



4th Session

6 basic rules in

Geopolymer Cement processing

J. Davidovits

Rule nr. 1

Master the alumino-silicates

Fly ash-based geopolymer

Chapter 12

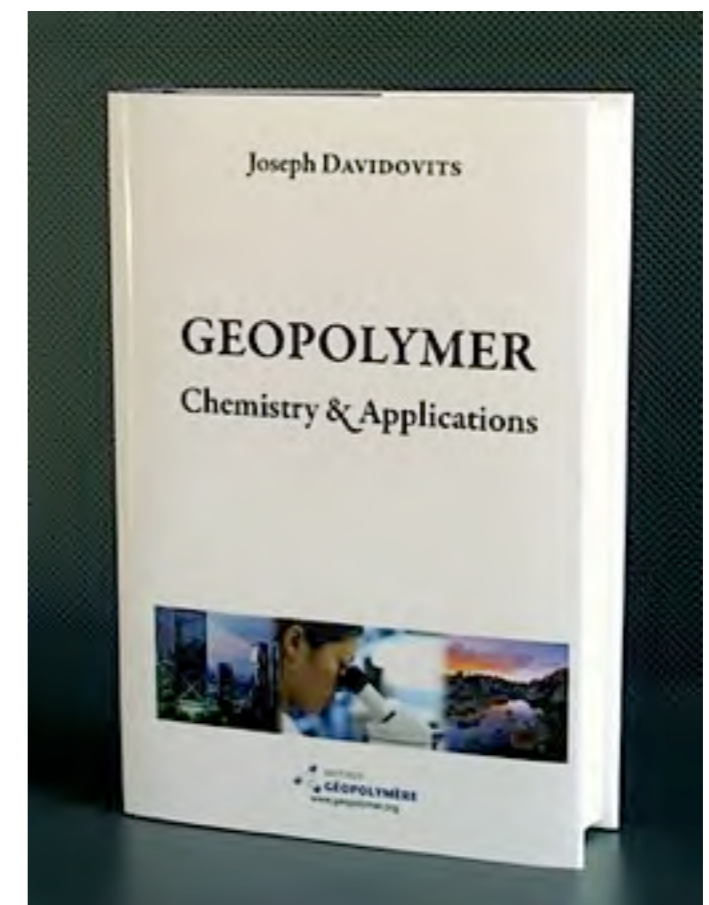
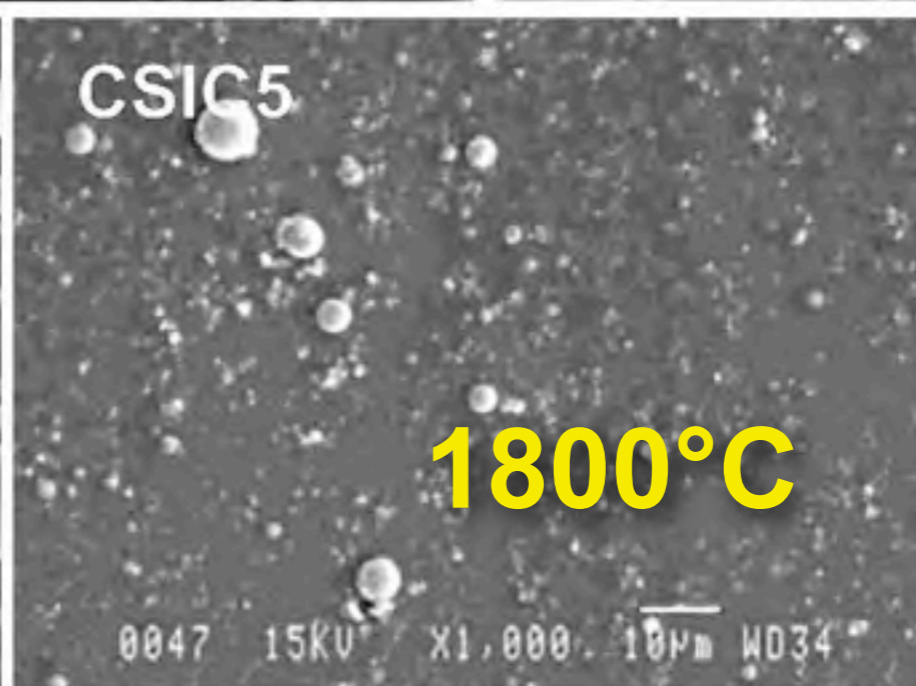
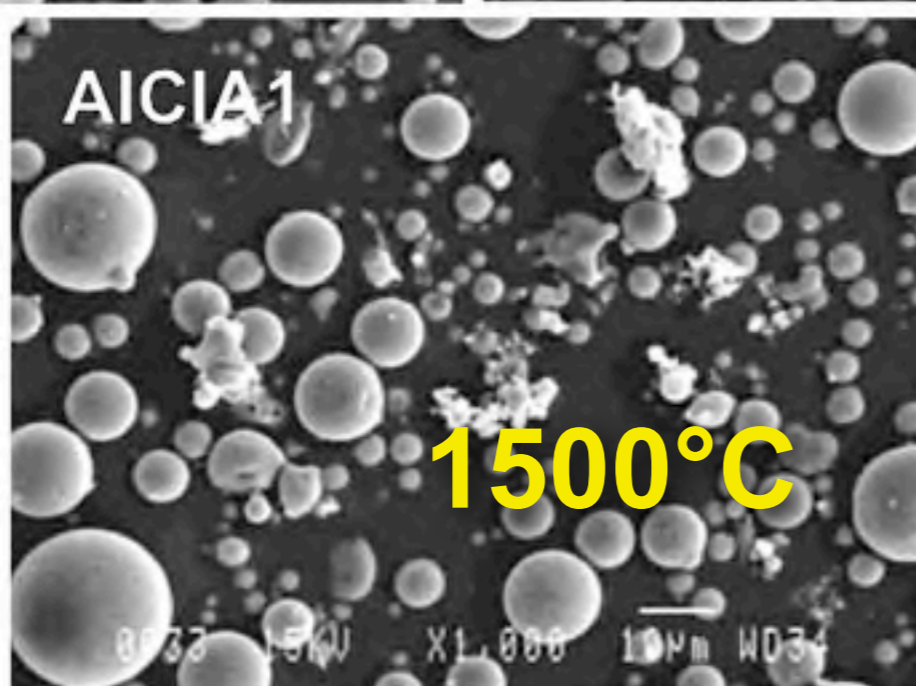
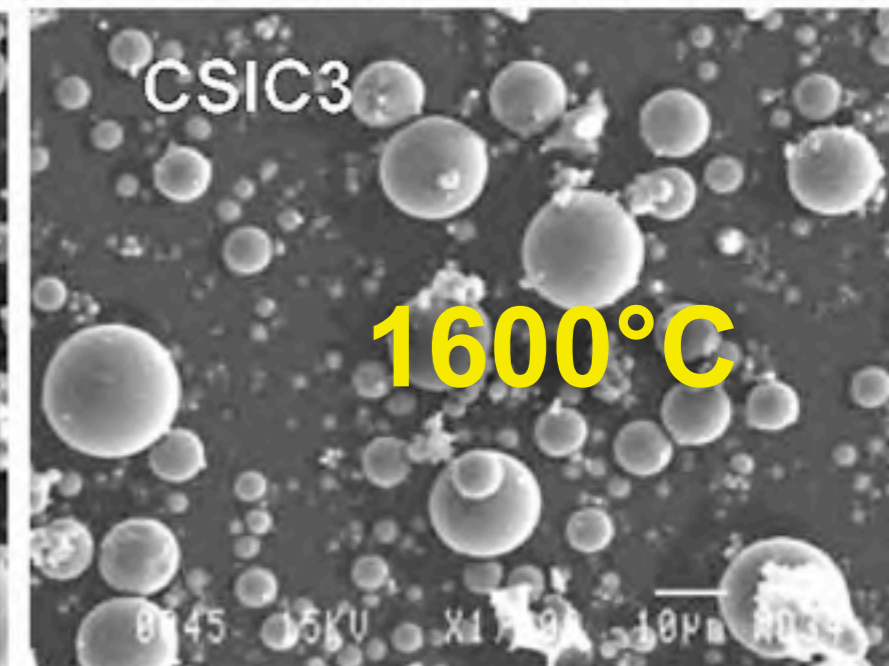
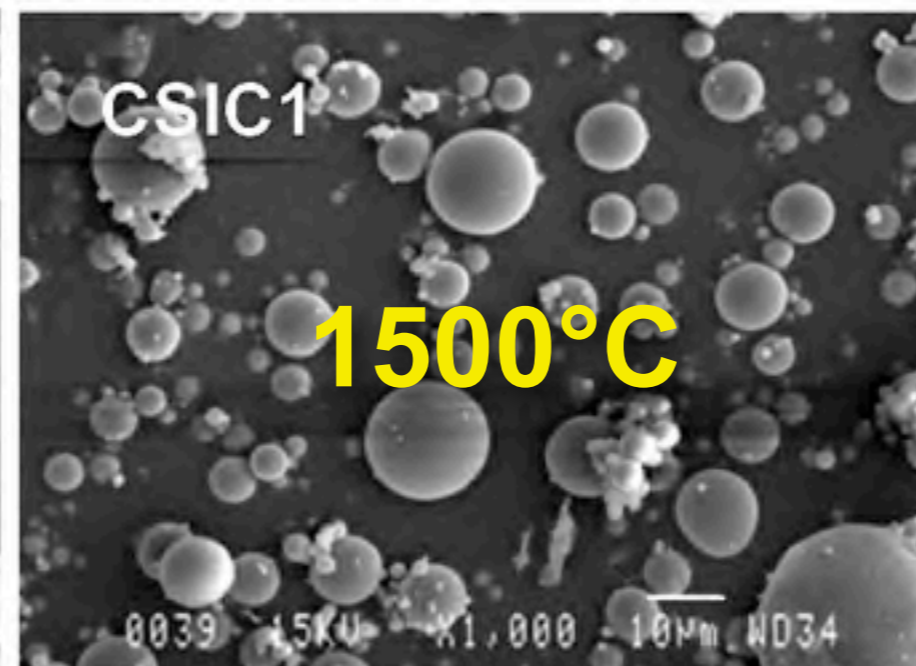
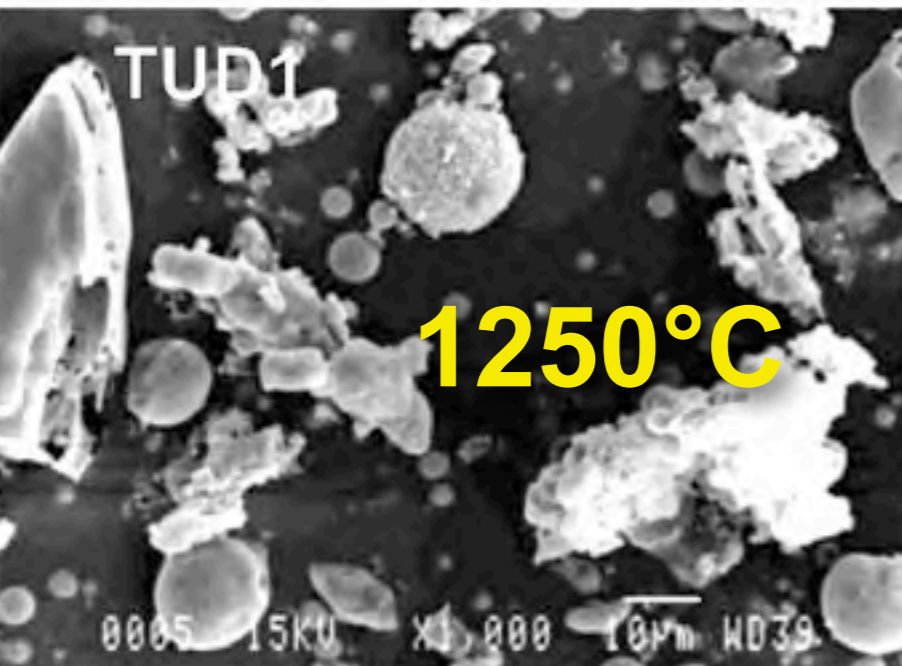
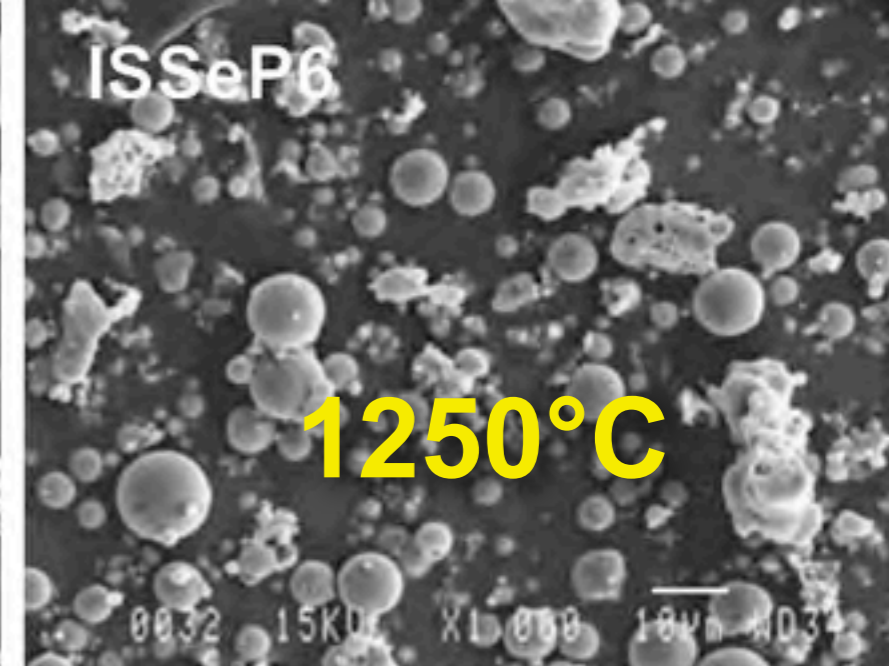
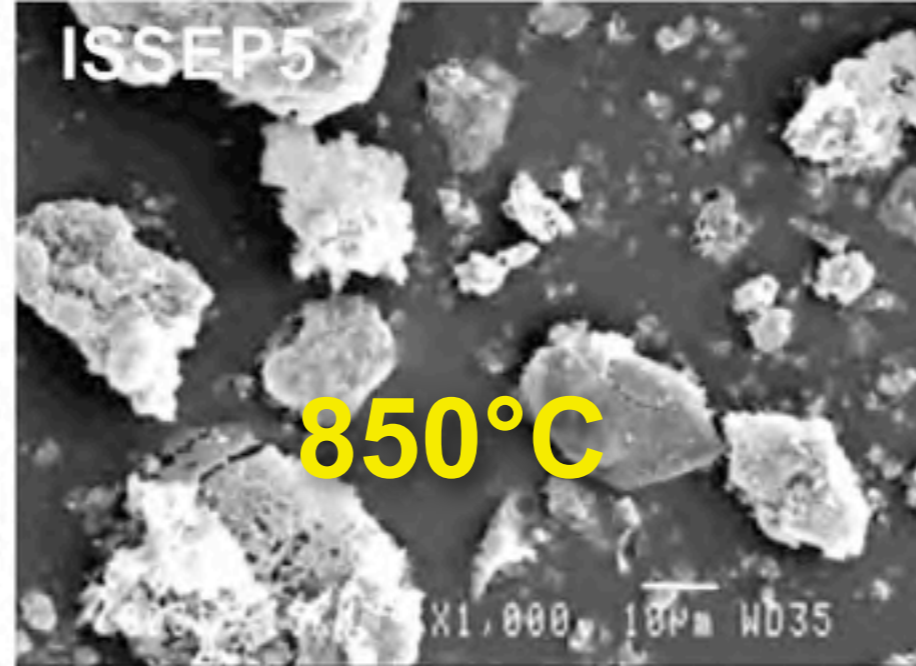
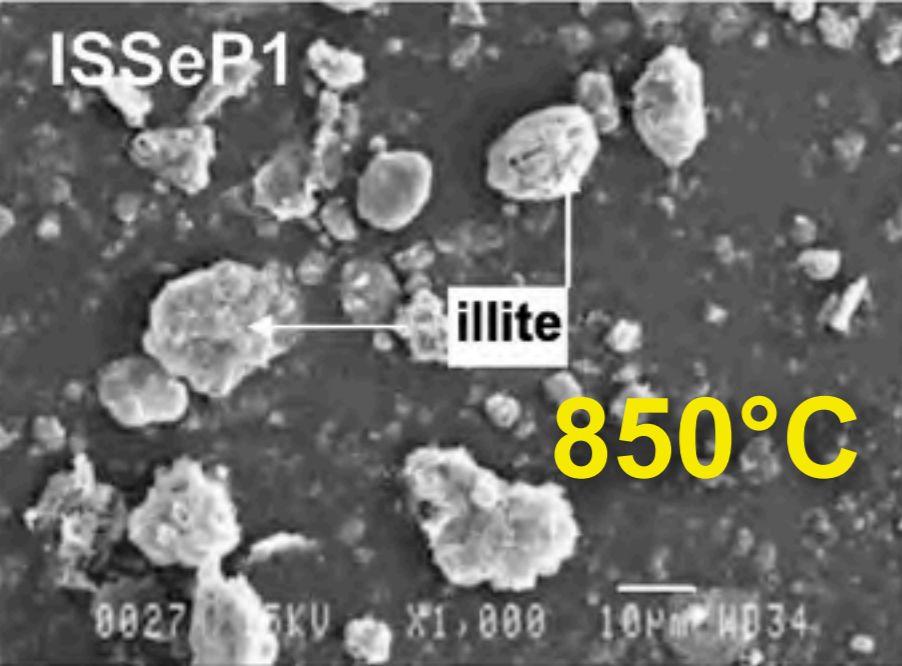


Table 12.5: The principal phases found in coals and the phases formed after combustion.

Common coal minerals	Phases formed after combustion		
	850°C	1500°C	1800°C
Quartz	quartz	cristobalite	glass
Kaolinite	metakaolin	glass + mullite	glass
Illite	illite	glass + mullite	glass
Pyrite FeS_2	iron sulphide FeS/FeO	Fe_2O_3 haematite + glass Fe_3O_4 magnetite + glass	glass
Calcite	lime CaO	glass	glass



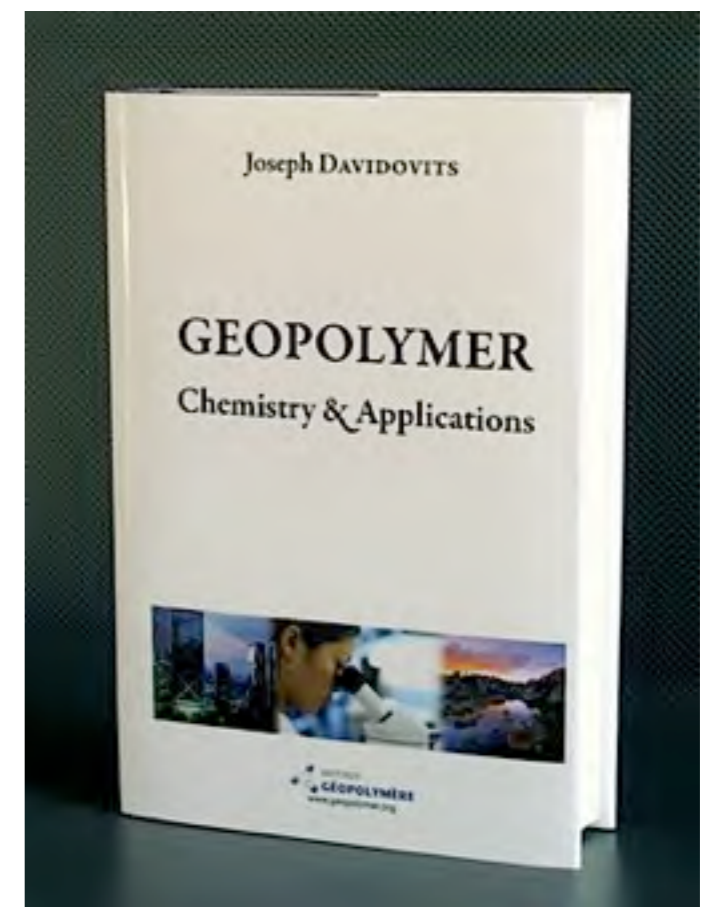
Rule nr. 2

Understand their chemical reactivity

kaolinite/metakaolin/quartz/

feldspar/pozzolan

Chapter 18



not oxide elemental analysis

but mineralogy

Oxides	1	2	3
SiO ₂	63.11	40.60	46.61
Al ₂ O ₃	21.20	27.14	14.33
CaO	0.32	0.04	7.59
MgO	0.43	0.05	5.95
Na ₂ O	0.14	0.00	2.76
K ₂ O	0.68	0.06	1.41
Fe ₂ O ₃	4.05	17.73	13.95
TiO ₂	1.99	0.19	0.00
L.O.I.	5.60	11.20	0.90
Minerals	Kaolinite Quartz Rutile Goethite	Kaolinite Quartz Ilmenite Hematite Rutile	Anorthite Quartz Diopside Enstatite Ilmenite Plagioclase

Rule nr. 3

User-friendly systems

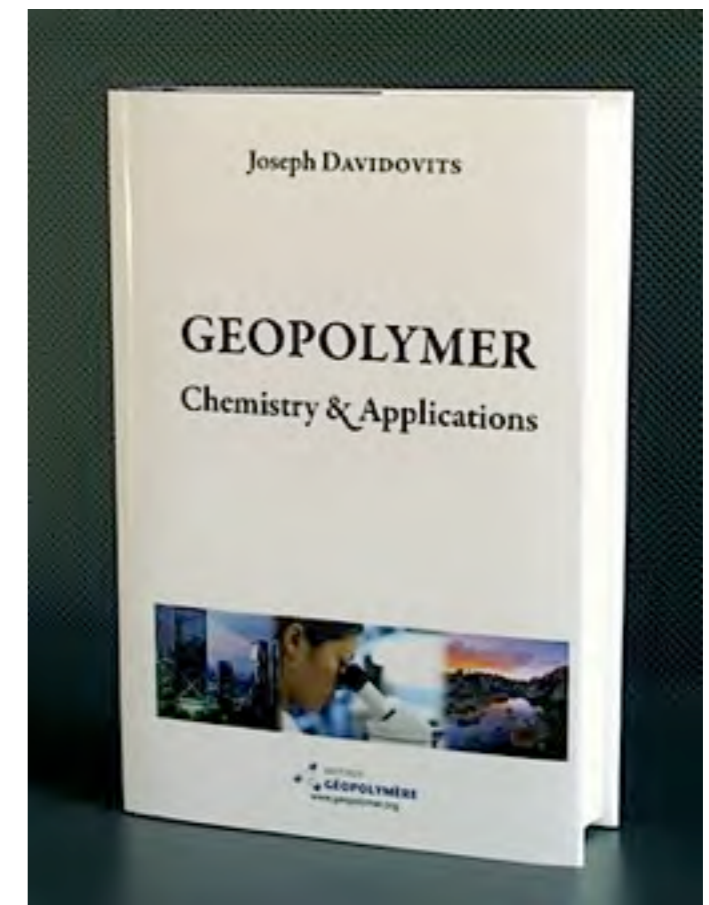
Chapter 19



Corrosive



Irritant



Corrosive and irritant chemicals



Hostile

CaO (quick lime)

NaOH

KOH

Sodium metasilicate
 $\text{SiO}_2:\text{Na}_2\text{O} = 1$

Any soluble silicate
 MR $\text{SiO}_2:\text{M}_2\text{O} < 1.65$

Friendly



$\text{Ca}(\text{OH})_2$

Portland cement

Iron slag

Slurry soluble silicate/kaolin
 MR $1.25 < \text{SiO}_2:\text{M}_2\text{O} < 1.65$

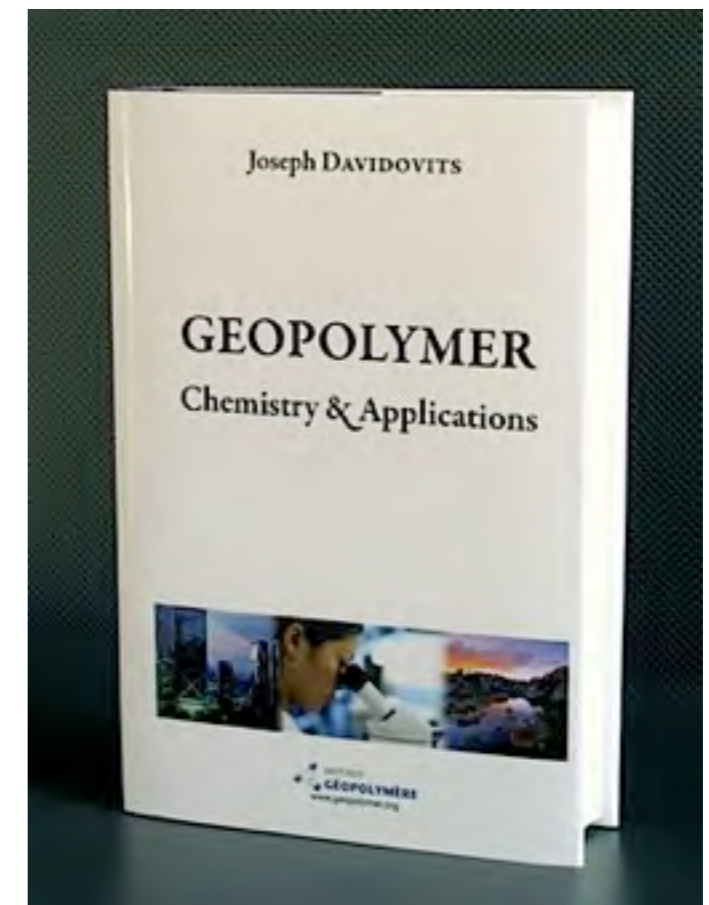
Any soluble silicate
 MR $\text{SiO}_2:\text{M}_2\text{O} > 1.65$

Rule nr. 4

Master the soluble silicate

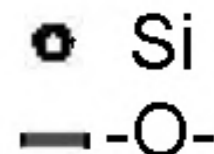
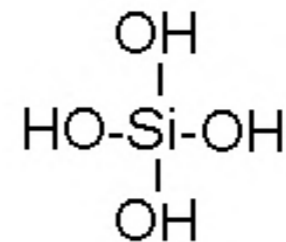
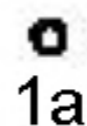
Molecular structure

Chapter 5

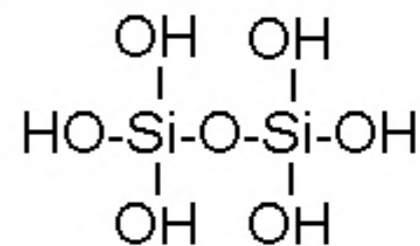
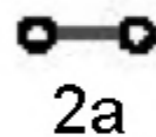


Total of silicon atoms

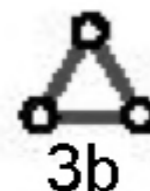
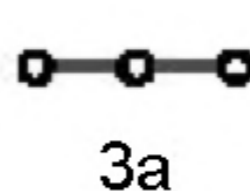
n = 1 oligomer



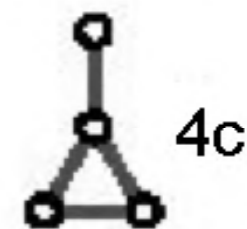
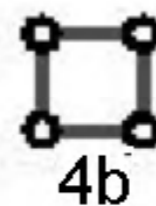
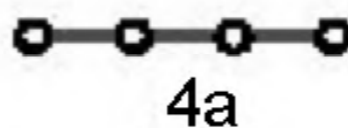
n = 2 dimer



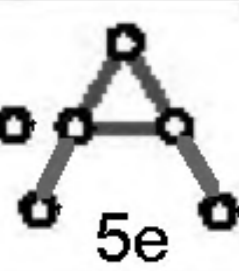
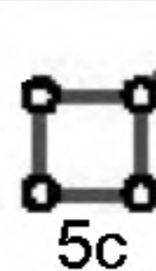
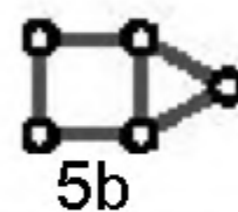
n = 3 trimer



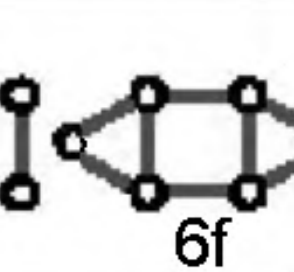
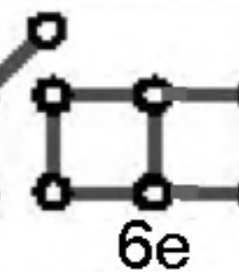
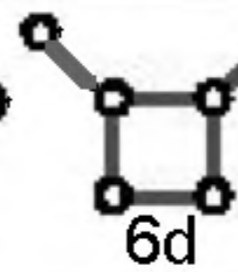
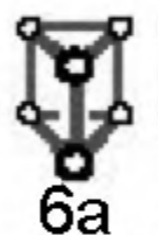
n = 4 tetramer



n = 5 pentamer



n = 6 hexamer



n = 8 octomer



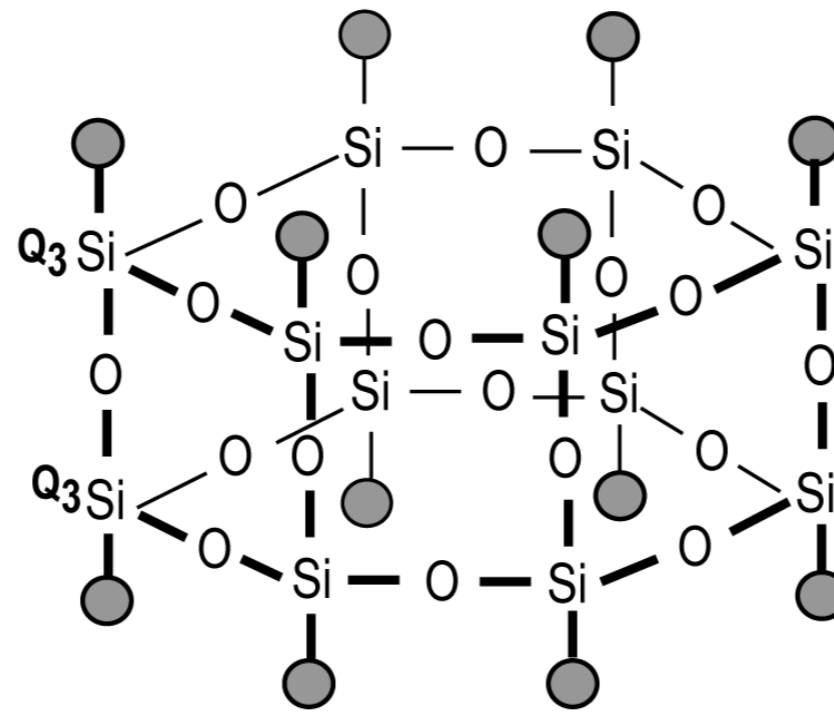
Na-silicate
molecules
(oligomers)
in solution

MR = 3,3

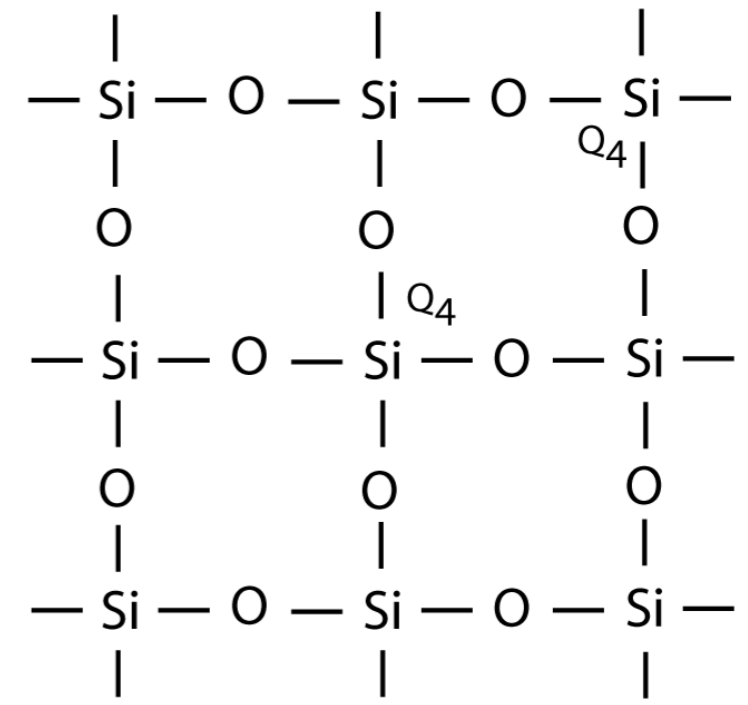
(12 Q₃ + 9 Q₄)

solid Na-glass

● Na⁺ O⁻



Na-disilicate



quartz

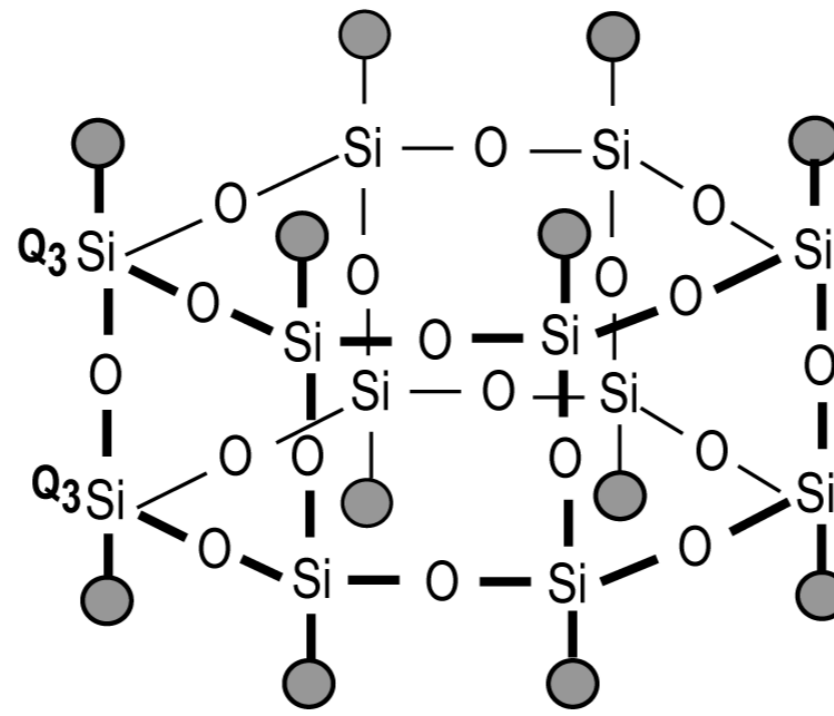
MR = 3,3

(12 Q₃ + 9 Q₄)

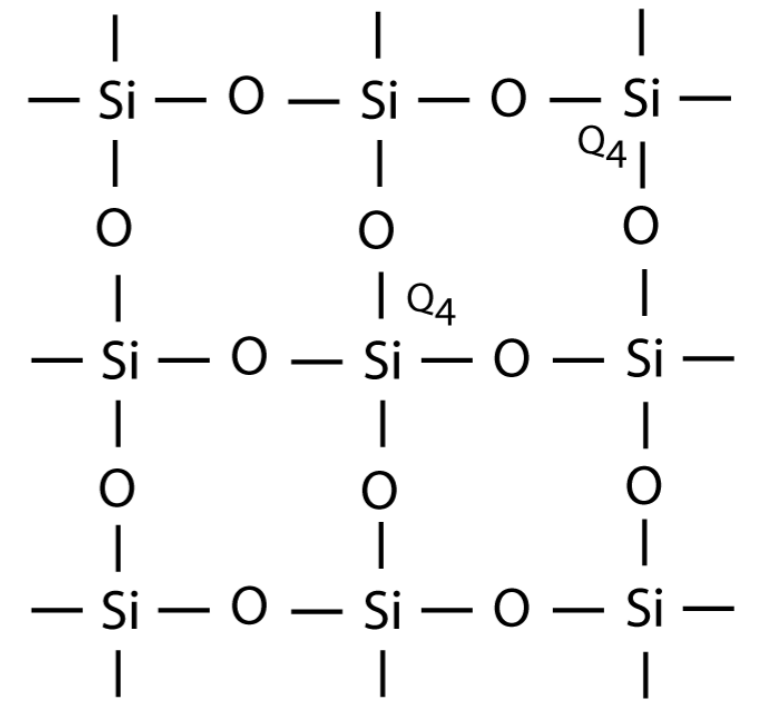
solid Na-glass

● Na⁺ O⁻

○ OH



Na-disilicate

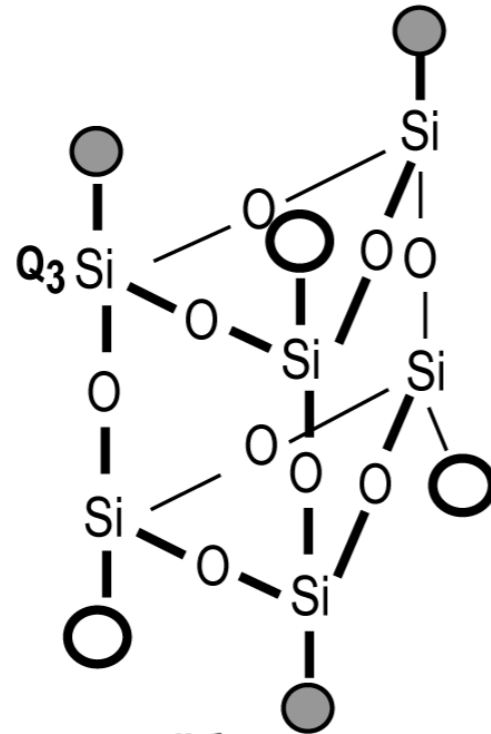


quartz

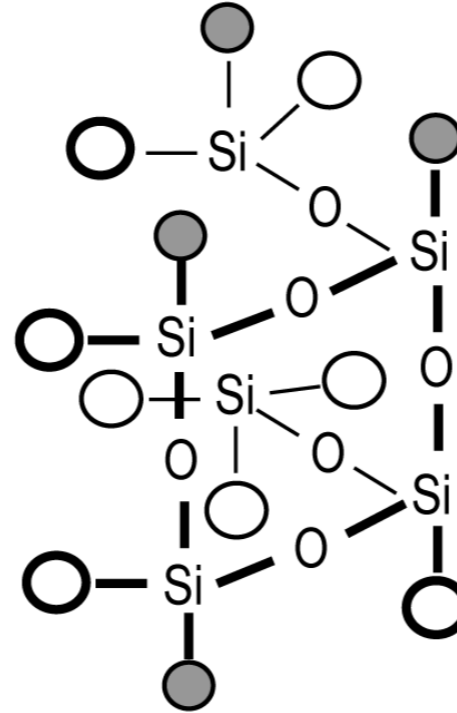
dissolution

**(2Q₁ + 6Q₂
+ 10Q₃+1Q₄)**

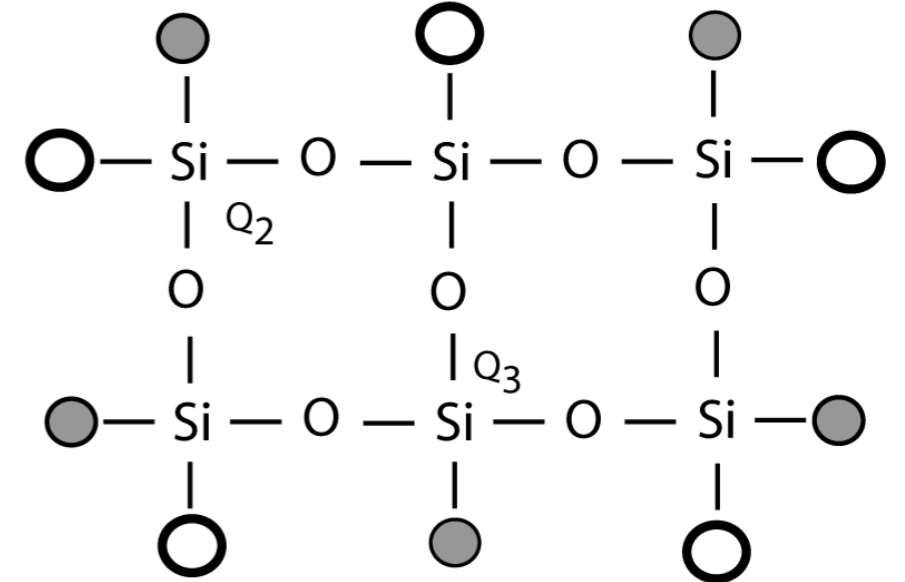
Na-solution



#6a



#6d



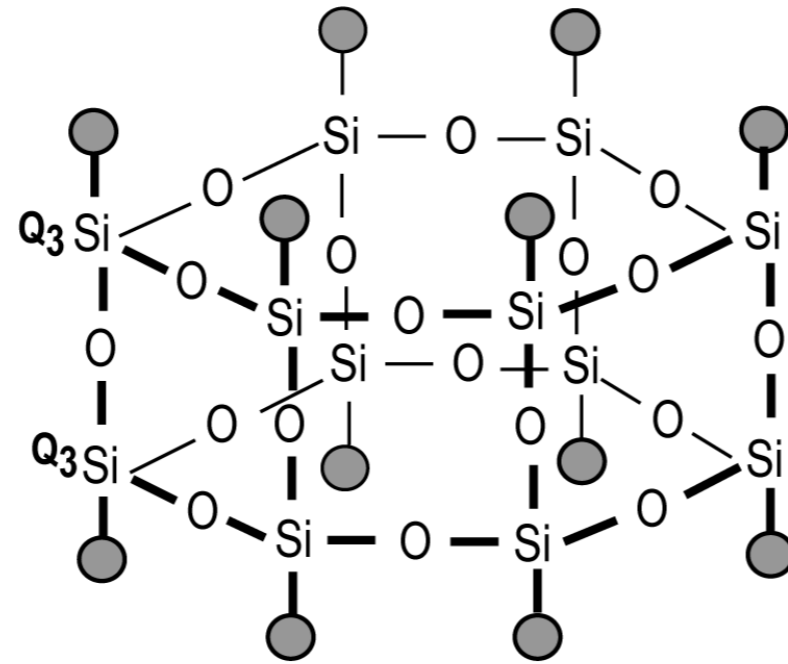
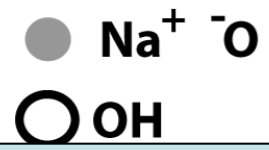
#6e

+ quartz Q₄

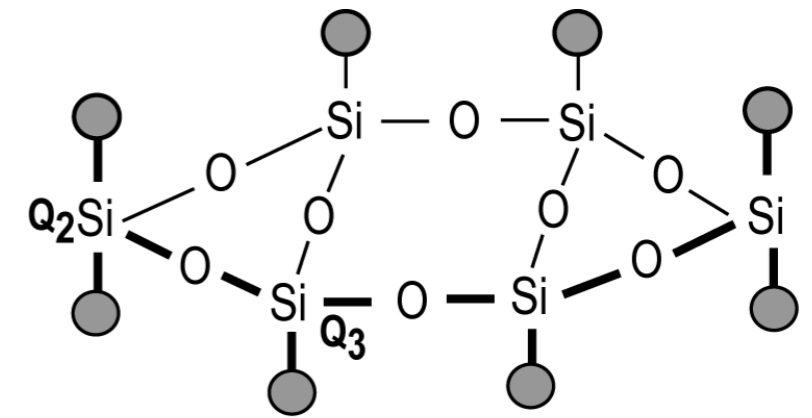
MR = 2

(1Q₂ + 6Q₃ + 1Q₄)

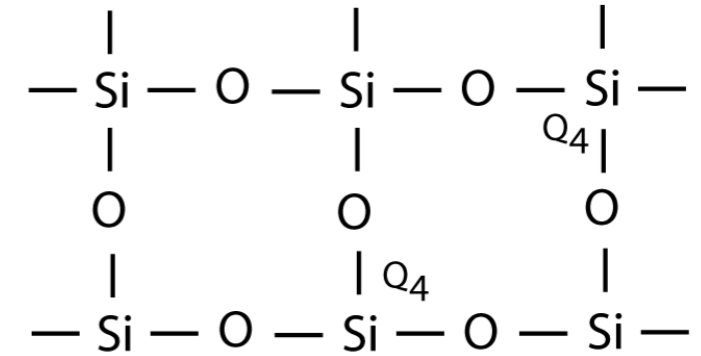
solid Na-glass



Na-dodeca-siloxonate



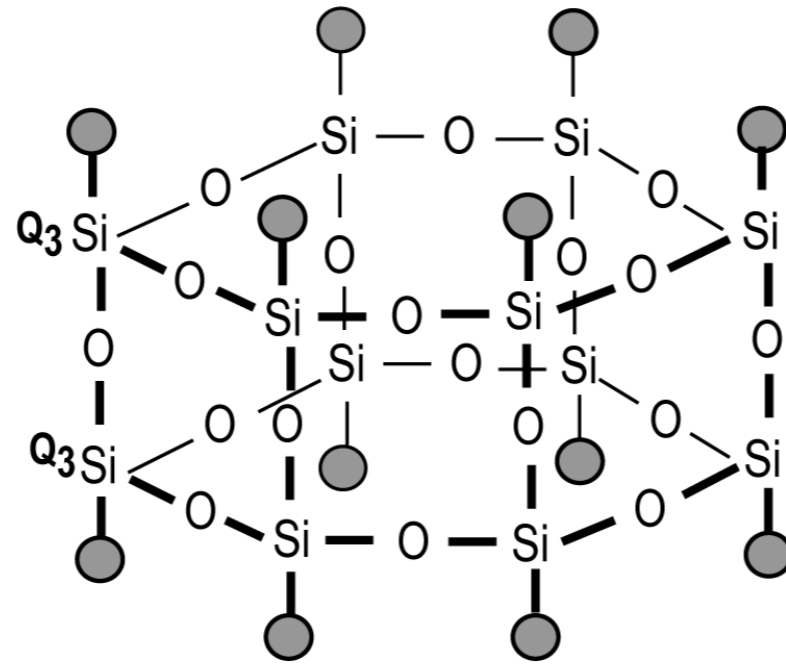
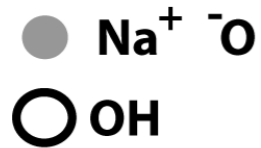
+ Na-hexa-siloxonate



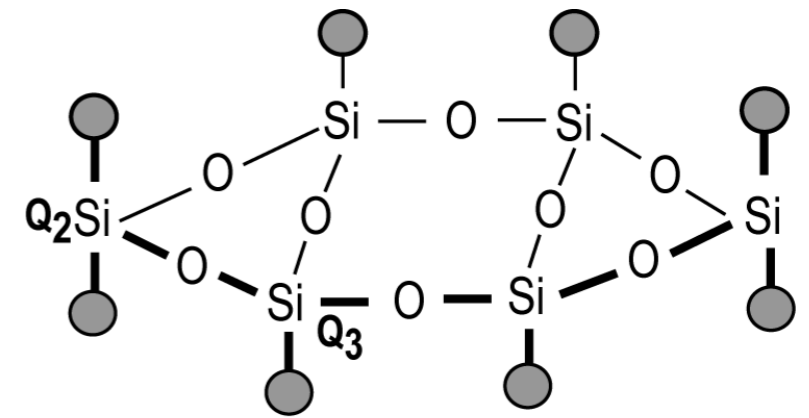
MR = 2

(1Q₂ + 6Q₃ + 1Q₄)

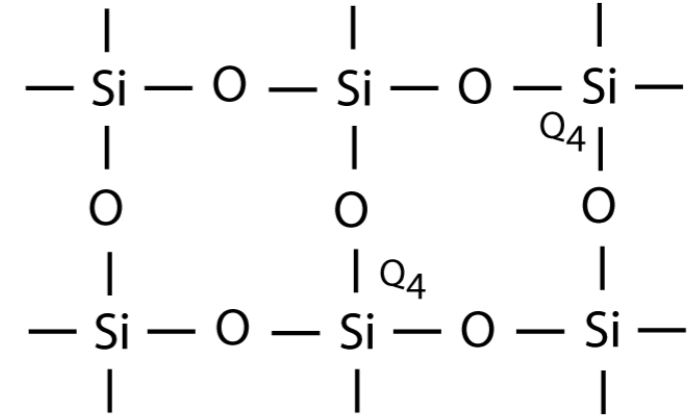
solid Na-glass



Na-dodeca-siloxonate



+ Na-hexa-siloxonate

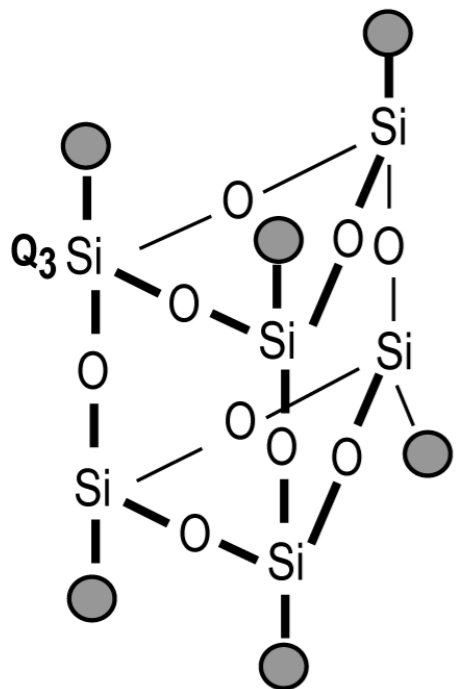


+ quartz

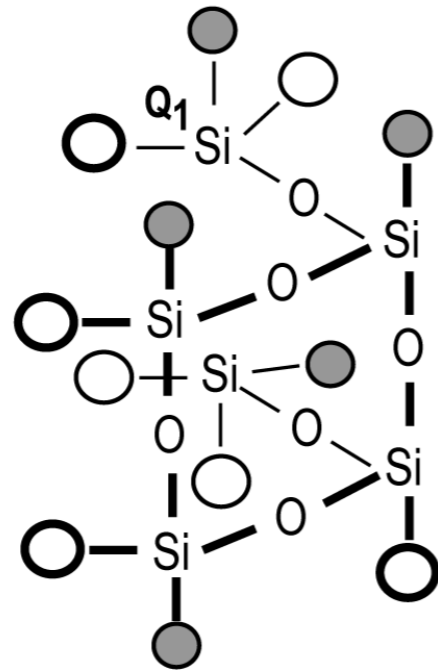
dissolution

(5Q₁ + 12Q₂ + 5Q₃)

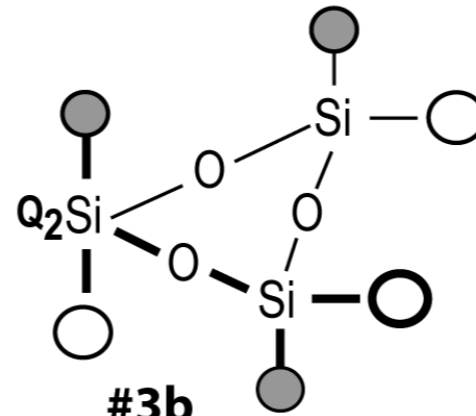
Na-solution



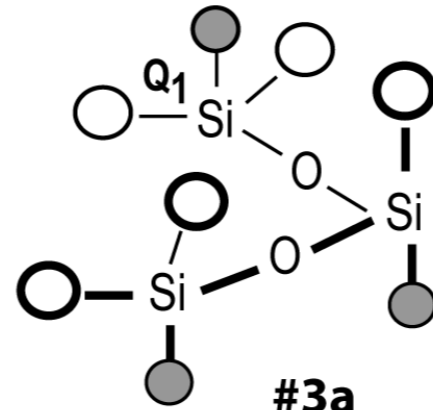
#6a



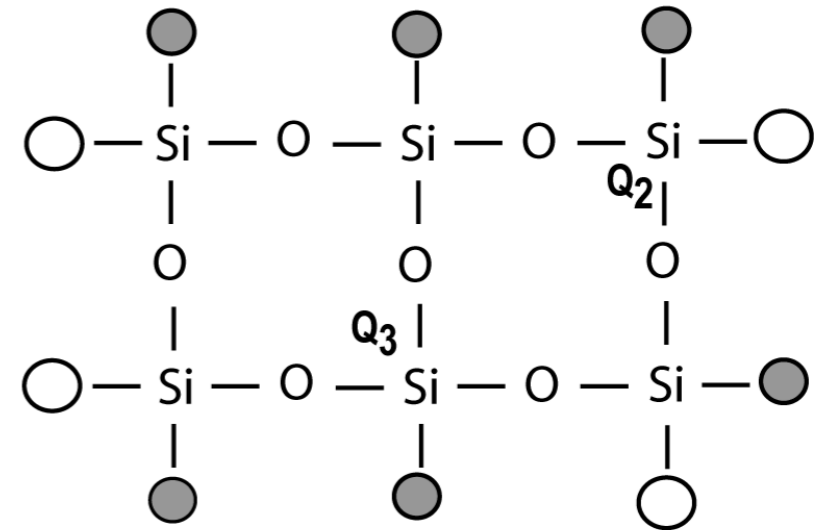
#6d



#3b



#3a



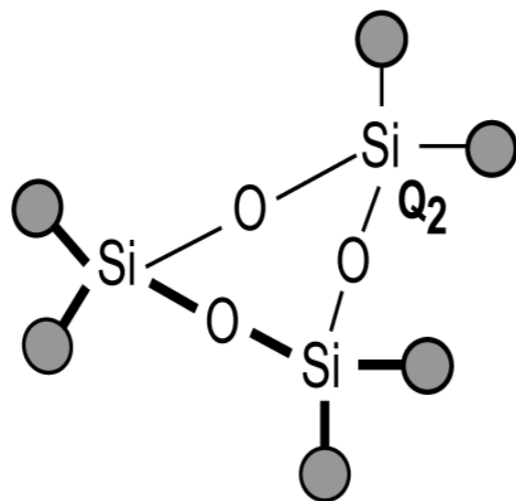
#6e

MR = 1

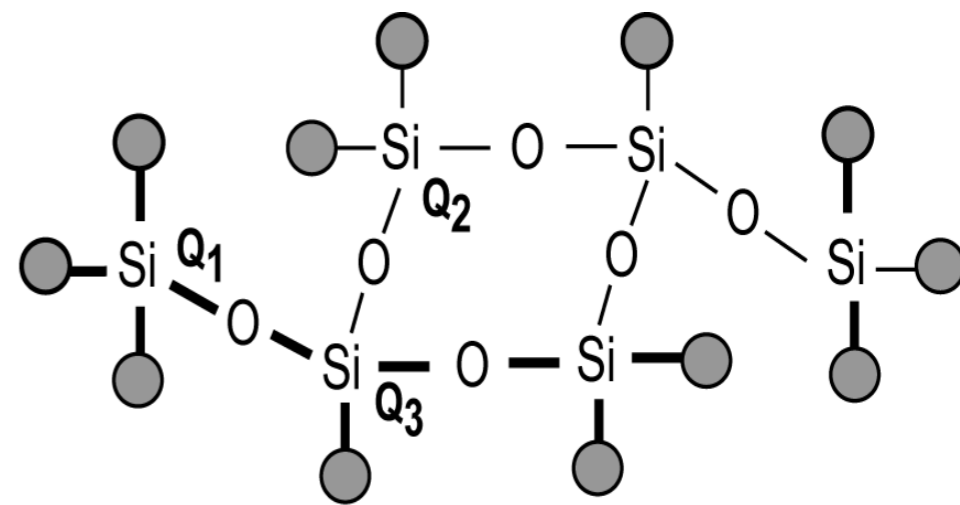
(2Q₁ + 5Q₂ + 2Q₃)

solid Na-glass

● Na⁺ ○ O



Na-tri-siloxonate



Na-hexa-siloxonate

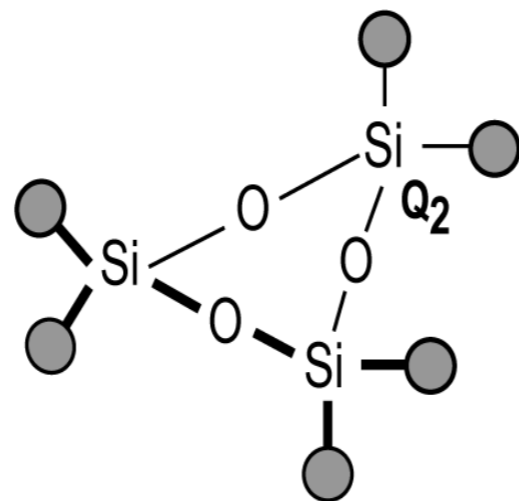
MR = 1

(2Q₁ + 5Q₂ + 2Q₃)

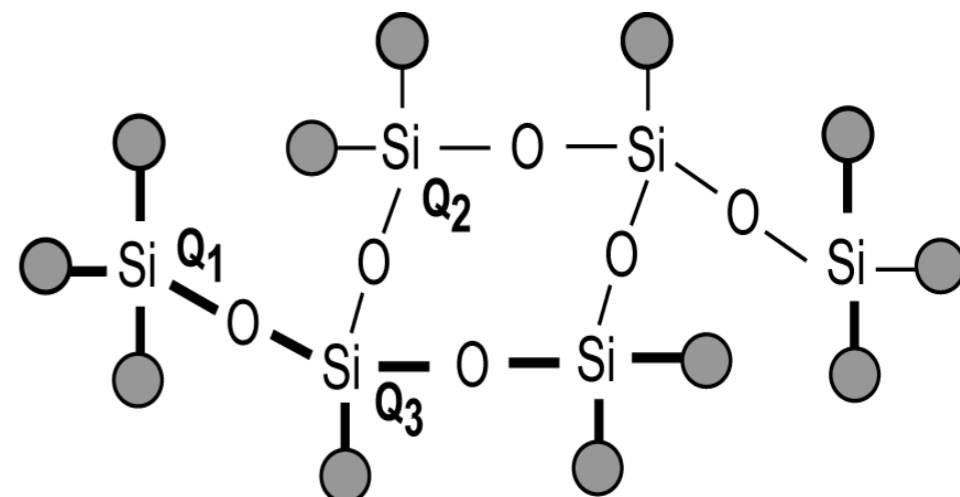
solid Na-glass

● Na⁺ O⁻

○ OH



Na-tri-siloxonate

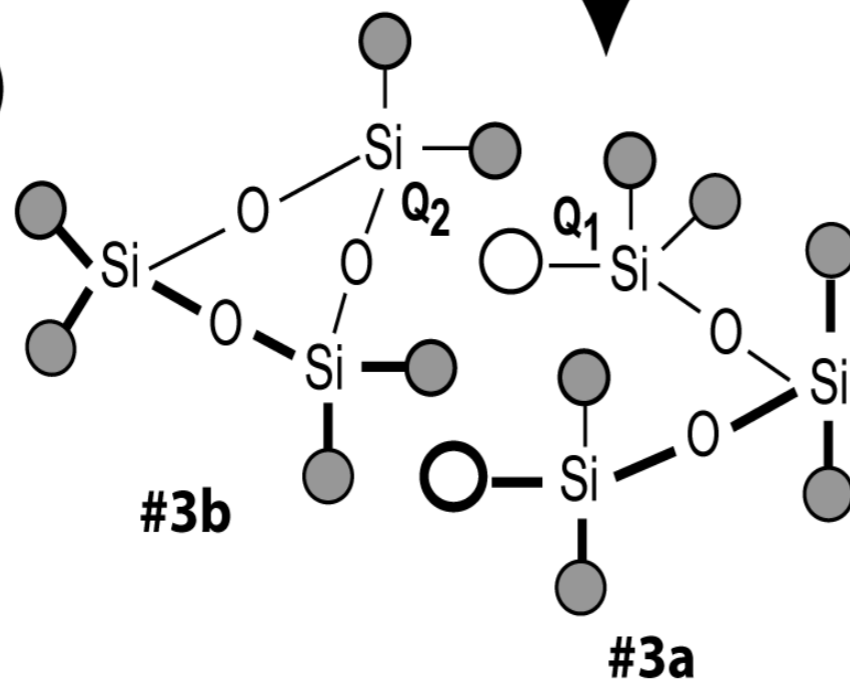


Na-hexa-siloxonate

dissolution

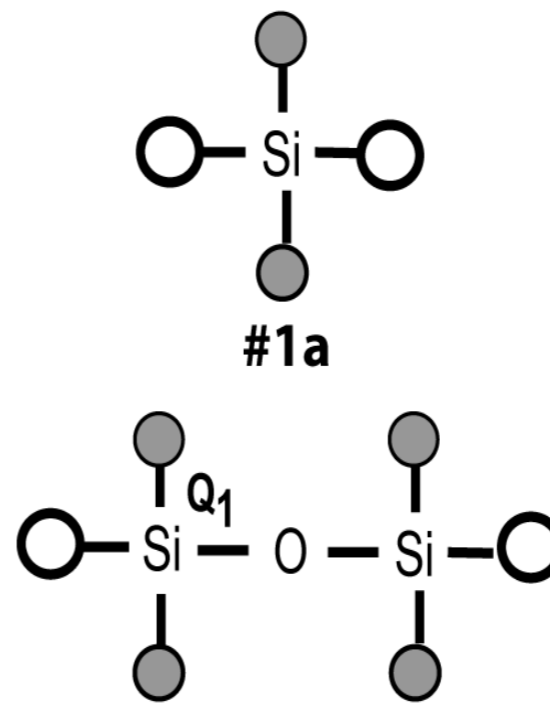
(2Q₀ + 3Q₁ + 4Q₂)

Na-solution



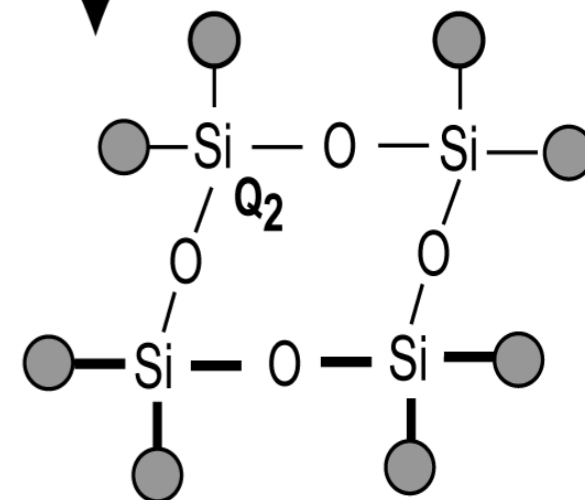
#3b

#3a



#1a

#2a



#4b

Very often: preparation of
soluble silicate with silica fume
+ NaOH/KOH

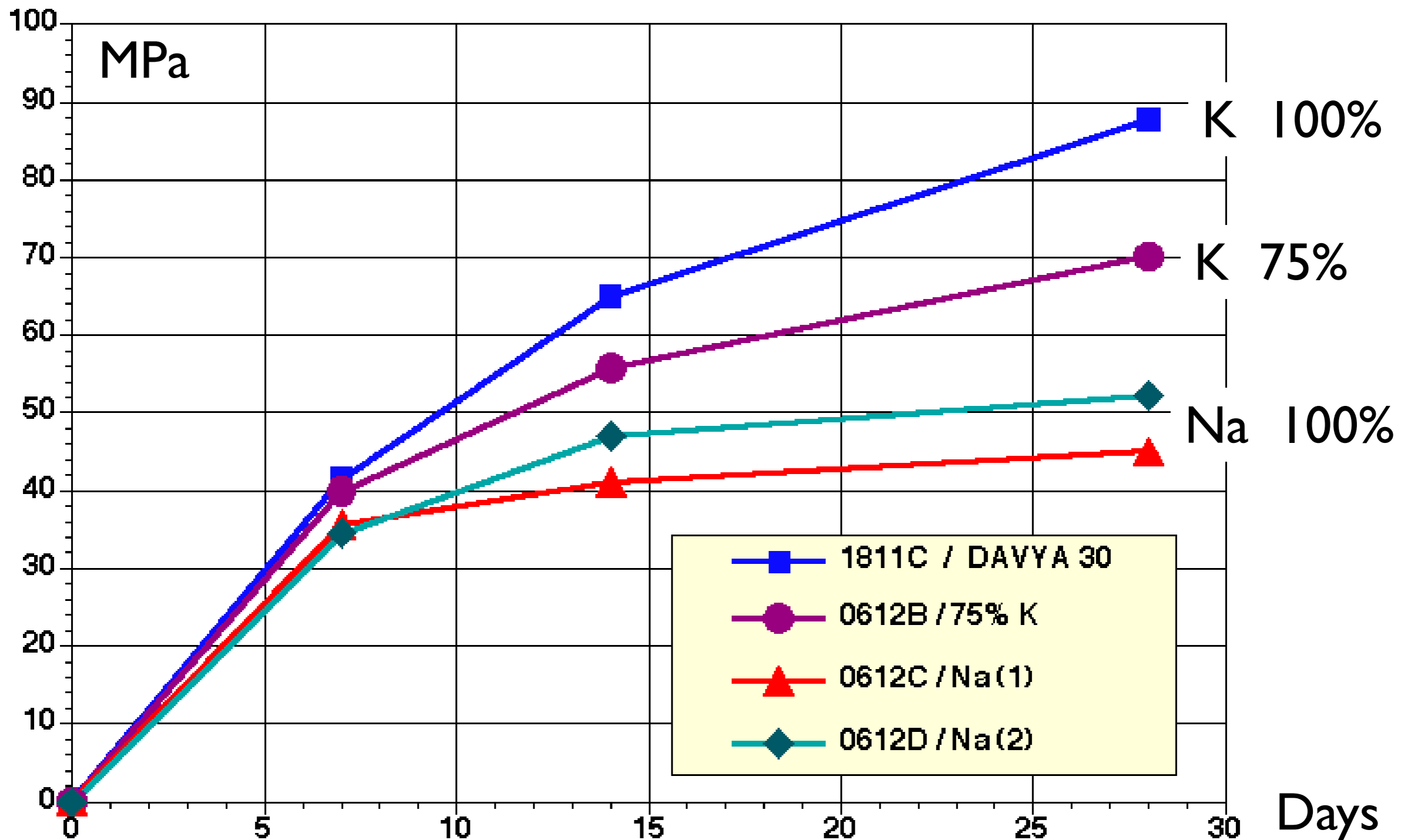
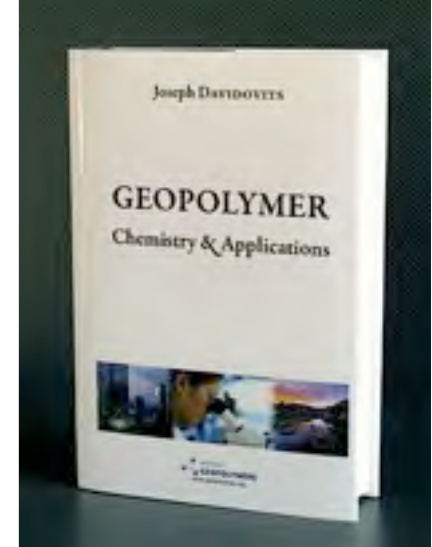
One and only criteria:
transparent solution.

No structural analysis.

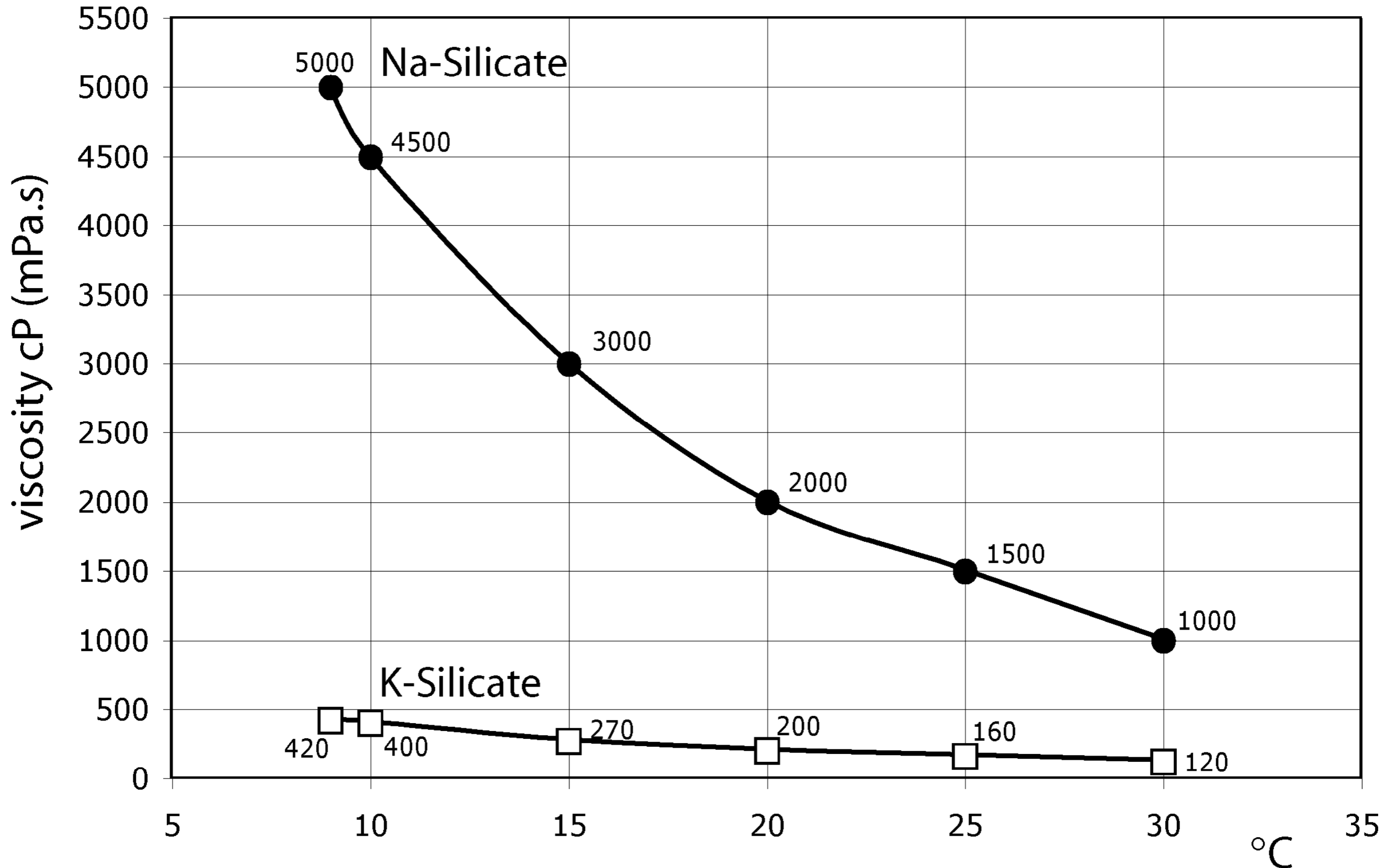
Rule nr. 5

Chapter 19

Replace Na^+ by K^+

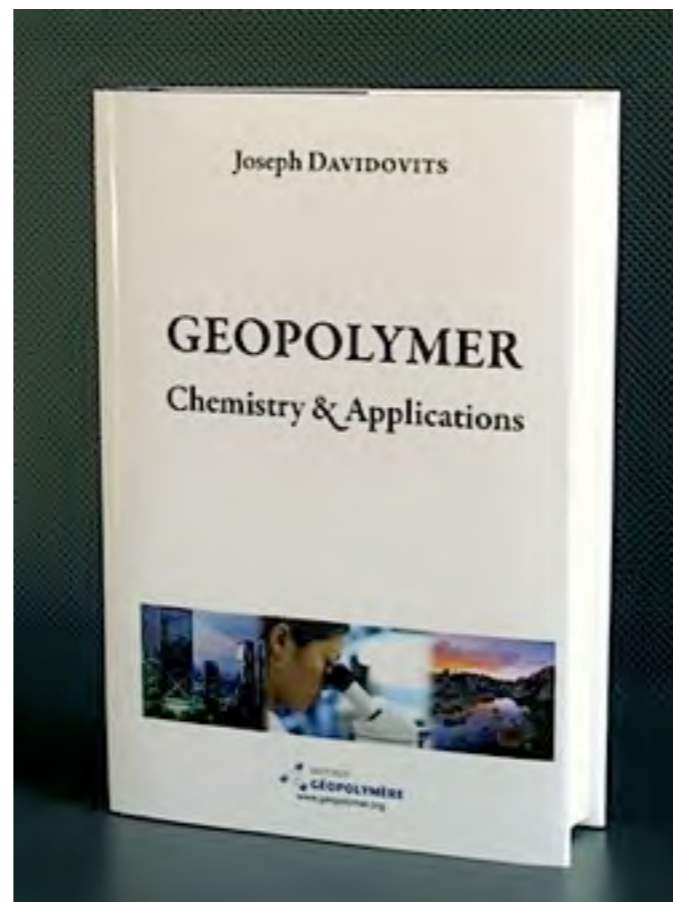


Replace Na⁺ by K⁺

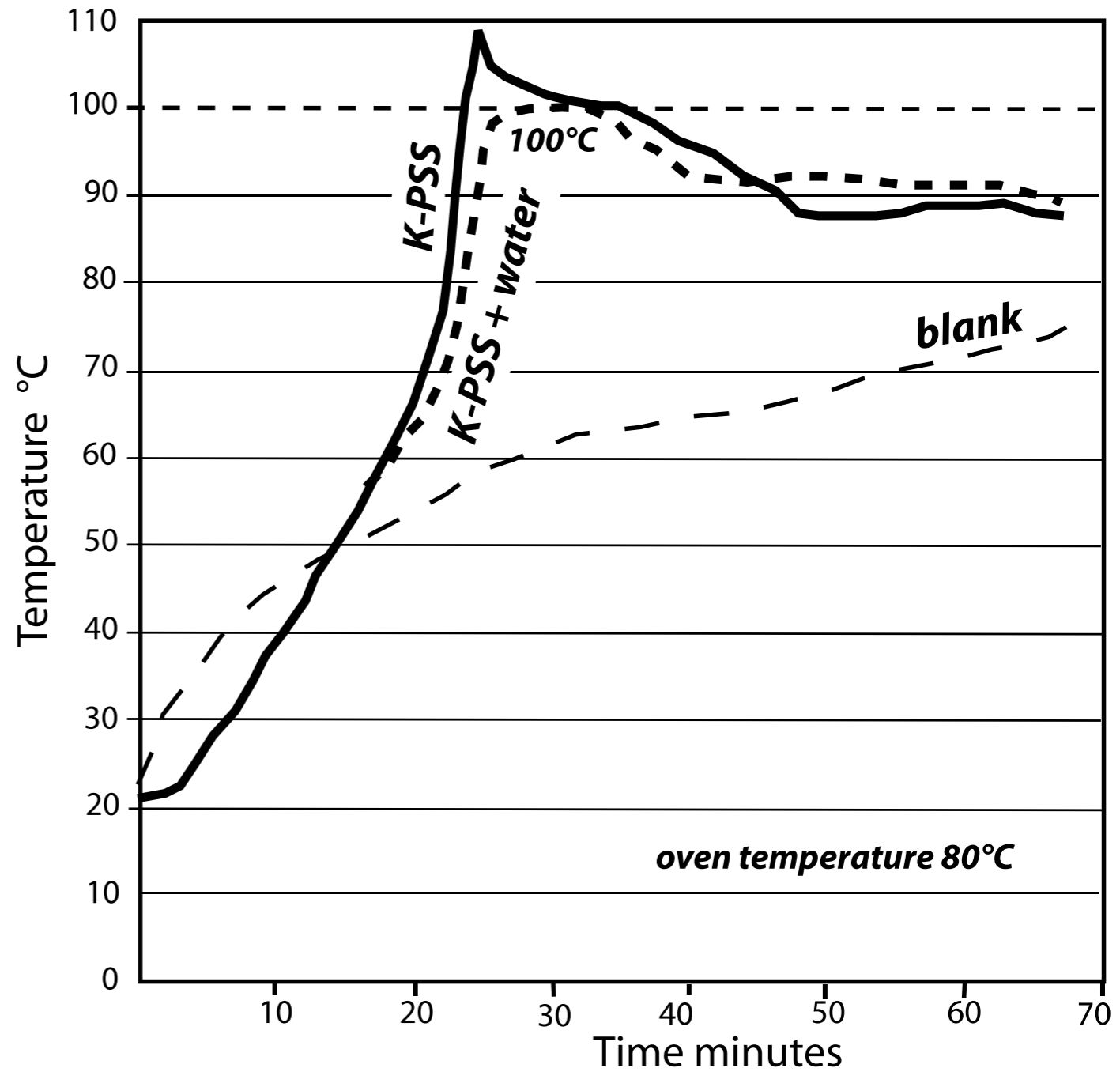
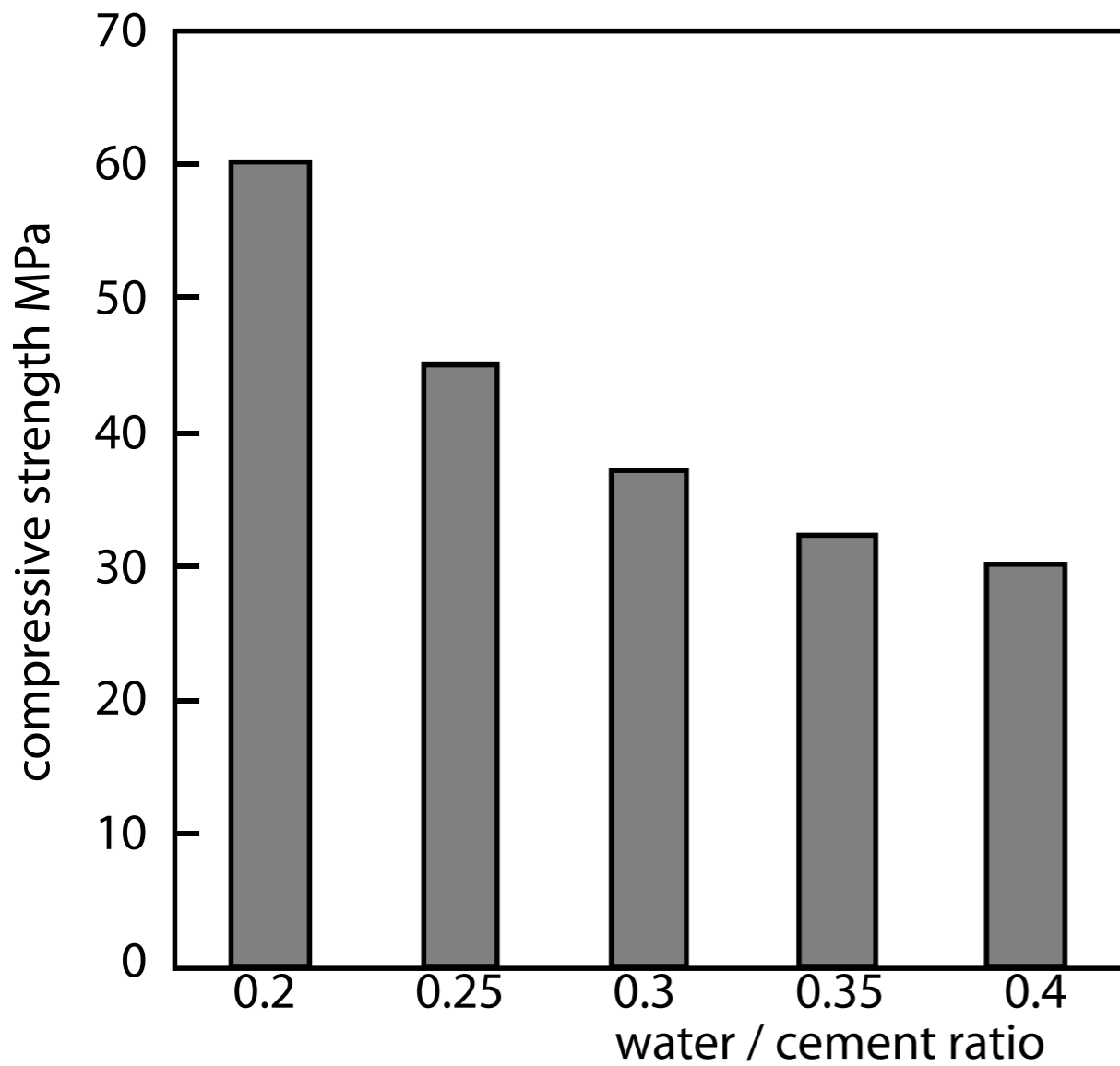


Rule nr. 6

Mixing steps must be well defined and
always respected



Avoid adding water in the mix



Do not mix all powders together

Prepare the geopolymer binder

**Do not mind storing binder and
fillers in a cold chamber**



4th Session

6 basic rules in

Geopolymer Cement processing

J. Davidovits