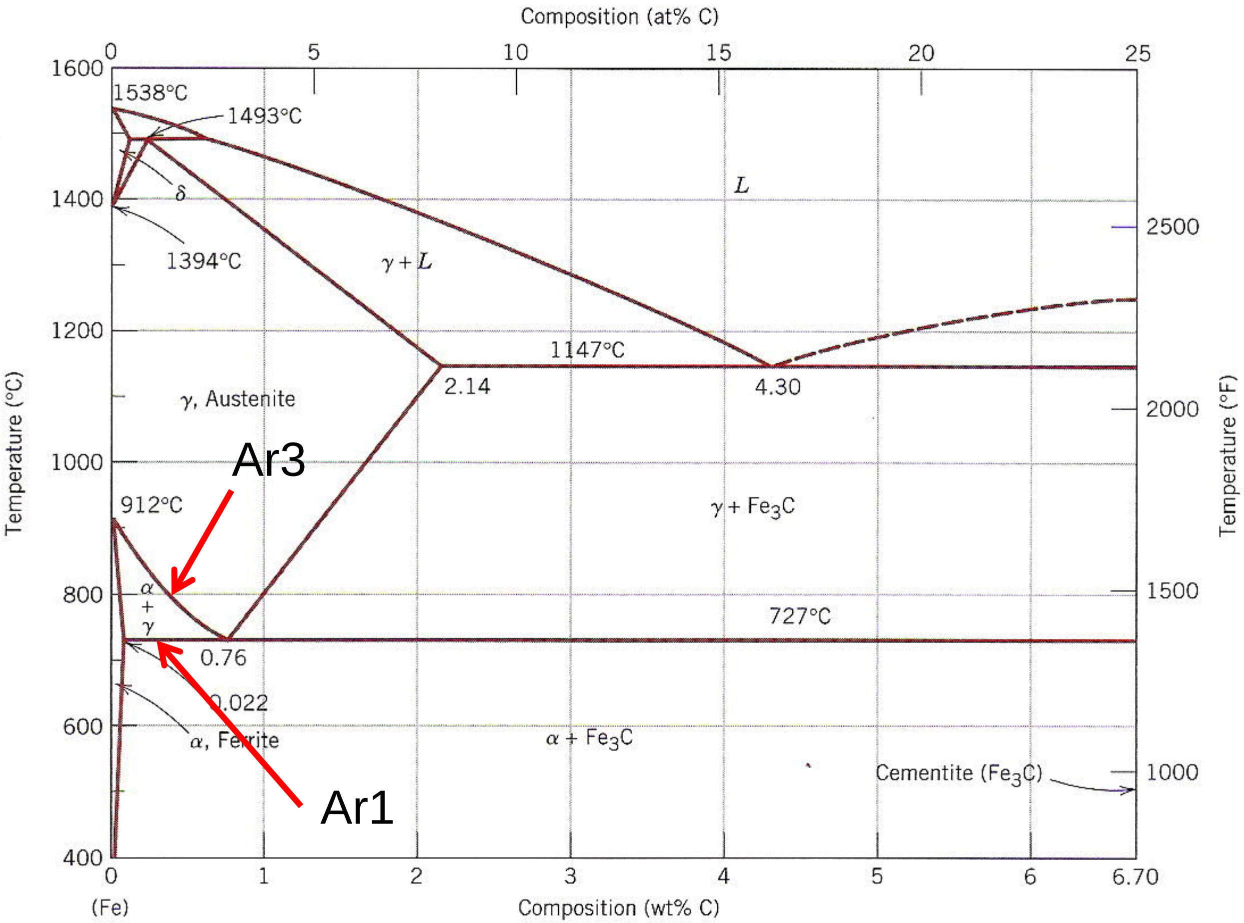
Case 7: Nb-, V- and Ti- carbide and nitride precipitation in microalloyed steels

Carbide and Nitride precipitation in microalloyed steels

Microalloyed steels are used for special high-strength applications such as pipelines. In order for the steel to acquire good mechanical properties, it needs to be thermo-mechanically treated. FactSage can help in finding the correct temperatures for treating these steels.

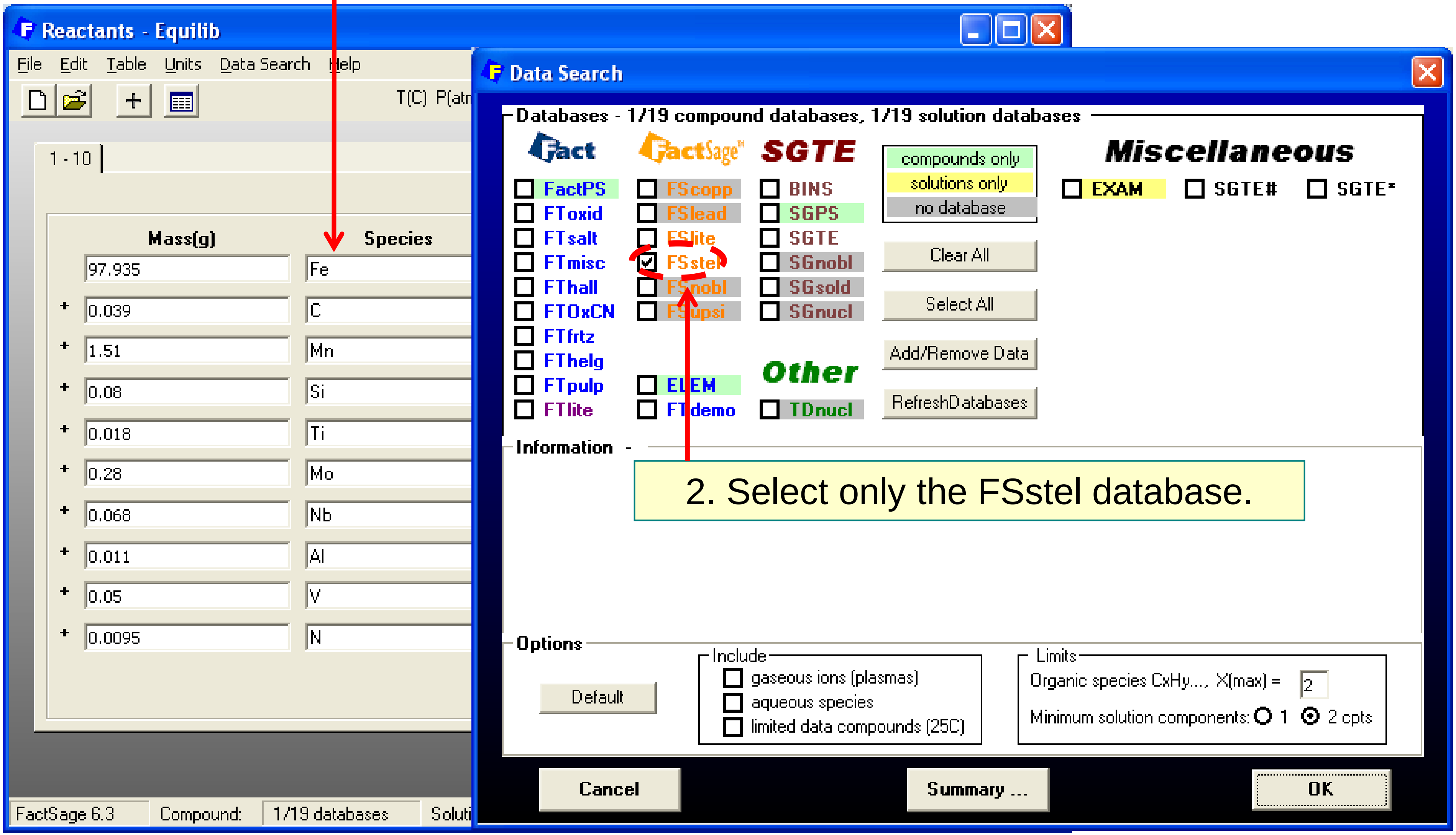


The steel is annealed in the austenite region an then cooled through the temperatures Ar3 and Ar1 temperatures (continuous cooling austenite to ferrite transformation start and finish.

The goal of this study is to find the ideal annealing temperatures to avoid precipitation of Nb carbonitrides and promote precipitation of NbC

Carbide and Nitride precipitation in microalloyed steels

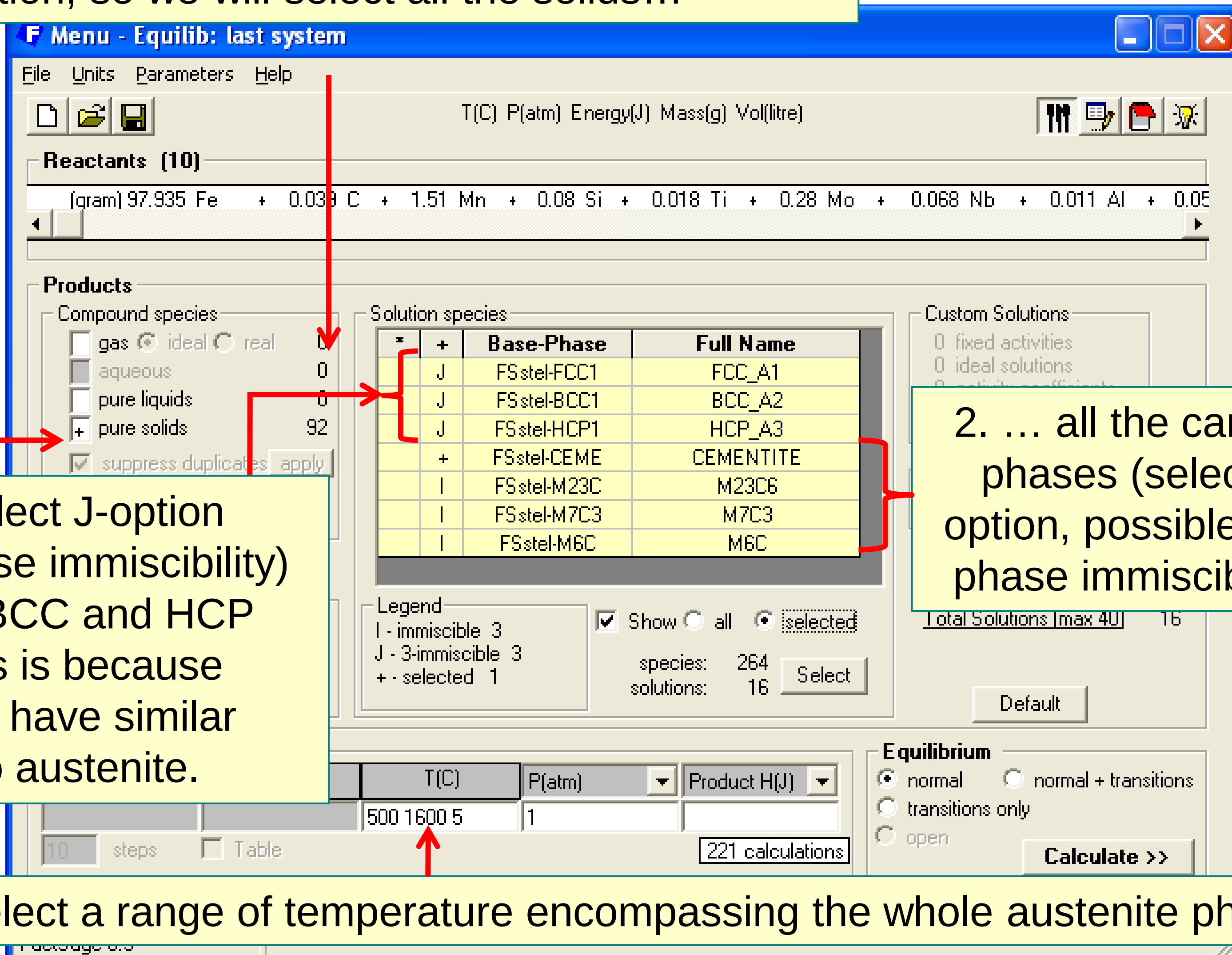
1. A typical microalloyed steel composition is entered (For more information, refer to J. Calvo et al. / Materials Science and Engineering A 520 (2009) 90–96)



2. Select only the FSstel database.

Carbide and Nitride precipitation in microalloyed steels

1. We are interested in carbide, nitride and carbonitride precipitation, so we will select all the solids…



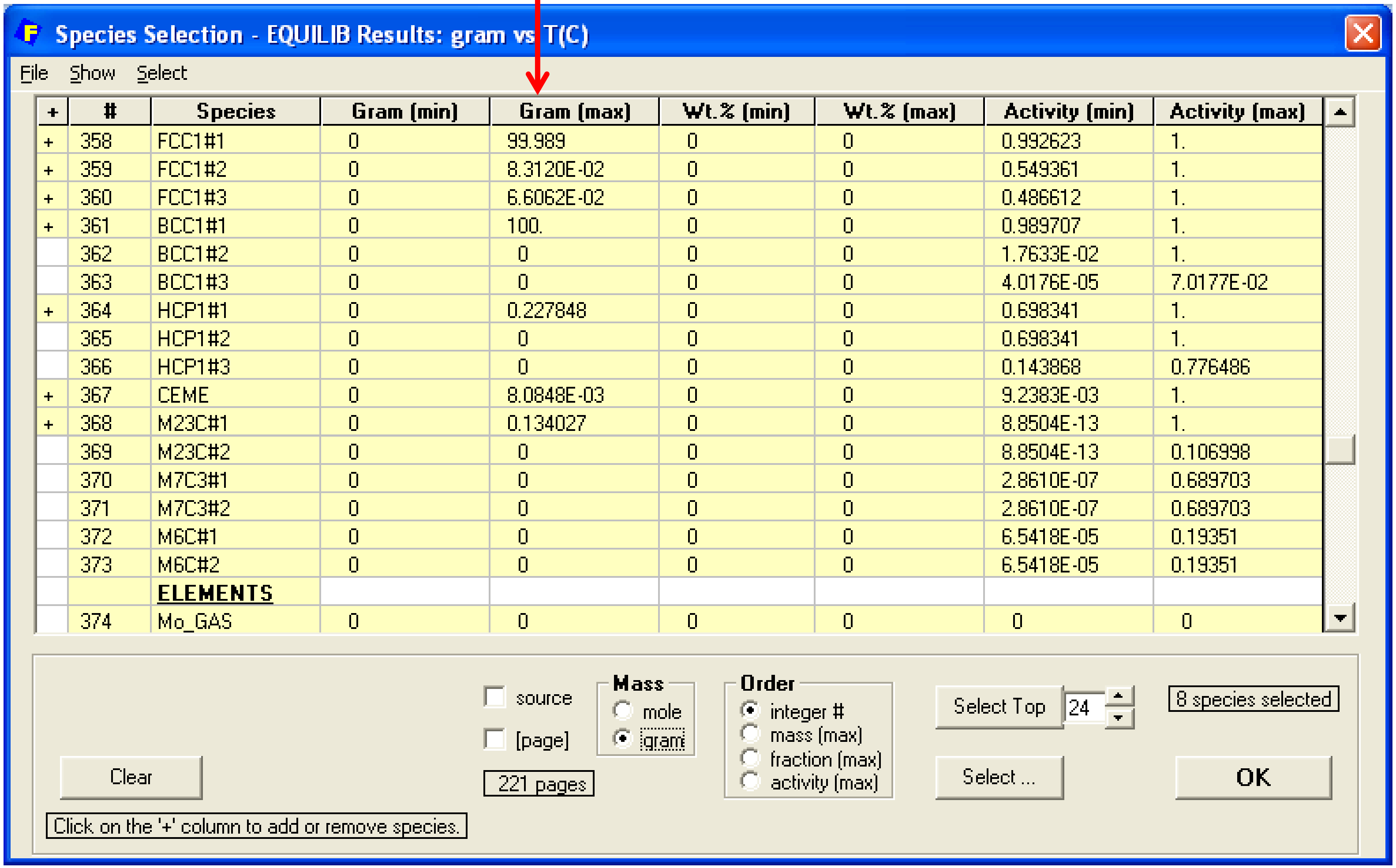
3. … and select J-option (possible 3-phase immiscibility) for the FCC, BCC and HCP phases. This is because carbonitrides have similar structure to austenite.

2. … all the carbide phases (select I-option, possible two-phase immiscibility)

4. We will select a range of temperature encompassing the whole austenite phase.

Carbide and Nitride precipitation in microalloyed steels

1. Plot g vs T(C) for all solids and solutions having a maximum weight greater than 0

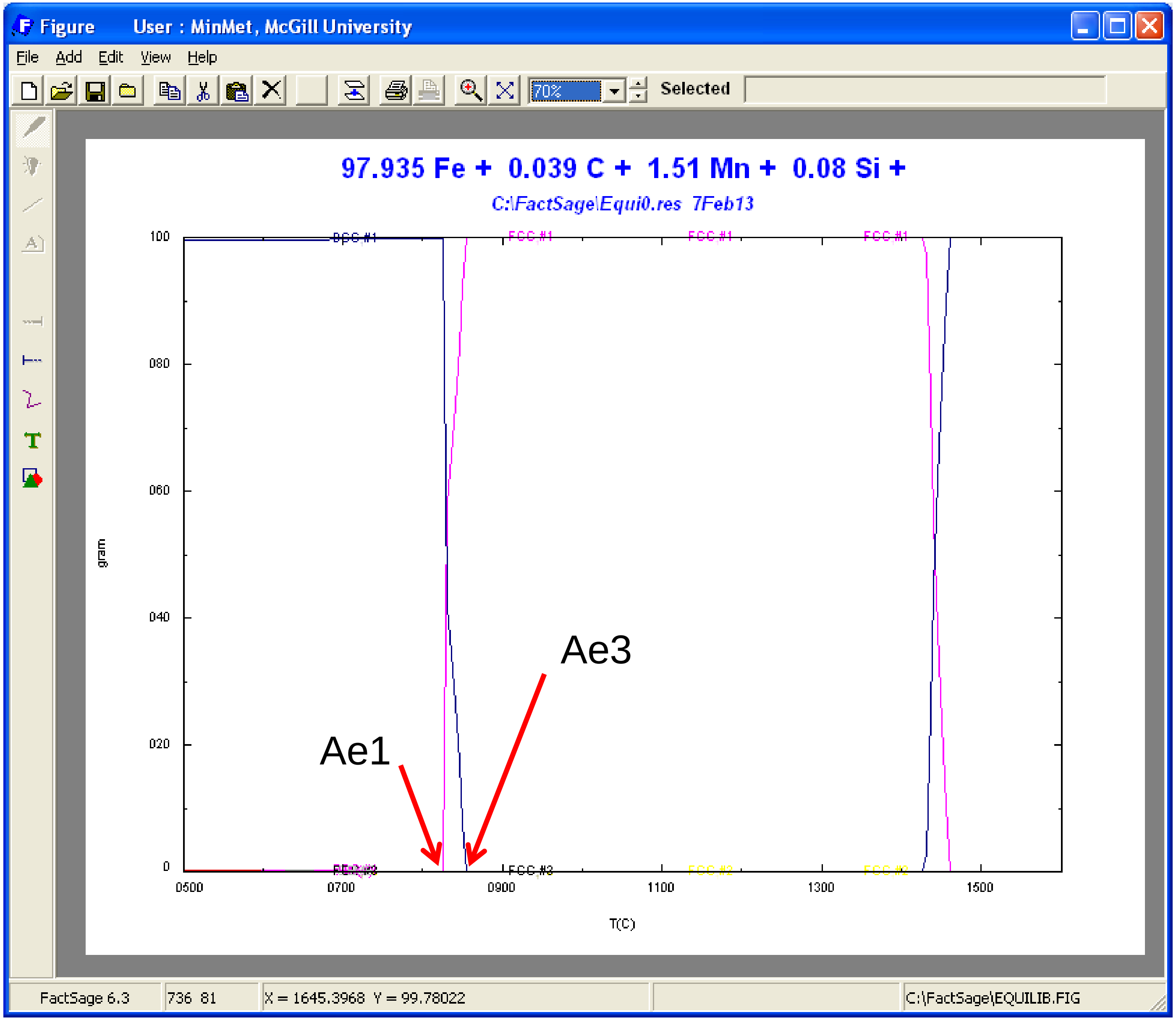


+	#	Species	Gram (min)	Gram (max)	Wt.% (min)	Wt.% (max)	Activity (min)	Activity (max)
+	358	FCC1#1	0	99.989	0	0	0.992623	1.
+	359	FCC1#2	0	8.3120E-02	0	0	0.549361	1.
+	360	FCC1#3	0	6.6062E-02	0	0	0.486612	1.
+	361	BCC1#1	0	100.	0	0	0.989707	1.
	362	BCC1#2	0	0	0	0	1.7633E-02	1.
	363	BCC1#3	0	0	0	0	4.0176E-05	7.0177E-02
+	364	HCP1#1	0	0.227848	0	0	0.698341	1.
	365	HCP1#2	0	0	0	0	0.698341	1.
	366	HCP1#3	0	0	0	0	0.143868	0.776486
+	367	CEME	0	8.0848E-03	0	0	9.2383E-03	1.
+	368	M23C#1	0	0.134027	0	0	8.8504E-13	1.
	369	M23C#2	0	0	0	0	8.8504E-13	0.106998
	370	M7C3#1	0	0	0	0	2.8610E-07	0.689703
	371	M7C3#2	0	0	0	0	2.8610E-07	0.689703
	372	M6C#1	0	0	0	0	6.5418E-05	0.19351
	373	M6C#2	0	0	0	0	6.5418E-05	0.19351
		ELEMENTS						
	374	Mo_GAS	0	0	0	0	0	0

Carbide and Nitride precipitation in microalloyed steels

1. From the graph, we can deduce equilibrium transformation temperatures from austenite to ferrite.

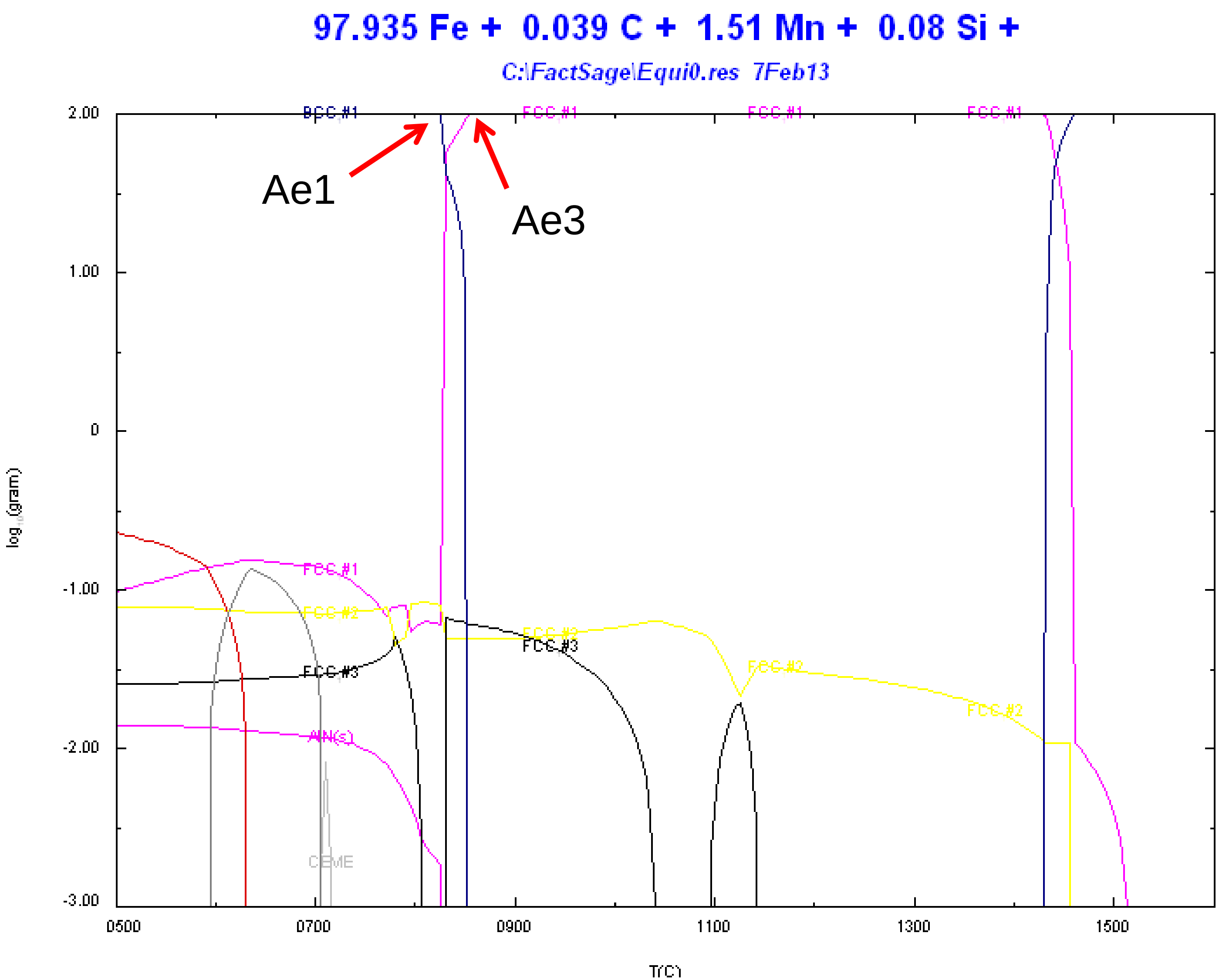
2. We should also look at the very low compositions, since all the microalloyed elements will be present in very small quantities.



Carbide and Nitride precipitation in microalloyed steels

1. Using a log scale is very convenient for looking at the microalloyed elements.

2. It is clearly seen that the FCC#1, #2 and #3 phases are forming. In this case, they are probably carbides and nitrides.
We can chack this by plotting their composition with temperature



1. We will first select all the species in FCC#1 and se how they are distributed.

Species Selection - EQUILIB Results: log10(gram) vs T(C)

File Show Select

+	#	Species	Gram (min)	Gram (max)	Wt.% (min)	Wt.% (max)	Activity (min)	Activity (max)
	FSstel-	FCC1						
+	1	Al1C1(FCC1#1)	0	2.8766E-05	7.9756E-15	5.1234E-05	8.7763E-18	1.2864E-10
+	2	Fe1C1(FCC1#1)	0	0.215328	3.8087E-03	1.314	6.5735E-06	6.7745E-04
+	3	Mn1C1(FCC1#1)	0	3.3298E-03	6.2789E-05	0.675137	9.7070E-06	5.0046E-03
+	4	Mo1C1(FCC1#1)	0	7.4076E-02	6.9437E-05	47.762	8.0782E-05	0.12863
+	5	Nb1C1(FCC1#1)	0	6.7085E-02	4.9567E-06	83.734	1.6287E-02	0.836682
+	6	Si1C1(FCC1#1)	0	2.0667E-04	1.8057E-12	3.8675E-04	1.2475E-12	9.0385E-10
+	7	Ti1C1(FCC1#1)	0	7.3481E-03	1.3825E-08	12.548	4.4916E-04	3.0424E-03
+	8	V1C1(FCC1#1)	0	5.1529E-02	7.2485E-05	49.327	2.7622E-04	0.461906
+	9	Al1N1(FCC1#1)	0	4.7620E-06	3.0668E-17	9.2009E-06	6.7633E-21	1.6310E-10
+	10	Fe1N1(FCC1#1)	0	3.4952E-02	1.4342E-05	20.023	5.1621E-10	8.7625E-05
+	11	Mn1N1(FCC1#1)	0	5.4179E-04	2.2803E-05	1.0966E-02	4.2497E-07	3.1491E-05
+	12	Mo1N1(FCC1#1)	0	7.5293E-04	3.5533E-06	1.0079	1.8266E-07	1.9718E-05
+	13	Nb1N1(FCC1#1)	0	3.0861E-03	2.8472E-08	5.0603	8.9778E-04	0.281682
+	14	Si1N1(FCC1#1)	0	3.4189E-05	1.5918E-13	6.7809E-05	4.4179E-23	4.7008E-09
+	15	Ti1N1(FCC1#1)	0	1.4035E-02	8.0528E-11	70.308	0.187213	0.5254
+	16	V1N1(FCC1#1)	0	2.3014E-02	4.7227E-07	36.827	4.4993E-03	0.360668
+	17	Al1Va1(FCC1#1)	0	1.0984E-02	5.6111E-16	1.1347E-02	1.2484E-11	3.8179E-06
+	18	Fe1Va1(FCC1#1)	0	97.787	3.1869E-04	97.895	0.773257	0.979434
+	19	Mn1Va1(FCC1#1)	0	1.5077	2.0503E-05	1.8985	1.0308E-02	5.7561E-02
+	20	Mo1Va1(FCC1#1)	0	0.279503	2.5722E-05	4.0232	1.0273E-03	4.0175E-03
+	21	Nb1Va1(FCC1#1)	0	6.7649E-02	1.8085E-03	1.5027	3.6155E-10	2.3636E-04
+	22	Si1Va1(FCC1#1)	0	7.9880E-02	1.0528E-14	8.2395E-02	1.2847E-13	2.1733E-06
+	23	Ti1Va1(FCC1#1)	0	1.0950E-02	4.5537E-06	1.9022	9.4298E-14	1.1330E-05
+	24	V1Va1(FCC1#1)	0	4.9850E-02	9.8645E-03	4.0583	2.7361E-07	1.1268E-04
	FSstel-	FCC1						
	25	Al1C1(FCC1#2)	0	7.3049E-14	6.2376E-16	5.6239E-05	8.7763E-18	1.2864E-10
	26	Fe1C1(FCC1#2)	0	8.3548E-04	6.3416E-04	1.8592	6.5735E-06	6.7745E-04

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221 pages

Mass: mole, gram

Order: integer #, mass (max), fraction (max), activity (max)

Select Top 24

24 species selected

Clear

Select ...

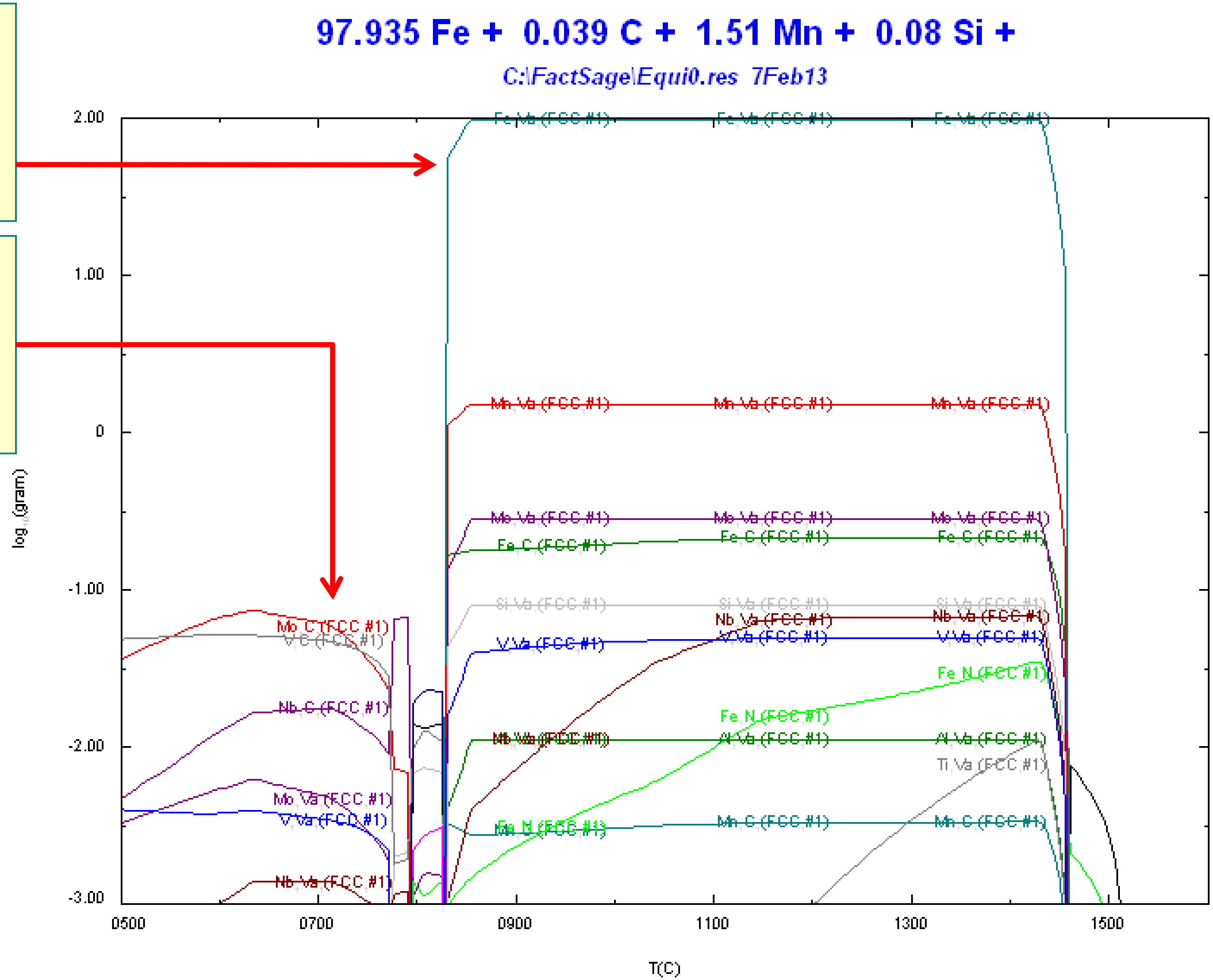
OK

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

Carbide and Nitride precipitation in microalloyed steels

1. In the austenite region, the FCC#1 phase is composed mostly of iron (FeVa)

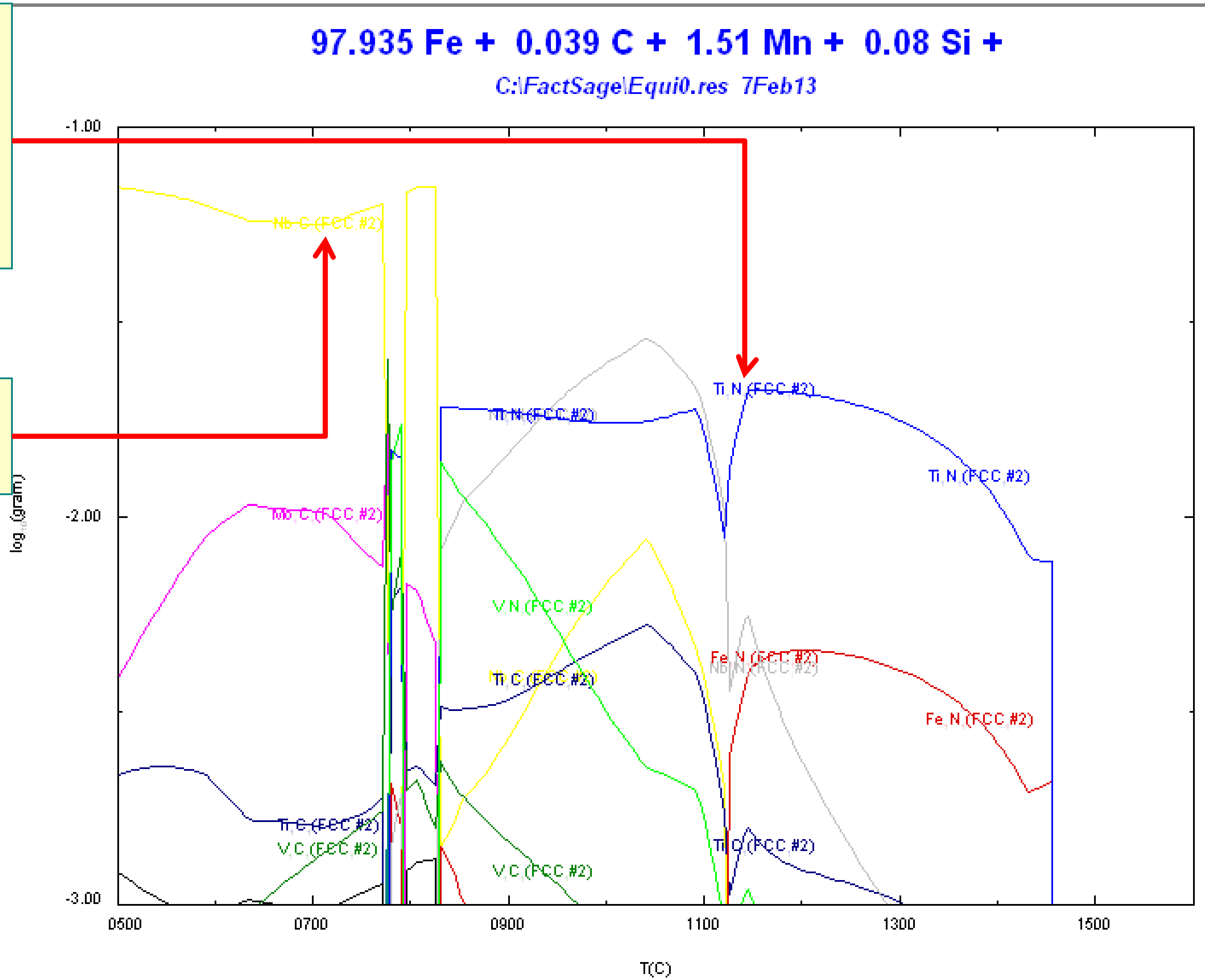
2. But below Ae3, the dominant species are MoC, VC and NbC



Carbide and Nitride precipitation in microalloyed steels

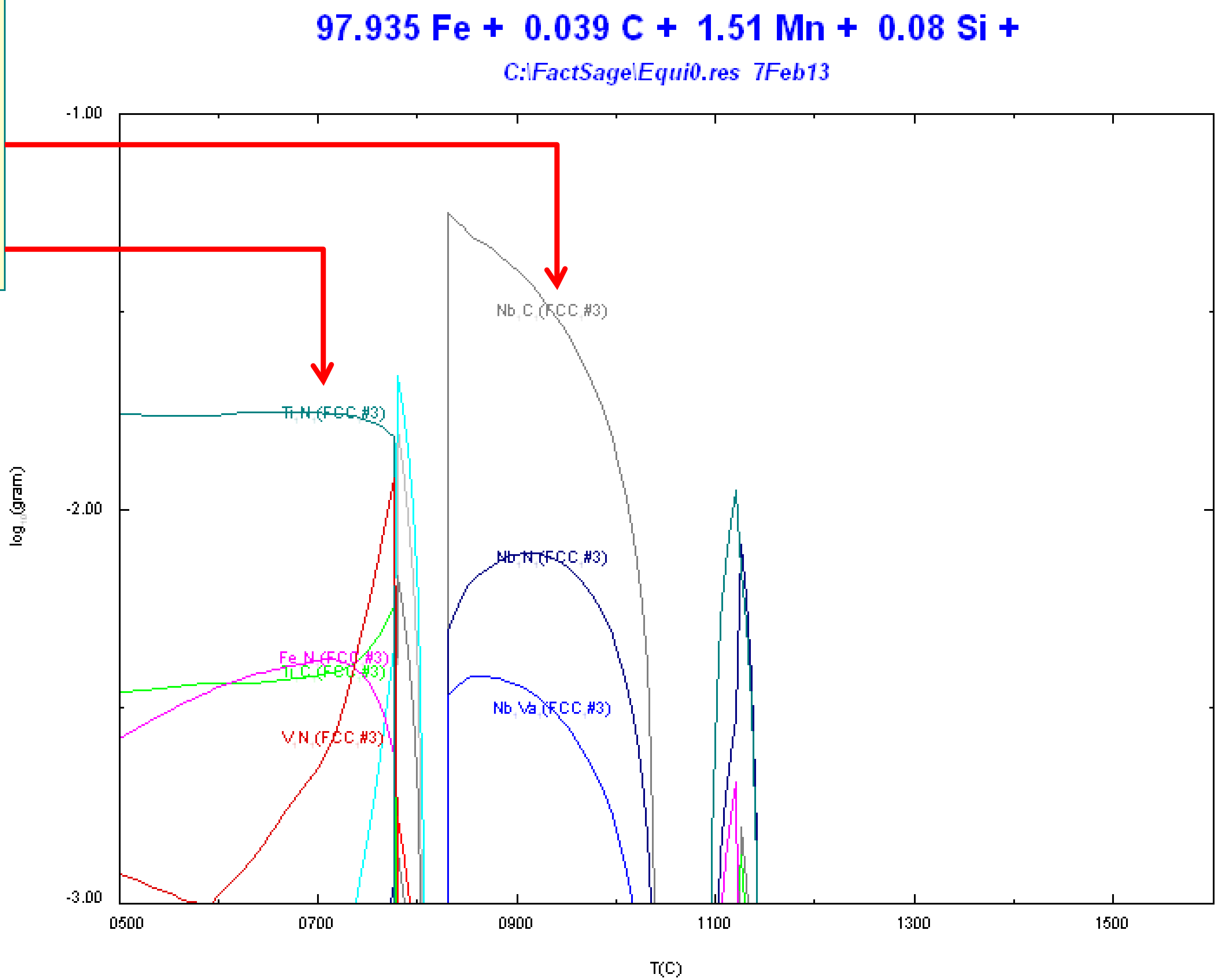
1. The FCC#2 phase is composed mainly of TiN and NbN at austenite temperatures…

2. … and of NbC below Ae3



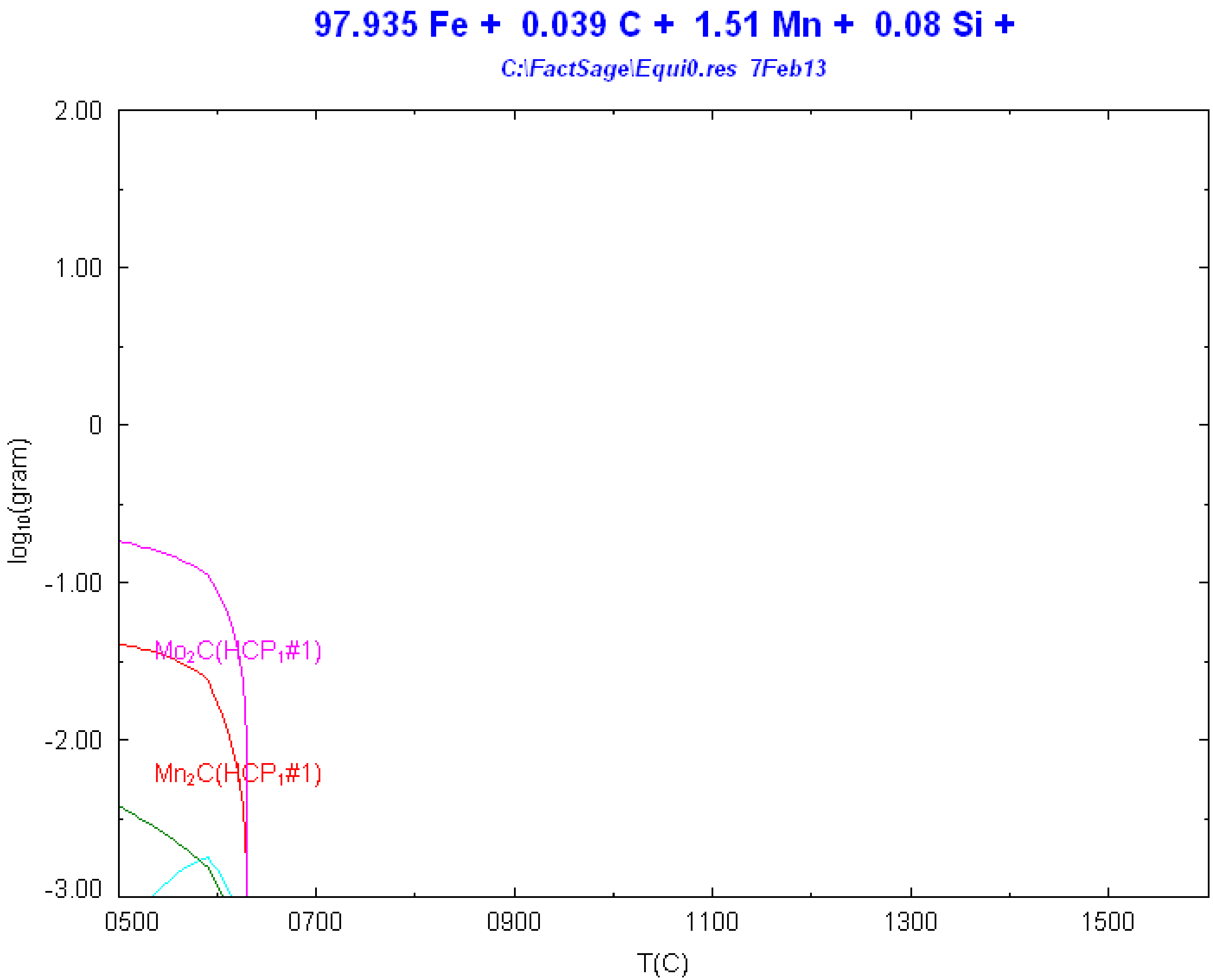
Carbide and Nitride precipitation in microalloyed steels

1. Finally, the FCC#3 phase is composed of Nb(C,N) at the austenite temperatures and of TiN below Ae3



Carbide and Nitride precipitation in microalloyed steels

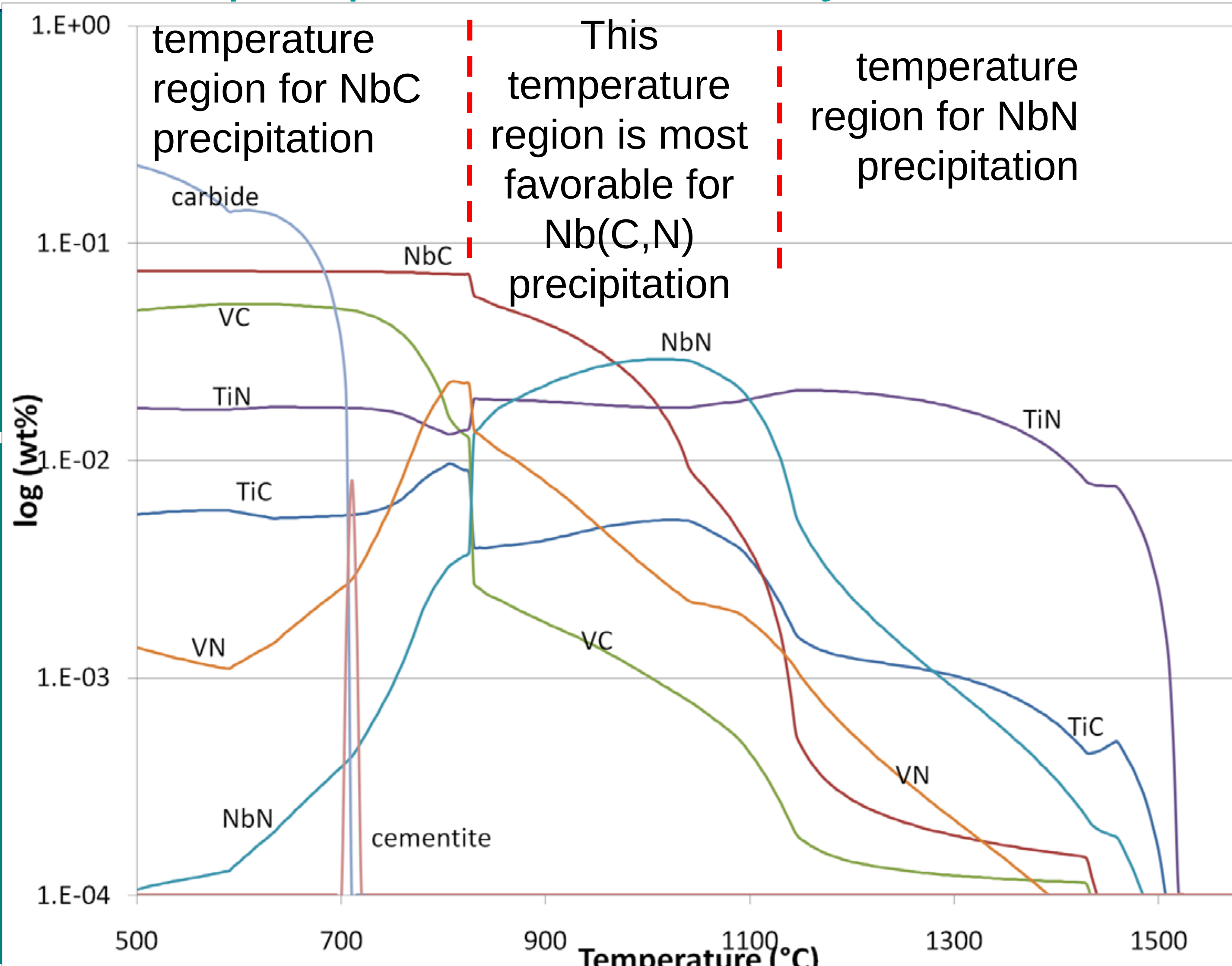
1. We also note that there is an HCP#1 phase present, which appears only below Ae3 and is composed primarily of Mo2C and Mn2C



Carbide and Nitride precipitation in microalloyed steels

1. Now that we know what each phase is composed of, it would be convenient to plot the species that interest us the most, namely (Nb,Ti,V)(C,N)

2. Copying the amounts of NbC, TiC, … species contained in FCC#1, FCC#2 and FCC#3 as well as the carbide and cementite phases to Excel, the following graph is obtained.



3. In summary, we can now figure out what the equilibrium precipitates will be at each temperature for designing the thermal treatment needed.