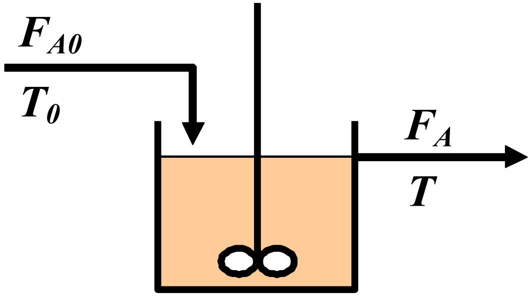
Operação não adiabática

Non-adiabatic operation

CSTR



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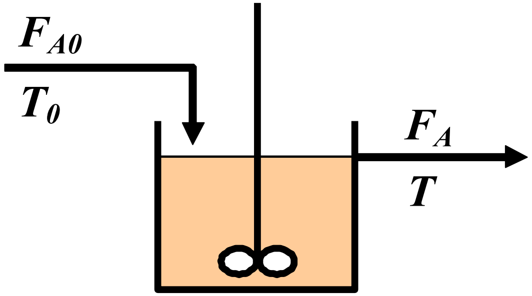

$$A \longrightarrow B$$

Operação não adiabática
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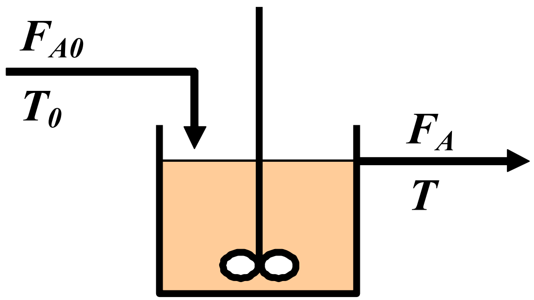

Exemplo:

$$A \longrightarrow B$$

Lei cinética:
Kinetic law

$$-r_A = k\,C_A = k\,C_{A0}\,(1 - X)$$

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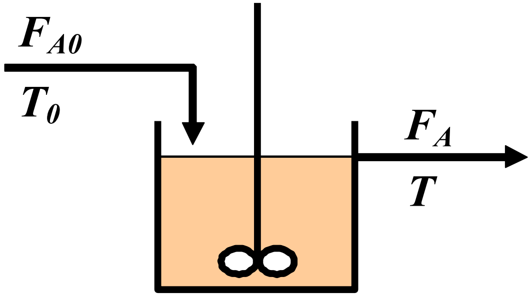

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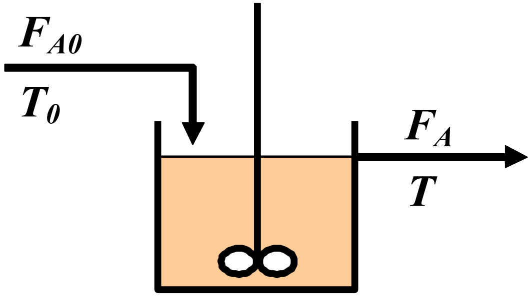

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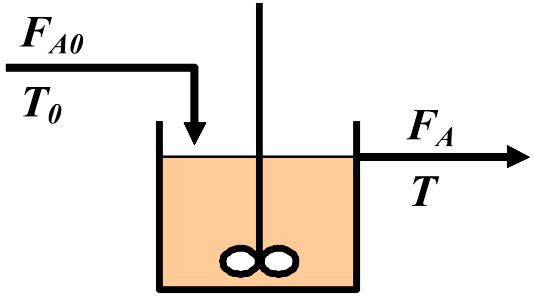

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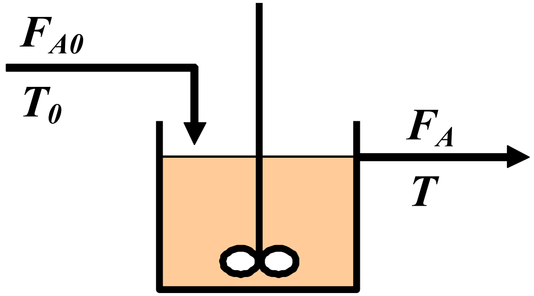

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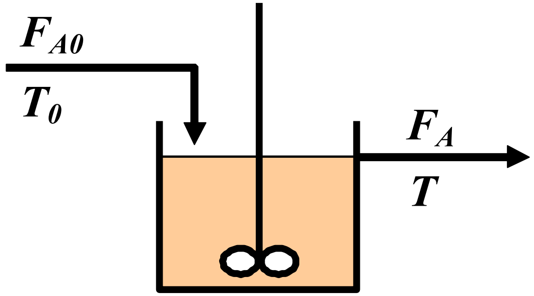

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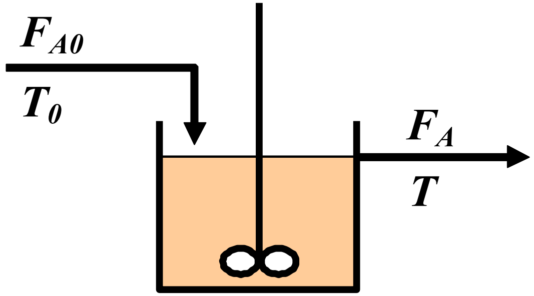

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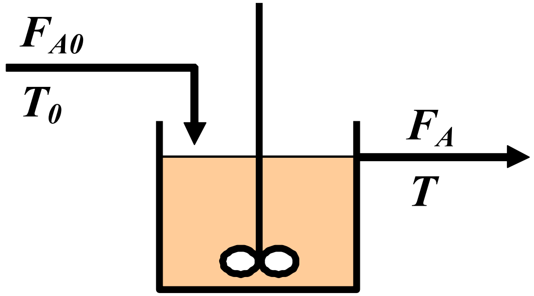

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Balanço de energia

Energy balance

$$\dot{Q} - F_{A0}\sum_i \theta_i C_{pi}\left(T - T_0\right) - F_{A0}\left[\Delta H_R^o + \sum_i \upsilon_i C_{pi}\left(T - T_R\right)\right]X = 0$$

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Case 1: constant external temperature (ex.: saturated vapour; non-jacketed reactor)

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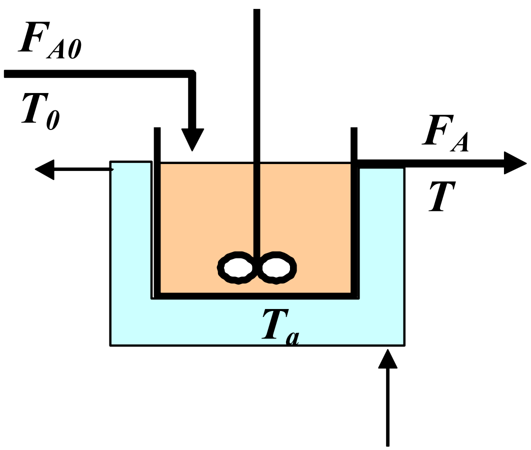

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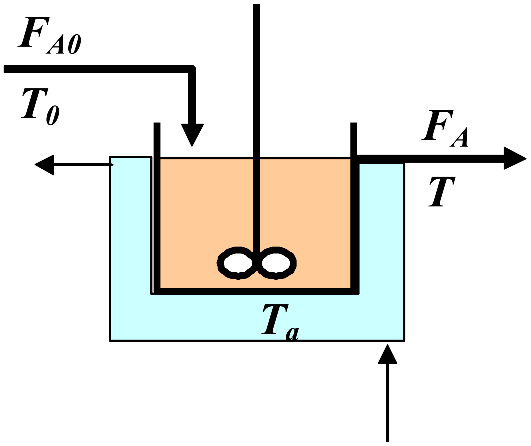

$$\dot{Q} = U\,A\left(T_a - T\right)$$

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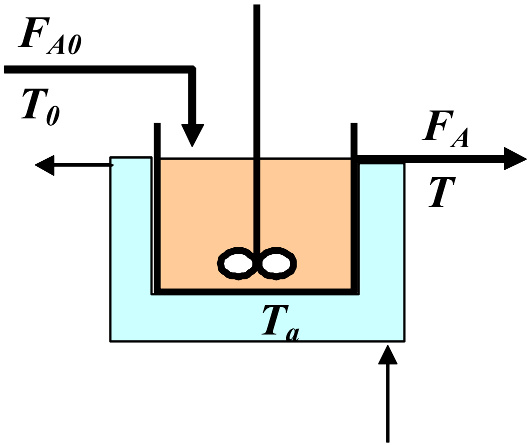

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Caso 2: a temperatura externa varia entre a entrada e a saída da camisa

Case 2: external temperature changes between the jacket entrance and the jacket exit.

Balanço de energia
Energy balance

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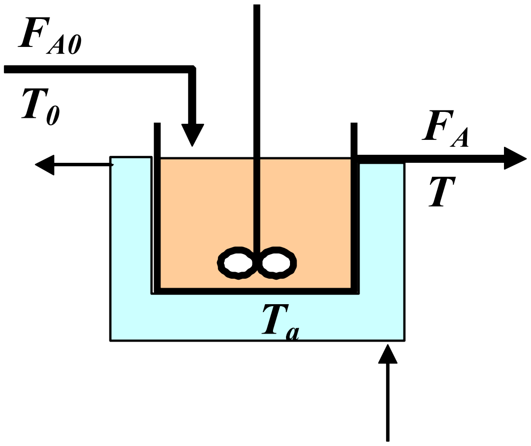

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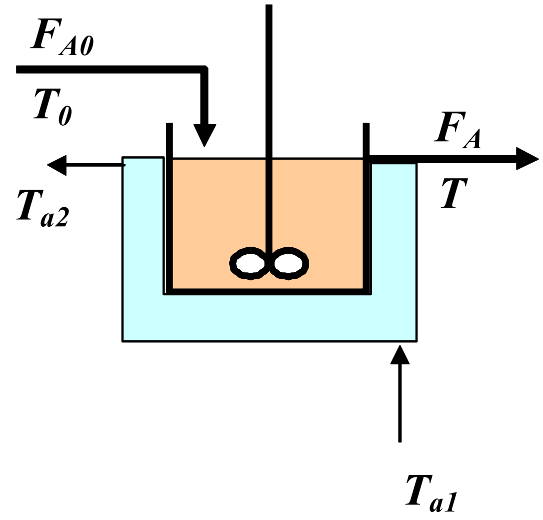

Balanço de energia

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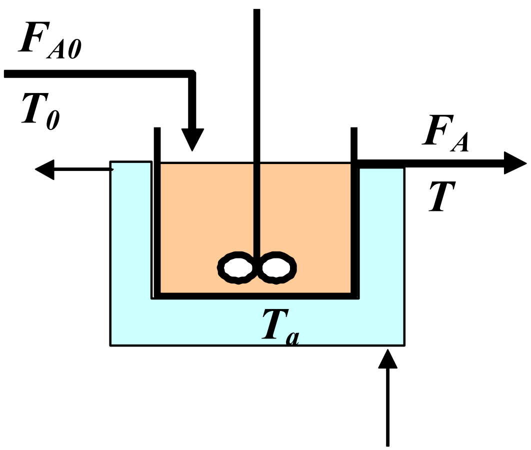

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Caso 2: a temperatura externa varia entre a entrada e a saída da camisa

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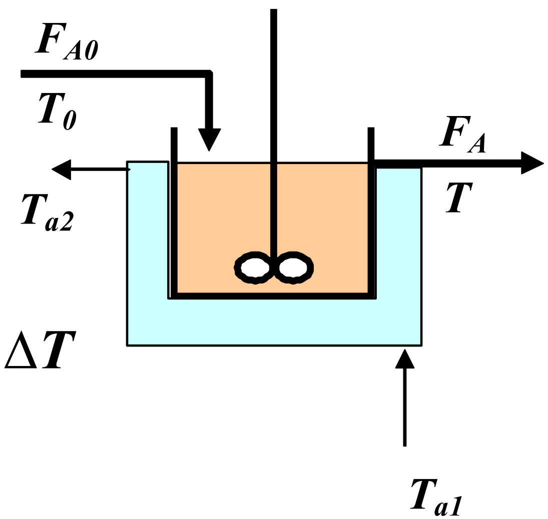

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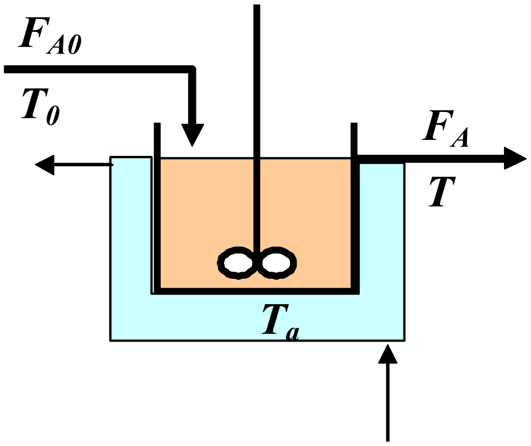

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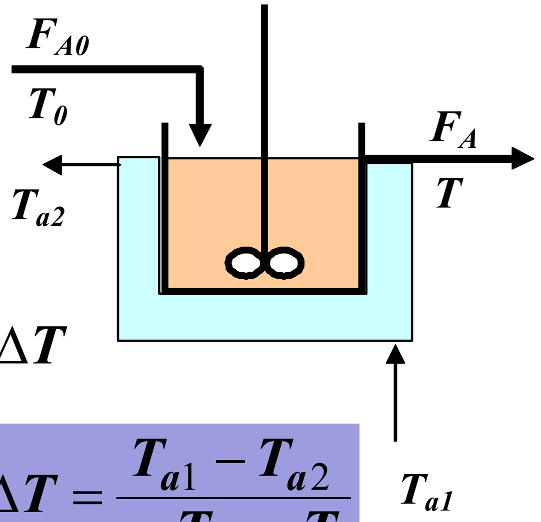

$$\dot{Q} = U\,A\,\Delta T$$

$$\Delta T = \frac{T_{a1} - T_{a2}}{\ln \dfrac{T_{a1} - T}{T_{a2} - T}}$$

Operação não adiabática

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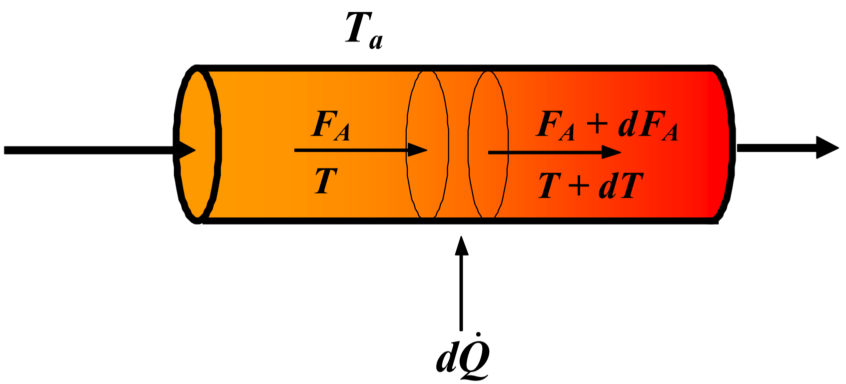

PFR

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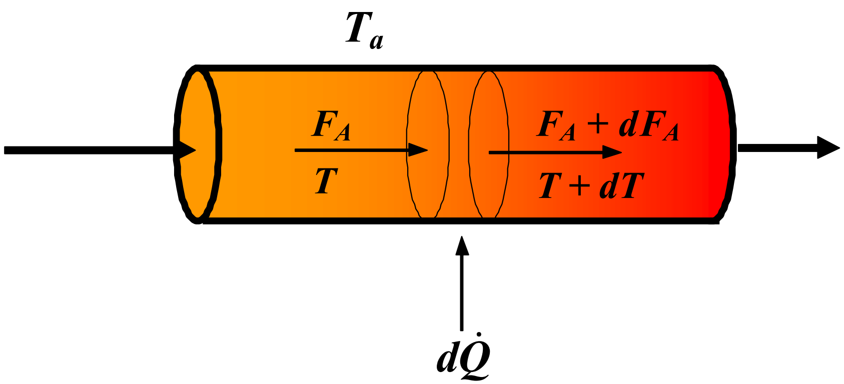

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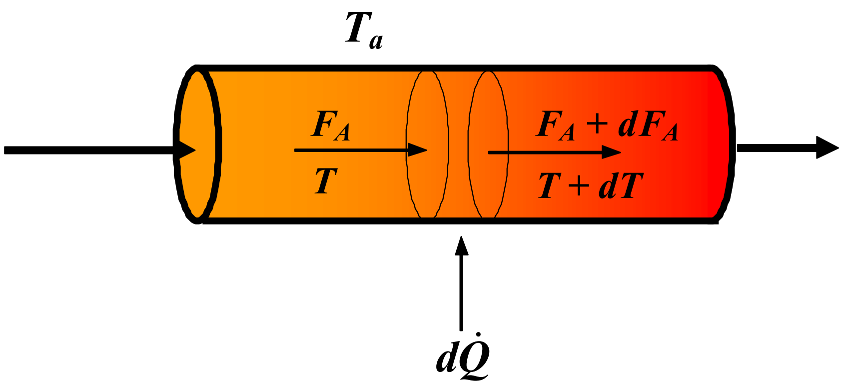

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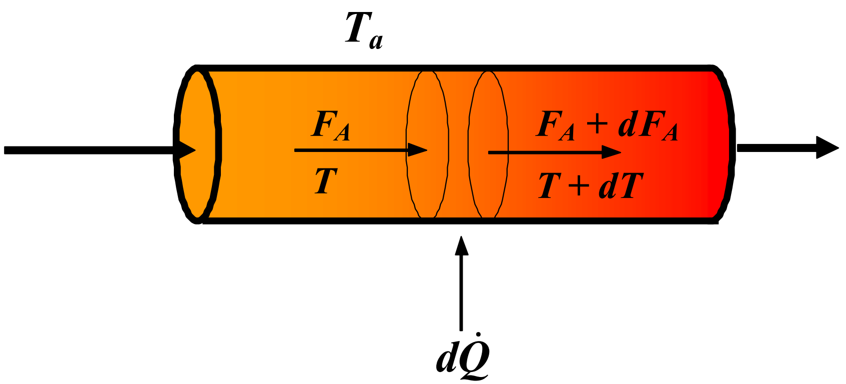

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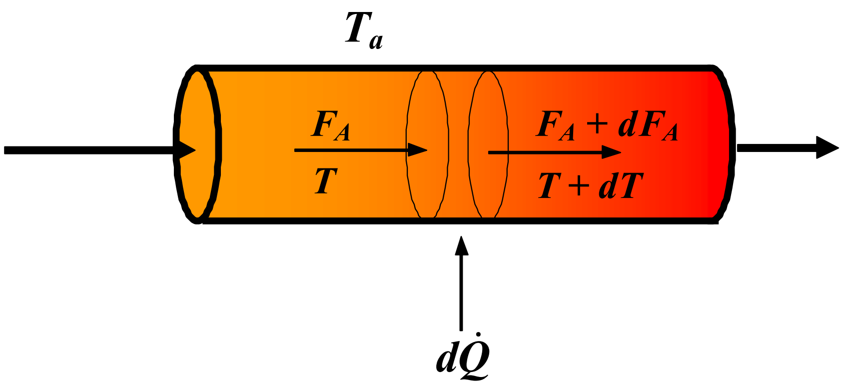

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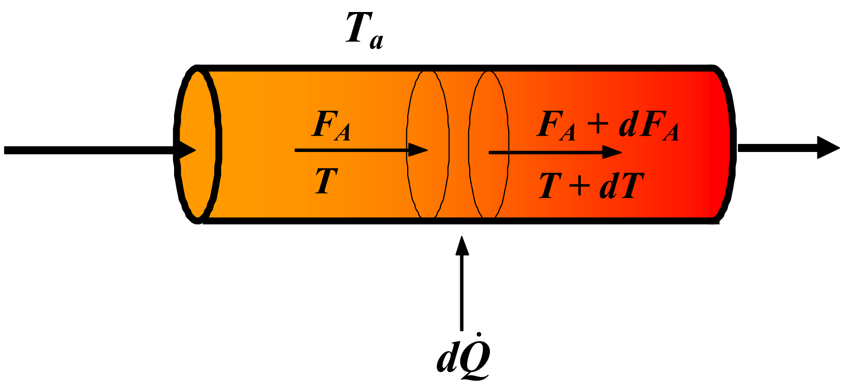

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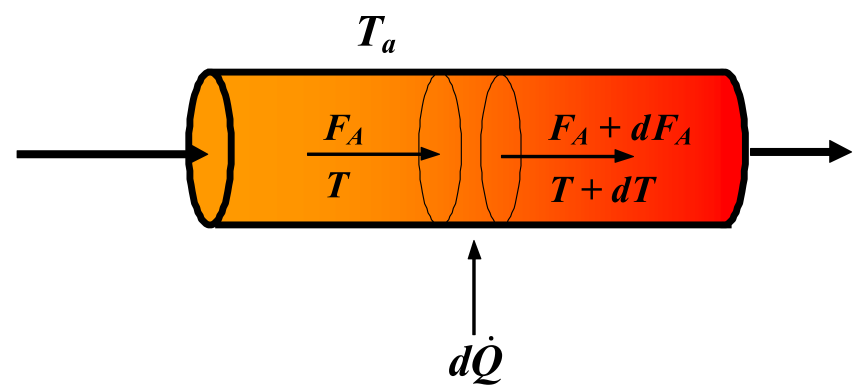

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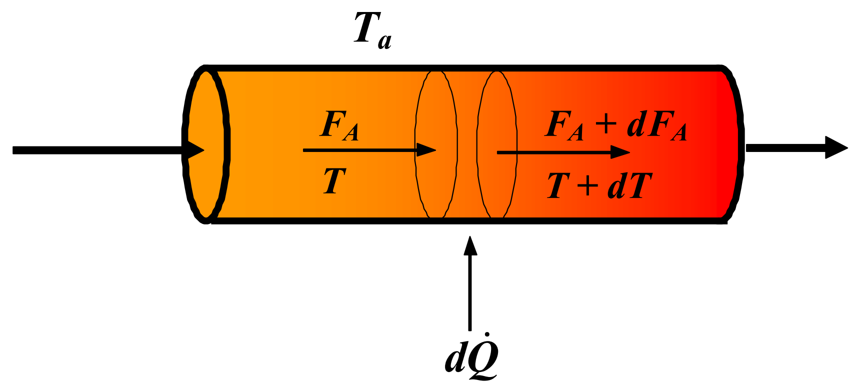

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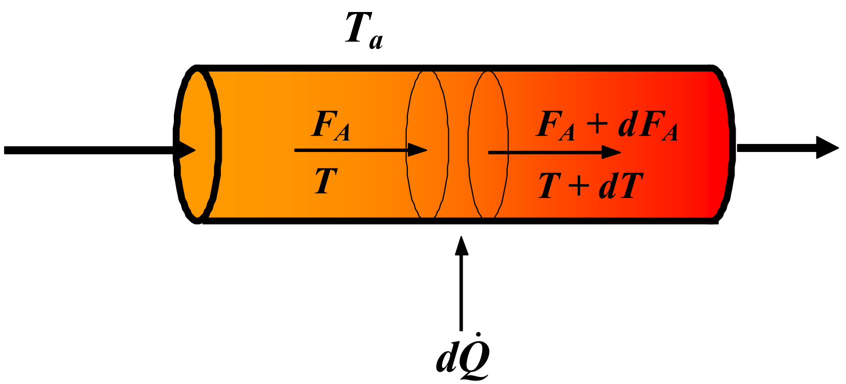

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Similarly to the mole balance, the energy balanced is performed on aelemental volume dV

$$d\dot{Q} + \sum_i F_i\,H_i - \sum_i (F_i + dF_i)(H_i + dH_i) = 0$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i dH_i + H_i dF_i + dH_i dF_i \right) = 0$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i dH_i + H_i dF_i + dH_i dF_i \right) = 0$$

$$d\dot{Q} + F_A H_A + F_B H_B + F_C H_C + F_D H_D - F_A H_A - F_A dH_A - H_A dF_A -$$
$$- dH_A dF_A - F_B H_B - F_B dH_B - H_B dF_B - dH_B dF_B - F_C H_C - F_C dH_C -$$
$$- H_C dF_C - dH_C dF_C - F_D H_D - F_D dH_D - H_D dF_D - dH_D dF_D = 0$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$\boxed{d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i\, dH_i + H_i\, dF_i + dH_i\, dF_i\right) = 0}$$

$$d\dot{Q} + \cancel{F_A H_A} + F_B H_B + F_C H_C + F_D H_D - \cancel{F_A H_A} - F_A\, dH_A - H_A\, dF_A -$$
$$- dH_A\, dF_A - F_B H_B - F_B\, dH_B - H_B\, dF_B - dH_B\, dF_B - F_C H_C - F_C\, dH_C -$$
$$- H_C\, dF_C - dH_C\, dF_C - F_D H_D - F_D\, dH_D - H_D\, dF_D - dH_D\, dF_D = 0$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i dH_i + H_i dF_i + dH_i dF_i \right) = 0$$

$$d\dot{Q} + \cancel{F_A H_A} + \cancel{F_B H_B} + F_C H_C + F_D H_D - \cancel{F_A H_A} - F_A dH_A - H_A dF_A -$$
$$- dH_A dF_A - \cancel{F_B H_B} - F_B dH_B - H_B dF_B - dH_B dF_B - F_C H_C - F_C dH_C -$$
$$- H_C dF_C - dH_C dF_C - F_D H_D - F_D dH_D - H_D dF_D - dH_D dF_D = 0$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i dH_i + H_i dF_i + dH_i dF_i \right) = 0$$

$$d\dot{Q} + \cancel{F_A H_A} + \cancel{F_B H_B} + \cancel{F_C H_C} + F_D H_D - \cancel{F_A H_A} - F_A dH_A - H_A dF_A -$$
$$- dH_A dF_A - \cancel{F_B H_B} - F_B dH_B - H_B dF_B - dH_B dF_B - \cancel{F_C H_C} - F_C dH_C -$$
$$- H_C dF_C - dH_C dF_C - F_D H_D - F_D dH_D - H_D dF_D - dH_D dF_D = 0$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$\boxed{d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i\, dH_i + H_i\, dF_i + dH_i\, dF_i\right) = 0}$$

$$d\dot{Q} + \cancel{F_A H_A} + \cancel{F_B H_B} + \cancel{F_C H_C} + F_D H_D - \cancel{F_A H_A} - F_A\, dH_A - H_A\, dF_A -$$
$$- dH_A\, dF_A - \cancel{F_B H_B} - F_B\, dH_B - H_B\, dF_B - dH_B\, dF_B - \cancel{F_C H_C} - F_C\, dH_C -$$
$$- H_C\, dF_C - dH_C\, dF_C - F_D H_D - F_D\, dH_D - H_D\, dF_D - dH_D\, dF_D = 0$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i\, dH_i + H_i\, dF_i + dH_i\, dF_i \right) = 0$$

$$d\dot{Q} + \cancel{F_A H_A} + \cancel{F_B H_B} + \cancel{F_C H_C} + F_D H_D - \cancel{F_A H_A} - F_A\, dH_A - H_A\, dF_A -$$
$$- dH_A\, dF_A - \cancel{F_B H_B} - F_B\, dH_B - H_B\, dF_B - dH_B\, dF_B - \cancel{F_C H_C} - F_C\, dH_C -$$
$$- H_C\, dF_C - dH_C\, dF_C - F_D H_D - F_D\, dH_D - H_D\, dF_D - dH_D\, dF_D = 0$$

$$A + \frac{b}{a}B \longrightarrow \frac{c}{a}C + \frac{d}{a}D$$

$$d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i dH_i + H_i dF_i + dH_i dF_i \right) = 0$$

$$d\dot{Q} + \cancel{F_A H_A} + \cancel{F_B H_B} + \cancel{F_C H_C} + \cancel{F_D H_D} - \cancel{F_A H_A} - F_A dH_A - H_A dF_A -$$
$$- dH_A dF_A - \cancel{F_B H_B} - F_B dH_B - H_B dF_B - dH_B dF_B - \cancel{F_C H_C} - F_C dH_C -$$
$$- H_C dF_C - dH_C dF_C - \cancel{F_D H_D} - F_D dH_D - H_D dF_D - dH_D dF_D = 0$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$\boxed{d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i\, dH_i + H_i\, dF_i + dH_i\, dF_i\right) = 0}$$

$$d\dot{Q} + \cancel{F_A H_A} + \cancel{F_B H_B} + \cancel{F_C H_C} + \cancel{F_D H_D} - \cancel{F_A H_A} - F_A\, dH_A - H_A\, dF_A -$$
$$- dH_A\, dF_A - \cancel{F_B H_B} - F_B\, dH_B - H_B\, dF_B - dH_B\, dF_B - \cancel{F_C H_C} - F_C\, dH_C -$$
$$- H_C\, dF_C - dH_C\, dF_C - \cancel{F_D H_D} - F_D\, dH_D - H_D\, dF_D - dH_D\, dF_D = 0$$

$$\therefore \quad d\dot{Q} - F_A\, dH_A - H_A\, dF_A - dH_A\, dF_A - F_B\, dH_B - H_B\, dF_B - dH_B\, dF_B -$$
$$- F_C\, dH_C - H_C\, dF_C - dH_C\, dF_C - F_D\, dH_D - H_D\, dF_D - dH_D\, dF_D = 0$$

$$A + \frac{b}{a}B \longrightarrow \frac{c}{a}C + \frac{d}{a}D$$

$$d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i dH_i + H_i dF_i + dH_i dF_i\right) = 0$$

$$d\dot{Q} + \cancel{F_A H_A} + \cancel{F_B H_B} + \cancel{F_C H_C} + \cancel{F_D H_D} - \cancel{F_A H_A} - F_A dH_A - H_A dF_A -$$
$$- dH_A dF_A - \cancel{F_B H_B} - F_B dH_B - H_B dF_B - dH_B dF_B - \cancel{F_C H_C} - F_C dH_C -$$
$$- H_C dF_C - dH_C dF_C - \cancel{F_D H_D} - F_D dH_D - H_D dF_D - dH_D dF_D = 0$$

$$\therefore \quad d\dot{Q} - F_A dH_A - H_A dF_A - dH_A dF_A - F_B dH_B - H_B dF_B - dH_B dF_B -$$
$$- F_C dH_C - H_C dF_C - dH_C dF_C - F_D dH_D - H_D dF_D - dH_D dF_D = 0$$

$$\therefore \quad d\dot{Q} - F_{A0}(1-X)dH_A + H_A F_{A0}\, dX + dH_A F_{A0}\, dX - F_{A0}\left(\theta_B - \frac{b}{a}X\right)dH_B +$$
$$+ H_B F_{A0}\frac{b}{a}dX + dH_B F_{A0}\frac{b}{a}dX - F_{A0}\left(\theta_C + \frac{c}{a}X\right)dH_C - H_C F_{A0}\frac{c}{a}dX -$$
$$- dH_C F_{A0}\frac{c}{a}dX - F_{A0}\left(\theta_D + \frac{d}{a}X\right)dH_D - H_D F_{A0}\frac{d}{a}dX - dH_D F_{A0}\frac{d}{a}dX = 0$$

$$\mathbf{A} + \frac{b}{a}\mathbf{B} \longrightarrow \frac{c}{a}\mathbf{C} + \frac{d}{a}\mathbf{D}$$

$$d\dot{Q} + \sum_i F_i H_i - \sum_i \left(F_i H_i + F_i dH_i + H_i dF_i + dH_i dF_i \right) = 0$$

$$d\dot{Q} + \cancel{F_A H_A} + \cancel{F_B H_B} + \cancel{F_C H_C} + \cancel{F_D H_D} - \cancel{F_A H_A} - F_A dH_A - H_A dF_A - dH_A dF_A - \cancel{F_B H_B} - F_B dH_B - H_B dF_B - dH_B dF_B - \cancel{F_C H_C} - F_C dH_C - H_C dF_C - dH_C dF_C - \cancel{F_D H_D} - F_D dH_D - H_D dF_D - dH_D dF_D = 0$$

$$\therefore \quad d\dot{Q} - F_A dH_A - H_A dF_A - dH_A dF_A - F_B dH_B - H_B dF_B - dH_B dF_B - F_C dH_C - H_C dF_C - dH_C dF_C - F_D dH_D - H_D dF_D - dH_D dF_D = 0$$

$$\therefore \quad d\dot{Q} - F_{A0}(1 - X) dH_A + H_A F_{A0} dX + dH_A F_{A0} dX - F_{A0}\left(\theta_B - \frac{b}{a}X\right) dH_B + H_B F_{A0}\frac{b}{a} dX + dH_B F_{A0}\frac{b}{a} dX - F_{A0}\left(\theta_C + \frac{c}{a}X\right) dH_C - H_C F_{A0}\frac{c}{a} dX - dH_C F_{A0}\frac{c}{a} dX - F_{A0}\left(\theta_D + \frac{d}{a}X\right) dH_D - H_D F_{A0}\frac{d}{a} dX - dH_D F_{A0}\frac{d}{a} dX = 0$$

$$d\dot{Q} - F_{A0}(1-X)dH_A + H_A F_{A0}\,dX + dH_A\,F_{A0}\,dX - F_{A0}\left(\theta_B - \frac{b}{a}X\right)dH_B +$$

$$+ H_B\,F_{A0}\frac{b}{a}dX + dH_B\,F_{A0}\frac{b}{a}dX - F_{A0}\left(\theta_C + \frac{c}{a}X\right)dH_C - H_C\,F_{A0}\frac{c}{a}dX -$$

$$- dH_C\,F_{A0}\frac{c}{a}dX - F_{A0}\left(\theta_D + \frac{d}{a}X\right)dH_D - H_D\,F_{A0}\frac{d}{a}dX - dH_D\,F_{A0}\frac{d}{a}dX = 0$$

$$d\dot{Q} - F_{A0}(1-X)dH_A + H_A F_{A0}\,dX + dH_A\,F_{A0}\,dX - F_{A0}\left(\theta_B - \frac{b}{a}X\right)dH_B +$$

$$+ H_B\,F_{A0}\frac{b}{a}dX + dH_B\,F_{A0}\frac{b}{a}dX - F_{A0}\left(\theta_C + \frac{c}{a}X\right)dH_C - H_C\,F_{A0}\frac{c}{a}dX -$$

$$- dH_C\,F_{A0}\frac{c}{a}dX - F_{A0}\left(\theta_D + \frac{d}{a}X\right)dH_D - H_D\,F_{A0}\frac{d}{a}dX - dH_D\,F_{A0}\frac{d}{a}dX = 0$$

$$d\dot{Q} = U\,a\left(T_a - T\right)dV$$

$$d\dot{Q} - F_{A0}(1-X)dH_A + H_A F_{A0}\,dX + dH_A\,F_{A0}\,dX - F_{A0}\left(\theta_B - \frac{b}{a}X\right)dH_B +$$

$$+ H_B\,F_{A0}\frac{b}{a}dX + dH_B\,F_{A0}\frac{b}{a}dX - F_{A0}\left(\theta_C + \frac{c}{a}X\right)dH_C - H_C\,F_{A0}\frac{c}{a}dX -$$

$$- dH_C\,F_{A0}\frac{c}{a}dX - F_{A0}\left(\theta_D + \frac{d}{a}X\right)dH_D - H_D\,F_{A0}\frac{d}{a}dX - dH_D\,F_{A0}\frac{d}{a}dX = 0$$

$$d\dot{Q} = U\,a(T_a - T)dV$$

$$dH_i = Cp_i\,dT$$

$$d\dot{Q} - F_{A0}(1-X)dH_A + H_A F_{A0}\,dX + dH_A F_{A0}\,dX - F_{A0}\left(\theta_B - \frac{b}{a}X\right)dH_B +$$

$$+ H_B F_{A0}\frac{b}{a}dX + dH_B F_{A0}\frac{b}{a}dX - F_{A0}\left(\theta_C + \frac{c}{a}X\right)dH_C - H_C F_{A0}\frac{c}{a}dX -$$

$$- dH_C F_{A0}\frac{c}{a}dX - F_{A0}\left(\theta_D + \frac{d}{a}X\right)dH_D - H_D F_{A0}\frac{d}{a}dX - dH_D F_{A0}\frac{d}{a}dX = 0$$

$$d\dot{Q} = U\,a(T_a - T)dV \qquad\qquad dH_i = Cp_i\,dT$$

$$U\,a(T_a - T)dV - (Cp_A + \theta_B Cp_B + \theta_C Cp_C + \theta_D Cp_D + \theta_I Cp_I)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \left(-H_A - \frac{b}{a}H_B + \frac{c}{a}H_C + \frac{d}{a}H_D\right)F_{A0}\,dX$$

$$-\left(-dH_A - \frac{b}{a}dH_B + \frac{c}{a}dH_C + \frac{d}{a}dH_D\right)F_{A0}\,dX = 0$$

$$d\dot{Q} - F_{A0}(1-X)dH_A + H_A F_{A0}\,dX + dH_A\,F_{A0}\,dX - F_{A0}\left(\theta_B - \frac{b}{a}X\right)dH_B +$$

$$+ H_B\,F_{A0}\frac{b}{a}dX + dH_B\,F_{A0}\frac{b}{a}dX - F_{A0}\left(\theta_C + \frac{c}{a}X\right)dH_C - H_C\,F_{A0}\frac{c}{a}dX -$$

$$- dH_C\,F_{A0}\frac{c}{a}dX - F_{A0}\left(\theta_D + \frac{d}{a}X\right)dH_D - H_D\,F_{A0}\frac{d}{a}dX - dH_D\,F_{A0}\frac{d}{a}dX = 0$$

$$d\dot{Q} = U\,a\left(T_a - T\right)dV \qquad\qquad dH_i = Cp_i\,dT$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \left(-H_A - \frac{b}{a}H_B + \frac{c}{a}H_C + \frac{d}{a}H_D\right)F_{A0}\,dX$$

$$-\left(-dH_A - \frac{b}{a}dH_B + \frac{c}{a}dH_C + \frac{d}{a}dH_D\right)F_{A0}\,dX = 0$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX - d\left(\Delta H_R\right)F_{A0}\,dX = 0$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX - d\left(\Delta H_R\right)F_{A0}\,dX = 0$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX - d\left(\Delta H_R\right)F_{A0}\,dX = 0$$

$$-\,d\left(\Delta H_R\right)F_{A0}\,dX$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX - d\left(\Delta H_R\right)F_{A0}\,dX = 0$$

$$\cancel{-\,d\left(\Delta H_R\right)F_{A0}\,dX}$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX - d\left(\Delta H_R\right)F_{A0}\,dX = 0$$

$$\cancel{-\,d\left(\Delta H_R\right)F_{A0}\,dX}$$

$$U\,a\left(T_a - T\right)dV - \sum_i \theta_i\,Cp_i\,F_{A0}\,dT - \sum_i \upsilon_i\,Cp_i\,F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX = 0$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX - d\left(\Delta H_R\right)F_{A0}\,dX = 0$$

$$\cancel{-\,d\left(\Delta H_R\right)F_{A0}\,dX}$$

$$U\,a\left(T_a - T\right)dV - \sum_i \theta_i\,Cp_i\,F_{A0}\,dT - \sum_i \upsilon_i\,Cp_i\,F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX = 0$$

$$\therefore U\,a\left(T_a - T\right)dV - \left[F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)\right]dT - \Delta H_R\,F_{A0}\,dX = 0$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX - d\left(\Delta H_R\right)F_{A0}\,dX = 0$$

$$\cancel{-\,d\left(\Delta H_R\right)F_{A0}\,dX}$$

$$U\,a\left(T_a - T\right)dV - \sum_i \theta_i\,Cp_i\,F_{A0}\,dT - \sum_i \upsilon_i\,Cp_i\,F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX = 0$$

$$\therefore U\,a\left(T_a - T\right)dV - \left[F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)\right]dT - \Delta H_R\,F_{A0}\,dX = 0$$

$$\therefore U\,a\left(T_a - T\right) - \left[F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)\right]\frac{dT}{dV} - \Delta H_R\,F_{A0}\,\frac{dX}{dV} = 0$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX - d\left(\Delta H_R\right)F_{A0}\,dX = 0$$

$$\cancel{-\,d\left(\Delta H_R\right)F_{A0}\,dX}$$

$$U\,a\left(T_a - T\right)dV - \sum_i \theta_i\,Cp_i\,F_{A0}\,dT - \sum_i \upsilon_i\,Cp_i\,F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX = 0$$

$$\therefore U\,a\left(T_a - T\right)dV - \left[F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)\right]dT - \Delta H_R\,F_{A0}\,dX = 0$$

$$\therefore U\,a\left(T_a - T\right) - \left[F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)\right]\frac{dT}{dV} - \Delta H_R\,F_{A0}\,\frac{dX}{dV} = 0$$

$$U\,a\left(T_a - T\right) - \left[F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)\right]\frac{dT}{dV} - \Delta H_R\,\underbrace{\left(-r_A\right)}_{F_{A0}\frac{dX}{dV}} = 0$$

$$U\,a\left(T_a - T\right)dV - \left(Cp_A + \theta_B\,Cp_B + \theta_C\,Cp_C + \theta_D\,Cp_D + \theta_I\,Cp_I\right)F_{A0}\,dT -$$

$$-\left(-Cp_A - \frac{b}{a}Cp_B + \frac{c}{a}Cp_C + \frac{d}{a}Cp_D\right)F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX - d\left(\Delta H_R\right)F_{A0}\,dX = 0$$

$$\cancel{-\,d\left(\Delta H_R\right)F_{A0}\,dX}$$

$$U\,a\left(T_a - T\right)dV - \sum_i \theta_i\,Cp_i\,F_{A0}\,dT - \sum_i \upsilon_i\,Cp_i\,F_{A0}\,X\,dT - \Delta H_R\,F_{A0}\,dX = 0$$

$$\therefore U\,a\left(T_a - T\right)dV - \left[F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)\right]dT - \Delta H_R\,F_{A0}\,dX = 0$$

$$\therefore U\,a\left(T_a - T\right) - \left[F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)\right]\frac{dT}{dV} - \Delta H_R\,F_{A0}\,\frac{dX}{dV} = 0$$

$$U\,a\left(T_a - T\right) - \left[F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)\right]\frac{dT}{dV} - \Delta H_R\,\underbrace{\left(-r_A\right)}_{F_{A0}\frac{dX}{dV}} = 0$$

$$\boxed{\therefore \quad \frac{dT}{dV} = \frac{U\,a\left(T_a - T\right) + \left[-\Delta H_R\left(T\right)\right]\left(-r_A\right)}{F_{A0}\left(\sum_i \theta_i\,Cp_i + X\sum_i \upsilon_i\,Cp_i\right)}}$$

$$\begin{cases} \dfrac{dT}{dV} = \dfrac{U\,a\left(T_a - T\right) + \left[-\Delta H_R(T)\right]\left(-r_A\right)}{F_{A0}\left(\sum_i \theta_i\, Cp_i + X \sum_i \upsilon_i\, Cp_i\right)} \\ \\ \dfrac{dX}{dV} = \dfrac{\left(-r_A\right)}{F_{A0}} \end{cases}$$

A reacção de 1ª ordem, em fase líquida, A → B, é conduzida num reactor PFR de 5 mm de diâmetro interno e 50 cm de comprimento. A alimentação ao reactor, a um caudal volumétrico de 0.004 dm^3/min., é constituída por A(11.1 mol%) e por um inerte I .

The liquid phase 1st order reaction A→B is carried out in a 50 cm lemght by 5 mm cros-section diameter. A (11,1 mole %) and an inert I are fed to the reactor at a volumetric flow rate of 0.004 dm3/min.

k(300 K) = 0.4 min^{-1}; ΔH_R = -22.5 kcal/mol; E = 10 kcal/mol;
Cp_A = Cp_B = 8 cal/mol.K; Cp_I = 6 cal/mol.K; R = 1.987 cal mol-1 K-1.
U = 9x10-5 cal m-2 min-1 K-1

$$\begin{cases} \dfrac{dT}{dV} = \dfrac{U\,a\left(T_a - T\right) + \left[-\Delta H_R(T)\right] k\left(T_R\right) e^{-\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_R}\right)}\left(1 - X\right)}{v_0\left(Cp_A + \theta_I\,Cp_I + X\left(-Cp_A + Cp_B\right)\right)} \\[2em] \dfrac{dX}{dV} = \dfrac{k\left(T_R\right) e^{-\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_R}\right)}\left(1 - X\right)}{v_0} \end{cases}$$

$$\begin{cases} \dfrac{dT}{dV} = \dfrac{U\,a\left(T_a - T\right) + \left[-\Delta H_R\left(T\right)\right]k\left(T_R\right)e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{T_R}\right)}\left(1-X\right)}{v_0\left(Cp_A + \theta_I\,Cp_I + X\left(-Cp_A + Cp_B\right)\right)} \\[2em] \dfrac{dX}{dV} = \dfrac{k\left(T_R\right)e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{T_R}\right)}\left(1-X\right)}{v_0} \end{cases}$$

$$a = \frac{2\pi\,r\,L}{\pi\,r^2\,L} = \frac{2}{r} = \frac{2}{\frac{d}{2}} = \frac{4}{d}$$

$$\begin{cases} \dfrac{dT}{dV} = \dfrac{U\,a\left(T_a - T\right) + \left[-\Delta H_R(T)\right]k\left(T_R\right)e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{T_R}\right)}\left(1-X\right)}{v_0\left(Cp_A + \theta_I\,Cp_I + X\left(-Cp_A + Cp_B\right)\right)} \\ \\ \dfrac{dX}{dV} = \dfrac{k\left(T_R\right)e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{T_R}\right)}\left(1-X\right)}{v_0} \end{cases}$$

$$a = \frac{2\pi r L}{\pi r^2 L} = \frac{2}{r} = \frac{2}{\frac{d}{2}} = \frac{4}{d}$$

$$\theta_I = \frac{F_{I0}}{F_{A0}} = \frac{y_{I0}}{y_{A0}} = \frac{1-0.111}{0.111} = 8.01$$

$$\begin{cases} \dfrac{dT}{dV} = \dfrac{U\,a\left(T_a - T\right) + \left[-\Delta H_R(T)\right] k(T_R) e^{-\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_R}\right)} (1 - X)}{v_0 \left(Cp_A + \theta_I\, Cp_I + X\left(-Cp_A + Cp_B\right)\right)} \\[2em] \dfrac{dX}{dV} = \dfrac{k(T_R) e^{-\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_R}\right)} (1 - X)}{v_0} \end{cases}$$

$$a = \frac{2\pi r L}{\pi r^2 L} = \frac{2}{r} = \frac{2}{\frac{d}{2}} = \frac{4}{d}$$

$$\theta_I = \frac{F_{I0}}{F_{A0}} = \frac{y_{I0}}{y_{A0}} = \frac{1 - 0.111}{0.111} = 8.01$$

$$\begin{cases} \dfrac{dT}{A_c dz} = \dfrac{U\,a\left(T_a - T\right) + \left[-\Delta H_R^0(T_R)\right] k(T_R) e^{-\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_R}\right)} (1 - X)}{v_0 \left(Cp_A + \theta_I\, Cp_I\right)} \\[2em] \dfrac{dX}{A_c dz} = \dfrac{k(T_R) e^{-\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_R}\right)} (1 - X)}{v_0} \end{cases}$$

$$
\begin{cases}
\dfrac{dT}{dz} = \dfrac{U\,a\left(T_a - T\right) + \left[-\Delta H_R^0\left(T_R\right)\right] k\left(T_R\right) e^{-\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_R}\right)} \left(1 - X\right)}{v_0\left(Cp_A + \theta_I\, Cp_I\right)} A_c \\[2em]
\dfrac{dX}{dz} = \dfrac{k\left(T_R\right) e^{-\frac{E}{R}\left(\frac{1}{T} - \frac{1}{T_R}\right)} \left(1 - X\right)}{v_0} A_c
\end{cases}
$$

$$
\left\{
\begin{aligned}
\frac{dT}{dz} &= \frac{U\,a\left(T_a - T\right) + \left[-\Delta H_R^0\left(T_R\right)\right] k\left(T_R\right) e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{T_R}\right)}\left(1-X\right)}{v_0\left(Cp_A + \theta_I\,Cp_I\right)} A_c \\
\frac{dX}{dz} &= \frac{k\left(T_R\right) e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{T_R}\right)}\left(1-X\right)}{v_0} A_c
\end{aligned}
\right.
$$

Método de Euler:

Euler method

$$\begin{cases} \dfrac{dT}{dz} = \dfrac{U\,a\left(T_a - T\right) + \left[-\Delta H_R^0\left(T_R\right)\right] k\left(T_R\right) e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{T_R}\right)}\left(1-X\right)}{v_0\left(Cp_A + \theta_I\,Cp_I\right)} A_c \\ \\ \dfrac{dX}{dz} = \dfrac{k\left(T_R\right) e^{-\frac{E}{R}\left(\frac{1}{T}-\frac{1}{T_R}\right)}\left(1-X\right)}{v_0} A_c \end{cases}$$

Método de Euler:

Euler method

$$\begin{cases} T_{i+1} = T_i + \dfrac{800\,U\left(298 - T_i\right) + 22500 \times k\left(T_R\right) e^{-\frac{10000}{1.987}\left(\frac{1}{T_i}-\frac{1}{300}\right)}\left(1-X_i\right)}{v_0\left(8 + 8.01 \times 6\right)} \pi \dfrac{d^2}{4} \Delta z \\ \\ X_{i+1} = X_i + \dfrac{k\left(T_R\right) e^{-\frac{10000}{1.987}\left(\frac{1}{T_i}-\frac{1}{300}\right)}\left(1-X_i\right)}{v_0} \pi \dfrac{d^2}{4} \Delta z \end{cases}$$

Folha de Cálculo