Evaluating properties of pure substances

Pure substance

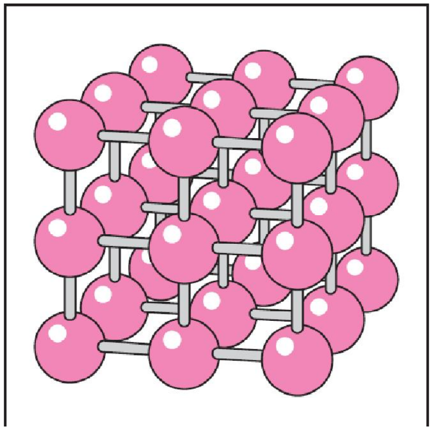
- A pure substance has the same chemical composition throughout.
- Are the following confined in a fixed volume pure substances:
  - Ice (single component, single phase) **Y**
  - A mixture of water and water vapor (single component, multiphase) **Y**
  - Air in gas phase (multi-component, single phase) **Y**
  - Oil in contact with water (multi-component single phase) **N**
  - A gaseous mixture containing N_2,O_2,H_2O, CO_2 obtained from burning kerosene (multicomponent, single phase) **Y**
  - Liquid air in contact with gaseous air (multicomponent, multiphase) **N**
    Objective: evaluating the properties for single component pure substances existing in one or more phases (multiphase).

Alert: in chemistry a pure substance is defined such that it consists of one component (chemical species) and therefore must be "non-mixture". We follow a different definition (see above) in engineering thermodynamics.

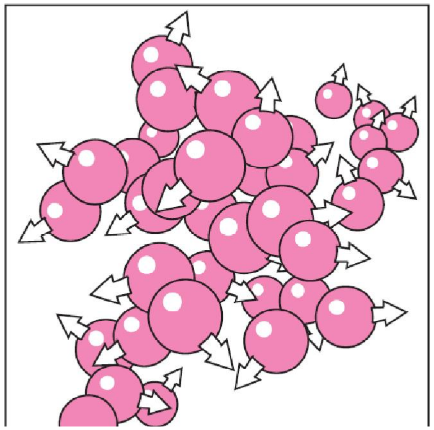
Phases

A region within matter with distinct molecular arrangement that is homogeneous throughout that region which is separated from other regions (if any) by distinct boundary surfaces. Physical properties (like density and refractive index) of each phase is different.

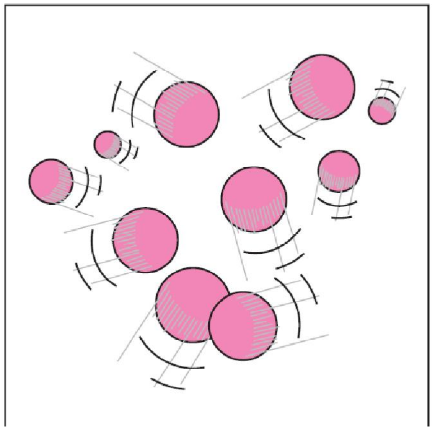
The three principal phases:



Solid



Liquid

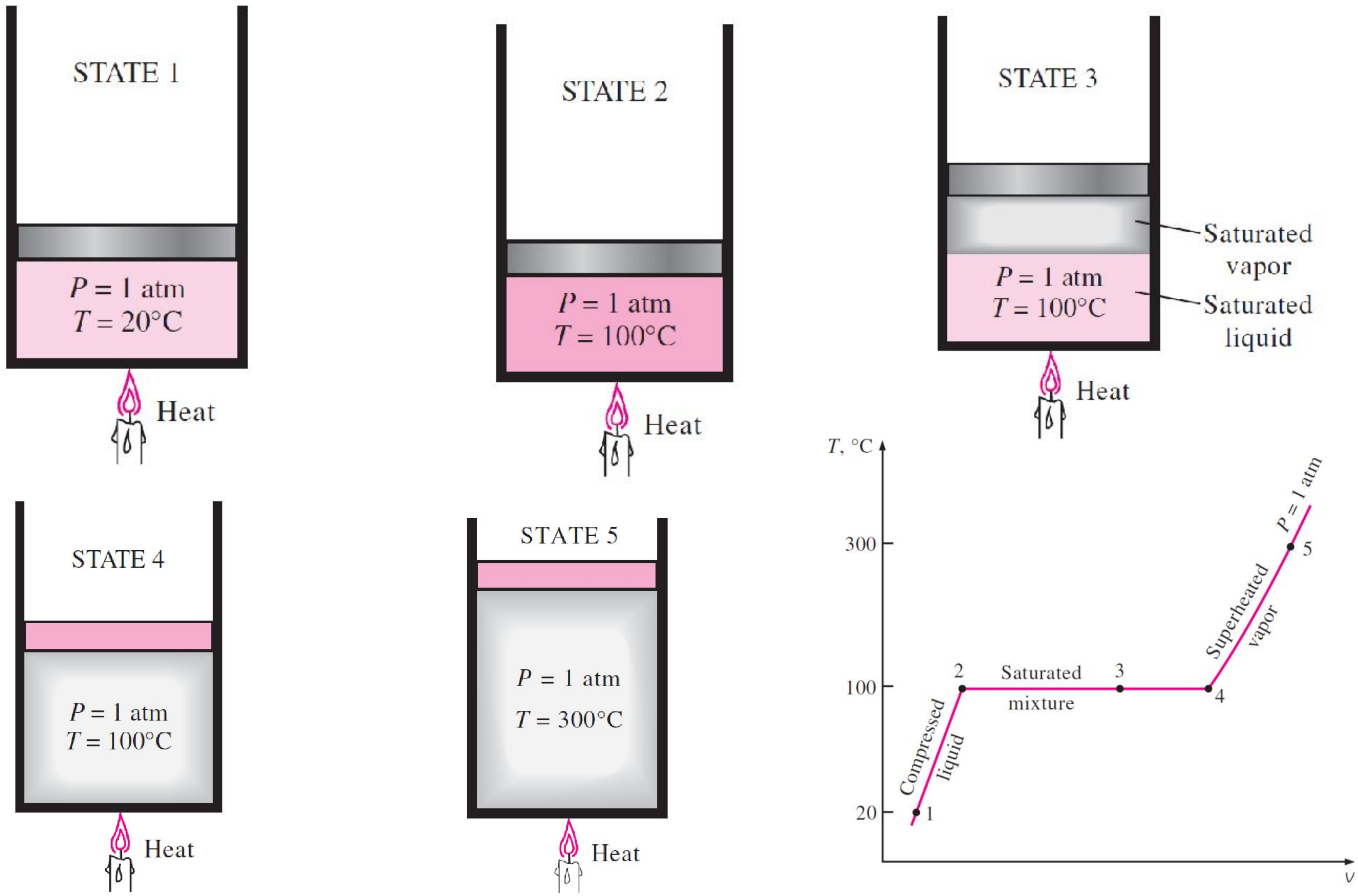


Gas

The state postulate

- A **property** is characteristic of the system such as specific volume (*v*), temperature (*T*), pressure (*P*), (specific) internal energy (*u*).
- A **state** is the condition of a system as determined by its properties.
- A **simple compressible system** is **a system** whose only mode of performing quasi-equilibrium work is through a change of its volume against a pressure**.**
- The **state postulate**: The state of a simple compressible system consisting of a pure substance is completely specified by two independent intensive properties.
- The **state postulate** can be represented by an **equation of state** such as $f(p,v,T)=0$ (or say $g(p,v,u)=0$)*.* It is often convenient to represent this functional relationship by
  - A surface in p,v,T (or u,p,v) space or **more commonly** its **projections on (p,v), (T,v) and (p,T) planes.**
  - **Tables of properties**

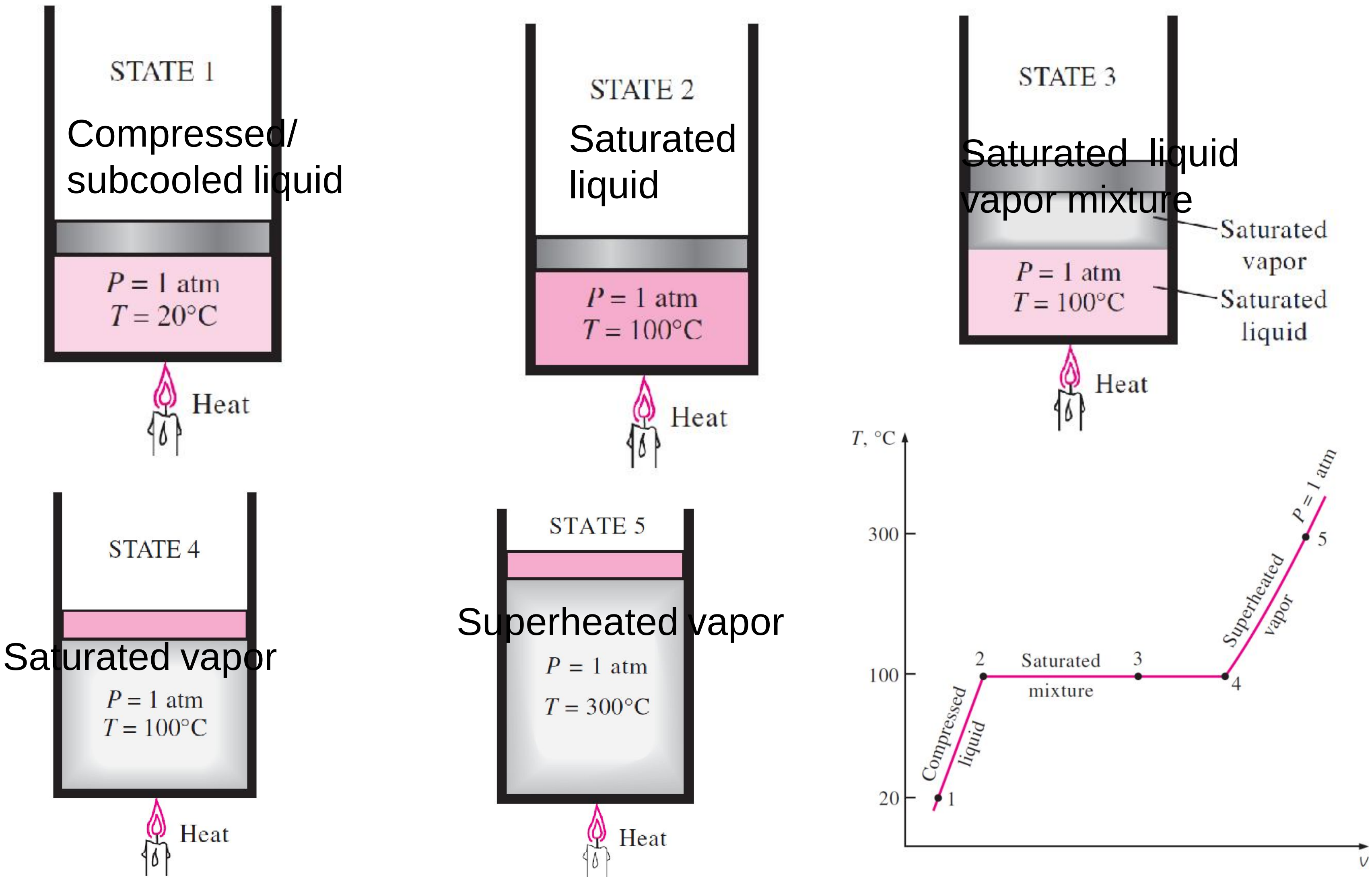
Phase change processes



Some terminology

- Compressed liquid or sub-cooled liquid: Liquid which is not about to vaporize (State 1)
- Saturated liquid: liquid which is about to vaporize (State 2)
- Saturated vapor: vapor which is about to condense (State 4)
- Saturated liquid-vapor mixture: a mixture of saturated liquid and saturated vapor (State 3)
- Superheated vapor: vapor that is not about to condense (State 5)

Phase change processes



Latent heat

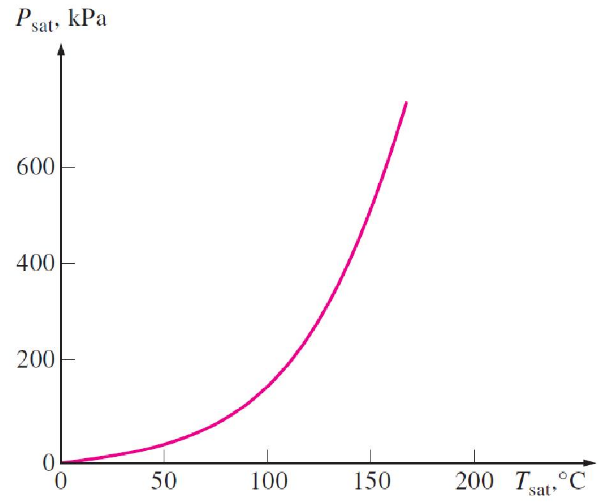
- The energy absorbed by a system during a phase change process at a given pressure/temperature is called latent heat.
  - Latent heat of fusion (melting)
  - Latent heat of vaporization (boiling)
- Latent heat goes to change the molecular potential energy; in-fact temperature, a measure of molecular kinetic energy remains constant during a phase change process.

Saturation temperature, saturation pressure and saturation curve

- Phase change processes (e.g. “saturated liquid” boiling to “saturated vapor”) under a given pressure (“saturation pressure” or P_{sat}) take place at a given temperature

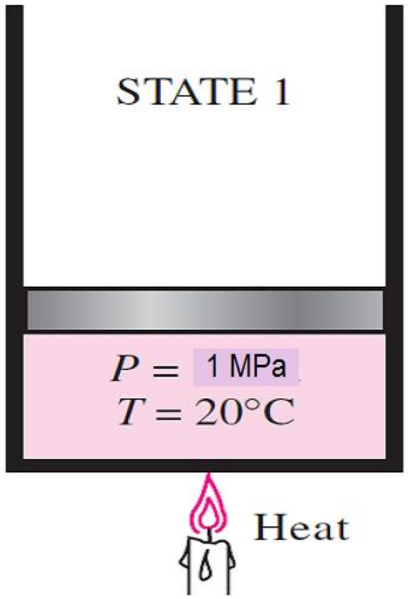
(“saturation temperature” or T_{sat}).

- Therefore P_{sat}=f (T_{sat}). A plot of this function is the **saturation curve**

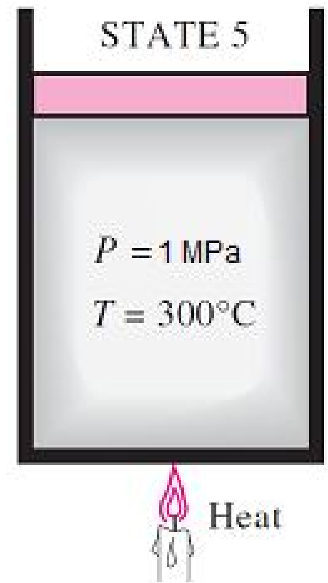


Saturation curve for water

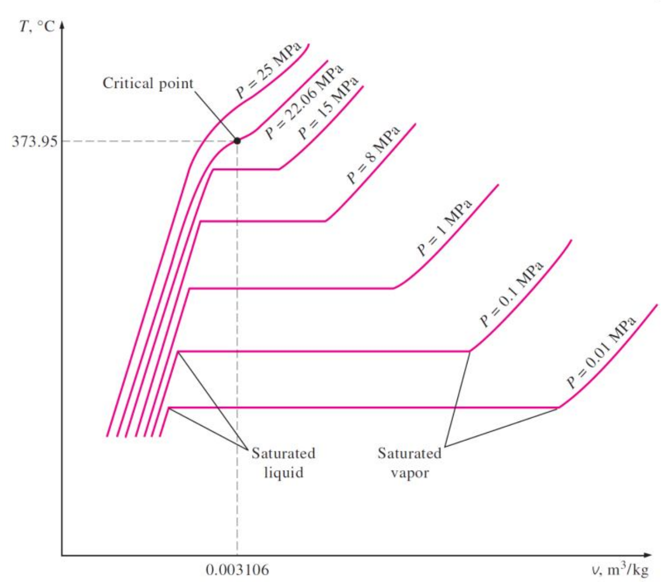
Property diagram for phase change processes: the T-v diagram.



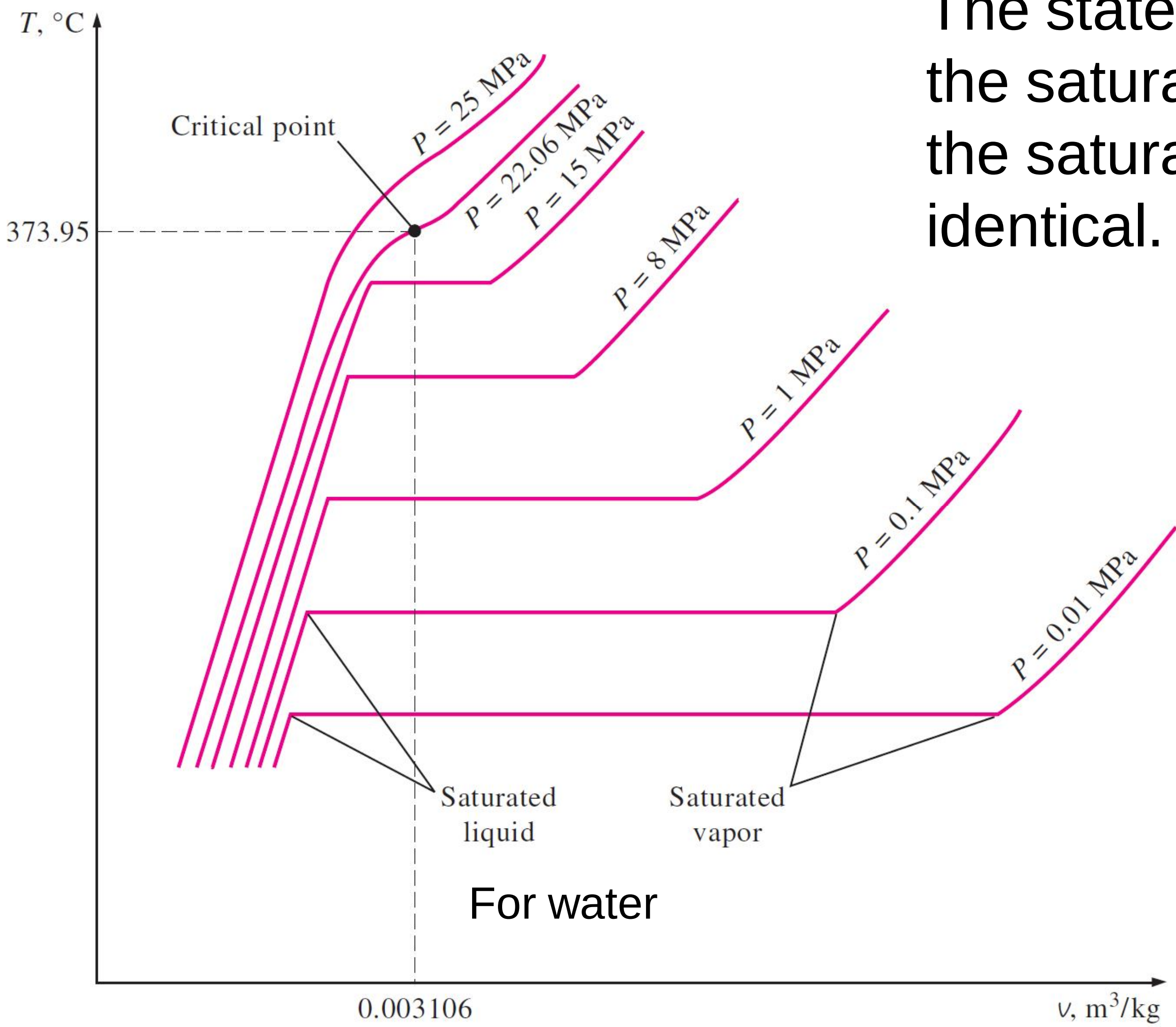
→2→3→4



Construct at different pressures

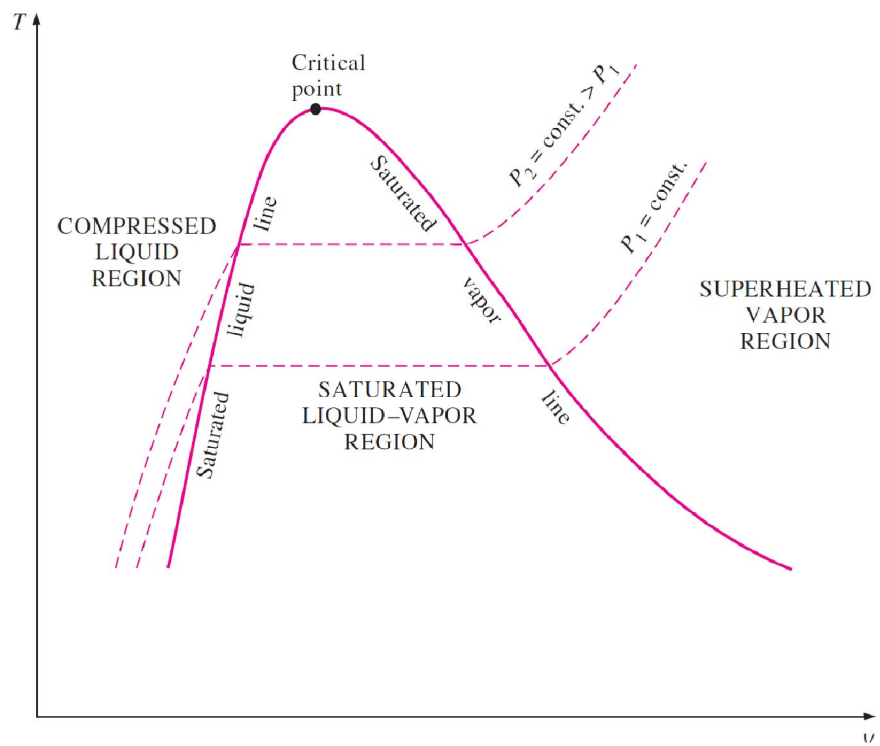


The critical point



The state (“point”) at which the saturated liquid and the saturated vapor states are identical.

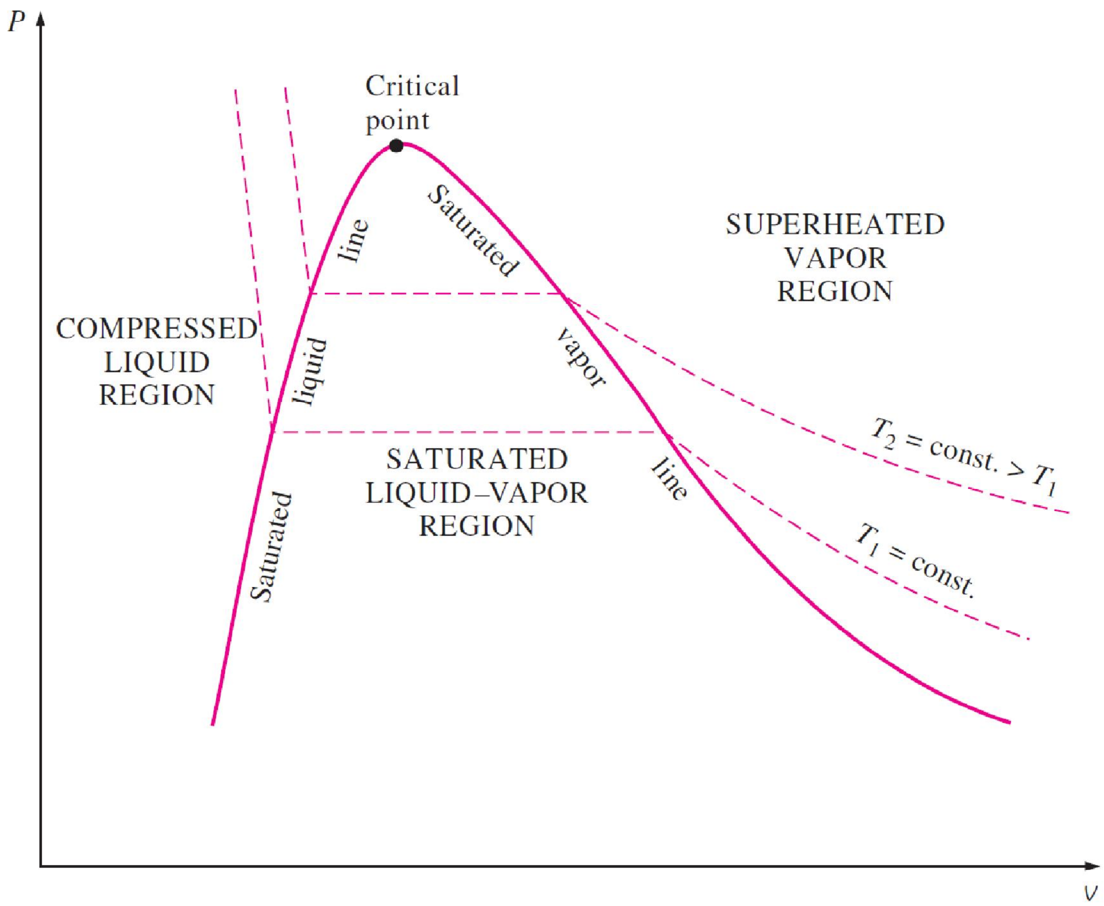
The T-v diagram: saturated liquid line and the saturated vapor line

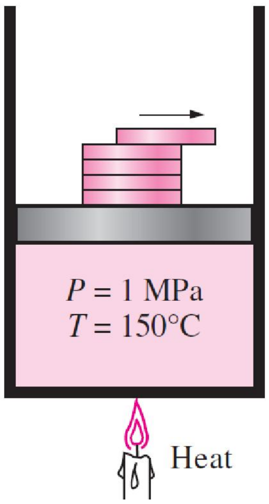


Shows isobars on T-v diagram

Saturated liquid and saturated vapor lines meet at the critical point.

The P-v diagram





Remove weights to change pressure during 1-2, 4-5 (not during 2-3-4)

Shows isotherms on P-v diagram