The gas phase decomposition of dimethyl ether follows first order kinetics,

$$CH_3OCH_{3(g)} \rightarrow CH_{4(g)} + H_{2(g)} + CO_{(g)}$$

The reaction is carried out in a constant volume container at $500^{\circ}C$ and has a half-life of 14.5 minutes. Initially, only dimethyl ether is present at a pressure of 0.40 atm. Which of the following is the total pressure of the system after 12 minutes? Assume ideal gas behaviour.

(A) 0.575 atm (B) 0.75 atm (C) 0.925 atm (D) 0.225 atm

Solution

$$\underset{\substack{(t=0)P_0 \\ (t=12\min.)P_0-P}}{CH_3OCH_{3(g)}} \rightarrow \underset{\substack{0 \\ P}}{CH_{4(g)}} + \underset{\substack{0 \\ P}}{H_{2(g)}} + \underset{\substack{0 \\ P}}{CO_{(g)}}$$

[$P \propto n$ at constant V, T and therefore pressure has been used like moles in the above equation.]

For 1st order reaction, $k = \frac{2.303}{t}\log\frac{a}{a-x} = \frac{2.303}{t}\log\frac{P_0}{P_0-P}$

$$\therefore \frac{0.693}{14.5} = \frac{2.303}{12}\log\frac{0.40}{0.40-P}$$

$$\Rightarrow \frac{18}{14.5\times 5} \approx \log\frac{0.40}{0.40-P}\left[\because \frac{2.303}{0.693} \approx \frac{10}{3}\right]$$

$$\therefore P \approx 0.175atm$$

Total pressure after 12 min. = $P_0 - P + P + P + P = P_0 + 2P = 0.40 + 2 \times 0.175 = 0.75$ atm

Hence, (B)