5.1 Properties and state

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS state • saturation dome • quality • ideal gas

Objective

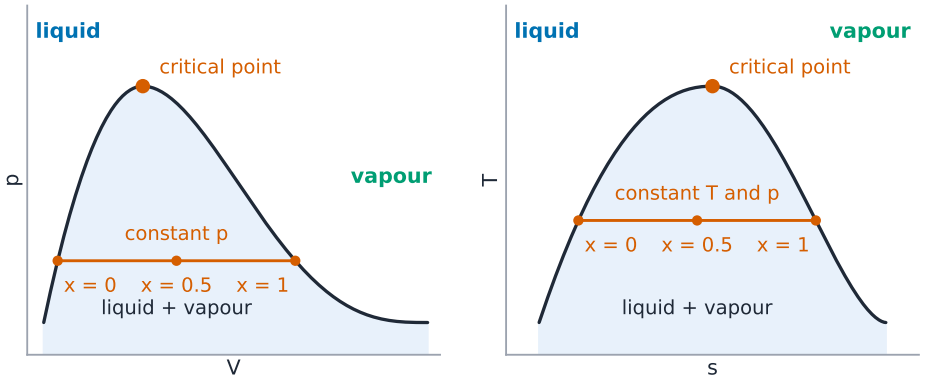
Pin down a state with two properties, walk the saturation dome with quality, and use the ideal-gas law only where it is valid.

1 Key knowledge and worked examples

■ Two numbers and a walker

$v = v_f + x(v_g - v_f)$ and $h = h_f + x\,h_{fg}$ inside the dome; $pv = RT$ outside it, with $R = 0.287$ kJ/(kg K) for air.

the same two-phase region, two axes



*The same two-phase region on p-V and T-s axes

■ Worked example. Saturated water at 100 °C

At $x = 0.5$: $v = 0.001044 + 0.5(1.6729 - 0.001044) = 0.837$ m^3/kg; $h = 419.04 + 0.5 \times 2257.0 = 1547.5$ kJ/kg ✓ - one table row, one multiplication.

2 Practice

Saturated water at 100 °C (from the table): $p_{sat} = 101.35$ kPa, $v_f = 0.001044$, $v_g = 1.6729$ m^3/kg, $h_f = 419.04$, $h_{fg} = 2257.0$ kJ/kg. Air has $R = 0.287$ kJ/(kg K).

2.1 For saturated water at 100 °C ($v_f = 0.001044$ and $v_g = 1.6729$ m^3/kg, $h_f = 419.04$ and $h_{fg} = 2257.0$ kJ/kg): at qualities $x = 0.3$ and $x = 0.8$, the specific volume and the enthalpy (three decimals for v, one for h). [4]

2.2 A sealed vessel holds 2 kg of this two-phase mixture at $x = 0.3$: the mass of vapour and the mass of liquid (kg, one decimal). [2]

2.3 Air ($R = 0.287$ kJ/(kg K)) at 400 K and 200 kPa: the specific volume (three decimals, m^3/kg), and the pressure at which $v = 1.000$ m^3/kg at the same temperature (one decimal, kPa). [4]

2.4 One sentence each: why must quality be a mass fraction rather than a volume fraction, and why does $pv = RT$ fail inside the dome? [4]

Solutions

2.1

- $v(0.3) = 0.001044 + 0.3 \times 1.671856 =$ **0.503** m^3/kg; $h(0.3) = 419.04 + 0.3 \times 2257.0 =$ **1096.1** kJ/kg.
- $v(0.8) = 0.001044 + 0.8 \times 1.671856 =$ **1.339** m^3/kg; $h(0.8) = 419.04 + 0.8 \times 2257.0 =$ **2224.6** kJ/kg.

2.2

- Vapour mass $= 2 \times 0.3 =$ **0.6** kg.
- Liquid mass $= 2 - 0.6 =$ **1.4** kg. ✓

2.3

- $v = RT/p = 0.287 \times 400/200 =$ **0.574** m^3/kg.
- $p = RT/v = 0.287 \times 400/1.000 =$ **114.8** kPa.

2.4

- Volume fractions weight the phases by v, which differs by three orders of magnitude across the dome; only the mass fraction makes $v = v_f + x(v_g - v_f)$ linear and additive.
- Inside the dome p and T are not independent (they lock on the saturation line) and molecules interact during phase change, so the two-variable ideal-gas equation of state does not apply.

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