

Orders, rate constants and activation energy

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Lab answers

The model answers use the sample times in the tables. Check how concentration and $1/t$ are combined to deduce the order, how the Arrhenius gradient gives the activation energy, and how the sources of error are linked to improvements.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB R2.2

Question 1 Concentrations and rates

$[S_2O_3^{2-}] = 0.150 \times V / 50$: **0.120, 0.096, 0.072, 0.048 and 0.024 mol/dm³**. $1000 / t$:
 $1000/22 = 45.5$, $1000/28 = 35.7$, $1000/37 = 27.0$, $1000/55 = 18.2$, $1000/110 = 9.09$.

Question 2 Order with respect to thiosulfate

Dividing $1000/t$ by concentration gives 379, 372, 375, 379 and 379, a constant value within experimental error. Rate is proportional to concentration (a straight line through the origin), so the reaction is **first order in thiosulfate**.

Question 3 Why use $1/t$

The same amount of sulfur precipitate must form to hide the cross in every run, so the average rate is proportional to the amount divided by the time, that is to **$1/t$** .

Question 4 Data for the Arrhenius plot

$T = 293, 303, 313$ and 323 K. $1/T = 3.413 \times 10^{-3}, 3.300 \times 10^{-3}, 3.195 \times 10^{-3}, 3.096 \times 10^{-3}$ K⁻¹. $\ln(1/t) = -3.61, -2.94, -2.30, -1.70$.

Question 5 Activation energy

Gradient = $(-1.70 - (-3.61)) / (3.096 \times 10^{-3} - 3.413 \times 10^{-3}) = 1.91 / (-3.17 \times 10^{-4}) = -6.01 \times 10^3$ K. $E_a = 6.01 \times 10^3 \times 8.314 = 5.0 \times 10^4$ J/mol = **50 kJ/mol**.

Question 6 Sources of error

Judging when the cross vanishes varies between people (random error, giving scatter), and the temperature drifts during the run (systematic error that makes **the high temperature rate appear too low**). The thermometer also reads only to 1 °C.

Question 7 Improvements

Use a light sensor and a data logger to detect when the transmitted light falls to a set value, and run the mixture in a thermostatic water bath so the temperature stays constant. **The same person should judge the end point if a sensor is not available.**

Question 8 Plan to find the order in acid

Keep the thiosulfate volume, total volume and temperature fixed and change only the volume of acid (making up the volume with water). Measure t each time, calculate $1000/t$ and compare how it changes with acid concentration: **a straight line through the origin means first order.**