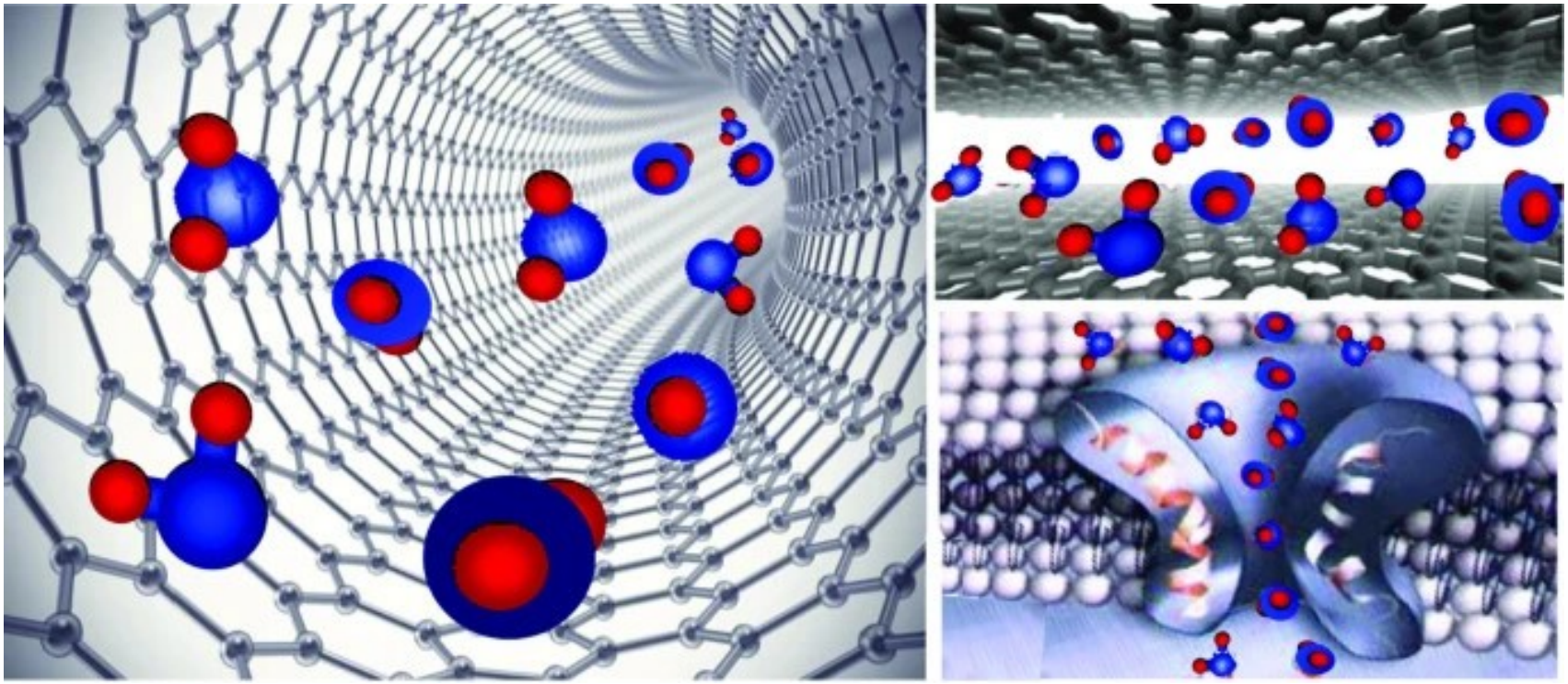
Nanoconfined Water



https://link.springer.com/article/10.1140/epje/s10189-021-00136-4

Summary

Phase Transitions-
Water Anomalies

Nanoconfined Water in
Solid State Materials

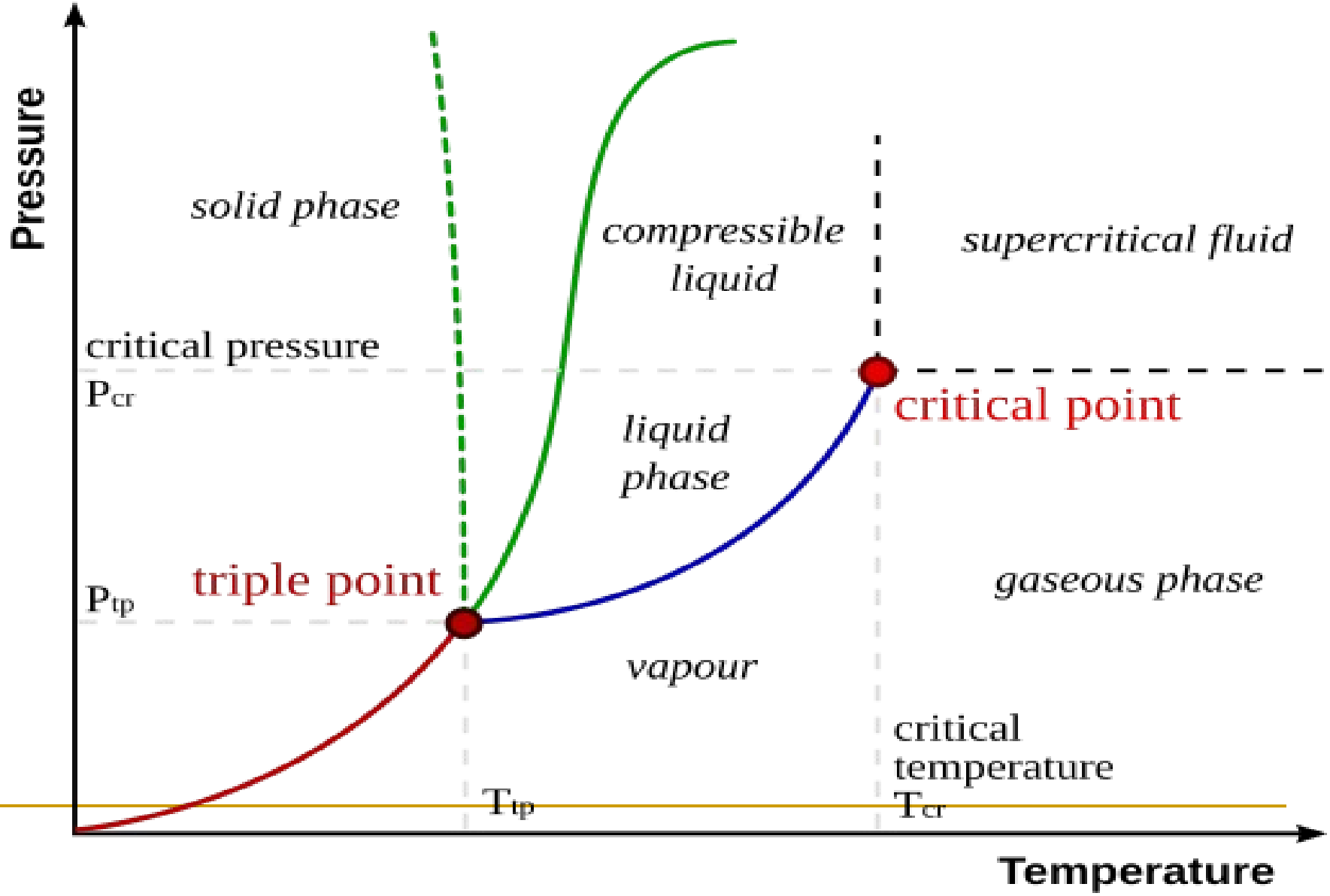
Nanoconfined Water in
Biology

Criticality – Water Anomalies

photo by Clóvis Jardim

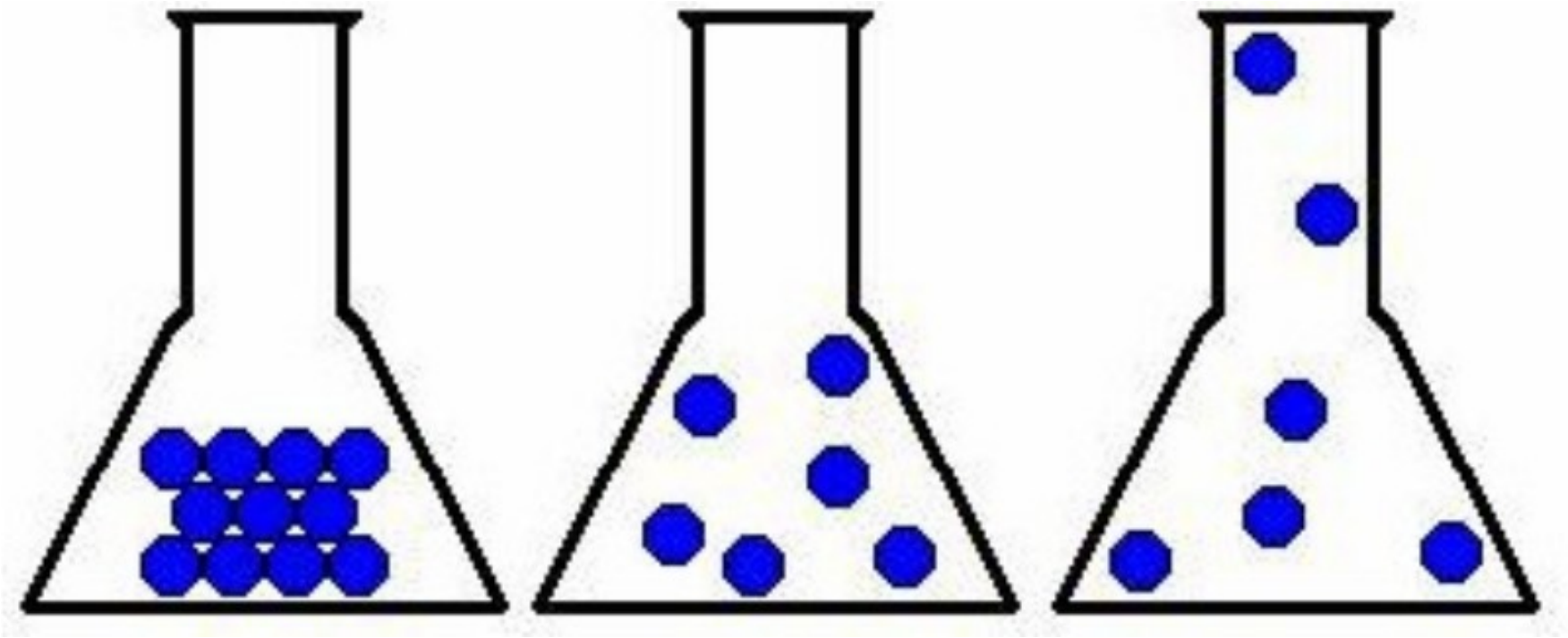
PHASE TRANSITIONS

Phase Transitions

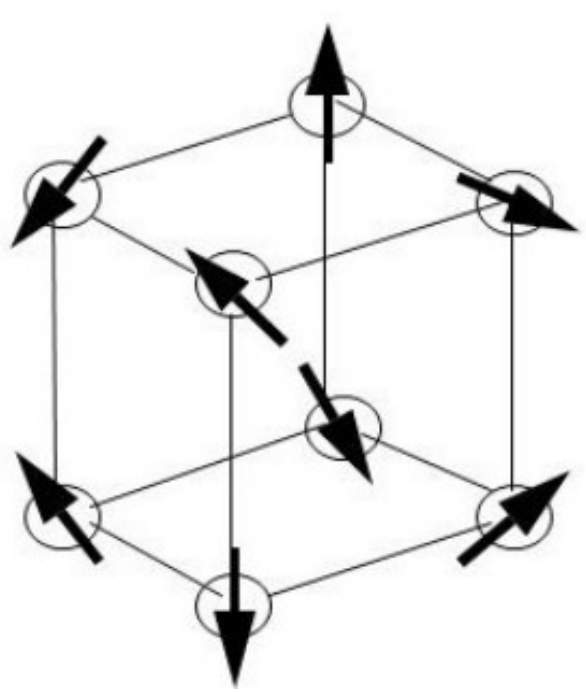


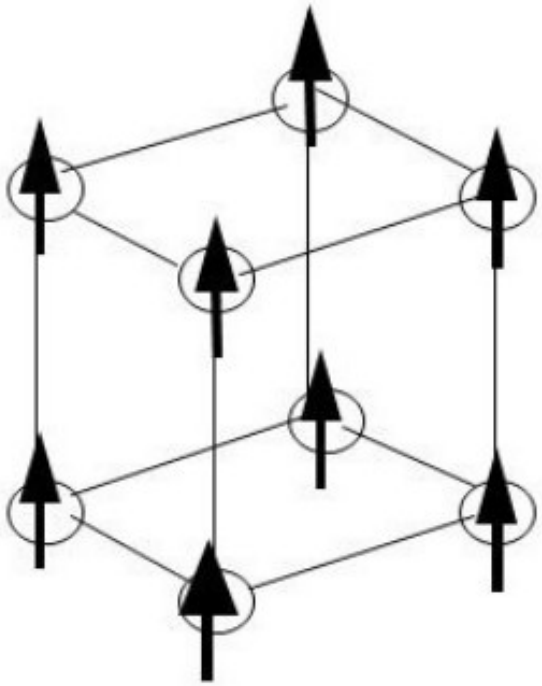
PHASES

Simple Materials
Solid Liquid Gas

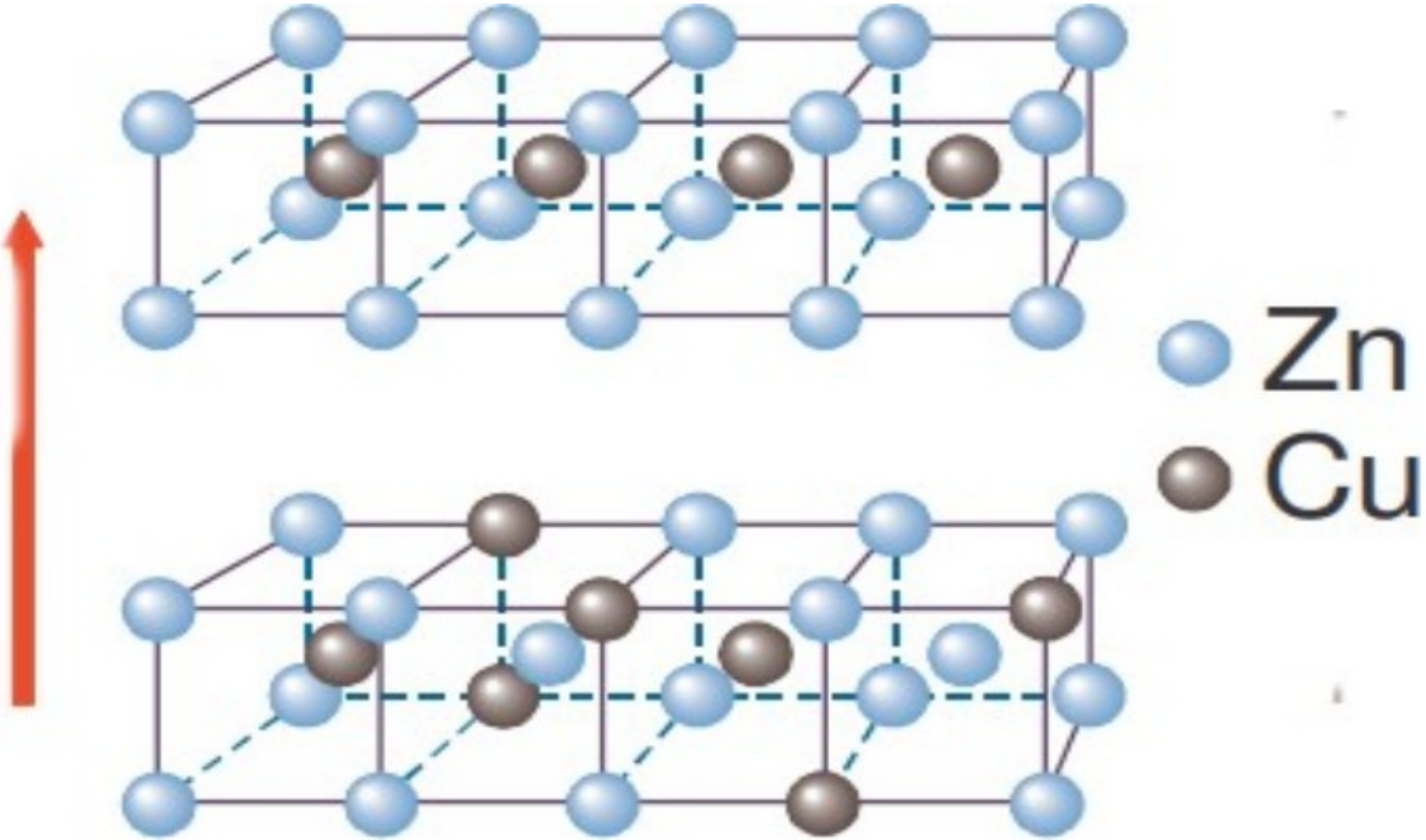


Simple Magnetic Materials
Paramagnetic e Ferromagnetic



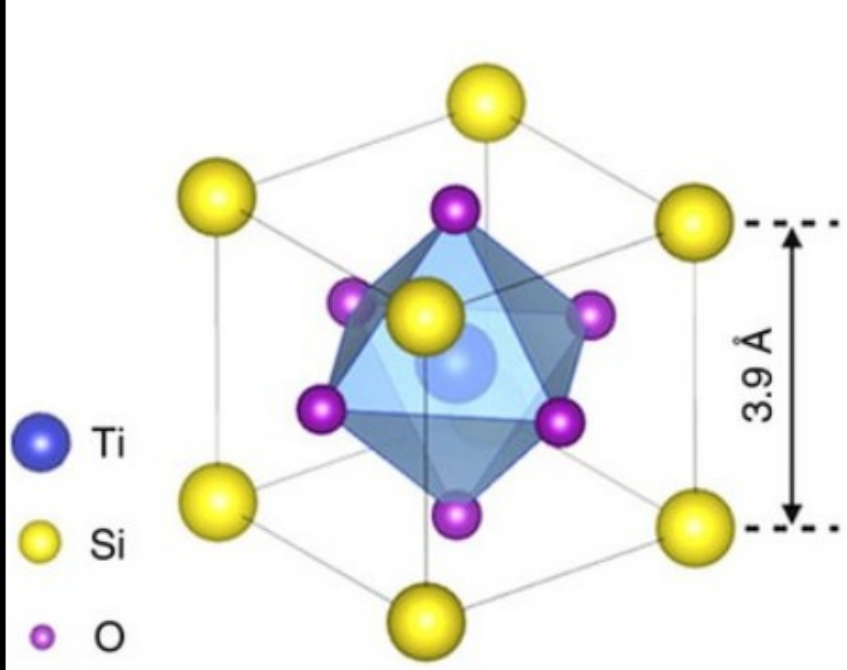


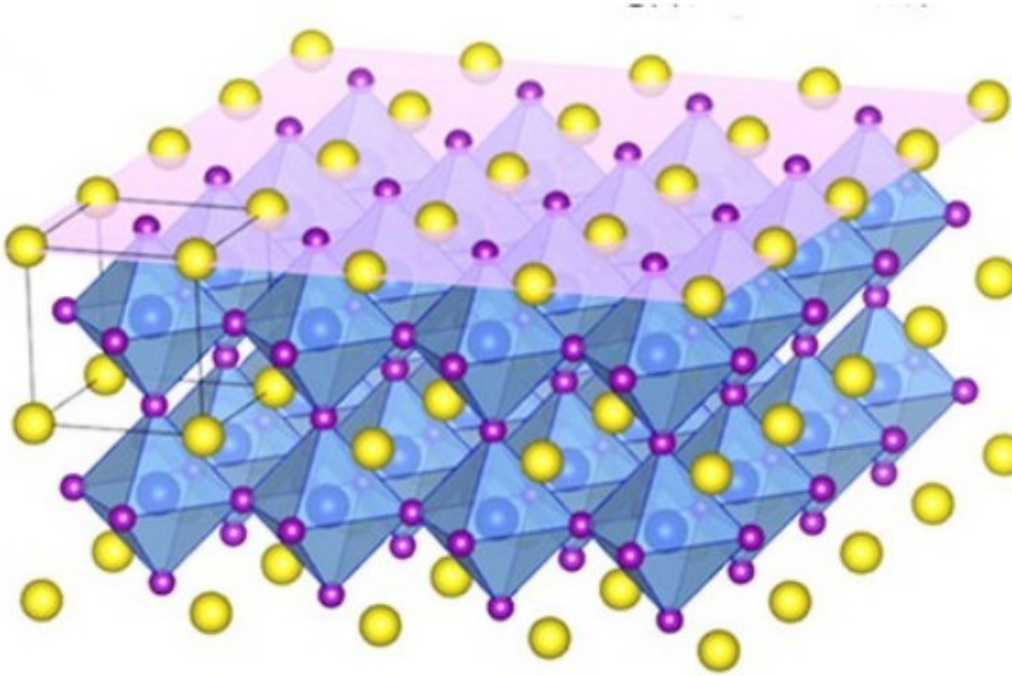
Phases - ZnCu



https://www.edinst.com/phase-transitions-halide-perovskite/

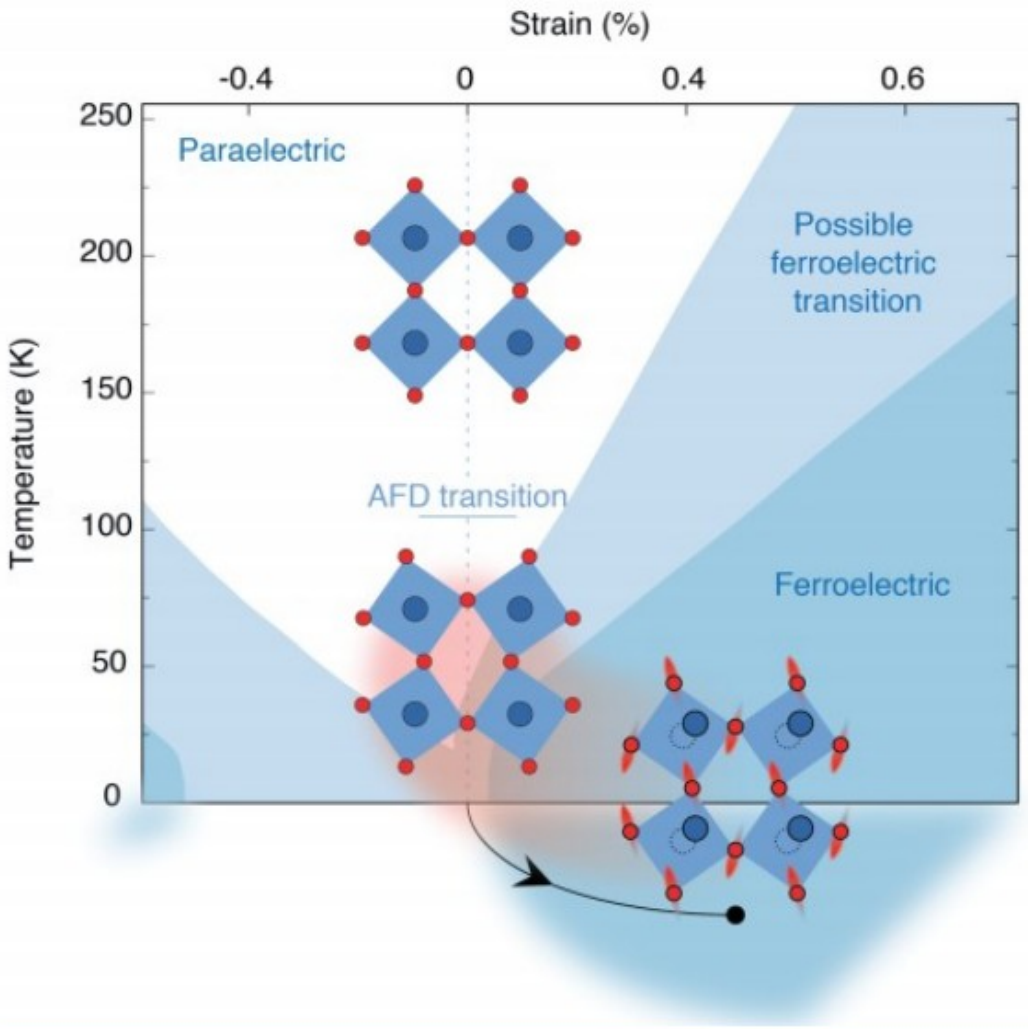
$SrTiO_3$





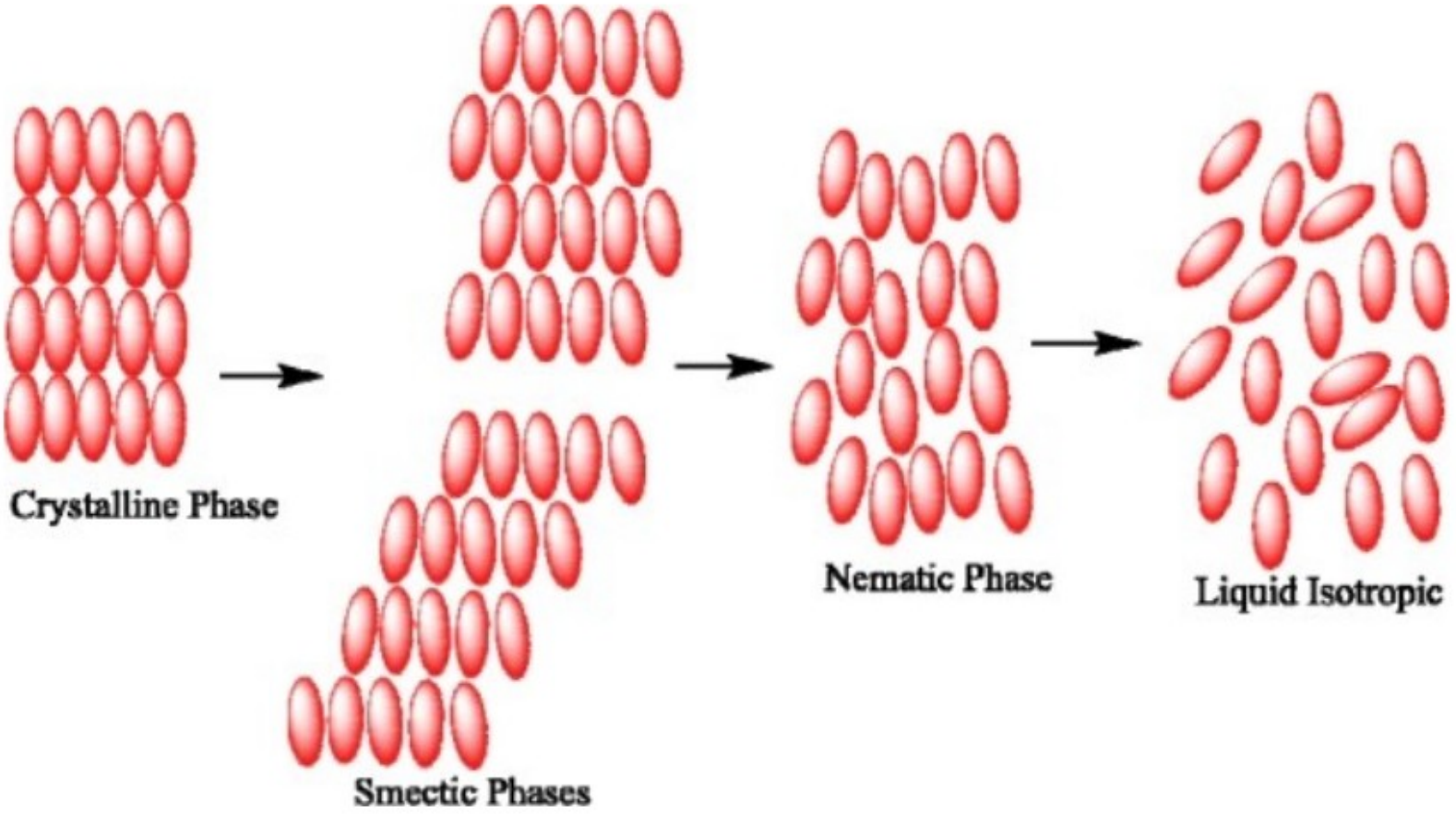
https://arxiv.org/pdf/1812.10560.pdf

$SrTiO_3$



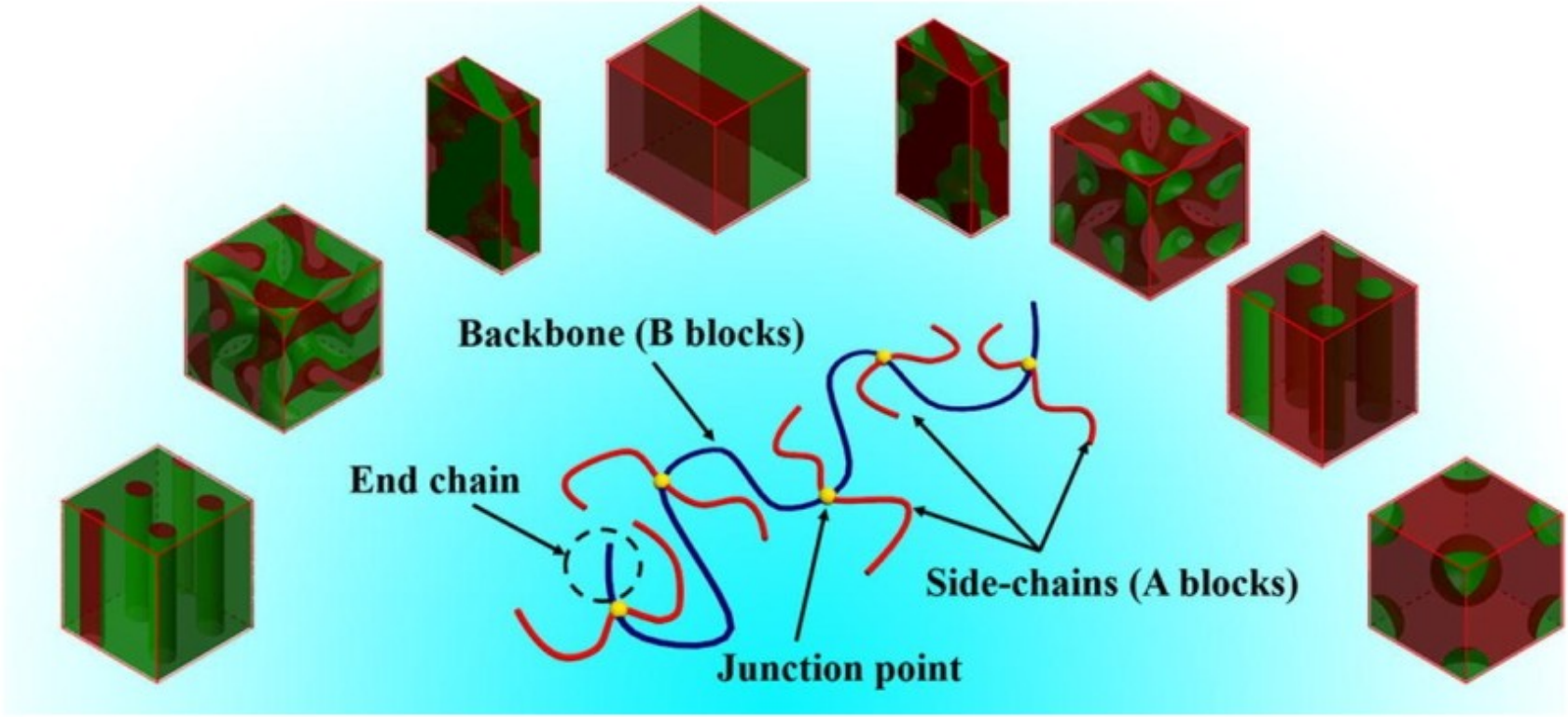
https://arxiv.org/pdf/1812.10560.pdf

Liquid Cristals



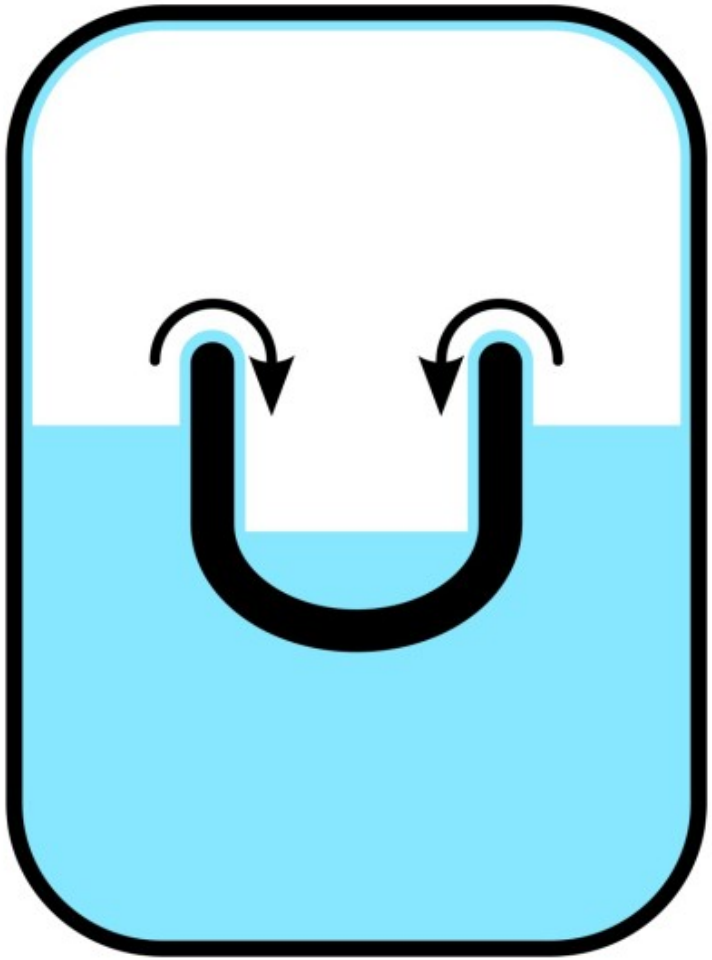
https://www.researchgate.net/figure/Phase-transition-between-crystals-smectic-nematic-and-isotropic-liquid-phases-for-a_fig1_41089547

Block Copolymers



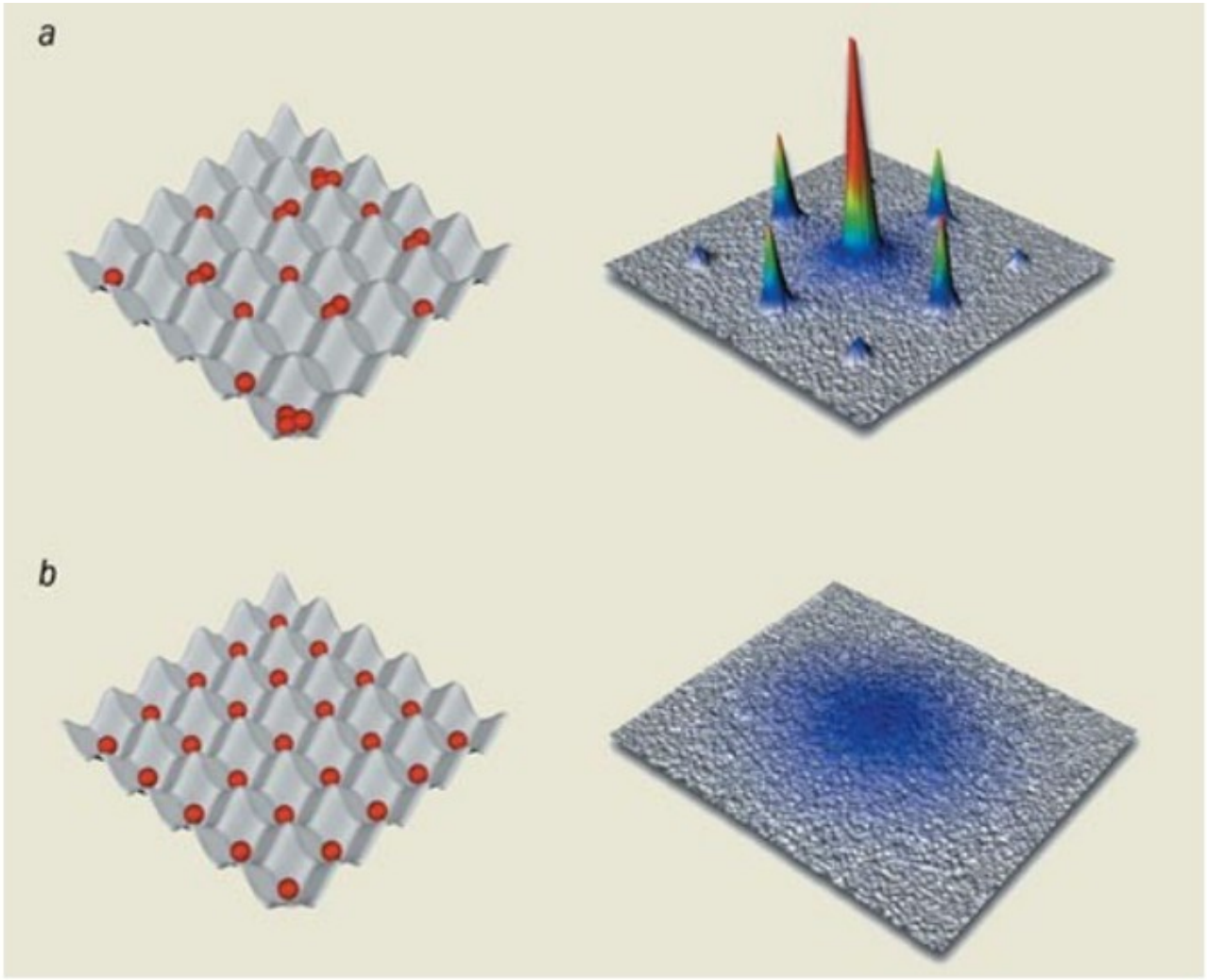
https://ars.els-cdn.com/content/image/1-s2.0-S0009261419301198-ga1_lrg.jpg

Superfluid Helium



https://en.wikipedia.org/wiki/Helium

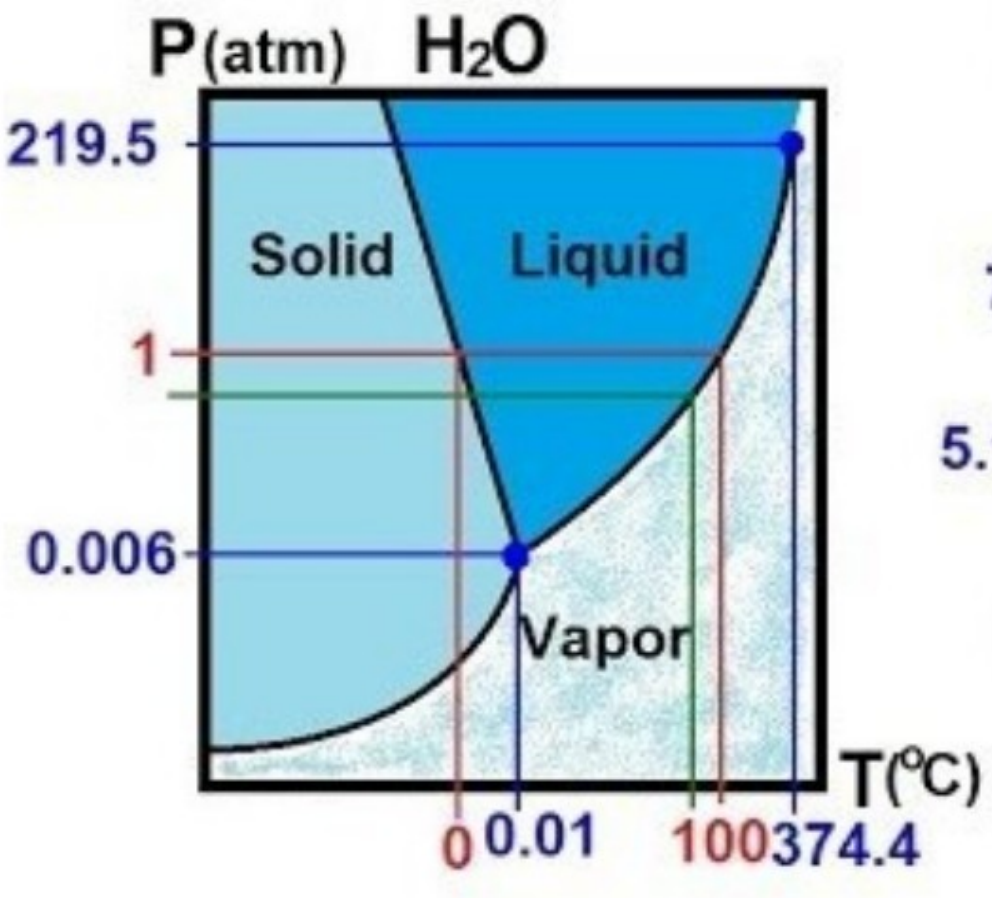
Cold Atoms in Lattice

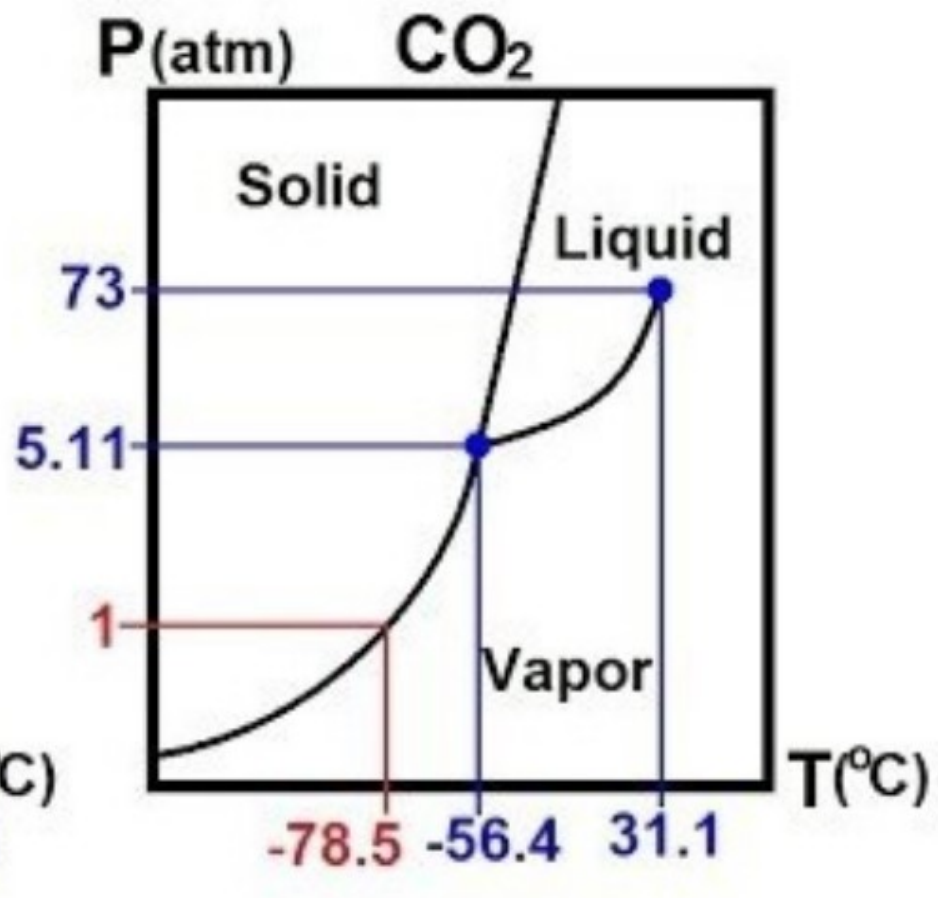


https://physicsworld.com/a/quantum-gases-in-optical-lattices/

PHASE DIAGRAMS

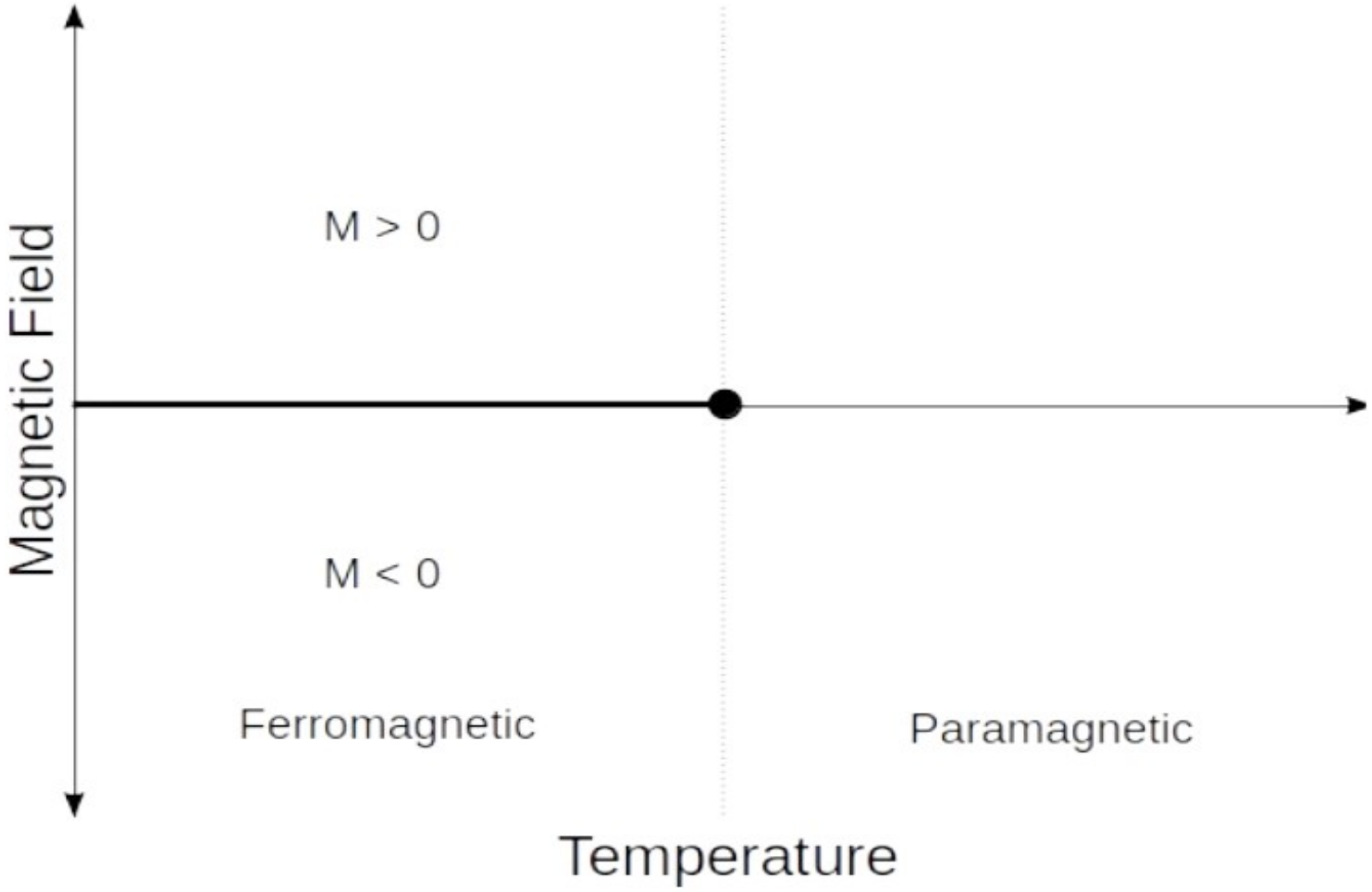
Phase Diagram





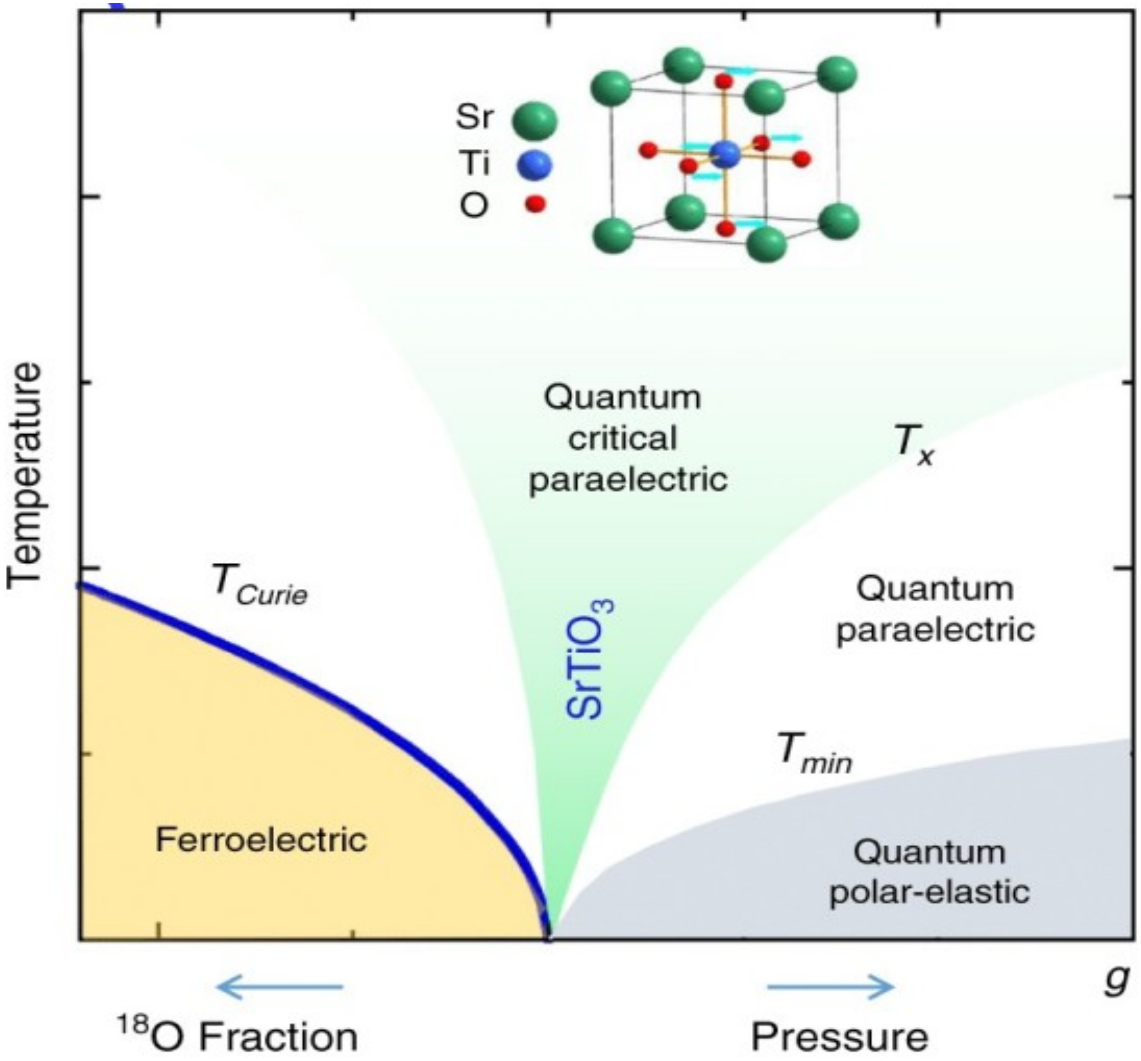
https:youtube.com/watch?v=aNhhttps://www.youtube.com/watch?v=aNhYb-_Kq8sYb-_Kq8s

Magnetic Phase Transition



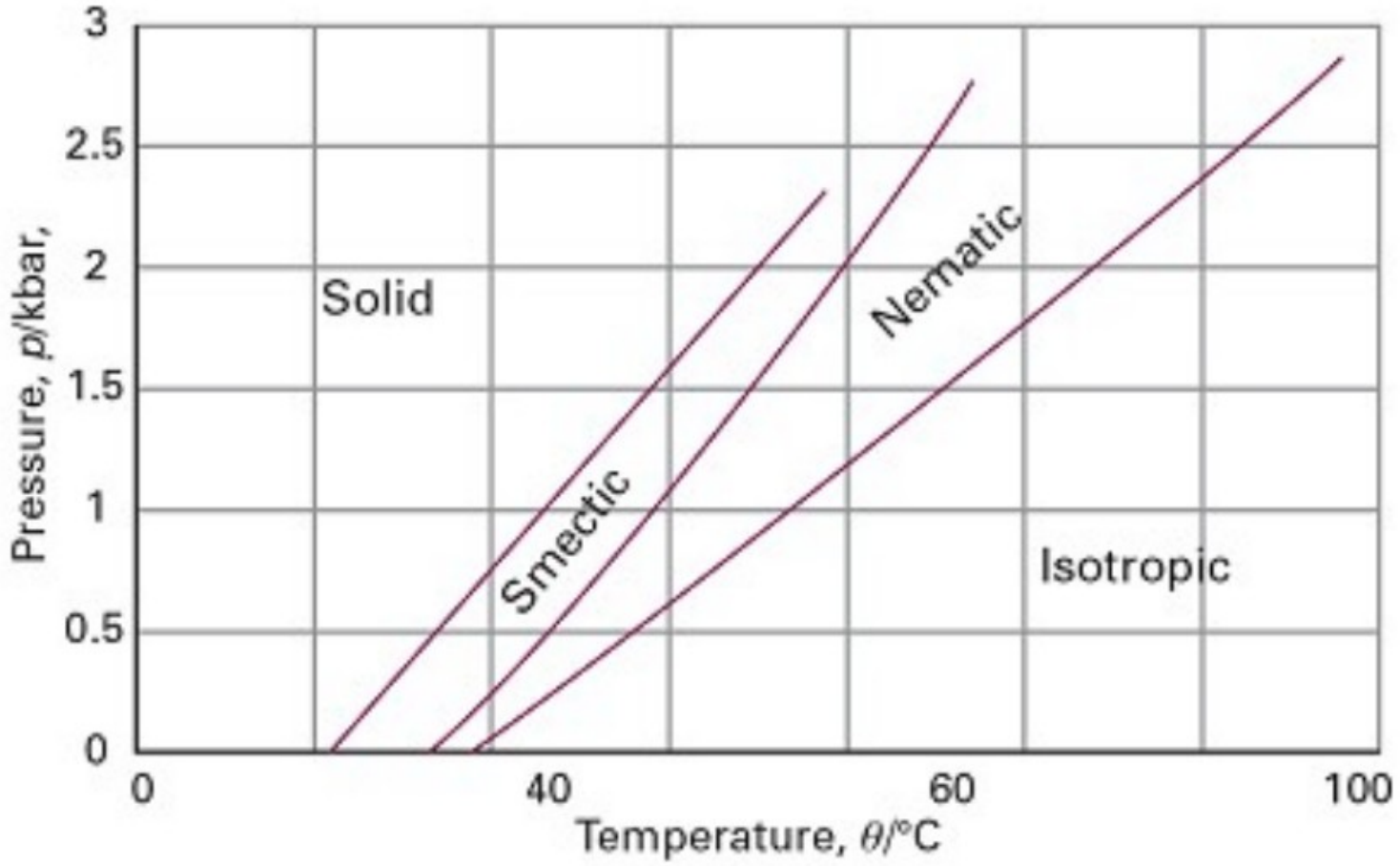
https://web.stanford.edu/~peastman/statmech/phasetransitions.html

$SrTiO_3$

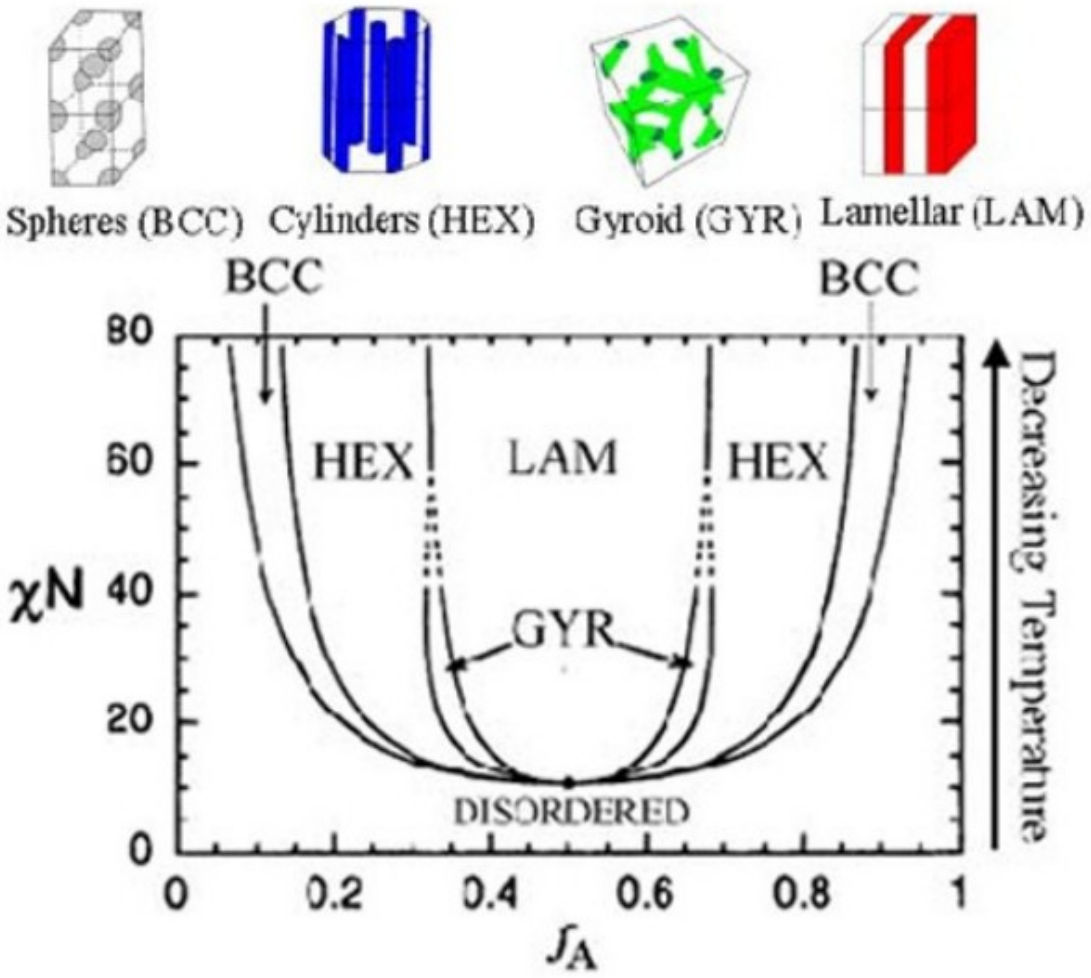


https://www.researchgate.net/figure/The-phase-diagram-of-SrTiO3-based-on-a-quantum-ph-self-consistent-field-model-of-a_fig1_344407753

Liquid Crystal

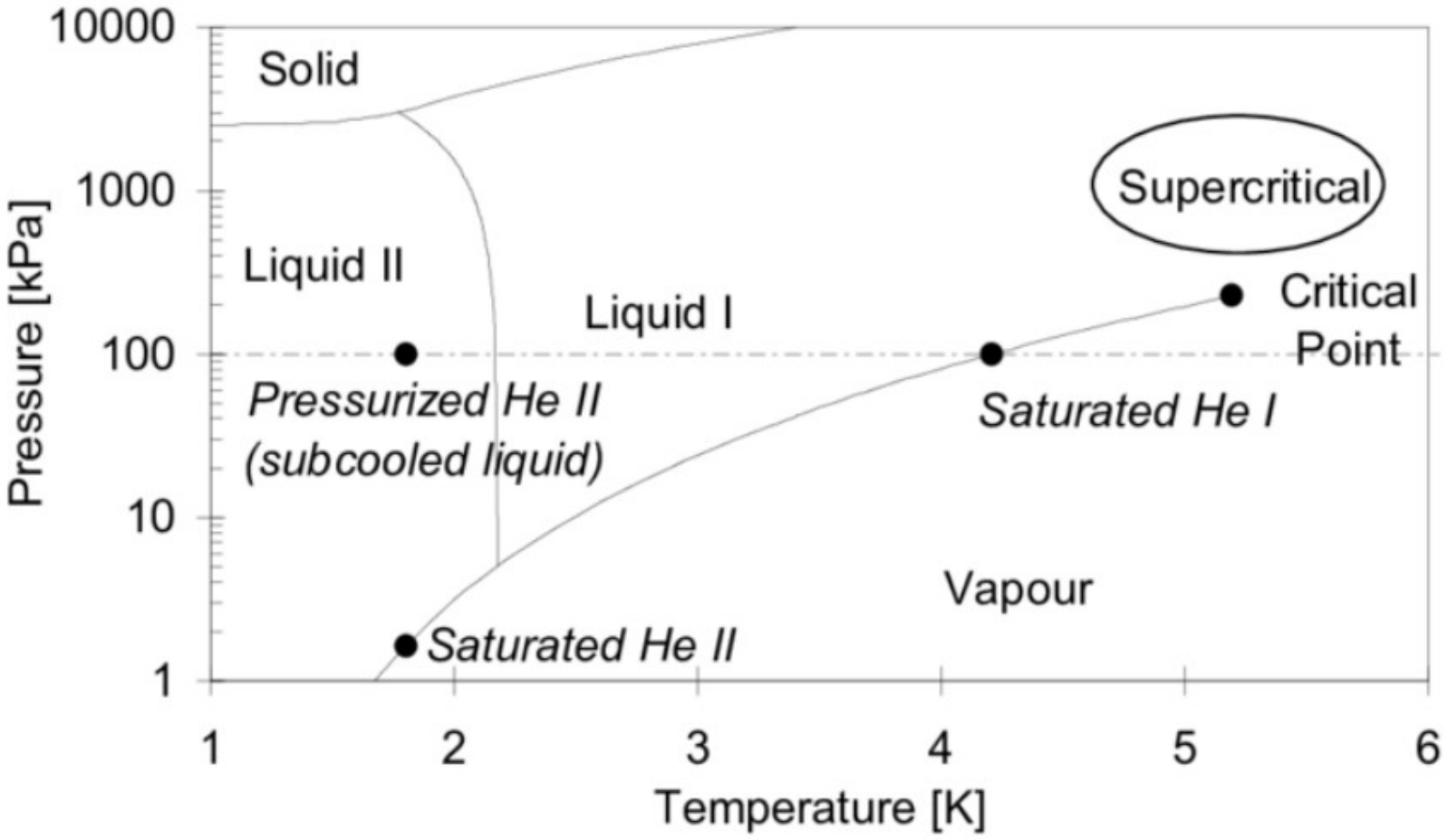


Block Copolymeres



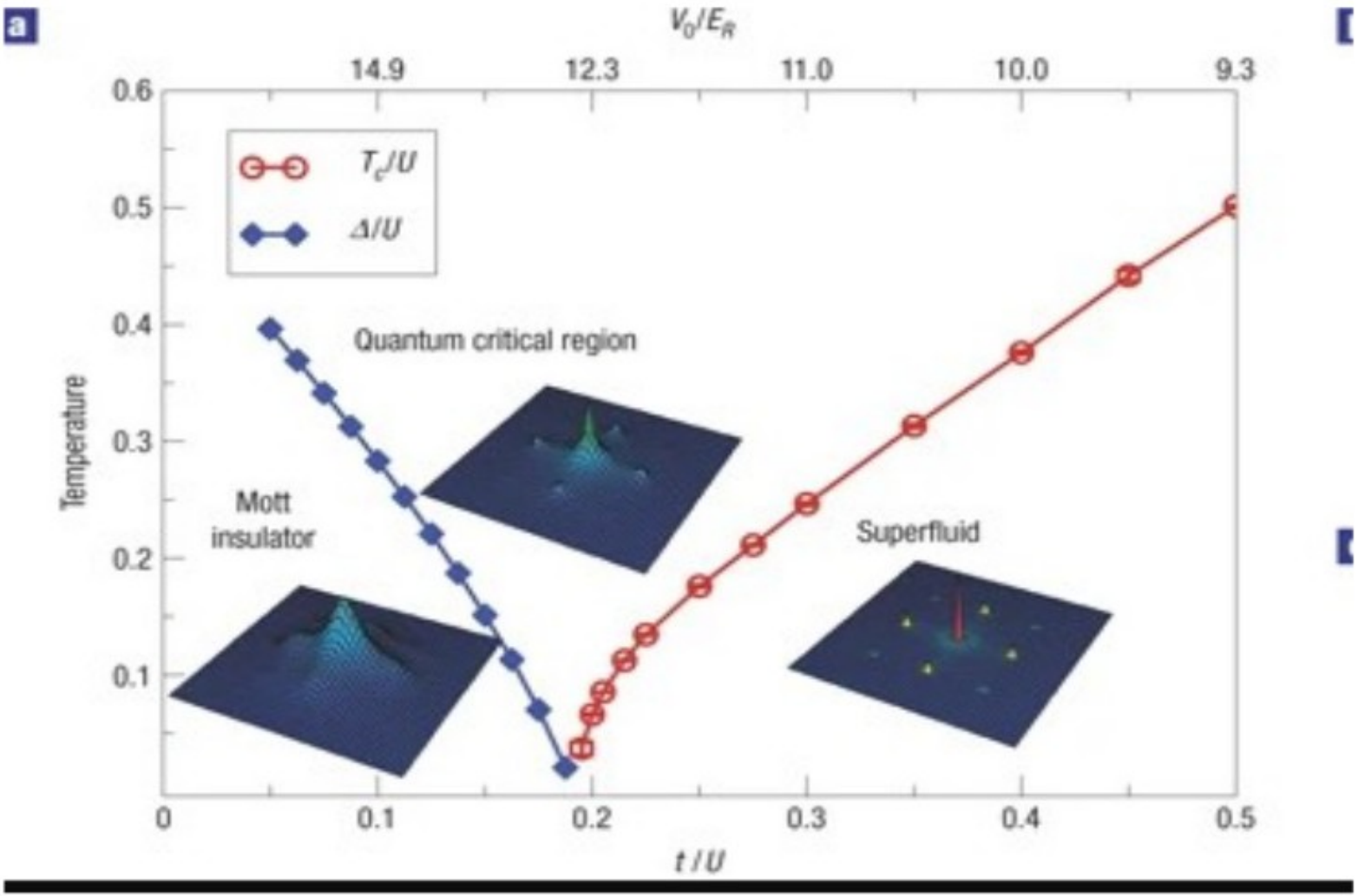
https://web.mit.edu/8.334/www/grades/projects/projects10/AlexanderPapageorge/Page6.html

Superfluid Helium



https://www.researchgate.net/figure/The-phase-diagram-of-helium_fig9_271532273

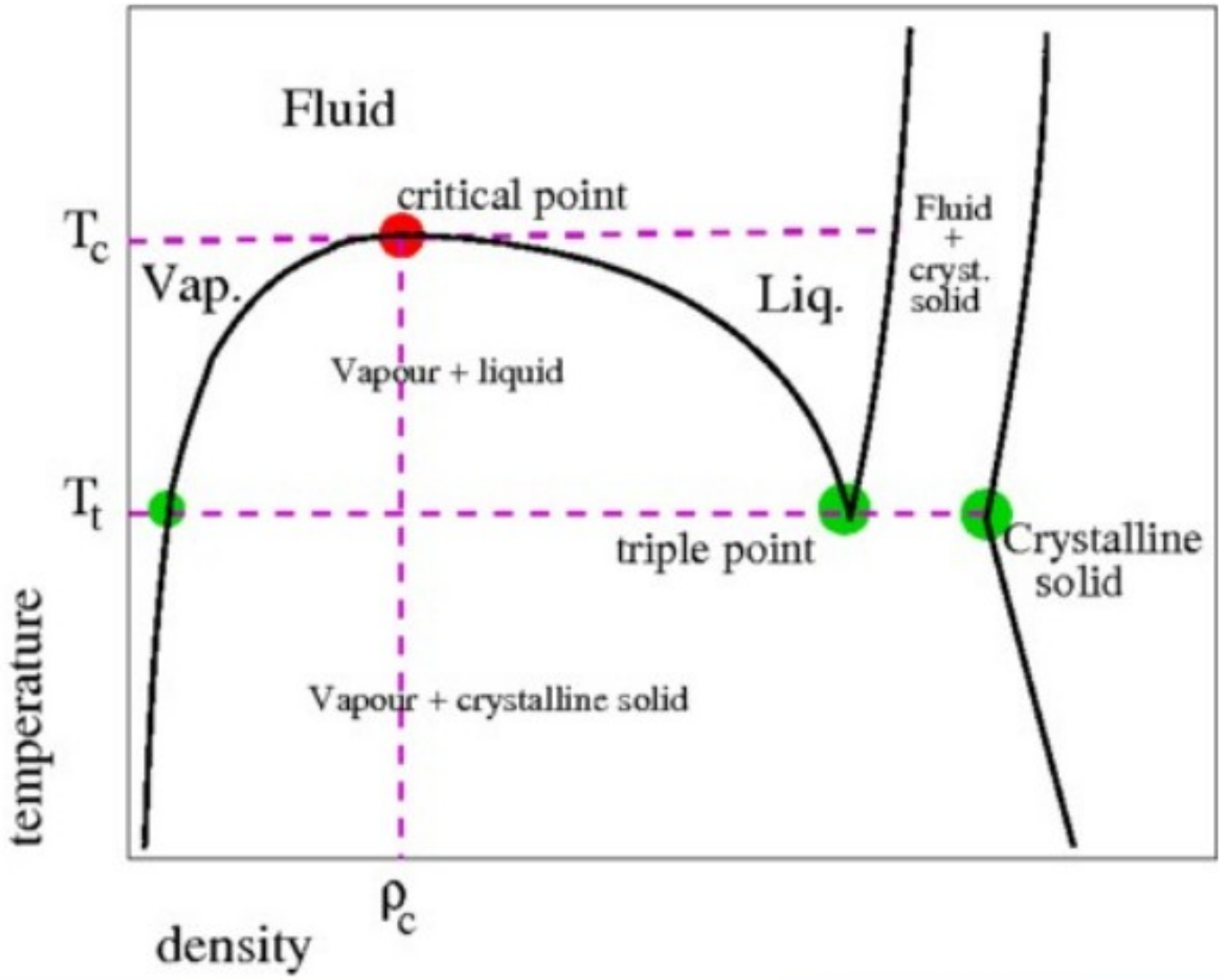
Quantum Systems



https://www.nature.com/articles/nphys983

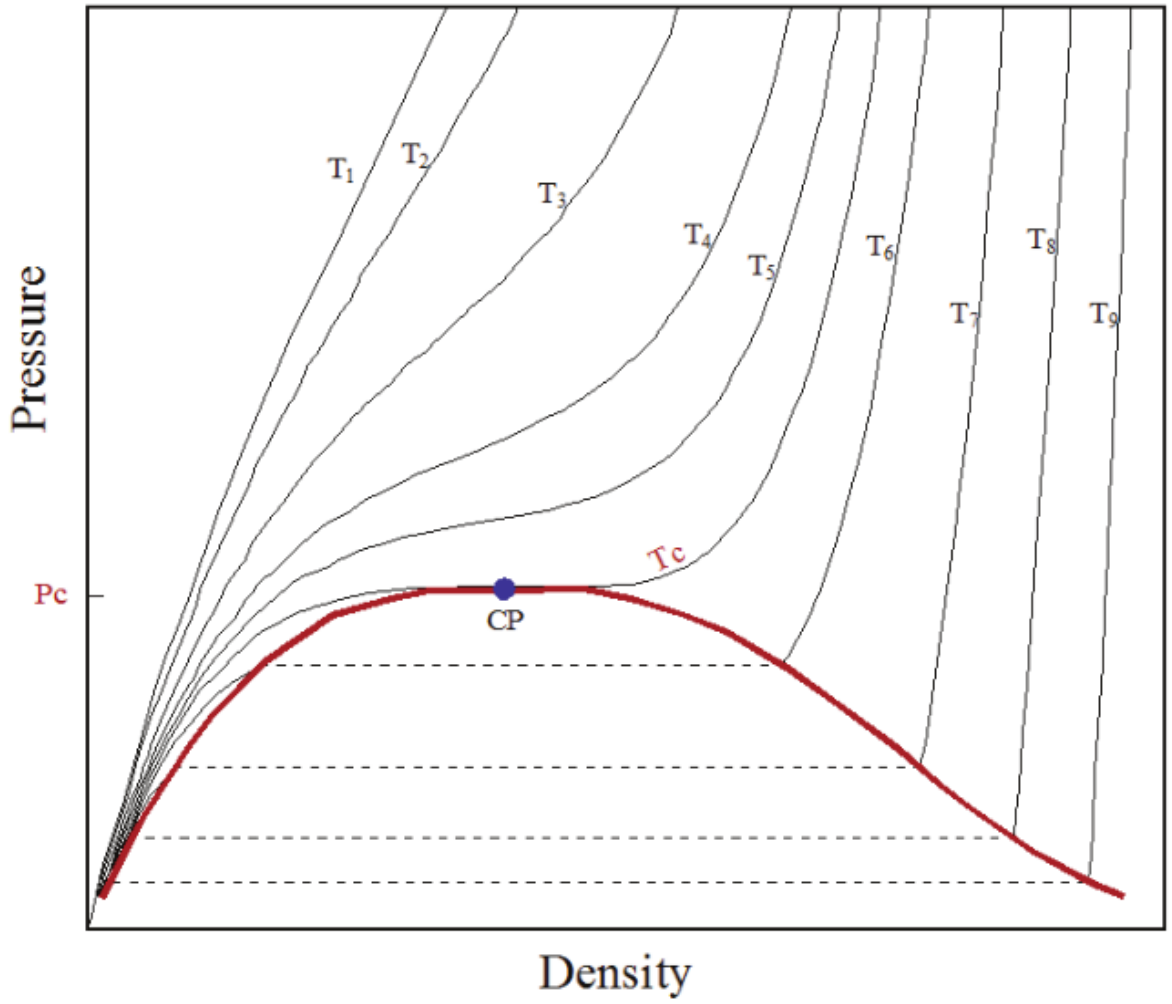
PHASE TRANSITION

Simple Fluids



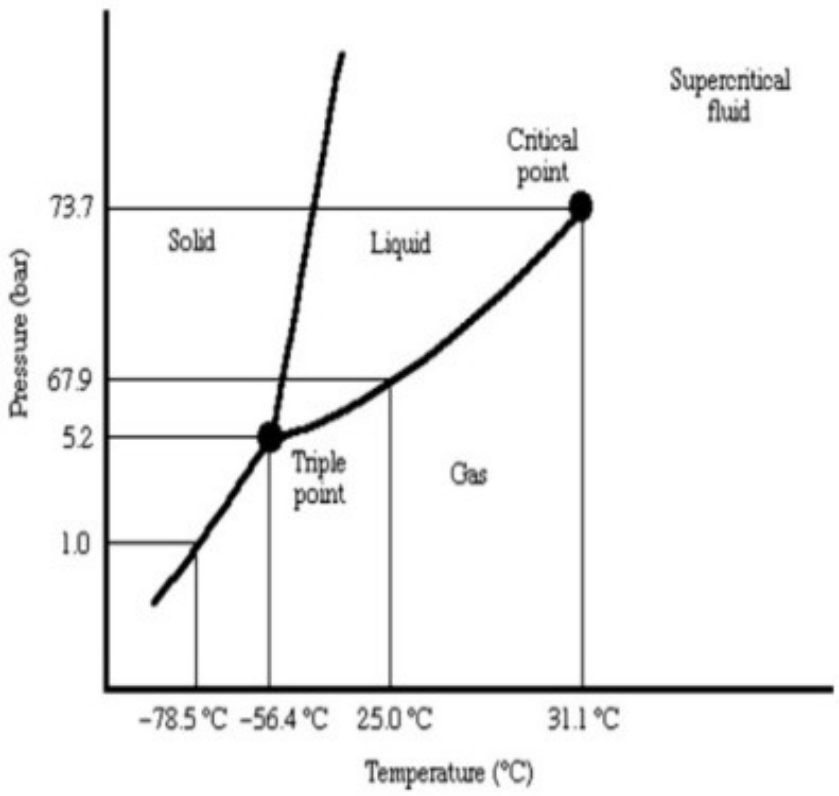
http://www.sklogwiki.org/SklogWiki/index.php/Phase_diagrams:_Density-temperature_plane

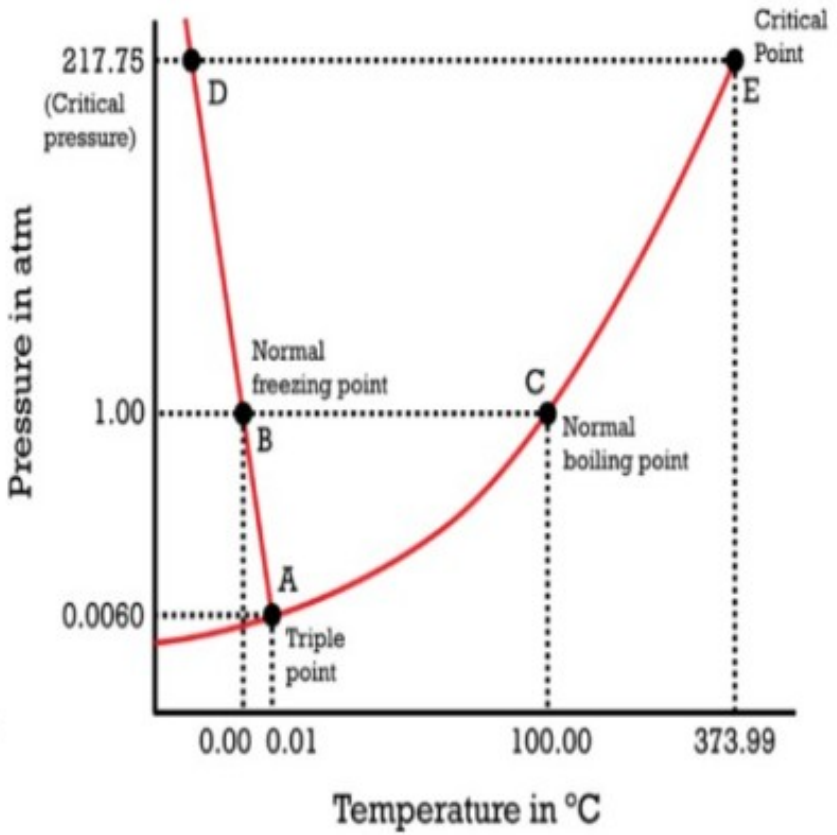
First Order Transition



https://www.intechopen.com/books/carbon-dioxide-chemistry-capture-and-oil-recovery/carbon-dioxide-use-in-high-pressure-extraction-processes

First Order Transition

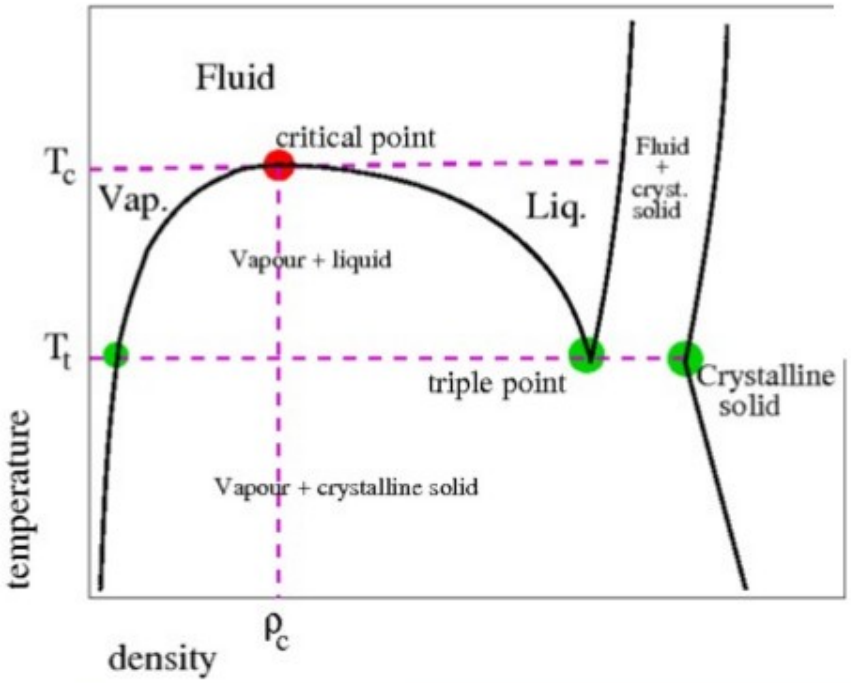


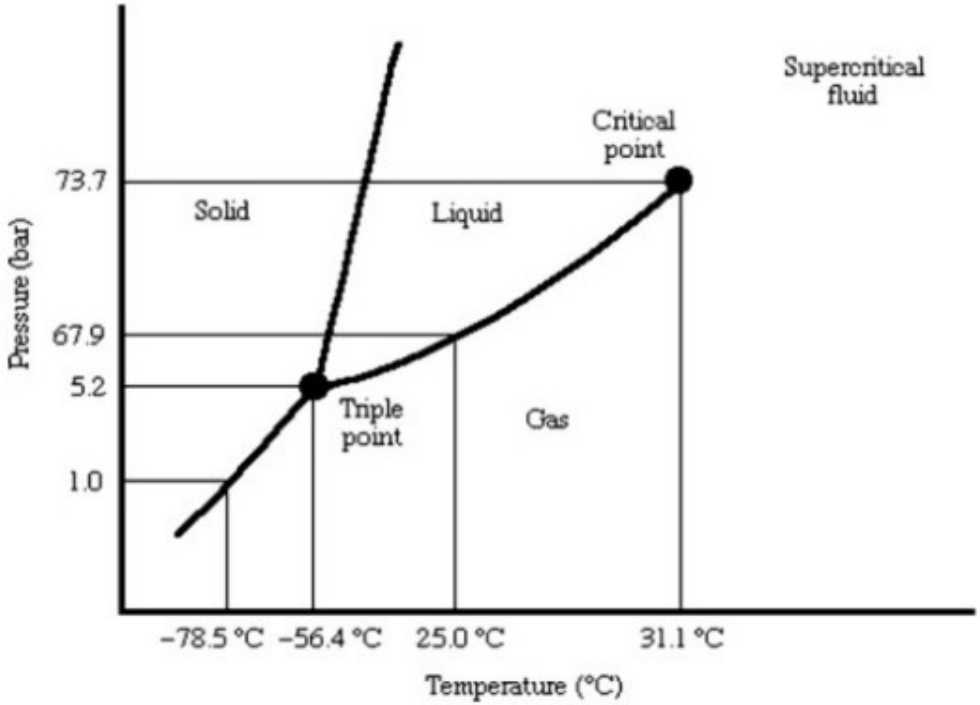


https://socratic.org/questions/how-are-the-conditions-of-pressure-and-temperature-at-which-two-phases-coexist-i

https://perminc.com/resources/fundamentals-of-fluid-flow-in-porous-media/chapter-5-miscible-displacement/fluid-phase-behavior/pressure-temperature-diagram-p-t-diagram/

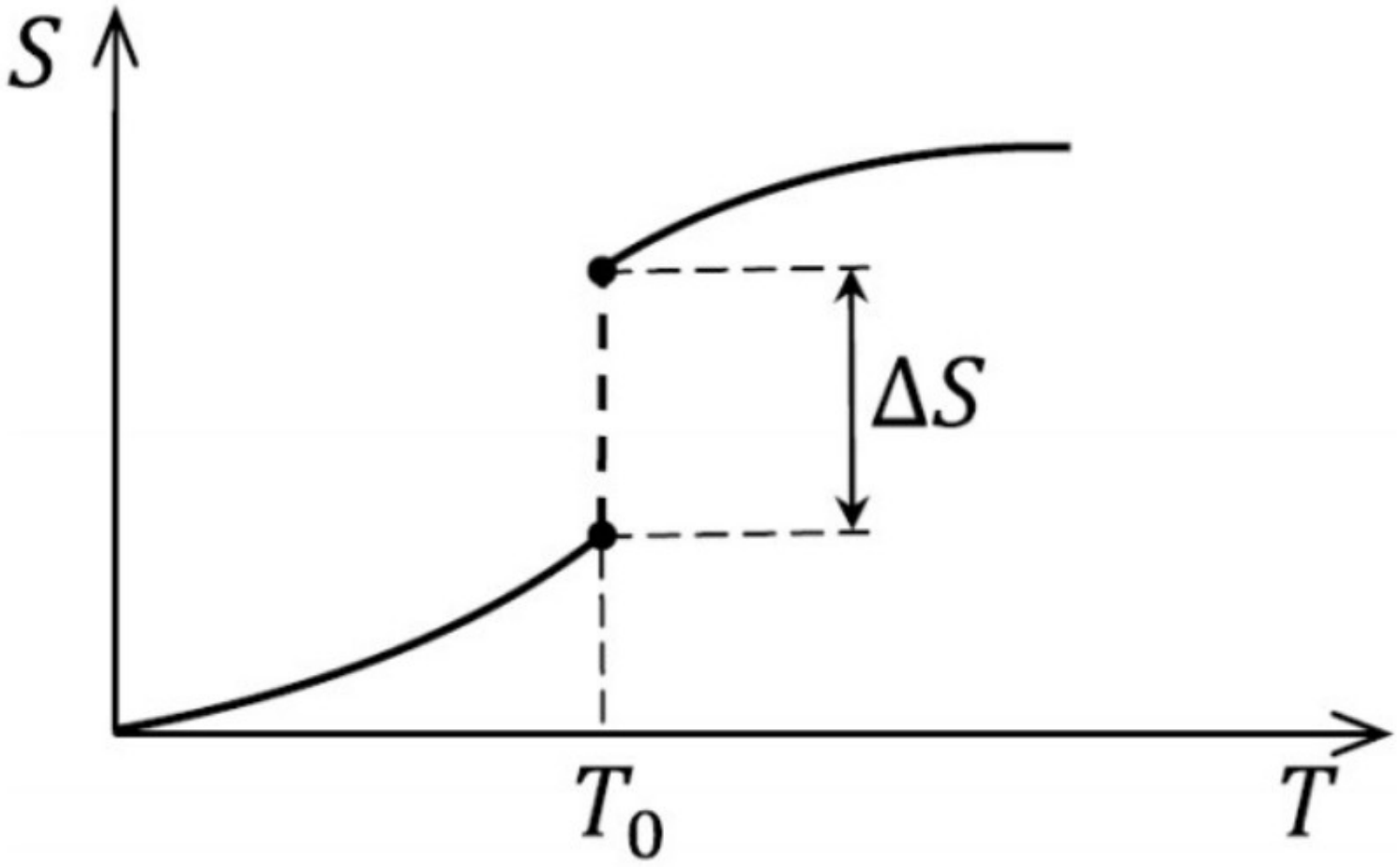
Simple Fluids





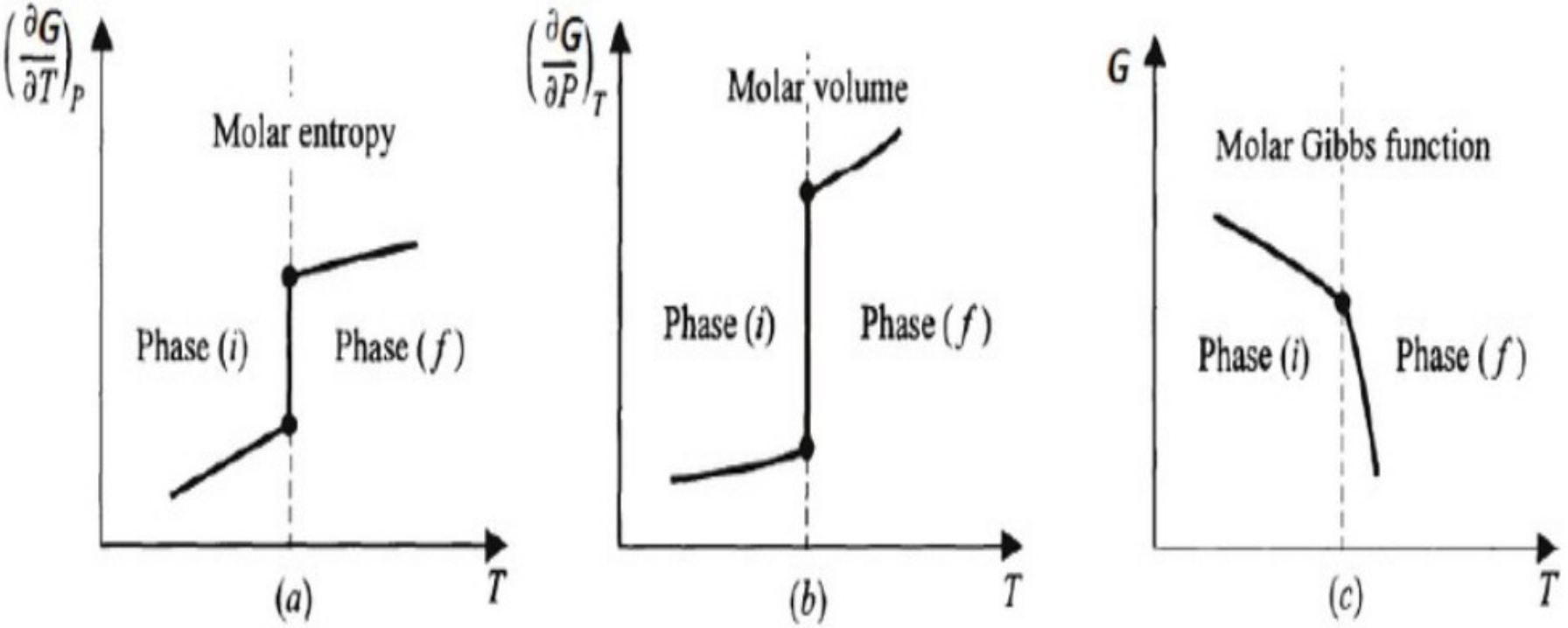
http://www.sklogwiki.org/SklogWiki/index.php/Phase_diagrams:_Density-temperature_plane

First Order Transition



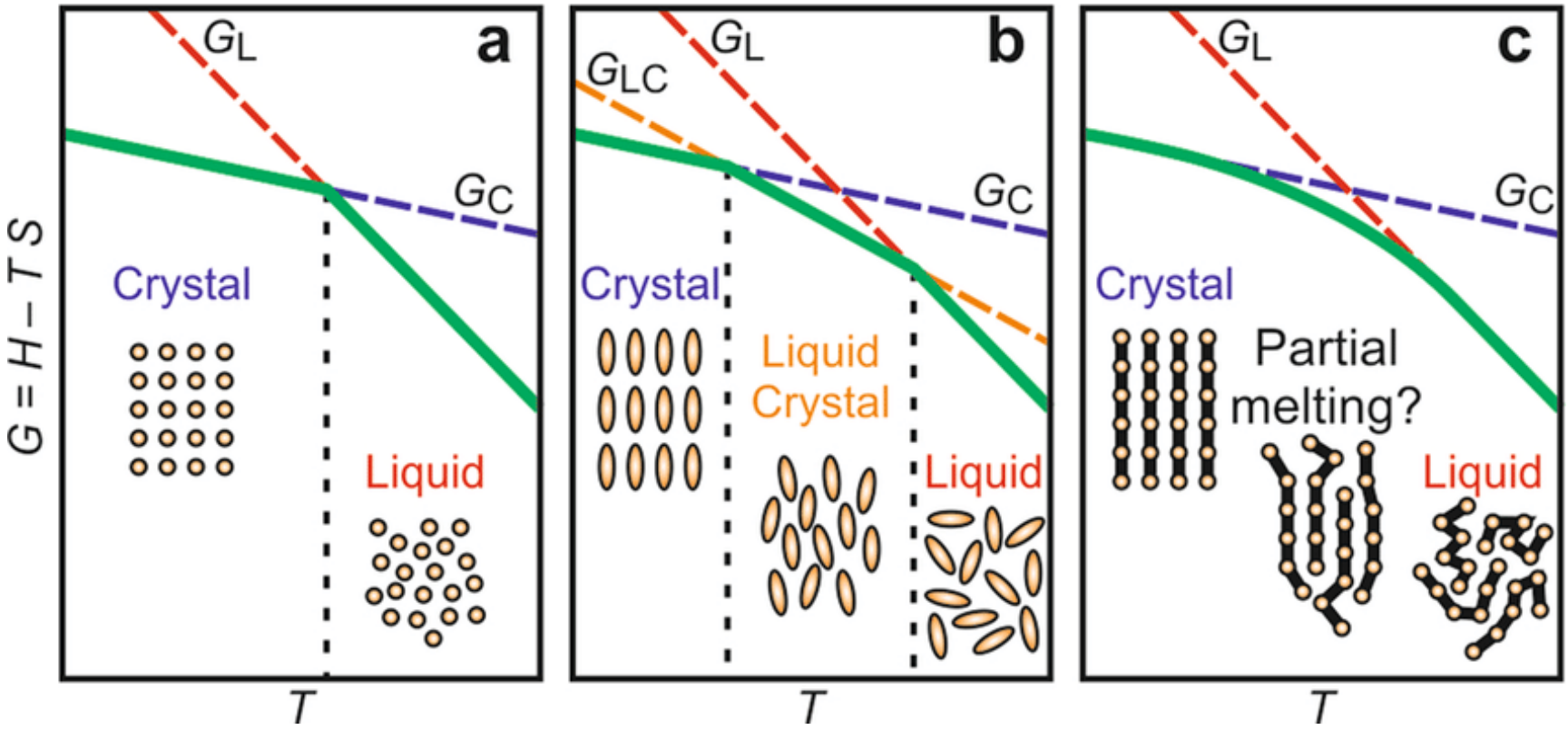
https://itp.uni-frankfurt.de/~gros/Vorlesungen/TD/6_Phase_transitions.pdf

First Order Transition



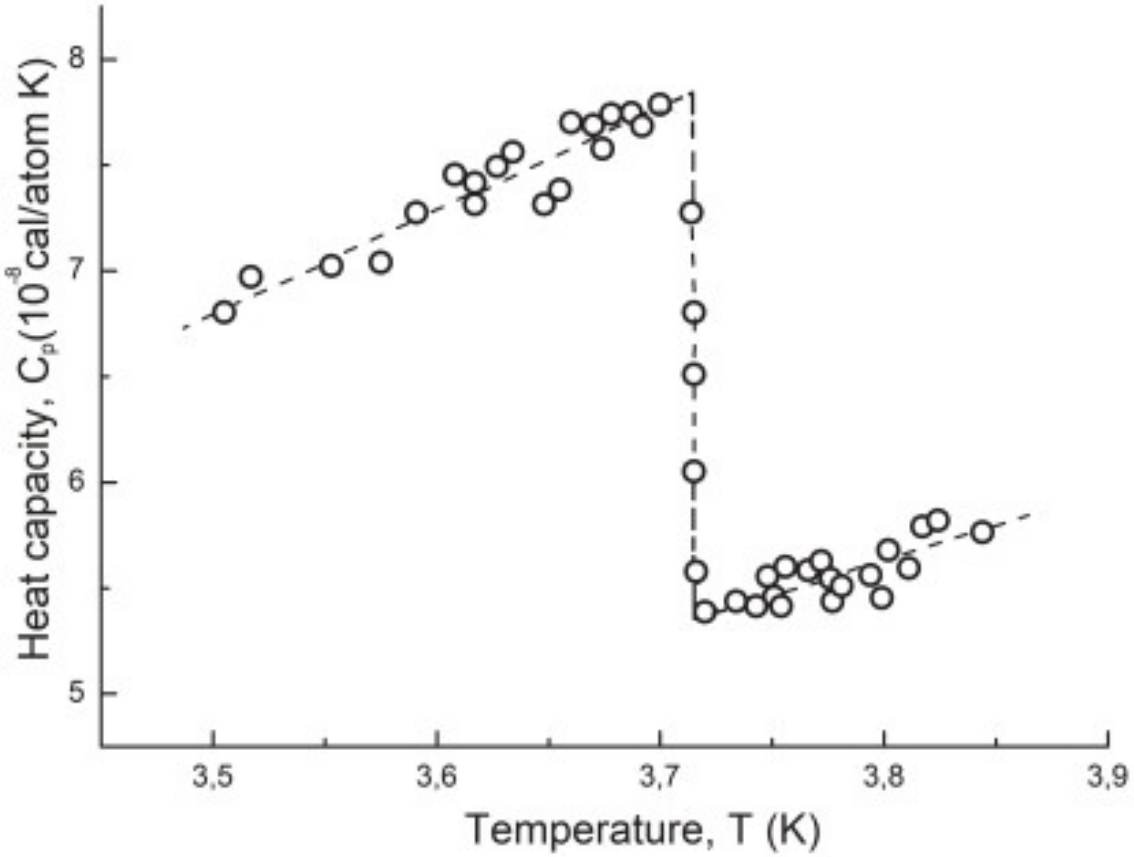
https://www.researchgate.net/figure/Characteristics-of-a-first-order-phase-transition-There-are-discontinuous-changes-in-a_fig1_268404976

First Order Transition



https://www.researchgate.net/figure/Schematic-free-energy-temperature-profiles-for-crystal-liquid-phase-transition-a-A-normal_fig1_350127478

First Order Heat Capacity



https://www.worldscientific.com/doi/pdf/10.1142/9789813274181_0001

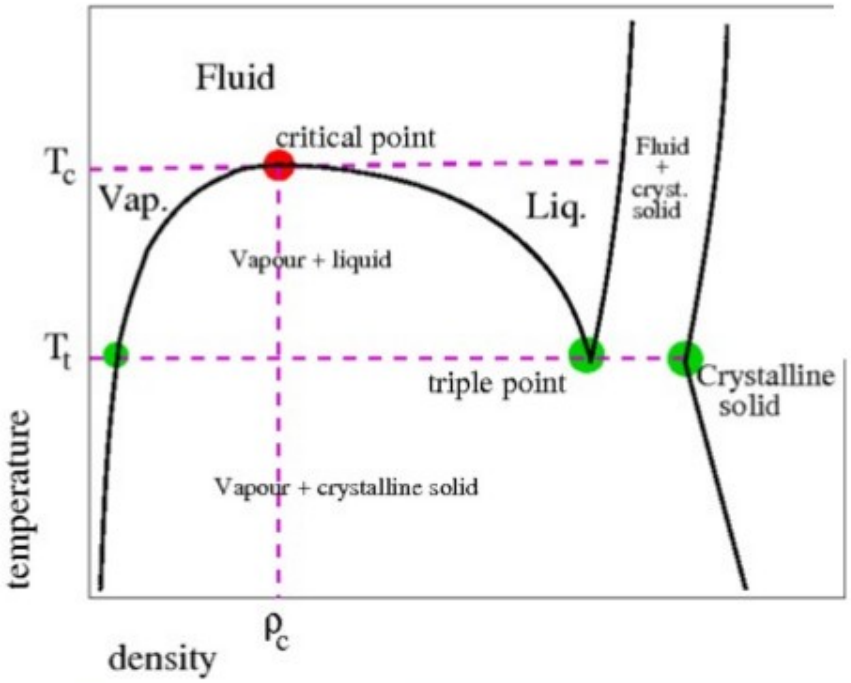
First Order Phase Transition

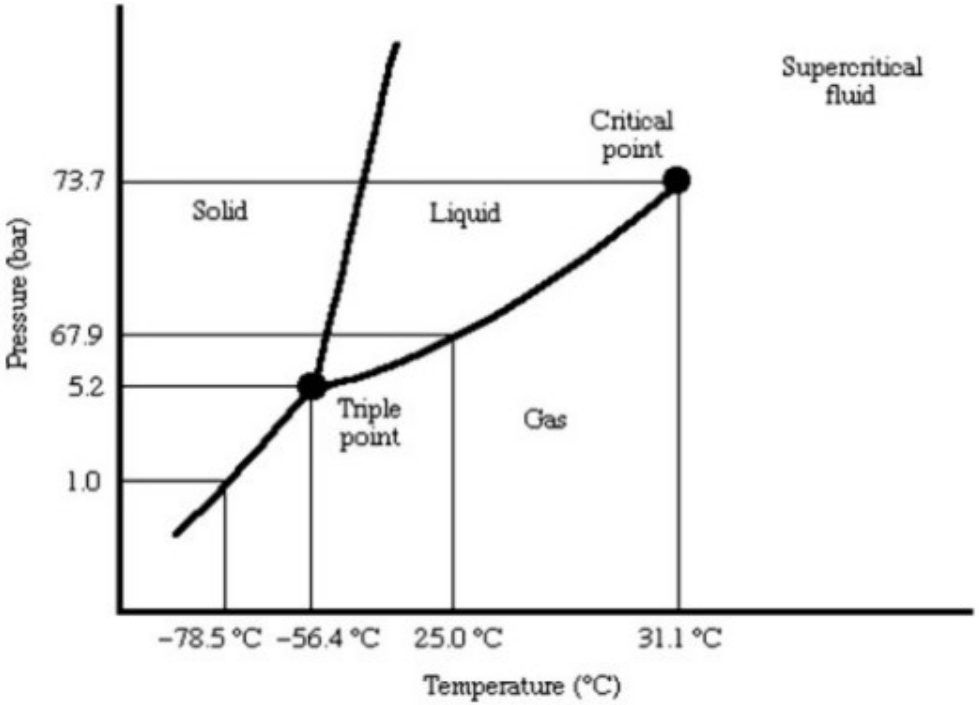
Discontinuity of the derivative of the Gibbs Free energy with respect to the intensive parameter

Non zero Latent Heat

Discontinuous Heat Capacity at Constant Pressure

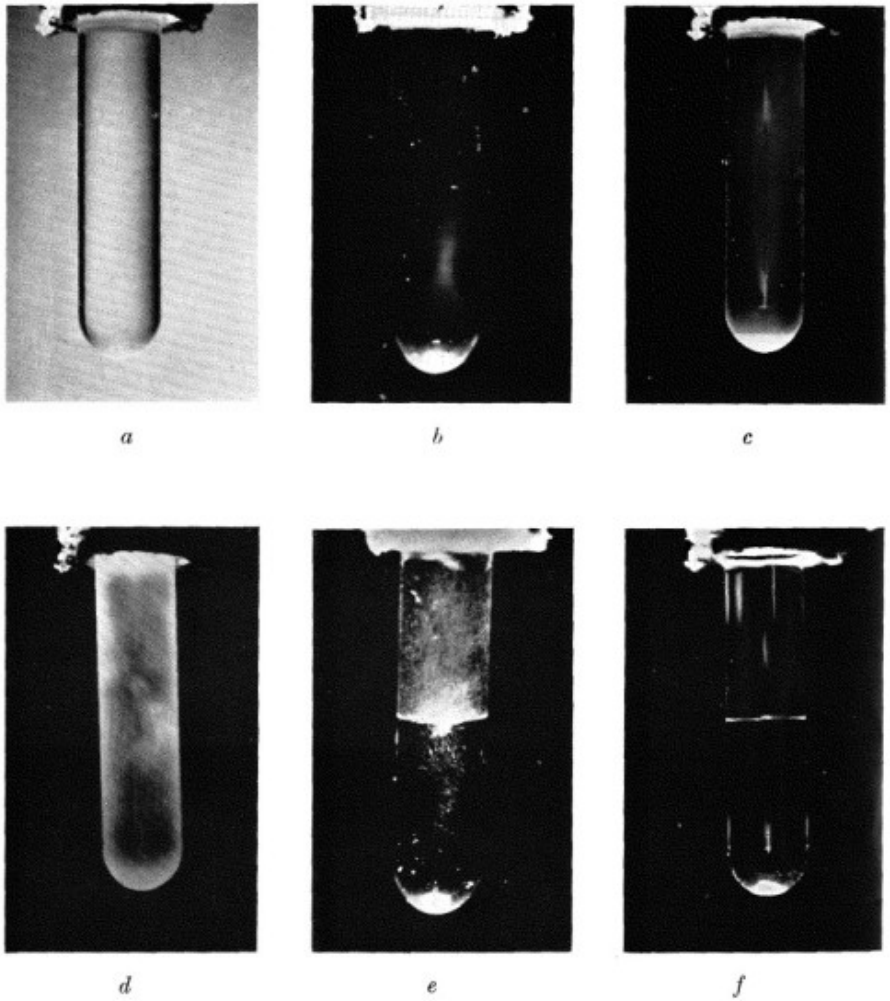
Second Order – Continuos Phase Transtion





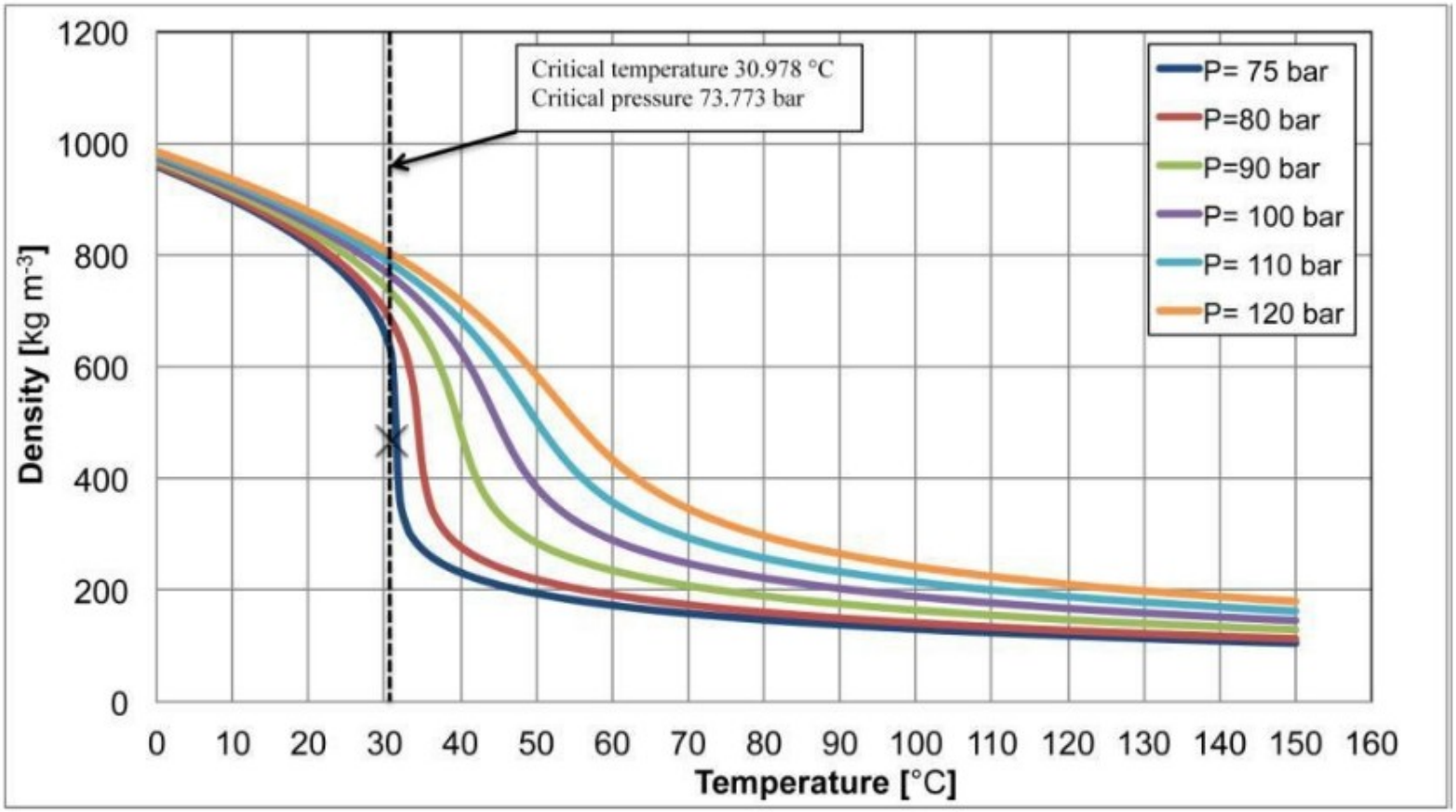
http://www.sklogwiki.org/SklogWiki/index.php/Phase_diagrams:_Density-temperature_plane

Second Order Phase Transition



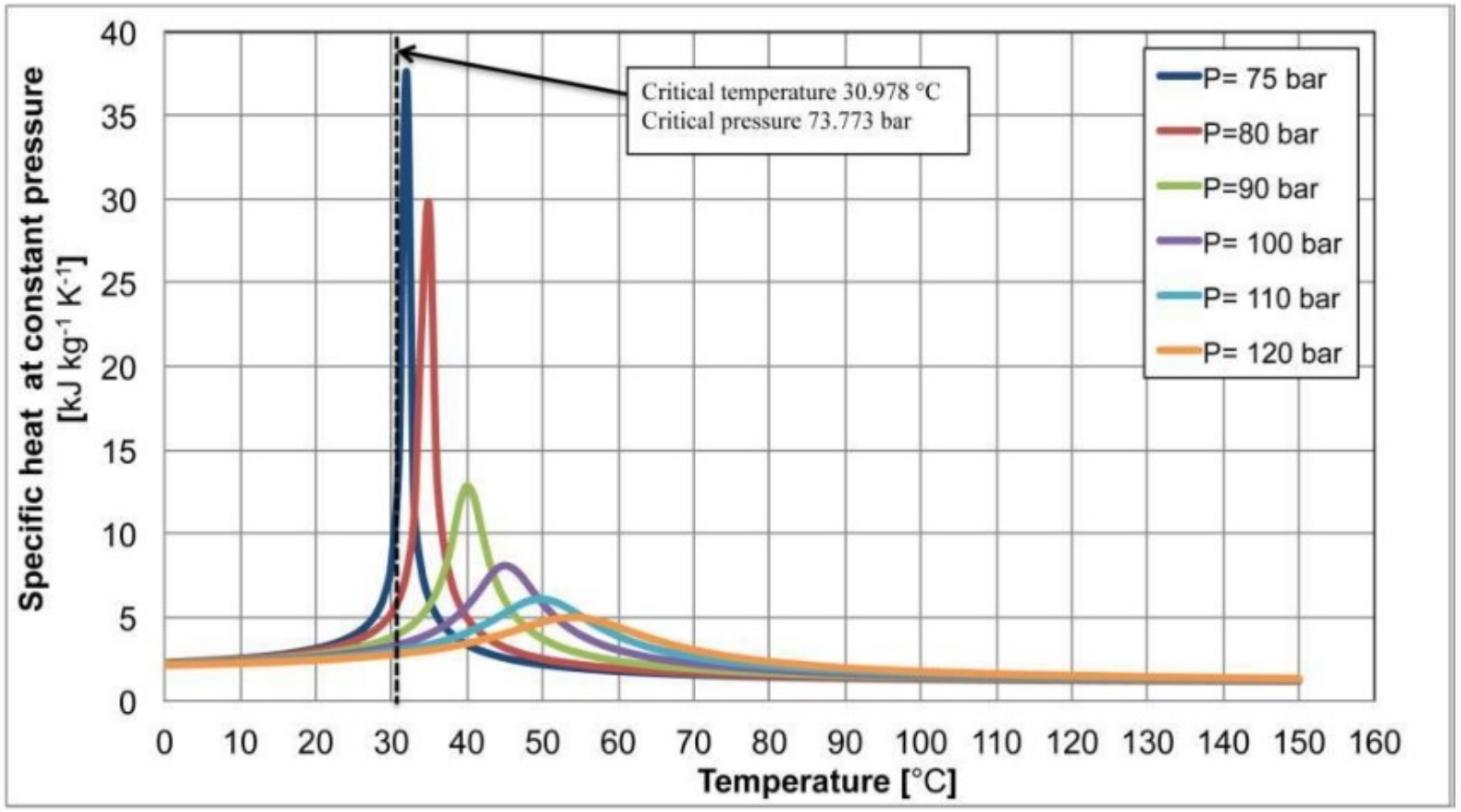
Mistura de ciclohexano e anilina Ferrel 1968

Second Order Phase Transition



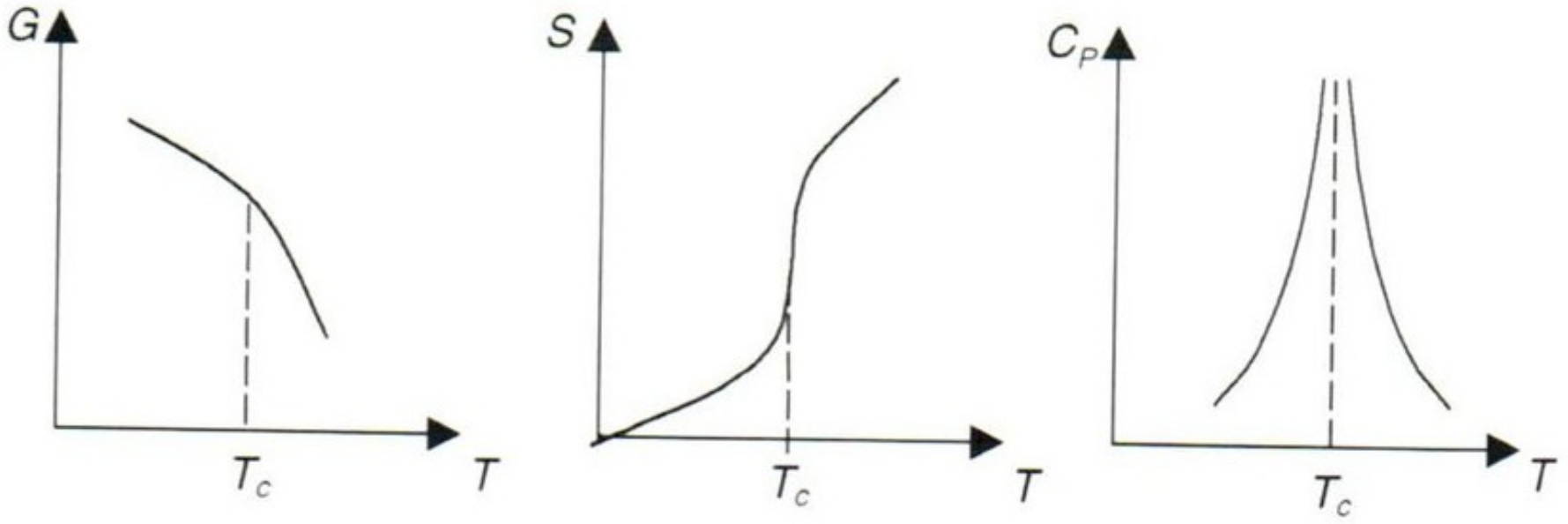
https://www.unilab.eu/articles/fluid-properties-near-critical-point/

Second Order Phase Transition



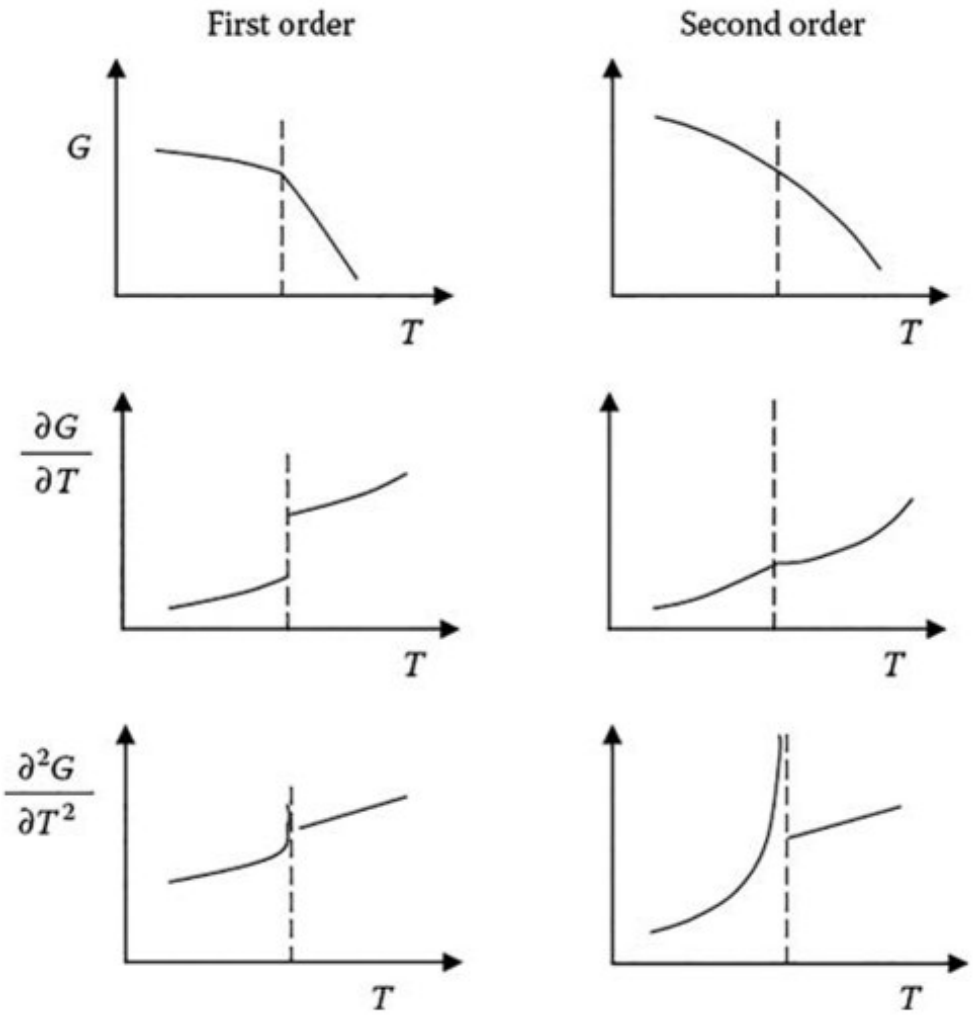
https://www.unilab.eu/articles/fluid-properties-near-critical-point/

Continuous Phase Transition



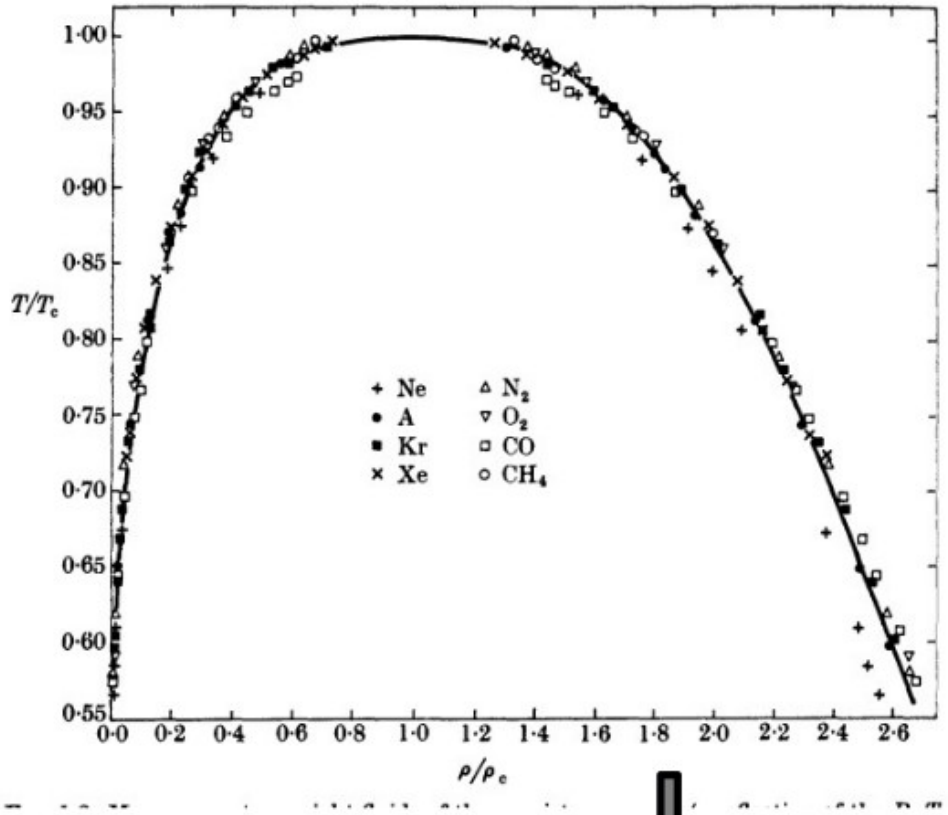
https://www.researchgate.net/figure/Examples-of-phase-transitions-a-first-order-phase-transitions-potentials-such-as-G_fig3_239857178

Phase Transitions



https://ebrary.net/196881/mathematics/classification_phase_transitions

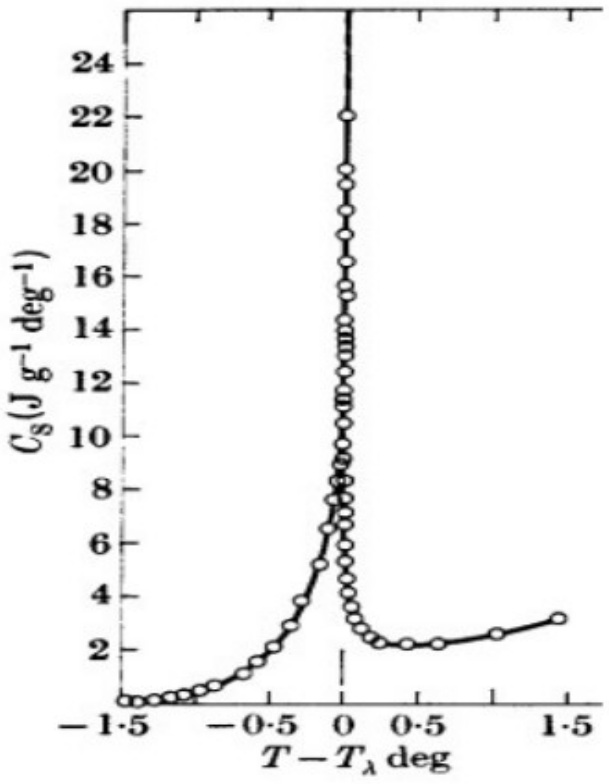
Density



$$C_{V=V_c} \sim (-\epsilon)^{-\alpha'} \qquad \rho_L - \rho_G \sim (-\epsilon)^{\beta} \qquad K_T \sim (-\epsilon)^{-\gamma'}$$

E. A. Guggenheim, Journal Chem. Phys. 13M 253 (1945)

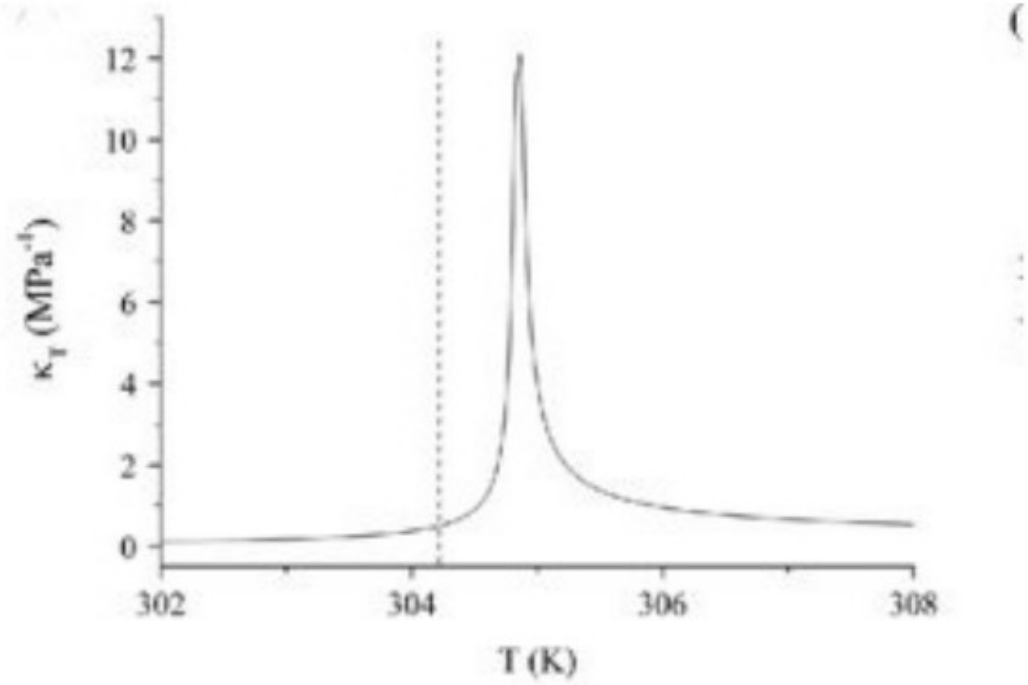
Specific Heat



$$C_{V=V_c} \sim (-\epsilon)^{-\alpha'} \qquad \rho_L - \rho_G \sim (-\epsilon)^{\beta} \qquad K_T \sim (-\epsilon)^{-\gamma'}$$

H. E. Stanley, Phase Transition and Critical Phenomena.

Compressibility



$$C_{V=V_c} \sim (-\epsilon)^{-\alpha'} \qquad \rho_L - \rho_G \sim (-\epsilon)^{\beta} \qquad K_T \sim (-\epsilon)^{-\gamma'}$$

https://link.springer.com/article/10.1007/s12665-014-3716-5

Scaling

$$\alpha' + 2\beta + \gamma' = 2$$

Scattering - Correlation

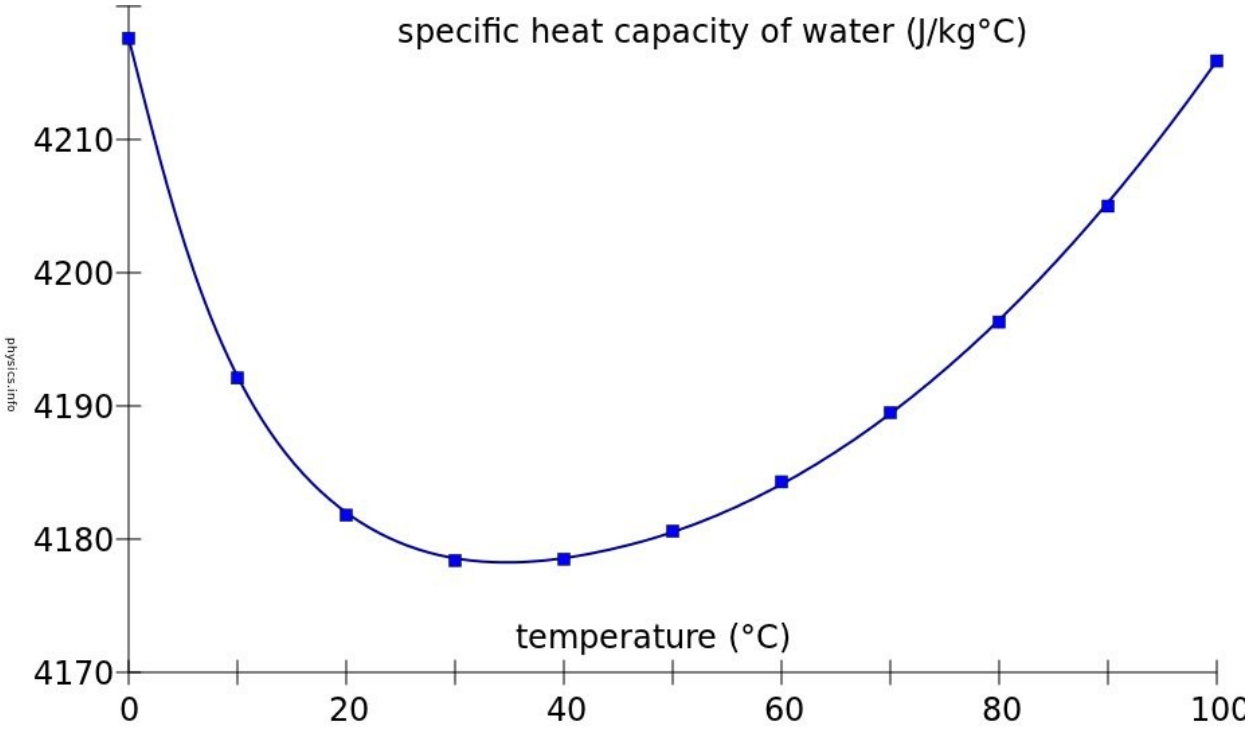
WATER ANOMALIES

Water Anomalies

photo by Clóvis Jardim

Specific Heat

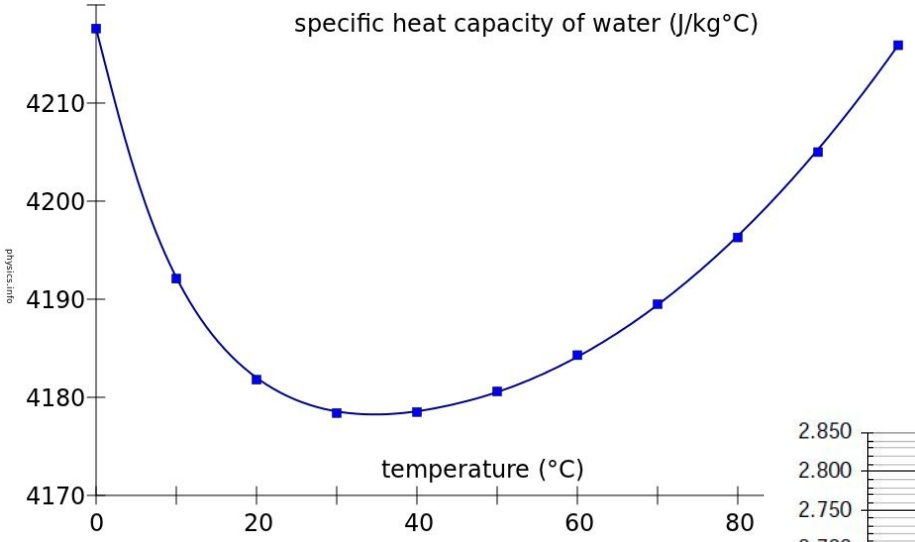
Methanol: Lombari, Ferrari, Salvetti, CPL 300 (99)
Water: G. S. Kell, J. Chem. Eng. Data 20, 97 (75)



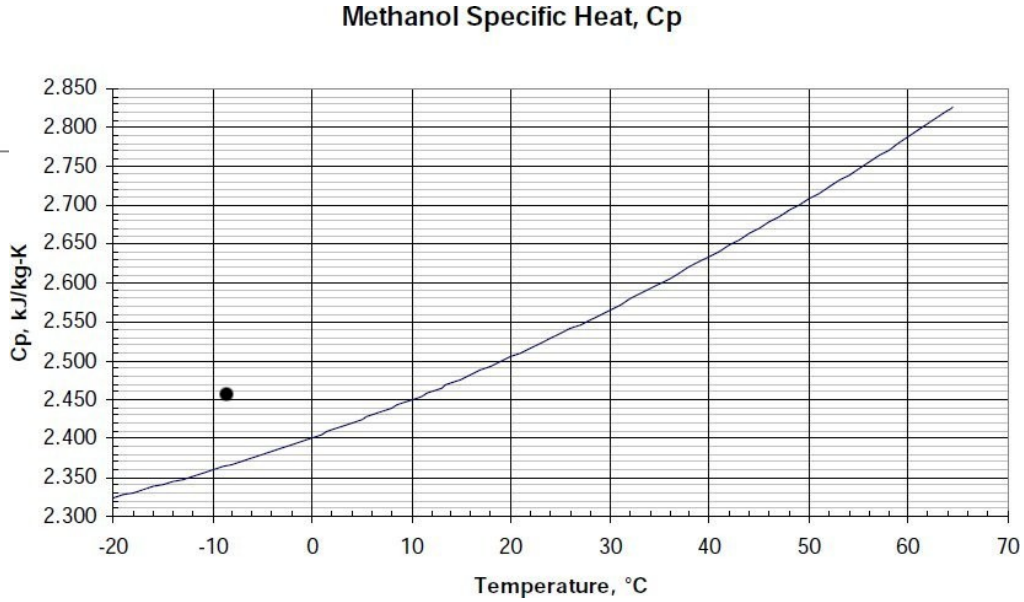
$$C_p = dQ_P/dT$$

Specific Heat

Methanol: Lombari, Ferrari, Salvetti, CPL 300 (99)
Water: G. S. Kell, J. Chem. Eng. Data 20, 97 (75)



$$C_p = dQ_P/dT$$



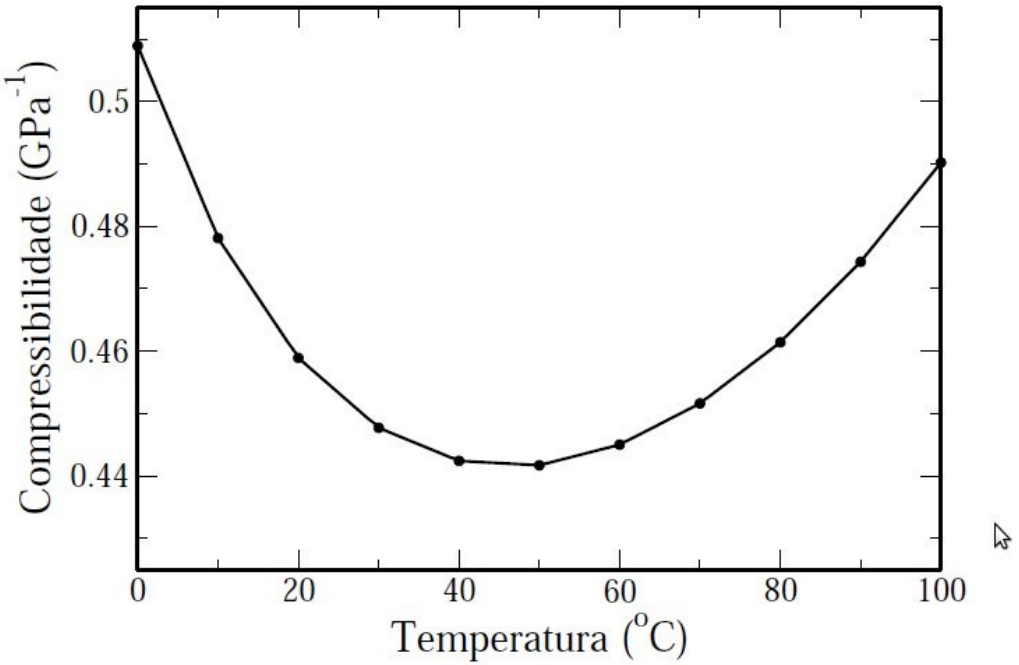
Specific Heat

Water → 4.18 kJ/kg°C
Silica → 0.68 kJ/kg°C

Compressibility

water: Speedy, Angell, JCP 65, 351 (76)
toluene: Minassian, Bouzar, Alba, JPC 92, 487 (88)

$$\kappa_T = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T,$$



Compressibility

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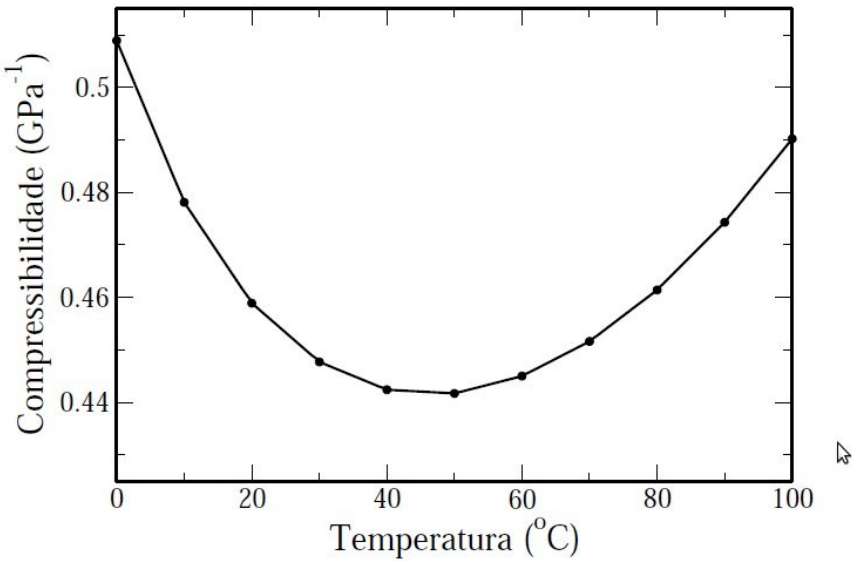
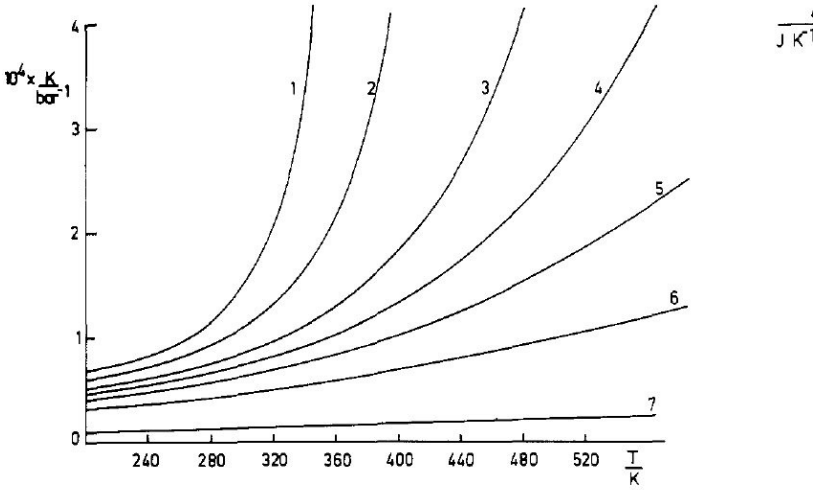


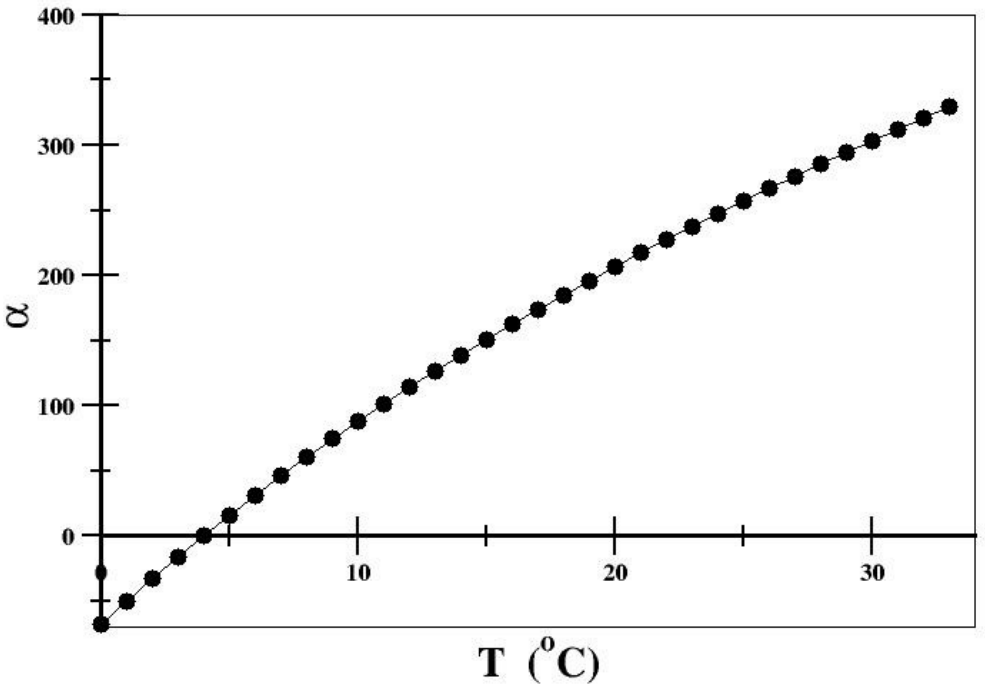
$$\kappa_T = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T ,$$



Thermal Expansion Coefficient

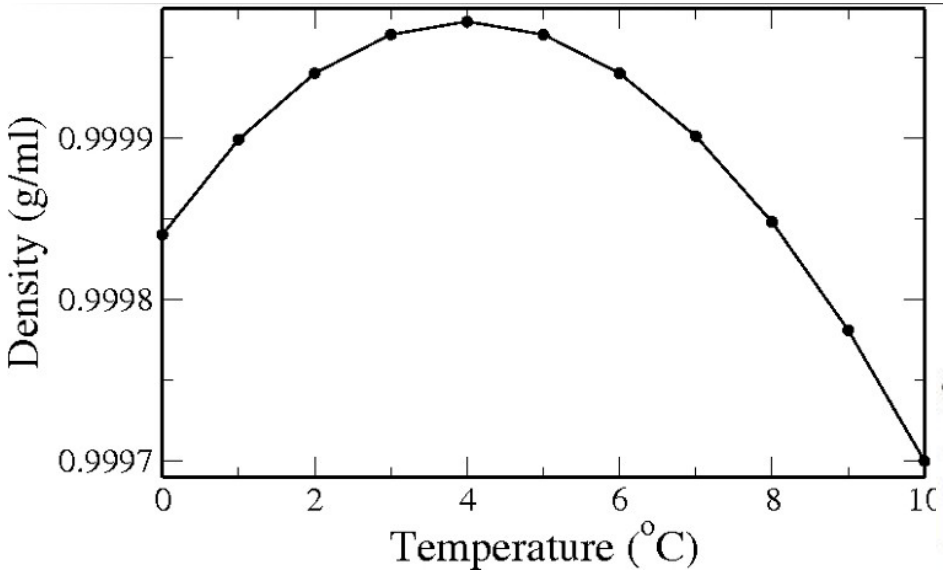
water: Kell, J. Chem. Eng. Data 20, 97 (75)

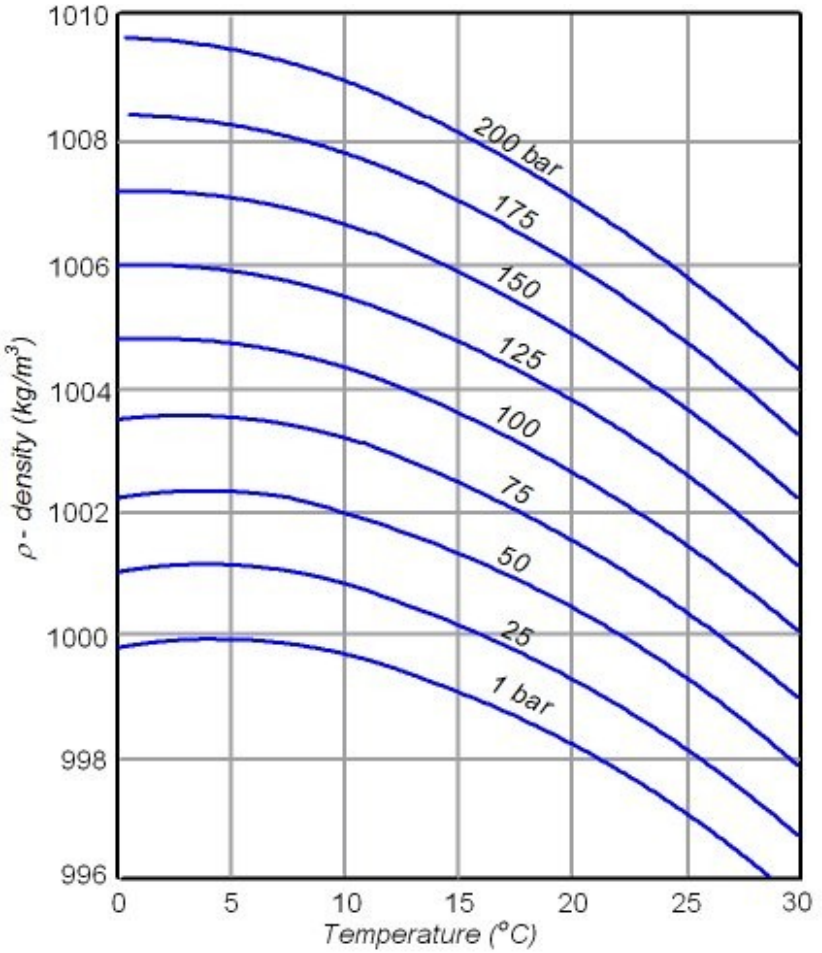
$$\alpha = \alpha_V = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p$$



Density

water: Kell, J. Chem. Eng. Data 20, 97 (75)





Density

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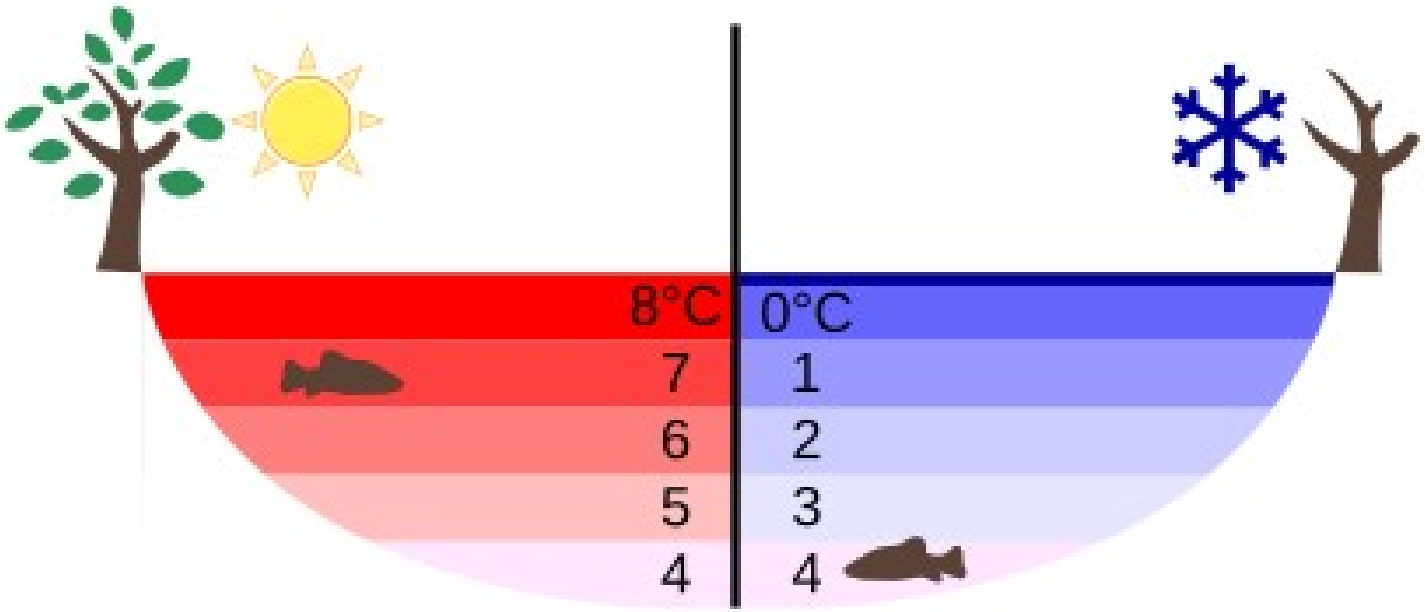

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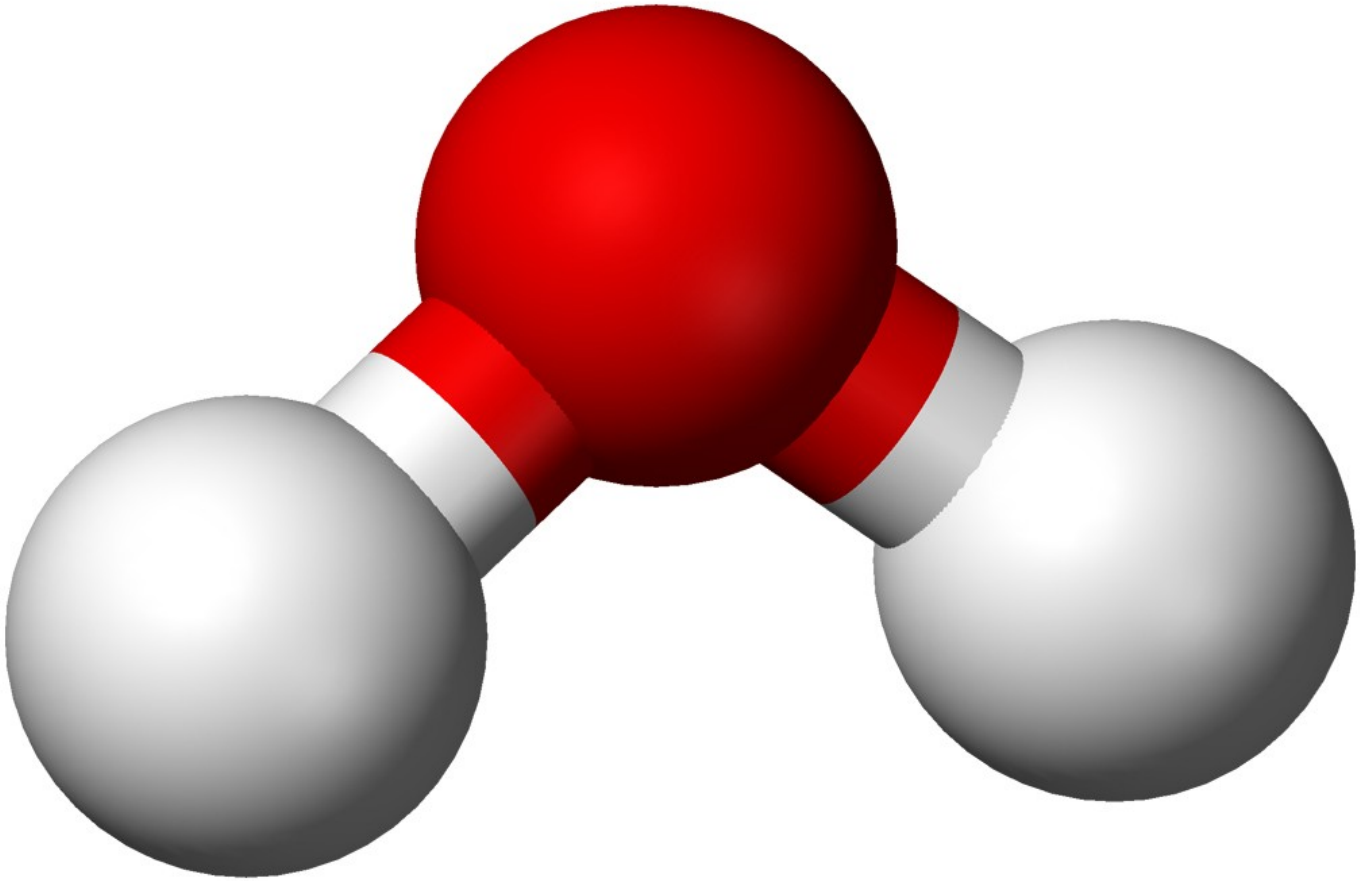

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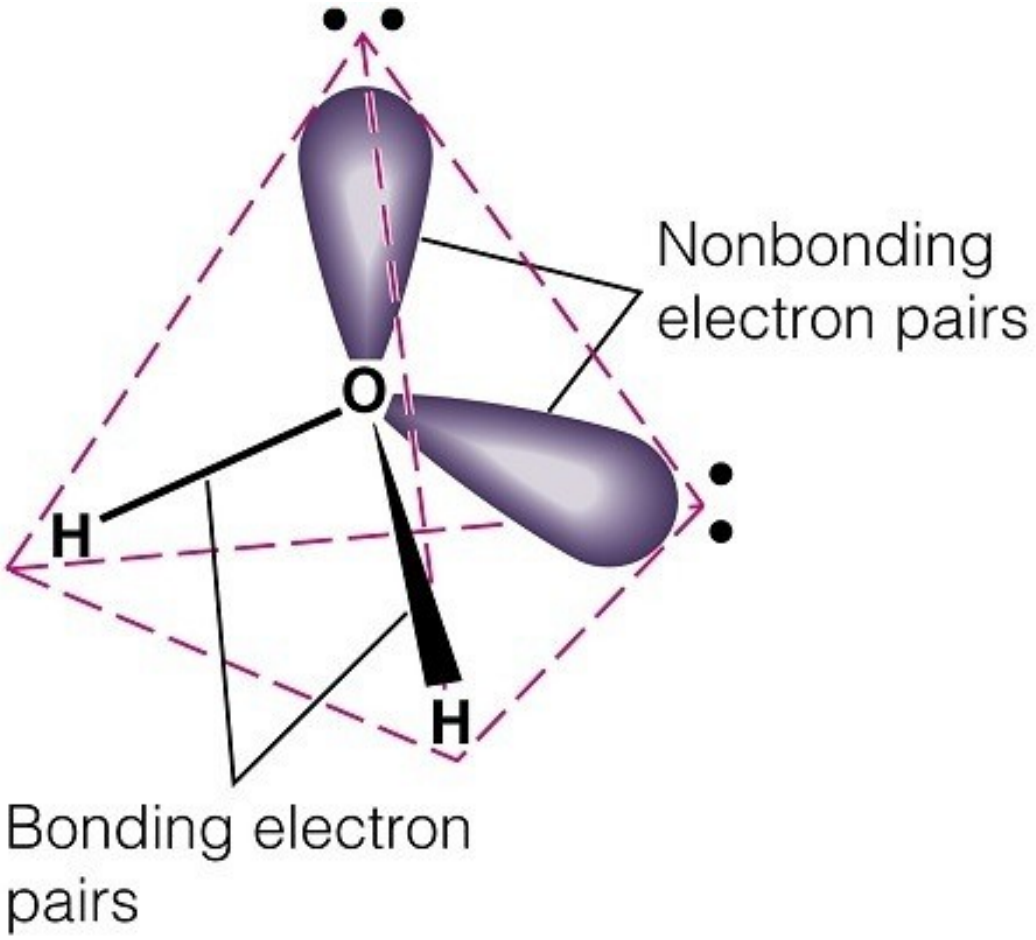
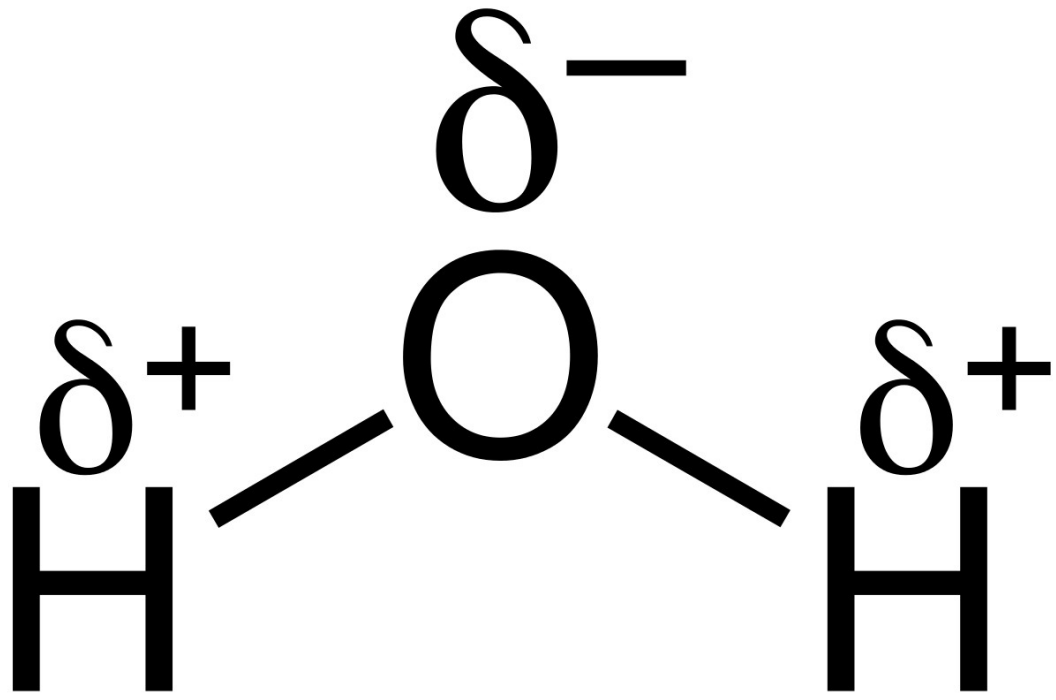
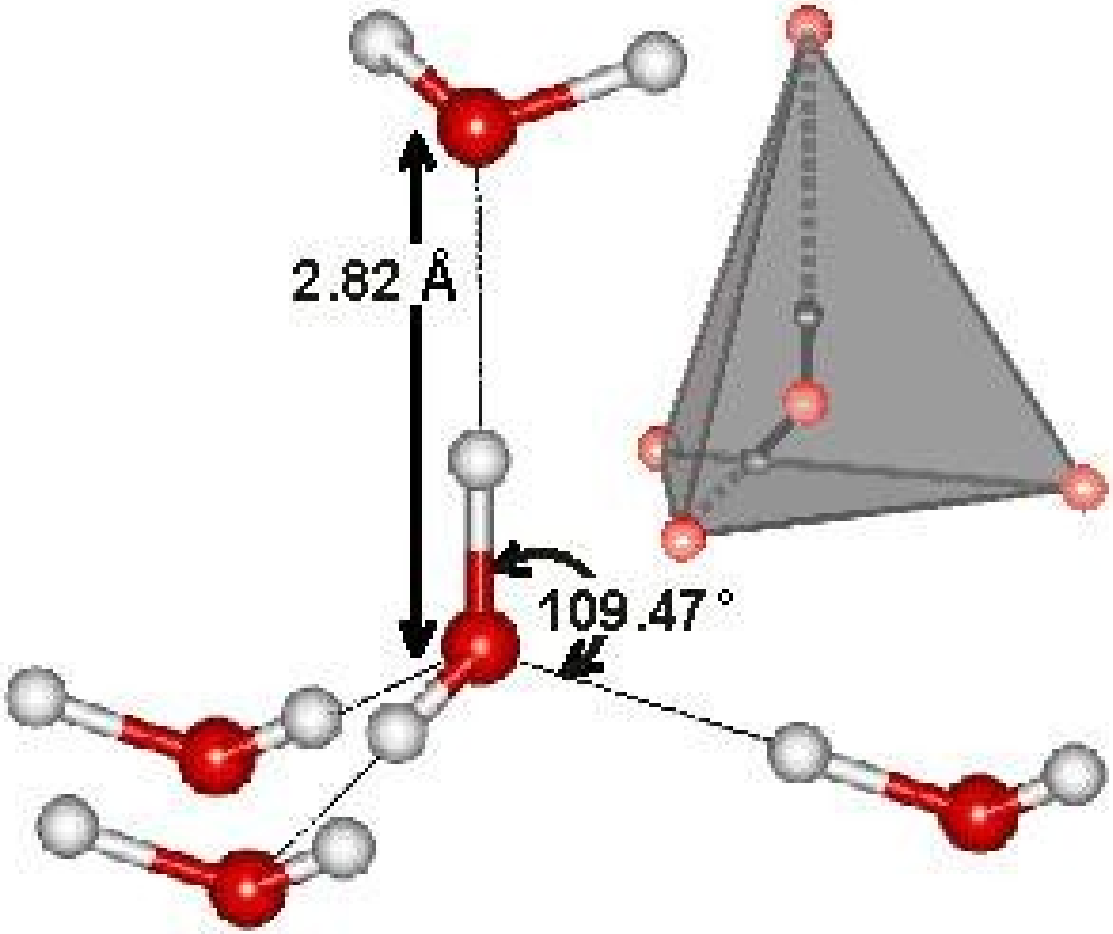


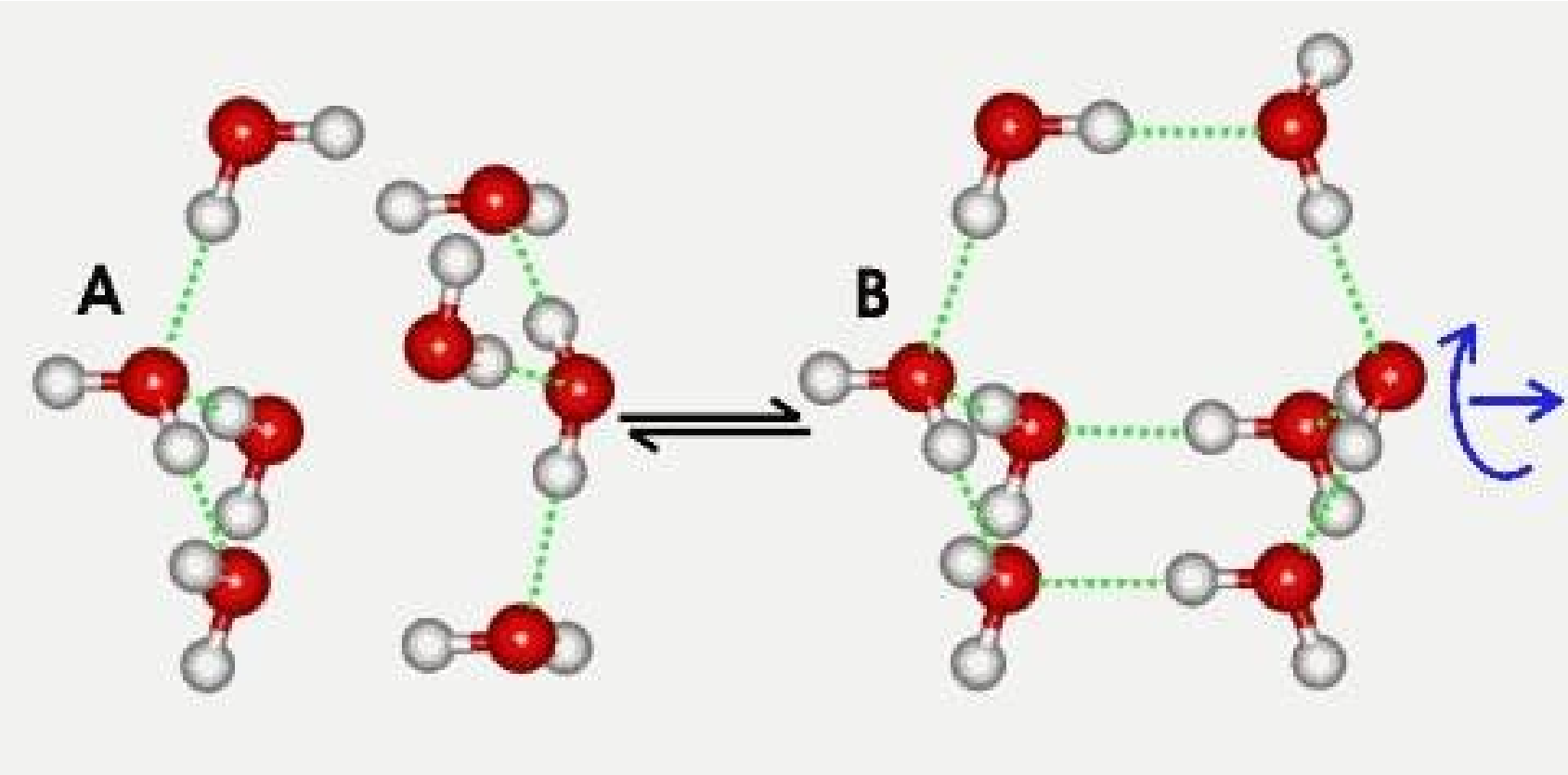
Water



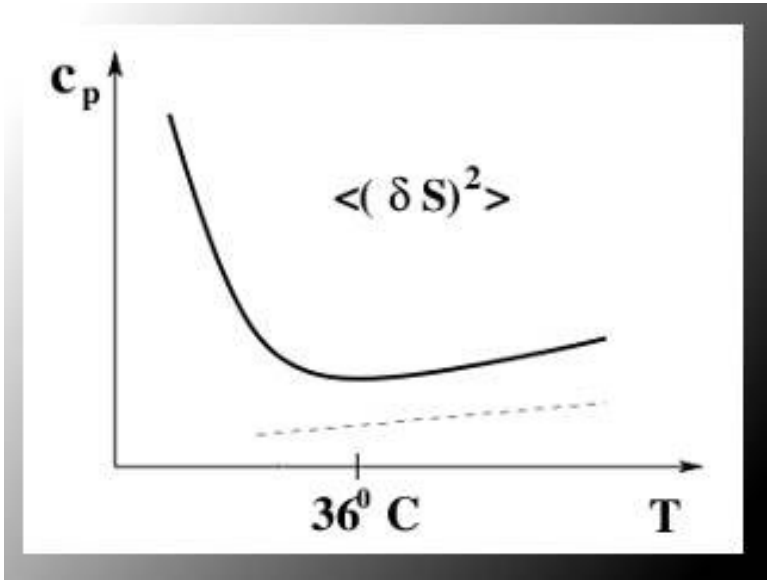
Hydrogen Bonds

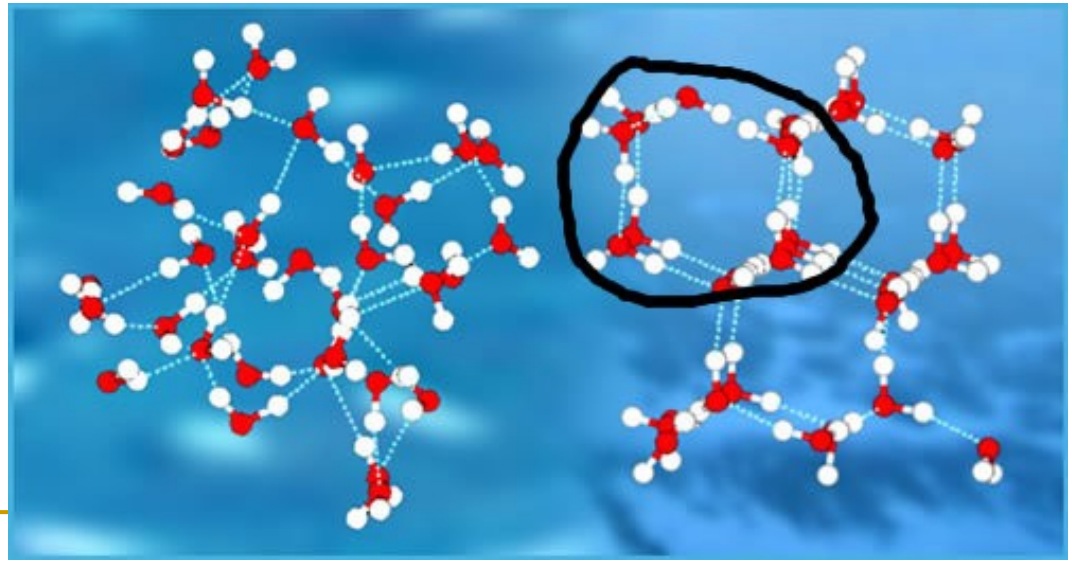


Tetramers Open and Closed

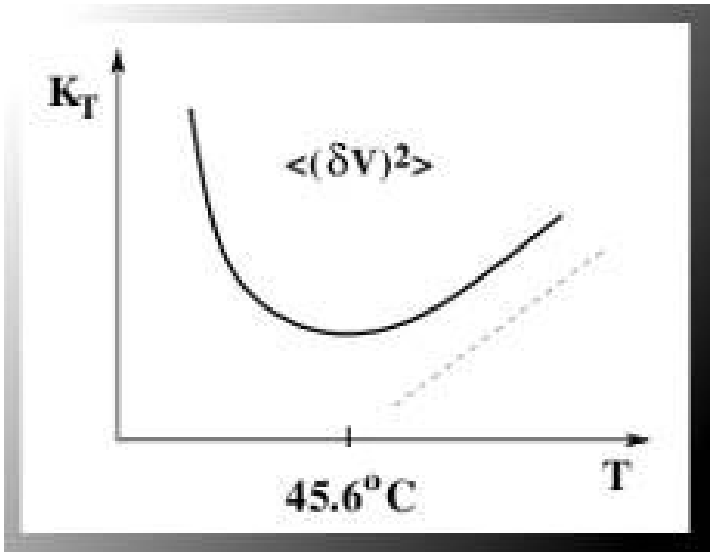


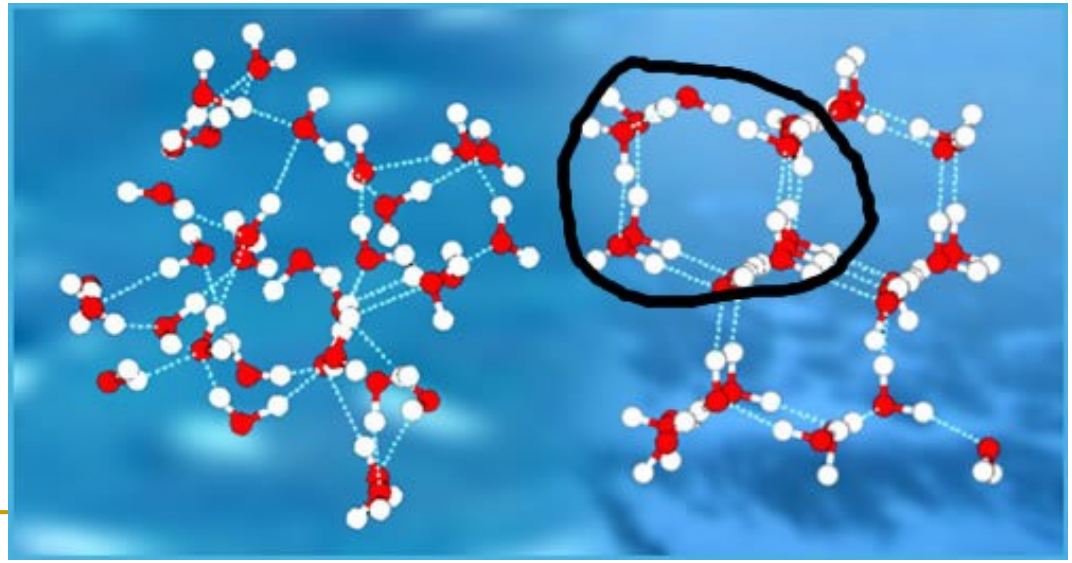
Specific Heat



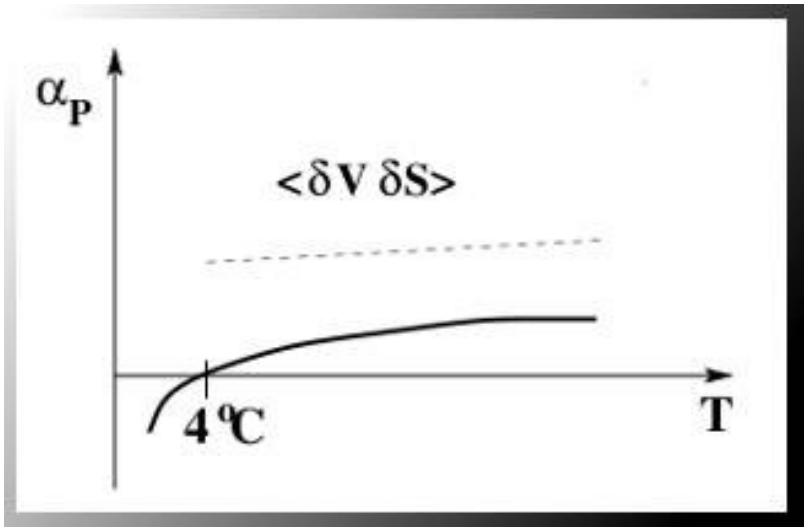


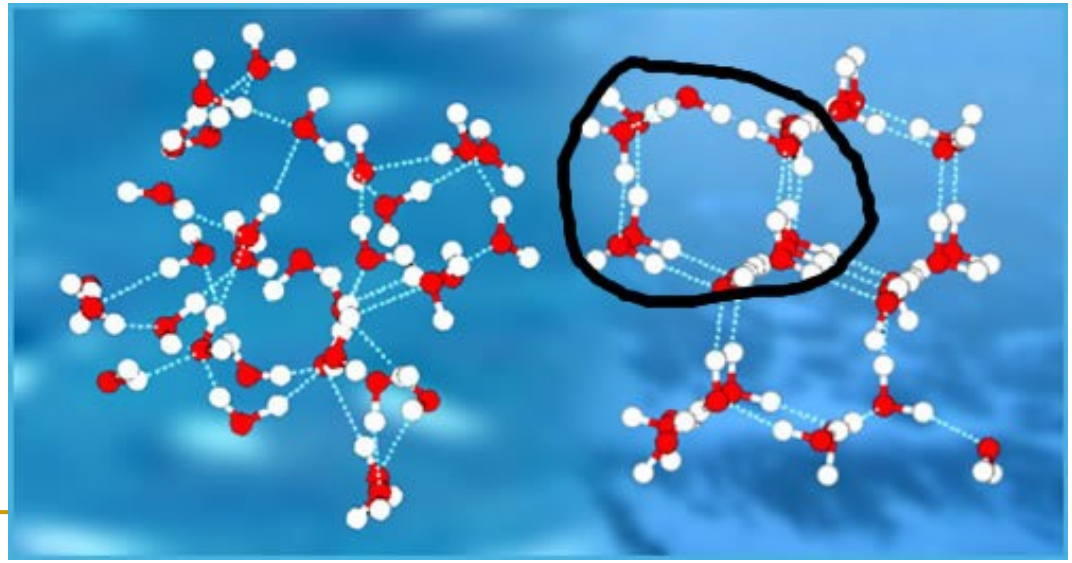
Compressibility



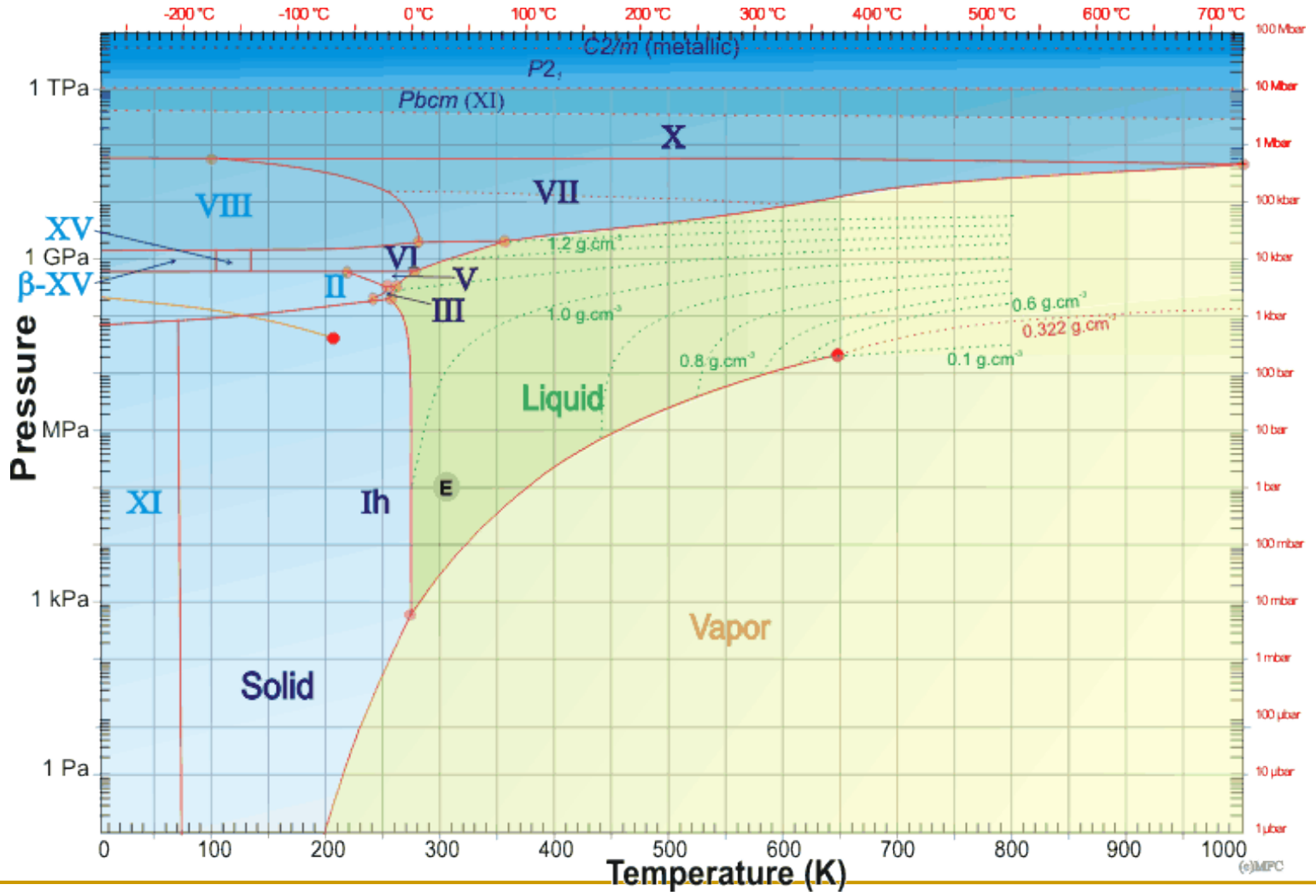


Thermal Expansion Coefficient



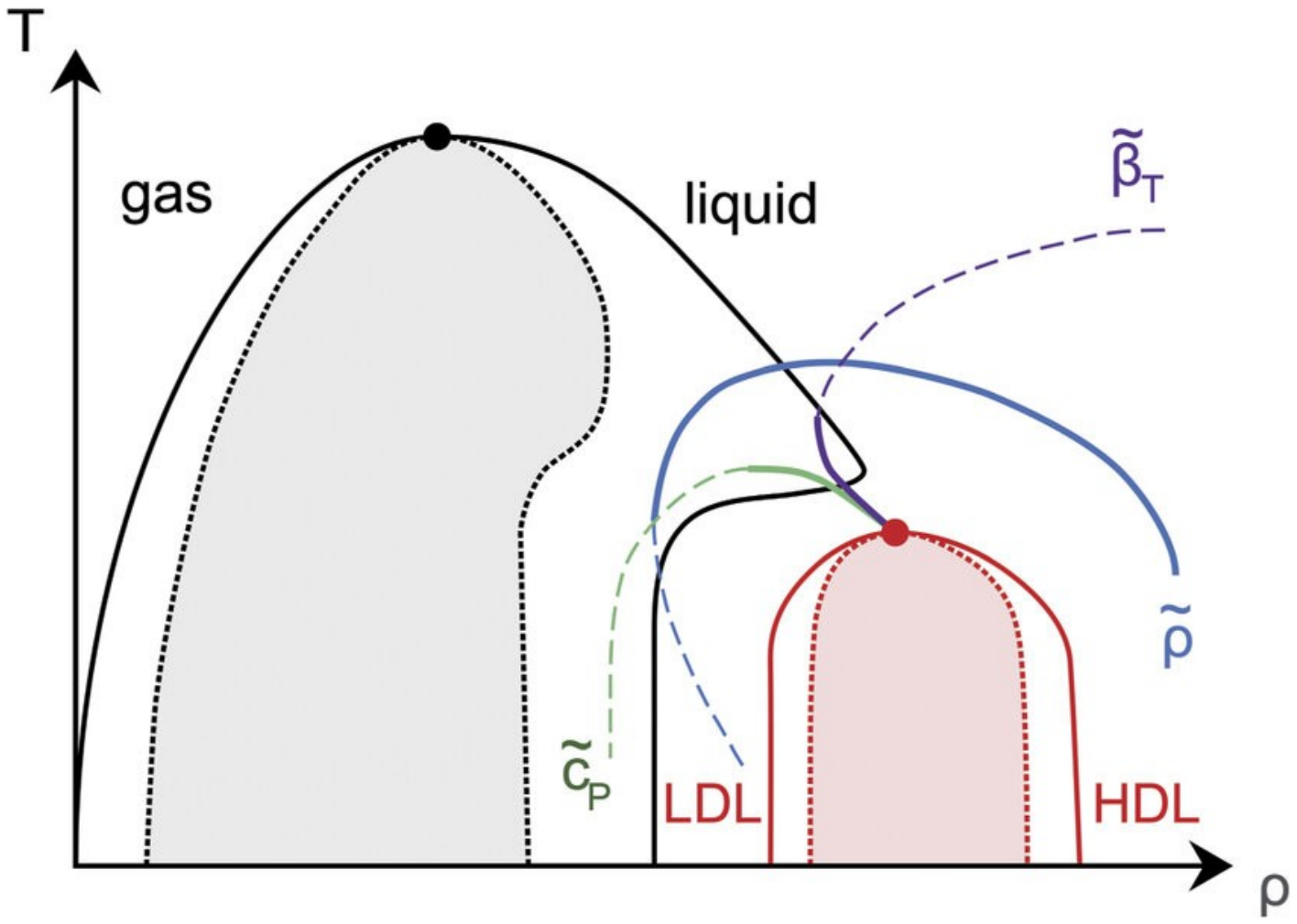


Water Phase Diagram

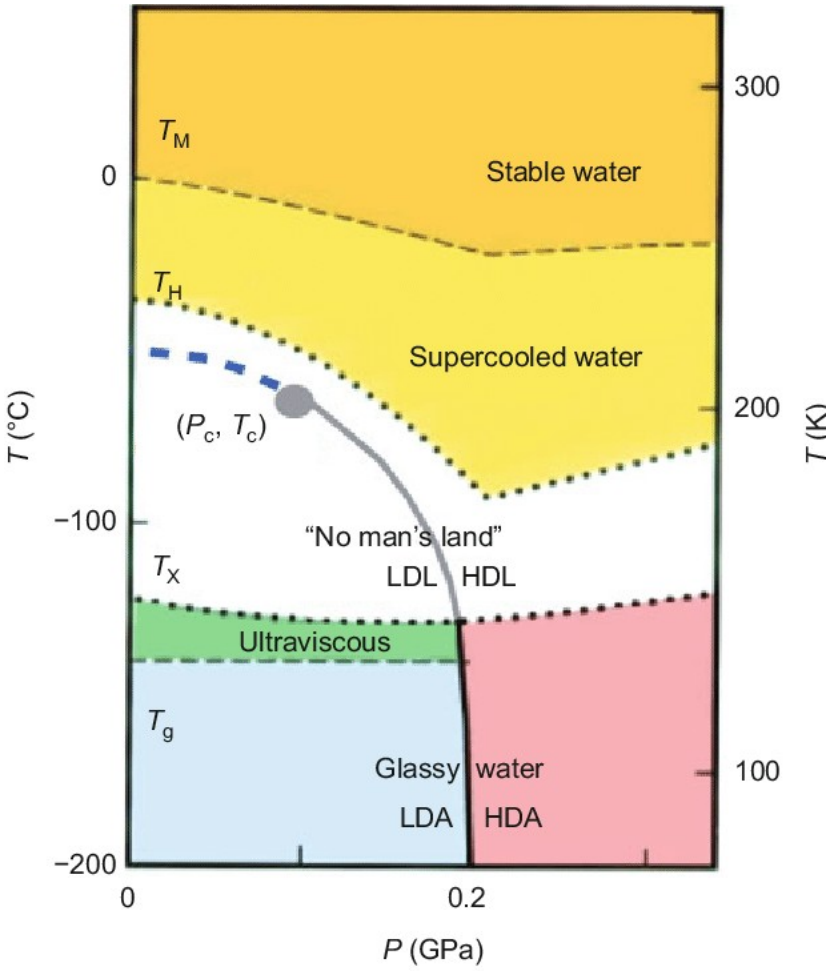


https://water.lsbu.ac.uk/water/water_phase_diagram.html

Water Phase Diagram



Water Phase Diagram



https://www.researchgate.net/figure/The-phase-diagram-of-water-adapted-from-ref-25-A-first-order-LLPT-line-is-shown_fig3_262992946

Next

Phase Transitions-
Water Anomalies

Nanoconfined Water in
Solid State Materials

Nanoconfined Water in
Biology