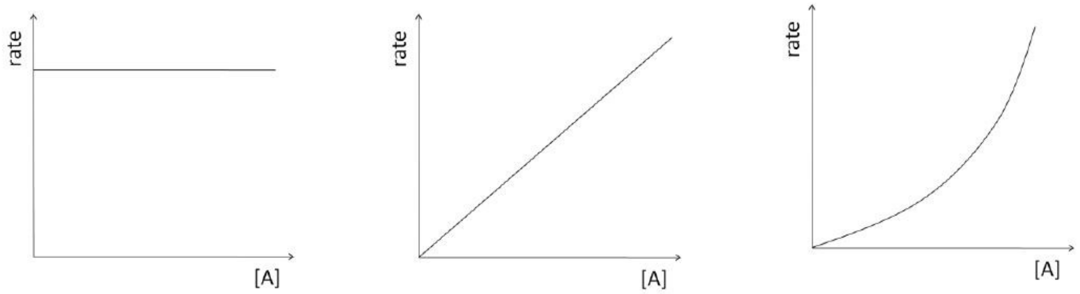
Problem 7: Iodination inquiry

Teacher and Technician Pack

Pre-Lab answers

1.

a) i. **zero order** wrt A; ii. **first order** wrt A; iii. **second order** wrt A



b) Step one, the slow step is the rate-determining step

2a.

I. $Mg + 2\ HCl \rightarrow MgCl_2 + H_2$

Measure the time taken to produce a certain amount of H2 gas

II. $Na_2S_2O_3 + 2\ HCl \rightarrow 2\ NaCl + S + SO_2 + H_2O$

Measure the time taken for the solution to turn sufficiently cloudy as a result of the colloidal suspension of sulphur that forms that you cannot see through the flask

III. $CH_3CH_2Cl + OH^- \rightarrow CH_3CH_2OH + Cl^-$

Add a certain amount of silver nitrate solution to the reaction and measure the time taken for a white precipitate (of AgCl) to form

Alternatively, the rate of each of the reactions above could be measured using a pH meter to determine the change in concentration of H^+ with unit time.

2b) The reaction rate is defined as the change in concentration of reactants or products per unit time. Therefore to convert the reaction time into a reaction rate you would need to determine the change in concentration of the reactant / product at the point when you stopped the clock and divide this concentration (mol dm^{-3}) by the time (s) it took for this change to occur.

3.

a) By comparing **exp 1** and **2**, the reaction is second order wrt [Q]

By comparing **exp 1** and **exp 3**, the reaction is first order wrt [R]

Therefore the rate equation for the reaction is **rate = *k*[Q]2[R]**

b) 5.24×10^{-3} mol dm^{-3} s^{-1} = k × 0.300^2 mol^2 dm^{-6} × 0.300 mol dm^{-3}

Hence, k = 0.194 mol^{-2} dm6 s^{-1}

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Proposed method

Students trial the initial combination of reagents given

5 cm^3 2 M propanone **[Highly flammable, irritant]**
5 cm^3 1 M HCl **[Low hazard]**
2 cm^3 0.005 M I_2 **[Low hazard]**
13 cm^3 water

By trialling the reaction, the students identify that the easily recognisable event in this case is the disappearance of the last trace of colour from the reactant iodine.†

2.0 M propanone / cm^3	1.0 M HCl / cm^3	0.005 M I_2 / cm^3	H_2O / cm^3	Time / s
5	5	2	13	279

† The clock is started on addition of the iodine solution

WARNING! The product from the reaction, iodopropanone is a **lachrymator** (strongly irritant to the eyes). The reaction mixture should be poured down a fume cupboard sink with plenty of running water immediately once each measurement is complete.

Students decide on suitable combinations of reagents to determine the order of the reaction wrt propanone, I_2 and H^+

Three runs of each experiment are completed and an average time taken

2.0 M propanone / cm^3	1.0 M HCl / cm^3	0.005 M I_2 / cm^3	H_2O / cm^3	Time / s
5	5	2	13	279
10	5	2	8	145
5	10	2	8	141
5	5	1*	14	143

* If the students opt to change [I_2] they must also take into account that they are changing the amount of the reaction they are measuring the time of.

Analysis of the results reveal the rate equation to be;

rate = $k[CH_3COCH_3][H^+]$

∴ step 1 is the rds

$k = 1.8 \times 10^{-5}\ mol^{-1}\ dm^3\ s^{-1}$

Using the initial experimental run, calculating the initial concentrations:

$[I_2] = \frac{\text{no. of moles of } I_2}{0.025\ dm^3} = \frac{0.005\ mol\ dm^{-3} \times 0.002\ dm^3}{0.025\ dm^3} = 4 \times 10^{-4}\ mol\ dm^{-3}$

$[CH_3COCH_3] = \frac{\text{no. of moles of } CH_3COCH_3}{0.025\ dm^3} = \frac{2.0\ mol\ dm^{-3} \times 0.005\ dm^3}{0.025\ dm^3} = 0.4\ mol\ dm^{-3}$

$[H^+] = \frac{\text{no. of moles of } H^+}{0.025\ dm^3} = \frac{1.0\ mol\ dm^{-3} \times 0.005\ dm^3}{0.025\ dm^3} = 0.2\ mol\ dm^{-3}$

$\text{Rate} = \frac{\text{change in } [I_2]}{\text{time taken}} = \frac{4 \times 10^{-4}\ mol\ dm^{-3} - 0}{279\ s} = 1.43 \times 10^{-6}\ mol\ dm^{-3}\ s^{-1}$ (assuming $[I_2]$ went to zero)

$\therefore k = \frac{\text{rate}}{[\text{propanone}][H^+]} = \frac{1.43 \times 10^{-6}\ mol\ dm^{-3}\ s^{-1}}{0.4\ mol\ dm^{-3} \times 0.2\ mol\ dm^{-3}} = 1.8 \times 10^{-5}\ mol^{-1}\ dm^3\ s^{-1}$

NOTE The choice of the observed change in [I2] as a method for measuring the initial rate of this reaction only works because the reaction is zero order with respect to iodine. Therefore the concentration of iodine does not affect the reaction rate and hence we can study the rate by making iodine the limiting reagent present in a large excess of propanone and acid. If iodine was involved in the rate determining step, as its concentration decreased the reaction would become slower and slower and the results would be skewed.
You may wish to discuss this point with your more able students.

Equipment list

Each group will need;

- 100 cm^3 of 2.0 M propanone solution [Highly flammable; Irritant]
- 100 cm^3 of 1.0 M HCl solution [Low hazard]
- 30 cm^3 of 0.005 M Iodine solution in aqueous potassium iodide [Low hazard]
- Distilled water
- 4 × burettes, burette stands and clamps and funnels (1 for each solution and water) (these can be shared
- between groups if needed)
- 2 × 100 cm^3 conical flask
- Test tubes (for storage of acid and iodine solutions before addition)
- Stopwatch
- 2 × white tile or white paper

Health and safety note

The product of the reaction, iodopropanone, is a lachrymator (strongly irritant to eyes). The reaction mixture must therefore be disposed of as soon as measurements have been taken by flushing down a fume cupboard sink with lots of running water.