# Chapter 3

## Evaluating Properties
## Continued

# State Principle for Simple Compressible Systems

- For a simple compressible system, values for *any two* independent intensive properties determine the values of *all other* intensive properties. This is the **state principle for simple compressible systems**.

# State Principle for Simple Compressible Systems

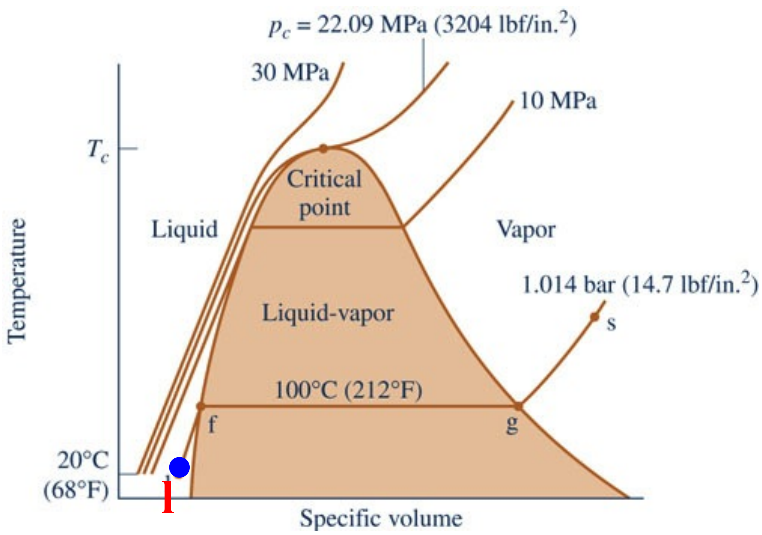
- ►For a simple compressible system, values for *any two* independent intensive properties determine the values of *all other* intensive properties. This is the **state principle for simple compressible systems**.
- ►Among alternative sets of two independent intensive properties, **($T$, $v$)** and **($p$, $v$)** are frequently convenient.

# State Principle for Simple Compressible Systems

- ►For a simple compressible system, values for *any two* independent intensive properties determine the values of *all other* intensive properties. This is the **state principle for simple compressible systems**.
- ►Among alternative sets of two independent intensive properties, **($T$, $v$)** and **($p$, $v$)** are frequently convenient. We soon show that pressure and temperature are not always an independent set.

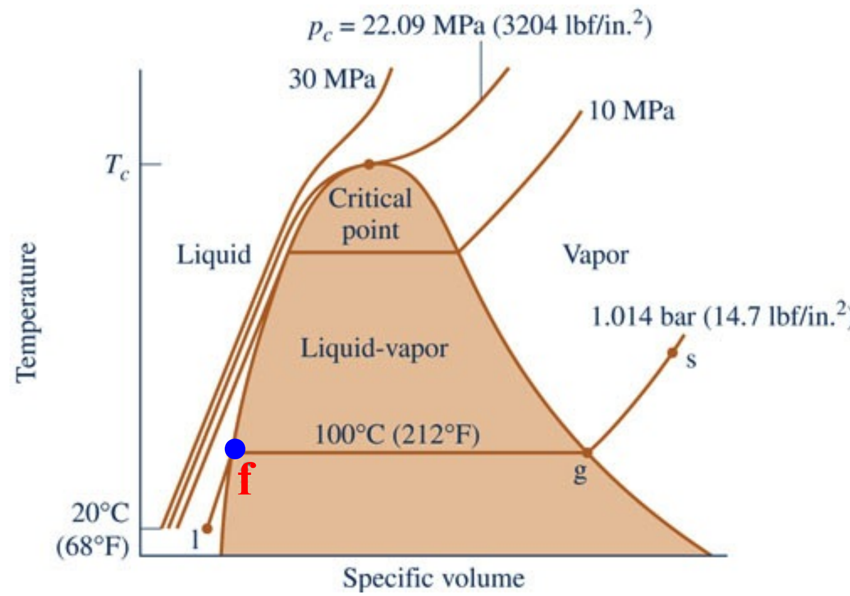
# Phase Change

- Consider a closed system consisting of a unit mass of liquid water at 20°C contained within a piston-cylinder assembly.
- This state is represented by **l** (highlighted by the blue dot).
- Liquid states such as this, where temperature is lower than the saturation temperature corresponding to the pressure at the state, are called **compressed liquid** states.

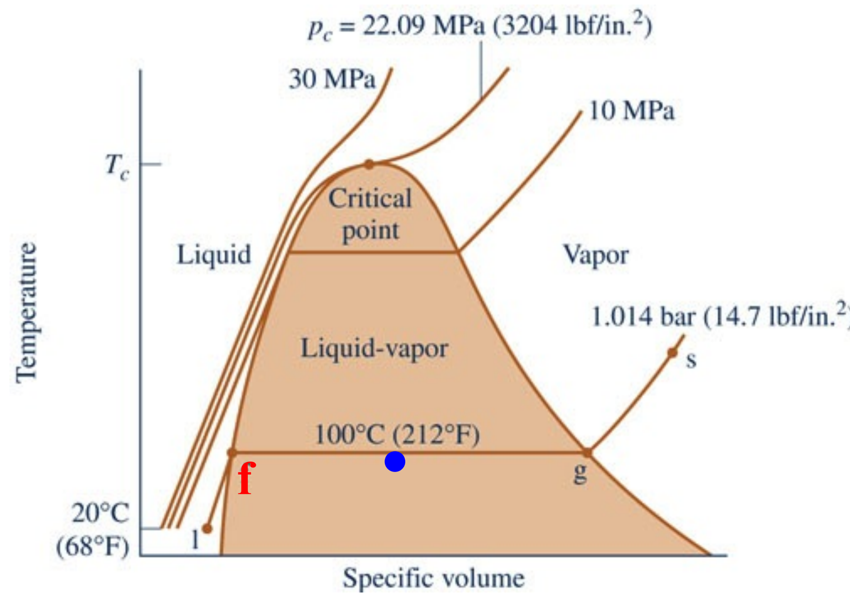
# Saturated Liquid

- As the system is heated at constant pressure, the temperature increases considerably while the specific volume increases slightly.
- Eventually, the system is brought to the state represented by **f** (highlighted by the blue dot).
- This is the **saturated liquid** state corresponding to the specified pressure.

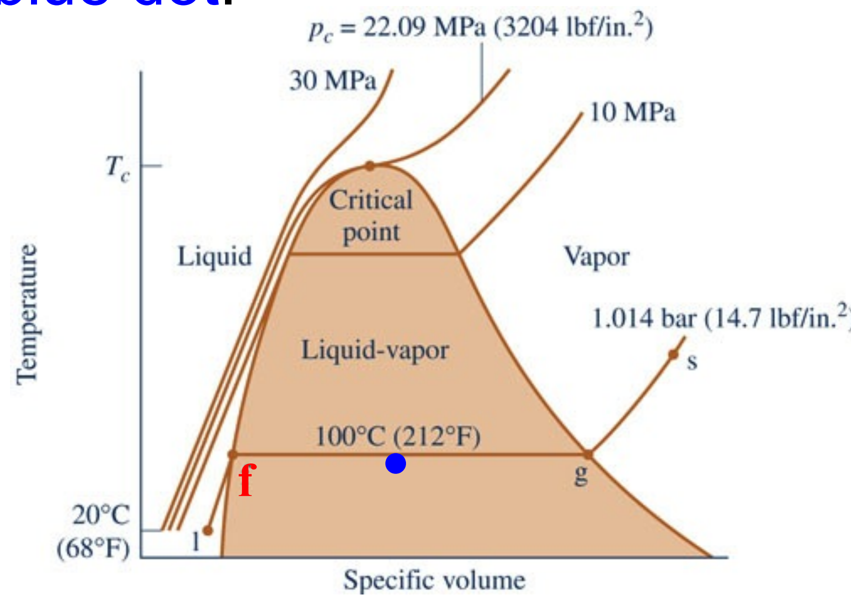
# Two-Phase Liquid-Vapor Mixture

► When the system is at the saturated liquid state, additional heat transfer at fixed pressure results in the formation of vapor without change in temperature but with a considerable increase in specific volume as shown by movement of the blue dot.

# Two-Phase Liquid-Vapor Mixture

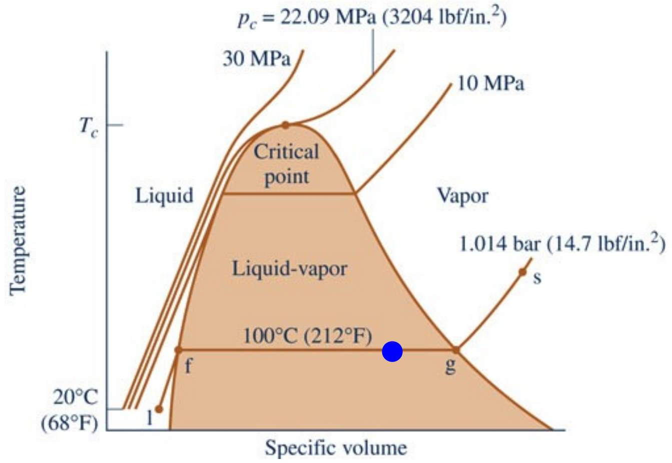
- When the system is at the saturated liquid state, additional heat transfer at fixed pressure results in the formation of vapor without change in temperature but with a considerable increase in specific volume as shown by movement of the blue dot.
- With additional heating at fixed pressure, more vapor is formed and specific volume increases further as shown by additional movement of the blue dot.
- At these states, the system now consists of a **two-phase liquid-vapor mixture**.

# Two-Phase Liquid-Vapor Mixture

- When a mixture of liquid and vapor exists in equilibrium, the liquid phase is a saturated liquid and the vapor phase is a saturated vapor.
- For a two-phase liquid-vapor mixture, the ratio of the mass of vapor present to the total mass of the mixture is its **quality**, $x$.

$$x = \frac{m_{\text{vapor}}}{m_{\text{liquid}} + m_{\text{vapor}}}$$

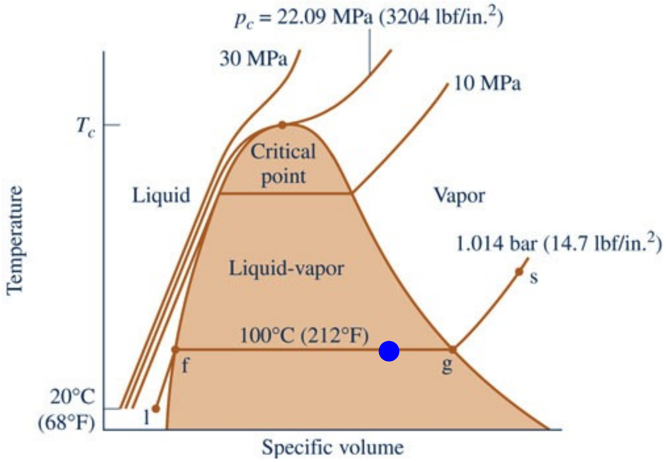



# Two-Phase Liquid-Vapor Mixture

- ► When a mixture of liquid and vapor exists in equilibrium, the liquid phase is a saturated liquid and the vapor phase is a saturated vapor.
- ► For a two-phase liquid-vapor mixture, the ratio of the mass of vapor present to the total mass of the mixture is its **quality**, $x$.

$$x = \frac{m_{\text{vapor}}}{m_{\text{liquid}} + m_{\text{vapor}}}$$

- ► The value of quality ranges from 0 to 1.
- ► At saturated liquid states, $x = 0$.

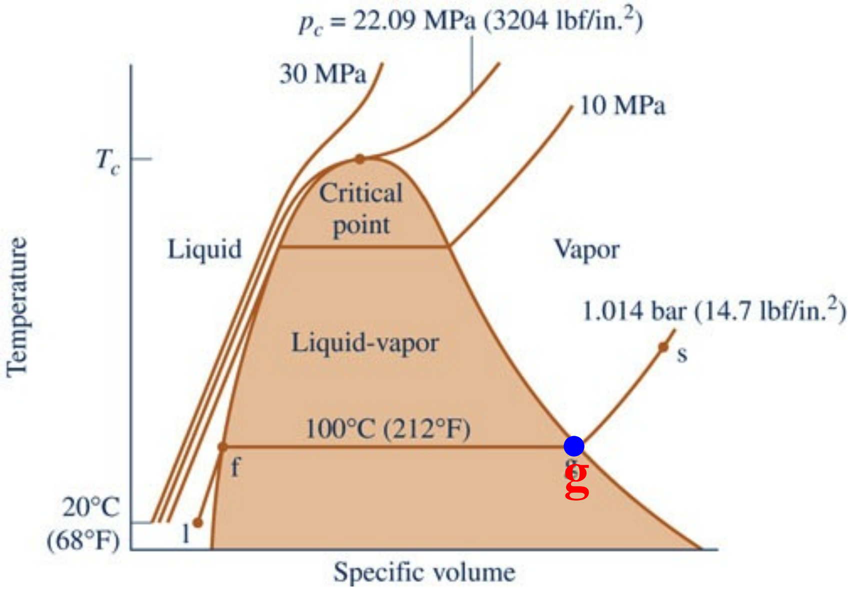



# Saturated Vapor

► If the system is heated further until the last bit of liquid has vaporized it is brought to the **saturated vapor** state.

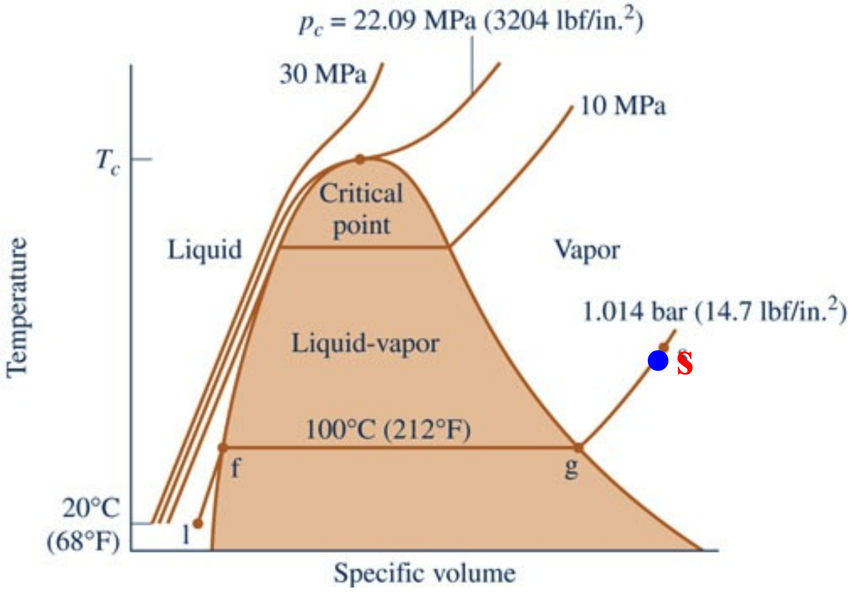
► This state is represented by **g** (highlighted by the blue dot).

► At saturated vapor states, $x = 1$.

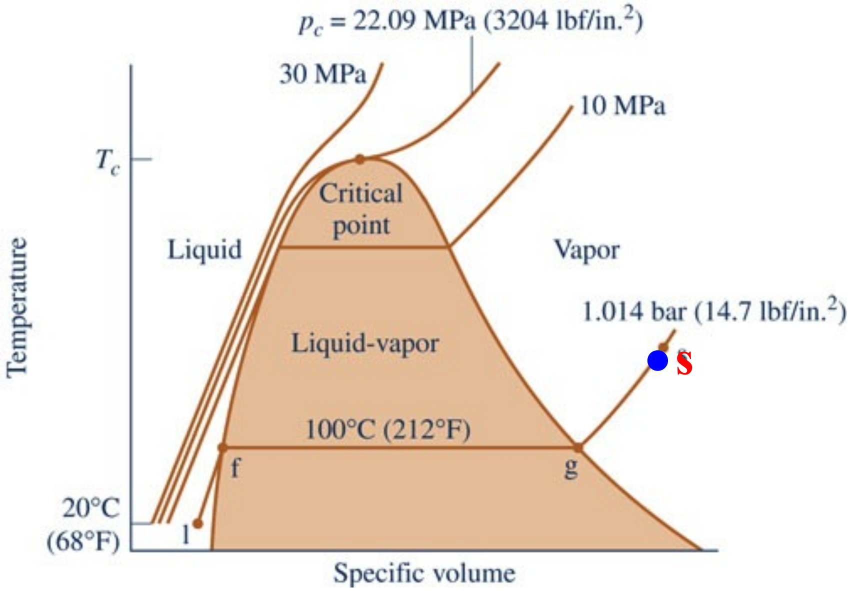
# Superheated Vapor

- ► When the system is at the saturated vapor state, further heating at fixed pressure results in increases in both temperature and specific volume.
- ► This state is represented by **s** (highlighted by the blue dot).

# Superheated Vapor

- When the system is at the saturated vapor state, further heating at fixed pressure results in increases in both temperature and specific volume.
- This state is represented by **s** (highlighted by the blue dot).
- Vapor states such as this, where temperature is higher than the saturation temperature corresponding to the pressure at the state, are called **superheated vapor** states.

# Steam Tables

- ►Tables of properties for different substances are frequently set up in the same general format. The tables for water, called the steam tables, provide an example of this format. The steam tables are in appendix tables A-2 through A-5.
  - ►Table A-4 applies to water as a superheated vapor.
  - ►Table A-5 applies to compressed liquid water.
  - ►Tables A-2 and A-3 apply to the two-phase, liquid-vapor mixture of water.