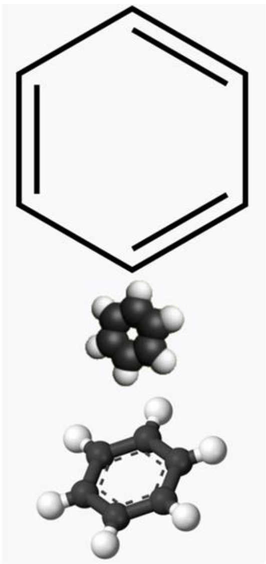
Answer on Question #84727 – Chemistry – Other

Task:

Calculate the heat flow when 13.8 g of benzene at 10.0°C is cooled to -10.0°C.

Solution:

Benzene



Thermodynamic properties

Phase behavior	
Triple point	278.5 K (5.4 °C), 4.83 kPa
Critical point	562 K (289 °C), 4.89 MPa
Std enthalpy change of fusion, $\Delta_{fus}H^o$	9.9 kJ/mol at 5.42 °C
Std entropy change of fusion, $\Delta_{fus}S^o$	35.5 J/(mol·K) at 5.42 °C
Std enthalpy change of vaporization, $\Delta_{vap}H^o$	33.9 kJ/mol at 25°C 30.77 kJ/mol at 80.1°C
Std entropy change of vaporization, $\Delta_{vap}S^o$	113.6 J/(mol·K) at 25°C 87.1 J/(mol·K) at 80.1°C

Solid properties	
Std enthalpy change of formation, $\Delta_f H^o_{solid}$	? kJ/mol
Standard molar entropy, S^o_{solid}	45.56 J/(mol K)
Heat capacity, c_p	118.4 J/(mol K) at 0°C
Liquid properties	
Std enthalpy change of formation, $\Delta_f H^o_{liquid}$	+48.7 kJ/mol
Standard molar entropy, S^o_{liquid}	173.26 J/(mol K)
Enthalpy of combustion, $\Delta_c H^o$	–3273 kJ/mol
Heat capacity,[2] c_p	134.8 J/(mol K)

Benzene freezes at 5.5°C = 278.65 K (melting point of benzene).

Benzene liquid at 10°C.

Benzene solid at -10°C.

Heat capacity for liquid benzene = 134.8 J/mol*K.

Heat capacity for solid benzene = 118.4 J/mol*K.

Enthalpy change of fusion for benzene = 9.9 kJ/mol.

Molar mass of benzene = 78.11 g/mol.

Convert these values from J/mol*K to J/K:

Heat capacity for liquid benzene = $C(C_6H_6, \text{liquid}) = (134.8\ J\ mol^{-1}\ K^{-1}) / (78.11\ g\ mol^{-1}) = 1.726$ J/K = 1.726 J/°C;

Heat capacity for liquid benzene = 1.726 J/°C.

Heat capacity for solid benzene = C(C_6H_6, solid) = (118.4 J mol^{-1} K^{-1}) / (78.11 g mol^{-1}) = 1.516 J/K = 1.516 J/°C;

Heat capacity for solid benzene = 1.516 J/°C.

Enthalpy change of fusion for benzene = $\Delta_{fus}H°$ = (9900 J mol^{-1}) / (78.11 g mol^{-1}) = 126.744 J/g;

Enthalpy change of fusion for benzene = 126.744 J/g.

Liquid benzene will release some of its internal energy to the surroundings when it cools and then solidifies. Solid benzene will also release some of its internal energy when it cools.

1) lowering liquid benzene temperature from 10°C to 5.5°C;
2) freezing the benzene;
3) cooling the solid benzene from 5.5°C to -10°C.

1) **Cooling liquid benzene:**

$$\Delta Q = Cm\Delta T$$

Where:

ΔQ – amount of heat; **C** -specific heat capacity; **m** – material mass; **ΔT** – temperature rise.

Then,

$$\Delta Q_1 = Cm\Delta T = (1.726\,\mathrm{J/g{\cdot}°C})*(13.8\mathrm{g})*(5.5°\mathrm{C} - 10°\mathrm{C}) = -107.1846\,\mathrm{J}$$
$$\Delta Q_1 = -107.1846\,\mathrm{J}$$

2) **Solidification:**

$$\Delta Q = m * L$$

Where:

ΔQ – amount of heat; **L = -Δ_{fus}H°** - heat of fusion; **m** – material mass.

Then,

$$\Delta Q_2 = m * L = (13.8\mathrm{g})*(\text{-}126.744\,\mathrm{J/g}) = -1749.0672\,\mathrm{J}$$
$$\Delta Q_2 = -1749.0672\,\mathrm{J}$$

3) **Cooling solid benzene:**

$$\Delta Q = Cm\Delta T$$

Where:

ΔQ – amount of heat; **C** -specific heat capacity; **m** – material mass; **ΔT** – temperature rise.

Then,

$$\Delta Q_3 = Cm\Delta T = (1.516\,\text{J/g}\cdot{}^\circ\text{C})*(13.8\text{g})*(-10^\circ\text{C} - 5.5^\circ\text{C}) = -324.2724\,\text{J}$$
$$\Delta Q_3 = -324.2724\text{J}$$

Finally, the total energy released is:

$$\Delta Q = \Delta Q_1 + \Delta Q_2 + \Delta Q_3 = (-107.1846\,\text{J}) + (-1749.0672\,\text{J}) + (-324.2724\,\text{J}) = -2180.5242\,\text{J}$$
$$\Delta Q = -2180.5\,\text{J} \approx -2.18\,\text{kJ}$$

The negative sign represents energy lost by the system.

Answer: Heat flow = -2.18 kJ.