Problem 7: Iodination inquiry

Curriculum links;
rate equations, rate determining step

Practical skills;
clock reactions, accuracy

A teacher asks the students to design a clock reaction to determine which is the rate determining step in the iodination of propanone.

Pre-Lab questions
(Remember to give full references for any information beyond A-level that you find out)

1. Consider the reaction: 2 A + B → C + D

    a) Sketch a graph to show how the reaction rate (taken here as the change in [C] per unit time) would vary with [A] if the reaction was;

    I.   zero order with respect to A
    II.   first order with respect to A
    III. second order with respect to A

    b) A detailed study of the kinetics of the reaction revealed that the mechanism involved the formation of an intermediate E;

Step one: A + A → C + E slow
Step two: E + B → D fast

Which step is the rate determining step in the reaction?

2. The rate of a reaction can be determined experimentally using an initial rate method. This involves measuring the time it takes for some easily recognisable event to occur very early on in a reaction (usually when less than 10% of the reaction has occurred).

    a) For each of the following reactions identify a visual change that you could measure the time taken to occur and hence use to determine the initial rate of the reaction;
    I. $Mg + 2 HCl \rightarrow MgCl_2 + H_2$
    II. $Na_2S_2O_3 + 2 HCl \rightarrow 2 NaCl + S + SO_2 + H_2O$
    III. $CH_3CH_2Cl + OH^- \rightarrow CH_3CH_2OH + Cl^-$

    b) In each of these reactions, the reaction time for the observed change is measured. Define the term "reaction rate" and hence explain how the reaction time can be converted into a reaction rate in any one of the reactions above.

3. The reaction **Q** + **R** → **P** was studied using the method of initial rates. The initial rate of formation of was measured in three different experiments. The data are provided below.

| Experiment	[Q] / mol dm^{-3}	[R] / mol dm^{-3}	Initial Rate / mol dm^{-3} s^{-1}
1	0.300	0.300	5.24×10^{-3}
2	0.600	0.300	2.10×10^{-2}
3	0.300	1.000	1.75×10^{-2}

a) Use the data above to determine the rate equation for the reaction.
b) What is the value of the rate constant, k ?

Dear scientist,

Help me please! I am a new teacher in a sixth form college in Newcastle and I am being observed by senior management in a couple of weeks time. They want to assess my ability to run a sixth form practical.

I would like the students to complete a practical to determine the rate equation for the iodination of propanone and use this information to identify the rate-determining step. The equation for the reaction is;

$$CH_3COCH_3 + I_2 \xrightarrow[\text{conditions}]{\text{acidic}} ICH_2COCH_3 + H^+ + I^-$$
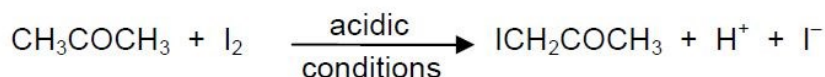
A diagram showing the four steps involved in the mechanism is attached to this letter. I have carried out some research on the internet and understand that the order of the reaction with respect to propanone, acid and iodine can be determined using a simple initial rate method. For this reaction, if much higher concentrations of propanone and acid are used, the initial rate of the reaction can be determined by the time needed for the iodine to be used up. A suitable starting mixture would be 5 cm3 of a 2.0 M solution of propanone, 5 cm3 of 1.0 M HCl and 2 cm3 of 0.005 M of I2 solution made up to 25 cm3 total volume by the addition of water.

Please can you help me out by trialling some different combinations of initial concentrations of reactants which will help the students determine which of the four steps is the rate determining step. Based on your trials, please provide a detailed experimental Student Worksheet for the students to follow for the experiment and the associated analysis of results, together with a set of model results including identification of the rate determining step and a full rate equation for the reaction.

Please provide these in a separate document headed "Teacher Answers". I would like to extend the "A" grade students by asking them to calculate a value for the rate constant, k. Please add these calculations to your Teacher Answers. I do not have time to do the reaction myself so will be fully reliant on you!

Finally, I will need to provide a differentiated set of learning objectives for the lesson which will show the progress the students are making. Can you please include these on the top of your Student Worksheet.

Many thanks for your help,

Sarah Tressed

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Proposed mechanism for the iodination of propanone

Step 1

Step 2

Step 3

Step 4

Overall reaction