Investigations for MYP Sciences

FOR USE WITH THE I.B. PROGRAMME

2nd EDITION

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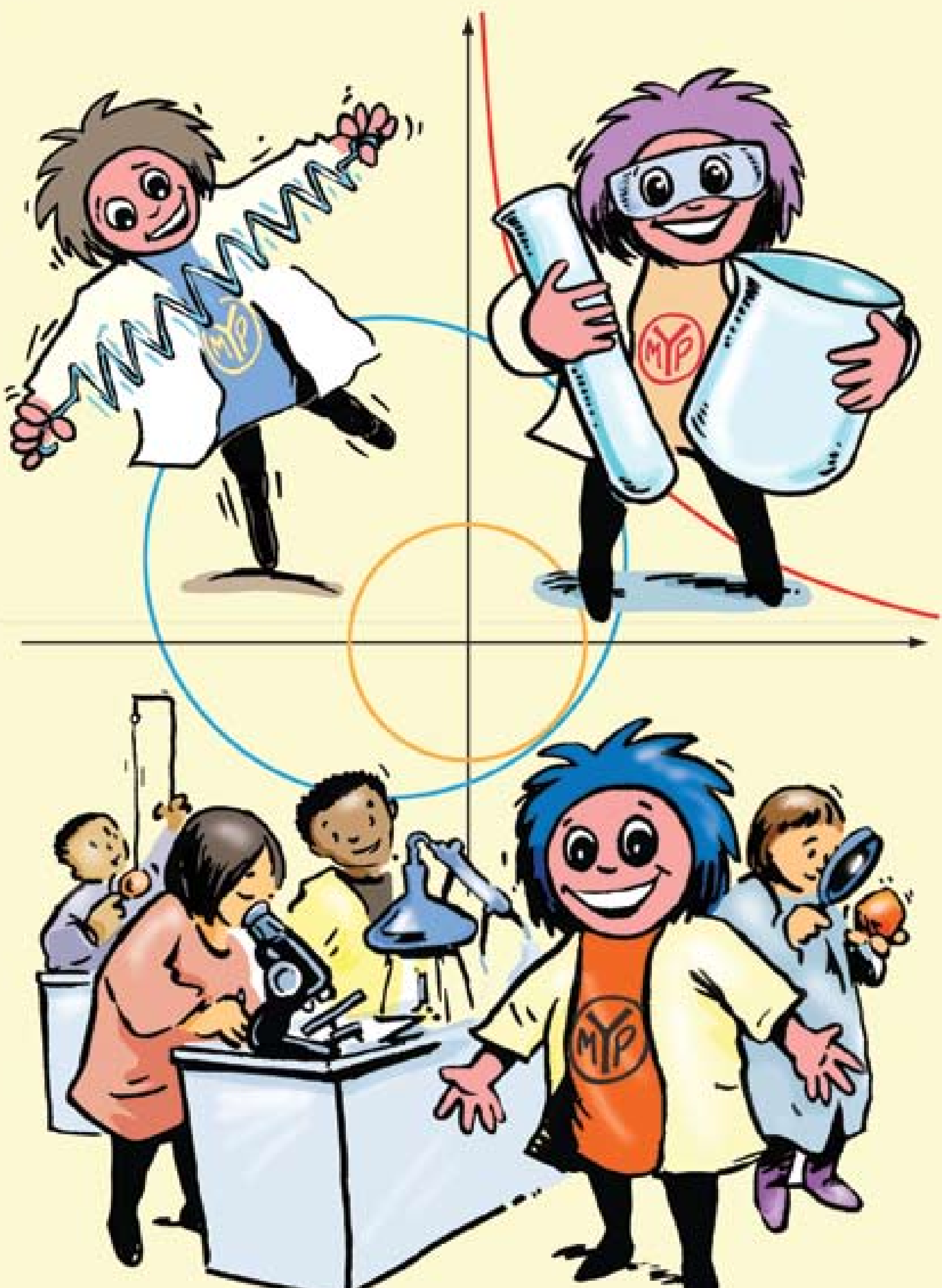
MYP



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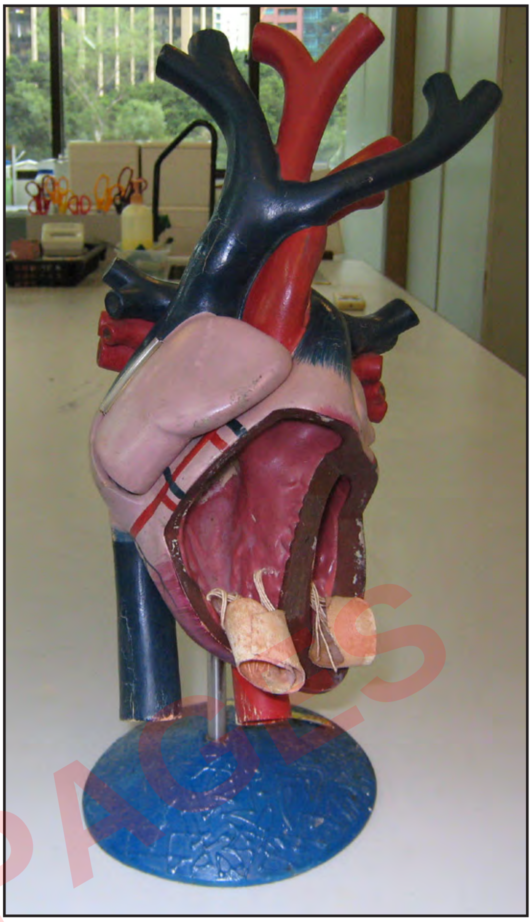
INTRODUCTION

The function of the heart during exercise is to pump sufficient blood to the muscles to allow them to function effectively when you exercise. This means providing them with the glucose and oxygen required for aerobic respiration and removing the excretory products, urea and carbon dioxide, and the excess heat produced during respiration. One measure of fitness is how quickly your heart rate returns to the resting rate after exercise.

The maximum rate that your heart can beat per minute tends to decrease with age, and this can be roughly estimated using the following empirical relationship:

[Maximum heart rate per minute] = [220] minus [your age in years].

The anaerobic threshold is approximately 85% of maximum heart rate.



AIM

To design, carry out and evaluate an experiment to investigate the effect of exercise on heart rate.

MATERIALS

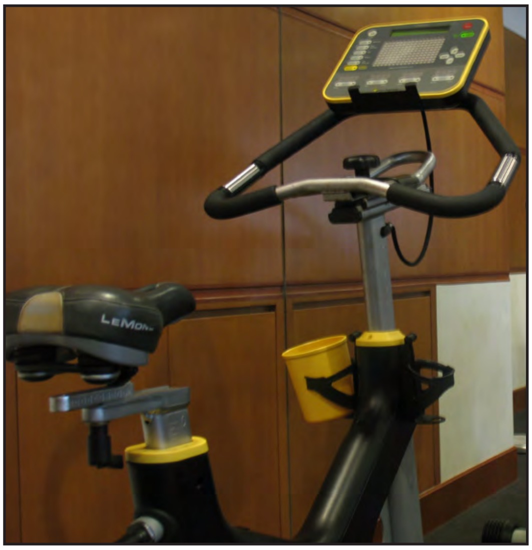
YOU WILL BE PROVIDED WITH:

Heart rate monitor

Exercise equipment, for example, a rowing or cycling machine that displays duration, instantaneous power and average power.

If access to a gym is not possible then your heart rate can be monitored using a finger placed lightly on top of an artery in the neck or wrist.

A controlled and well defined amount of exercise can be used in the place of gym equipment.



SAFETY

WARNING: Do not participate in this investigation if you are feeling unwell or taking medication. Stop if you are feeling very tired or unwell. Do not exceed your maximum heart rate for your age.

INTRODUCTION

Milk is a very nutritious and versatile food. People enjoy drinking milk in its natural form and also use it to make a wide range of food products, including cream, butter, yoghurt, cheese, and ice cream. People drink the milk produced from a variety of domesticated mammals, including goats, sheep, camels, reindeer, buffaloes, and llamas, although the major source for commercial production and consumption is from cows. Milk is composed of water, protein, lactose and fat which is dispersed throughout the milk in globules.

The relative densities of milk can be determined by measuring the time taken for droplets of milk to sink through a solution of copper(II) sulfate. The droplets are held intact due to the formation of a layer of copper proteinate at the surface.

AIM

To design, carry out and evaluate an experiment to investigate one or more of the variables that affect the density of milk.

MATERIALS

YOU WILL BE PROVIDED WITH:

Two droppers or teat pipettes

Two measuring cylinders (100 cm^3)

Stopwatch

0.1 mol dm^{-3} copper(II) sulfate

Milk samples: skimmed, semi-skimmed and full fat (different brands)

SAFETY

Copper(II) sulfate solution is harmful if swallowed and irritating to eyes and skin. Safety glasses must be worn at all times.

INTRODUCTION

Reaction time is the ability to respond quickly with proper posture and control to a stimulus such as sound or sight. In many sports, maximum speed is rarely reached or needed, but a fast reaction is often necessary. A fast reaction time may save your life when you are driving by allowing you to react quickly to an event, such as when braking a car, or dodging a braking car!

One simple approach to measuring reaction times involves dropping a ruler between the fingers and thumb of the subject who has to grip it as soon as he or she sees it move. The speed of the subject's reaction is a function of the distance the ruler falls before it is arrested.

The reaction time (s) can be established from the following equation:

$$t = \sqrt{\frac{2d}{g}},$$

where g represents the acceleration due to gravity (9.80 m/s^2) and d represents the distance measurement from the ruler (in metres).

There are two much more accurate ways to measure reaction time:

Find and use a website such as <http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=137>

OR start two identical stopwatches simultaneously by pressing their start buttons together. Now if one person (observer) presses the stop button, the sound will be a stimulus for the second person (subject) to press the stop button on the other stopwatch and the difference will be the reaction time.

AIM

To design, carry out and evaluate an experiment to investigate one or more of the variables that affect the reaction time of humans.

MATERIALS

YOU WILL BE PROVIDED WITH

Metre rules

2 electronic stopwatches

Bathroom scales (to measure mass of students)

SAFETY

DANGER

This activity could be harmful and affect your health. Any plan involving food or drink must be approved by your Teacher.

INTRODUCTION

'Acid rain', which causes corrosion of buildings and death of trees and freshwater fish, is caused by the gases sulfur dioxide and nitrogen dioxide. These gases are released into the atmosphere when fossil fuels, such as coal and fuel oil, are burnt. These fuels contain small quantities of sulfur and when the fuels burn, the sulfur reacts with the oxygen in the air to form sulfur dioxide. The polluting gases come from a variety of sources including chimney smoke (particularly from factories), and car exhausts. These gases are soluble in water and react to ultimately form sulfuric and nitric acids. These then react with stonework and metals, such as iron.

AIM

To design, carry out and evaluate an experiment to investigate one or more of the variables that affect the rate of a reaction involving dilute acid.

MATERIALS

YOU WILL BE PROVIDED WITH:

Gas syringe	Conical flasks
Delivery tube and bung	Electronic stopwatch
Ruler	Fine sand paper
Clamp stand	Measuring cylinders
Rubber tubing	Glass trough
Burette	Boiling tubes
Pestle and mortar	2 M nitric acid, HNO_3 (aq)
2 M ethanoic acid	Marble chips (calcium carbonate)
Kettle	Magnesium ribbon
Glass trough	Magnesium powder
Digital balance	Copper
Copper(II) oxide	Zinc
2 M hydrochloric acid, HCl	
2 M copper(II) sulfate solution	

SAFETY

Safety glasses must be worn at all times during the investigation. Dilute acid is corrosive – if it comes into contact with skin or eyes, then the affected area must be washed with a stream of cold water. Disposable gloves should be worn during the practical. Copper(II) sulfate solution is harmful if swallowed and irritating to eyes and skin. Copper(II) oxide is harmful.

INTRODUCTION

Neutralisation occurs when an acid reacts with a base to form a salt and water only. Acid rain in lakes and in soil is often neutralised by adding calcium oxide or calcium hydroxide. Many toothpastes and chewing gums are alkaline and help to neutralise the acids produced by bacteria respiring sugars in your mouth. When neutralisation occurs there are changes in pH, concentration, conductivity and temperature which can be measured when an alkali is progressively added to an acid, or vice versa.

AIM

To design, carry out and evaluate an experiment to investigate the reaction between a dilute acid and a dilute alkali (soluble base).

MATERIALS

YOU WILL BE PROVIDED WITH:

Funnel	Pipette and filler
Burette	White tile
Conical flask	Measuring cylinder (25 cm^3)
0.1 M sodium hydroxide	1 M sulfuric acid
0.1 M sulfuric acid	Distilled water
0.1 M nitric acid	0.1 M hydrochloric acid
0.1 M ammonia	0.1 M ethanoic acid
Universal indicator solution	pH probe and meter (and data-logger if available)
Thermometer	Temperature probe (and data-logger if available)
Conductivity probe and meter	1 M hydrochloric acid
1 M sodium hydroxide	Two insulated styrofoam or polystyrene cups
Burette stand	A range of commercial antacids

SAFETY

Safety glasses must be worn at all times during the investigation. Dilute acid and alkali are corrosive – if they come into contact with skin or eyes, then the affected area must be washed with cold water.

Day/Date of lesson ________________ **Period** __________

Teacher __________________________ **Room** __________

No. of students/groups __________

APPARATUS REQUIRED (PER GROUP)

Stopwatch

Access to exercise equipment in a gym (for example, a rowing or cycling machine that displays duration, instantaneous power and average power.)

SAFETY

WARNING: Do not allow students to participate in this investigation if they are feeling unwell or taking medication. Stop if they are feeling very tired or unwell. Do not allow them to exceed the maximum heart rate for their age.

SUGGESTED RESEARCH QUESTION

To examine the heart rate of a rower as he or she exercises aerobically to maintain a series of constant power outputs.

SUGGESTED VARIABLES

The independent variable is the power output during rowing; the dependent variable is the heart rate. The controlled variables are the air temperature, clothing and the make of rowing machine. The physiological condition of the exercising student is assumed to be unchanged between tests.

BACKGROUND THEORY

An athlete will eventually reach a point where he or she can no longer improve on his/her power output and/or his/her heart rate. During exercise the metabolic rate of the muscles increases and generates a rising demand for oxygen. The pacemaker of the heart can be increased (via the sympathetic nerve) or slowed down (via the vagus nerve). Blood flow (cardiac output) is determined by the volume delivered by each heart beat (stroke volume) and the number of beats per minute (heart rate). During exercise both stroke volume and heart rate increase. The presence of the hormone adrenaline increases the heart rate. High levels of carbon dioxide will decrease the heart rate and dilate the peripheral blood vessels. During exercise the breathing rate and tidal volume both increase so more oxygen is supplied to the blood in the lungs.

If insufficient oxygen is present at high power outputs the rower will have insufficient oxygen in his muscles and the cells switch to anaerobic respiration. The resulting lactic acid will build up in the muscle, making contraction more difficult. It is generally triggered at approximately 85% of maximum heart rate. An oxygen debt will be created and the rower will feel pain. The lactic acid will be converted back into pyruvic acid once sufficient oxygen is supplied to the muscle cells.

SUGGESTED METHOD

The subject needs to warm up so the 'resting' heart rate can be recorded. This can be used a base level to which the exercising student has to recover before embarking on any of the exercises or tests. The subject can then row at given power outputs for a fixed period of time. The maximum heart rate and power output should be recorded.

GRAPHICAL RELATIONSHIP

A line graph should be drawn of maximum heart rate (*y* axis) versus power output (*x* axis). The relationship will not be linear and the rate of increase of heart rate is smaller for larger power output values. A linear graph can be obtained by plotting $\log_{10}$ (maximum heart rate) versus $\log_{10}$ (power output).

EVALUATION

Students should note that lower power values, because they require minimal exertion, were the hardest to keep constant. Recovery times become longer after the bursts of higher power rowing. The exercise is assumed to be aerobic, but at high power output the person rowing (or doing other exercise) may be respiring anaerobically or a mixture of the two.

SUGGESTED EXTENSION WORK

Another very good indicator of cardio-vascular fitness is 'recovery time' which is variously defined. Students could devise and conduct an experiment, or series of experiments to investigate a factor(s) that may affect recovery time.

Day/Date of lesson ______________ **Period** ________

Teacher ______________________ **Room** ________

No. of students/groups ________

APPARATUS REQUIRED (PER GROUP)

Two droppers or teat pipettes   Two measuring cylinders (100 cm^3)

Stopwatch

CHEMICALS REQUIRED

0.1 mol dm^{-3} copper(II) sulfate

Milk samples: skimmed, semi-skimmed and full fat (different brands)

SAFETY

Copper(II) sulfate solution is harmful if swallowed and irritating to eyes and skin. Safety glasses must be worn at all times.

SUGGESTED RESEARCH QUESTION

To discover the relationship between the fat content of skimmed and semi-skimmed milk and the time taken for a droplet to sink through a solution of 0.1 mol dm^{-3} copper(II) sulfate.

SUGGESTED VARIABLES

The independent variable is the fat content of the milk; the dependent variable is the time taken for a droplet to sink through a solution of 0.1 mol dm^{-3} copper(II) sulfate. Controlled variables include the concentration and temperature of copper(II) sulfate solution, the volume of milk droplet; the depth of sampling, the freshness of the milk (time between opening and testing).

BACKGROUND THEORY

The composition of milk affects its density. The higher the amount of fat relative to proteins in the milk sample, the lower its density. The relative densities of different samples and types of milk can be determined by measuring the time taken for their droplets to sink through a solution of copper(II) sulfate.

In fresh milk, the fat droplets are uniformly dispersed, but when milk is allowed to stand the droplets rise to the top of the milk and form a layer of cream. Milk can be treated to prevent the formation of a cream layer. This type of milk is known as homogenised milk and is prepared by forcing milk under pressure through very small holes. The fat is broken down into smaller droplets which remain evenly dispersed and the milk has the same composition throughout. Homogenised milk is whiter, more opaque (cloudy), and more viscous than unhomogenised milk with the same fat content.

SUGGESTED METHOD

Fill the two measuring cylinders with copper(II) sulfate solution. Release a drop of the milk sample just below the surface of the copper(II) sulfate solution. Record the time taken for the drop to fall between the 100 and 10 cm^3 marks. Repeat and average the results.

GRAPHICAL RELATIONSHIP

A bar chart should be drawn of brand of milk versus average time for the drop to fall a fixed distance. A line graph could be drawn if a range of milks (of known fat composition) were tested.

EVALUATION

Students should be aware of random and systematic errors present in the manual timing. A taller measuring cylinder should be used so the times are longer and the effect of the errors reduced. Random errors in the size of the milk drop and its position of release should also be noted.

SUGGESTED EXTENSION WORK

The density of various brands of milk could be calculated from accurate measurements of the mass and volume of milk samples. It is assumed that changes in the fat content are responsible for changes in the density of the milk samples.

Day/Date of lesson ______________ **Period** __________

Teacher ______________________ **Room** __________

No. of students/groups __________

APPARATUS REQUIRED (PER GROUP)

Metre rulers

Electronic stopwatches

Bathroom scales (to measure mass of students)

SAFETY

You are not allowed to take large quantities of food or drinks, such as coffee or coca cola beforehand.

SUGGESTED RESEARCH QUESTION

To discover the relationship between the average reaction time of male and female students aged between 14 and 15 years old.

SUGGESTED VARIABLES

The independent variable is the gender and the dependent variable is the average reaction time for three trials. The controlled variable is the age of the students. Uncontrolled variables might include illness, fatigue, distraction, height, mood, muscular tension, vision and drugs/medication.

BACKGROUND THEORY

Cells in the retina detect the movement of the falling ruler (the stimulus), the optic nerve then sends impulses to the cerebral cortex of the brain. The visual cortex sends an impulse to the motor cortex and the motor cortex of the brain sends an impulse to the spinal cord. The spinal cord sends an impulse to the hand/finger muscles which contract to catch the ruler.

In almost every age group experiments have shown that men have faster reaction times than women, perhaps because of the greater involvement of men in sports, driving and computer games. Reaction times are shortest in the late twenties and then increase slowly with age. Shorter people have faster reaction time because shorter people have a shorter transit time for stimuli initiated in the brain.

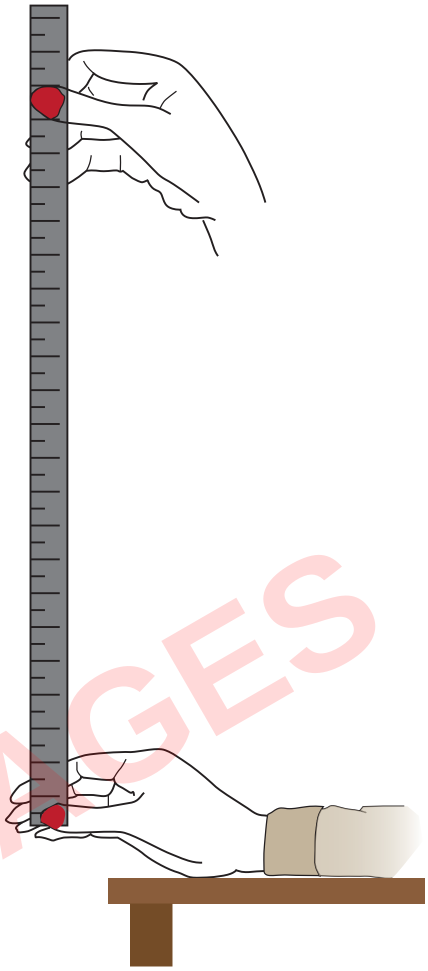
SUGGESTED METHOD

The subject marks a pencil line down the centre of his thumb-nail and sits sideways at a bench or table with the forearm resting flat on the bench and the hand over the edge (see Figure over). The student holds a ruler vertically between the subject's first finger and thumb with the zero opposite the line on the thumb but not quite touching either the thumb or fingers. The subject watches the zero mark and, as soon as the experimenter releases the ruler, the subject grips it between finger and thumb to stop it falling any further. The distance on the ruler opposite the mark on the thumb is recorded. This is repeated a number of time times and the average distance calculated. This distance can be converted to a time by the use of the equation in the student instruction sheet.

Two other, more accurate methods are briefly described in the Student sheets.

GRAPHICAL RELATIONSHIP

A bar chart should be plotted of average reaction time for a sample of male students versus the average reaction time for a sample of female students.



EVALUATION

The students should recognise that the sample size is relatively small and many of the potentially important controlled variables are not controlled. The speed of impulse conduction is so rapid that very large differences in distance would be needed to produce a measurable difference in reaction time by this crude method.

SUGGESTED EXTENSION WORK

The experiment could be repeated with the same student but this time the student lets the ruler rest lightly against the thumb or fingers, with closed eyes, and grips the ruler as quickly as possible after he or she feels it begin to fall. The average class results will probably not show any significant difference (at the 5% level of confidence if analysed statistically) between the reaction times. These are likely to be in the region of 0.2 seconds in both cases.

Students could also repeat the experiment to investigate the effect of left versus right hand. The left hemisphere is regarded as the verbal and logical brain, and the right hemisphere is thought to govern creativity, spatial relations, face recognition, and emotions, among other things. Also, the right hemisphere controls the left hand, and the left hemisphere controls the right hand. Students could also investigate the effect of direct vision versus peripheral vision. The fastest reaction time comes when a stimulus is seen by the cone cells in the retina (when the student is looking right at the stimulus). If the stimulus is picked up by rod cells (around the edge of the eye), the reaction is slower.

Students may also use the ‘two-stopwatch’ method to test right and left or sight and sound stimuli. This method produces much more consistent and accurate results. Some websites convert reaction time to braking distance (see Student sheets) and this could lead good students to investigate this mathematically.

Day/Date of lesson ______________ **Period** __________

Teacher ______________________ **Room** __________

No. of students/groups __________

APPARATUS REQUIRED (PER GROUP)

Gas syringe	Conical flasks
Delivery tube and bung	Electronic stopwatch
Ruler	Fine sand paper
Clamp stand	Measuring cylinders
Rubber tubing	Glass trough
Burette	Boiling tubes
Pestle and mortar	Gas syringe and rubber delivery tube
Kettle	Glass trough

Digital balance capable of weighing to at least 0.01 g

SUGGESTED CHEMICALS

Magnesium ribbon	Magnesium powder
2 M nitric acid, HNO_3 (aq)	2 M ethanoic acid
Marble chips (calcium carbonate)	Zinc
2 M copper(II) sulfate solution	Copper

Copper(II) oxide

2 M hydrochloric acid, HCl (aq) (students should dilute the acid as appropriate)

SAFETY

Safety glasses must be worn at all times during the investigation. Dilute acid is corrosive – if it comes into contact with skin or eyes, then the affected area must be washed with cold water. Iron should not be supplied to students since iron sulfide impurities generate the very poisonous gas, hydrogen sulfide. Calcium is too reactive and should not be given to students. The magnesium must only be reacted with acid - it must not be heated directly. Powdered magnesium is dangerous if blown into a Bunsen burner flame. Any heating of dilute acid must be done using a water bath. Copper(II) sulfate solution is harmful if swallowed and irritating to eyes and skin. Copper(II) oxide is harmful.

SUGGESTED RESEARCH QUESTION

To determine the relationship between the rate of reaction (as measured by the time for completion) and concentration for the reaction between magnesium and hydrochloric acid. (There are other possibilities).

SUGGESTED VARIABLES

The concentration of the hydrochloric acid is an independent variable and the time (for the reaction to go to completion) is the dependent variable. Controlled variables are the volume and temperature of hydrochloric acid and the mass and total surface area of magnesium.

BACKGROUND THEORY

Magnesium reacts with dilute acid to release hydrogen gas: Mg (s) + $2H^+$ (aq) → Mg^{2+} (aq) + H_2 (g). Calcium carbonate reacts with dilute acid to release carbon dioxide gas:

CO_3^{2-} (aq) + $2H^+$ (aq) → CO_2 (g) + H_2O (l).

The relative rate of a chemical reaction can be explained by reference to simple collision theory. If a solid reactant is broken down into smaller pieces the rate of reaction increases. The rate increase happens because smaller pieces of the same mass of solid have a greater surface area compared with larger pieces of the solid. Therefore, there is more chance that a reactant particle will hit the solid surface and react (in the same amount of time). When gases or liquids are heated, the particles gain kinetic energy and move faster. The increased speed increases the frequency of collisions between reactant molecules and the reaction rate increases. In addition heated molecules have a greater average kinetic energy, and so, at higher temperatures, a greater proportion of them have the required activation energy to react. It is important to remember that any discussion of factors affecting the rate of a reaction must refer to the number of collisions in a given amount of time.

If concentration is chosen as the independent variable then a quantitative prediction supported by a quantitative explanation could be expected, e.g. if the concentration of acid is halved, then students may predict the rate will be halved (assuming the reaction is first order). Quantitative predictions for changes in surface area are difficult to verify because of the difficulties in producing a series of marble chips whose surface areas can be measured and be related one to another, e.g.×2, ×4 etc. Your School's MYP Science course may not include the mole concept. It is, therefore, acceptable for students to describe the concentration in terms of the ratio of the volume of water to the volume of 2 M hydrochloric acid. Some prior teaching of how to perform a serial dilution will probably be required.

Able students should realise the effects of changes in surface area, however, this provides a challenging investigation for able students, because of the difficulty in measuring the surface areas and the difficulty in reproducing identical surface areas in order to repeat the results.

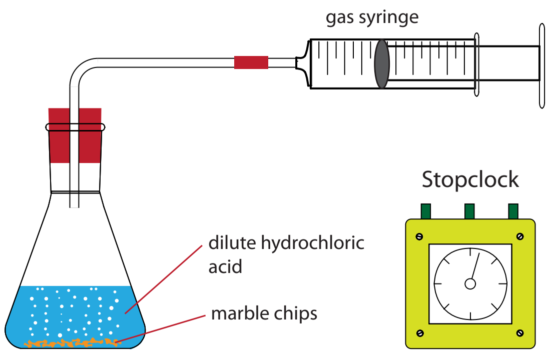
Reaction temperature is also very difficult to control since the reaction between magnesium and hydrochloric acid is very exothermic. A simple water bath, for example, a beaker of water can be employed in an effort to maintain a reasonably constant temperature.

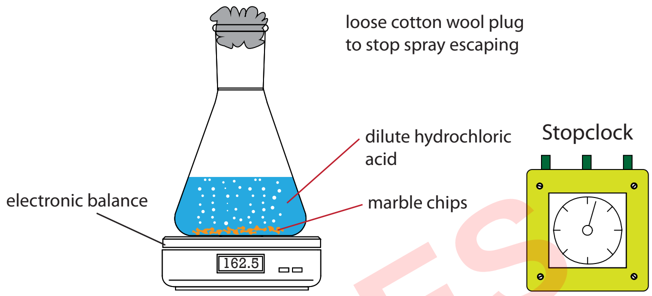
SUGGESTED METHOD

There are a variety of methods for measuring the rate of reactions that produce gas. The simplest approach is to use 1/time (reciprocal of seconds, s^{-1}) (for completion of reaction) as a measure of the average rate during the reaction. Students may use an electronic balance and an open flask (with some cotton wool in the neck to prevent acid spray splashing on the balance) to follow the loss in mass (due to release of gas) or a sealed gas syringe to record increase in total gas volume. Students using a gas syringe or balance will be able to plot graphs that will allow instantaneous rates to be obtained from gradients. Alternatively, the gas produced might be collected by downward displacement of water in an inverted measuring cylinder.

Be aware that students will often plan to measure the time taken for calcium carbonate to fully react and the products dissolve into solution, not realising that this will not work if the acid is the limiting reagent.

Note that as hydrochloric acid is diluted below approximately 1 mol dm^{-3} that the time taken for the reaction to go to completion is on the order of several minutes. Therefore students should either work at concentrations between 1 M and 2 M, or set up multiple test tubes simultaneously to expedite data collection.





GRAPHICAL RELATIONSHIP

Graphs of concentration (*x* axis) versus rate: change in mass or volume per unit time (*y* axis) may be directly proportional (provided the reaction is first order). A graph of temperature of acid (*x* axis) versus rate (*y* axis) should be exponential, provided a wide range of temperature is studied. A graph of surface area (*x* axis) versus rate (*y* axis) will be linear, provided surface area can be calculated.

EVALUATION

Students should be aware of random errors present in their measurements of mass, volume and time. Temperature can be controlled using a thermostatically controlled water bath. It is difficult to control the temperature of the reaction between magnesium and hydrochloric acid because it is significantly exothermic.

SUGGESTED EXTENSION WORK

Students could repeat the experiment using a different strong acid or a weak acid or choose another independent variable for the set of reactants. The most able students could try to establish a rate law. The students could perform the reaction between magnesium and dilute acid in the presence of copper(II) sulfate solution – the copper formed (via a displacement reaction) slows the reaction down as unreactive copper is deposited onto the surface of the magnesium.

Day/Date of lesson ________________ **Period** __________

Teacher ___________________________ **Room** __________

No. of students/groups __________

APPARATUS REQUIRED (PER GROUP)

Funnel

Pipette and filler

Burette

White tile

Conical flask

Measuring cylinder (25 cm^3)

Burette stand

Styrofoam or polystyrene cup

pH probe and meter (and data-logger if available)

Temperature probe (and data-logger if available)

Conductivity probe and meter (and data-logger if available)

CHEMICALS REQUIRED

0.1 M nitric acid

0.1 M sulfuric acid

0.1 M sodium hydroxide

0.1 M hydrochloric acid

0.1 M ammonia

0.1 M ethanoic acid

Distilled water

Universal indicator solution

A range of commercial antacids, ideally a single pure chemical, (e.g., milk of magnesia)

SAFETY

Safety glasses must be worn at all times during the investigation. Dilute acid and alkali are both corrosive – if they come into contact with skin or eyes, then the affected area must be washed with cold water. Universal indicator may be harmful if swallowed and may temporarily mark skin.

SUGGESTED RESEARCH QUESTION

To investigate the change in temperature as 25.0 cm^3 of 0.1 M hydrochloric acid is neutralised by 50.0 cm^3 of 0.1 M sodium hydroxide.

SUGGESTED VARIABLES

The independent variable is the volume of sodium hydroxide and the dependent variable is the temperature of the solution. The controlled variables are the equipment used, the concentrations and starting temperatures of the acid and alkali solutions.

THEORY

Neutralisation is the reaction between an alkali and an acid to form a salt and water only. It is an exothermic reaction: heat is released from the chemicals into the surroundings. The reaction between sodium hydroxide (a strong alkali) and hydrochloric acid (a strong acid) can be described by the following equations:

$NaOH\ (aq) + HCl\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$; $H^+\ (aq) + OH^-\ (aq) \rightarrow H_2O\ (l)$

The equivalence point is when stoichiometric amounts of acid and alkali are present, for example, 25 cm^3 of 0.1 M NaOH and 25 cm^3 of 0.1 M HCl - there is only sodium chloride and water present.

During this neutralisation the temperature rises up to the equivalence point. The temperature then decreases since addition of further acid involves no chemical reaction. A similar graph is obtained if higher concentrations of acid and alkali are used, but the two lines will meet at a higher peak.

If conductivity is monitored then there will be a decrease down to the equivalence point since two ions are replaced by one ion and a molecule. The conductivity will rise after the equivalence point as excess hydrochloric acid (hydrogen and chloride ions) is added to the sodium chloride solution.

The pH changes abruptly near the equivalence point since a relatively small change in hydrogen ion concentration causes a large change in pH. A symmetrical curve centred around the equivalence point is obtained due to the logarithmic nature of pH. $pH= - \log_{10} [H^+ (aq)]$.

SUGGESTED METHOD

Stand an insulated (or styrofoam) cup in a beaker for support. Using a pipette and safety filler, transfer 25 cm^3 of the sodium hydroxide solution into the cup, and measure the steady temperature. Using the burette, add a small portion (2–4 cm^3) of dilute hydrochloric acid to the solution in the cup, noting down the actual volume reading. Stir by swirling the cup and measure the highest temperature reached. Immediately add a second small portion of the dilute hydrochloric acid, stir, and again measure the highest temperature and note down the volume reading. Continue in this way until there are enough readings to decide the maximum temperature reached during this experiment. You will need to add at least 30 cm^3 of the acid.

EVALUATION

Students should be aware of random errors present in all the measurements of volume including those present in the technician's preparation of the solutions. Sodium hydroxide absorbs carbon dioxide from the atmosphere, thereby reducing its stated concentration. The main concern in this experiment is the heat loss. If possible a lid should be used. More reliable results can be achieved using two polystyrene cups (one inside the other).

SUGGESTED EXTENSION WORK

Students could follow the pH during neutralisation using indicator solution or, preferably using a pH probe and meter. The conductivity could also be monitored using a conductivity probe and meter. Students could also investigate the volume of acid required to neutralise different commercial antacids.