Ceramic Materials Engineering

A.Y. 2018-2019

Homework n. 1

Some data and universal constants are not given and shall be found elsewhere (handbooks, textbooks, internet) or hypothesized.

1. Estimate the hydration cloud extension and mass for dissolving MgO (bond energy = 1000 kJ/mol) and NaCl (bond energy = 640 kJ/mol) if the hydrogen bond has an energy of 51 kJ/mol.

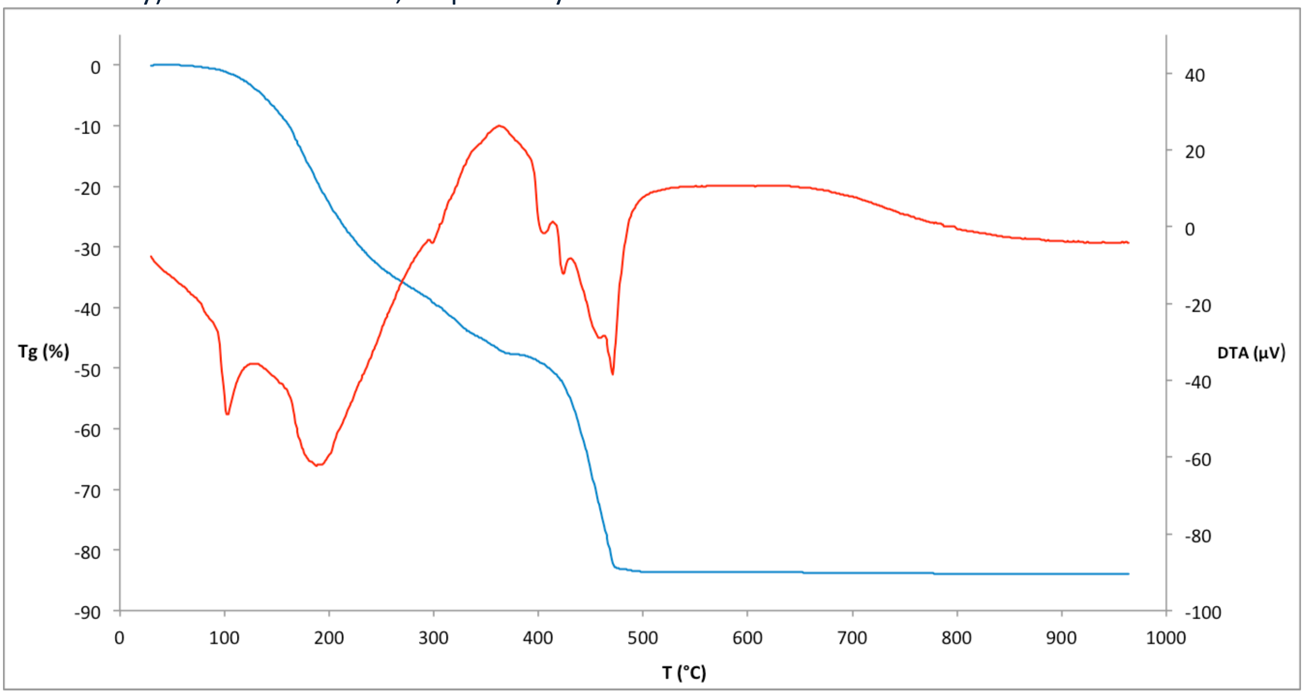
2. In calcite ($CaCO_3$) the Ca^{2+} ion has a CN 6. Using the appropriate Pauling rule, determine the ion environment around each O^{2-} ion.

3. Use the Pauling' s rules to define the structure of calcium titanate.

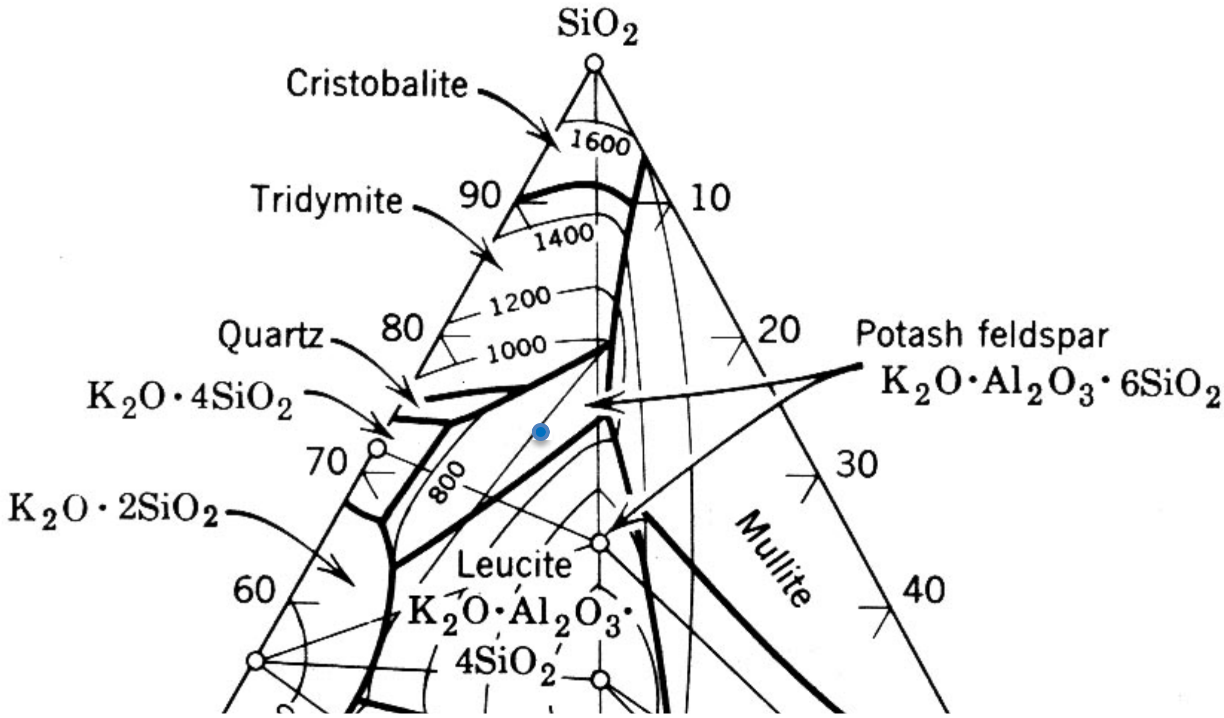
4. Draw in detail the TG, DTA e DTG diagrams for a one-to-two (in weight) mixture of calcite e kaolinite ($Al(Si_2O_5)_2(OH)_4$) from 25°C to 1200°C at fixed heating rate; the first decomposes at 900°C and the second decomposes at 600°C and the residual recrystallize at 1100°C. Draw the diagrams also for higher and lower heating rate.

5. The TGA/DTA diagram for magnesium nitrate hexahydrate is shown. Identify (quantitatively) possible evolution reactions.

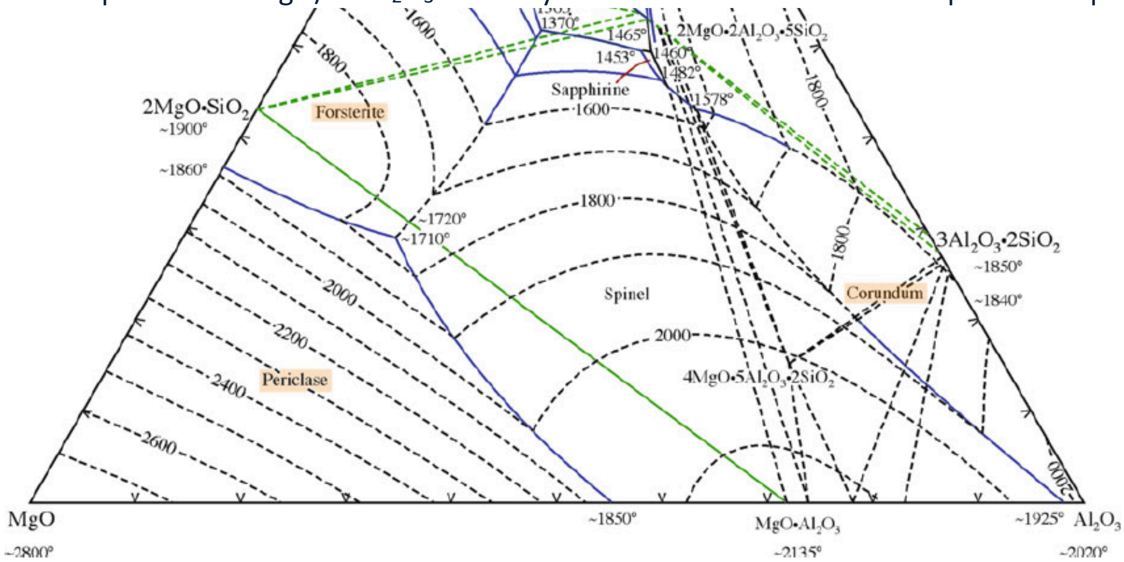
6. Determine the linear and volume shrinkage that occurs during the drying and sintering of a gel containing 5 vol% solids if the dried gel and the sintered one have a solid content (relative density) of 50% and 100%, respectively.



7. Describe the behaviour of a liquid with the composition indicated by the blue circle when it is cooled down to room temperature.



8. Calculate the composition of the phases obtained by cooling a liquid down to room temperature with composition 70 MgO/20 Al_2O_3. Identify also all transformations with specific temperatures.



9. In a nitrogen adsorption experiment at the boiling point of liquid nitrogen, the volume V of gas adsorbed at a pressure p was determined as follows:

p (mm Hg):	80	100	125	140	200
V (cm^3/g):	0.420	0.439	0.464	0.476	0.534

Determine the surface area of the powder (area of the adsorbed N_2 molecule = 16.2 x 10^{-20} m^2).

10. The following data were obtained in a liquid pycnometry experiment at 20°C: mass of the pycnometer = 35.827 g, mass of the pycnometer + powder = 46.402 g, mass of the pycnometer and water = 81.364 g, mass of the pycnometer + powder + water = 89.894 g. If the theoretical density of the solid is 5.605 g/cm^3, determine the amount of closed porosity in the powder.

11. Compare the settling times for alumina particles of 0.1 µm diameter for a settling height of 1 cm under gravitational conditions and in a 3600 rpm centrifuge with an initial radial position of 10 cm.

12. The mass of a fragment of ceramic material is 19.65 g. By Hg intrusion porosimetry a bulk volume equal to 10 cm^3 and an open porosity of 2 cm^3 are calculated. After careful milling (with final particle size lower than 100 nm), a density equal 2.62 g/cm^3 is measure by picnometry. Determine the absolute and relative closed porosity, the apparent and bulk density of the ceramic material.

13. The following batch for a slurry is to be spray dried into a granulated pressing powder. What is the composition proportioned by volume?
    - alumina (ρ_A = 3.98 g/cm^3) – 73.22 wt%
    - water (ρ_A = 1.00 g/cm^3) – 23.23 wt%
    - polyacrylate deflocculant (ρ_A = 1.25 g/cm^3) – 2.45 wt%
    - polyvinyl alcohol binder (ρ_A = 1.27 g/cm^3) – 0.98 wt%
    - ethylene glycol plasticizer (ρ_A = 1.13 g/cm^3) – 0.12 wt%

14. The following results were obtained for a powder by a sieving test:

Mesh number	mass on the sieve (%)
20	8
40	18
60	32
80	17
100	12
120	9
170	2
230	2

Represent in a diagram the particle size distribution. Assuming spherical particles, calculate the average size on the surface and on the volume with density variable from 2 e 5 g/cm^3.

15. The following distribution is given for barium titanate powder:

size	CNPF (%)
4.0	100
3.0	99
2.0	98
1.5	92
1.0	80
0.6	58
0.4	36
0.2	10
0.1	2

Fit the data with normal and log-normal distribution. Compare the average particle size calculated analytically (by integration) and by the finite summation.

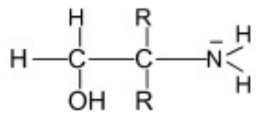
16. Two powder distributions with average size equal 100 µm and 2 µm are given. For the first PF = 0.6; for the second PF = 0.64. Calculate the optimal mixture for maximizing the green density and draw the corresponding mixture diagram.

17. Calculate the energy required to mill an alumina powder from 400 µm to 20 µm by vibratory mill (A_c = 500 kWh µm^m / T, m = 1.8)

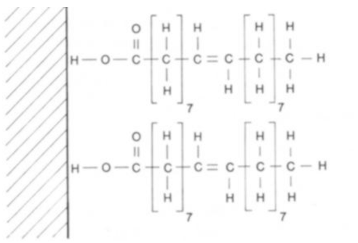
18. Calculate the Debye length for a suspension of alumina powder (IEP = 9) at pH = 7 in water containing 0.01 M $MgCl_2$ and 0.02 M di Na_2SO_4. Draw the corresponding relative electrical potential curve. How does the Debye length change if the temperature is increased (draw a diagram)? What does it happen if methanol is used instead of water?

19. Try to estimate the equilibrium constants corresponding to the acid-base behaviour of TiO_2 (rutile) surface in water.

20. Titania (IEP = 4) powder is mixed with bi-distilled water containing 15 ppm CaCl2. Calculate the Debye length. Describe the behaviour and represent the surface of the particles (at atomic/molecular level) in case of the addition of aminoalcohol – see figure - (R = CH_3) to the mixture and energetic mixing as a function of pH.

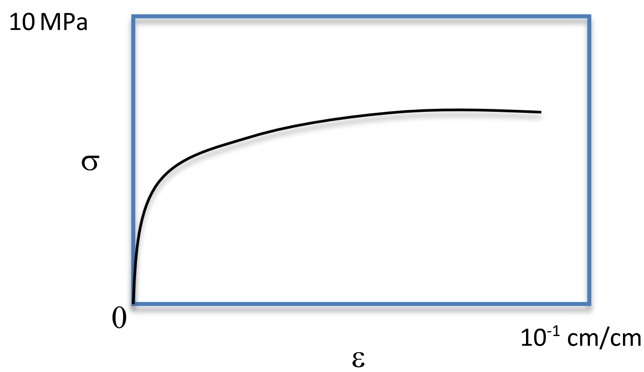


21. Calculate the Debye length and zeta potential for a suspension containing 0.01 M HNO_3 at 20°C. Compare it with the thickness generated by the adsorption of oleic acid (C-C: 1.54 Å, C-H: 1.09 Å, C=C: 1.34 Å) as shown below (pay attention to the bonds angle)



22. Calculate and draw the attraction potential (Van der Waals) U_A, the electrostatic repulsion potential U_R, the gravitational potential U_G and the total potential U_T generated between two colloids (density = 4 g/cm^3) with radius variable from 0.1 µm to 5 µm in a water solution containing HCl (5 mM) at 27°C, with A_h = 10-20 J and surface electrical potential = ψ_0 = 25 mV.

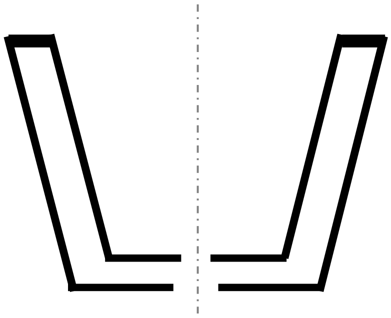
23. Estimate the minimum force needed in pressing a ceramic granulate characterized by the stress – strain curve below, to produce tiles 30 cm x 60 cm.



24. Calculate the viscosity of a water-base suspension containing 45 wt% of alumina (d = 3.99 g/cm^3)? Represent the behaviour in case of reopecticity and thixotropicity.

25. A green disc (thickness = 4.00 mm diameter = 60.0 mm) shall be produced by uniaxial pressing. Silicon carbide granules (fill density = 32%, mean particle size = 0.4 µm, granule density = 46%, granule mean size = 180 µm) are used. The compaction ratio ($D_{pressed}/D_{fill}$) is 1.8. The spring-back is 1.8%. The maximum applied pressure is 70 MPa. Specify the fundamental dimensions of the die and the minimum displacements.

26. The ceramic component (with axial symmetry) shown in the figure has to be produced. Which forming process can be used. Why? Are there any critical aspects that need to be changed or shapes to be modified?



27. Estimate the effect of gravity on the thickness of the cake in slip casting for mould heights variable from 20 cm to 1 m.