# *Reaction rates* Teaching and learning plan

## Learning intentions

Students will be able to:

* observe and understand that chemical reactions take place at different rates
* identify factors which can affect reaction rates
* explain the effect of surface area, concentration and temperature on reaction rate
* plan appropriate investigation methods to manipulate the rate of a chemical reaction, taking account of fair testing
* make careful and accurate observations
* make predictions based on scientific understanding
* construct graphical representations of data and use these to determine relationships between variables
* construct conclusions based on evidence.

## Suggested timeframe

The time needed to complete the *Reaction rates CLE* will depend on the depth of the prior knowledge of students, the time to perform the five investigations (‘Surface area and reaction rate’, ‘Concentration and reaction rate’, ‘Temperature and reaction rate’, ‘Catalysts and reaction rate’, ‘Challenge – You are the process chemist’) and follow up with any further extension activities. Allow 4–6 hours.

## [Planning ahead and equipment list](http://assist.asta.edu.au/sites/assist.asta.edu.au/files/Planning%20and%20equipment%20list_Yr10_Reaction%20rates.docx)

## Safety considerations

When you and your class are completing your Risk Assessment consider the following safety points and add any other relevant ones to the list.

### Introduction

Teacher demonstration – burning magnesium ribbon

* Burning magnesium yields a white dazzling light that can cause temporary loss of sight. Students should observe using their peripheral vision.
* Wear Personal Protective Equipment.
* Bunsen burner safety:
* Check gas supply and Bunsen burner to gas tap connections.
* Ensure air intake is closed to light.
* Light the Bunsen burner and adjust the flame to light blue.
* Hold one end of the magnesium ribbon with tongs and place the other end in the flame until it ignites. Note: Hold the burning magnesium ribbon at arm’s length.
* When the magnesium starts to burn remove from flame and hold over heatproof tile to catch the powdery white magnesium oxide. Magnesium oxide is a respiratory irritant. Do not inhale the powder.
* When cooled to room temperature, discard the magnesium oxide in a waste container.
* Turn the gas tap off ensuring that the flame is extinguished.

### Investigation 1 – Surface area and reaction rate

* Sodium hydroxide is corrosive and an irritant.
* Wear Personal Protective Equipment.
* In case of a spill:
* If exposed, wash affected areas with large amounts of water.
* If exposed, flush eyes with fresh running water for at least 20 minutes. Seek medical advice if necessary.
* Dam the spill and neutralise with vinegar. Sweep up the dammed spill into a bucket. Test contents of the bucket with universal indicator and dispose the contents accordingly
* Phenolphthalein solution is alcohol-based and a flammable liquid. Keep away from heat and sources of ignition. Seek medical advice if swallowed.
* The gelatine with phenolphthalein is safe to handle.
* Demonstrate to students how to safely transport and use a knife/cutting implement.
* Provide students with 2 3x3x3 cm cubes of gelatine with phenolphthalein and advise them to cut one the cube into 9 x 1x1x1 cm cubes.
* Wear safety glasses and use the plastic spoons to transfer the cubes into the beaker containing sodium hydroxide.
* Wear gloves when handling the soaked cubes.

### Investigation 2 – Concentration and reaction rate

* Hydrochloric acid is corrosive, lung and skin irritant, and toxic if ingested.
* Wear Personal Protective Equipment.
* In case of a spill:
* If exposed, wash affected skin with soap and water and flush eyes with fresh running water for at least 20 minutes. Seek medical advice if necessary.
* Dam the spill and neutralise it with sodium bicarbonate. Sweep up the dammed spill into the bucket. Test contents of the bucket with universal indicator and dispose the contents accordingly
* Read the labels carefully and return the lids to the containers to avoid mixing or using the incorrect concentrations.

### Investigation 3 – Temperature and reaction rate

***Safety warning****:* The reaction between hydrochloric acid and sodium thiosulphate produces sulfur a yellow precipitate. The reacting mixture will turn an opaque yellow colour while the reaction is occurring and eventually the solution will turn completely opaque. Sulfur dioxide is also generated during this reaction. This reaction should be carried out in a well- ventilated room of fume cupboard.  
 Note: The reaction should not be performed if students are allergic to sulfur products.

HCl + sodium thiosulfate *arrow* sodium chloride + sulfur dioxide + sulfur + water.

* Sulphur dioxide is an acidic gas an irritant. Do not inhale the fumes as they can cause breathing difficulties.
* Hydrochloric acid is corrosive, a lung and skin irritant and toxic if ingested.
* Wear Personal Protective Equipment.
* In case of a spill:
* If exposed, wash affected skin with soap and water and flush eyes with fresh running water for at least 20 minutes. Seek medical advice if necessary.
* Dam the spill and neutralise it with sodium bicarbonate. Sweep up the dammed spill into the bucket. Test contents of the bucket with universal indicator and dispose the contents accordingly.
* Hot liquids that can cause burns. If necessary, demonstrate how hot water can be transported. Discuss appropriate behaviour and awareness to avoid accidents. Water spilled on the floor may be a slip hazard.
* This reaction can be done at temperatures below 50°C.
* Do not dispose of chemical wastes from this reaction down the sink; use chemical waste services available.

### Investigation 4 – Catalysts and reaction rate

* Both hydrogen peroxide solution and manganese dioxide are oxidising agents and are irritants.
* Wear Personal Protective Equipment.
* If exposed to a spill, wash affected skin areas with large amounts of water and flush eyes with fresh running water for at least 20 minutes.
* Do not dispose of chemical wastes from this reaction down the sink; use chemical waste services available.

### Investigation 5 – Challenge: You are the process chemist

* Hydrochloric acid is corrosive, a lung and skin irritant and toxic if ingested.
* Wear Personal Protective Equipment.
* In case of a spill:
* If exposed, wash affected skin with soap and water and flush eyes with fresh running water for at least 20 minutes. Seek medical advice if necessary.
* Dam the spill and neutralise it with sodium bicarbonate. Sweep up the dammed spill into the bucket. Test contents of the bucket with universal indicator and dispose the contents accordingly
* Read the labels carefully and return the lids to the containers to avoid mixing or using the incorrect concentrations.
* Calcium carbonate is insoluble in water and any unreacted calcium carbonate (powder and chips) should be placed in a waste container and can be recycled by the technicians.
* This reaction can be carried out at temperatures below 50°C. Students should find alternative factors to manipulate the reaction time.

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## Introduction

This CLE focuses on reaction rates and the factors that affect reaction rates [the type of chemicals, the surface area (solids), concentration (liquids) / pressure (gases), temperature and catalysts] and links to year 10 Australian Curriculum: Science.

### Teacher demonstration

### Equipment needed

* rusted nail
* 2 cm magnesium ribbon
* Bunsen burner
* matches
* metal tongs
* heat proof tile
* Personal Protective Equipment

### What to do

1. Revise the following two concepts.

* Chemical reactions involve rearranging atoms to form new substances.
* During a chemical reaction there is conservation of mass, i.e. mass is not created or destroyed.

1. Show the students a rusted nail. Explain that the rust is evidence of a chemical reaction where the iron has reacted with oxygen from the air to form rust. Rusting is one of the slowest reactions. It can take months or even years to occur.
2. In contrast, the reaction of magnesium with oxygen is very fast. Demonstrate burning a piece of magnesium using the Bunsen burner flame.
3. Ask students what they think affects how fast a reaction takes place and why it could be important to know about the factors that affect reaction rates.
4. Show students the video clip ‘Dust Explosions–Cool Science Experiment’, SpanglerScienceTV, YouTube (3:47 min) <https://www.youtube.com/watch?v=jENpGlJ0dzA>
5. Discuss with the students how dust explodes in the video but that a pile of dust will not explode.

## Core

### Investigation 1 – Surface area and reaction rate

This investigation allows students to explore the effect of surface area on the rate of reaction. This is a simulation and NOT a chemical reaction. The NaOH is absorbed into the gelatine cubes (physical process) and the distance that it penetrates in a set time is taken as a simulated measure of reaction rate.

### Equipment needed

Per group:

* 2 x 3x3x3 cm cubes of gelatine with phenolphthalein (see [Planning ahead and equipment list](http://assist.asta.edu.au/sites/assist.asta.edu.au/files/Planning%20and%20equipment%20list_Yr10_Reaction%20rates.docx))
* knife
* cutting board
* 2 x 500 mL beaker
* 250 mL 1 M NaOH
* stopwatch
* plastic ruler
* 100 mL measuring cylinder
* spatulas/plastic spoons
* paper towel
* Personal Protective Equipment

### What to do

1. Demonstrate to the class that a colour change takes place when a gelatine cube is submerged in the 1 M NaOH (clear to pink – The ‘reaction’ is the colour change which occurs when the sodium hydroxide diffuses into the cube and affects with the indicator).
2. Explain to the students that they will be comparing the distance/depth to which the pink colour has penetrated into each of the 3 cm sided cubes and the 9 x 1 cm sided cubes. This will be used to simulate reaction rate.
3. Establish that the mass of the gelatine is the same, but the 9 x 1 cm sided cubes have a larger surface area compared to the volume available for the reaction to take place compared to the 3 cm sided cube.
4. Ask the students to predict whether there will be a difference in the distance of absorption.
5. Instruct students to prepare the 9 x 1 cm sided cubes by cutting up one of the 3 cm sided cubes. They then use the spatula/plastic spoon to place the cubes in a 500 mL beaker.
6. Instruct the students to carefully pour in sufficient NaOH to cover the cubes and start the stopwatch and to record what they observe.
7. Instruct students that after 5 minutes they must use a spatula to remove the cubes and place them in the second beaker with water to rinse off the NaOH then remove the cubes and place them on the cutting board.
8. Instruct students to wear gloves when handing the cubes. Blot the cubes with paper towel.
9. Instruct each group to cut all of the 1 cm and one 3 cm sided cubes through the middle to make two equal halves. They can use a ruler to measure the distance from the outside of the cubes to the position of colour change boundary to determine how far the NaOH has penetrated.
10. The students should add the 9 distances from the 9 x 1cm sided cubes together to get a total absorption distance for these 9 cubes as compared to the 3 cm sided cube that has the same total mass.
11. Ask students to compare the results to their prediction and to write a generalisation about how the surface area available affects the distance of absorption.
12. Discuss how this can be used as a model of how surface area affects the rate of a chemical reaction.

### Expected results and explanations

There is a colour change as the NaOH soaks into the gelatine and meets the phenolphthalein indicator, which changes to pink. There is the assumption that the chemical travels into the cubes at the same rate.

In the smaller 1 cm sided cubes (with a volume of 1 cm3 and surface area of 6 cm2) there is a larger surface area compared to the volume. There is also only 0.5 cm distance from the surface of the cube to the middle of the cube. In the larger 3 cm sided cube (with a volume of 27 cm3 and a surface area of 54 cm2), the distance is 1.5 cm.

A chemical reaction starts when the NaOH chemical comes in contact with the phenolphthalein indicator. This happens on the surface first then reactions continue as the NaOH penetrates the gelatine.

The expected results are that the 1 cm sided cubes should be almost, if not entirely, pink showing the chemical reactions have taken place through the whole cube. The larger 3 cm sided cube will still have some unreacted clear parts close to the centre showing the chemical reactions have not taken place throughout the whole cube.

The total of all 9 x 1 cm sided cubes has the same mass as 1 x 3 cm sided cube. Absorption distance is greater in total for the mass with the larger surface area.

Students should think (for the same amount of mass) the absorption distance is greater if the surface area is greater. This is because there is increased opportunity for the particles to contact each other.

### Investigation 2 – Concentration and reaction rate

In this investigation, students explore the effect of concentration on rate of reaction. The time taken for the bubbles of hydrogen gas to cease forming is measured as the concentration of HCl is changed. Please refer to safety advice.

### Equipment needed

Per group:

* 3 x 1 cm magnesium ribbon
* steel wool
* 0.1 M HCl (10 mL)
* 1.0 M HCl (10 mL)
* 2.0 M HCl (10 mL)
* 3 x test tube
* test tube rack
* 10 mL measuring cylinder
* stopwatch
* Personal Protective Equipment

### What to do

1. Instruct students to lightly rub the magnesium ribbon with the steel wool to remove any surface tarnish then place the cleaned 1 cm magnesium ribbon in a test tube.
2. Instruct students to use the 10mL measuring cylinder to transfer 10 mL of 0.1 M HCl to the test tube and start the stopwatch.
3. Instruct students to stop timing when the bubbling stops and to record the time in a table.

|  |  |
| --- | --- |
| Concentration of HCl (M) | Reaction time in seconds (s) |
| 0.1 M |  |
| 1.0 M |  |
| 2.0 M |  |

1. Instruct students to repeat steps 1–3 with the 1.0 M HCl and then the 2.0 M HCl.
2. Students should construct a graph of their data and use this to determine the relationship between concentration and rate of reaction.
3. Ask the students to write a generalisation about how concentration affects the rate of reaction.

### Expected results and explanations

An increase in concentration means there are more particles in the same volume of water, so 1.0 M has 10 times more particles than the 0.1 M. The results should show that the reaction occurs more quickly when the concentration is higher. The increase in concentration increases the frequency of collisions between reacting particles per unit time and hence the rate of reaction will increase.

### Investigation 3 – Temperature and reaction rate

**Safety warning:** This reaction produces sulfur and sulfur dioxide. The reaction should not be performed if students are allergic to sulfur products. Even if there are no allergies, the reaction should be performed in a well-ventilated room or fume cupboard.

HCl + sodium thiosulfate arrow sodium chloride + sulfur dioxide + sulfur + water

Following the experiment, the wastes should be collected and disposed of appropriately. Consult a laboratory technician for disposal procedure.

This investigation allows students to explore the effect of temperature on the rate of a chemical reaction. The time taken for a sulfur precipitate to obscure a marked cross is taken as a measure of rate of reaction.

### Equipment needed

Per group:

* 0.1 M sodium thiosulfate (hypo) (200 mL)
* 2.0 M HCl (40 mL)
* 3 x 250 mL conical flask
* 2 x 500 mL beaker
* test tube
* ice
* hot water
* thermometer
* white paper
* pencil
* 50 mL measuring cylinder
* 10 mL measuring cylinder
* stopwatch
* paper towels
* Personal Protective Equipment

### What to do

1. Instruct students to use the 50 mL measuring cylinder to transfer 50 mL of sodium thiosulfate solution into a conical flask.
2. Students then use the thermometer to record the temperature of the sodium thiosulfate.
3. Instruct students to draw a cross on a piece of white paper and place the conical flask on the cross. They should view the marked cross from directly above and through the solution in the conical flask.
4. Instruct students to measure 10 mL of HCl using the 10 mL measuring cylinder and then carefully pour the HCl into the conical flask, swirl the flask to mix. They should start the stopwatch upon addition of the HCl to the flask.
5. Instruct students to view the cross from above.
6. Instruct students to stop the stopwatch when they can no longer see the cross (as the solution becomes cloudy) and then record the time taken for the cross to disappear in a table.

|  |  |
| --- | --- |
| Temperature or reacting mixture (ºC) | Time taken for the cross to disappear (s) |
| Examples 10ºC |  |
| 20ºC |  |
| 30ºC |  |
| 40ºC |  |

1. Students should now repeat steps 1–6 using sodium thiosulfate at different temperatures. To achieve different temperatures, students will place hot or cold/ice water in a 500mL beaker and place the conical flask in the beaker until the temperature is either 10ºC (or more) higher or lower. Students then measure 10 mL of HCl into a test tube and stand the test tube in the conical flask of sodium thiosulfate. This will ensure the two solutions are at the same temperature when mixed.
2. When the desired temperature has been reached students remove the test tube, pour the HCl into the flask and swirl to mix.
3. Instruct students to construct a graph of their data.
4. Ask students these questions.

* How do the results from the different experiments compare? (refer to your graphs)
* How are the results different from those in investigation 2?
* What might be the reason for this?

1. Ask the students to write a generalisation about how temperature affects the rate of reaction.
2. Remind the students that the waste from the experiment needs to be collected and not poured down the sink.

### Expected results and explanations

An increase in temperature increases the average kinetic energy of the reactant molecules. The reactant particles will move faster and collide more frequently per unit time and a greater proportion of these collisions will be successful. This leads to a greater increase in the reaction rate compared with concentration. This relationship should be obvious in the graph.

### Investigation 4 – Catalysts and reaction rate

This investigation allows students to explore the effect of a catalyst on the rate of a chemical reaction. A catalyst increases the rate of a chemical reaction without being permanently used up in the reaction. The intensity of bubbling is taken as a measure of rate.

### Equipment needed

Per group:

* 3.0% H2O2 hydrogen peroxide solution (50 mL)
* 5 g manganese dioxide
* spatula
* 5 mL detergent
* 1 mL transfer pipette/dropper
* 2 x test tube
* test tube rack
* 10 mL measuring cylinder
* 250 mL beaker
* warm water
* thermometer

### What to do

1. Instruct students to use a measuring cylinder to transfer 5 mL of hydrogen peroxide solution into each of 2 test tubes.
2. Students then gently place one drop of detergent on the surface of the hydrogen peroxide solution in each test tube and note the intensity of bubbling.
3. Instruct students to carefully place both test tubes into a 250 mL beaker of warm water (40–50ºC).
4. Students are to take note of the intensity of the bubbling in each test tube. (The bubbling should be very similar if not the same.)
5. Instruct students to place a ‘rice grain’ amount of magnesium dioxide (a known catalyst for this reaction) into just one of the test tubes and observe any changes in the intensity of the bubbling and to record their observations in a table.

|  |  |
| --- | --- |
| Reaction conditions | Bubbling rate |
| At room temperature |  |
| Water bath at 40–50ºC |  |
| In the presence of a catalyst |  |

1. Remind the students that the waste from the experiment needs to be collected and not poured down the sink.
2. Ask the students to write a generalisation about how the catalyst affects the rate of reaction.

### Expected results and explanations

The reaction takes place more quickly when a catalyst is present compared to when the catalyst is not present.

### Investigation 5 – Challenge: You are the process chemist

The duties of a process chemist include being a troubleshooter to identify what is going wrong in a chemical reaction and to determine how the issue can be fixed. A process chemist must have theoretical knowledge about how the reaction takes place and some practical experience to enable a solution to be found.

This activity gives the students the opportunity to apply their knowledge about factors affecting reaction rates.

### Equipment needed

Per group:

* 1.0 M HCl (40 mL)
* 0.1 M HCl (40 mL)
* 2.0 M HCl (40 mL)
* calcium carbonate (powder ≤1 mm diameter)
* calcium carbonate (‘sand’ 1–3 mm diameter) This can be purchased or generated by using a mortar and pestle
* calcium carbonate (chips 4–10 mm)
* test tube rack
* 5 x test tube
* 250ml beaker (for hot or cold water)
* 5 mL measuring cylinder (for liquid reactants)
* stopwatch
* electronic mass balance (± 0.01 g if possible)
* watch glass (for weighing calcium carbonate on the scale)
* thermometer
* hot water
* ice
* Personal Protective Equipment
* student investigation sheet

### What to do

1. Explain to the students that their task is to manipulate the reactants to make the reaction last for exactly 120 seconds or 2 minutes.
2. Instruct the students to perform the experiment as directed on their student investigation worksheet and to complete the ‘Proposed change’ section in the worksheet each time they attempt a new trial.
3. Tell students calcium carbonate is insoluble in water and any unreacted calcium carbonate (powder and chips) should be placed in a waste container for recycling.
4. Conditions:

* Students must always use 0.1 grams of calcium carbonate and 5 mL of HCl.
* Students may use any of the materials listed in the ‘Equipment needed’.
* Temperatures must remain below 50°C.

### Expected results and explanations

The students should complete the initial investigation and collect data about how the reaction proceeds. If their data shows the reaction takes longer than 120 seconds they should propose and test a method to decrease the time to 120 seconds based on the knowledge and understanding of the factors which determine reaction rates. They may choose to increase the temperature if the reaction is too slow. They should be able to justify their actions and link the theory to the practical approach. They should only alter one variable at a time, for example temperature, as they need to justify their actions and conduct the experiment, taking note of the principles of fair testing.

## Conclusion

Students should reflect on their trials and determine if they have appropriately linked their learning about the factors that affect reaction rates and their practical application. Sample questioning could involve asking why they took actions like increasing the temperature. Some investigation skill questions could also be asked – Why only change one variable at a time and why do the trial 3 times?

The rate at which a reaction occurs is very important. Explosions must have a fast reaction rate if they are to be useful. The rusting of iron has a slow reaction rate. Chemists have a role to ensure that some reactions occur quickly enough to be useful, but not too quick so as to be explosively dangerous and some where reactions are slowed down, for example in preserving food and preventing rusting.

In the chemical manufacturing industry controlling the rate of reaction is vital. Reactions that are too slow are not economical as the equipment is tied up for a long time. Reactions that are too fast need to be controlled, or contained in strong reaction vessels. Chemists and chemical engineers have the role of making chemical reactions as cheap as possible. A large part of this is achieved by controlling the rate of reaction, which depends on knowledge and understanding about the factors that affect the reaction rates.

### Assessment opportunities

Investigation 5 provides an opportunity to assess student understanding of the concepts related to factors which affect chemical reaction rates. The student worksheet along with class discussion can be used to assess communication of these ideas.

In addition, the level of student achievement of the science inquiry skills, **questioning and predicting**, **planning and conducting**, and **processing and analysing data and information** could be assessed.