Problem 1-08 Second-order reactions[*V*]

An unidirectional reaction between ideal gases,

$$A(g) = R(g) + \tfrac{1}{2}\,S(g),$$

takes place in the reactor of constant volume at the temperature of 337 K. The rate constant is $k_c = 0.035\ \mathrm{dm^3\,mol^{-1}\,min^{-1}}$. What will be the concentration of A ($\mathrm{mol\,dm^{-3}}$) in the reaction mixture if the reactor, initially filled by pure A to a pressure of 109 kPa, was tempered for one hour to a temperature of 337 K?

[$c_A = 0.03596\ \mathrm{mol\,dm^{-3}}$]

Solution :

$k_c = 0.035\ \mathrm{dm^3\,mol^{-1}\,min^{-1}}$

$\tau = 1\ \mathrm{h} = 60\ \mathrm{min}$

$T = 337\ \mathrm{K}$, $p = 109\ \mathrm{kPa}$

$pV = n_{A0}\,\boldsymbol{R}T$

$$c_{A0} = \frac{n_{A0}}{V} = \frac{p}{\boldsymbol{R}T} = \frac{109\cdot 10^3}{8.314\cdot 337} = 38.9\ \mathrm{mol\,m^{-3}} = 0.0389\ \mathrm{mol\,dm^{-3}}$$

Reaction order from the dimension of the rate constant:

$\mathrm{dm^3\,mol^{-1}\,min^{-1}} = (\mathrm{mol\,dm^{-3}})^{-1}\,\mathrm{min^{-1}}$

$(\text{concentration})^{-1}\,\text{time}^{-1} = (\text{concentration})^{(1-n)}\,\text{time}^{-1}$

$(1-n) = -1 \quad \Rightarrow \quad n = 2 \Rightarrow$ second-order reaction

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

The concentration of remaining A:

$$\frac{1}{c_A} = k_c\cdot\tau + \frac{1}{c_{A0}} = 0.035\cdot 60 + \frac{1}{0.0389} = 27.8069$$

$c_A = 0.03596\ \mathrm{mol\,dm^{-3}}$