Please determine the boiling temperature of water at pressure 0.1 bar, if it is 184°C at 10 bar?

Assume that the specific volume of the boiling liquid is much smaller than the specific volume of vapour, so that it can be neglected.

Also assume that water vapour is ideal gas with specific gas constant R=0.46 J/g·K

The enthalpy of vaporization is constant in our considered range of Δh_V=h'' – h'=2266 J/g

Solution:

State 1: (p1,ϑ1)=(10 bar, 184°C)

State 2: (p2,ϑ2)=(0.1 bar, ?)

In order to solve this problem, we should use Clausius – Clapeyron – Equation:

$$\frac{dp}{dT} = \frac{\Delta h_V}{T \cdot \Delta v}$$

Since the specific volume of the boiling liquid is small enough to be neglected,

Δv=v'' – v'   &   v' « v'' → Δv=v''

In addition, water vapour is assumed to be ideal gas:

$$p \cdot v'' = R \cdot T \ \Longrightarrow \ v'' = \frac{R \cdot T}{p}$$

Therefore the Clausius – Clapeyron – Equation can be rewritten as:

$$\frac{dp}{dT} = \frac{\Delta h_V}{R} \cdot \frac{p}{T^2} \ \Longrightarrow \ \frac{dp}{p} = \frac{\Delta h_V}{R} \cdot \frac{dT}{T^2}$$

$$\Longrightarrow \int_1^2 \frac{dp}{p} = \frac{\Delta h_V}{R} \cdot \int_1^2 \frac{dT}{T^2} \Longrightarrow \ln\left(\frac{p_2}{p_1}\right) = \frac{\Delta h_V}{R} \cdot \left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

So we can now calculate the boiling temperature at pressure 0.1 bar:

$$\frac{1}{T_2} = \frac{1}{T_1} - \frac{R}{\Delta h_V} \cdot \ln\left(\frac{p_2}{p_1}\right) = \frac{1}{(184 + 273.15)\,K} - \frac{0.46\,J/g}{2266\,J/g \cdot K} \cdot \ln\left(\frac{0.1\,bar}{10\,bar}\right)$$

$$\Longrightarrow \ T_2 = 320.27\,K \quad \& \quad \vartheta_2 = 47.12°C$$