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Examiners' report

CHEMISTRY B (SALTERS)

H433

For first teaching in 2015

H433/03 Summer 2023 series

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Paper 3 series overview

The H433/03 component assesses content from across all teaching modules but places particular emphasis on practical skills.

Candidates are required to use knowledge and understanding of principles and concepts in the planning of experimental and investigative work and in the analysis and evaluation of data.

Chemical literacy is assessed through extended response questions as well as the comprehension of, and use of, data from a Practical Insert.

Question styles include short answer (structured questions, problem solving, calculations, practical) and extended response questions.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• wrote clearly and logically taking points in the question in sequence (either using full sentences or bullet points) • laid out calculations carefully, explaining what each step represented, for example moles of a reactant or mass of a product • logically addressed all the chemistry knowledge and understanding needed to fully answer Level of Response (LoR) questions.	• did not take the care needed with laying out calculations and so missed the possibility of error carried forward marks • did not relate the number of marks for a question with the detail needed in their answer • did not read the question stem (including the Insert) carefully enough and produced responses which were not addressing the questions asked.

Question 1 (b) (i)

(b) Tropospheric ozone is produced by the reactions of nitrogen oxides, NO_x, and hydrocarbons. These, together with carbon monoxide, CO, are pollutants produced by motor vehicles.

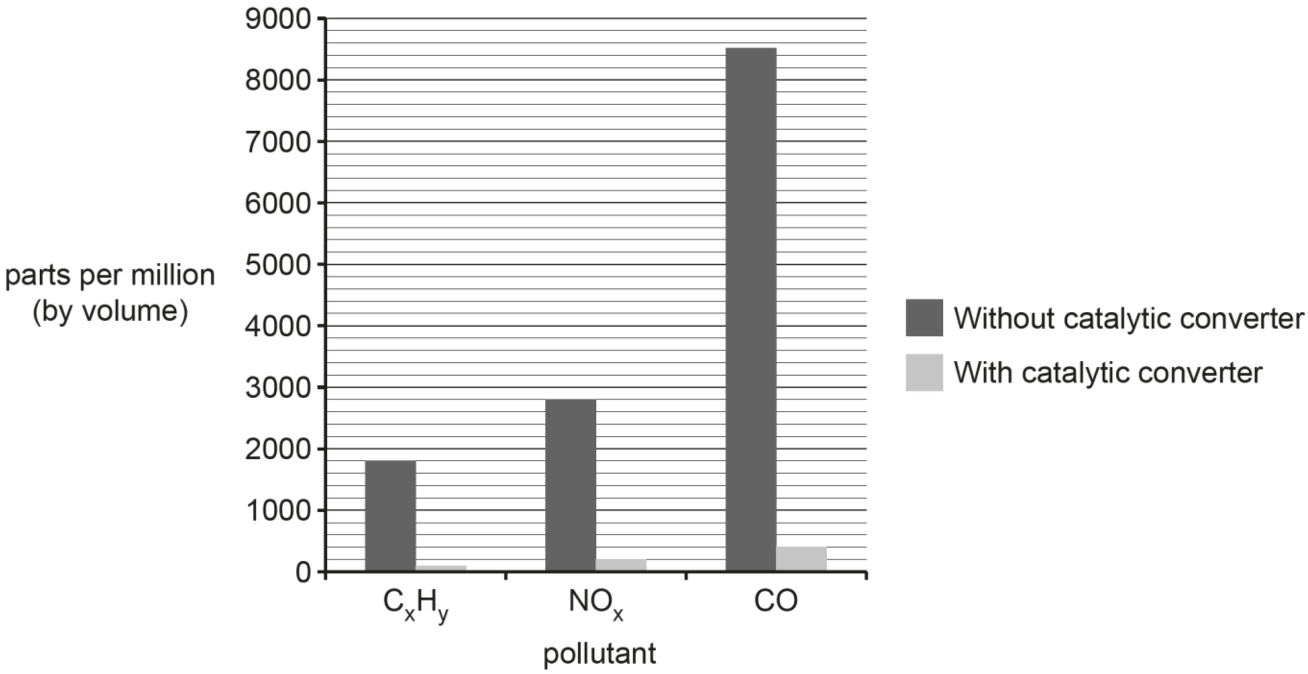
Catalytic converters in vehicle exhausts catalyse the reaction in **Equation 1.1** and also the oxidation of hydrocarbons to carbon dioxide and water.

$2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$ **Equation 1.1**

(i) The bar chart below shows the reduction in the various pollutant levels when a suitable catalytic converter is fitted.

Calculate the percentage reduction in $\mathbf{NO_x}$ levels when a catalytic converter is fitted.

Give your answer to **2** significant figures.



percentage reduction .... % **[2]**

The majority of candidates correctly calculated this, with only a small number giving an answer with the wrong number of significant figures.

Question 1 (b) (ii)

(ii) A student says that the reactions in a catalytic converter decrease car pollution to zero.

Comment on this statement.

....

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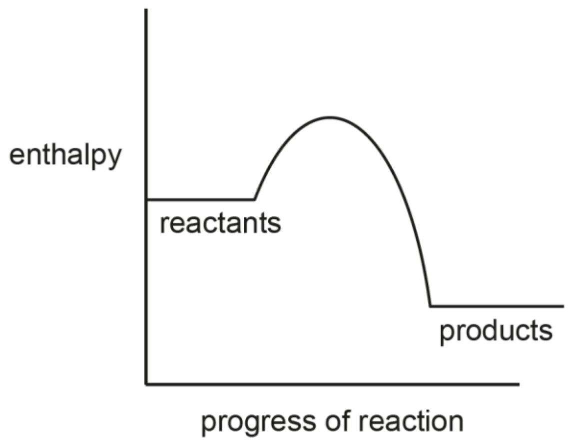
....

.... **[3]**

Many candidates comfortably scored 2 of the 3 marks available. The fact that carbon dioxide was produced was common but the associated problem, greenhouse gas, was often missed.

Question 1 (b) (iii)

(iii) The diagram below represents an energy profile for the catalysed reaction in **Equation 1.1**.



On the diagram:

- Indicate the activation enthalpy of the catalysed reaction.
- Draw a progress curve for the uncatalysed reaction.

[1]

The majority of candidates scored this mark; the correct position of E_a occasionally caught out some.

Question 1 (c)

(c) In the stratosphere, nitrogen monoxide removes ozone molecules by the sequence of reactions below.

$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$ **Reaction 1**

$NO_2(g) + O(g) \rightarrow NO(g) + O_2(g)$ **Reaction 2**

A student suggests that the NO molecule is behaving as a heterogeneous catalyst.

Use your chemical knowledge to comment on the student's suggestion.

....

....

....

.... **[2]**

In the main, candidates scored well on this question. The explanation of why NO was acting as a catalyst was occasionally missed.

Question 1 (d)

(d) Chlorine atoms also act as catalysts to remove ozone.

The atoms can be formed by the reaction shown below.

$Cl_2 \rightarrow 2Cl$

What conditions are needed for this reaction to occur and what **type** of bond fission occurs?

Conditions ....

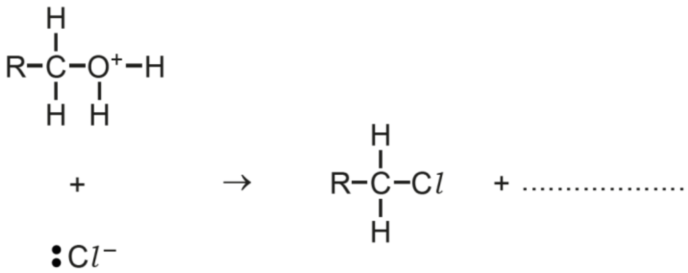
Type of bond fission .... **[2]**

This question was generally well answered.

Question 1 (e)

(e) By contrast, chloride **ions** react in a different way, for example in the reaction below.

Mark 'curly arrows' on the diagram and give the other product.



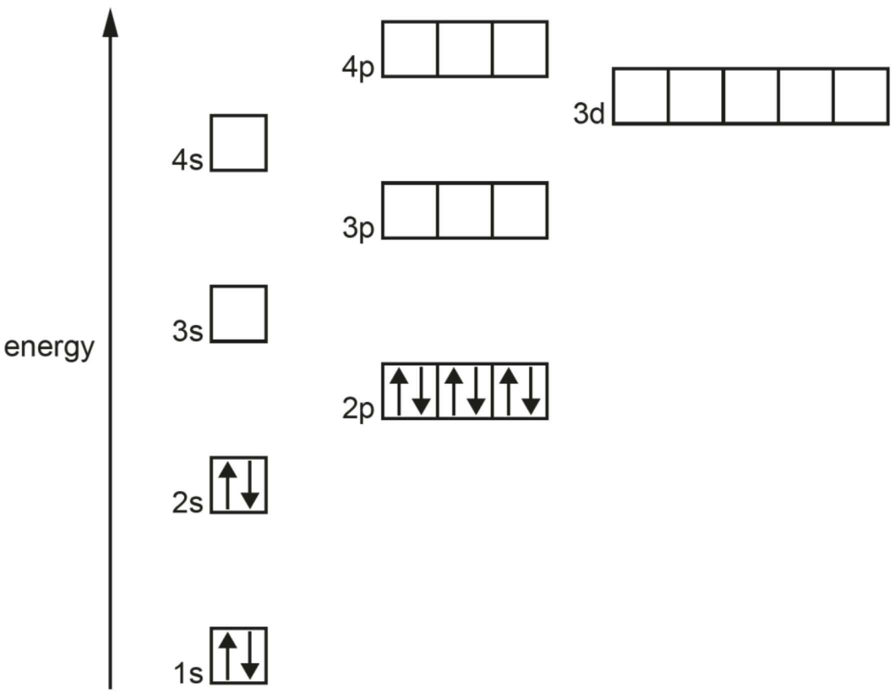
[2]

Broadly speaking most candidates were more successful at starting and finishing the 'curly arrows' in the mechanism in the correct location than in previous years.

Question 2 (a) (i)

2 Copper is a d-block metal and forms many complexes.

(a) (i) Complete the diagram below to show the electronic configuration of a **Cu^{2+} ion**.



[2]

The 3s and 3p orbital were almost always filled but the 4s and 3d electronic structures were less well attempted.

Question 2 (a) (ii)

(ii) Explain why copper is classed as a transition metal.

....

.... **[1]**

The key word 'ion' was missed by many candidates.

Question 2 (b)*

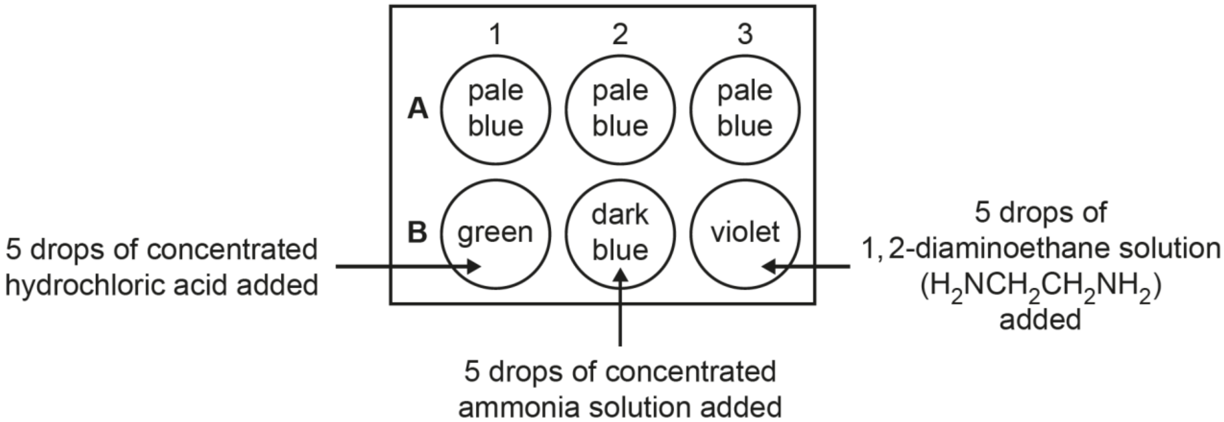
(b)* The Cu^{2+} ion forms several complex ions with different ligands.

A group of students performs a simple microscale experiment to investigate some copper(II) complexes.

They use a plate with small wells into which drops of solutions can be placed.

Their method and the results are shown below.

- **All** wells have 5 drops of copper(II) sulfate solution added to them.
- Wells **B**1, 2 and 3 have drops of other solutions added as identified in the diagram.



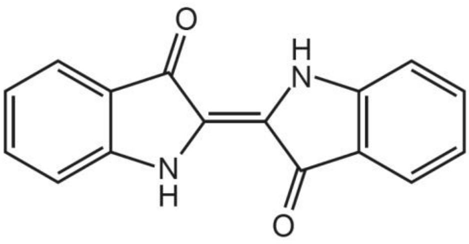
Use the student results to explain the meaning of the term **ligand** and suggest formulae and shapes for the complexes formed.

Use diagrams in your answer. **[6]**

This question scored the complete range of marks. Good answers spotted the request to use diagrams. Weaker areas included the overall charge of the various complex ions formed and the actual number and nature of the ligands surrounding the central copper ion. HCl was a common mistake for the chloride ion ligand.

Question 3 (a) (i)

3 Indigo is a natural blue dye that can be extracted from various plants.



Indigo

(a) (i) The IR spectrum of indigo has a significant absorption around 3300 cm^{-1}.

Suggest the most likely bond in indigo responsible for this absorption.

.... **[1]**

Question 3 (a) (ii)

(ii) Indigo is used to dye cotton. The cotton structure has many –OH groups.

Suggest the strongest type of intermolecular bond that binds indigo to cotton.

.... **[1]**

Question 3 (b) (i)

(b) A frequency of yellow light has a wavelength of 5.90×10^{-7} m.

(i) Calculate the energy (in kJ) associated with one mole of photons of this wavelength.

energy = ... kJ **[3]**

The first two parts of this question were generally well-answered, and many correct answers were also seen for this question part. The most common error here was omitting the 'x 6.02×10^{23}' necessary to get the answer per mole.

Question 3 (b) (ii)

(ii) Explain why indigo has a blue colour.

....

....

....

....

....

.... **[3]**

The general idea of the origin of colour appeared to be understood by most candidates, but often detail was missing. For example, candidates needed to identify that orange light is absorbed (not just light). Some candidates contradicted themselves by describing light being emitted by electrons dropping down energy levels.

Misconception

A common misconception here was that the colour of a dye is due to emission of light, caused by electrons emitting photons of light when dropping back from higher excited energy levels, rather than by reflection or transmission of wavelengths not absorbed by the dye molecule.

Question 3 (c)*

(c)* Benzene rings in dyes are usually represented as shown in **Fig. 3.1**. However, benzene rings in other organic molecules are often represented as shown in **Fig. 3.2**.

Fig. 3.1

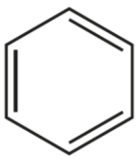


Fig. 3.2

Explain why **Fig. 3.2** is a better match for the actual **structure** and **reactions** of benzene molecules.

....

....

....

....

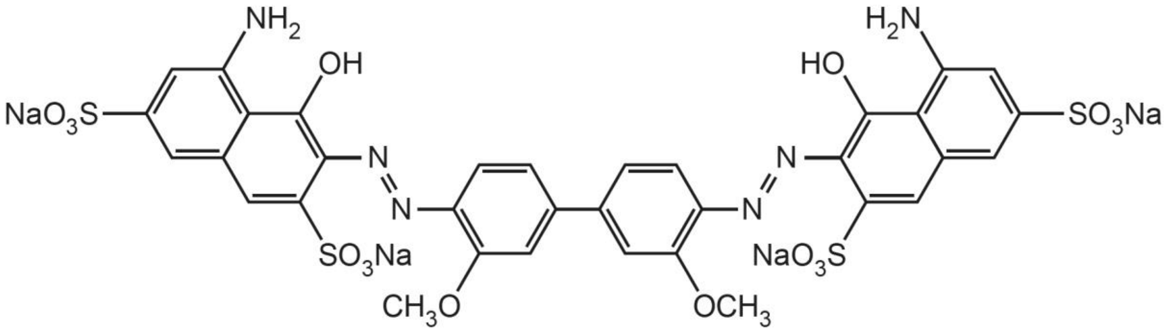
....

.... **[6]**

This Level of Response question gave plenty of opportunity to score highly. Those that did well broke the answer down into sections where comparisons could be made, for example electrophilic substitution or addition depending on the correct structure.

Question 3 (d) (i)

(d) (i) The dye **direct blue 15** does not fade, whereas indigo does.



Direct blue 15

This dye is made by sulfonation.

Give the reagents and conditions used in the sulfonation of **benzene**, the name of the mechanism of the reaction and a property of **direct blue 15** that is caused by the sulfonation.

Reagents and conditions ....

....

Name of mechanism ....

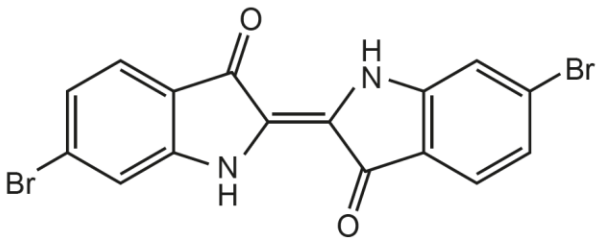
Property of **direct blue 15** ....

.... **[4]**

'Concentrated' was a common omission in candidate answers; the type of reaction seemed well understood, but the change to the structure and increased solubility not so well.

Question 3 (d) (ii)

(ii) Dibromoindigo can be prepared synthetically by reacting indigo with bromine, using an iron catalyst.



Dibromoindigo

The reaction has the same type of mechanism as sulfonation.

Explain the role of the iron in forming Br^+.

....

....

....

.... **[2]**

This question received a mixed bag of answers. A significant minority of candidates were too generalised in their answer, although one 'catch all' mark was awarded for 'halogen carrier'.

Question 4 (a) (i)

4 This question refers to the **Practical Insert** that is provided as an insert to this paper.

(a) (i) Explain why the results of **Experiment 1** show that the rate of reaction does **not** vary with the iodine concentration.

....

....

....

.... **[2]**

This question was not answered well. The idea that the titre values were proportional to iodine concentration proved difficult to score, but some candidates were able to explain the constant gradient and its link to rate.

Question 4 (a) (ii)

(ii) During **Experiment 1**, the students ensured the concentration of propanone remained virtually constant.

How did they do this?

....

.... **[1]**

This question received a very mixed bag of answers but a significant minority did explain how this works.

Question 4 (b)

(b) Suggest why the total volume is kept constant in **Experiment 2**.

....

.... **[1]**

This question did not score well. A problem may have been the difficulty of explaining the reason (although many alternative ways were suggested in the mark scheme guidance).

Question 4 (c) (i)

(c) (i) An extended version of **Table 4.1** from the Insert is given below.

Use the data in this table to calculate the rates of reaction (in cm^3 of iodine solution decolorised per second) in **Run B** and **Run C**.

Give your answers to **2** significant figures and write your values in the appropriate blank boxes in the table.

Table 4.1

	Run A	**Run B**	**Run C**
Volume of 2.0 $mol\,dm^{-3}$ HCl / cm^3	20.0	10.0	20.0
Volume of 2.0 $mol\,dm^{-3}$ propanone / cm^3	8.0	8.0	4.0
Volume of water / cm^3	0	10.0	4.0
Volume of 0.010 $mol\,dm^{-3}$ iodine / cm^3	4.0	4.0	4.0
Total volume in flask / cm^3	32.0	32.0	32.0
Time for colour to disappear	115	234	240
Rate of reaction of iodine / $cm^3\,s^{-1}$	0.035		
Rate of reaction of iodine / $mol\,dm^{-3}\,s^{-1}$	1.1×10^{-5}		

[1]

Generally, this question scored well, though significant figures occasionally lost candidates the mark.

Question 4 (c) (ii)

(ii) The students do a text book search and find that the rate equation for the reaction is:

Rate = k [propanone][H^+]

Explain whether the results of **Experiment 1** and **Experiment 2** support this rate equation.

....

....

....

....

....

.... **[3]**

Although a complete range of marks were awarded for this question, many candidates missed out on all 3 marks by not using the data/runs in the insert, despite the stem of the question asking for the use of the results in any explanation.

Question 4 (d) (i)

(d) (i) Show why the rate of reaction of iodine in **Run A** is 1.1×10^{-5} mol dm^{-3} s^{-1}.

[1]

A minority of candidates scored this mark but many did not show how the figures provided gave that answer.

Question 4 (d) (ii)

(ii) Using the data in **Table 4.1** for **Experiment 2 Run A**, calculate the initial concentrations of hydrochloric acid and propanone in the flask.

Use these values, along with the rate from **(d)(i)**, to calculate the value of the rate constant, *k*, with its units.

[HC*l*] = ... $mol\,dm^{-3}$

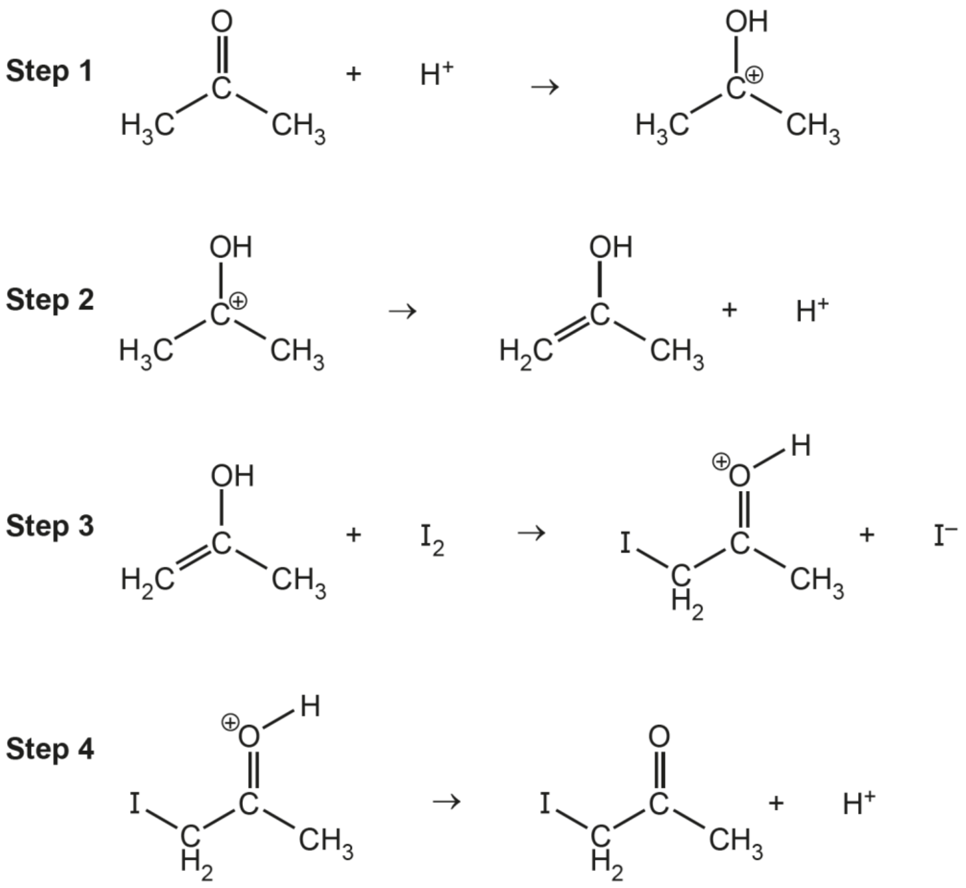
[propanone] = ... $mol\,dm^{-3}$

k = ... units .... **[4]**

Many candidates knew what to do here but didn't always start with the correct figures. Error carried forward marks gave many candidates 3 marks, but many scored 4/4. The units challenged some candidates.

Question 4 (e)

(e) A student proposes the reaction mechanism below for the iodination of propanone.



Assuming the rate equation below to be correct, identify and explain the **rate determining step** in the student's mechanism.

Explain why the reactant iodine does not feature in the rate equation.

Rate = *k* [propanone][H^+]

....

....

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....

.... **[4]**

Many candidates did not explain the idea of a rate determining step and very few explained that iodine must be in a later fast step. A common score of 2 marks was given for this question (for the identification of the rate determining step and why it shows first order kinetics for propanone and the acid).

Exemplar 1

Iodine doesn't feature in the rate equation as it is not part of the rate determining step. Step 1 is ~~the~~ rate determining step as it shows 1 molecule of propanone and 1 molecule of H^+ reacting together which corresponds to the rate equation ~~which~~ as it shows that the rate of reaction is first order with respect to the concentration of propanone and the concentration of H^+. **[4]**

In this exemplar we see a commonly occurring error. Many candidates did not link the 4 marks available to the stem of the question and missed out an explanation of the rate determining step and why, in terms of the <u>given mechanism</u>, iodine was not involved in the rate equation. 2 marks, for step 1 being identified as the rate determining step and the order with respect to those reactants, were commonly scored.

Question 4 (f)

(f) The students wear safety goggles and protective gloves when carrying out the experiments.

Using the information from the insert, suggest **one other** necessary health and safety measure.

....

.... **[1]**

This question scored well apart from a small minority of candidates being too generalised in their answer (for example, 'wear safety clothing'). Where a question asks for health and safety measures to be identified, it is good practice to identify those specific to the particular procedure, rather than general laboratory safety steps.

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