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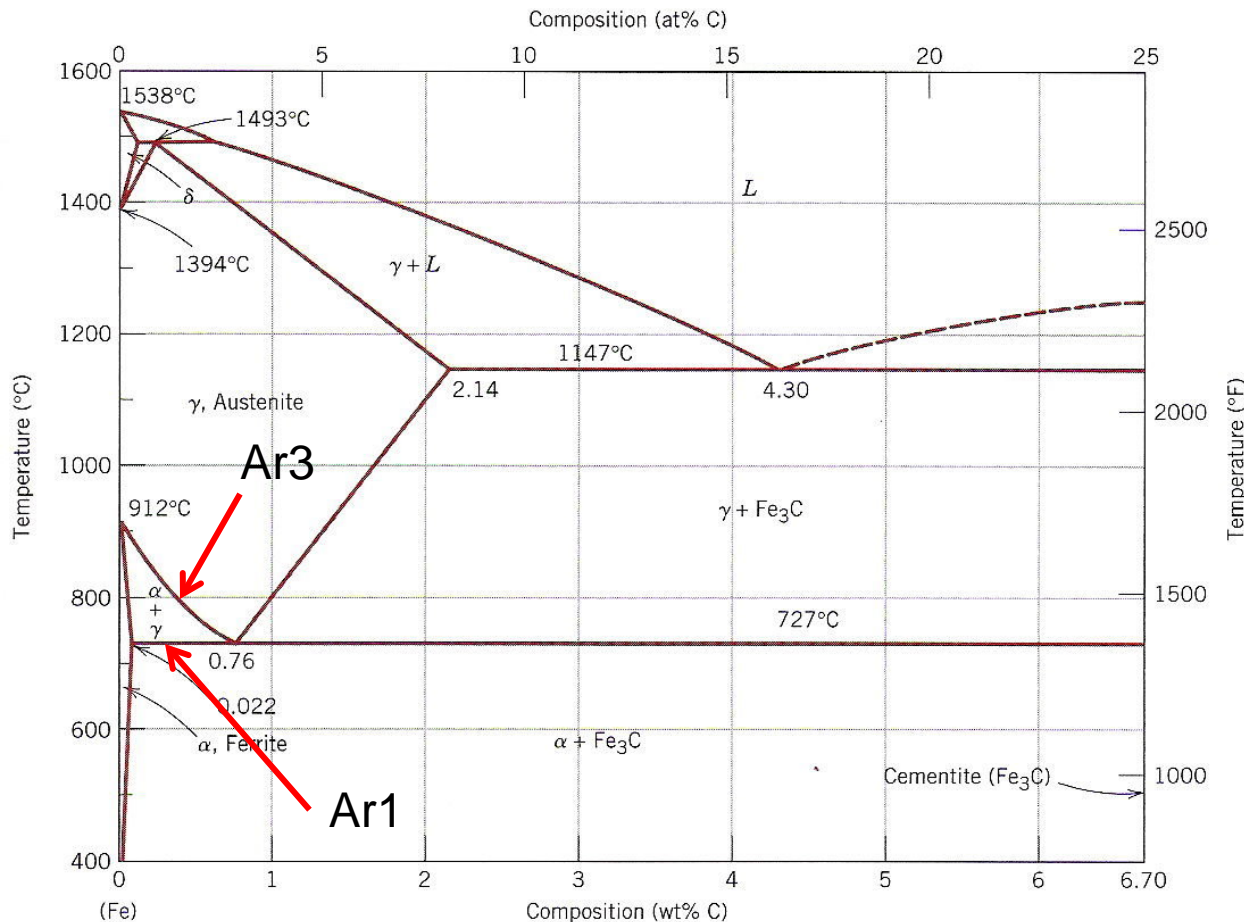
# Case 7: Nb-, V- and Ti- carbide and nitride precipitation in microalloyed steels

# 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 and 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)

**F Reactants - Equilib**

Mass(g)	Species
97.935	Fe
+ 0.039	C
+ 1.51	Mn
+ 0.08	Si
+ 0.018	Ti
+ 0.28	Mo
+ 0.068	Nb
+ 0.011	Al
+ 0.05	V
+ 0.0095	N

**F Data Search**

Databases - 1/19 compound databases, 1/19 solution databases

**Fact**

- FactPS
- FToxid
- FTsalt
- FTmisc
- FTHall
- FT0xCN
- FTfrtz
- FTHehg
- FTpulp
- FTlite

**FactSage™**

- FSscopp
- FSlead
- FSstel
- FSnobl
- FSupsi

**SGTE**

- BINS
- SGPS
- SGTE
- SGnobl
- SGsold
- SGnucl

**Other**

- ELEM
- FTdemo
- TDnucl

**Miscellaneous**

- EXAM
- SGTE#
- SGTE\*

compounds only  
solutions only  
no database

Clear All  
Select All  
Add/Remove Data  
RefreshDatabases

**Information**

2. Select only the FSstel database.

**Options**

Default

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

# Carbide and Nitride precipitation in microalloyed steels

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

**F Menu - Equilib: last system**

File Units Parameters Help

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

Reactants (10)

(gram) 97.935 Fe + 0.038 C + 1.51 Mn + 0.08 Si + 0.018 Ti + 0.28 Mo + 0.068 Nb + 0.011 Al + 0.05 N

Products

Compound species

- gas
- ideal
- real
- aqueous
- pure liquids
- pure solids
- suppress duplicates

apply

Solution species

*	+	Base-Phase	Full Name
J		FSstel-FCC1	FCC_A1
J		FSstel-BCC1	BCC_A2
J		FSstel-HCP1	HCP_A3
	+	FSstel-CEME	CEMENTITE
I		FSstel-M23C	M23C6
I		FSstel-M7C3	M7C3
I		FSstel-M6C	M6C

Legend

- I - immiscible 3
- J - 3-immiscible 3
- + - selected 1

Equilibrium

- normal
- normal + transitions
- transitions only
- open

Calculate >>

221 calculations

500 1600 5

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 Selection - EQUILIB Results: gram vs T(C)

	#	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
		<b>ELEMENTS</b>						
	374	Mo_GAS	0	0	0	0	0	0

source  [page] 221 pages

Mass:  mole  igrain

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

Select Top 24 8 species selected

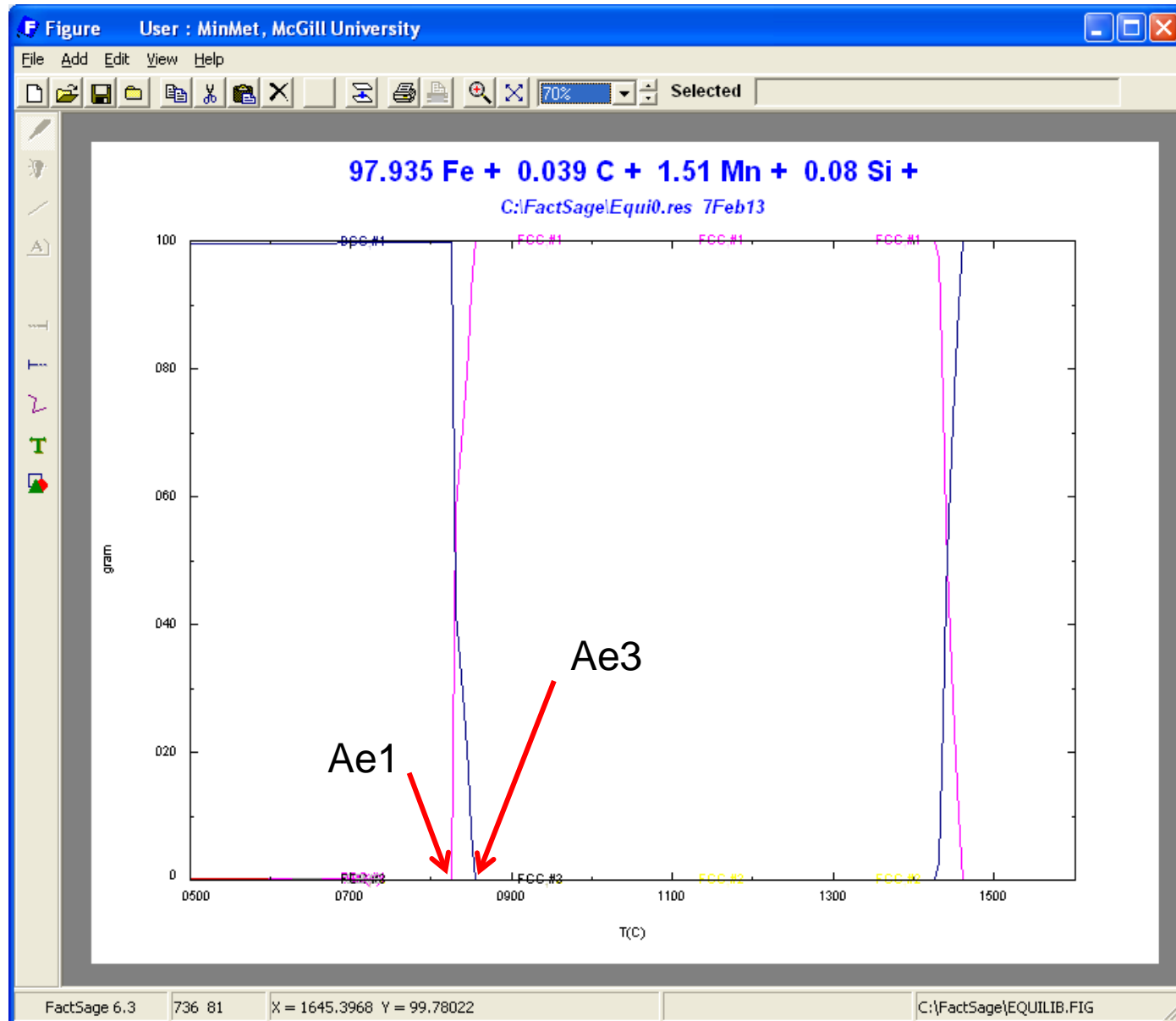
Clear Select ... OK

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

# Carbide and Nitride precipitation in microalloyed steels

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

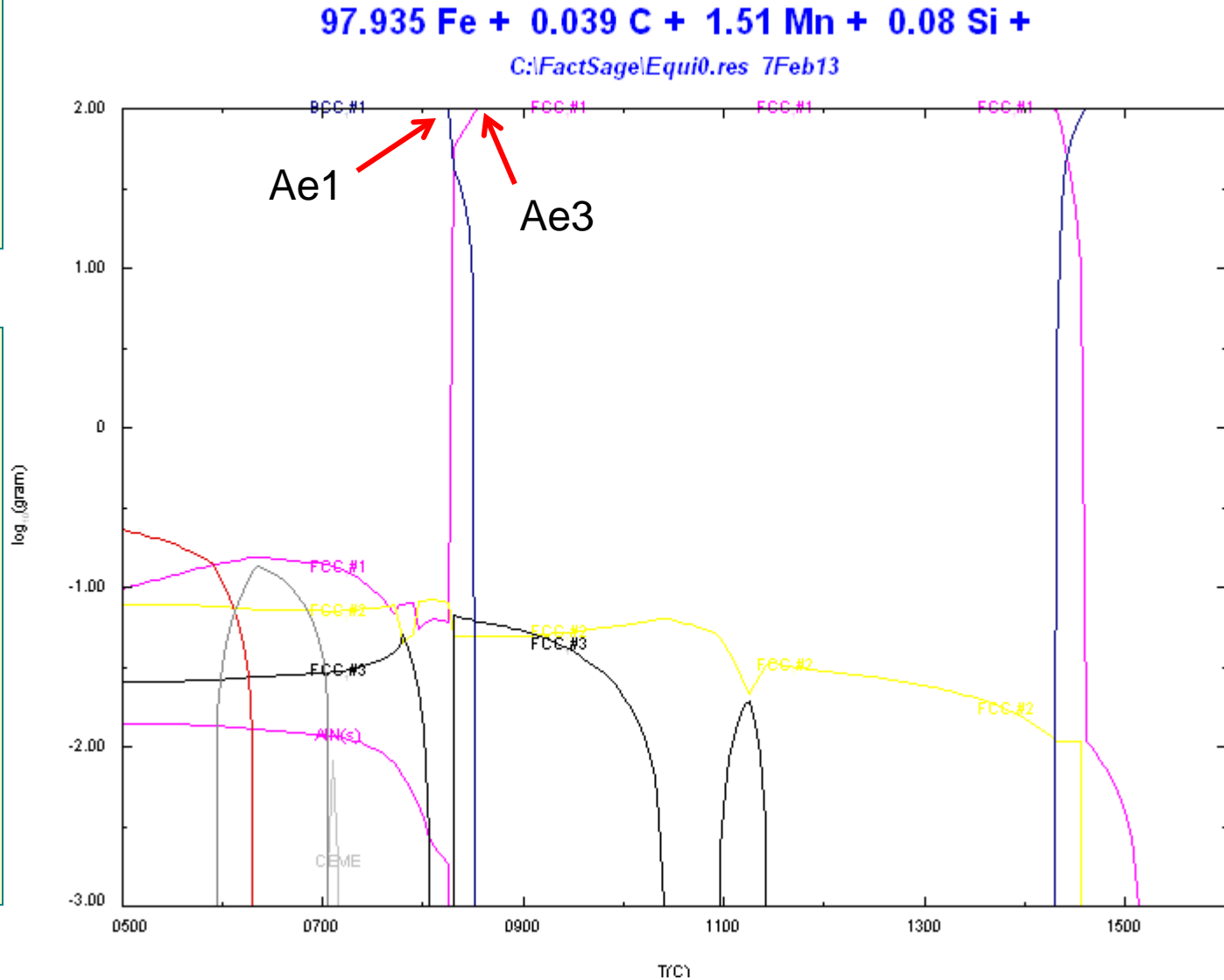
2. We should also look at the very low compositions, since all the microalloyed elements will be present in very small quantities.



# 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 check this by plotting their composition with temperature



# Carbide and Nitride precipitation in microalloyed steels

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

**F 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)
		<b>FSstel- FCC1</b>						
+	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
		<b>FSstel- FCC1</b>						
	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

source    **Mass**     mole    **Order**     integer #  
 [page]     gram     mass (max)  
 fraction (max)  
 activity (max)

Clear    221 pages    Select Top 24    24 species selected    Select ...    OK

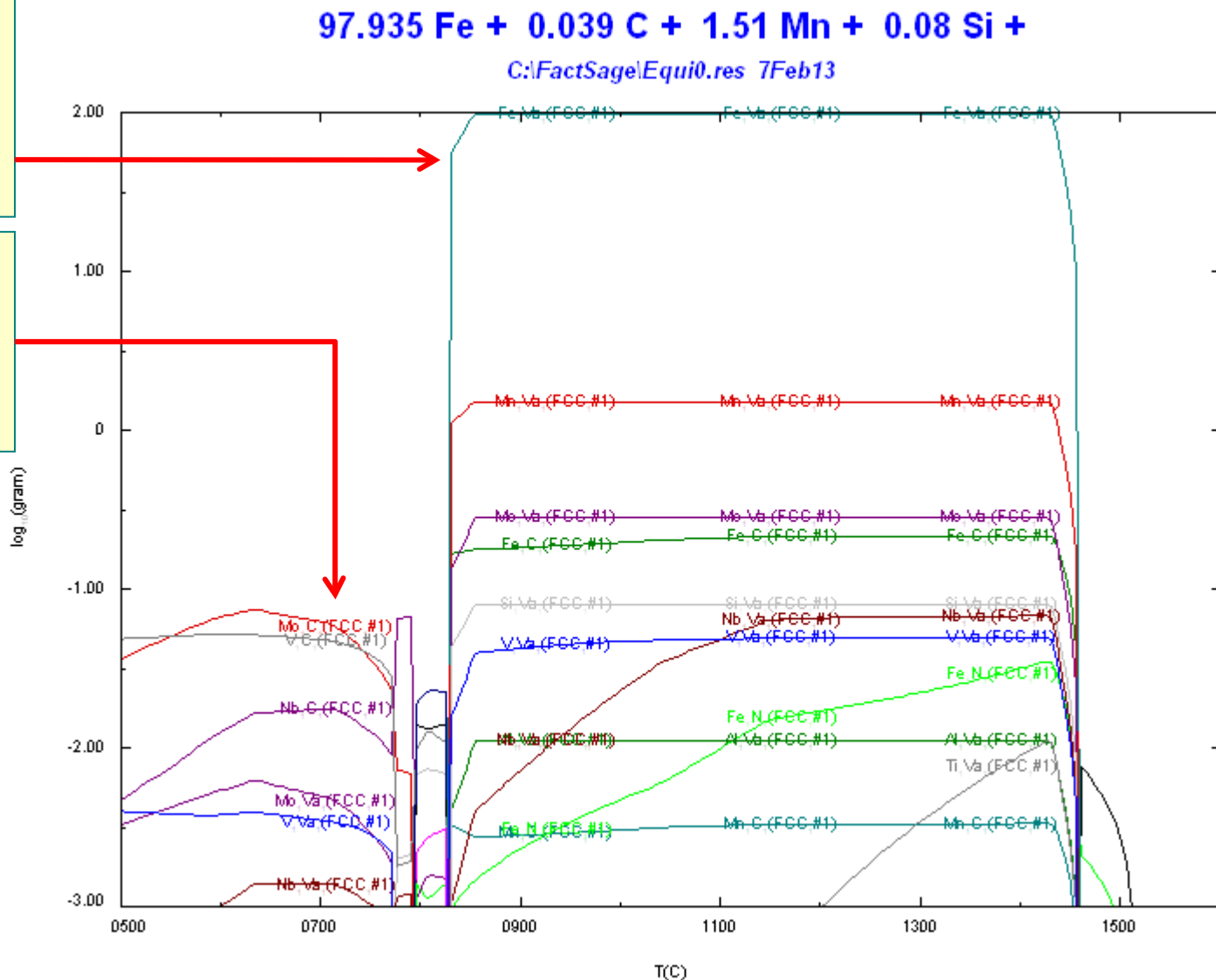
Click on the '+' column to add or remove species.



# 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  $A_{e3}$ , the dominant species are MoC, VC and NbC



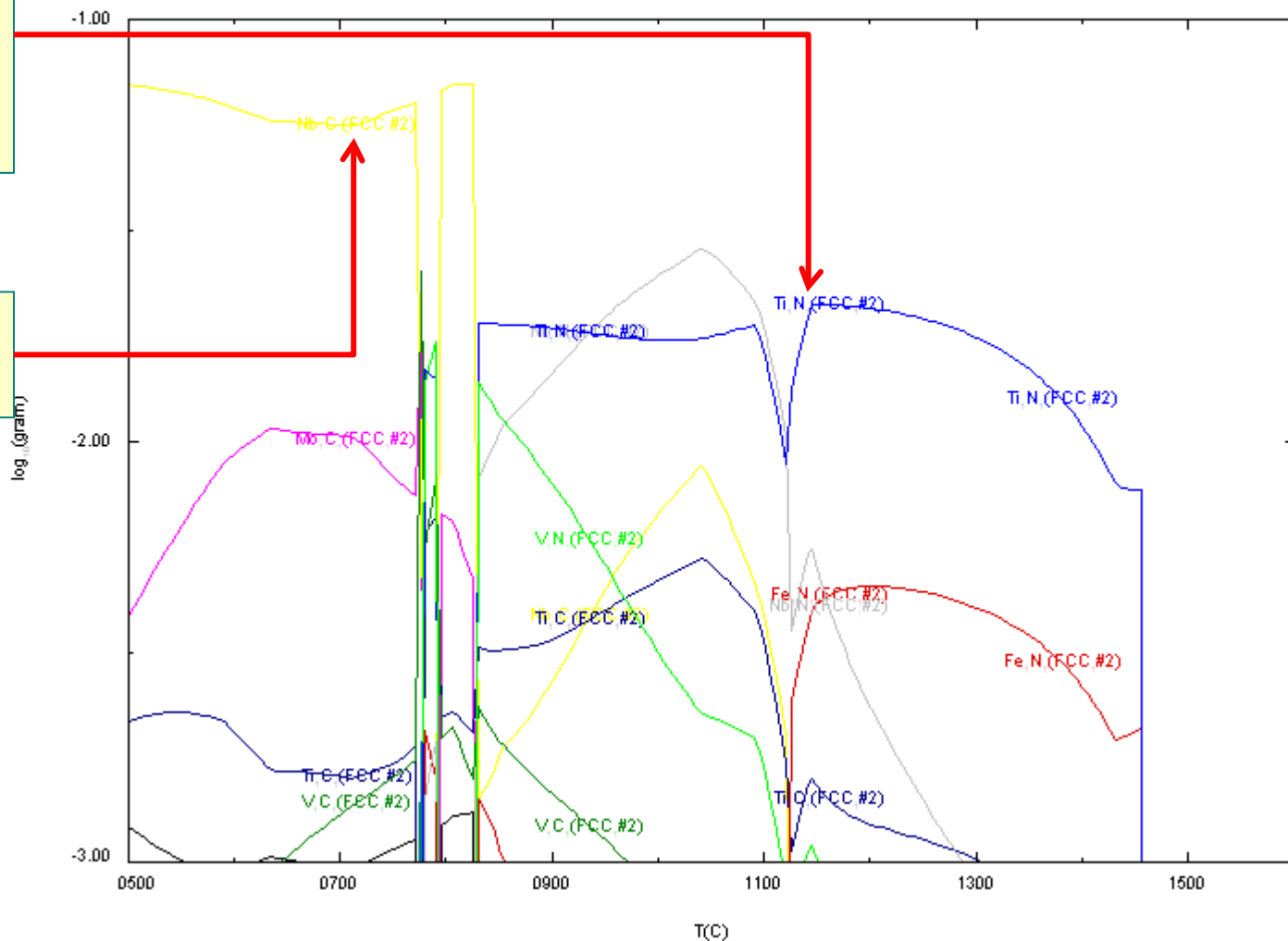
# Carbide and Nitride precipitation in microalloyed steels

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

2. ... and of NbC below Ae3

97.935 Fe + 0.039 C + 1.51 Mn + 0.08 Si +

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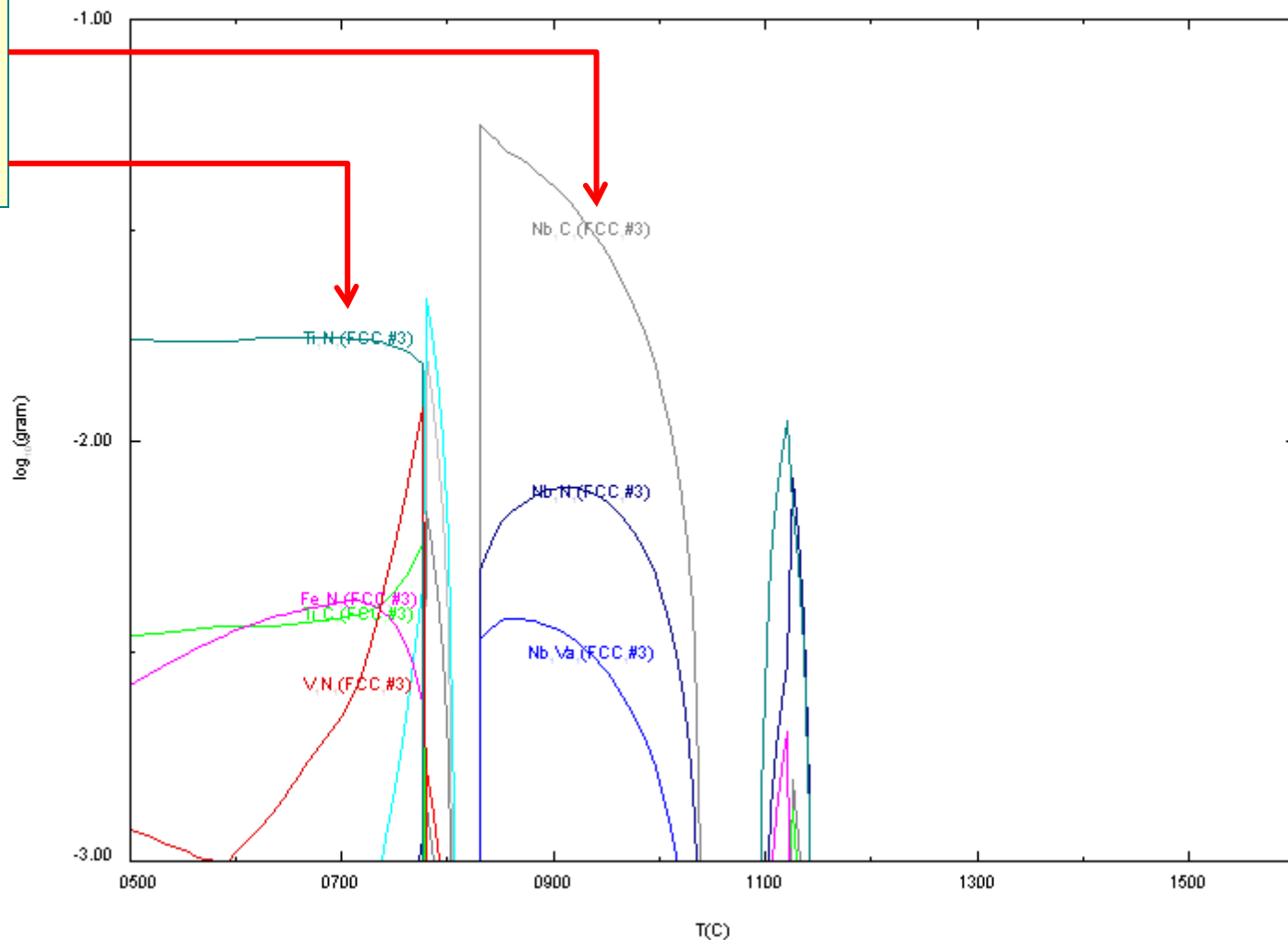


# Carbide and Nitride precipitation in microalloyed steels

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

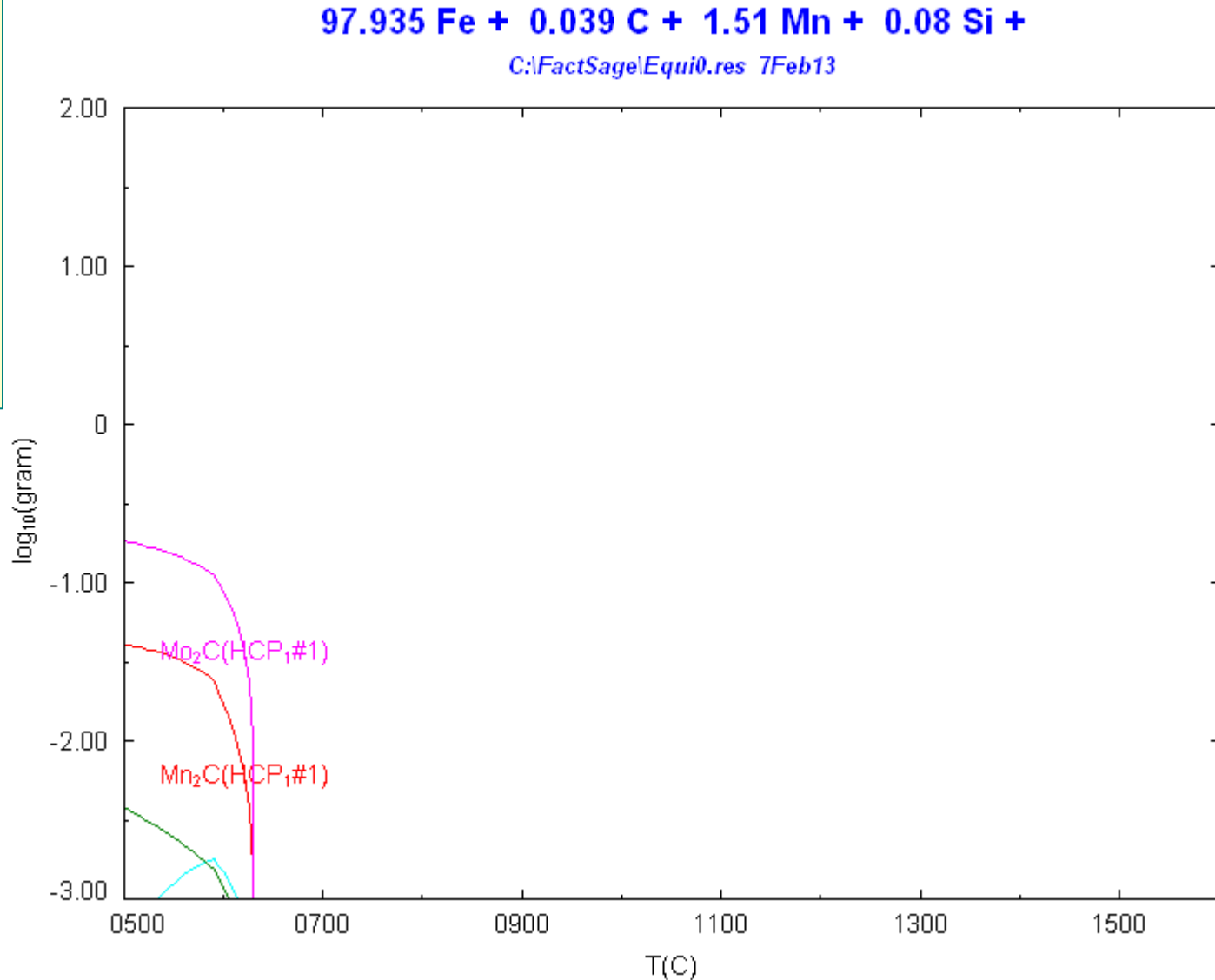
97.935 Fe + 0.039 C + 1.51 Mn + 0.08 Si +

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# Carbide and Nitride precipitation in microalloyed steels

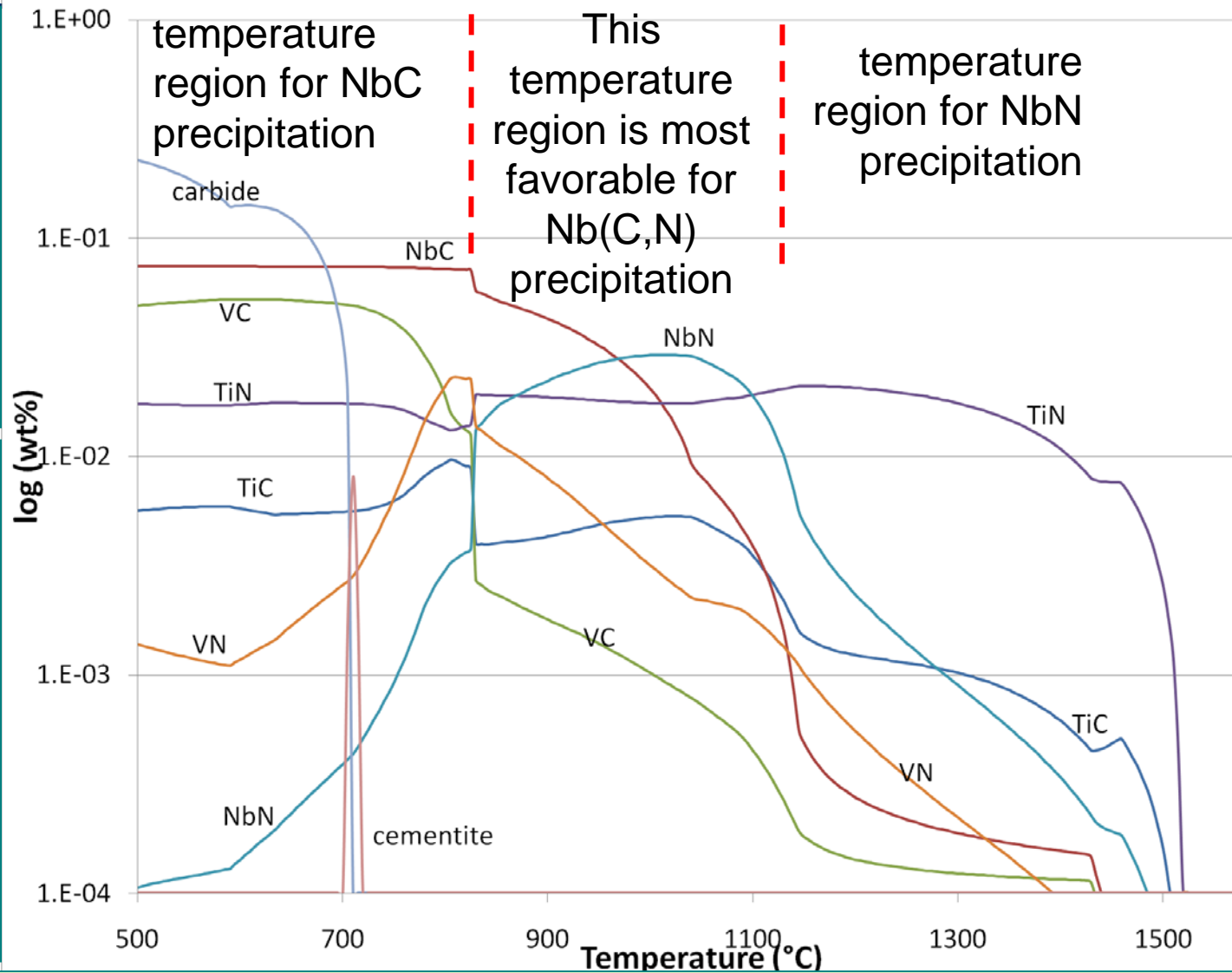
1. We also note that there is an HCP#1 phase present, which appears only below  $A_{e3}$  and is composed primarily of  $Mo_2C$  and  $Mn_2C$



# 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.