Marks 5

- Phosgene is a toxic gas prepared by the reaction of carbon monoxide with chlorine:

$$CO(g) + Cl_2(g) \rightarrow COCl_2(g)$$

The following data were obtained in a kinetics study of its formation at 150 °C.

Experiment	initial [CO] (M)	initial [Cl_2] (M)	Initial rate ($M\ s^{-1}$)
1	1.00	0.100	1.29×10^{-29}
2	0.100	0.100	1.33×10^{-30}
3	0.100	1.00	1.30×10^{-29}
4	0.100	0.0100	1.32×10^{-31}

Determine the rate law for the reaction.

Between experiments (1) and (2), $[Cl_2]_{initial}$ is kept constant and $[CO]_{initial}$ is reduced by a factor of 10. The rate decreases by a factor of $\frac{1.29\times10^{-29}}{1.33\times10^{-30}} \sim 10$. Hence the reaction is first order with respect to CO.

Between experiments (1) and (3), $[Cl_2]$ is increased by a factor of 10 and $[CO]_{initial}$ is decreased by a factor of 10. The rate does not change. As this change in $[CO]_{initial}$ is known from above to increase the rate by a factor of 10, the change in $[Cl_2]_{initial}$ must be decreasing the rate by a factor of 10. Hence, the reaction is also first order with respect to Cl_2.

Hence, overall,

$$\textbf{rate} = k[CO][Cl_2]$$

Calculate the value of the rate constant at 150 °C.

Using experiment (1), when [CO] = 1.00 M and $[Cl_2]$ = 0.100 M, the rate is 1.29×10^{-29} M s^{-1}. Hence from the rate law:

$$1.29 \times 10^{-29}\ M\ s^{-1} = k \times (1.00\ M) \times (0.100\ M)$$

$$k = \frac{1.29\times10^{-29}\ M\ s^{-1}}{(1.00\ M)\times(0.100\ M)} = 1.29\times10^{-28}\ M^{-1}\ s^{-1}$$

Answer: $1.29 \times 10^{-28}\ M^{-1}\ s^{-1}$

Calculate the rate of appearance of phosgene when [CO] = $[Cl_2]$ = 1.3 M.

$$\text{rate} = k[CO][Cl_2] = (1.29 \times 10^{-28}\ M^{-1}\ s^{-1})\times(1.3\ M)\times(1.3\ M) = 2.2 \times 10^{-28}\ M\ s^{-1}$$

Answer: $2.2 \times 10^{-28}\ M\ s^{-1}$