Complex Liquids and Soft Condensed Matter

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LESSON 02

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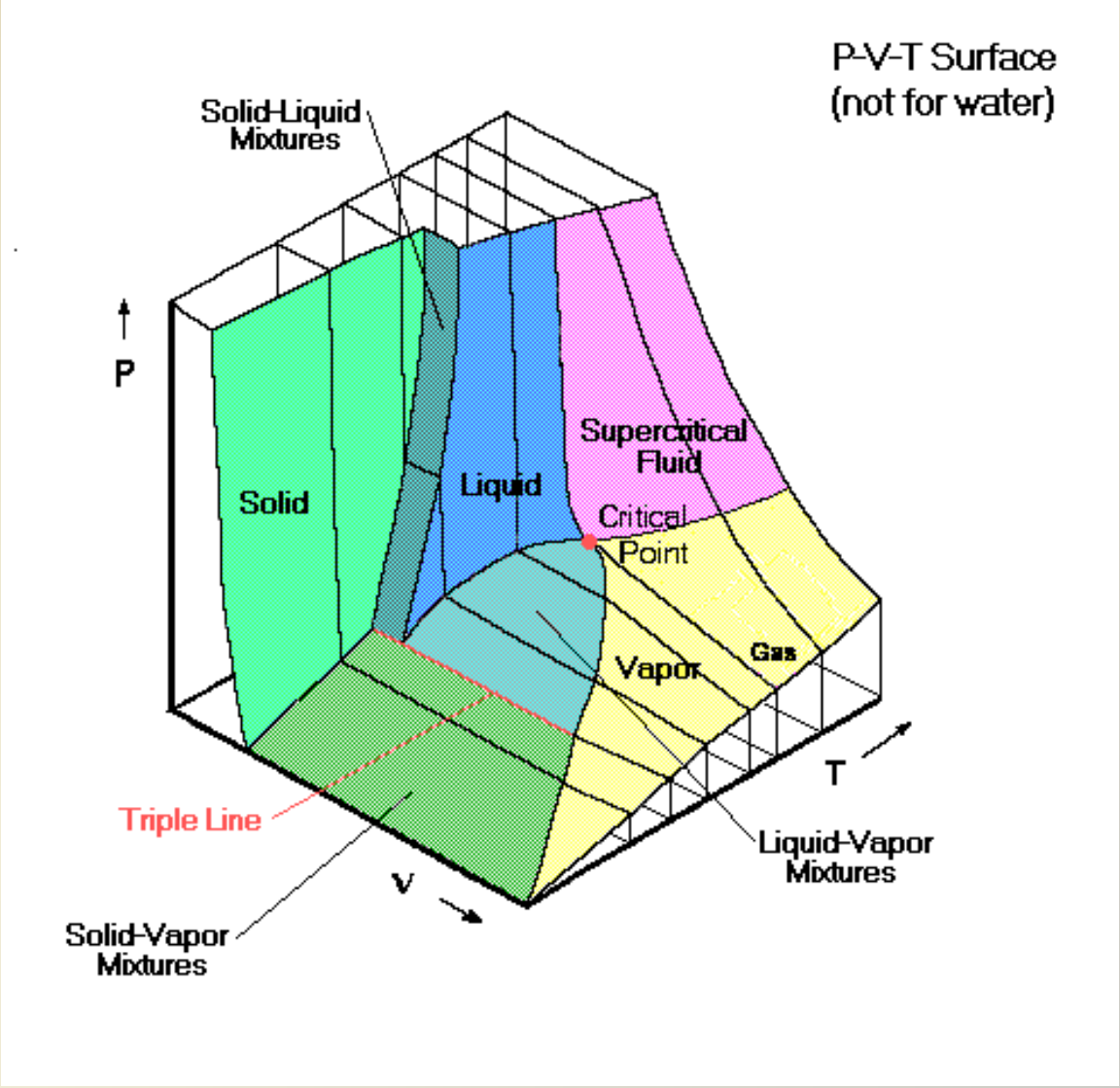
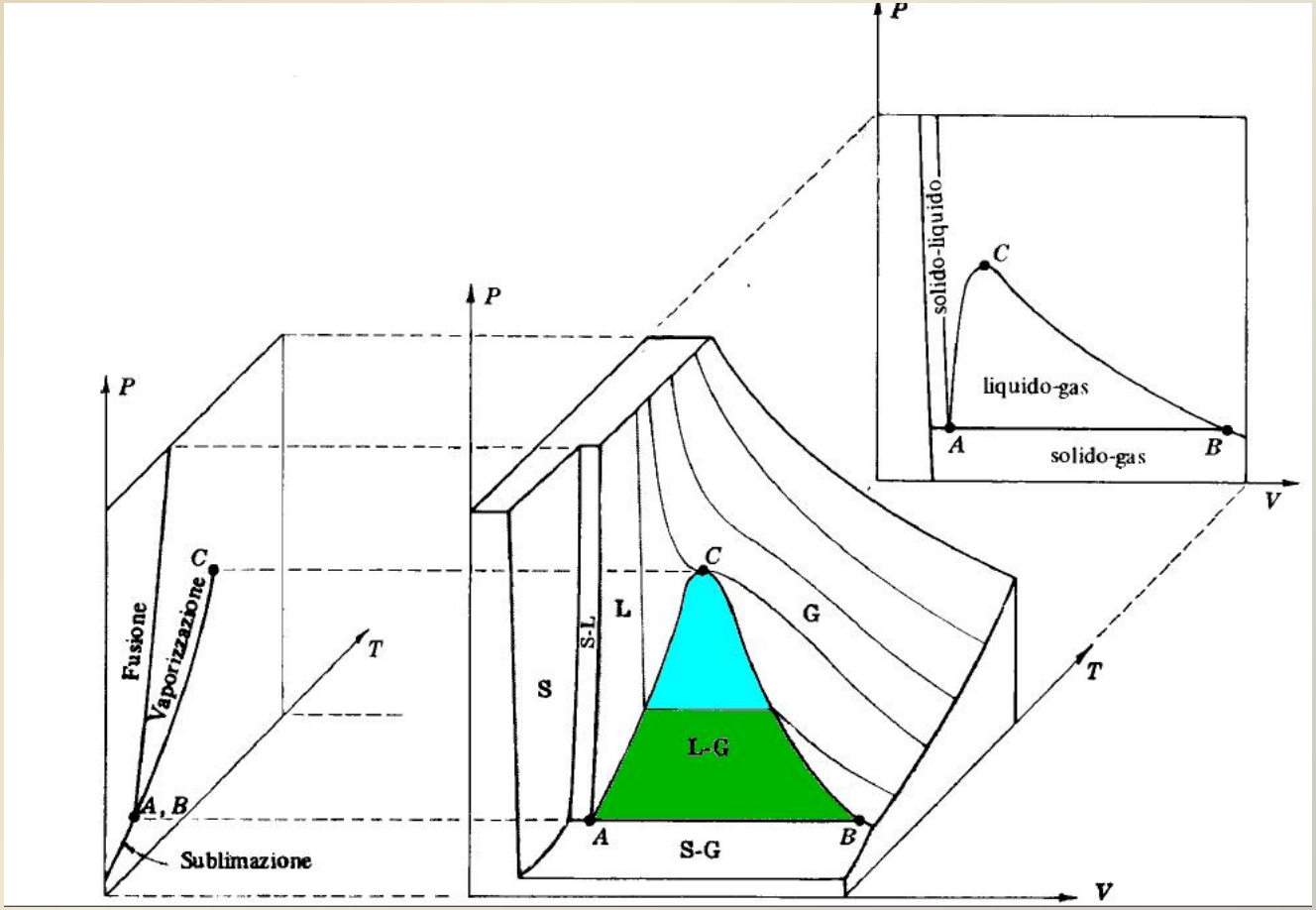
R.A.L. Jones, *Soft Condensed Matter*, Oxford Univ. Press 2002

Thermodynamic Equilibrium



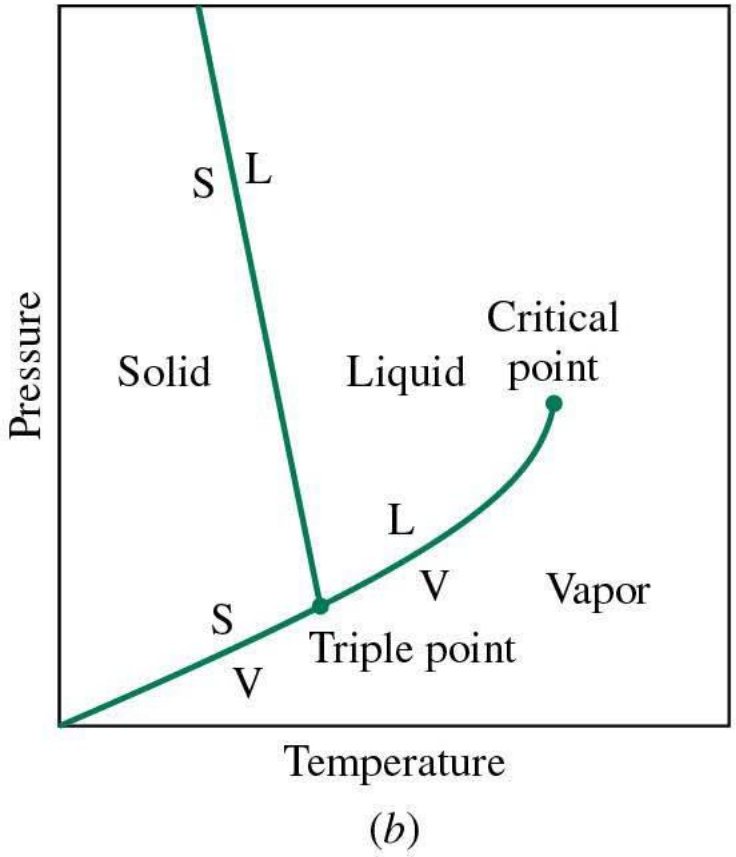
Equilibrium

PT and PV projections

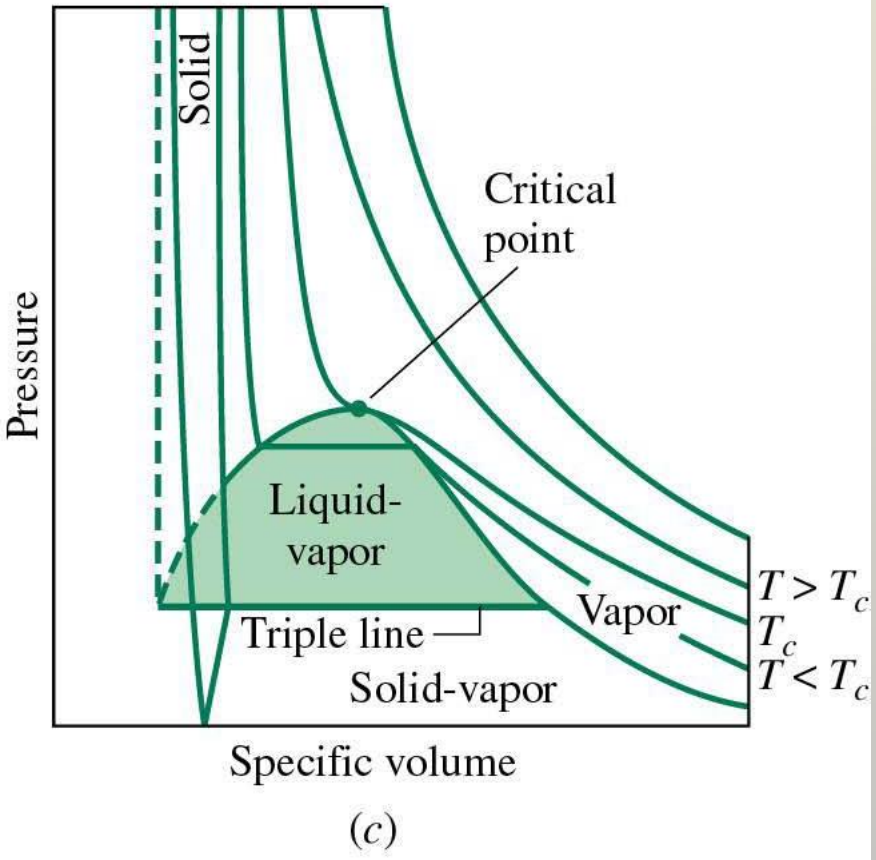


Equilibrium Diagrams

P-T



P-V



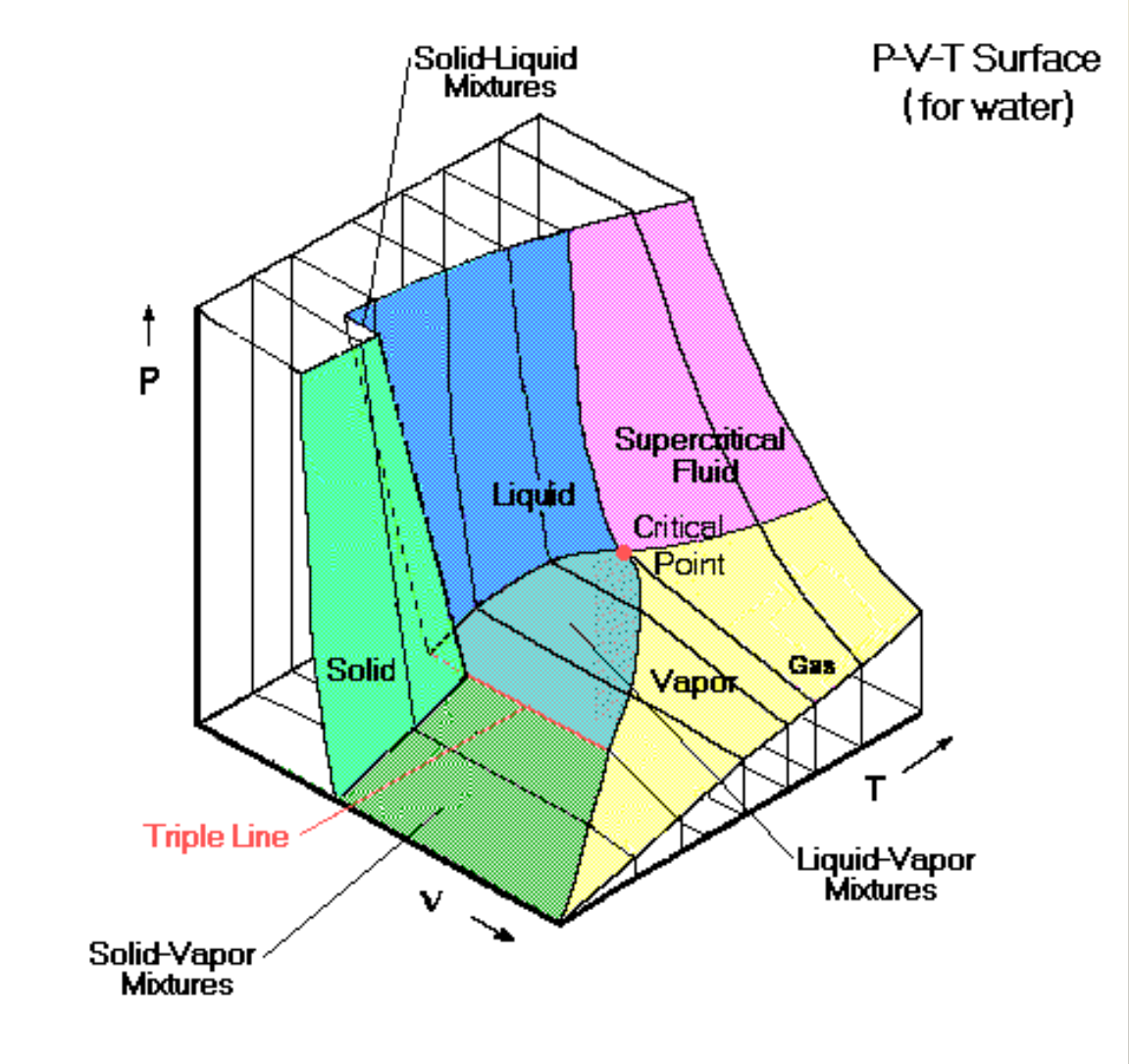
Equilibrium surfaces for pure matter are defined by the

State Equation: $f(V, P, T) = 0$

Gas ideale: $P = R\frac{T}{V}$; *R = costante universale dei gas*

Gas reale: $P = R\frac{T}{V-b} - \frac{a}{V^2}$ *Eq. di Van der Waals*

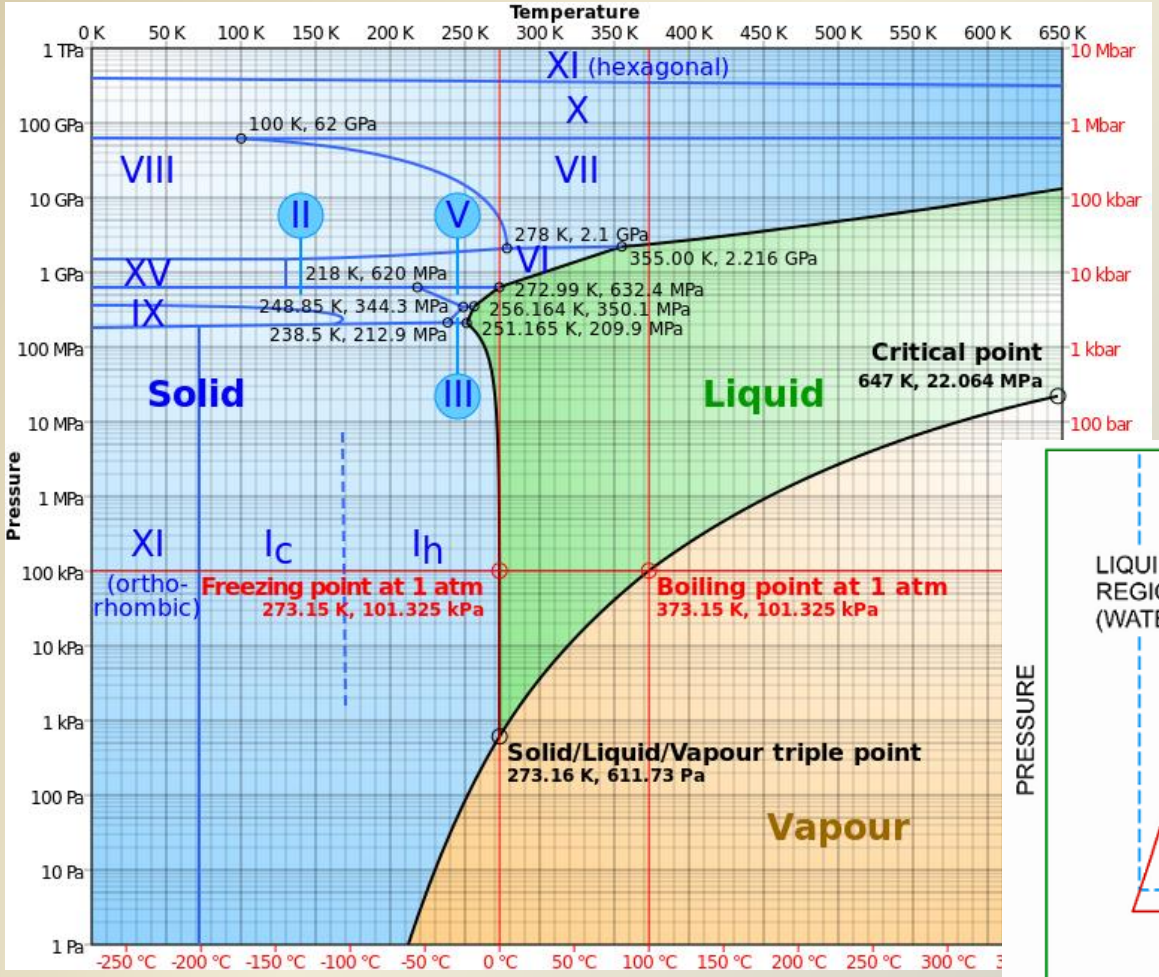
$P = R\frac{T}{V-b} - \frac{a}{T^2V(V+b)}$ *Eq. di Redlich/Kwong*


Solid-Liquid Mixtures
P-V-T Surface (for water)
P
Supercritical Fluid
Liquid
Critical Point
Solid
Vapor
Gas
T
Triple Line
Liquid-Vapor Mixtures
V
Solid-Vapor Mixtures

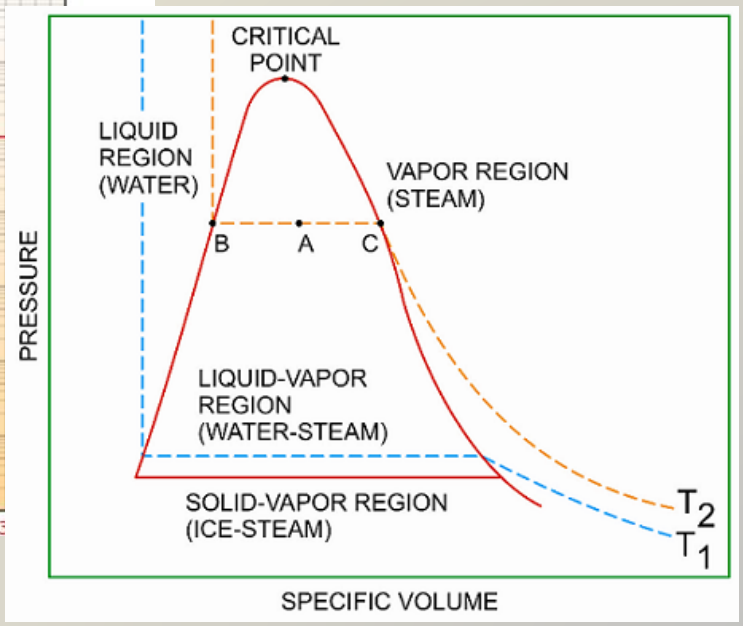
Equilibrium

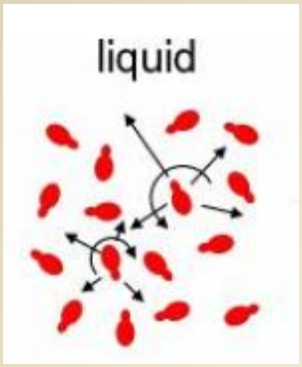
Water

P-T

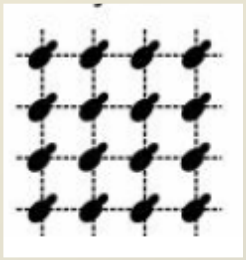


P-V





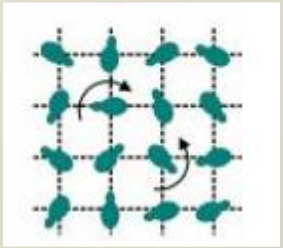
R, θ



Ordered Crystal

Translational ordering

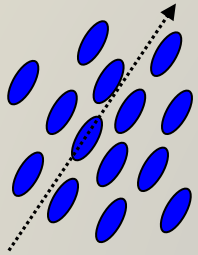
R



Plastic Crystal

Orientational ordering

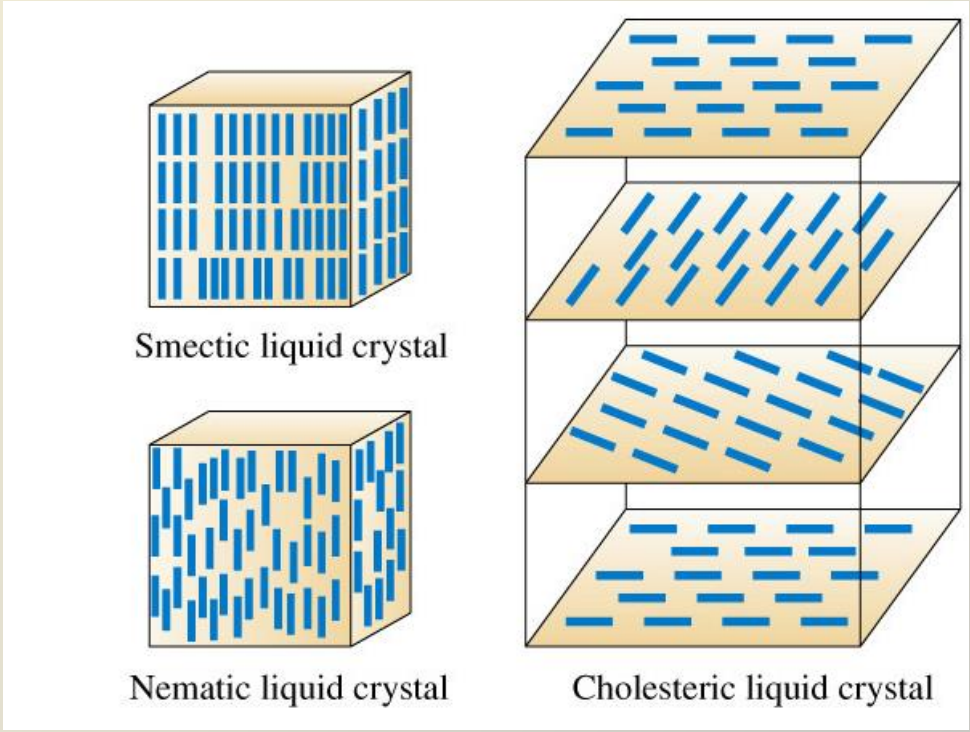
θ



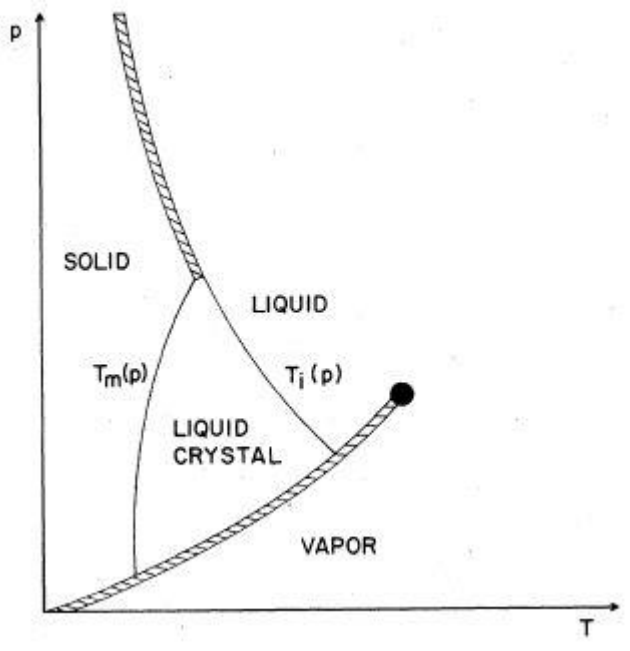
Liquid Crystal

Partial translational and/or orientational ordering

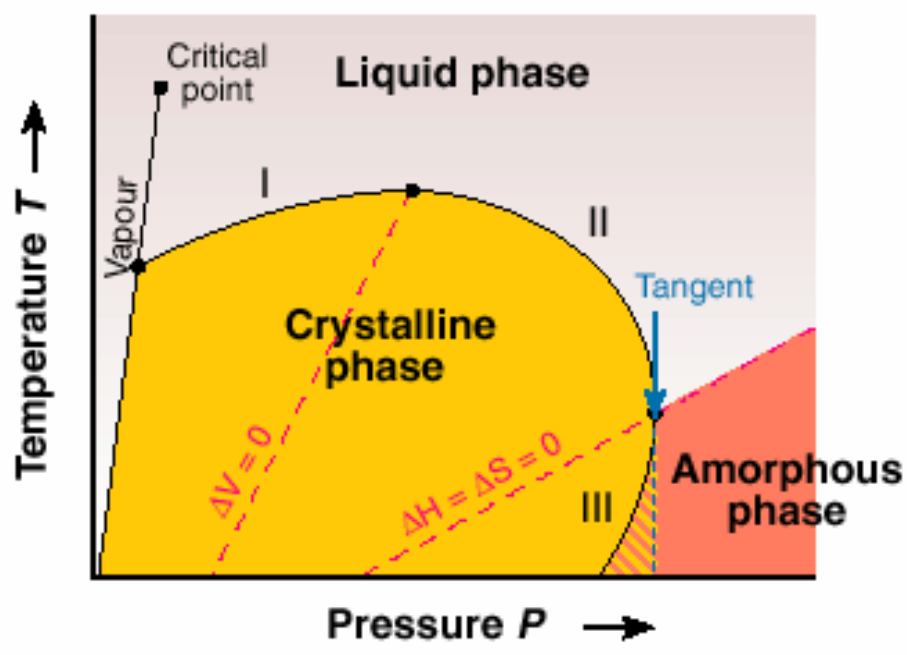
R_i , θ



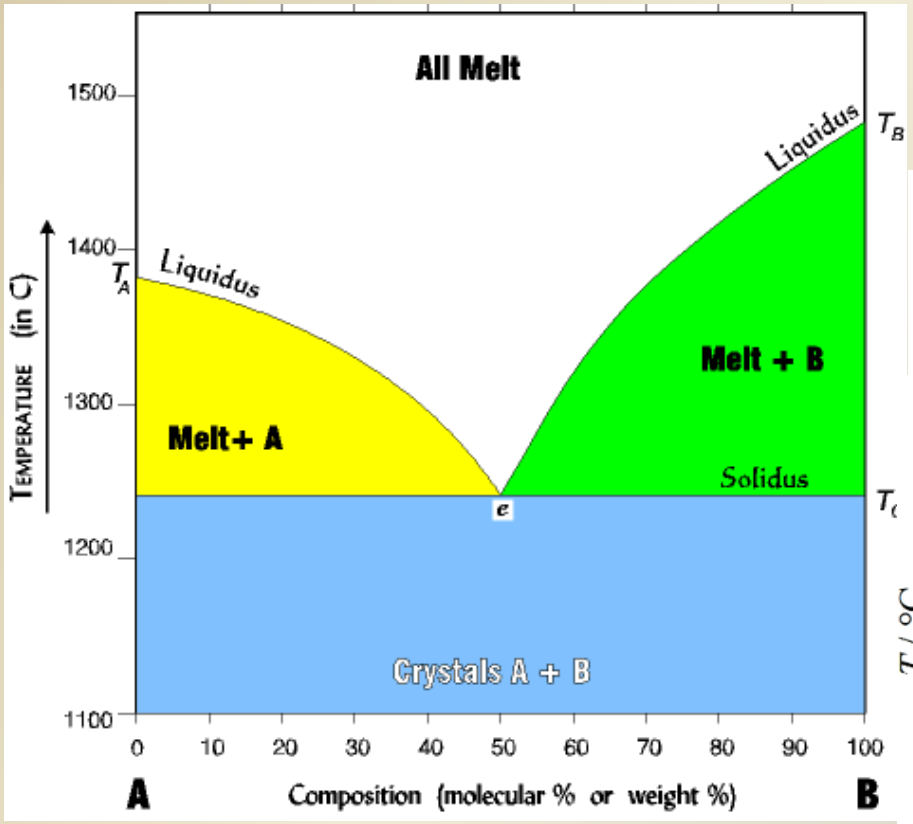
Liquid Crystal thermotropic

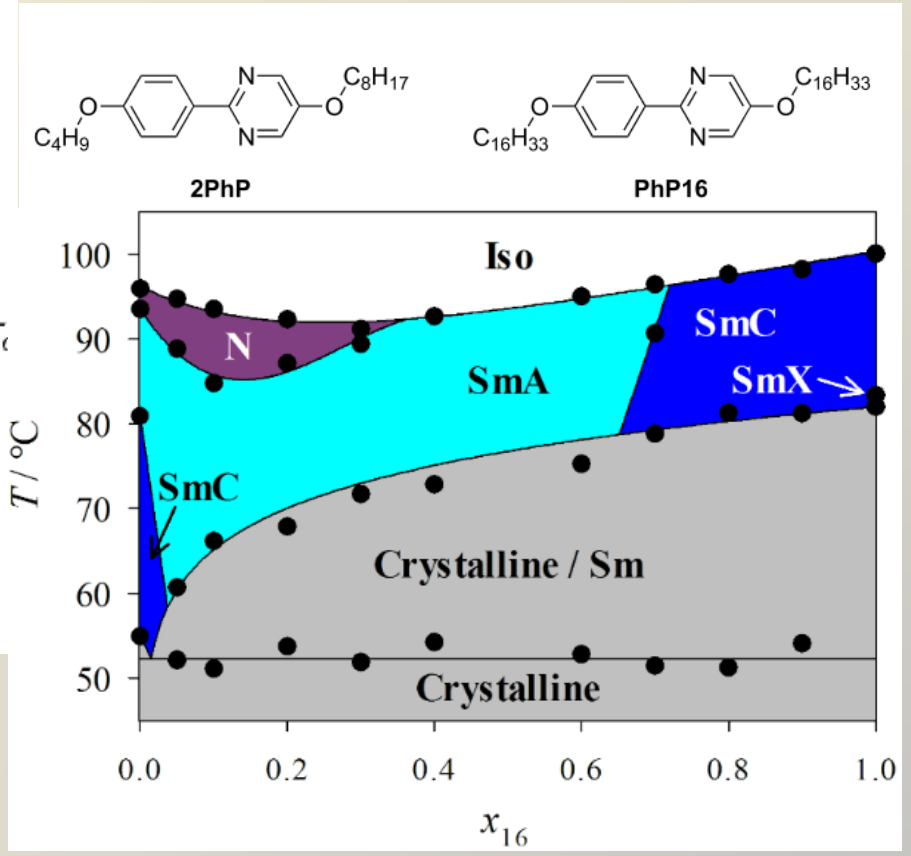


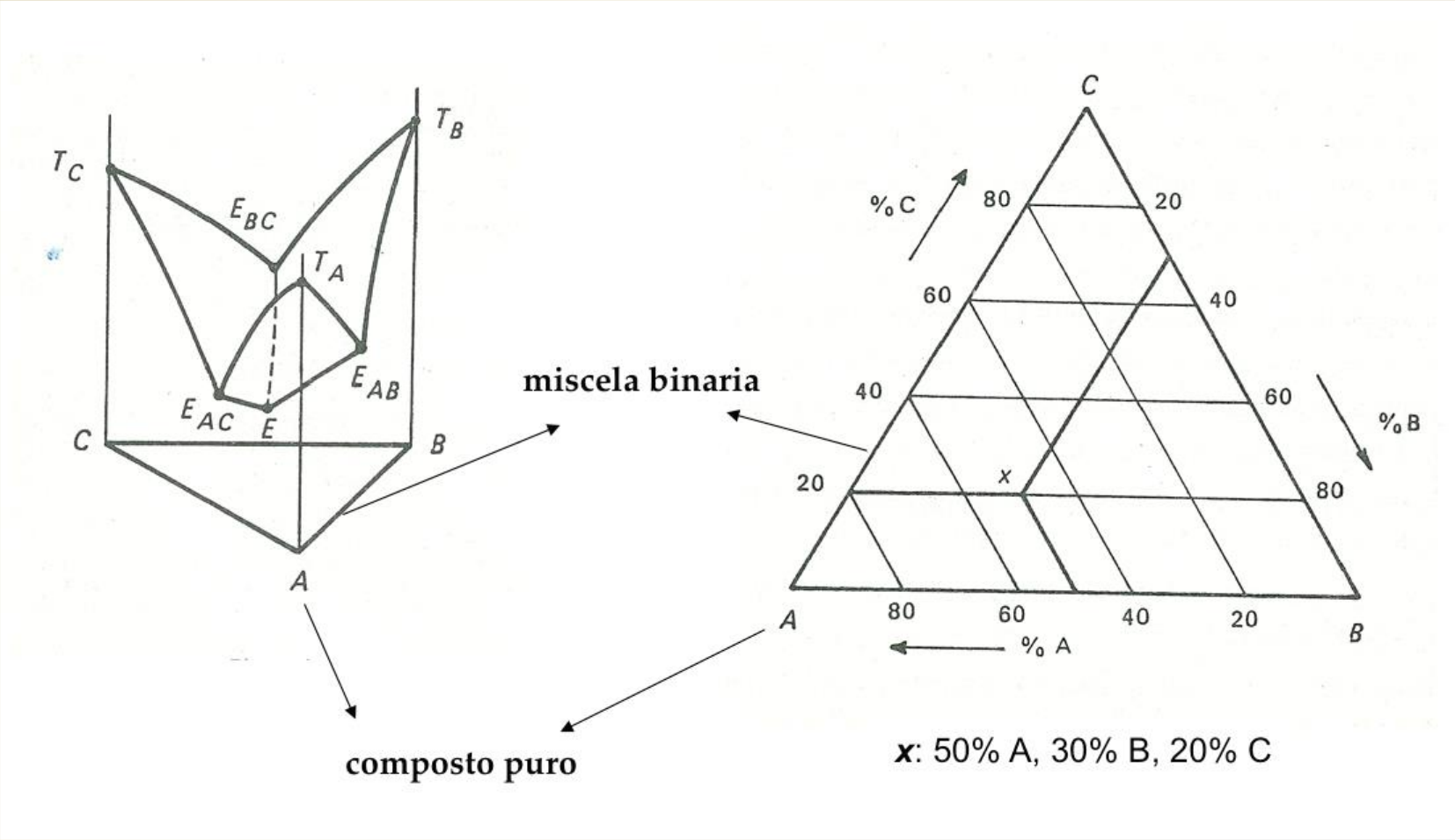
Polymer



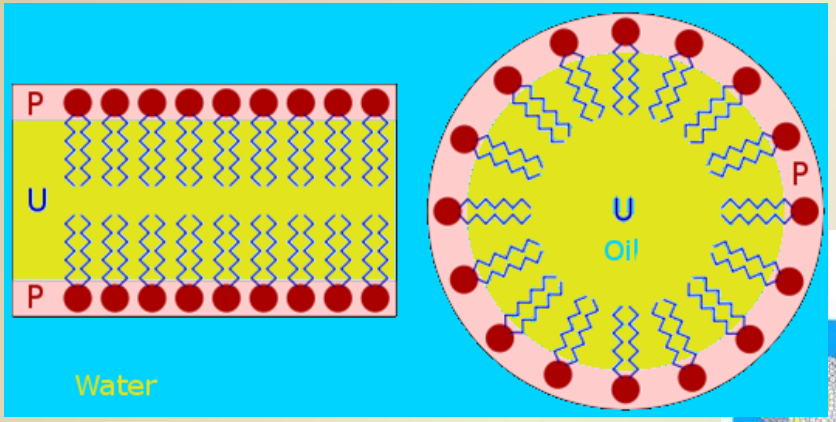
Equilibrium two component systems



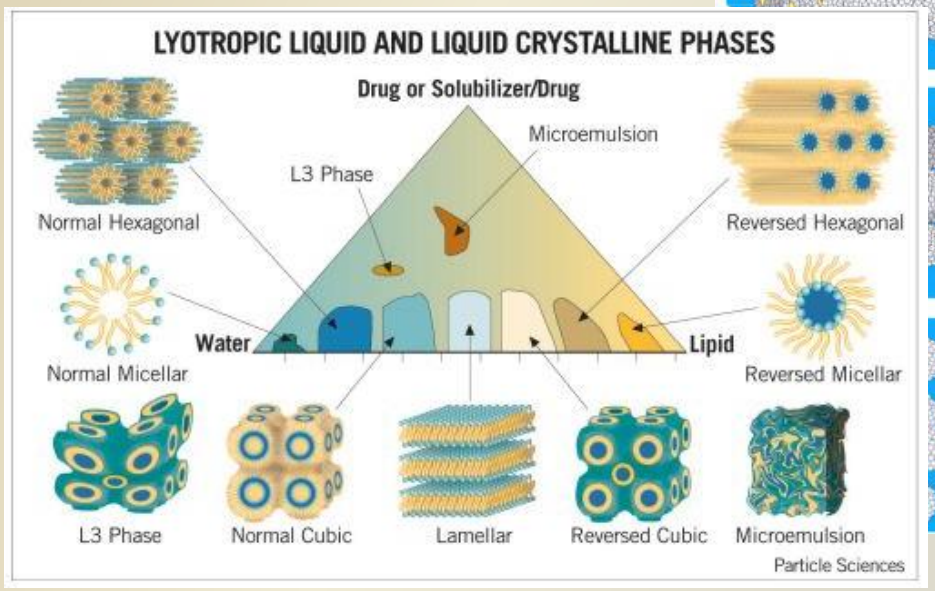


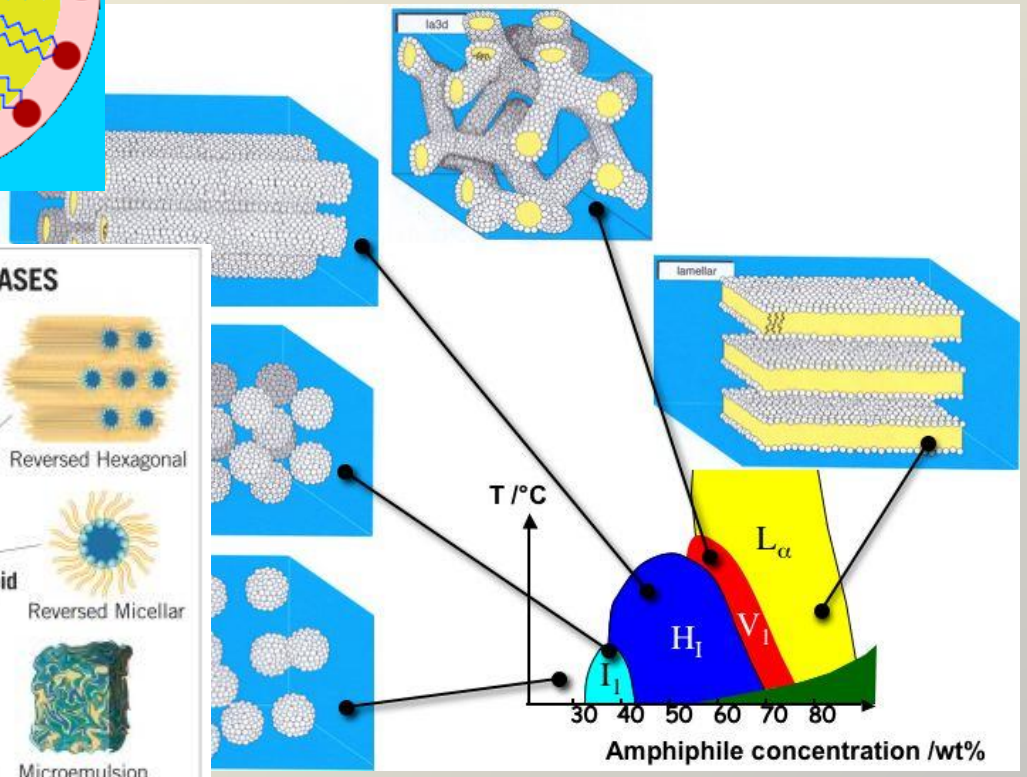

T_C
T_B
E_{BC}
T_A
E_{AB}
E_{AC}
E
C
B
A
miscela binaria
composto puro
C
% C
80
20
60
40
40
60
% B
20
x
80
A
80
60
40
20
B
% A
x: 50% A, 30% B, 20% C

Equilibrium three component systems



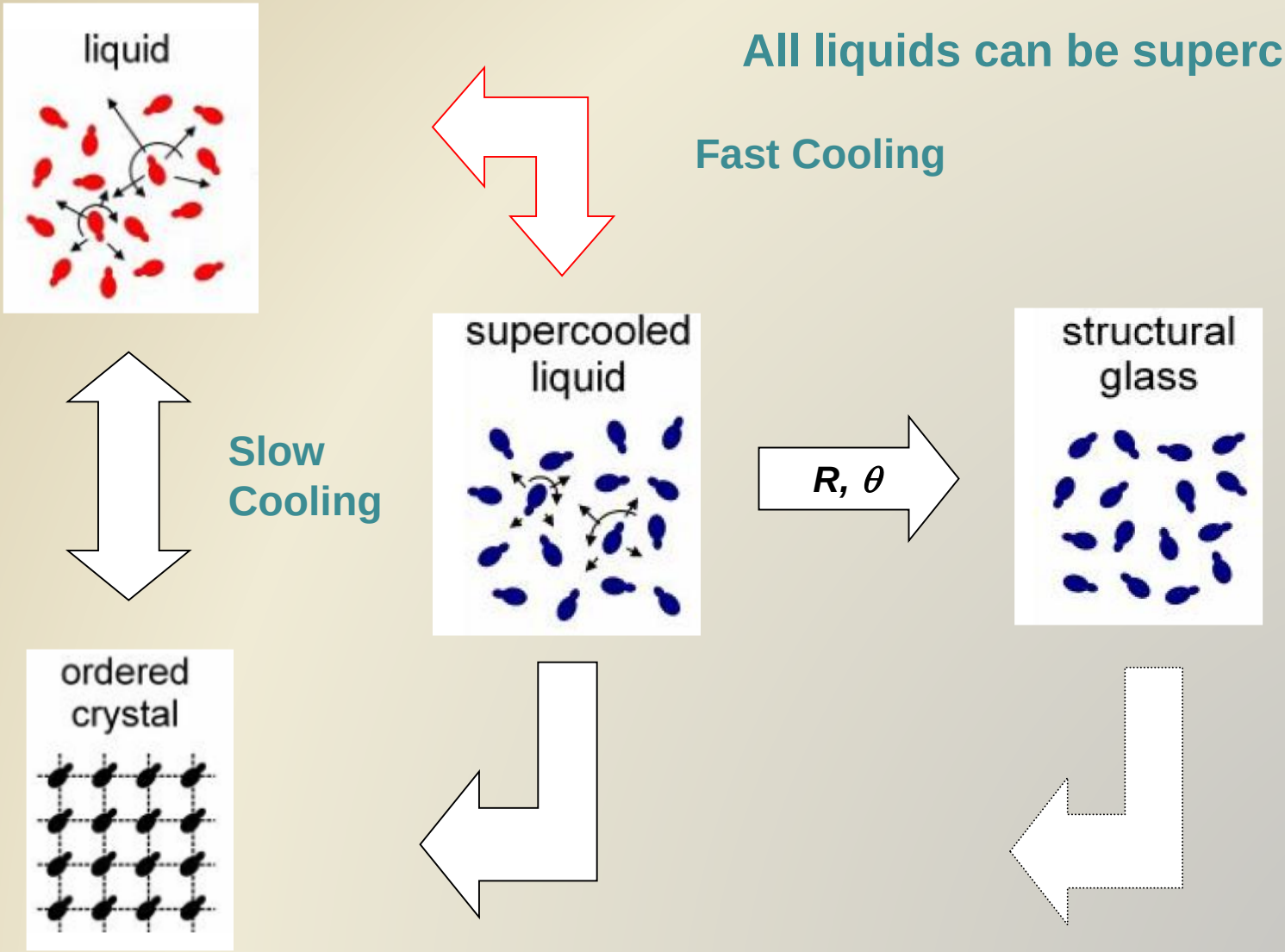
Amphiphilic Self-Assembly or
Liquid Crystal Lyotropic





Non-Equilibrium

www.youtube.com/watch?v=95GnYW6kgLs&feature=youtu.be



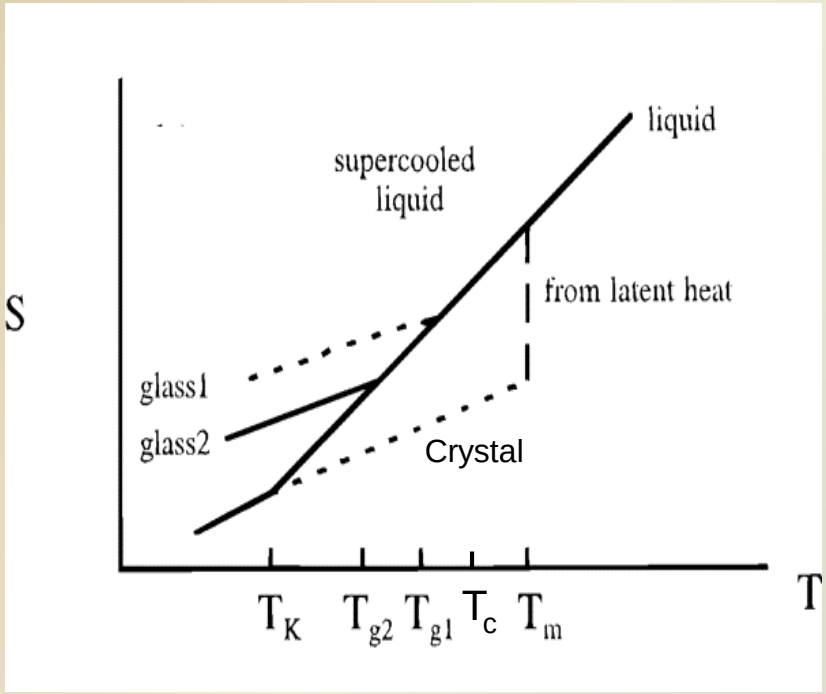
All liquids can be supercooled !

Fast Cooling

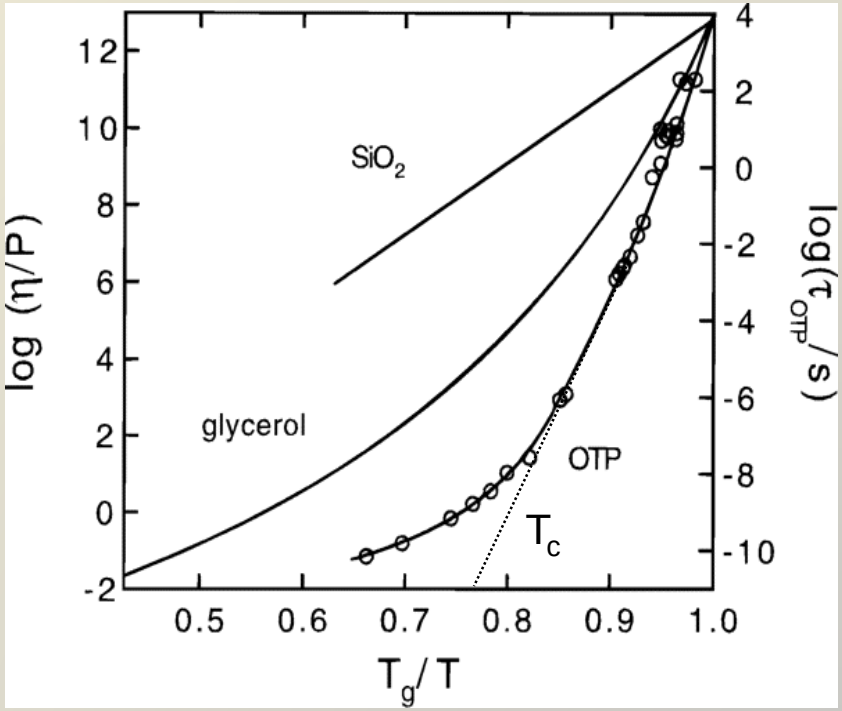
Slow Cooling

Non-Equilibrium Supercooling and Glass

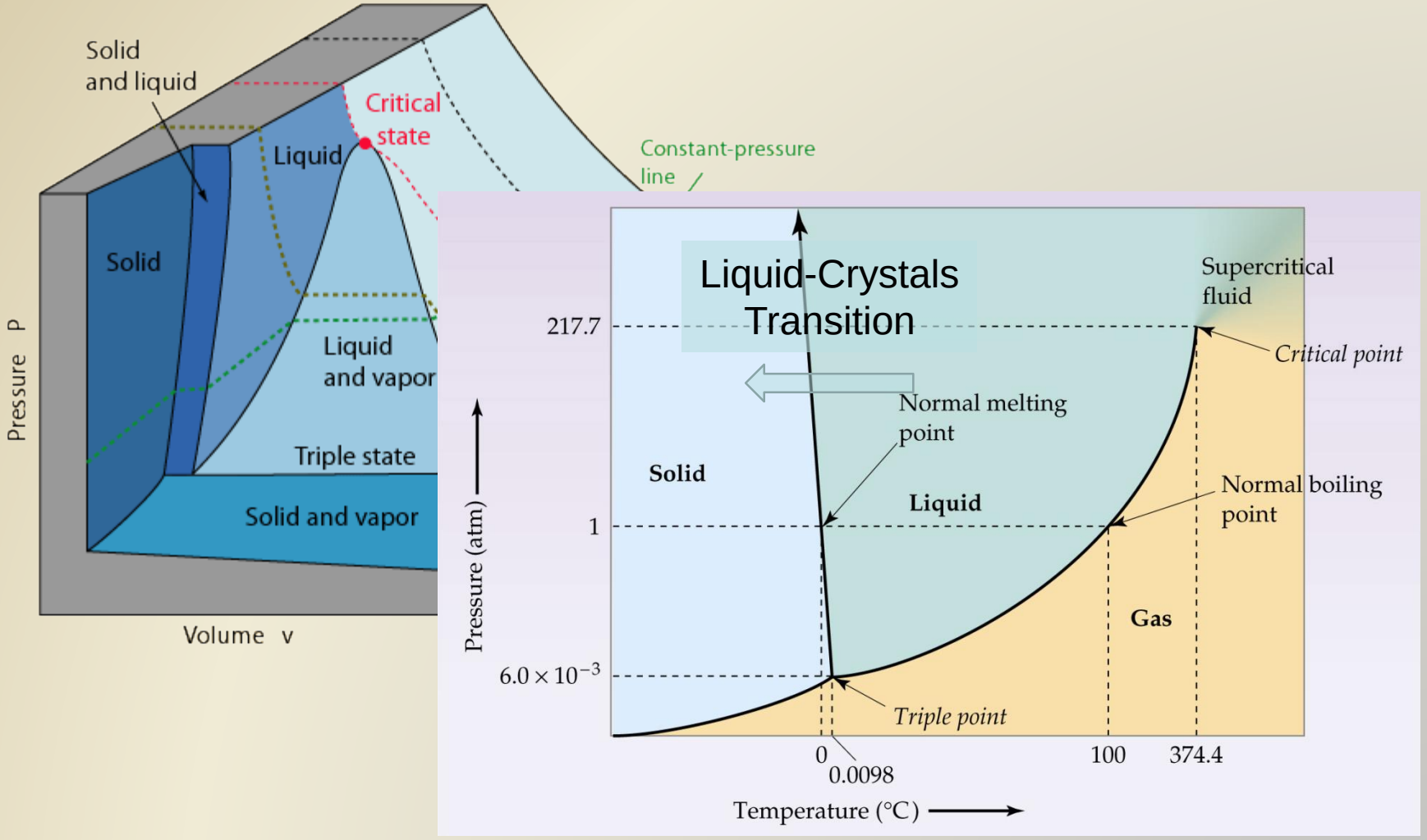
Thermodynamics



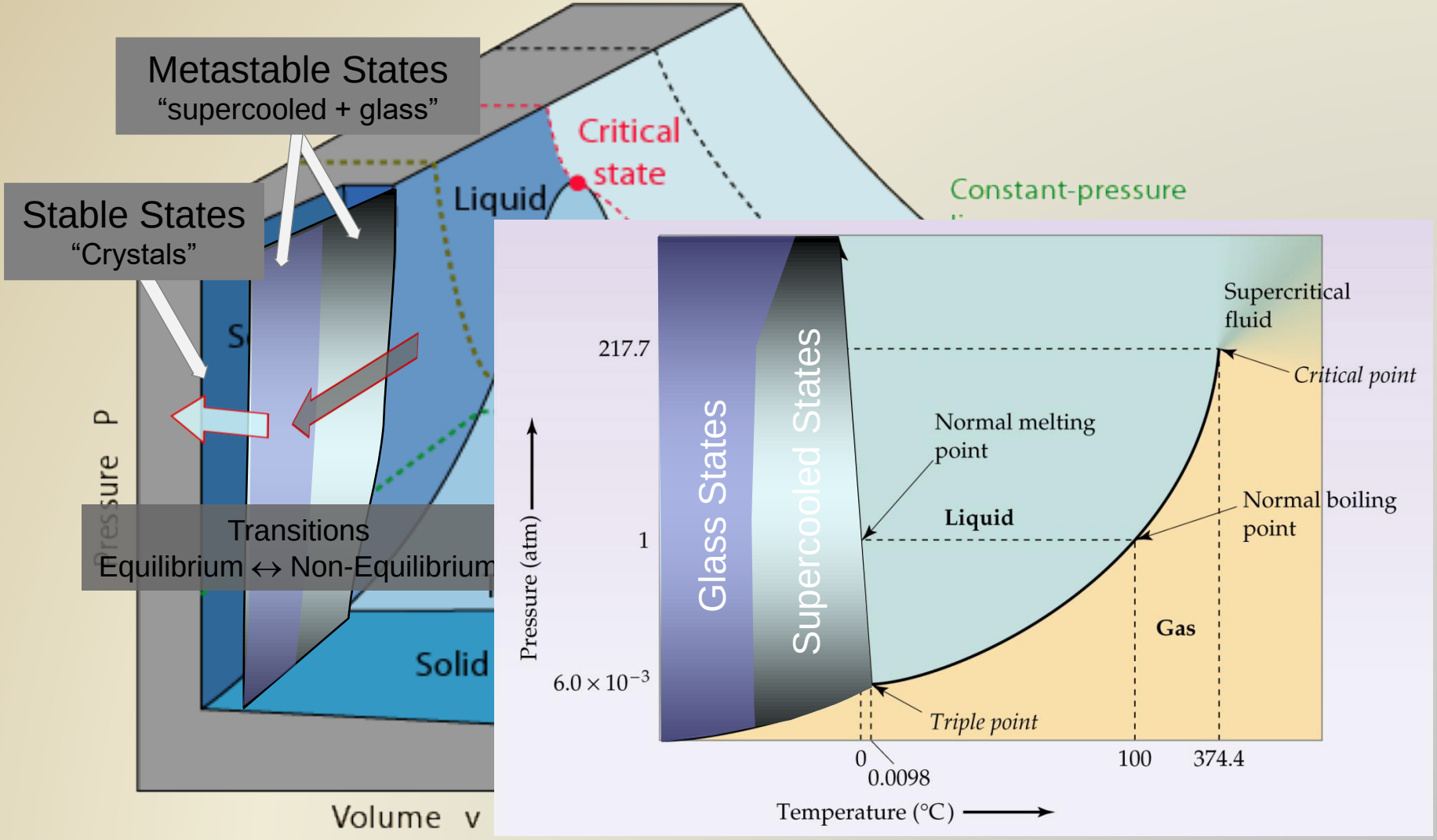
Dynamics



Equilibrium Phase Transitions



Non-Equilibrium Transitions



Non-Equilibrium → Equilibrium Transitions

Nucleation Processes

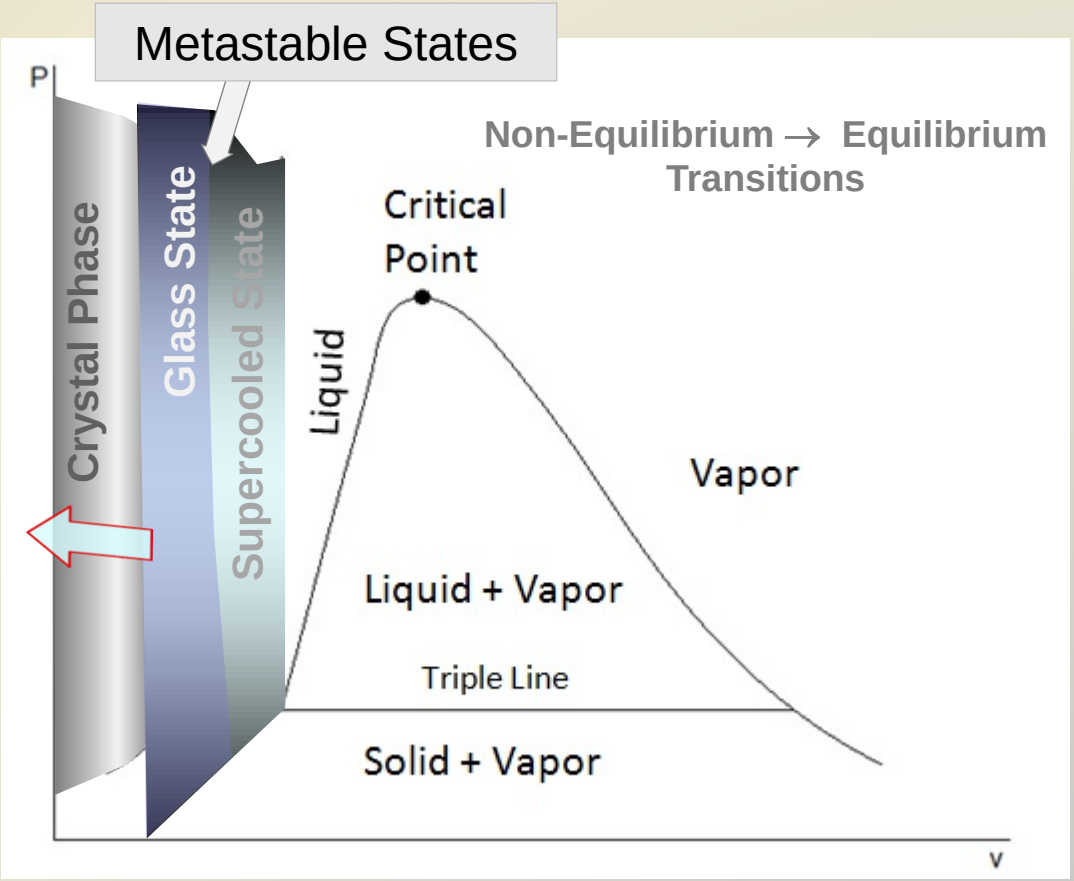
Supercooled Water → Ice
Supercooled Liquids → Crystals

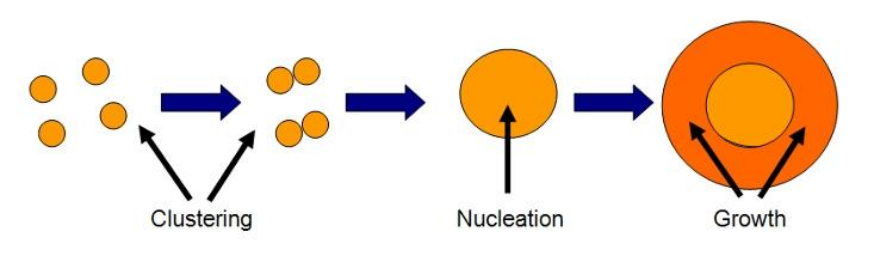
Aging Processes

Glass/Amorphous → Crystal

Time Dependent Transitions

Rare and random events

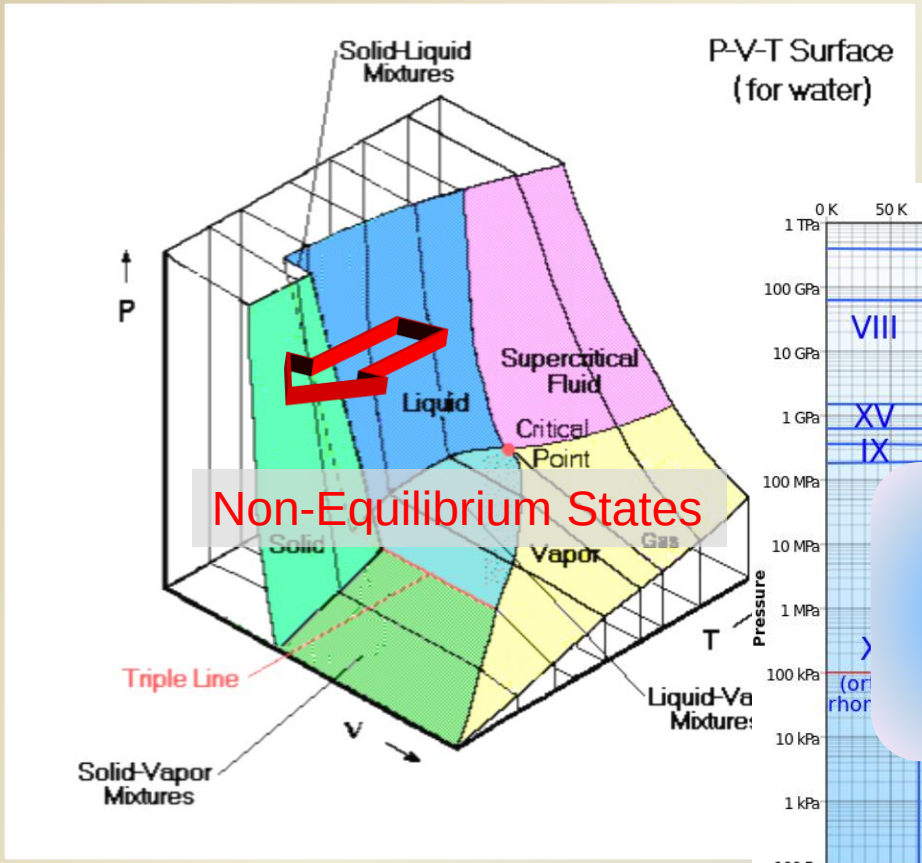


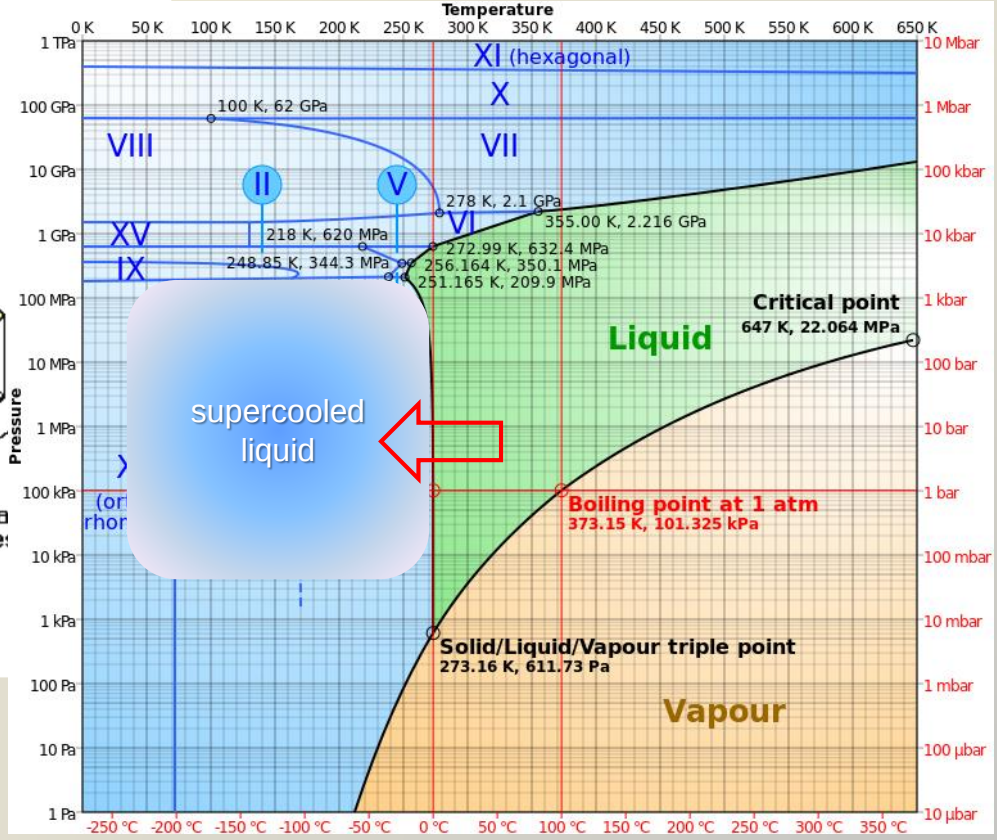


Different steps in the crystallization process

Non-Equilibrium

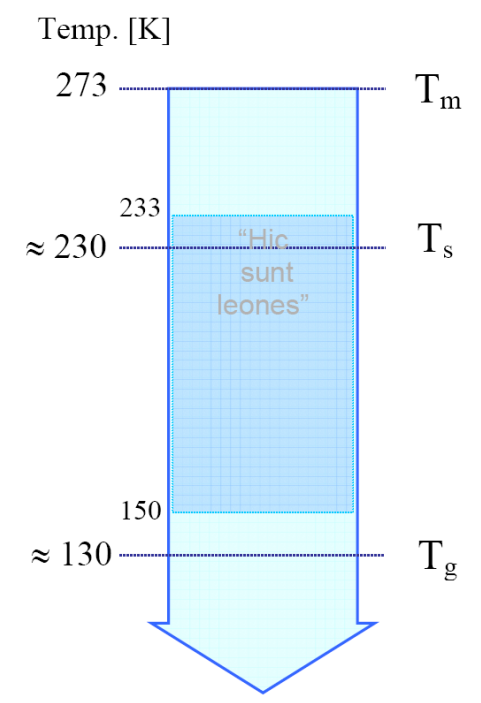
Supercooling Water





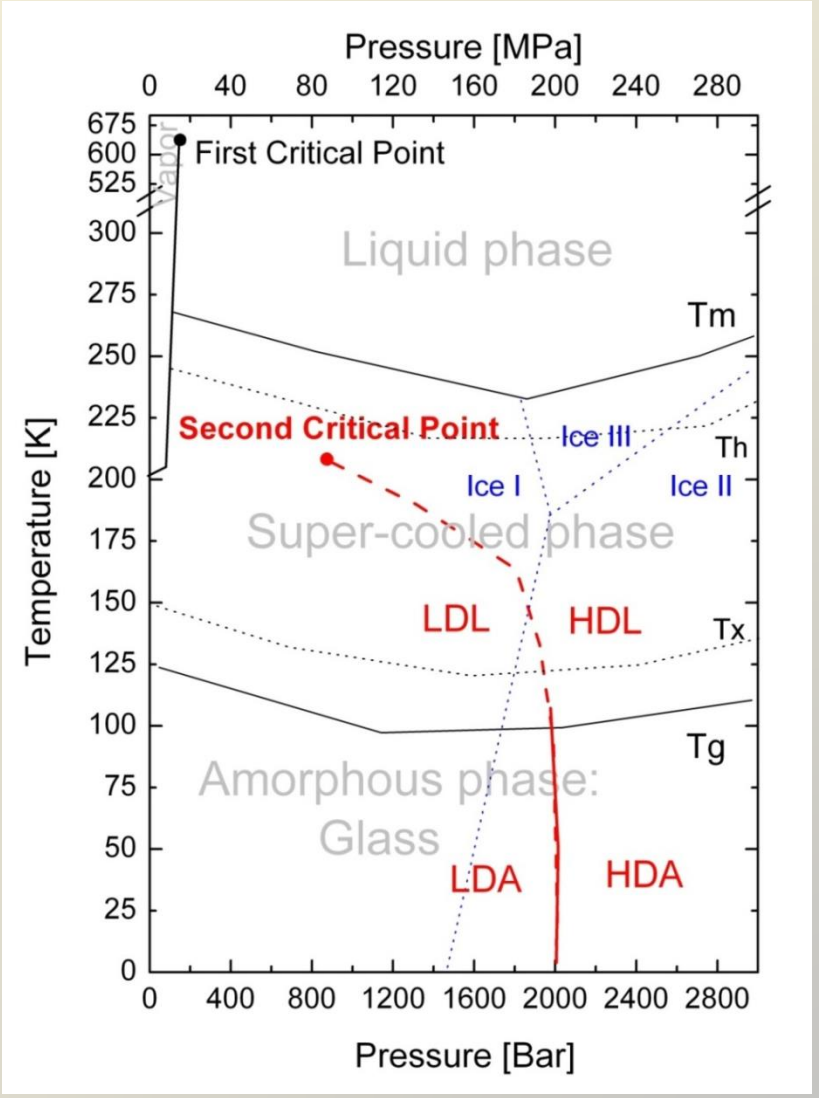
Non-Equilibrium

Water P-T Diagrams



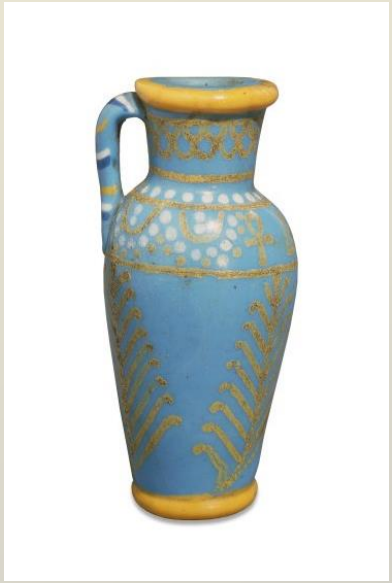
Supercooled **T= 273-230 K**
(nano-confinements, in bio)

Glass **T≤ 150/130 K**
(cooling at 10^6 K/sec)



First Manufactured Glass

Probably from the tomb of Thutmose III,
Thebes, Egypt 18th Dynasty, around 1400 BC (British Museum)



Silica (oxide) Glasses:

5000 B.C. First Glass from Fenici (Syria)
3500 B.C First Manufactured Glass from Egipt (Egitto e Mesopotania)
100 A.C First blow glasses from Romans (Italia)

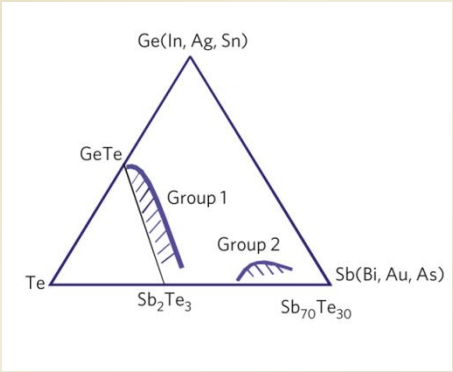
		SiO_2 %	CaO %	Na_2O %	altri %	
1450	A.Barovier (Venezia)	75	5	15	2	FeO_3
1500	Cristalli di Boemia (Praga)	75	11	13	0.5	
1675	Ravenscroft “Flint” (Londra)	65	3	7	21	PbO
1800	Franklin (USA) “CORNING”	85	1	1	5	TiO_2
1800	Schott (Germania) ”ZEISS”	80	0	4	13	B_2O_3

Sodic-calcium (finestre etc..), Thermal glasses (high temperature), Lead Glasses (TV and raggi x tube), Tempered Glasses (automobile) etc..

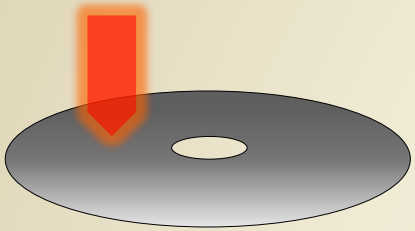
Chalcogenide glasses:

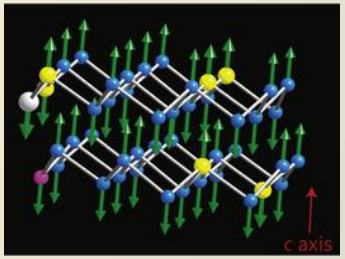
GeAsSe
GeS, GeSI
GeSbTe

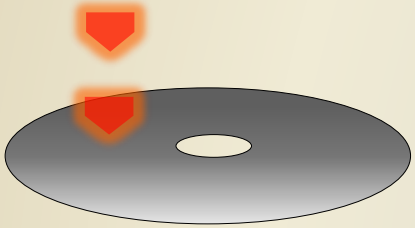
AgInSbTe

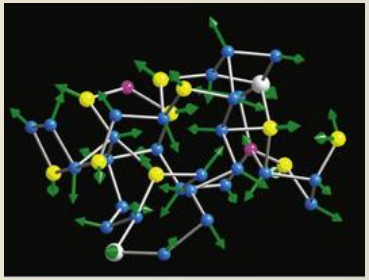


Rewritable Optical Disc





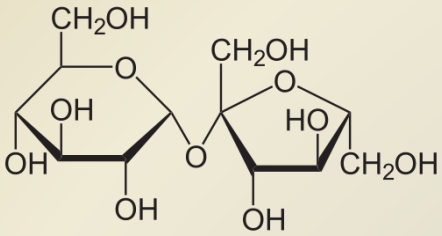




- During writing, the material is **first erased**, initialized into its crystalline state, with long, lower-intensity laser irradiation. The material heats up to its crystallization temperature, but not up to its melting point, and crystallizes in a **metastable** crystalline structure.
- Then the information is **written on** the crystalline phase, by heating spots of it with short (<10 ns), high-intensity laser pulses; the material locally melts and is quickly cooled, remaining in the **amorphous phase**.
- The amorphous phase has lower reflectivity than the crystalline phase, the bitstream can be recorded as "dark" amorphous spots on the crystalline background. A low laser **beam read** the spot using their different reflectivity.

Organic glasses:

Methanol
Glycerol
Sucrose



Polymer glasses:

Polyethylene	(film and bags)	–(CH2-CH2)n–
Poly(vinyl chloride)	(pipe, plastic cover)	–(CH2-CHCl)n–
Polystyrene	(toys and soft objects)	–[CH2-CH(C6H5)]n–

Metallic glasses:

Metallic alloy obtained by **extremely rapid cooling**.

The first was produced at Caltech in 1960 ($Au_{75}Si_{25}$). Alloy of 77.5% palladium, 6% copper, and 16.5% silicon was found to have critical cooling rate between 100 to 1000 K/s.

Samples of the new titanium-based metallic-glass composites showing their toughness and ductility