Answer on Question #79452 - Physics - Molecular Physics, Thermodynamics

How much heat is needed to turn the 1 kg of ice at -4°C into vapor at 100°C?

Solution.

The necessary constants:

Specific heat capacity of ice c_{ice} = 2.09 kJ/(kg °C)

(https://www.engineeringtoolbox.com/specific-heat-solids-d_154.html)

Specific heat capacity of water c_{water} = 4.19 kJ/(kg °C)

(https://www.engineeringtoolbox.com/specific-heat-fluids-d_151.html)

Latent heat of fusion of water λ_{water} = 334 kJ/kg = 334 kJ/kg

Latent heat of vaporization of water L_{water} = 2264 kJ/kg

(https://en.wikipedia.org/wiki/Latent_heat)

The process consists of four stages:

1. Heating of ice to its melting point (0°C).
2. Ice melting (the temperature remains constant until all of the ice turns to water).
3. Heating of water to its boiling temperature (100°C).
4. Vaporization of water at a constant temperature.

The energy required to heat the ice of mass m = 1 kg from t_1 = -4°C to t_2 = 0°C:

$$Q_1 = c_{ice} m(t_2 - t_1) = 2.09 \frac{kJ}{kg\ °C} \times 1\ kg \times 4°C = 8.36\ \text{kJ}$$

The amount of heat needed to melt the ice:

$$Q_2 = \lambda_{water} m = 334\ \frac{kJ}{kg} \times 1\ kg = 334\ \text{kJ}$$

The energy that is necessary to heat water from t_2 = 0°C to t_3 = 100°C:

$$Q_3 = c_{water} m(t_3 - t_2) = 4.19\ \frac{kJ}{kg\ °C} \times 1\ kg \times 100°C = 419\ \text{kJ}$$

The heat required to turn all the water into vapor:

$$Q_4 = L_{water} m = 2264\ \frac{kJ}{kg} \times 1\ kg = 2264\ \text{kJ}$$

The total heat needed to turn 1 kg of ice at -4°C into vapor at 100°C:

$$Q = Q_1 + Q_2 + Q_3 + Q_4 = (8.36\ + 334 + 419 + \ 2264)\text{kJ} = 3025.36\ \text{kJ} = 3025.36 \times 10^3\ \text{J}$$

Answer: $Q = 3025.36$ kJ.