Answer on Question #76832, Physics / Molecular Physics | Thermodynamics

An unknown material has a normal melting/freezing point of -27.8 °C, and the liquid phase has a specific heat capacity of 157 J/(kg C°). One-tenth of a kilogram of the solid at -27.8 °C is put into a 0.169-kg aluminum calorimeter cup that contains 0.101 kg of glycerin. The temperature of the cup and the glycerin is initially 26.6 °C. All the unknown material melts, and the final temperature at equilibrium is 18.3 °C. The calorimeter neither loses energy to nor gains energy from the external environment. What is the latent heat of fusion of the unknown material?

Solution

When an unknown material is put into aluminum calorimeter cup that contains glycerin a heat exchange takes place: an unknown material absorbs heat that aluminum and glycerin give off until the system comes to the state of heat equilibrium at temperature 18.3^0C. The value of heat absorbed is equal to the value of heat given off.

$Q_{absorbed} = Q_{given\ off}$

1. $Q_{absorbed} = Q_1+Q_2$

Where

a) Q_1 – the heat of phase change of an unknown material:

$Q_1 = m\cdot L_{f,}$

m- mass of an unknown material, m=0.1 kg,

L_f = latent heat of fusion.

$Q_1 = 0.1\cdot L_f$

b) Q_2 – heat that is required to raise the temperature of 0.1 kg of unknown material from

-27.8^0C to 18.3^0C.

$Q_2 = cm(T_2-T_1)$

c- specific heat capacity of an unknown material, c =157 J/(kg C°),

m-mass of an unknown material, m= 0.1 kg

$T_2=18.3^0$C

$T_1 = -27.8^0$C

$Q_2 = 157\cdot0.1(18.3- (-27.8)) =723.77$ (J).

Then $Q_{absorbed} = 0.1\cdot L_f +723.77$ (J)

2. $Q_{given\ off} = Q_{Al} + Q_{gly}$

Where

a) Q_{Al} – the heat that 0.169 kg of aluminum calorimeter cup gives off when the temperature decreases from 26.6^0C to 18.3^0C.

$Q_{Al} = cm(T_2-T_1)$

c- specific heat capacity of aluminum, c =900 J/(kg C°),

m- mass of aluminum calorimeter cup, m= 0.169 kg,

$T_2=18.3^0$C

$T_1=26.6^0$C

$Q_{Al} = 900 \cdot 0.169 \cdot (18.3-26.6) = -1262.43$ (J).

b) Q_{gly} – the heat that 0.101 kg of glycerin gives off when the temperature decreases from 26.6^0C to 18.3^0C.

$Q_{gly} = cm(T_2-T_1)$

c- specific heat capacity of glycerin, c =2410 J/(kg C°),

m- mass of glycerin, m= 0.101 kg,

$T_2=18.3^0$C

$T_1=26.6^0$C

$Q_{Al} = 2410 \cdot 0.101 \cdot (18.3-26.6) = -2020.3$ (J).

Then $Q_{given\ off} = -1262.43-2020.3 = -3282.73$ (J).

Minus before value of $Q_{given\ off}$ shows that the system (aluminum and glycerin) looses heat.

Find L_f from the equation:

$$|Q_{absorbed}| = |Q_{given\ off}|$$

$$0.1 \cdot L_f + 723.77 = 3282.73,$$

$$L_f = 25589.6 \text{ J/kg} = 25.6 \text{ kJ/kg}.$$

Answer: 25.6 kJ/kg