ESO 201A: Thermodynamics

2016-2017-I semester

Properties: part 1

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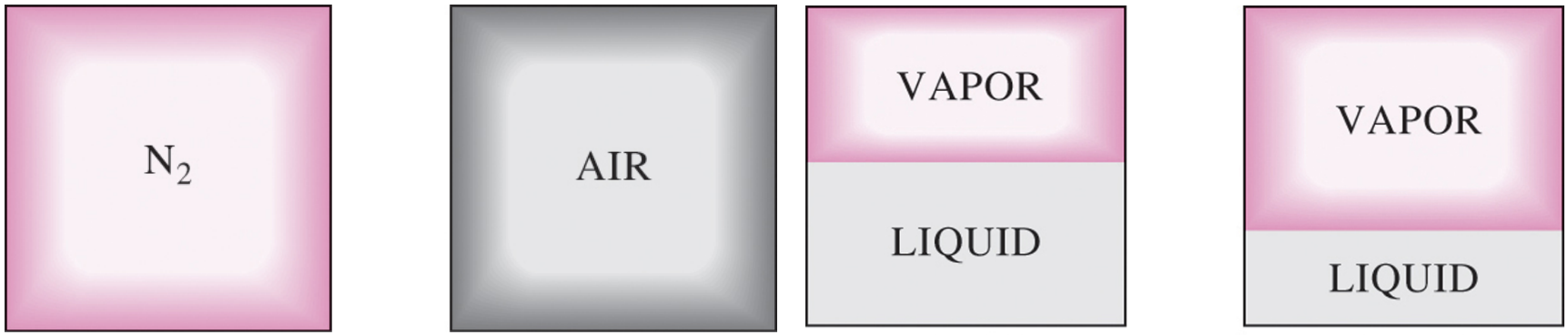
Learning objectives

1. Introduce the concept of a pure substance.
2. Discuss the physics of phase change processes.
3. Illustrate the P-v, T-v and P-T property diagram, and P-v-T surfaces of pure substances.
4. Obtaining thermodynamic properties of a pure substance from a property table.

5. Define Ideal gas equation of state and demonstrate its use.
6. Introduce to compressibility.
7. Present the commonly used equation of states.

Pure substance

- **Pure substance**: A substance that has a fixed chemical composition throughout.
- Air is a mixture of several gases, but it is considered to be a pure substance.

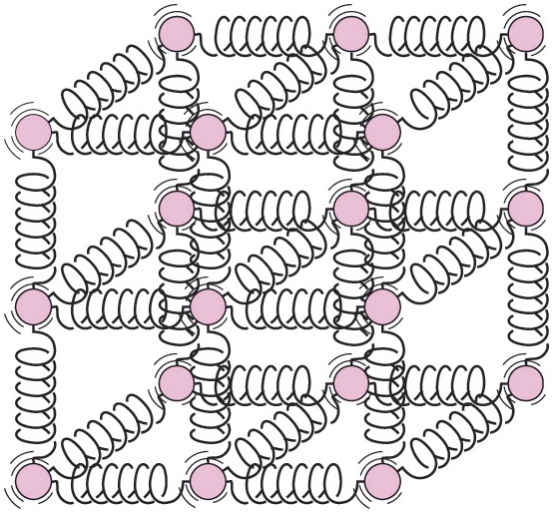


Nitrogen and gaseous air are pure substances.

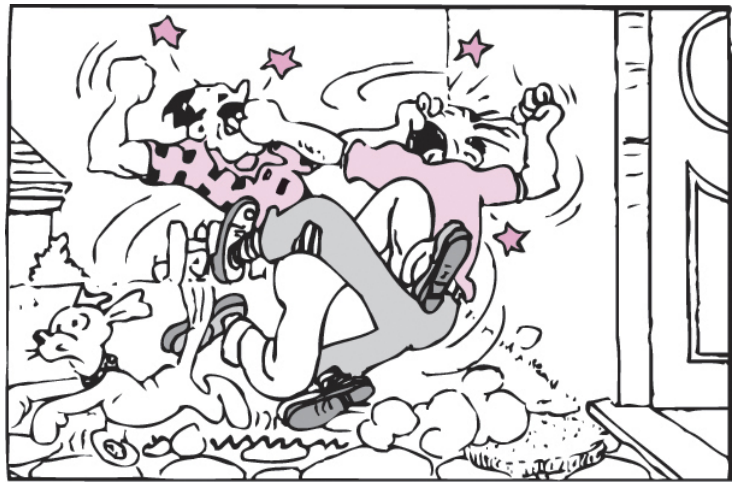
(*a*) H_2O (*b*) AIR

A mixture of liquid and gaseous water is a pure substance, but a mixture of liquid and gaseous air is not.

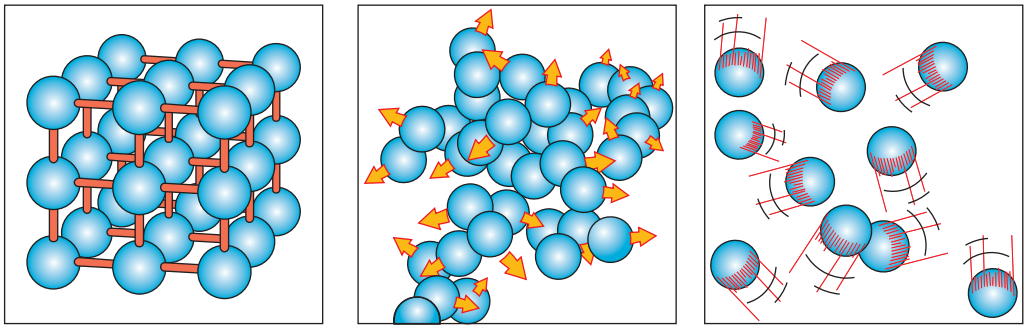
Phases of pure substance



The molecules in a solid are kept at their positions by the large springlike inter-molecular forces.



In a solid, the attractive and repulsive forces between the molecules tend to maintain them at relatively constant distances from each other.

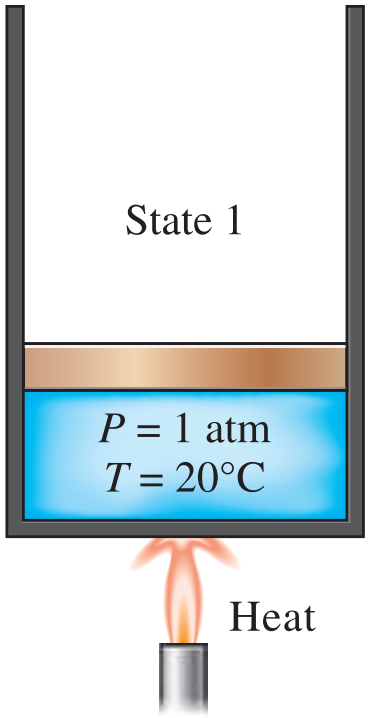


(*a*) (*b*) (*c*)

The arrangement of atoms in different phases: (*a*) molecules are at relatively fixed positions in a solid, (*b*) groups of molecules move about each other in the liquid phase, and (*c*) molecules move about at random in the gas phase.

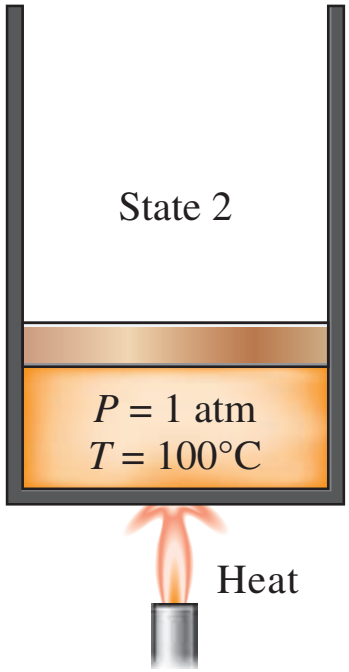
Phase change processes of pure substances

- **Compressed liquid (subcooled liquid)**: A substance that it is *not about to vaporize.*
- **Saturated liquid**: A liquid that is *about to vaporize.*



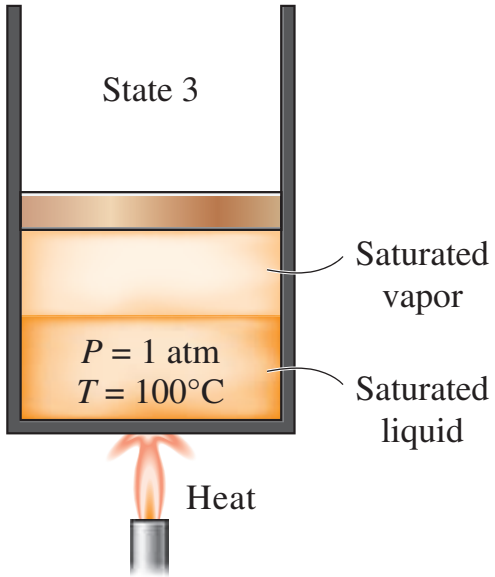
At 1 atm and 20°C, water exists in the liquid phase (***compressed liquid***).

At 1 atm pressure and 100°C, water exists as a liquid that is ready to vaporize (***saturated liquid***).

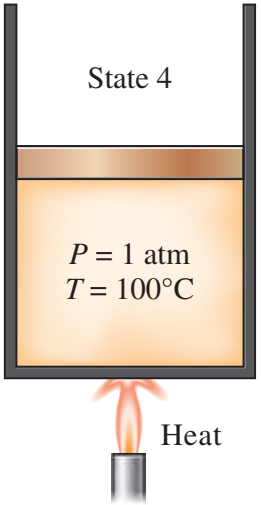


Phase change processes of pure substances

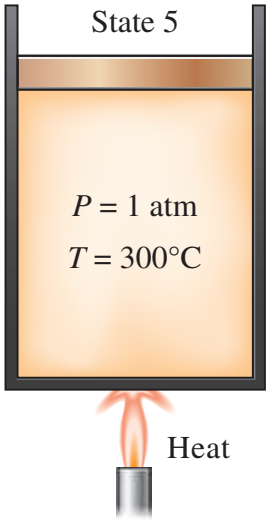
- **Saturated vapor**: A vapor that is *about to condense.*
- **Saturated liquid–vapor mixture**: The state at which the *liquid and vapor phases coexist* in equilibrium.
- **Superheated vapor**: A vapor that is *not about to condense* (i.e., not a saturated vapor).



As more heat is transferred, part of the saturated liquid vaporizes (***saturated liquid–vapor mixture***).

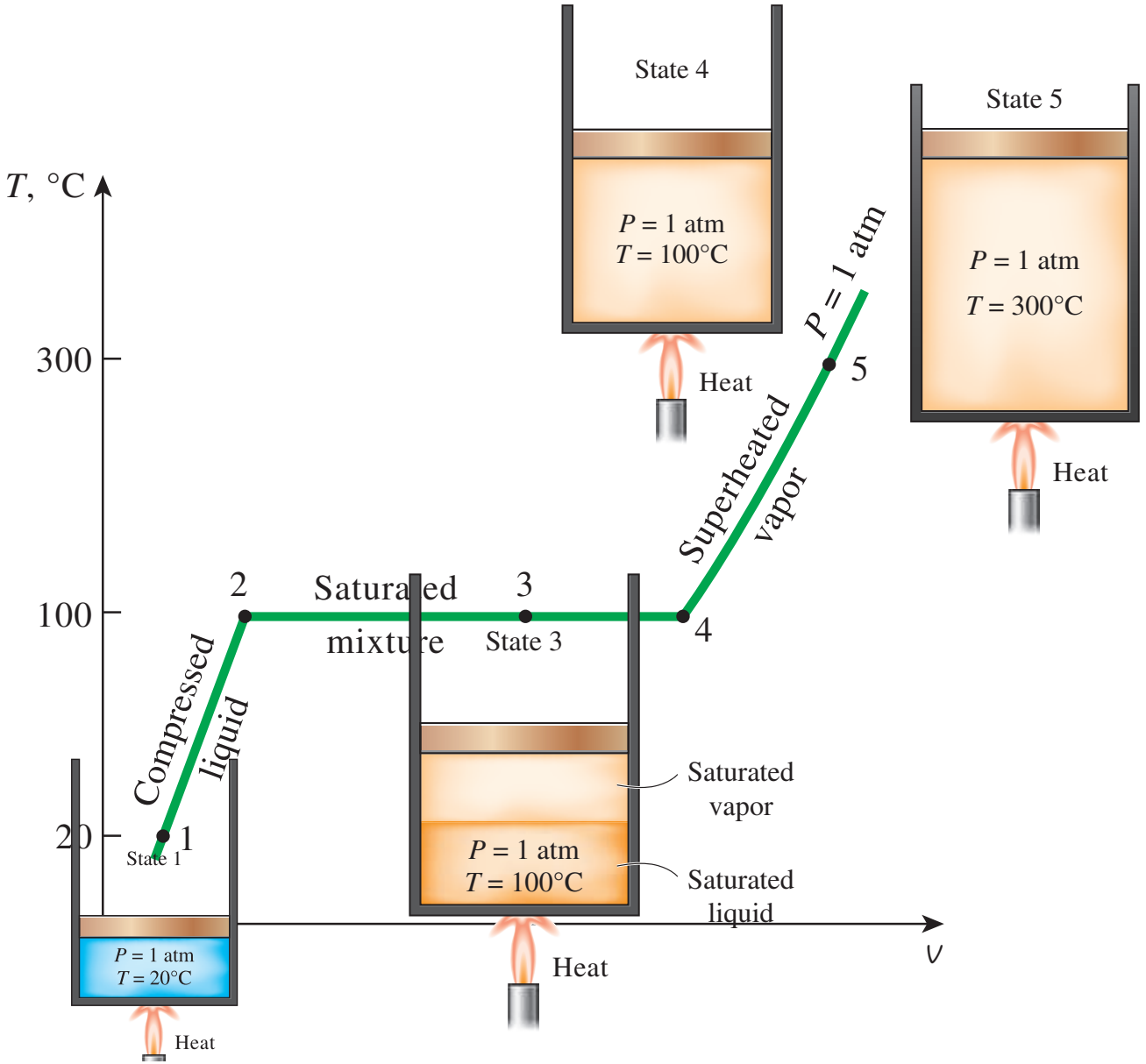


At 1 atm pressure, the temperature remains constant at 100°C until the last drop of liquid is vaporized (***saturated vapor***).

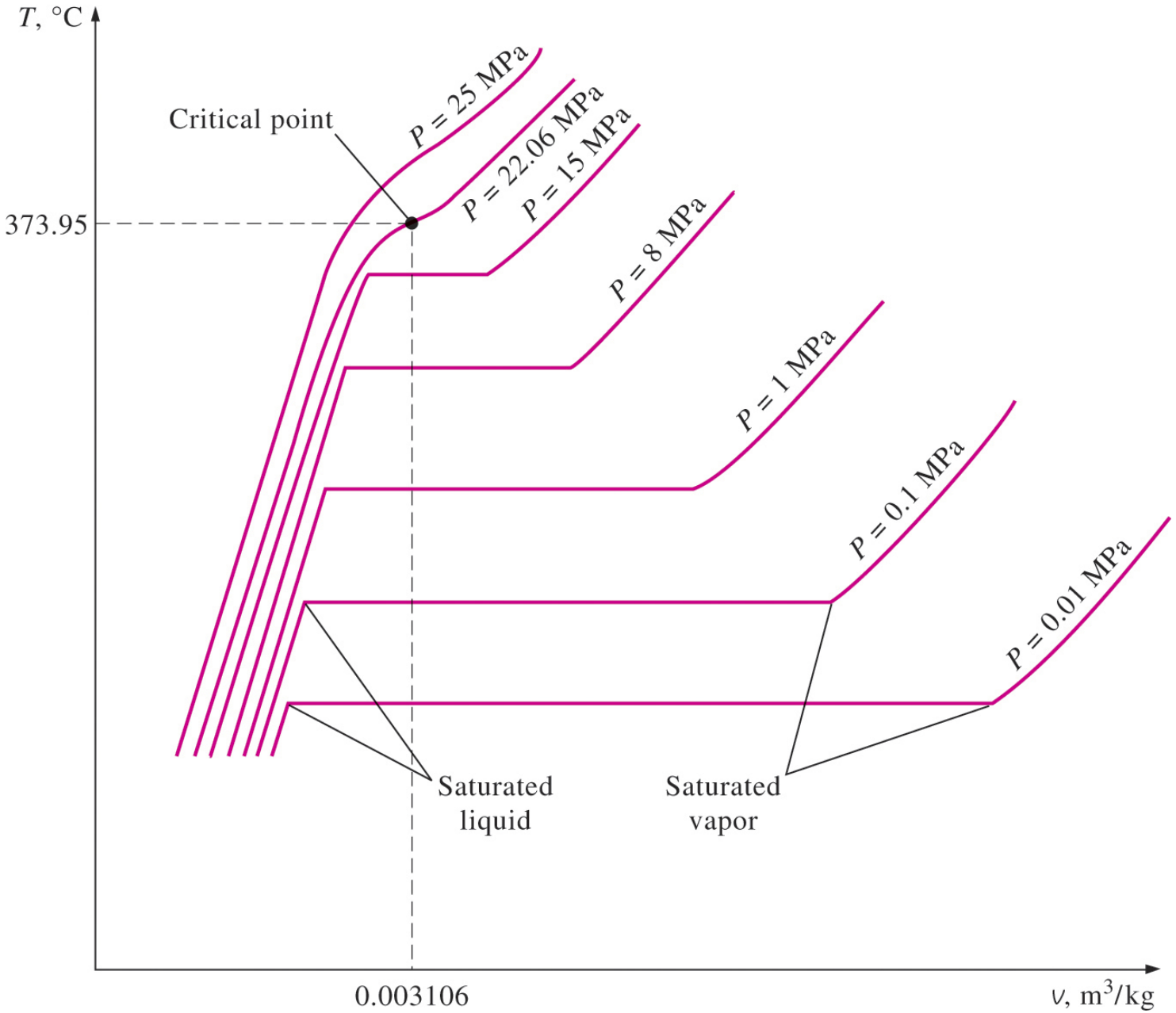


As more heat is transferred, the temperature of the vapor starts to rise (***superheated vapor***).

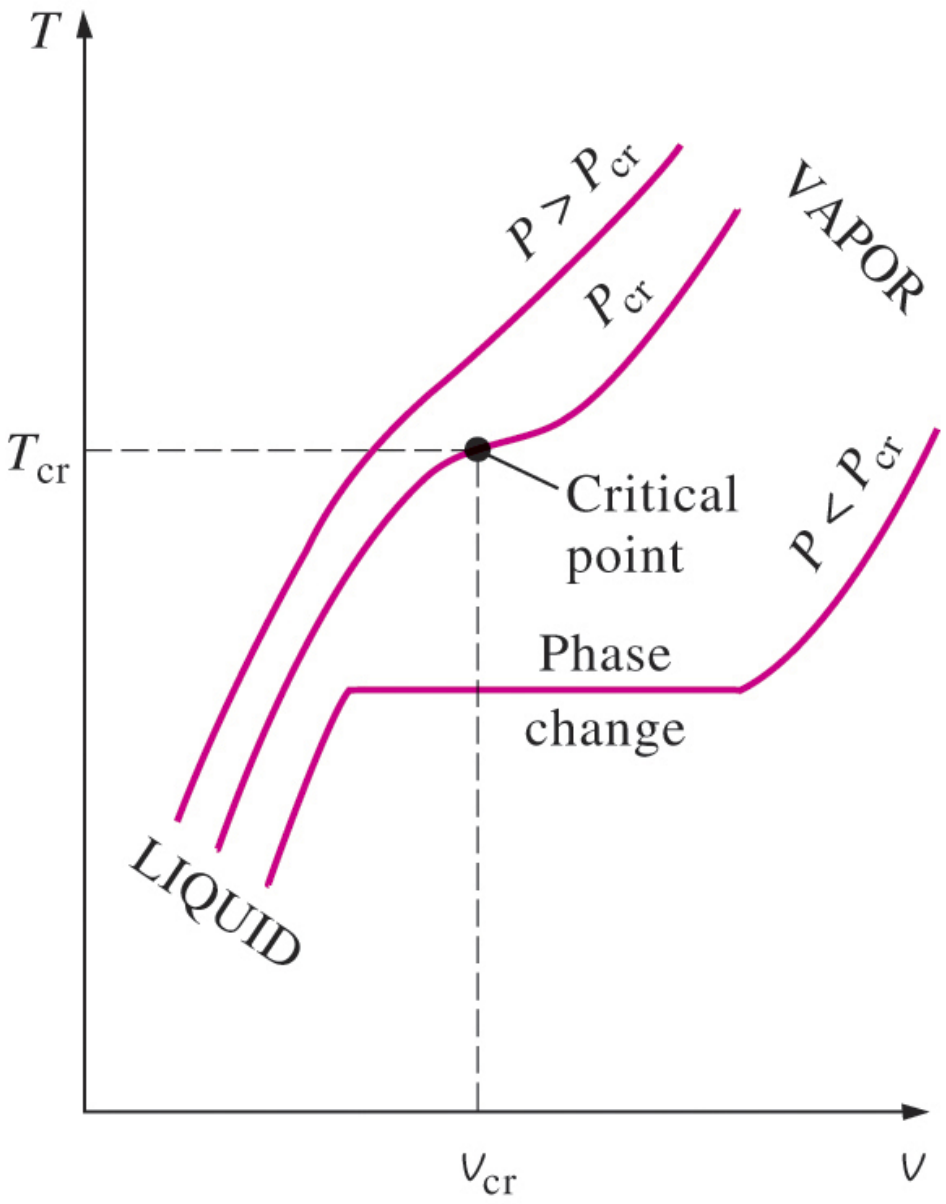
T-v diagram of the heating of water at constant pressure



T-v diagram of constant pressure phase change of water



T-v diagram of constant pressure phase change of water

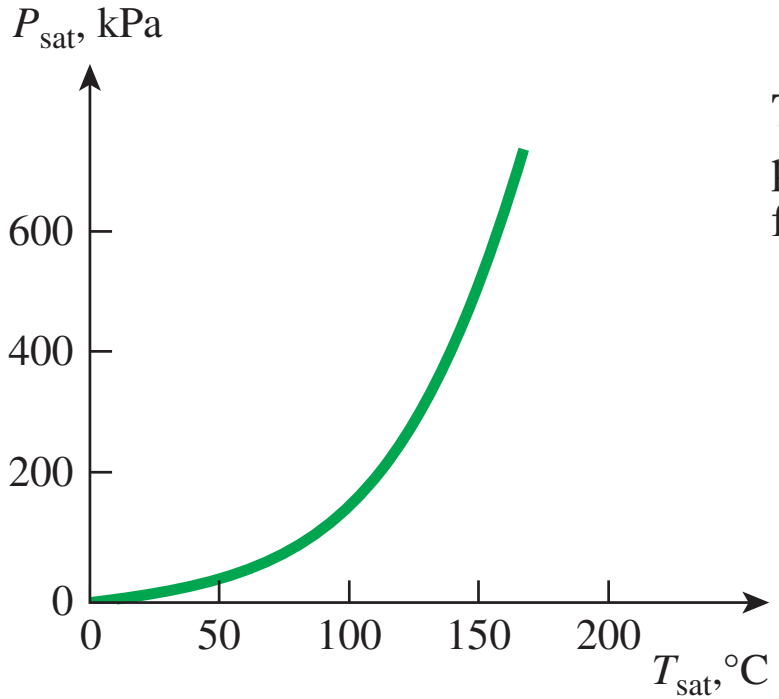


At supercritical pressures ($P > P_{cr}$), there is no distinct phase-change (boiling) process.

Critical point: The point at which the saturated liquid and saturated vapor states are identical.

Water phase change

- The temperature at which water starts boiling depends on the pressure; therefore, if the pressure is fixed, so is the boiling temperature.
- Water boils at 100° C at 1 atm pressure.
- **Saturation temperature T_{sat}**: The temperature at which a pure substance changes phase at a given pressure.
- **Saturation pressure P_{sat}**: The pressure at which a pure substance changes phase at a given temperature.



The liquid–vapor saturation curve of a pure substance (numerical values are for water).

Next lecture

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