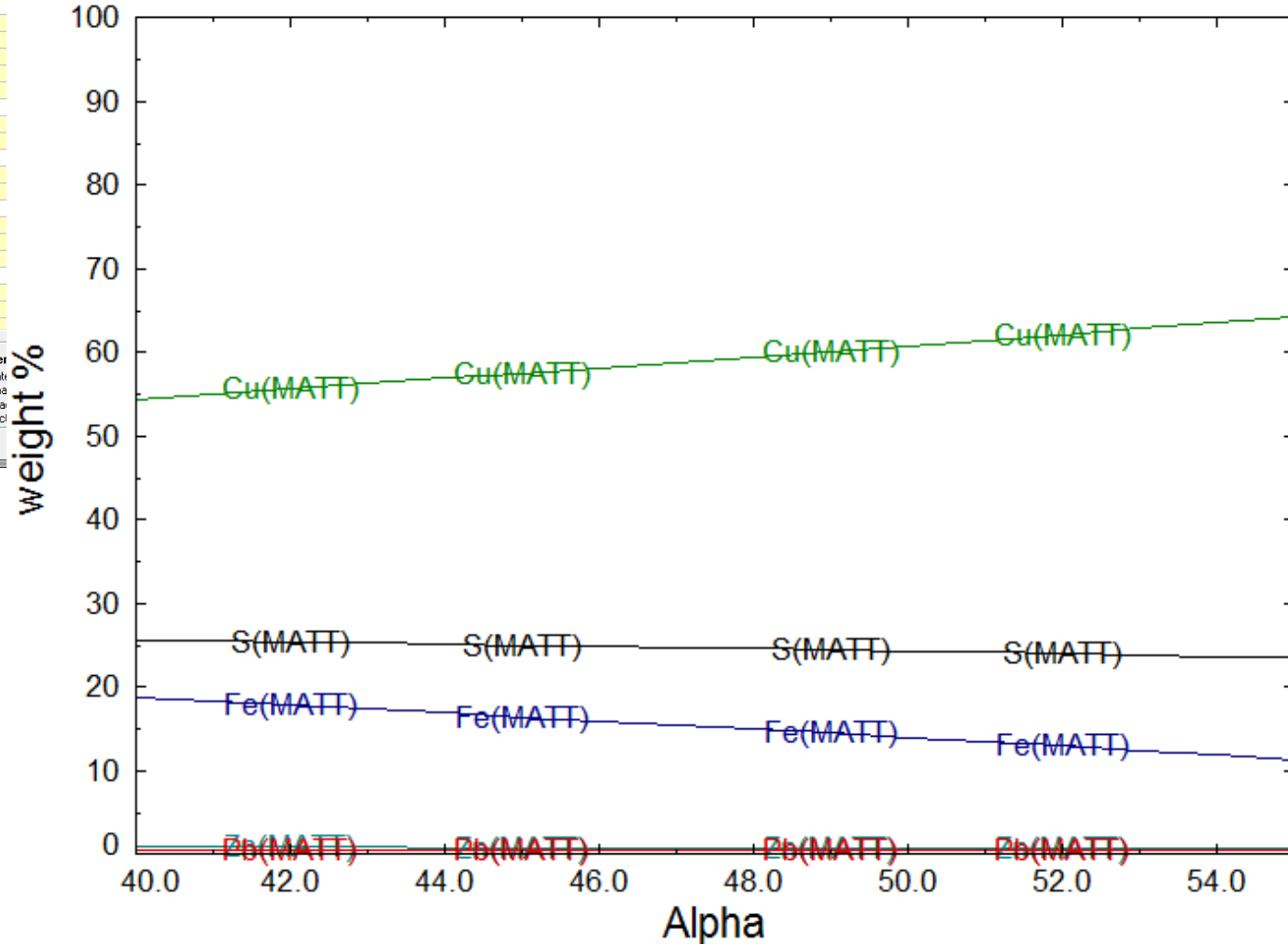
Results: Cu matte grade

Species Selection - EQUILIB Results: weight % vs Alpha

#	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	0.161453	0.000000	0.000000
FTmisc: MATI							
+ 75	Si(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)	0.269828	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	1.0922	2.2769			

source [page] 15 pages
 Mass mole Order ink ma fra ac
 gram mole gram

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



Results: Slag composition

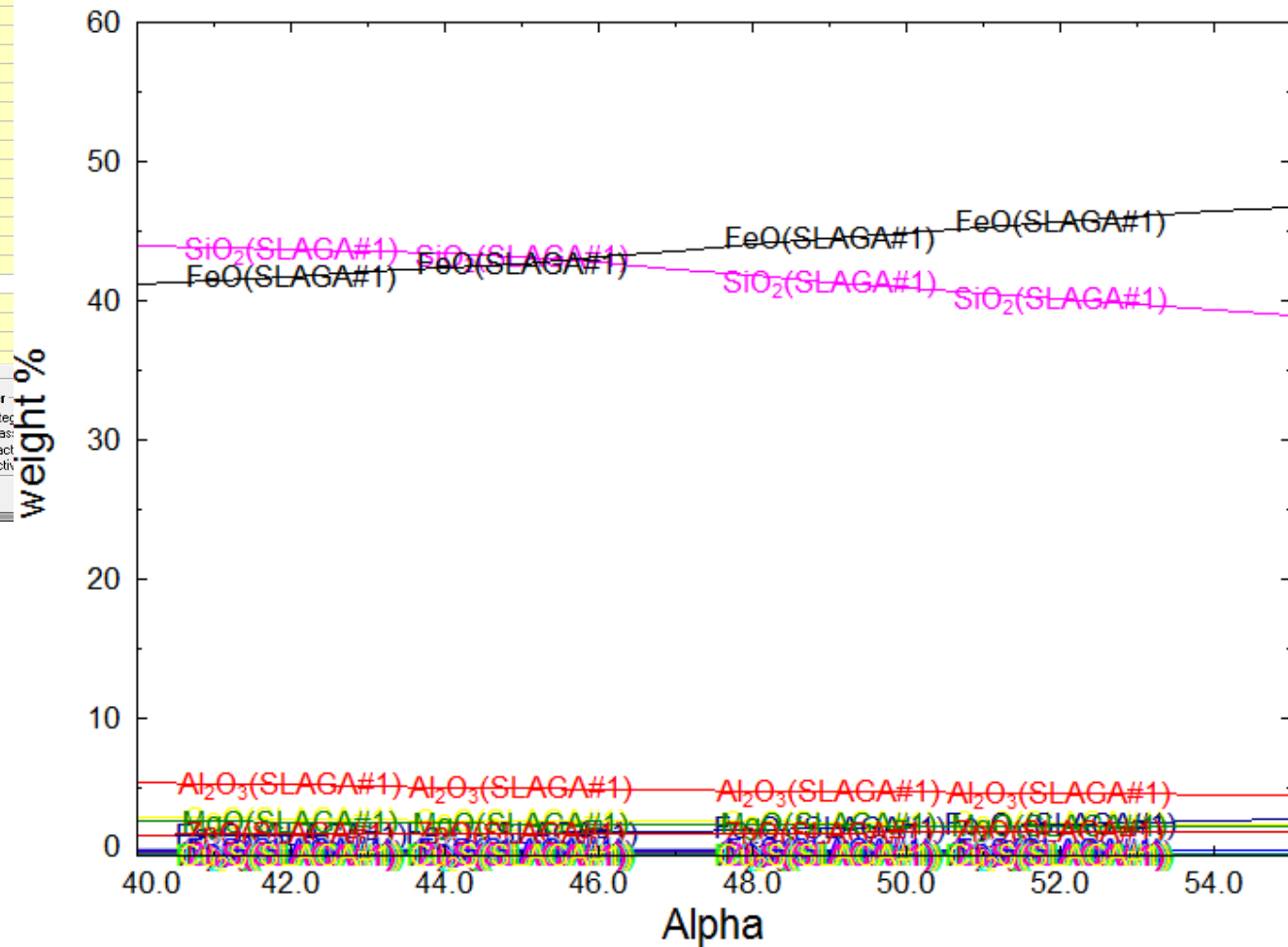
Species Selection - EQUILIB Results: weight % vs Alpha

#	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] 16 pages
 mass: mole gram
 inter mass fract act*

Clear

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



Save/Import matte for converting process

Results - Equilib A=50 (page 11/16)

Output Edit Show Pages

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

Plot

Equilib Results file A=45 | A=46 | A=47 | A=48 | A=49 | A=50 - | A=51 | A=52 | A=53 |

Stream File Recycle all streams ...

Format Save stream file

Fact-XML

Fact-Optimal

Fact-Function-Builder

Refresh ...

195.27 litre, 3.0891E-04 gram/cm3
a=1.0000

(0.70830	N2	FactPS
+ 0.28030	SO2	FactPS
+ 8.1747E-03	S2	FactPS
+ 1.5892E-03	SO	FactPS
+ 7.3018E-04	SSO	FactPS
+ 5.0686E-04	PbS	FactPS
+ 3.4982E-04	Zn	FactPS
+ 2.7120E-05	Pb	FactPS
+ 7.3391E-06	S3	FactPS
+ 4.8087E-06	S	FactPS
+ 2.4569E-06	PbO	FactPS
+ 1.8563E-06	CuS	FactPS
+ 1.1401E-06	Cu	FactPS
+ 8.3507E-07	SO3	FactPS
+ 5.5354E-07	ZnS	FactPS
+ 2.7189E-07	NO	FactPS
+ 5.3106E-08	NS	FactPS

Save "Stream"

Reactants - Equilib

File Edit Table Units Data Search Help

Add a new Reactant Ctrl+R Energy(J) Mass(g) Vol(litre)

Insert new reactant before ...

Delete reactant ...

Delete all blank reactants

Mixtures and Streams

Re-order the reactants

Export list of reactants

Import list of reactants

Clear

Example

Import a mixture

Import a stream (or single-line mixture)

Edit a mixture or stream

Directory (C:\Hatch) ...

Case8-Matte FTmisc-MATT Matte stream

Initial Conditions

Next >>

Import "Stream"

Converting process: input

Mass(g)	Species
0	Cu
+ 0	Fe
+ 0	S
+ 0	SiO2
+ 0	Al2O3
+ 0	CaO
+ 0	MgO
+ 0	Zn
+ 0	Pb
+ <0.98B>	SiO2

Mass(g)	Species	Phase	T(C)	P(total)**	Stream#	Data
+ <0.01B>	Al2O3				1	
+ <0.01B>	CaO				1	
+ <0.38A>	O2				1	
+ <0.62A>	N2				1	
+ 100%	[Case8-Matte]					

Matte imported from the previous calculations

Converting process: phase selection

Menu - Equilib: comments

File Units Parameters Help

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

Reactants (15)

(gram) 0 Cu + 0 Fe + 0 S + 0 SiO2 + 0 Al2O3 + 0 CaO + 0 MgO + 0 Zn + 0 Pb + <0.98B> SiO2 + <C

Products

Compound species

- gas ideal real 68
- aqueous 0
- pure liquids 0
- * pure solids 218
- suppress duplicates **apply**
- * - custom selection
- species: 286

Target

- none -

Estimate T(K):

Mass(g):

Solution species

*	+	Base-Phase	Full Name
	+	FTmisc-CuLQ	Cu-liq_or_speiss
	+	FTmisc-MATT	Matte
	+	FTmisc-SPHA	Sphalerite
	+	FTmisc-WURT	Wurtzite
	+	FTmisc-Cu2SA	ACu2S-s.s.
	I	FToxid-SLAGA	ASlag-liq all oxides + S
	I	FToxid-SPINA	ASpinel
	I	FToxid-MeO_A	AMonoxide

Legend

I - immiscible 6
+ - selected 15

Show all selected

species: 219
solutions: 27 **Select**

Custom Solutions

- fixed activities
- ideal solutions
- activity coefficients

Details ...

Pseudonyms

apply **List ...**

include molar volumes

Total Species (max 1500) 505
Total Solutions (max 40) 27

Default

Final Conditions

<A>		T(C)	P(atm)	Product H(J)
20 50 1	8	1250	1	

10 steps Table **31 calculations**

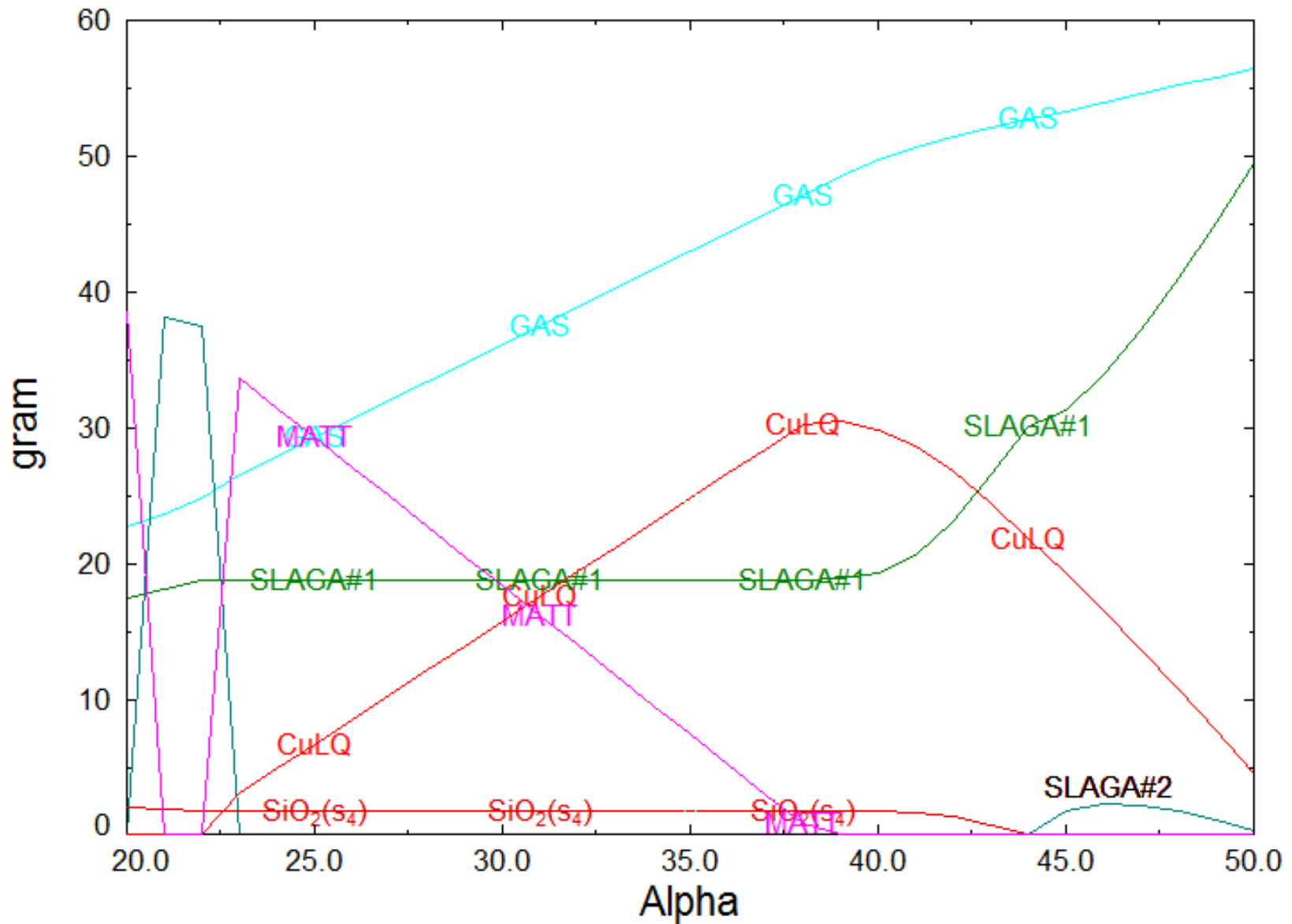
Equilibrium

- normal normal + transitions
- transitions only
- open

Calculate >>

FactSage 6.3 C:\Hatch\EquiCase8-Converter.DAT

Results: Overview of products



Results: Cu-liquid

