Problem 1-10 Second-order reactions [*V*], temperature dependence

The rate constant of the second-order reaction in solution, described by stoichiometry $\mathbf{3A \rightarrow B}$, has the value k_c = 0.0967 dm^3 mol^{-1} min^{-1} at 380 K and its activation energy is E^* = 74 kJ mol^{-1}. What time is needed to decompose 28 % of the reactant A at the temperature of 420 K, if its initial concentration is c_{A0} = 0.023 mol dm^{-3}.

[τ = 6.262 min]

Solution:

$\mathbf{3A \rightarrow B}$

$c_{A0} = 0.023$ mol dm^{-3}

$$\frac{\mathrm{d}c_A}{(-3)\,\mathrm{d}\tau} = k_c \cdot c_A^2 \quad (\nu_A = -3)$$

$$\frac{1}{c_A} - \frac{1}{c_{A0}} = 3k_c \cdot \tau$$

$c_A = c_{A0} - x$

$x = c_{A0} - c_A = 0.28\ c_{A0}$

$c_A = 0.72\ c_{A0}$

$$\ln\frac{k_{c2}}{k_{c1}} = \frac{E^*}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) = \frac{74000}{8.314}\cdot\left(\frac{1}{380} - \frac{1}{420}\right) = 2.23074$$

$k_{c2} = 9.3067 \cdot 0.0967 = 0.9$ dm^3 mol^{-1} min^{-1}

$$\tau = \frac{1}{3k_2}\cdot\left(\frac{1}{c_A} - \frac{1}{c_{A0}}\right) = \frac{1}{3\cdot 0.9}\cdot\left(\frac{1}{0.72\cdot 0.023} - \frac{1}{0.023}\right) = 6.26_{23}\ \text{min}$$