Q1 (15 POINTS)

Calculate the heat that must be transferred in each of the following cases assuming ideal gas behavior

1. **Nitrogen gas contained in a 5-liter flask at an initial pressure of 3 bar is cooled from 90 °C to 30°C.**
2. **A stream of nitrogen flowing at a rate of 100 mol/min is heated from 20°C to 100°C.**

Remark: For the C_p use only the first two terms (a and b) of the polynomial of Table B.2

N_2 Ideal

closed

$V = 5L$ $T_1 = 90°C$

$p = 3 bar$ $T_2 = 30°C$

$Q = ?$

$cp = cv + R$

$\Delta KE + \Delta PE + \Delta \hat{U} = Q - W$

$\Delta U = n \Delta \hat{U} = Q$

$\Delta \hat{U} = \int_{T_1}^{T_2} cv \, dT$

$\Delta \hat{U} = \int_{90°}^{30°} 29 \times 10^{-3} + 0.2199 \times 10^{-5} T \, dT$

$= 29 \times 10^{-3} T + 0.2199 \times 10^{-5} \frac{T^2}{2} \Big|_{90}^{30}$

$= 0.870 - 2.6189 = -1.319$

$cv = cp - R$

$R = 8.314 \text{ J/mol K}$ units

$cp = cv + R$

$cv = cp - R$

[15 mol/K]

$\int_{90°}^{30} 29 \times 10^{-3} - 8.314 \times 10^{-3} + 0.2199 \times 10^{-5} T$

$0.029 + 0.2199 \times 10^{-5} T$

$\int 0.029 T + 0.2199 \times 10^{-5} \frac{T^2}{2} \Big|_{90}^{30}$

$\Delta U = \ldots - \quad = 0.870 - 2.6189 = -1.319 \text{ KJ}$

$\Delta U = Q$ $Q = -1.319 \text{ KJ}$

$V = 5L$

$= 5mol$

$\Delta\hat{U} = Q$

Q_2

$\Delta\hat{U} = \Delta U\, n$

$= -1.319\ KJ$

$\times\ 5mol$

$= -6.595\ KJ$

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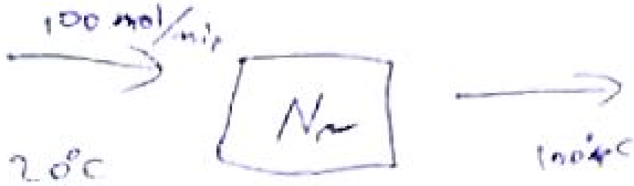
(2)



$\Delta KE + \Delta PE + \Delta\dot{H} = Q - W_s$ (open)

$\Delta\dot{H} = Q$

$\Delta\dot{H} = \int_{T_1}^{T_2} Cp\ dT$

$= \int_{20}^{100} 29\times10^{-3} + 0.219\times10^{-5}\ T$

$= 29\times10^{-3}\ T + 0.219\times10^{-5}\ \frac{T^2}{2}\Big|_{20}^{100}$

100

$2.910995 - 0.5804 = 2.33\ KJ/mol$

$\Delta\dot{H} = \Delta\hat{H}\ n = 2.3306\ \frac{KJ}{mol} \times 100\ \frac{mol}{min}$

$= 233.06\ \frac{KJ}{min}$

$Q = 233.061\ \frac{KJ}{min}$

$\Delta\dot{H} = Q$

4) steam tables are most accurate because Data come from experiments not from estimations [illegible] in Heat capacity

Q2 (15 POINTS)

A stream of water vapor flowing at a rate of 250 mol/h is cooled from 600 °C and 10 bar to 100 °C and 1 atm. Calculate the cooling duty (kW) using: Q = ?

1. Steam Tables
2. Table B8.
3. Heat capacity data for water reported in Table B2
4. Which of the answers in 1, 2, and 3 above is most accurate, and why?

A is most accurate

1) $\Delta \dot{H} = \dot{Q}$

$\Delta \hat{H} = 2676 - 3697 = -1021 \frac{kJ}{kg}$

$\Delta \dot{H} = -1021 \frac{kJ}{kg} \times$

$= -1021 \frac{kJ}{kg} \times 1.251 \times 10^{-3} \frac{kg}{s}$

$= -1.277 \frac{kJ}{s} = kW$

$250 \frac{mol}{h} \times \frac{1 h}{3600 s} = 0.06944 \frac{mol}{s}$

$0.06944 \frac{mol}{s} \times 18.016 \frac{g}{mol}$

$\dot{m} = 1.251 \times 10^{-3} \frac{kg}{s} \times \frac{1 kg}{1000 g}$

2) $\Delta \dot{H} = \dot{Q}$

ref H_2O (Gas, 25 °C, 1 atm)

$\Delta \hat{H} = 2.54 - 20.91 = -18.37 \frac{kJ}{mol\ H_2O}$

$\Delta \hat{H} \times n = \Delta \dot{H}$

H_2O (gas, 600, 10 bar) → H_2O (gas, 100 °C, 1 atm)

$-18.37 \frac{kJ}{mol} \times 0.06944 \frac{mol}{s}$

$= -1.2756 \frac{kJ}{s}$

③

~~$\Delta \dot{H} = Q$~~

~~$\Delta \hat{H} = \int_{T_1}^{T_2} C_p \, dT$~~

~~$= \int$~~

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③ H_2O (gas, 600°, 10 bar) ⟶ H_2O (gas, 100°, 1 bar)

ΔP ↓

H_2O (gas, 600°, 1 bar) ↗ ΔT

ΔP: $\Delta \hat{H} = 0$ for gases

ΔT:

$$\Delta \hat{H} = \int_{T_1}^{T_2} C_p \, dT$$

$$= \int_{600}^{100} 33.46 \times 10^{-3} + 0.685 \times 10^{-5} T \, dT$$

$$= 33.46 \times 10^{-3} (T) + 0.685 \times 10^{-5} \frac{T^2}{2} \Big|_{600}^{100}$$

$$= 3.38025 - 21.309$$

$$= -17.92875 \text{ kJ/mol}$$

$n \Delta \hat{H} = \Delta \dot{H}$

$$\Delta \dot{H} = -17.92875 \frac{\text{kJ}}{\text{mol}} \times 0.06944 \frac{\text{mol}}{\text{s}}$$

$$= -1.209 \text{ kJ/mol}$$

Q3 (20 POINTS)

Air at wet-bulb temperature of 27 °C and 20% relative humidity is cooled to 18 °C at a constant pressure of 1 atm. Use the psychrometric chart to determine the following:

3. Dry-bulb temperature, absolute humidity, dew-point temperature and enthalpy of air entering and leaving the condenser.
4. The rate of water condensed in the condenser.
5. The rate of heat that must be removed to deliver 600 m^3/min of humid air at the final condition.

Use as a basis of calculation 500 kg DA/min.

Dry bulb T for inlet = 48 °C

// outlet = 34 °C

//

hA : inlet = 0.014 $\frac{kg\ H_2O}{kg\ DA}$