Answer on Question #83277, Chemistry / General Chemistry

The reaction A (aq) -> B (aq) + C (aq) is a first-order reaction. The half-life of A (aq) is 92.3 s at 25.0°C and its half-life is 70.9 s at 45.0°C. What is its half-life (in s) at 65.0°C?

Solution

For first-order reaction:

$T_{1/2} = \frac{\ln 2}{k_1}$; where $T_{1/2}$ – the half-life, k_1 – reaction rate constant upon certain temperature.

Find k_1 and k_2 for the reaction at 25.0°C (298 K) and 45.0°C (318 K)

$k = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{T_{1/2}}$;

$k_1 = \frac{0.693}{92.3} = 7.51 \times 10^{-3}$ (s^{-1}) – reaction rate constant upon 298 K;

$k_2 = \frac{0.693}{70.9} = 9.77 \times 10^{-3}$ (s^{-1}) – reaction rate constant upon 318 K.

According to Arrhenius equation:

$k = A \times e^{-\frac{E_a}{RT}}$; where

k – reaction rate constant upon certain temperature;

A – Arrhenius constant or frequency factor;

E_a – activation energy;

R,T – gas constant and temperature.

After logarithmization the equation looks:

$\ln k = \ln A - \frac{E_a}{RT}$;

Mark lnA as X and E_a as Y, then

$\ln k = X - Y/RT$

$X = \ln k + Y/RT$

As X and Y are constants specific for the reaction and temperature independent, find them using the system of equations:

$$X = \ln (7.5 \times 10^{-3}) + \frac{Y}{8.314 \times 298} = -4.89 + \frac{Y}{2477.5}$$

$$X = \ln (9.8 \times 10^{-3}) + \frac{Y}{8.314 \times 318} = -4.63 + \frac{Y}{2643.9}$$

$$-4.89 + \frac{Y}{2477.5} = -4.63 + \frac{Y}{2643.9}$$

$\frac{Y}{2477.5} - \frac{Y}{2643.9} = -4.63 + 4.89 = 0.26$

$2643.9Y - 2477.5Y = 0.26 \times 2643.9 \times 2477.5$

$166.4Y = 1703068$

$Y = 10\ 234.8$

$X = -4.89 + \frac{10234.8}{2477.5} = -0.76$

Find k for the reaction upon 65.0°C (338 K)

$\ln k = -0.76 - \frac{10234.8}{8.314 \times 338}$

$\ln k = -0.76 - 3.64$

$\ln k = -4.4$

$k = e^{-4.4} = 1.22 \times 10^{-2}$

Find the half-life of A (aq) at 65.0°C:

$T_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{0.0122} =$ **56.8 (s)**

Answer

The half-life of A (aq) is **56.8 s** at 65.0°C