CAIE Chemistry A-level

Topic 26 - Reaction Kinetics

(A level only)

Flashcards

What is meant by *rate of reaction*?

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The change in concentration of reactants or products over time.

How does concentration affect rate of reaction?

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Increasing the concentration increases the number of molecules per unit volume. This leads to more frequent collisions and hence a greater frequency of successful collisions.

This increases the rate of reaction.

What is a rate equation?

What is a rate equation?

For a reaction between A and B:

$$\text{Rate} = k[A]^m[B]^n$$

- *m* and *n* represent the orders with respect to each reactant.
- *k* is the rate constant.

What is linked by the rate constant?

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Rate of reaction and the concentrations of the reactants raised to their orders in the rate equation.

How do you work out the units of a rate constant?

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- Rearrange the rate equation to make *k* the subject.
- Substitute units into the equation.
- Cancel the common units to find the units for *k*.

Work out the units of the rate constant in the following equation: Rate = $k[A][B]^2$

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$$k = \frac{Rate}{[A][B]^2}$$

$$k = \frac{\cancel{mol\ dm^{-3}}\ s^{-1}}{\cancel{mol\ dm^{-3}} \times (mol\ dm^{-3})^2} = k = \frac{s^{-1}}{mol^2\ dm^{-6}}$$

$$k = dm^6\ mol^{-2}\ s^{-1}$$

How is the order of reaction used in the rate equation? What is meant by the overall order?

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- The order with respect to a reactant is the power to which the concentration of that reactant is raised to in the rate equation.
- Overall order = sum of the orders of each reactant in an equation.

How does the order with respect to a reactant affect rate?

How does the order with respect to a reactant affect rate?

- Zero order: if rate $\propto [A]^0$ then the rate of reaction is unaffected by changing [A].
- First order: if rate $\propto [A]^1$ then rate of reaction increases at the same rate as [A] increases.
- Second order: if rate $\propto [A]^2$ then rate will increase by the square of the factor [A] increases by.

Draw a rate-concentration graph for a zero order reactant

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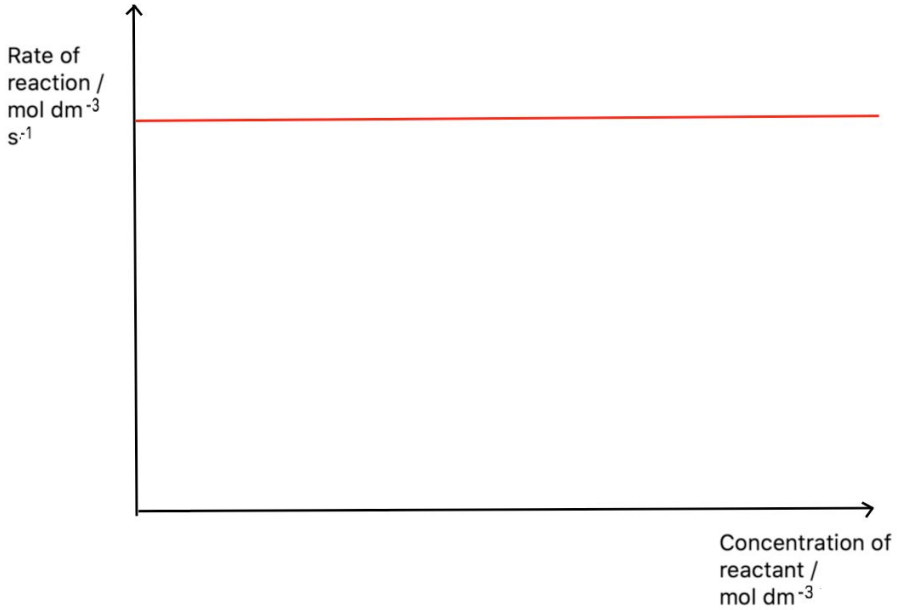

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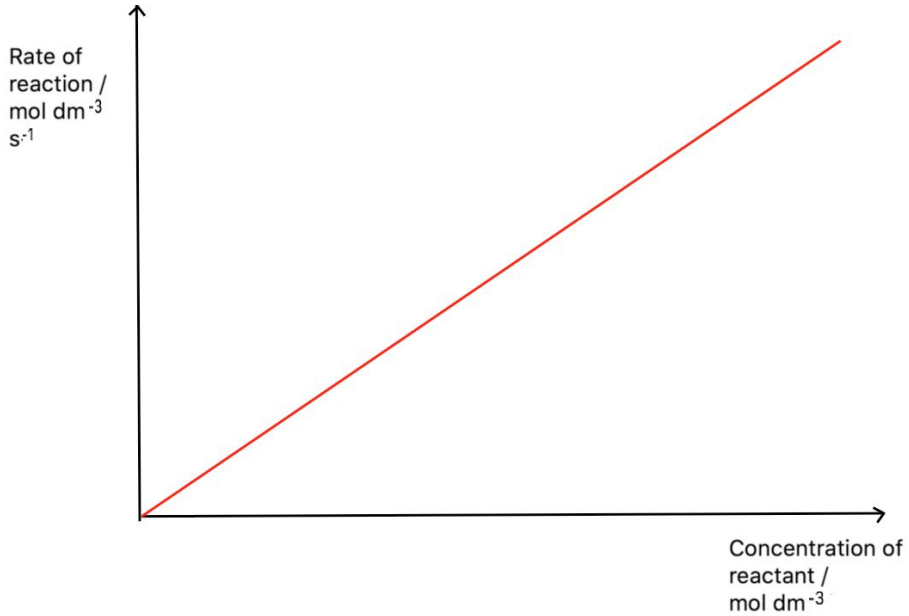

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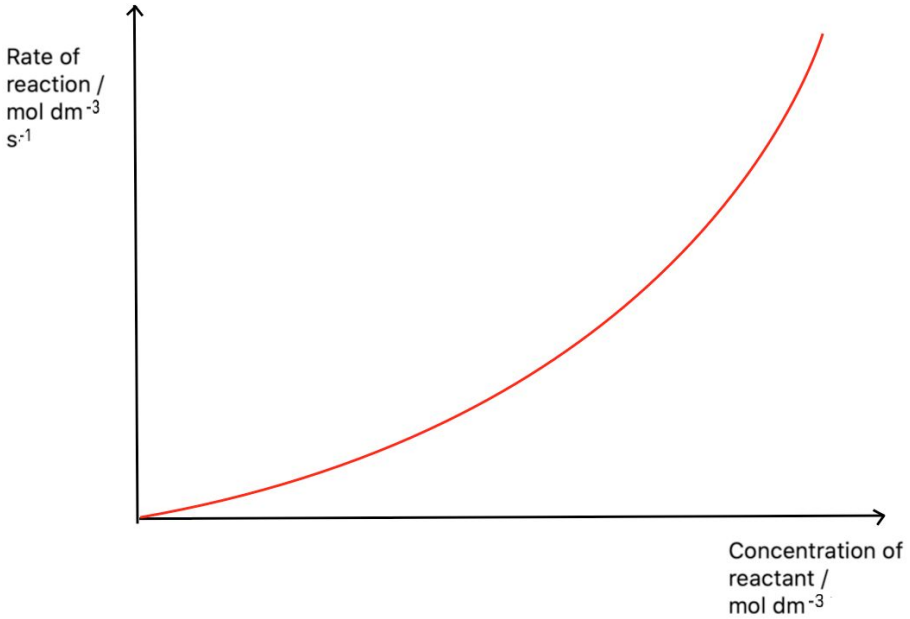

What is meant by the half-life of a reaction?

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The average time taken for the concentration of the reactant to decrease by half, $t_{1/2}$.

How do you calculate the rate constant, k from half life, $t_{1/2}$, for a first order reaction?

How do you calculate the rate constant, *k* from half life, $t_{1/2}$, for a first order reaction?

$$k = \ln 2 / t_{1/2}$$

- This equation applies to first-order reactants only.
- The half life of a first order reactant is independent of concentration.

Draw a concentration-time graph for a zero order reactant

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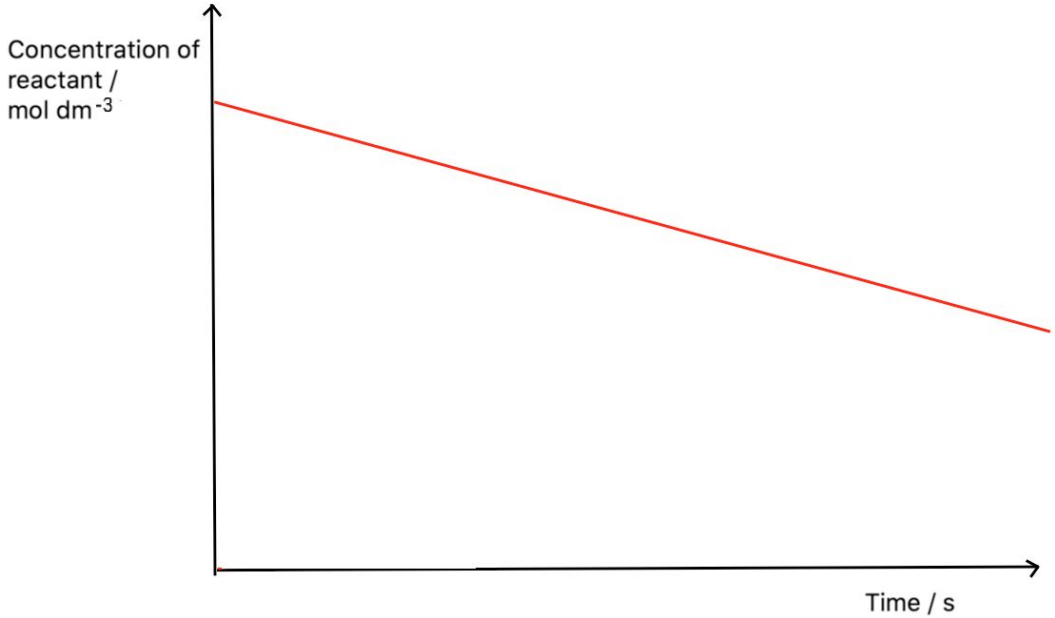

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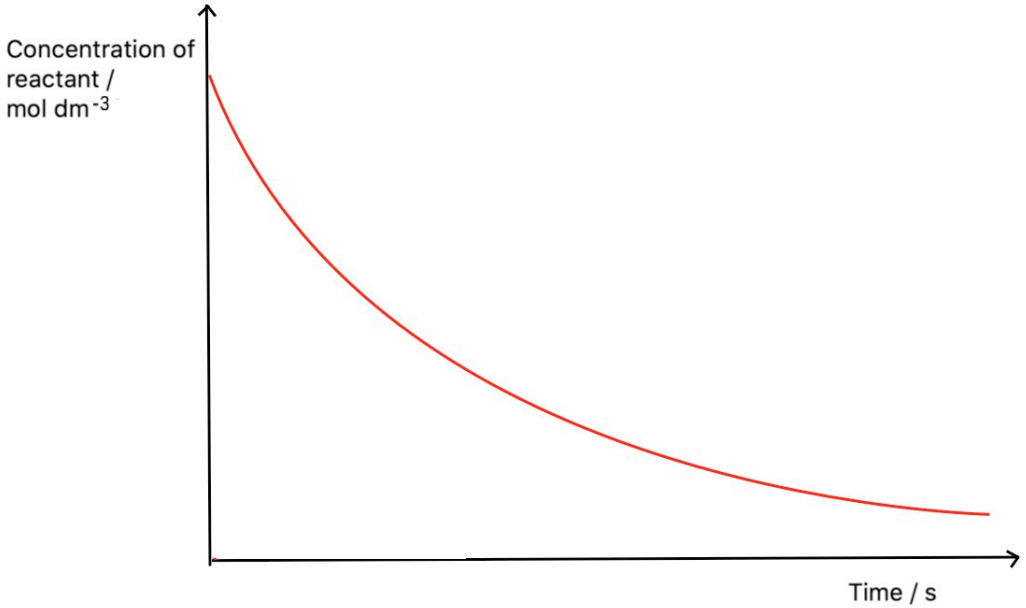

How do you calculate half life from a first order concentration-time graph?

How do you calculate half life from a first order concentration-time graph?

Using the graph, find the time taken for the concentration to halve. Then find the time taken for it to halve again (to increase accuracy). Calculate the average of these values and this will be the half life.

How do you calculate the rate from a first order concentration-time graph?

How do you calculate the rate from a first order concentration-time graph?

- Draw a tangent at the time you want the rate of reaction.
- The gradient of this tangent will equal the rate of reaction.

Gradient = change in y ÷ change in x

How do you calculate *k* from a first order rate-concentration graph?

How do you calculate *k* from a first order rate-concentration graph?

- Calculate the gradient of the line of best fit (change in y ÷ change in x).
- The gradient will equal the rate constant, *k*.

What is the rate-determining step?

What is the rate-determining step?

- The slowest step of the reaction.
- Only species that take part in the rate determining step (or steps that take place before it) affect the rate.

What is the relationship between the rate-determining step and the rate equation?

What is the relation between the rate-determining step and the rate equation?

- The species present in the rate equation are those that take part in the rate determining step.
- For any reactant in the rate equation, the order attached to it tells you how many molecules of it are involved in the rate determining step.

Suggest a step-by-step reaction mechanism for the reaction below:

Overall equation: $CO_{(g)} + NO_{2(g)} \rightarrow CO_{2(g)} + NO_{(g)}$

Rate equation: rate = $k[NO_2]^2$

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Step 1: $2NO_2 \rightarrow NO + NO_3$ (slow)

Step 2: $NO_3 + CO \rightarrow NO_2 + CO_2$

How can the order of a reactant be predicted using a reaction mechanism?

How can the order of a reactant be predicted using a reaction mechanism?

- Identify the rate-determining step.
- Observe how many molecules of each reactant react in the rate-determining step.

For example, if two molecule of reactant A react in the rate determining step, the reaction is second order with respect to A.

How does the rate constant, *k*, vary with increasing temperature?

How does the rate constant, *k,* vary with increasing temperature?

- As temperature increases there are more particles with energy above the activation energy. As a result, there are more frequent successful collisions so rate of reaction increases.
- An increase in temperature therefore causes an increase in *k.*
- For every 10℃ increase, the rate and k both approximately double.

What is catalysis?

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The increase in the rate of a chemical reaction due to the addition of a catalyst.

What is a homogeneous catalyst?

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A catalyst that is in the same state as the reactants.

What is a heterogeneous catalyst?

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What catalyst is used in the Haber process? Describe the role of this catalyst

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Heterogeneous iron catalyst.

- The iron also has KOH added to it to act as a promoter.
- Nitrogen and hydrogen are adsorbed onto the catalyst surface, breaking the bonds in the nitrogen and hydrogen molecules.
- New bonds form between the iron and individual nitrogen and hydrogen atoms.
- Nitrogen then bonds to hydrogen to form ammonia which desorbs from the catalyst.

How does a catalytic converter reduce harmful emissions from a car exhaust?

How does a catalytic converter reduce harmful emissions from a car exhaust?

Heterogeneous catalyst made of metals such as platinum, palladium and rhodium. Removes harmful gases such as carbon monoxide and nitrogen monoxide.

$$2CO + 2NO \rightarrow 2CO_2 + H_2$$

How do oxides of nitrogen catalyse the oxidation of sulfur dioxide?

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Nitrogen dioxide acts as a homogeneous catalyst. Nitrogen dioxide reacts with sulfur dioxide before being regenerated:

$$SO_2(g) + NO_2(g) \rightarrow SO_3(g) + NO(g)$$

$$NO(g) + \tfrac{1}{2}O_2(g) \rightarrow NO_2(g)$$

How do iron ions act as a catalyst in the $I^-/S_2O_8^{2-}$ reaction?

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Homogeneous iron catalyst (either Fe^{2+} or Fe^{3+}).

$$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2.$$

Iron ions react with the reactants to form intermediates. This is a much more successful pathway as two negatively charged reactants do not have to collide.