1. **The entropy of evaporation of cyclohexane at its normal boiling point (1 atm, 197.3 °C) is 85.1 J/(molK). Calculate its heat of evaporation at this temperature.**

Equation:

$$\Delta S_m = \frac{\Delta H_m}{T} \text{ (slide number: 20)}$$

where, ΔH_m is molar enthalpy of evaporation [J/mol]; ΔS_m is molar entropy of evaporation [J/(mol/K)]; T is temperature [K]

Data collected from the text:

$\Delta H_m = ?$

$\Delta S_m = 85.1 \ \frac{J}{mol * K}$

$T = 197.3$ °C

1. Step: Unit conversion:

$T = 197.3$ °C = (197.3 + 273.15) K = 470.45 K

2. Step: Replacement for the equation:

$$\Delta H_m = S_m * T = 85.1 \ \frac{J}{mol*K} * 470.45 \ K = 40035.295 \ \frac{J}{mol}$$

<u>Answer:</u>

The heat of evaporation of cyclohexane at 197.3 °C is 40035.295 J/mol ~ 40.0 kJ/mol.

2. **The boiling point of nitrogen is -196 °C. Estimate the change of entropy if 15 liter of liquid nitrogen is evaporated at atmospheric pressure? The density of the liquid nitrogen is 0.81 g/cm^3 ? What will be the sign of the change and explain why.**

Equation::

$$\Delta S = \frac{\Delta H}{T} \text{ (slide number: 18)}$$
$$\Delta H = \Delta H_m(evaporation)*\text{n}$$
$$n = \frac{m}{M}$$
$$m = \rho * \text{V}$$

where, ΔS is change of entropy [J/K]; ΔH is change of enthalpy [J]; T is the temperature [K]; ΔH_m(evaporation) is molar heat of evaporation [J/mol]; m is the mass [g]; M is the molar mass [g/mol]; n is the amount [mol]

Data collected from the text:

V = 15 liter
$T_{boiling}$ = -196 °C
ρ = 0.81 g/cm^3

1. Step: Unit conversion

V = 15 liter = 15 dm^3 = 15000 cm^3
$T_{boiling}$ = -196 °C = [(-196) + 273.15] K = 77.15 K

2. Step: Calculation the amount of N_2 (n)

M (N_2) = 28 g/mol

$$n = \frac{m}{M} = \frac{\rho*\text{V}}{M} = \frac{0.81\,\frac{g}{cm^3}*15000\,cm^3}{28\,\frac{g}{mol}} = 433.928\,mol \sim 434 \text{ mol}$$

3. Step: Searching for ΔH_m(evaporation) data of N_2 in database

ΔH_m(evaporation) = 2.79 kJ/mol = 2790 J/mol
(https://en.wikipedia.org/wiki/Enthalpy_of_vaporization)

4. Step: Calculation of the change of entropy

$$\Delta S = \frac{\Delta H}{T} = \frac{\Delta H_m(evaporation) * \text{n}}{T} = \frac{2790\,\frac{J}{mol} * 434\,mol}{77.15\,K} = 15694.88\,\frac{J}{K}$$

Answer:
The change of entropy during the evaporation of 15 liter N_2 at its boiling point -196 °C is 15694.88 J/K ~ 15.7 kJ/K. Liquid nitrogen is converted into gaseous state during the phase transition, the evaporation. In the liquid phase the nitrogen molecules are more organized, while in the gas phase they can move more freely and are less organized. The increase of entropy indicates that the degree of disorder of the N_2 molecules grows.

How much heat should be removed from the system if we intend to cool 5 m^3 ethane gas from 140 °C to 30 °C? The temperature dependence of the molar heat can be neglected.

Equation:

$$Q = C_m * n * \Delta T \text{ (slide number: 14)}$$
$$p * V = n * R * T$$

where, C_m is the molar heat capacity [J/(mol*K)]; n is the amount [mol]; T is temperature [K]; R is the ideal gas constant [8,314 J/(mol*K)]; p is the pressure [Pa] and V is the volume [m^3]

Data collected from the text:

$V_{initial}$ ($T_{initial}$ = 140 °C) = 5 m^3
$T_{initial}$ = 140 °C
T_{final} = 30 °C

1. Step: Unit exchange

   $T_{initial}$ = 140 °C = (140 + 273,15) K = 413.15 K
   T_{final} = 30 °C = (30 + 273,15) K = 303.15 K

2. Step: Calculation the amount of ethane

$$p * V = n * R * T$$

Assuming that, the phase transition occurs at atmospheric pressure p = 101325 Pa

$$n = \frac{p * V_{initial}}{R * T_{initial}} = \frac{101325\ Pa * 5\ m^3}{8.314\ \frac{J}{mol * K} * 413.15\ K} = 147{,}5\ mol$$

3. Step: Searching for C_m data of ethane in database

   C_m = 52.49 J/(mol*K)
   https://en.wikipedia.org/wiki/Ethane_(data_page)

4. Calculation of the heat

$$Q = C_m * n * \Delta T = 52.49 \frac{J}{mol * K} * 147{,}5\ mol * (303.15 - 413.15)$$
$$Q = -70{,}38\ J$$

Answer:

70,38 J should be removed from the system if we intend to cool 5 m^3 ethane gas from 140 °C to 30 °C.