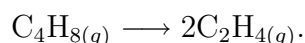


Chemistry 192  
Recitation Section Problems  
April 16, 2018  
Solutions

1a. Cyclobutane ( $C_4H_8$ ) decomposes to form ethylene ( $C_2H_4$ ) when heated according to the balanced reaction



At time  $t = 0$  a reaction vessel is filled with pure cyclobutane gas, and the volume and temperature are kept constant. The reaction is known to be first order with a rate constant  $k = 2.48 \times 10^{-4} \text{ s}^{-1}$ . Calculate the half life of the reactant.

**Answer:**

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{2.48 \times 10^{-4} \text{ s}^{-1}} = 2.79 \times 10^3 \text{ s}$$

1b. If the initial concentration of cyclobutane is  $4.00 \times 10^{-2} \text{ M}$ , calculate the time at which the concentration of cyclobutane is  $3.6 \times 10^{-2} \text{ M}$ .

**Answer:**

$$\begin{aligned} \ln \frac{[C_4H_8]_t}{[C_4H_8]_0} &= -kt \\ \ln \frac{3.6 \times 10^{-2}}{4.00 \times 10^{-2}} &= (-2.48 \times 10^{-4} \text{ s}^{-1})t \\ t &= 4.2 \times 10^2 \text{ s} \end{aligned}$$

1c. Calculate the time necessary for the concentration of the ethylene (the product) to reach  $1.00 \times 10^{-2} \text{ M}$ .

**Answer:**

At time  $t$  the concentration of ethylene is  $1.00 \times 10^{-2} \text{ M}$ . From the stoichiometry of the reaction, at time  $t$   $[C_4H_8]_t = 4.00 \times 10^{-2} \text{ M} - 0.500 \times 10^{-2} \text{ M} = 3.50 \times 10^{-2} \text{ M}$ . Then

$$\begin{aligned} \ln \frac{3.50 \times 10^{-2}}{4.00 \times 10^{-2}} &= (-2.48 \times 10^{-4} \text{ s}^{-1})t \\ t &= 5.38 \times 10^2 \text{ s} \end{aligned}$$

1d. Let  $P_0$  be the initial pressure in the reaction vessel. First predict whether the total pressure in the vessel must increase or decrease with increasing time. Then derive an expression for the total pressure as a function of  $P_0, k$  and the time  $t$ .

**Answer:**

Because 2 moles of ethylene are formed for every mole of cyclobutane that dissociates, the pressure must increase with time. Let  $n_0$  be the initial number of moles of cyclobutane introduced into the vessel. Then

	$n_{C_4H_8}$	$n_{C_2H_4}$
initial	$n_0$	0
change	$-\alpha n_0$	$2\alpha n_0$
final	$n_0(1 - \alpha)$	$2\alpha n_0$

$$n_{tot} = n_{C_4H_8} + n_{C_2H_4} = n_0(1 + \alpha)$$

$$P_0 = \frac{n_0 RT}{V}$$

$$P_{tot} = \frac{n_{tot} RT}{V} = \frac{n_0(1 + \alpha) RT}{V} = P_0(1 + \alpha)$$

Letting  $n$  be the number of moles of cyclobutane at time  $t$

$$n = n_0 e^{-kt}$$

$$n_0(1 - \alpha) = n_0 e^{-kt}$$

or

$$\alpha = 1 - e^{-kt}$$

$$P_{tot} = P_0(1 + \alpha) = P_0(2 - e^{-kt})$$

1e. If the initial pressure of cyclobutane is 1.00 bar, calculate the time required for the total pressure to be 1.50 bar.

**Answer:**

$$P_{tot} = P_0(2 - e^{-kt})$$

$$1.50 = 1.00(2 - e^{-kt})$$

$$e^{-2.48 \times 10^{-4} \text{ s}^{-1} t} = 0.50$$

$$-2.48 \times 10^{-4} \text{ s}^{-1} t = \ln(0.50)$$

$$t = -\frac{\ln(0.50)}{2.48 \times 10^{-4} \text{ s}^{-1}} = 2.8 \times 10^3 \text{ s}$$