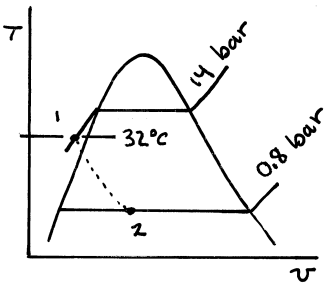
PROBLEM 4.74*

KNOWN: Ammonia expands through a valve from a known pressure and temperature to a given final pressure.

FIND: Determine the exit quality.

SCHEMATIC & GIVEN DATA:

$P_1 = 1.4$ MPa $= 14$ bar
$T_1 = 32$ °C
(1) → (2)
$P_2 = 0.08$ MPa $= 0.8$ bar
$x_2 = ?$



ASSUMPTIONS: (1) A control volume enclosing the valve is at steady state. (2) The refrigerant undergoes a throttling process; $h_1 = h_2$.

ANALYSIS: According to data from Table A-14, at $P_1 = 14$ bar; $T_{sat} = 36.26$ °C. Since $T_1 < T_{sat}$, state 1 is in the compressed liquid region. For simplicity, ① we use Eq. 3.14 to evaluate h_1, as follows:

$$h_1 \approx h_f(T_1) = 332.17 \text{ kJ/kg}$$

where the value is obtained from Table A-13.

By assumption (2)

$$h_1 = h_2$$
$$= h_{f_2} + x_2 h_{fg_2}$$

Solving and inserting data from Table A-14 at $P_2 = 0.8$ bar

$$x_2 = \frac{h_1 - h_{f2}}{h_{fg_2}}$$
$$= \frac{332.17 \text{ kJ/kg} - 9.04 \text{ kJ/kg}}{1382.73 \text{ kJ/kg}}$$
$$= 0.2337 \ (23.37\%) \quad x_2$$

1. Here, we have ignored the effect of pressure on the specific enthalpy of liquid refrigerant. We could have used Eq. 3.13 to estimate the effect of pressure. In that case, h_1 would have been 332.44 kJ/kg, and the exit quality would have been $x_2 = 0.2339$ (23.39%). Thus, using Eq. 3.14 is very accurate in this case, and the approximation of Eq. 3.14 is commonly used when refrigeration systems are analyzed.