Cambridge Assessment International Education

Skills Pack

Disappearing Cross Reaction

Cambridge International AS & A Level Chemistry 9701

Version 0.1

Cambridge Pathway

Contents

Icons used in this pack:

Briefing lesson

Planning lesson

Lab lesson

Debriefing lesson

Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Skills Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 3 (Advanced Practical Skills) or Paper 5 (Planning, Analysis and Evaluation).

This is one of a range of *Skills Packs* and each pack is based on one experiment. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson reinforces the key concepts, relevant skills, knowledge and understanding linked to the experiment.

↓

Planning lesson (1 hour*)
This lesson focuses on planning an experiment.
It ends with a demonstration video of the experiment.

↓

Lab lesson (1 hour*)
This lesson focuses on carrying out the experiment including the collection and recording of observations, measurements and estimates.

↓

Debriefing lesson (1 hour*)
This lesson focuses on the analysis and interpretation of data.
This includes making conclusions, evaluating methods and the quality of data and how improvements could be made.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack you will find lesson plans, worksheets and teacher resource sheets.

Experiment: Disappearing Cross

This *Skills Pack* focuses on collision theory and the rate of reaction.

This experiment has links to the following syllabus content (see syllabus for detail):

- Paper 3 Advanced Practical Skills

The experiment covers the following experimental skills, as listed in **AO3: Experimental skills and investigations:**

- plan experiments and investigations
- collect, record and present observations, measurements and estimates
- analyse and interpret data to reach conclusions
- evaluate methods and quality of data and suggest improvements.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 2.3 Formulas

Briefing **lesson**

Resources	• Worksheets A, B, C
Learning objectives	By the end of the lesson: • ***All learners should be able to collect appropriate experimental observations relating to the identification of metal ions.*** • ***Most learners should be able correctly predict the identify of metal ions based on model scientific data.*** • ***Some learners should be able to make connections between their observations and the chemistry of the different metals.***

Timings	Activity
10	**Starter/Introduction** • Hand out WS A • In pairs, ask the learners to discuss collision theory and the factors affecting rate of reaction. When they have recalled/researched these, ask them to complete WS A, then carry out the calculation. If necessary, remind them of the formula: Average rate (cm^3/s) = $\frac{volume\ of\ gas\ produced\ (cm^3)}{time\ taken\ (s)}$
30-40	**Main lesson** • Discuss the learners' answers for Q1 and Q2 on WS A. Probe their understanding of collision theory by asking them how the different factor increase rate. For example, increasing concentration affect frequency of particle collision, adding a catalyst increases the proportion of the particles with sufficient energy to react. • Show pictures of different standard scale rates of reactions set-up. For example, using a gas syringe to measure volumes of gases, or conical flask on top-pan balances to measure mass reduction during reaction. Discuss some disadvantages of these methods, including large amounts of chemicals required, and potential health hazards if toxic products are produced, eg sulfur dioxide. • Introduce the small scale disappearing cross reaction, highlighting the large reduction in volumes of solutions used, the limited amount of toxic sulfur dioxide produced and the speed of collection of data as benefits for this method. • Hand out WS B. The pupils' task is to device a method for collecting a set of data to determine how the concentration of sodium thiosulfate affects the rate of the reaction between thiosulfate and acid. With appropriate guidance, ask learners to write a concise method using all equipment/materials.

10-20	**Plenary** • Show the learners the expected method in WS C, and discuss any differences they may have. • Ask the learners to write out a set of control measures beside their equipment, particularly focussed on the toxic sulfur dioxide being produced. Remind them about general good laboratory practice including typing hair back, wearing eye protection, good ventilation in the laboratory, not eating or drinking etc.

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • Worksheets B, C, D • Equipment as outlined in the notes
Learning objectives	By the end of the lesson: • ***All learners should be able to collect appropriate experimental data to infer the connection between volume of sodium thiosulfate added and the rate of reaction.*** • ***Most learners should also be able to plot an appropriate graph of the data collected in the experiment.***

Timings	Activity
10	**Starter/Introduction** Distribute the standard method to the learners – WS C. Discuss the importance of all learners working to the same method to allow data from across the group to be used. Demonstrate the method, particularly modelling the importance of labelling measuring cylinders/pipettes to stop cross contamination, adding the acid and starting the timer simultaneously, and placing the completed reactions in the stop bath.
30-40	**Main lesson** •Arrange the learners in groups of 2-3. One student should be responsible for making the observation of the disappearing cross. Once a reaction is running, the second student can be getting the solutions measured for the next reaction – this will increase the group's efficiency. The learners can swap over roles for each reaction. This may introduce a small additional uncertainty with different students judging when the cross disappears. However, it is important that all students practice this skill in this practical. •Learners perform the experiment following instructions on WS C carefully. •Issue the learners with WS D where they should write their results. **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate.
10-20	**Plenary** • Once the learners have completed their data collection, they should calculate the rate of reaction as 1/time. • Discuss the importance of graphing results to more easily identify patterns in the data. Remind students of the important aspects of a graph, including axis labels, linear scales, clear plotting of data point, and appropriate lines of best fit. Learners will combine their data as a class in the follow up lesson and plot individual graphs.

Teacher notes

Watch the identifying disappearing cross video and read these notes.

Each group will require:

- Plastic reaction box
- Glass vial (about 14 cm^3) with a large cross drawn on the base with glass marker pen
- Glass vial (about 14 cm^3) containing 10 cm^3 1 M hydrochloric acid
- Two measuring cylinders (10 cm^3), one labelled 'thiosulfate', one labelled 'water'
- Beaker (250 cm^3) containing 25 cm^3 0.5 M sodium carbonate (WARNING irritant) and a few drops of phenolphthalein indicator (WARNING highly flammable), labelled Stop Flask
- Beaker (100 cm^3) containing 50 cm^3 of 0.1 M sodium thiosulfate, labelled 'thiosulfate'
- Beaker (100 cm^3) containing 50 cm^3 of deionised water, labelled 'water'
- Plastic dropper pipettes
- Timer

Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

- Wear eye protection
- Work in a well-ventilated laboratory
- Do not inhale close the reaction vessel - a small amount of toxic sulfur dioxide is produced.
- Pour the completed reaction mixtures immediately into the Stop Flask.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance	Hazard	First aid
0.5 M sodium carbonate (WARNING: irritant)		Rinse any affected parts thoroughly with water.
Phenolphthalein	Highly flammable depending on the solvent used to make up the solution- ensure there are no sources of ignition in the laboratory.	
Sulfur dioxide (product)	Toxic – ensure good ventilation in the laboratory and that completed reaction mixtures are promptly poured into the Stop Flask.	If the vapour is breathed in, remove the casualty to fresh air and seek medical advice. Be particularly aware of those with respiratory conditions such as asthma.
1 M ammonia (freshly prepared) (WARNING: irritant)		

Experiment set-up

Teacher method

This is your version of the method for this experiment that accompanies the experiment video.

Do not share this method with learners.

Before you begin

Plan how you will group your learners during the experiment session.

Think about:

- the number of groups you will need (group size 2–4 learners)
- the amount of equipment/chemicals required

Experiment

Walk around the learners during the experiment in case they encounter any difficulties.

Step #	Method	Notes
1	Set up the equipment as show in the diagram.	Following this specific arrangement makes for a more efficient practical data collection.
2	Measure out 5 cm^3 of water into the labelled measuring cylinder, then transfer to the reaction vial.	
3	Measure out 5 cm^3 of sodium thiosulfate into the labelled measuring cylinder, then transfer to the reaction vial.	
4	Measure 1 cm^3 of acid with a plastic dropping pipette.	1 cm^3 pipettes will allow more accurate measurement of the acid volume than the 3 cm^3 pipettes
5	Simultaneously add the acid to the reaction vial and start the timer.	Learners may need to practice this step. If they aren't confident, have them practice pipetting water into the sink and starting the timer simultaneously.
6	Observe the cross on the bottom of the vial through the reaction mixture.	Ensure the learners don't get to close to the vial so they aren't breathing in high concentrations of the sulfur dioxide.
7	Stop the timer when the cross is no longer visible.	Remind the learners that the same person needs to observe from the same position each time.
8	Tip the completed reaction mixture into the Stop Flask, rinse the vial with	If the solutions lose their pink/purple colour, add more sodium carbonate

	tap water, and leave to drain for a minute on paper towels.	solution.
9	Repeat Steps 2-8 using the volumes indicated in the results table (WS D)	
10	Pour all unused acid into the Stop Flask. Pour all solution down the sink with additional water.	

Clean-up

After the experiment learners should:

- Tidy their workspace
- Ensure any spillages have been mopped up
- Return all equipment and unused chemicals to you.
- return all equipment and any unused chemicals to you.

Lab lesson: Option 2 – virtual experiment

Resources	• Experiment video
Learning objectives	By the end of the lesson: • ***All learners should be able to collect appropriate experimental data to infer the connection between volume of sodium thiosulfate added and the rate of reaction.*** • ***Most learners should also be able to plot an appropriate graph of the data collected in the experiment.***

Timings	Activity
10	**Starter/Introduction** Distribute the standard method to the learners – WS C. Discuss the importance of all learners working to the same method to allow data from across the group to be used. Demonstrate the method, particularly modelling the importance of labelling measuring cylinders/pipettes to stop cross contamination, adding the acid and starting the timer simultaneously, and placing the completed reactions in the stop bath.
30-40	**Main lesson** • Show the *Experiment video* from start to finish once though without stopping. • Give the learners a copy of WS D, allowing them time to look through and understand the questions. They should not write anything at this stage. Show the video again to the learners, stopping the video as necessary. Learners then work in pairs to complete the sheet, helping each other when required. Project the answer sheet and go over the answers, allowing them time to correct any mistakes. • Ask learners to verbally feedback on their observations and compare & contrast these with the expected observations.
10-20	**Plenary** • Once the learners have completed their data collection, they should calculate the rate of reaction as 1/time. • Discuss the importance of graphing results to more easily identify patterns in the data. Remind students of the important aspects of a graph, including axis labels, linear scales, clear plotting of data point, and appropriate lines of best fit. Learners will combine their data as a class in the follow up lesson and plot individual graphs.

Debriefing lesson: Consolidating the underlying chemistry

Resources	• WS E
Learning objectives	By the end of the lesson: • All learners should be able to competently answer questions related to collection and analysis of data related to rates of reaction

Timings	Activity
10	**Starter/Introduction** • Recap the practical method carried out in the previous lesson • If students haven't finished their data processing, give them time to do this now.
40	**Main lesson** • Give out WS E and ask learners to work in pairs through the questions. • If they find themselves struggling with any questions, encourage them to consult their textbook, then with another pair of learners before asking the teacher.
10	**Plenary** • Work through the answers to the questions, modelling your thinking to help students understand the mental processes you use when tackling questions.

Worksheets and answers

	Worksheet	Answers
For use in *Lab lesson*:		
A: [Starter]	**x**	**x**
B: Experimental set-up and method	**x**	**x**
C: Practical sheet for placing in plastic wallet	**x**	**x**
For use in *Debriefing lesson*		
D: Results and evaluation	**x**	**x**
E: Some questions	**x**	**x**

Worksheet A: Starter

1. State collision theory.

2. State the factors that can affect the rate of reaction.

3. A student measures 50 cm^3 of gas being produced in a reaction over 2 minutes. Calculate the rate of reaction, measured in cm^3/s. Show your workings.

Worksheet B: Planning the disappearing cross reaction

Instructions

Using all the equipment below, design an experiment for the determining the effect the concentration of sodium thiosulfate has on the rate of reaction between thiosulfate and acid.

- Plastic reaction box
- Glass vial (about 14 cm^3) with a large cross drawn on the base with glass marker pen
- Glass vial (about 14 cm^3) containing 10 cm^3 1 M hydrochloric acid
- Two measuring cylinders (10 cm^3), one labelled 'thiosulfate', one labelled 'water'
- Beaker (250 cm^3) containing 25 cm^3 0.5 M sodium carbonate (WARNING irritant) and a few drops of phenolphthalein indicator (WARNING highly flammable), labelled Stop Flask
- Beaker (100 cm^3) containing 50 cm^3 of 0.1 M sodium thiosulfate, labelled 'thiosulfate'
- Beaker (100 cm^3) containing 50 cm^3 of deionised water, labelled 'water'
- Plastic dropper pipettes
- Timer

Worksheet C: Experimental set-up and method

Method

1. Set up the equipment as show in the image below.
2. Measure out 5 cm^3 of water into the labelled measuring cylinder, then transfer to the reaction vial.
3. Measure out 5 cm^3 of sodium thiosulfate into the labelled measuring cylinder, then transfer to the reaction vial.
4. Measure 1 cm^3 of acid with a plastic dropping pipette.
5. Simultaneously add the acid to the reaction vial and start the timer.
6. Observe the cross on the bottom of the vial through the reaction mixture.
7. Stop the timer when the cross is no longer visible.
8. Tip the completed reaction mixture into the Stop Flask, rinse the vial with tap water, and leave to drain for a minute on paper towels.
9. Repeat Steps 2-8 using the volumes indicated in the results table (WS D)
10. Pour all unused acid into the Stop Flask. Pour all solution down the sink with additional water.

Equipment set up:

Worksheet D: Results and evaluation

Volume of H_2O / cm^3	Volume of $Na_2S_2O_3$ / cm^3	Concentration of $Na_2S_2O_3$ / $mol.dm^{-3}$	Time for cross to disappear / s	Rate of reaction as 1/time / s^{-1}	*Mean average of rate of reaction / s^{-1}*
5	5				
4	6				
3	7				
2	8				
1	9				
0	10				

1. Calculate the concentration of sodium thiosulfate for each of the reactions carried out. Hint – remember the final volume of the solution is 11 cm^3.

2. Calculate the rate of each reaction as 1/time – write your answer in the fifth column of the table.

3. If you are working as a class, contribute your rate values to mean average, and write the class mean average in the sixth column of the table.

4. Using graph paper, draw a graph of concentration of sodium thiosulfate against rate of reaction.

5. Identify any anomalous data on the graph by circling – do not take account of these points when drawing the line of best fit.

6. Draw a line of best fit – this should be a straight line passing through the origin.

7. How does the concentration of sodium thiosulfate affect the rate of reaction between thiosulfate and acid – refer to your graph in your answer.

8. Discuss any experimental errors that may have occurred when collecting your data.

Worksheet E: Consolidation questions

1. Calculate the mean rate of reaction for the following reactions:
    a. 25 cm^3 of carbon dioxide was produced in 15 seconds.
    b. 0.020 mol of sulfur was produced in 45 seconds.
    c. 1.2 g of ammonia was produced in 30 seconds.

2. Explain how increasing the concentration of sodium thiosulfate increases the rate of reaction between thiosulfate and acid.

3. Predict how the rate of reaction would be affected if you changed the concentration of the hydrochloric acid.

4. Describe the modification you would need to make to the practical method to ensure a valid method.

5. Explain how you could use a pH probe to monitor the progress of the reaction between sodium thiosulfate and hydrochloric acid.

6. A student carried out an investigation into the reaction between calcium carbonate and sulfuric acid. The calcium carbonate was in excess. The student collected the gas produced measuring the volume every 10 seconds until no further gas was produced.
    a. Sketch a graph showing the relationship between time and volume of gas collected.
    b. On the same graph, sketch lines for the data collected if the acid concentration was double and half the original concentration, with same total amount.

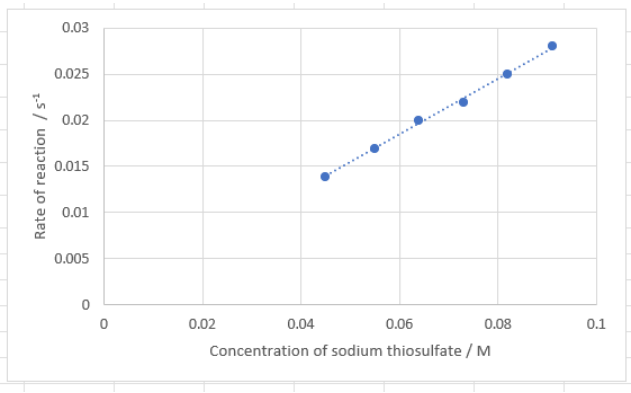
Worksheet A: Answers

1. A reaction will occur when reactant particles i) collide, ii) with sufficient energy. (The minimum energy required is called the activation energy).
2. Concentration, pressure and surface area of reactants. Temperature of the reaction. Presence of a catalyst.
3. Rate = volume / time; rate = 50 / (2 x 60) = 0.42 cm^3/s.

Worksheet D: Answers

Sample data:

Volume of H_2O / cm^3	Volume of $Na_2S_2O_3$ / cm^3	Concentration of $Na_2S_2O_3$ / $mol.dm^{-3}$	Time for cross to disappear / s	Rate of reaction as 1/time / s^{-1}
5	5	0.045	70	0.014
4	6	0.055	60	0.017
3	7	0.064	51	0.020
2	8	0.073	45	0.022
1	9	0.082	40	0.025
0	10	0.091	36	0.028

1. See table
2. See table
3. –
4. 

5. *Depends on data*
6. See graph
7. As the concentration of sodium thiosulfate increases, the rate of reaction increases in direct proportion. This is shown by the straight line of best fit, that passes through the origin.
8.
    a. Inaccurate measurement of volumes of solutions
    b. Inaccurate starting/stopping of the timer
    c. Incomplete mixing of the solution
    d. Not having the timer zeroed at the start of the reaction
    e. Contamination of the solutions between the different reactions
    f. Reaction vial not completely cleaned of previous reaction
    g. Reaction vial containing water from washing changing the concentration of the reactants.

Worksheet E: Answers

1.
    a. 25 / 15 = 1.7 cm^3 / s
    b. $4.4x10^{-4}$ mol / s
    c. 0.040 g / s
2. As the concentration of sodium thiosulfate increases, there are more particles of thiosulfate per unit volume. The particles of thiosulfate and acid therefore collide more frequently, increasing the rate of reaction.
3. If the concentration was increased, the rate of reaction would increase. If the concentration was decreased, the rate of reaction would decrease.
4. Keep the volume of sodium thiosulfate used the same each time. Change the volume of hydrochloric acid each time, altering the volume of water to keep the final volume of the reaction the same each time.
5. As the reaction proceeds, the hydrochloric acid is used up. A pH probe would measure the pH of the reaction mixture, from which we could monitor the change in concentration of the acid.
6.
7. A student carried out an investigation into the reaction between calcium carbonate and sulfuric acid. The calcium carbonate was in excess. The student collected the gas produced measuring the volume every 10 seconds until no further gas was produced.
    a. Sketch a graph showing the relationship between time and volume of gas collected.
    b. On the same graph, sketch lines for the data collected if the acid concentration was double and half the original concentration, with same total amount.

Cambridge Assessment International Education
1 Hills Road, Cambridge, CB1 2EU, United Kingdom
t: +44 1223 553554 f: +44 1223 553558
e: info@cambridgeinternational.org www.cambridgeinternational.org