Chapter 2 - Properties of a Pure Substance

Lecture 5
Section 2.5

MEMS 0051 Introduction to Thermodynamics

Mechanical Engineering and Materials Science Department
University of Pittsburgh

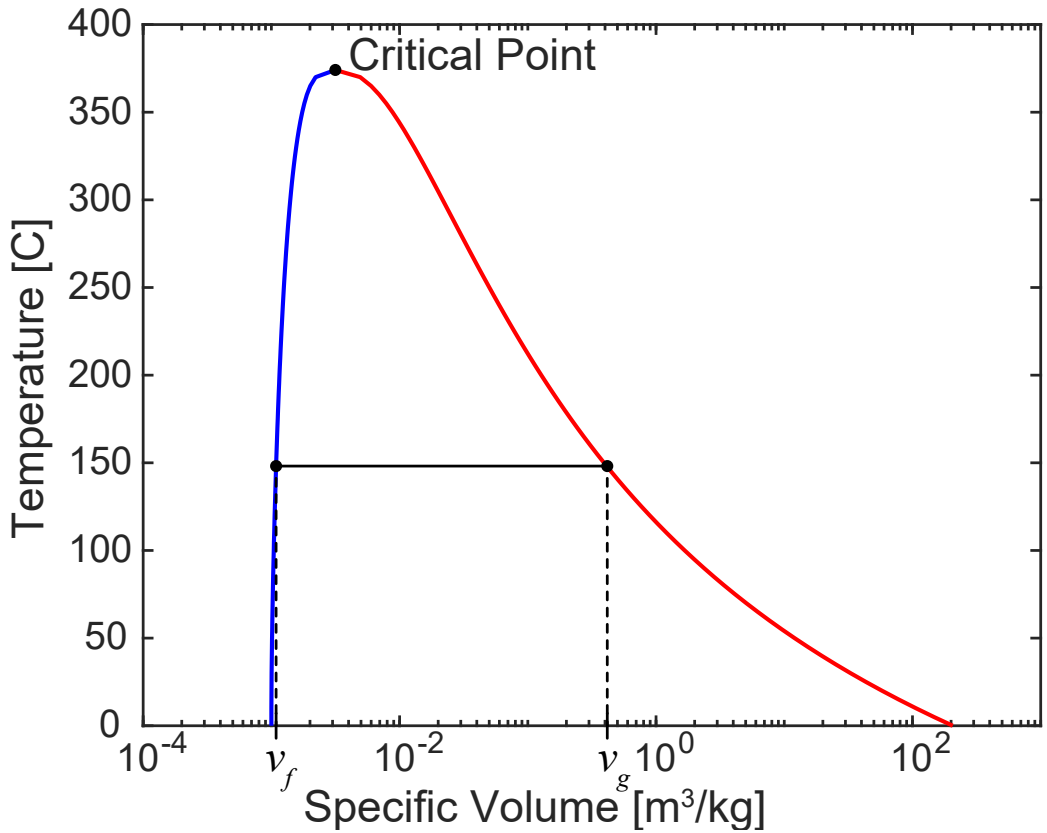
Student Learning Objectives

At the end of the lecture, students should be able to:

- Determine the quality of saturated water

Two-Phase States

- Recall the vapor dome is constructed by the combination of the saturated liquid and saturated vapor lines joining at the critical point.



Two-Phase States

- A **saturated liquid** is 100% liquid, whereas a **saturated vapor** is 100% vapor
- Whenever the state exists between the saturated liquid and saturated vapor lines, liquid and vapor states are existing simultaneously
- The total volume of the system would be the sum of the liquid and vapor volumes

$$\forall = \forall_{\text{liquid}} + \forall_{\text{vapor}} = m_{\text{liquid}}\nu_f + m_{\text{vapor}}\nu_g$$

Two-Phase States

- The average specific volume is simply the volume of the system per the mass of the system

$$\nu_{\text{avg}} = \frac{\forall_{\text{total}}}{m_{\text{total}}} = \frac{m_{\text{liquid}}\nu_f + m_{\text{vapor}}\nu_g}{m_{\text{liquid}} + m_{\text{vapor}}}$$

- Defining **quality**, x, as the ratio of the mass of the vapor to the total mass ($m_{\text{vapor}}/m_{\text{total}}$):

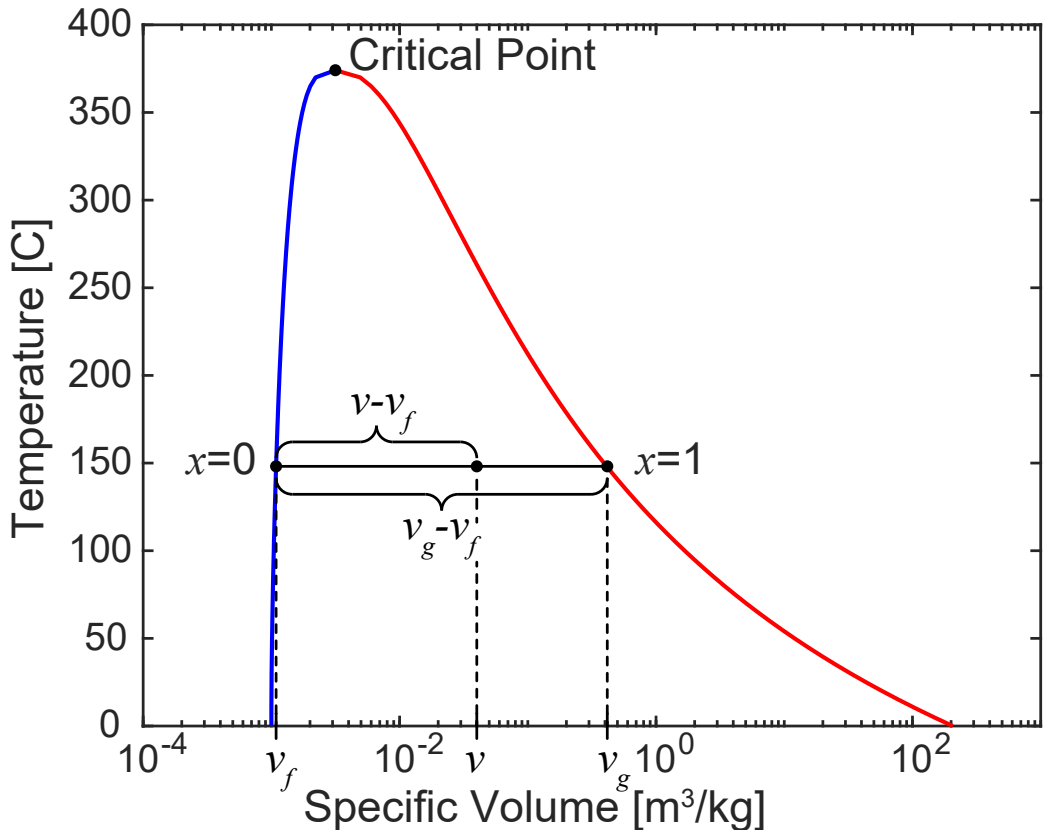
$$\nu = \frac{m_{\text{liquid}}\nu_f}{m_{\text{liquid}} + m_{\text{vapor}}} + \frac{m_{\text{vapor}}\nu_g}{m_{\text{liquid}} + m_{\text{vapor}}}$$

$$\boxed{\implies \nu = (1-x)\nu_f + x\nu_g = \nu_f + x\nu_{fg}}$$

- If x=0, ν=ν_f
- If x=1, ν=ν_g
- Anything in between is found using the lever rule as stated above

Two-Phase States

- The specific volume of a mixture of liquid and vapor can be visualized as follows:



Example #1

- Determine the specific volume and/or quality of the following states:
  1. Water at 500 [kPa] and 20 °C
  2. Water at 500 [kPa] and ν=0.20 [m^3/kg]
  3. Water at 1,400 [kPa] and 200 °C
  4. Water at 300 °C and x=0.8
- Solution:

Example #1

Example #2

- A pressure-cooker operating at 110 °C that has $\forall_{\text{liquid}}/\forall_{\text{vapor}}$=0.2 is heated until the pressure reaches 250 [kPa]. Find the final temperature and percentage of vapor.
- Solution:

Example #2

Example #2

Student Learning Objectives

At the end of the lecture, students should be able to:

- Determine the quality of saturated water
  - Quality is a measure of how much vapor exists in a liquid-vapor system. Quality is defined as the mass of the vapor per the total mass (that of liquid and vapor). Thus, when a fluid exists inside the vapor dome, we need a third property (specific volume) to define the state.

Suggested Problems

- 2.27, 2.28, 2.29, 2.32, 2.35, 2.37, 2.42, 2.44, 2.52, 2.62