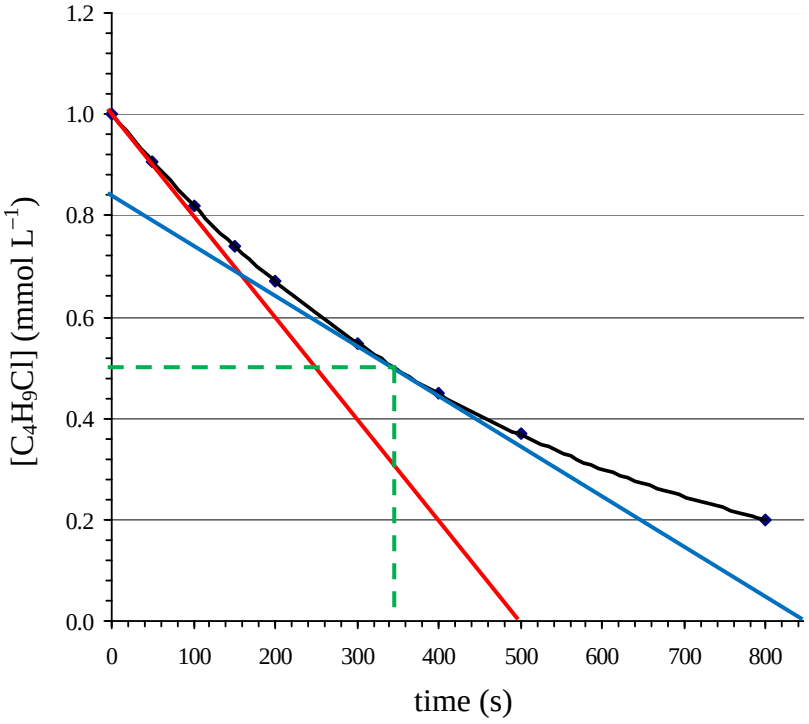
Marks 4

- The following chart shows the concentration of butyl chloride, C_4H_9Cl, as a function of time when it reacts with water according to the following equation:

$$C_4H_9Cl(aq) + H_2O(l) \rightarrow C_4H_9OH(aq) + H^+(aq) + Cl^-(aq)$$



Determine the instantaneous rate of reaction when $[C_4H_9Cl] = 1.0$ mmol L^{-1}.

The rate of the reaction at any point in time is given by:

$$\textbf{rate} = -\frac{\Delta[\mathbf{C_4H_9Cl}]}{\Delta t}$$

The rate when $[C_4H_9Cl] = 1.0$ mmol L^{-1} is given by the gradient of the curve at this point. This is shown by the red line above. Hence,

$$\textbf{rate} \approx -\frac{(0.0-1.0)\ \textbf{mmol L}^{-1}}{(500.-0.)\textbf{s}} = \textbf{0.0020 mmol L}^{-1}\ \textbf{s}^{-1}$$

Answer: **2.0×10^{-3} mmol L^{-1} s^{-1}**

Determine the instantaneous rate of reaction when $[C_4H_9Cl] = 0.5$ mmol L^{-1}.

The rate when $[C_4H_9Cl] = 0.5$ mmol L^{-1} is given by the gradient of the curve at this point. This is shown by the blue line above. Hence,

$$\textbf{rate} \approx -\frac{(0.00-0.84)\ \textbf{mmol L}^{-1}}{(840.\ -0.)\textbf{s}} = \textbf{0.001 mmol L}^{-1}\ \textbf{s}^{-1}$$

Answer: **1.0×10^{-3} mmol L^{-1} s^{-1}**

THIS QUESTION CONTINUES ON THE NEXT PAGE

What is the order of the reaction with respect to C_4H_9Cl?	**Marks 4**

From 2010-N-13, the rate of the reaction is:

rate = 2.0×10^{-3} mmol L^{-1} s^{-1} when $[C_4H_9Cl] = 1.0$ mmol L^{-1}

and

rate = 1.0×10^{-3} mmol L^{-1} s^{-1} when $[C_4H_9Cl] = 0.5$ mmol L^{-1}

Halving the concentration, halves the rate so the reaction is first order with respect to C_4H_9Cl.

Answer: **first order**

How long would be required for the concentration of C_4H_9Cl to reach 0.01 mmol L^{-1}?

From 2010-N-13, the time taken for the concentration to halve from its initial value of 1.0 mmol L^{-1} to 0.5 mmol L^{-1} is approximately 350 s. This is shown by the green dotted line on the figure in 2010-N-13.

The half life is ≈ 350 s. Hence, the rate constant is given by:

$$k = \ln(2) / t_{1/2} = \ln(2) / 350 \text{ s} = 0.0020 \text{ s}^{-1}$$

For a first order reaction, the concentration changes with time according to:

$$\ln[C_4H_9Cl] = \ln[C_4H_9Cl]_0 - kt$$

With $k = 0.0020$ s^{-1}, the time taken to reduce the concentration its starting value of $[C_4H_9Cl]_0 = 1.0$ mmol L^{-1} to $[C_4H_9Cl] = 0.01$ mmol L^{-1} can be found using:

$$\ln(0.01) = \ln(1.0) - 0.0020t \quad \text{so } t = 2300 \text{ s}$$

Answer: **2300 s**