Science

BTEC National Level 3

Practical Skills Pack

for BTEC National Applied Science Unit 3

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Contents

Teacher's Introduction

> **Remember!**
> Always check the exam board website for new information, including changes to the specification and sample assessment material.

This practical skills support pack has been designed as a tool to enable your students to gain mastery of the content required to succeed in Unit 3 of the BTEC Level 3 National Applied Science course. It aims to break away from the more prescriptive methods available, allowing students to grow in confidence and independence as they develop their practical skills.

This resource consists of 10 practicals; two for each section of the subject-specific content found in Unit 3. Each practical will allow students the opportunity to consolidate their learning and apply their scientific skills to planning, recording and interpreting data, and analysing and evaluating findings in preparation for their exam.

Each section of the pack includes the following:

- **Teacher's notes** – allows the teacher to plan for the lesson ahead and set the practical in the appropriate context. Hints for technicians are also provided along with suggested time frames and any unusual equipment requests.
- **Sample data** – useful for when an experiment doesn't quite go as planned, or as a basis for a discussion around reproducibility.
- **Pre-lab tasks** – ideal for use as homework or prep work before the practical lesson is undertaken.
- **Student instructions** – a scaffold for the students to use when conducting their practical work, often with prompts to encourage deeper understanding of the procedures they undertake.
- **Comprehension questions** – written following the same style as the part B examination questions. Assesses knowledge of the practical skills developed during the task.
- **Answers** – will speed up marking and allow the opportunity for self- or peer-marking when used by the students.

Please note that although all tasks contain relevant health and safety information you should always consult your head of department or a relevant body before undertaking any practical you are unsure of. It is also recommended you trial all tasks before carrying them out with a class to determine where best they would fit in with your planning.

July 2021

Specification Map

Essential Content	Practical Name	BTEC Specification Reference	Sp
D) Enzymes in Action	Enzymes and substrate concentration	D1, D2	• Studen choice justifica • A thoro method
	Enzymes and the effect of pH	D1, D3	• The con hypoth importa design • Studen part of
E) Diffusion of Molecules	Diffusion and concentration gradients	E1, E2	• Studen plannin • Error b also tes
	Diffusion and temperature	E1	• Evalua analysis
F) Plants and Their Environment	Photosynthesis and light intensity	F1	• Studen plannin
	pH and germination	F1, F2, F3	• Evalua • Carryin of anal
G) Energy Content of Fuels	Properties of fuels	G1, G2	• Analysis a hypo
	Energy from fuels	G1, G3	• Studen choice justifica • Use of a concl
H) Electrical Circuits	Resistance of a wire	H1	• Evalua
	LDR	H2, H3	• Studen plannin

Alongside this subject-specific content, the reoccurring themes in sections A (Pla B (Data collection, processing and analysis/interpretation) and C (Drawing conclu present repeatedly throughout each practical.

Students will repeatedly be directed to plan tables which will allow them to reco risk assessments and plot all data as graphs to help form a conclusion.

Experiment 1 – Investigating the effect of enz
on the initial rate of an enzyme-catalys

Teacher's Notes

Purpose
This practical allows the students to investigate the effect of changing the conce
its catalysed reaction. It also gives the opportunity to discuss the importance of
when comparing factors. Students will be introduced to the benefits of using a c
colour change.

Prior Learning
Students should already be aware of how to use a colorimeter, including the pro
Unit 2; a refresher course may be necessary. An awareness of enzyme structure
As part of the data analysis, students will be required to plot graphs and draw ta

Suggested Starter Questions
- What would be the benefit of carrying out this experiment using distilled wate
  - ✓ *To act as a control to determine whether the change in colour of solution enzyme or not.*
- Can you suggest some suitable control variables necessary in this investigati
  - ✓ *Temperature, pH, concentration of substrate, volume of enzyme solutio*
- What trend do you predict you will see in the initial transmittance vs time g
  - ✓ *In all experiments you would expect the rate to decrease as the reactio in the amount of substrate available, and, therefore, lower probability o*
- Can you suggest a qualitative way of carrying out this experiment?
  - ✓ *For example, waiting until a previously hidden image underneath the en visible. This can lead to an opportunity to discuss the inherent errors in*

Brief Outline of Method
Various concentrations of trypsin solutions are used to break down the casein in
digested, the cloudy solution begins to clear, the rate of which is measured via a
transmittance is monitored over a set period and then the data is used to plot gr
As an extension task, pupils could be asked to consider the changes they would n
procedure in order to investigate the effect of changing substrate concentration o

Required Equipment
In addition to standard laboratory apparatus, students will need access to:
- 1 % trypsin solution
- 10 cm^3 volumetric flask
- 10 cm^3 graduated pipette
- Distilled water
- Colorimeter
- Cuvette
- Casein solution
- 2 cm^3 graduated pipette ×2
- Stopwatch

Time Requirements
Suggested lab time: 2 hours

Health and Safety Considerations

All enzymes have the potential to be allergens. Any spillages should be cleaned u
should be avoided; however, if this occurs the affected area should be washed w

Practical Considerations

Students need access to 5 % milk powder solution and trypsin solution stabilised
will be diluted by the students to 1 %, 0.8 %, 0.6 %, 0.4 % and 0.2 %

Sample data

Time (s)	Transmittance			
	1.0 %	0.8 %	0.6 %	0.4 %
0	0.000	0.000	0.000	0.000
30	0.345	0.339	0.223	0.175
60	0.437	0.399	0.321	0.256
90	0.673	0.657	0.536	0.334
120	0.889	0.864	0.678	0.378
150	1.000	1.000	0.839	0.447
180	1.000	1.000	0.921	0.502
210	1.000	1.000	1.000	0.559
240	1.000	1.000	1.000	0.610
270	1.000	1.000	1.000	0.699
300	1.000	1.000	1.000	0.764

Pre-lab Tasks

1. Copy and complete the following paragraph to explain the structure and fu

   An enzyme is a ________________ ________________. It is a ___
   which ________________ up biological reactions, allowing us to sta
   lowering the ________________ ________________ of the biochem
   within our cells. The structure of an enzyme is vital for its function.
   ________________ chains folded together in a specific manner resu
   as an ________________ ________________, which is where the c

2. There are two theories as to how an enzyme and its substrate molecule inte the induced fit model. Produce a comic strip which shows these two model and differences between them.

3. Read the 'Student instructions' sheet and write a list of the equipment requ Ensure you select the most suitable piece of apparatus for each procedure.

4. Construct a risk assessment which considers all possible risks in this investig you will take to avoid them.

5. In this experiment you will be monitoring the initial rate of the reaction und enzyme. Use research to explain why the initial rate of reaction is the most

6. Sketch the general shape of the graph you will expect to obtain for each of th (there should be three distinct areas). Explain the reason for the changes in s

7. Annotate your graph from Q6 to explain how you will determine the initial r enzyme concentration.

Student Instructions

You are expected to ensure you are working safely and observing good laborat

Before beginning your practical work, you should read the instructions thorough and dependent variables. Once done, use this to design a results table which wi experimental data.

In this experiment you are investigating the hypothesis:

> 'The higher the concentration of enzyme, the faster the initial rate of the enzym to the increased probability of a collision between the enzyme and th

NB The following is an outline for the experiment you should carry out. It does detail so ensure you have read it thoroughly before beginning and have a clear method you will follow.

1. You will be provided with a 1 % solution of trypsin. Decide what concentratio
2. Transfer 2 cm^3 of the casein solution into a cuvette and record the initial tra the colorimeter.
3. Add 2 cm^3 of the trypsin solution and mix well.
4. Measure the transmittance of the solution at regular intervals for 5 minutes
5. Use distilled water to rinse out the cuvette.
6. Repeat steps 2–5 with the four other enzyme concentrations.

SAFETY INFORMATION!

All enzymes have the potential to be allergens. Any spillages should be clean should be avoided; however, if this occurs the affected area shou

Data Analysis and Evaluation

Data Analysis

For each concentration of enzyme, plot a graph of transmittance against time. U initial rate of reaction; to do this you will need to calculate the tangent at the be quote appropriate units.

Once you know the initial rate for each experiment, you should complete a final on your x-axis and initial rate on your y-axis.

Evaluation

The following factors could cause a lack of validity in your results:

- fluctuations in temperature
- lack of proof that the enzyme causes the change in colour

Explain how they could be addressed.

Comprehension Questions

1. Use information from your graph to describe how the change in concentrati the initial rate of casein breakdown.

2. Suggest one reason why you needed to thoroughly mix the casein and tryps

3. Enzyme activity can also be affected by temperature.

   (a) Explain how carrying out this experiment at a lower temperature would trypsin activity.

   (b) Explain how carrying out this experiment at increasingly higher tempera rate of trypsin activity.

4. Explain two ways you could extend this investigation in order to determine a optimum concentration of trypsin to use to breakdown casein.

5. A student investigated the effect of enzyme concentration on the initial rate

   Catalase speeds up the breakdown of hydrogen peroxide into water and oxy

   $$2H_2O_2 \rightarrow 2H_2O + O_2$$

   They follow the following method:

   - A potato cylinder is added to a tube of hydrogen peroxide
   - A bung and delivery tube are immediately inserted into the tube, with t under an inverted measuring cylinder, filled with water
   - The oxygen gas produced is collected

   The experiment is repeated with different sizes of potato cylinders.

   Evaluate this method. Highlight any areas where errors could be made, or w lacking detail, and suggest improvements.

Answer Sheets

Pre-lab Tasks

1. An enzyme is a *biological catalyst*. It is a *protein* molecule which *speeds* up biologic Enzymes work by lowering the *activation energy* of the biochemical processes occu of an enzyme is vital for its function. An enzyme is made up of *polypeptide* chains f resulting in a small area known as an *active site*, which is where the catalysis occurs

2. **Key features of the comic strip:**
   - Lock and key theory: an enzyme with a specific active site and substrate match The substrate should diffuse into the active site and form an enzyme-substrat out causing the substrate to break down into the product, leaving an enzyme- diffuse away, leaving behind the enzyme looking identical to the beginning of
   - Induced fit theory: similar to the lock and key comic strip, except this time the the shape of the substrate and then changes shape to closely bind to the subs products diffuse away the enzyme should revert to its original shape.

3. **Required equipment:**

   1 % trypsin solution
   10 cm^3 volumetric flask
   10 cm^3 graduated pipette
   Distilled water
   } Required for serial dilution to make the desired

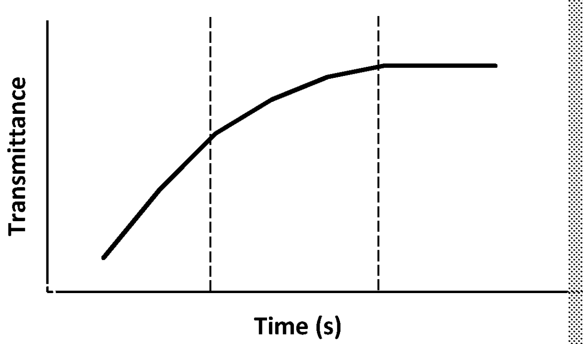
   Colorimeter
   Cuvette
   Casein solution
   2 cm^3 graduated pipette ×2
   Stopwatch
   } Required for measuring the transmittance of the

4.

Hazard	Risk	
Trypsin Solution	Enzyme solutions are potential allergens	Avoid contact with area should be imm Eye protection to b
Glassware	Could break and cause cuts	Ensure a tidy and c Any breakages sho
Colorimeter	Wires can cause a trip hazard	Ensure a tidy and c are contained with

5. In any enzyme-catalysed reaction, the rate naturally slows down as the reaction pro in amount of substrate available as it is converted into the desired products and, th and substrate colliding. Measuring the initial rate of reaction allows us to monitor t conditions are those which we desire.

6.



   - Section 1: initially transmittance will increase quickly as there is a high numbe combine with enzymes.
   - Section 2: the rate of increase in transmittance begins to slow as the amount o resulting in a lower probability of a reaction occurring.
   - Section 3: eventually the transmittance will plateau as all substrate molecules

7. The graph should show awareness of drawing a tangent at the beginning of the line The gradient of this line should then be calculated by dividing the change in the y-ax

Student Instructions

Model results table:

Concentration of Trypsin Solution (%)	Transmittance Reading		
	1	2	3

Evaluation

Fluctuations in temperature: occur due to changes within the environment. Therefore, t
using a water bath to maintain a constant temperature.
Lack of proof that the enzyme causes the change in colour: a control could be carried ou
2 cm^3 of trypsin solution.

Comprehension Questions

1. Any two from:
   - As the concentration of trypsin increases, the initial rate of reaction increases (
   - A comment on the proportionality of the relationship (1)
   - A comment referencing any plateauing of results (1)
2. To ensure the casein and trypsin solution is evenly distributed (1)
3. (a) Initial rate would be lower (1)
   Fewer enzyme-substrate complexes formed (1)
   Less kinetic energy (1)

   (b) To begin with, as temperature increases initial rate increases (1)
   More enzyme-substrate complexes formed (1)
   More kinetic energy (1)
   Mention of optimum temperature (1)
   Rate decreases due to denaturing of enzymes (1)
4. Any two points from below (4 marks total):
   - Carry out more repeats for the concentrations investigated (1); to allow you to sp
   - Use intermediate concentrations of trypsin around the suggested optimum va
     accurately determine the levelling off point (1)
   - Extend the concentration of trypsin beyond 1 % (1); to extend the range of res
     not suggest a levelling off
5. Any six from:
   - Diameter of potato cylinders not specified (1)
   - Length of cylinders to be investigated not specified (1)
   - Volume of hydrogen peroxide not specified (1)
   - Control temperature not referenced (1)
   - Control pH not referenced (1)
   - No end point to the reaction referenced, e.g. amount of oxygen to be collecte
   - No repeats suggested (1)
   - Counting bubbles can cause uncertainty due to speed or size of bubbles; woul
     measuring cylinder to determine a volume (1)

Experiment 2 – Investigating the optim
breakdown of starch by amyl

Teacher's Notes

Purpose
This is a straightforward, well-tested experiment. Students will use buffer soluti amylase at different pHs. From a graph of their results they will determine the o

Prior Learning
Students should have been introduced to the process of enzymes denaturing and also be discussing the idea of a null hypothesis and carrying out an unpaired stud need to have been introduced to these concepts and given the opportunity to pr

Suggested Starter Questions
- Based on your prior knowledge, do you have any predictions about what you wi
  - ✓ *Students may choose to discuss the function of amylase from GCSE Biol investigation, general discussion of enzymes being denatured, anticipat*
- How will you decide that all the starch has been broken down?
  - ✓ *Discussion of the colour change involved when using iodine to test for s Suggestion of a control to act as a colour comparison.*
- Why are we controlling the reaction at 35° C?
  - ✓ *Students can approach this in two different ways: either by discussing t factor that can affect the activity of enzymes or by focusing on the fact temperature, which is where amylase naturally exists.*

Brief Outline of Method
Using buffers to provide different pH environments, students will test samples of 10-second intervals to determine when all the starch has been broken down. Iod the absence of a blue-black colour once the amylase-starch solution has been add The rate of this enzyme-controlled reaction can then be calculated using 1 ÷ time. St pH buffers or carry out repeats of one pH and then pool class data dependent on the

Required Equipment
In addition to standard laboratory apparatus students will need access to:
- Water bath set at 35° C
- Amylase solution (1 %)
- Starch solution (1 %)
- Iodine solution
- Stopwatch
- Spotting tile ×2
- Dropping pipette
- 5 cm^3 syringes
- pH buffers (to cover a range of pHs)

Time Requirements
Suggested lab time: 1 hour

Health and Safety Considerations
- All enzymes have the potential to be allergens. Any spillages should be clea Skin contact should be avoided; however, if this occurs the affected area sh
- pH buffer solutions risk varies based on pH and manufacturer
- Iodine solution is low risk once made up

Practical Considerations
It is advisable to test the speed of the reaction with the volumes and concentrat advance. Ideally, at pH 6 the reaction should be complete in 60 seconds. Enzym activity of any previously made stock should also be checked if it is intended to b

Sample Data

pH	Time taken for starch to be fully	
	1	2
4	240	240
5	120	180
6	60	70
7	140	140
8	270	270

NB An anomaly has been included at pH 5, trial 2

Pre-lab Tasks

1. Define the following key terms:
   (a) Enzyme
   (b) Substrate
   (c) Active site
   (d) Denatured
   (e) Optimum

2. (a) What is meant by a 'hypothesis'?
   (b) Read the 'Student instructions' sheet for this experiment and suggest a
   (c) What would be the null hypothesis for this investigation?

3. This investigation requires small volumes of liquids to be measured out. Exp you would use to measure out 1 cm^3 pH buffer and why this is better than a

4. State two control variables in this experiment, describe how they will be co need to be controlled.

5. Copy and complete the following table to construct a risk assessment which investigation and details the precautions you will take to avoid them.

Hazard	Risk	

6. Design an appropriate results table to record the data required to investigat to break down starch.

Student Instructions

You are expected to ensure you are working safely and observing good laborat

NB The following is an outline for the experiment you should carry out. It does detail, so ensure you have read it thoroughly before beginning and have a clea method you will follow.

1. Collect the following equipment:
   - ☑ Water bath set at 35 °C
   - ☑ Amylase solution
   - ☑ Starch solution
   - ☑ Iodine solution
   - ☑ Stopwatch
   - ☑ Spotting tile x2
   - ☑ Dropping pipette
   - ☑ 5 cm^3 syringes
   - ☑ pH buffers
   - ☑ Test tubes
2. Place the starch and amylase solutions into the water bath and allow to acc
3. Use the dropping pipette to place one drop of iodine into each well of the s
4. Use separate syringes to place 2 cm^3 amylase and 1 cm^3 of pH buffer into a water bath.
5. Simultaneously add 2 cm^3 starch to the amylase/buffer solution and start th is combined thoroughly.
6. After 10 seconds remove one drop of mixture and test it with the iodine sol Repeat this every 10 seconds until the end point is reached.
7. Carry out any required repeats to ensure a full spread of data.

SAFETY INFORMATION!

- *All enzymes have the potential to be allergens. Any spillages should be cle Skin contact should be avoided; however, if this occurs the affected area s*
- *pH buffer solutions risk varies based on pH and manufacturer.*
- *Iodine solution is low risk once made up.*

Data Analysis and Evaluation

Data Analysis

For each pH tested you should calculate a mean and then use this to determine t calculated as 1 ÷ time taken. This data can then be plotted on a graph of rate vs

Use your graph to estimate the optimum pH of amylase and explain your answer

Evaluation

Suggest stages in your method which may have introduced error into your invest potentially be improved in future repeats.

Explain how a more precise value for the optimum pH for amylase activity could

Comprehension Questions

1. Use information from your graph to describe how the changes in pH affect th

2. State the independent and dependent variables in this experiment.

3. A second student carried out a similar investigation looking at the action of pH3 and pH8.

   (a) State a null hypothesis for this investigation.

   (b) The table below shows the time taken for the enzyme activity to be co

Repeat number	Time taken for reaction to be co	
	pH 3	pl
1	97.0	17
2	102.0	14
3	111.0	19
4	132.0	15
5	95.0	16
6	119.0	20
7	115.0	15
8	134.0	17
9	107.0	12
10	126.0	13
Mean time taken (s)	**113.8**	**16**
Standard deviation (s)	**13.93**	**26.**

   Use the unpaired t-test to calculate the value of t for this student's inve

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

   (c) Use $(n_1 + n_2) - 2$ to calculate the degrees of freedom for this investigatio

   (d) Use the t table below to give the critical value of t at the p = 0.05 level.

Degrees of freedom		P = 0.05
	15	2.13
	16	2.12
	17	2.11
	18	2.10
	19	2.09
	20	2.09
	21	2.08
	22	2.07

   (e) State, with reasons, whether you would accept or reject the null hypot

Answer Sheet

Pre-lab Tasks

1. (a) Enzyme – a biological catalyst; a protein molecule which speeds up biological p
   (b) Substrate – the substance which is acted on (broken down or built up) by the e
   (c) Active site – the area of the enzyme where the substrate binds and catalysis o
   (d) Denatured – name given to the process of an enzyme losing the shape of its ac
   (e) Optimum – a term to describe the conditions which will provide the fastest ra
2. (a) A hypothesis is a statement made about the predicted outcome of an investig the statement based on scientific facts.
   (b) The activity of amylase will vary at different pHs. Around pH 6 should give the the pH of the mouth, where amylase is naturally found. Outside of the optimu decrease as the shape of the active site is affected and the enzyme begins to b
   (c) There is no **significant** difference between the activity of amylase at any pH.
3. The most suitable piece of equipment to measure out 1 cm^3 of buffer solution wou pipette filler. This is due to the pipette being carefully calibrated making it more ac Using a 1 cm^3 pipette instead of a 2 cm^3 pipette will also reduce the percentage err
4. Temperature – a higher temperature can cause increased enzyme activity or denat colder temperature can cause the enzyme to work more slowly – a water bath will temperature is maintained.
   Amount of enzyme – this would change the amount of enzyme molecules in the mi each experiment in this investigation will used a measured portion of enzyme solut
5.

Hazard	Risk	
Amylase solution	Enzyme solutions are potential allergens	Avoid contact wit affected area sho
Iodine solution	Low hazard – can be harmful	Goggles should b cleaned up imme
Buffer solutions	Low hazard – can be harmful	Goggles should b cleaned up imme
Glassware	Could break and cause cuts	Ensure a tidy and breakages should

6.

pH	Time taken for starch to be fully bro		
	1	2	
4			
5			
6			
7			
8			

Evaluation

The main errors in this investigation are the thorough mixing of the enzyme/substrate/b nature of the reaction vessel and ensuring the aliquots are taken out at exactly 10 secon or underestimated.
A more precise value for the optimum pH can be determined by testing the pH in smalle suggested by the investigation.

Comprehension Questions

1. Any two from:
   - As the pH increases the rate of reaction increases. (1)
   - A comment on the peak value of the graph (1)
   - After the optimum value as pH increases the rate of reaction decreases (1)
2. Independent – pH of solution (1)
   Dependent – time taken for starch to be fully broken down (1)
3. (a) There is no **significant** difference (1) between the action of lipase at pH 3 or p
   (b) Difference in mean = 160.0 – 113.8 (1) = 46.2 (1)
   Standard error = $13.93^2/10 + 26.00^2/10$ (1) = 87 (1)
   Square root = 9.33 (1)
   t = 4.956 (1)
   (c) (10 + 10) – 2 (1) = 18 (1)
   (d) 2.10 (1)
   (e) As the t test value is above the critical value (1) there is significant difference b and pH8 (1), and, therefore, the null hypothesis should be rejected (1)

Experiment 3 – Investigating the effect of c rate of diffusion

Teacher's Notes

Purpose
In this practical, students are given a design brief and then asked to develop thei hypothesis and method to investigate this. Students will be looking at the effect rate of diffusion in agar jelly.

Prior Learning
An awareness of the process of diffusion is useful for this experiment. Students experience they have had so far in planning and designing methods. As part of t students will be expected to calculate standard deviation and apply this as error discussed and practised during teaching time.

Suggested Starter Questions
- In pairs, you have 2 minutes to tell each other everything you know about d
- Based on your prior knowledge, what are you expecting to observe during t
  - ✓ *The higher the concentration of the acid the further the acid should diff a faster rate of diffusion.*

Brief Outline of Method
Students will use alkaline agar jelly stained with phenolphthalein to monitor the concentrations. They will use a cork borer to form wells to fill with acid and then by this acid in a set time.

The pre-lab tasks given for this task require students to plan a method for this in guidance. A student instruction sheet has been provided that could help suppor method as described in the pre-lab tasks or could be used for the class to follow methods which are not feasible to conduct in the lab environment.

Required Equipment
In addition to standard laboratory apparatus students will need access to:
- Cork borer
- Dropping pipettes
- Ruler
- Petri dishes of agar jelly stained with phenolphthalein
- HCl:
  - 0.1 mol dm^{-3}
  - 0.5 mol dm^{-3}
  - 1 mol dm^{-3}
- Stopwatch

Time Requirements
Suggested lab time: 1 hour

Health and Safety Considerations
The hydrochloric acid and sodium hydroxide used in this practical are low enoug low hazard. Eye protection should be worn and any spillages should be cleaned

Practical Considerations

It would be advisable to try this experiment beforehand to have an idea of the ti diffusion of the weakest acid while ensuring the strongest acid does not diffuse u

The agar jelly should be made up with 0.01 mol dm^{-3} sodium hydroxide, coloured left to set in Petri dishes.

Sample Data

Concentration of hydrochloric acid (mol dm^{-3})	Distance travelled by hydrochl	
	1	2
0.1	2	3
0.5	7	6
1.0	15	13

NB An anomaly has been included at 1.0 mol dm^{-3}, trial 3

Pre-lab Tasks

- **We will place acidic solutions into wells made in agar jelly, containing a alkali, clear in acid).**
- **As the acid diffuses into the jelly, the jelly will turn clear. We will use d acid and measure how far they have diffused after a set amount of tim**

You will be provided with the following equipment:

☑	Petri dishes of agar jelly stained with phenolphthalein	☑	Cork b
☑	HCl: 0.1 mol dm^{-3}, 0.5 mol dm^{-3} and 1 mol dm^{-3}	☑	Dropp
☑	Stopwatch	☑	Ruler

Produce a fully detailed method explaining how you will carry out an investigatio concentration gradient affects the rate of diffusion.

You should include the following:

(a) A hypothesis which states what you believe the outcome of this investigatio to support your reasoning

(b) A description of the purpose of each piece of equipment

(c) A logical list of instructions, highlighting any stages you believe will ensure a

(d) Identification of the variables in your investigation: independent/dependen control/measure these, and are there any variables you believe will be diffic

(e) What range and interval will you select for your independent variable, and why

(f) How will you record your data? Draft a version of the results table you can experimental observations.

(g) What are the inherent risks within this experiment, and how will you minim

Student Instructions

You are expected to ensure you are working safely and observing good laborat

The following method can be used to aid you in the planning process. Conside the instructions to ensure that the practical you design shows good scientific p

1. Collect the following equipment:
   - ☑ 3 Petri dishes of agar jelly stained with phenolphthalein
   - ☑ HCl: 0.1mol dm^{-3}, 0.5 mol dm^{-3} and 1 mol dm^{-3}
   - ☑ Stopwatch
   - ☑ Cork borer
   - ☑ 3 dropping pipettes
   - ☑ Ruler

2. In each Petri dish make three holes in the agar jelly.

   Which piece of equipment will you use to do this? How will you space out th three holes in each dish when you have only three concentrations in total to

3. Use the dropping pipette to carefully add enough 0.1 mol dm^{-3} HCl to fill the

   How will you ensure this is consistent between all three wells? Why is it imp as possible?

4. After a defined amount of time, stop the reaction and use a ruler to measur well of acid.

   How will you decide how long to allow the acid to diffuse for? How could yo

5. Repeat for the other two acid concentrations.

SAFETY INFORMATION!

The hydrochloric acid and sodium hydroxide used in this practical are low considered low hazard. Eye protection should be worn and any spillages sho

Data Analysis and Evaluation

Data Analysis

For each concentration of acid calculate a mean and plot a graph of concentratio of diffusion.

Evaluation

For each concentration calculate the standard deviation for the set of results and to the points on your graph. Use this information to decide which concentration

Comprehension Questions

1. Use your graph to describe the relationship between concentration of acid a rate of diffusion.

2. When investigating the effect of concentration of the acid on average rate o control the temperature. Explain why.

3. Calculate the percentage error associated with the average distance the agar

4. State and explain the biggest factor responsible for inaccuracy in your exper overcome this.

5. Explain, using the concepts of repeatability and reproducibility, how you could t

6. Other than using a larger range of acid concentrations, explain two ways yo investigation further.

Answer Sheet

Pre-lab Tasks

Hypothesis: as the concentration of the acid increases you would expect the rate of diffu
the larger concentration gradient which would be created.

See 'Student instructions' sheet for suggested method

Concentration of hydrochloric acid (mol dm^{-3})	Distance travelled by hydrochlo		
	1	2	

Hazard	Risk	
Phenolphthalein cubes	Low hazard – can be harmful	Goggles should be worn
Hydrochloric acid	Low hazard – can be harmful	Goggles should be worn cleaned up immediately
Sodium hydroxide	Low hazard – can be harmful	Goggles should be worn cleaned up immediately
Glassware	Could break and cause cuts	Ensure a tidy and organi Any breakages should be

Comprehension Questions

1. As concentration increases the rate of diffusion increases (1)
   Comment on proportionality (1)
2. Temperature can also affect the rate of diffusion (1) the higher the temperature the
   have (1) and so the faster they diffuse (1)
3. Identification of absolute error being 0.5 mm (1)
   Absolute error ÷ mean reading at 0.5 mol dm^{-3} (1)
   ×100 (1)
4. Ensuring all wells diffuse for the same amount of time (1) as it is very difficult to add
   time and measure all three at the same time (1) this can be overcome by using three
   each well (1)
   Or any other sensible suggestion
5. Repeatability: repeat the experiment (1) while using the same equipment (1)
   Reproducibility: other students should carry out the experiment (1) and compare re
6. Any two points from (4 marks total):
   - Use a different type of acid (1), e.g. sulfuric acid (1)
   - Change the substrate diffusion occurs in (1), e.g. gelatine instead of agar (1)
   - Change the surface area of the well (1) use a different-sized cork borer (1)
   - Investigate different temperatures (1) use a water bath to heat the acid (1)

Experiment 4 – Investigating the effect of te rate of diffusion

Teacher's Notes

Purpose
In this investigation, students will be required to follow instructions given in a sk effect of temperature on the rate of diffusion. They will then be asked to consid and a similar one in a detailed set of evaluation comprehension questions.

Prior Learning
An awareness of the factors affecting diffusion will be necessary for this investig practical work involves comprehensive testing of students' evaluative skills, and, percentage error will be required.

Suggested Starter Questions
- Why can we only investigate moderate temperatures in this investigation an
  - ✓ *Too cold and diffusion would be too slow, and the agar could potentiall acid would be too hazardous to handle, or the agar could begin to melt*
- Can you suggest some suitable control variables necessary in this investigati
  - ✓ *Surface area of agar, concentration of acid, volume of acid, type of acic*
- What do you believe to be the biggest risk in this experiment, and how will y
  - ✓ *Irritation to skin or eyes from the hot acid – wear gloves and goggles*

Brief Outline of Method
In this practical, students will be using water baths to change the temperature o neutralise sodium-hydroxide-infused agar cylinders which have been stained wit taken for complete colour change to occur should be recorded and then used to diffusion at each temperature.

Required Equipment
In addition to standard laboratory apparatus students will need access to:
- Ice
- Water bath
- Agar cylinders
- White tile
- 1 mol dm^{-3} hydrochloric acid
- Thermometer
- Stopwatch

Time Requirements
Suggested lab time: 1.5 hours

Health and Safety Considerations
The hydrochloric acid and sodium hydroxide used in this practical are low enoug low hazard. Eye protection should be worn and any spillages should be cleaned u

Practical Considerations
The agar cylinders required for this practical should be made using a recipe of 10 2 g agar powder and 5 cm^3 phenolphthalein. They should be 2 cm in length and If they are made the night before they should be stored in the fridge and then re before they are required.

Sample Data

Temperature of acid (°C)	Time taken for colour change	
	1	2
10	401	396
20	312	304
30	210	213
40	124	121
50	24	26

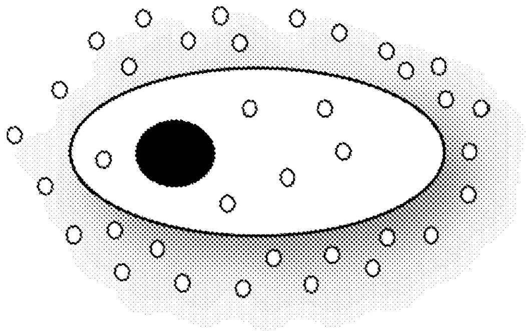
Pre-lab Tasks

1. Copy and complete the following sentences:

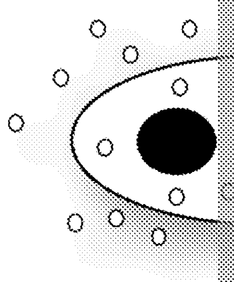
   Diffusion is the movement of a substance from an ____________ an ____________________. It can only occur in the __________ ____________________ state, as this is when the particles are al from place to place.

2. Take a look at the following diagrams. State in which direction (into or out the particles would be.

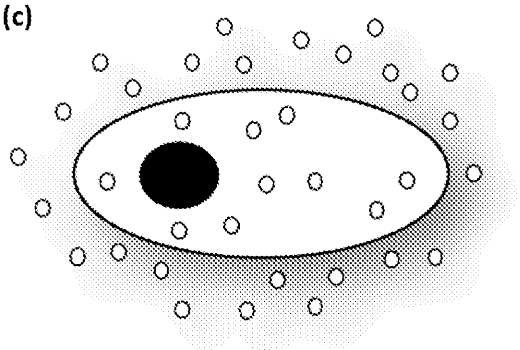
(a)



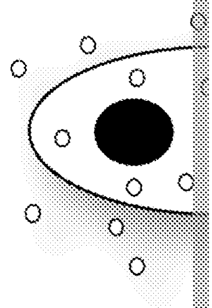
(b)



(c)



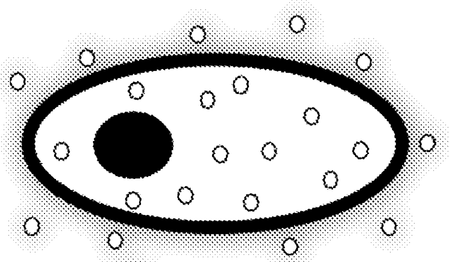
(d)



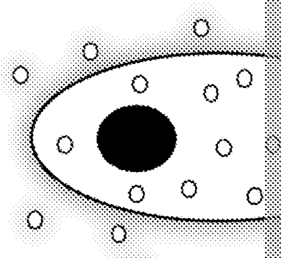
3. State the four factors which can affect the rate of diffusion of a molecule of

4. In each of the following diagrams state which would have the fastest rate of

(a)

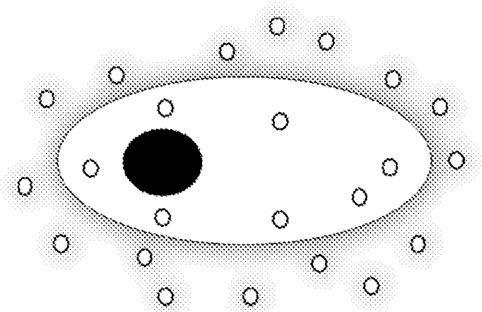


A

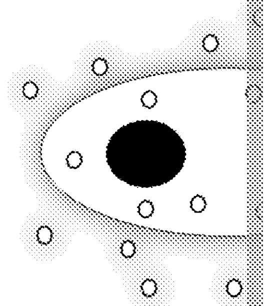


B

(b)

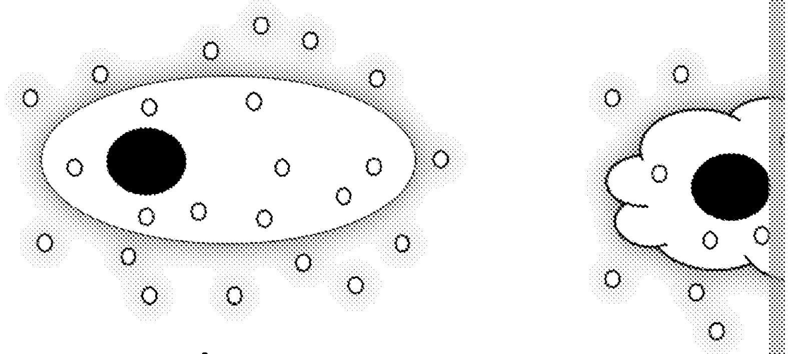


A



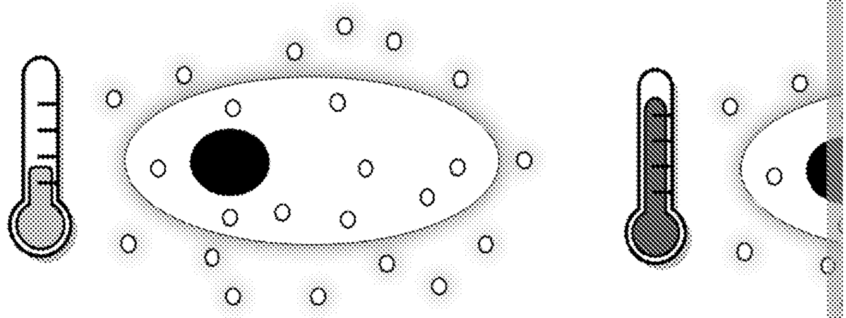
B

(c)



A

(d)



A

5. Read the student information sheet and identify the independent and depe investigation. Use this information to design a results table to be used to re

6. Construct a risk assessment which considers all possible risks in this investig you will take to avoid them.

Student Instructions

You are expected to ensure you are working safely and observing good laborat

In this experiment you are investigating the hypothesis:

'The higher the temperature, the faster the rate of diffusion. This is due to the molecules resulting in faster movement.'

NB The following is an outline for the experiment you should carry out. It does detail so ensure you have read it thoroughly before beginning and have a clear method you will follow.

1. Collect the following equipment:
   - ☑ 1 mol dm^{-3} hydrochloric acid
   - ☑ Small beaker
   - ☑ Thermometer
   - ☑ Boiling tube
   - ☑ Spatula
   - ☑ Stopwatch
   - ☑ Clamp and clam
   - ☑ Ice
   - ☑ Water bath
   - ☑ Measuring cylin
   - ☑ Agar cylinders
   - ☑ White tile
2. Identify five suitable temperatures of acid to investigate.
3. Place 10 cm^3 of HCl, which is at the first temperature you have chosen to inv
4. Transfer an agar cylinder into the boiling tube and immediately start the sto
5. Use the white tile to help you decide an end point and when to stop timing.
6. Repeat the experiment until you have three results for each temperature yo

SAFETY INFORMATION!

The hydrochloric acid and sodium hydroxide used in this practical are low e considered low hazard. Eye protection should be worn and any spillages shou

Data Analysis and Evaluation

Data Analysis

For each temperature of acid calculate a mean and then plot a graph of tempera diffusion (average rate is calculated using the following equation).

$$\text{average rate of diffusion } (s^{-1}) = \frac{1}{\text{average time (s)}}$$

Use your graph to describe the relationship between temperature and rate of di the hypothesis?

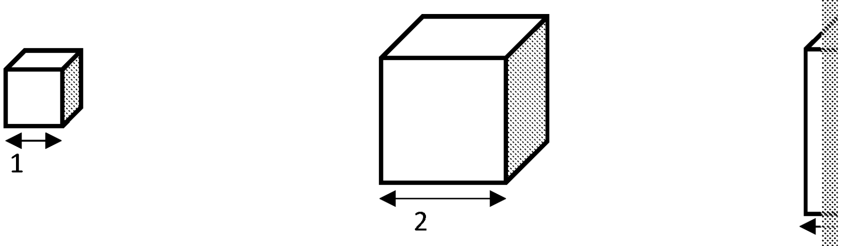
Evaluation

1. Identify any anomalies in your data and suggest what may have caused ther
2. State the name of the piece of equipment used to measure volumes in this e percentage error associated with this measuring equipment. Identify and ju device which would have improved accuracy when measuring volumes in th

Comprehension Questions

1. A student carried out a similar experiment to this; however, instead of chan they used agar cubes of different sizes. Write a hypothesis for this experim

2. The image below shows some of the blocks the student used. Calculate the surface-area-to-volume ratio for each block.



3. Here is the method the student followed for their investigation:
   - Collect a beaker of acid
   - Add the first cube to the acid
   - Start the stopwatch
   - Stop the stopwatch when all the colour has gone
   - Repeat for the other cubes

   Evaluate this method and the equipment used.

4. The table below shows the data obtained by the student. Identify the anom what may have caused it.

Length of side (cm)	Time taken for colour to disappe		
	1	2	3
1	172.54	150.65	168.62
1.5	234.00	230.87	250.34
2	383.84	433.65	373.54
2.5	539.65	560.76	553.12
3	726.03	696.83	711.14

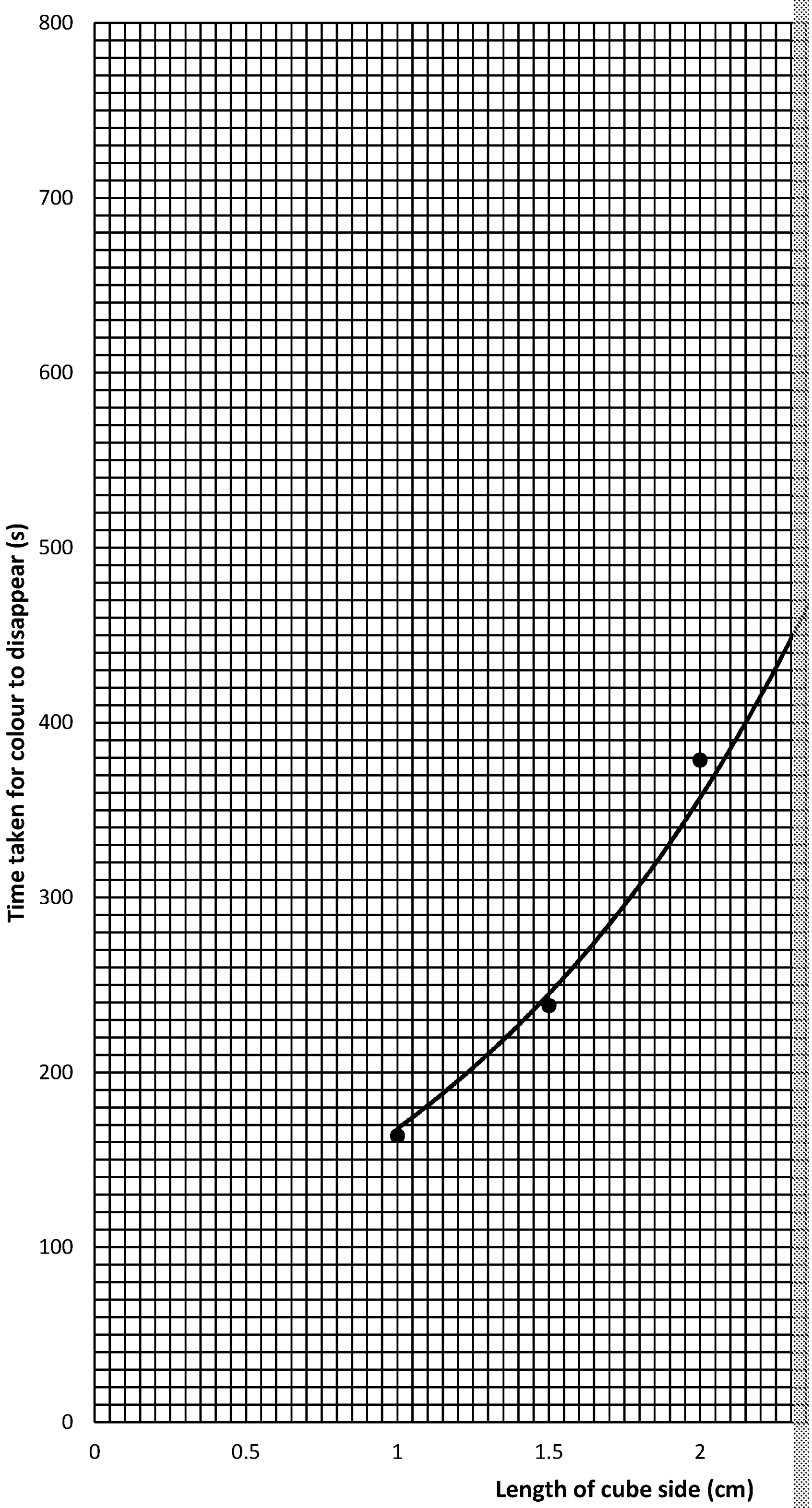
5. Calculate the mean time taken for colour to disappear for the results at cub

6. Calculate the standard deviation for the results recorded for the cube lengt

7. The student plotted a graph from this data (see appendix 1). Use the stand error bars to this graph.

8. Explain which cube length gave the least reliable set of data.

Appendix 1



Time taken for colour to disappear (s)
800
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
Length of cube side (cm)

Answer Sheets

Pre-lab Tasks

1. Diffusion is the movement of a substance from an **AREA OF HIGH CONCENTRATION** **CONCENTRATION**. It can only occur in the **LIQUID** and **GASEOUS** states, as this is w randomly and from place to place.
2. (a) into the cell
   (b) into the cell
   (c) into the cell
   (d) out of the cell
3. Temperature, surface area, concentration gradient, size of diffusion pathway
4. (a) B – it has the shorter diffusion pathway
   (b) A – there is a greater difference in concentration (higher concentration gradie
   (c) B – there is a larger surface area
   (d) B – the temperature is higher
5. Independent variable – temperature of acid (°C)
   Dependent variable – time taken for colour change to occur (s)

Temperature of acid (°C)	Time taken for colour change to		
	1	2	3

6.

Hazard	Risk	
Warm hydrochloric acid	Irritation to skin and eyes	Eye protection sh affected area sho
Agar cylinders	Irritation to skin and eyes	Eye protection sh cylinders without
Glassware	Could break and cause cuts	Ensure a tidy and Any breakages sh
Water bath	Wires can cause a trip hazard	Ensure a tidy and are contained wit

Data Analysis

References to any relationship should state the link between the two variables and then shape of curve.

Evaluation

1. Use the student's own results to identify anomalies
2. Measuring cylinder:
   Identification of absolute error being half the smallest division
   Absolute error ÷ 10
   ×100
   Pipette or burette as it has a smaller scale, resulting in a lower percentage error as to be transferred.

Comprehension Questions

1. The larger the surface-area-to-volume ratio of the cube, the faster the rate of diffus many contact points the acid can make with the agar block (1).
2.

	Surface area (cm^2)	Volume (cm^3
Block 1	(1 × 1) × 6 = 6	1 × 1 × 1 = 1
Block 2	(2 × 2) × 6 = 24	2 × 2 × 2 = 8
Block 3	(3 × 3) × 6 = 54	3 × 3 × 3 = 27

1 mark for each completely correct column (3)

3. Any four from:
   - Volume of acid not specified (1)
   - Control temperature not referenced (1)
   - Specific type of acid not referenced (1)
   - No repeats suggested (1)
   - Adding the cube to the acid instead of the other way around can cause the cu glassware resulting in timing problems (1)
   - No indication of use of a white tile to ensure colour change is completely finis
4. Anomaly = trial 2 for length of side 2 cm (1)
   Diffusion took longer than expected (1)
   Any linked pair from (2 marks):
   - Acid colder than normal (1) due to a change in room temperature (1)
   - Incorrect amount of acid added to the boiling tube (1) less surface area of the
   - Acid was a weaker concentration (1) water left in boiling tube when rinsing in
5. 551.18 (1)
6. 10.46 (1)
7. Use the standard deviations given on the table and the scale on the graph to check
   4/5 error bars correctly drawn (2) OR 2/3 error bars correctly drawn (1)
8. Length of side = 2 cm (1)
   Smallest standard deviation (1)

Experiment 5 – Investigating photosynt intensity

Teacher's Notes

Purpose
This is a straightforward, well-tested experiment. Students investigate the rate o counting bubbles at different intensities of light. This practical will allow student which are designed to ensure results are as accurate as possible.

Prior Learning
Students should have covered the theory of photosynthesis and have some awa limiting factors.

Suggested Starter Questions
- What is the word and balanced chemical equation for the process of photos
  - ✓ *Carbon dioxide + water → glucose + oxygen;* $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 +$
- How can the rate of photosynthesis be monitored in a plant using the produ
  - ✓ *Discussion of collecting the gas given off. Could discuss the difference b collecting gas and the benefits of each method.*
- What are the control variables in this experiment and how can they be controlle
  - ✓ *Temperature, carbon dioxide concentration. This can then lead into a d factors and their effect on photosynthesis, possibly the graphs linked w*

Brief Outline of Method
Students will use a light source at different distances from a sample of elodea an bubbles produced over a defined time period. A large beaker of water should be pondweed should be left to acclimatise for 5 minutes at each light intensity. On should convert the distances of light into light intensity using 1/distance^2 before

The pre-lab tasks given for this task require students to plan a method for this in guidance. A student instruction sheet has been provided that could help suppor method as described in the pre-lab tasks or could be used for the class to follow methods which are not feasible to conduct in the lab environment.

Required Equipment
In addition to standard laboratory apparatus students will need access to:
- Freshly cut 10 cm piece of pondweed (Elodea)
- Light source
- Stopwatch
- 0.2 % solution of sodium hydrogen carbonate solution
- Glass rod

Time Requirements
Suggested lab time: 1 hour

Health and Safety Considerations
- All chemicals used in this investigation are considered low risk
- Care should be taken with water and electrical power supply

Practical Considerations
The elodea in this experiment should be kept in a well-lit environment for 2–3 h undertaking the practical work. Low-energy light bulbs should not be used for t not give off enough energy for measurable photosynthesis to occur.

Sample data

Distance of lamp from pondweed (cm)	Number of bubbles produced	
	1	2
10	52	54
30	47	49
50	34	36
70	26	22
90	14	12

Pre-lab Tasks

Read the outline of the method for the practical on the student instructions shee
Use this outline to produce a full plan to investigate the effect of light intensity o

You should include the following:

(a) A hypothesis which states what you believe the outcome of this investigatio to support your reasoning

(b) A fully detailed equipment list and description of the purpose of each piece o

(c) A logical list of instructions, highlighting any stages you believe will ensure a

(d) Identification of the variables in your investigation: independent/dependen control/measure these, and are there any variables you believe will be diffic

(e) What range and interval will you select for your independent variable, and why

(f) How will you record your data? Draft a version of the results table you can u experimental observations.

(g) What are the inherent risks within this experiment, and how will you minim

(h) How will you analyse the data once collection is complete?

Student Instructions

The following method can be used to aid you in the planning process. Conside stage of the instructions to ensure that the practical you design shows good sci

You are expected to ensure you are working safely and observing good laborat

1. Set up a boiling tube in a test tube rack 10 cm away from a light source. Pla boiling tube and the light source.

   What is the purpose of the beaker of water?

2. Put sodium hydrogencarbonate solution into the boiling tube.

   How much sodium hydrogencarbonate will you use each time? Why have yo

3. Put the pondweed into the boiling tube with the cut end pointing upwards.

4. Turn off all external light sources, leave the pondweed for a little while and bubbles produced during photosynthesis.

   How long will you leave the pondweed for before counting the bubbles? Wh
   How long will you count the bubbles for?

5. Move the pondweed further away from the light source and repeat step 4.

   How much further away will you move the lamp? Why have you chosen this

6. Keep moving the pondweed further away and collecting data until you have

   What will a full set of results look like? How many repeats? How many diffe

SAFETY INFORMATION!

- *All chemicals used in this investigation are considered low risk*
- *Care should be taken with water and electrical power supply*

Data Analysis and Evaluation

Data Analysis

Convert each distance into a light intensity. Light intensity is proportional to 1/d calculate an average number of bubbles produced and then present this informa

Use your graph to describe the relationship between light intensity and the rate support your hypothesis?

Evaluation

Identify the two parts of the method most responsible for ensuring accurate res remove potential errors.

Comprehension Questions

1. The greater the light intensity, the greater the cost to supply it. Explain, usi what light intensity should be used in a greenhouse by a gardener to give th business, and why.

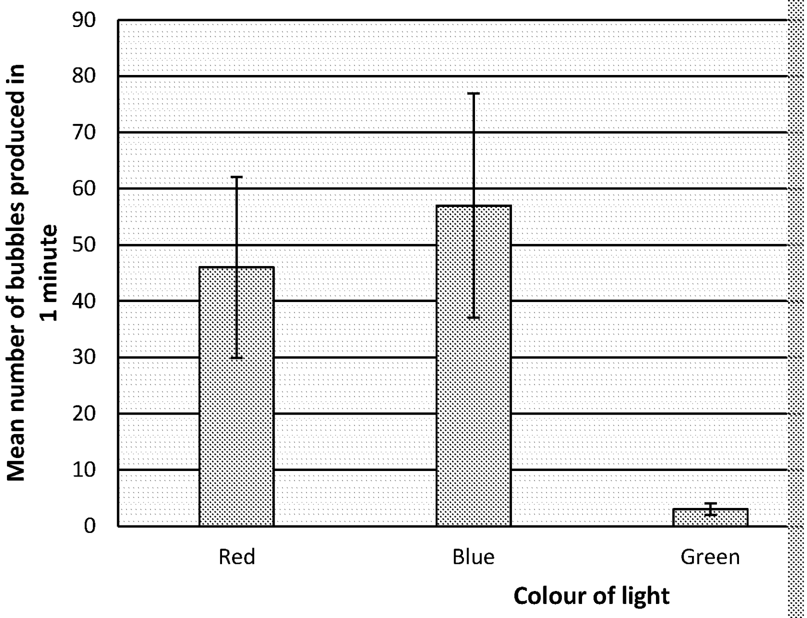
2. In this investigation you used a heat sink to control the temperature at whic Explain what the effect on photosynthesis would have been if
   (a) the temperature was raised too high
   (b) the temperature was dropped too low

3. Calculate the percentage error involved in measuring distance when carrying

4. Explain how you can use repeatability and reproducibility to test the reliabil

5. Explain two ways you could extend your investigation.

6. A student carried out a similar experiment to yours except instead of chang the wavelength, and, therefore, the colour, of light. Their results are shown



   (a) Explain, using the graph, whether there is a significant difference betw produced in 1 minute for each colour of light.

   (b) Use the data on the graph to explain which set of results was the least

7. Here is a small selection of the data the student obtained during their practic

Colour of light	Number of bubbles produce	
	1	2
Red	47	44
Blue	65	56

   (a) Calculate the mean for the set of results for red light

   (b) Explain which result is an anomaly

   (c) Explain how you would deal with this anomaly to ensure accurate resul

Answer Sheet

Pre-lab Tasks

- Hypothesis: as the light source is moved further away from the plant you would exp decrease. This is because light is a limiting factor in photosynthesis and is required
- Independent variable: distance of light from plant (cm)
- Dependent variable: number of bubbles given off in designated time period
- Control variables: temperature (controlled by using a low-power bulb and placing a up), type of plant (same specimen used each time)

See 'Student instructions' sheet for suggested method

Distance of lamp from pondweed (cm)	Number of bubbles produced in 1		
	1	2	3

Hazard	Risk	
Light source	Burns from light bulb heating after extended use	Turn off the light bet the lamp on the plas
Electrical wires	Interaction with water could cause electrical faults	Ensure any spillages Keep the lamp well a
Glassware	Can smash and cause cuts	Keep your workspace with equipment and

Evaluation

1. Allowing the plant to acclimatise for 5 minutes at each new light intensity – change not be instantaneous and this allows the new rate to be well established before any
2. Using a beaker of water as a heat sink – the enzymes that carry out photosynthesis As the light source moves closer to the pondweed the heat energy given off by the of reaction. The heat sink removes this issue.

Comprehension Questions

1. Selection of light intensity when levelling off of rate first begins OR if no levelling of the fastest production of bubbles (1). Explanation should link yield of plants and cos
2. (a) Either: photosynthesis would increase (1) as the enzymes would have more ki would stop (1) as the enzymes become denatured (1)
   (b) Photosynthesis would decrease (1) as the enzymes would have less kinetic ene
3. Error = 0.05 ÷ 10 = 0.005 × 100 = 0.5 % (1)
4. Repeatability: repeat the experiment (1) while using the same equipment (1)
   Reproducibility: other students should carry out the experiment (1) and compare re
5. Any two points from (4 marks total):
   - Use a different type of plant (1), e.g. cabomba (1)
   - Change the wavelength of the light (1) use filters over the lamp (1)
   - Change the concentration of carbon dioxide in the water (1) add sodium hydr
   - Investigate different temperatures (1) use a water bath to heat the acid (1)
6. (a) There is not a significant difference between red and blue light (1) as the error difference for green and yellow light with every other colour of light (1) as the any others (1)
   (b) Blue light (1) it has the largest error bar (1)
7. (a) 47 + 44 + 46 = 137 ÷ 3 = 46 (1)
   (b) Blue light, trial 3 (1) as it is very different from the other repeats (1)
   (c) Repeat the trial (1) calculate an average but discount the anomaly (1)

Experiment 6 – Investigating the effect
germination and growth

Teacher's Notes

Purpose
This investigation has frequently appeared in some form in the Unit 3 exam, as a
to carry out and in the form of planning an unknown task and evaluation of a stu

Prior Learning
While the majority of this task is very straightforward, students will need to be fa
calculation in order to analyse data.

Suggested Starter Questions
- What do you feel the main risks are in this investigation and how will you pr
  - ✓ *The different solutions with varying pHs. Care to be taken with solution up immediately. Eye protection to be worn throughout.*
- What are you expecting to record in this investigation, and how will you do
  - ✓ *Discussion of how the student will quantify the effect of pH on growth b grows to. Could lead into a discussion of potential problems – for exam for leaf formation rather than stem growth – and as such suggest other note regarding their seedlings.*
- When studying plants in situ you can use quadrats randomly placed or along the differences in each method.
  - ✓ *A randomly placed quadrat should have its location determined using a r an unconscious bias, whereas a transect would use predefined distances*
  - ✓ *Random sampling is for use in areas where the conditions remain fairly whereas sampling along a transect will produce data allowing you to in such as distance from the sea or from a path.*
- Other than soil pH, what factors can affect plant growth and distribution?
  - ✓ *Trampling, sunlight intensity, rainfall, competition*

Brief Outline of Method
Students will grow batches of mustard seeds in varying pH environments. Once t
reasonable growth, students will measure their heights in order to obtain an idea

Required Equipment
In addition to standard laboratory apparatus students will need access to:
- White mustard seeds
- Petri dishes
- Cotton wool
- Solutions buffered at pH 5–9

Time Requirements
Suggested lab time: 2 hours in two separate 1-hour sessions

Health and Safety Considerations
- The different pH solutions should be low enough in concentration to be con

Practical Considerations
This practical will need to take place over an extended period of time. One session
of the Petri dishes and seeds and then a return will be required no earlier than sev

White mustard seeds are suggested for use as they are large, easy to handle and
to germination.

Sample Data

pH	Height of plant (mm)						
	1	2	3	4	5	6	7
5	21	20	19	18	19	18	20
6	28	28	29	31	29	27	28
7	34	35	33	34	34	35	37
8	31	29	30	32	28	27	32
9	24	23	22	23	25	21	22

Pre-lab Tasks

1. This investigation requires you to measure the height of germinated plants. this as accurately as possible.

2. As well as the pH of the soil they are grown in, another factor that can affec weather conditions. Explain why weather is not a factor in your investigatic control this variable.

3. A general, basic method for the proposed investigation is given below. Eval improvements where possible.
   - Collect five beakers and put a dry cotton wool pad into each one
   - Label the beakers pH 5, 6, 7, 8 and 9
   - Onto each piece of cotton wool, place a mustard seed
   - Water the seed using water of the appropriate pH value
   - When the seeds have grown, measure the height of each seedling

4. Studies on plant growth can also be carried out by sampling in their natural env
   (a) use a quadrat to estimate the population of sunflowers in a field
   (b) use a transect to investigate the relationship between clover growth ar

Student Instructions

You are expected to ensure you are working safely and observing good laborat

Before beginning your practical work you should read the instructions thoroughly and dependent variables. Once done, use this to design a results table which wi experimental data.

In this experiment you are investigating the hypothesis:

> 'The pH a plant is grown in will affect its germination and growth. This is due to growth being affected by pH.'

NB The following is an outline for the experiment you should carry out. It does detail so ensure you have read it thoroughly before beginning and have a clear method you will follow.

1. Set up five Petri dishes containing equal amounts of cotton wool soaked in different pHs.
2. Into each Petri dish place 10 mustard seeds, ensuring the spaces between th
3. Place all five dishes in a warm, light space where they will not be disturbed.
4. Allow the mustard seeds to germinate. If the cotton wool becomes dry, add dish, ensuring it is the correct pH.
5. Once the seeds have germinated, remove seeds from the dishes until each germinated seeds.
6. After seven days, measure and record the height of each seedling.

SAFETY INFORMATION!

The different pH solutions should be low enough in concentration to

Data Analysis and Evaluation

Data Analysis

State two other observations (not height) about the plants you measured. Plot a soil pH and use it to describe the relationship between the two variables.

Evaluation

Calculate the percentage error of each of your average height measurements.

Explain how you could extend your investigation to obtain a more accurate value seed growth.

Comprehension Questions

These questions all focus on a similar experiment to yours where the effect of a … of a plant is studied. However, this time the factor is light, and the plants are i… artificially growing them in a lab environment.

1. Write a null hypothesis for the investigation carried out by the student.

2. The student investigates three areas: full light, partial light and shaded. The…

	Height of plant (mm		
	1	2	
Full light	22	25	
Partial light	15	15	
Shaded	7	9	

(a) Calculate the mean for the plants measured in the partial light

(b) Calculate the standard deviation for the plants measured in the shade

3. The student looked at the amount of clover found in each area by measurin… quadrat. Apart from the intensity of light in each area, suggest two other re… different amounts of clover found.

area	% clover
Full light	30
Partial light	75
Shaded	25

4. Based on experimental results from the previous year, the student expected t… cover in the full light area. Complete the table.

	Clover %	No c…
Observed		
Expected		

5. Use the chi-squared test and distribution table to determine whether the res… were to be expected.

		P
		0.05
Degrees of freedom	1	3.841
	2	5.991
	3	7.815
	4	9.488
	5	11.070

Answer Sheets

Pre-lab Tasks

1. Any detail from:
   - Place on a piece of white paper
   - Always start from where the shoot leaves the seed
   - Ensure the plant is held straight
   - Decide at the start on whether or not to include leaves in the height
2. All the seeds were grown indoors and so were unaffected by weather conditions OR variation in weather conditions
3. Areas to improve could be:
   - No detail of how to control temperature
   - No detail regarding how much water to use when watering the seeds
   - No detail regarding maintaining light intensity
   - No detail regarding the age/condition of the mustard seeds
   - No mention of how often to water the seedlings
   - No mention of how long to allow the seeds to grow for
   - Only one seed grown at each pH so will be difficult to spot anomalies
   - No detail regarding how to accurately measure the seeds
4. (a) Divide up the field into a grid and use a random number generator to decide w
   Count the number of sunflowers in that area and then repeat to obtain 10 me
   Deduce how many quadrats would fit into the area of the field and then scale u
   (b) Place a tape measure from the tree out into the fields. At regular intervals alo
   quadrat and estimate the percentage of the quadrat which contains clover.

Model Results Table

pH	Height of plant (mm)							
	1	2	3	4	5	6	7	
5								
6								
7								
8								
9								

Data Analysis

Allow comments on:

- The number of seeds which successfully germinated at each pH
- The colour of the seedlings in each pH
- Any dead seedlings
- The size of any leaves
- The number of leaves

Relationship: a simple pattern is described (1) optimum pH suggested (1) use of data to s

Evaluation

% error = (0.5 ÷ height measurement) × 100

Repeat this experiment using smaller intervals around the pH which has given the best g

Repeat this experiment growing the seeds in soil and water them with the appropriate p

Comprehension Questions

1. Differing light intensity has no **significant** differences in plant growth. (1)
2. (a) 15 + 15 + 14 = 44 ÷ 3 = 15 (1)
   (b) Check final answer, if 1 award all 5 marks, if not award marks as suggested bel
   <u>any stage of the calculation.</u>
      - For each number subtract the mean (1)
      - Square the result (1)
      - Add up these values (1)
      - Divide by one less than the sample number (1)
      - Square root this number to get the standard deviation (1)

3. Any two from:
   - The type of soil could be different (pH or soil composition) (1)
   - Animals could be grazing in some areas and not others (1)
   - People could walk more in some areas than others (1)
   - There could be different levels of competition from other plants (1)
4.

	Clover %	No clover %
Observed	30	70
Expected	45	55

All needed for the ma

5. $\frac{(O-E)^2}{E}$ for clover = 5 (1)
   $\frac{(O-E)^2}{E}$ for no clover = 4.09 (1)
   5 + 4.09 = 9.09 (1)
   n = 2 – 1 = 1 degree of freedom (1)
   (at n = 1 critical value is at 5 % value is 3.841) 9.09 > 3.841 so there is a significant d
   expected results (results are not consistent) (1)

Experiment 7 – Investigating the prope

Teacher's Notes

Purpose
This investigation allows students some experience in handling secondary data to
They will also be able to fully evaluate the procedures undertaken.

Prior Learning
An awareness of the desired properties of fuel is necessary to fully evaluate this i
knowledge of complete and incomplete combustion.

Suggested Starter Questions
- What are the desired properties in a fuel designed to be used to power vehi
  - ✓ *Low viscosity in order to flow easily through the pipes, high flammabilit volatility to allow it to be easily compressed within the storage system*
- What are the inherent risks within this practical and how will you protect yo
  - ✓ *The oils used are flammable and yet will require heating. They will be h avoiding them being in contact with a naked flame.*

Brief Outline of Method
Students will carry out two techniques to investigate how temperature affects th
viscometer and dropping glass beads through two points.

Required Equipment
In addition to standard laboratory apparatus students will need access to:
- A selection of oils:
  - Sunflower
  - Olive
  - Rapeseed
- Stopwatch
- Glass beads
- Oil
- Pipe clay triangle
- Thermometer
- 2 plastic cups

Time Requirements
Suggested lab time: 2 hours

Health and Safety Considerations
- Sesame and nut oils are not recommended due to their potential to be aller flammable and so should be kept away from naked flames.

Practical Considerations
If time is short, the class can be split into two groups which complete one practic
for comparison purposes.

Sample Data – Method A

Sunflower

Temperature of oil (°C)	Time taken for bead to drop	
	1	2
20	5	6
25	3	3
30	2	1
35	1	1
40	1	1

Olive

Temperature of oil (°C)	Time taken for bead to drop	
	1	2
20	7	7
25	4	3
30	2	2
35	1	2
40	1	1

Rapeseed

Temperature of oil (°C)	Time taken for bead to drop	
	1	2
20	7	7
25	5	6
30	3	2
35	2	2
40	2	1

Sample Data – Method B
Sunflower

Temperature of oil (°C)	Time taken to drain through visc[o…]	
	1	2
20	20	21
25	4	14
30	10	10
35	8	8
40	3	4

Olive

Temperature of oil (°C)	Time taken to drain through visc[o…]	
	1	2
20	24	25
25	19	18
30	14	14
35	11	12
40	6	7

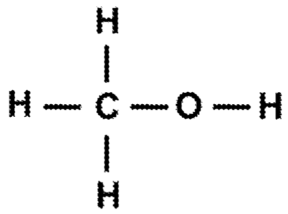
Rapeseed

Temperature of oil (°C)	Time taken to drain through visc[o…]	
	1	2
20	24	26
25	20	21
30	15	17
35	13	12
40	8	8

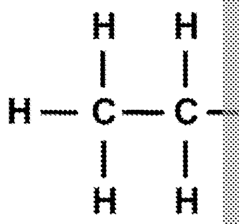
Pre-lab Tasks

1. Name the following organic fuels:

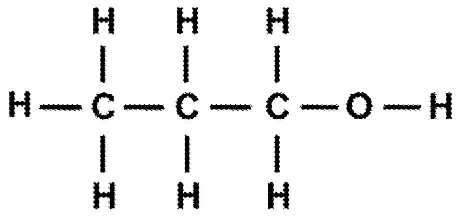
(a)



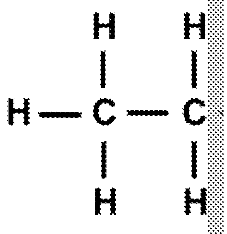
(b)



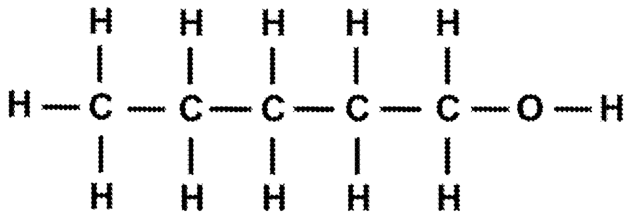
(c)



(d)



(e)



2. Give definitions for the following keywords:
   (a) Flammability
   (b) Toxicity
   (c) Incomplete combustion
   (d) Viscosity

3. Use the student instructions to help you draw labelled diagrams of the equi and, consequently, draw up an equipment list.

4. Construct a hypothesis for this investigation.

5. Identify the independent and dependent variables for the investigation. Us results table for your practical which will allow you to record all data.

6. Suggest two control variables and how they will be controlled.

7. Construct a risk assessment which considers all possible risks in this investig you will take to avoid them.

Student Instructions – Method A

You are expected to ensure you are working safely and observing good laborat

NB The following is an outline for the experiment you should carry out. It does detail so ensure you have read it thoroughly before beginning and have a clear method you will follow.

1. Set a beaker, filled approx. three quarters of the way with water, on a Buns 50 °C and 60 °C.
2. Fill a boiling tube with the oil to be tested and draw two marks on the side o test area. Place this tube in the water bath and use it to heat the oil to the r
3. Once the oil has reached the required temperature, remove it from the wat drop it into the boiling tube of oil. Start the timer as soon as it passes the fi stop the timer when it passes the second mark.
4. Record the time it takes to pass between the two points and then repeat, u Do not attempt to remove the glass beads from the boiling tube once used.
5. Allow the oil to reach the next temperature to be tested and repeat steps 3
6. For temperatures cooler than 20 °C you will need to use a water bath filled
7. Repeat the whole process for any additional oils to be tested.

Data Analysis

For each oil tested, plot a graph of temperature against time for the glass bead t graphs to describe the general trend in viscosity of oils as temperature changes.

Plot one final graph which compares the viscosity of all the oils tested at 30 °C. H the others you have plotted for this investigation, and why?

Student Instructions – Method B

1. Set a beaker, filled approx. three quarters of the way with water, on a Buns 50 °C and 60 °C.
2. Add 50 cm^3 of the oil to be tested to a plastic cup and heat this in the water b
3. While the oil is heating use the funnel, tripod and clay triangle to make a cu second plastic cup underneath.
4. Once the oil has reached the required temperature, remove it from the wat and start timing. Stop timing when the oil starts to drip and not flow.
5. Record the time it takes to flow through the cup viscometer and then repea
6. Allow the oil to reach the next temperature to be tested and repeat steps 3
7. For temperatures cooler than 20 °C you will need to use a water bath filled
8. Repeat the whole process for any additional oils to be tested.

Data Analysis and Evaluation

Data Analysis

For each oil tested, plot a graph of temperature against time for the cup viscome to describe the general trend in viscosity of oils as temperature changes.

Plot one final graph which compares the viscosity of all the oils tested at 30 °C. H the others you have plotted for this investigation, and why?

Evaluation

Use a comparison of the advantages and disadvantages of each method, includin control or manage, to discuss which method you believe to be the most accurate temperature of oil affects the viscosity.

Comprehension Questions

1. Look at the results below. Do they support the hypothesis you made at the
this investigation?

Results A

Temp of oil (°C)	Time
Room temp	
40	
50	
60	

Results B

Type of oil	Time taken to empty (s		
	1	2	
Sunflower	23	22	2
Vegetable	12	12	1
Rapeseed	16	15	1
Linseed	18	17	1

Results C

Temperature of the oil (°C)	Time taken to reach the bottom of		
	1	2	3
50	10	11	1(
60	9	8	8
70	3	3	4
80	3	2	3
90	2	2	2
100	2	2	2

2. The student plotted a graph from the data in results B (see appendix 2). Use
error bars to this graph.

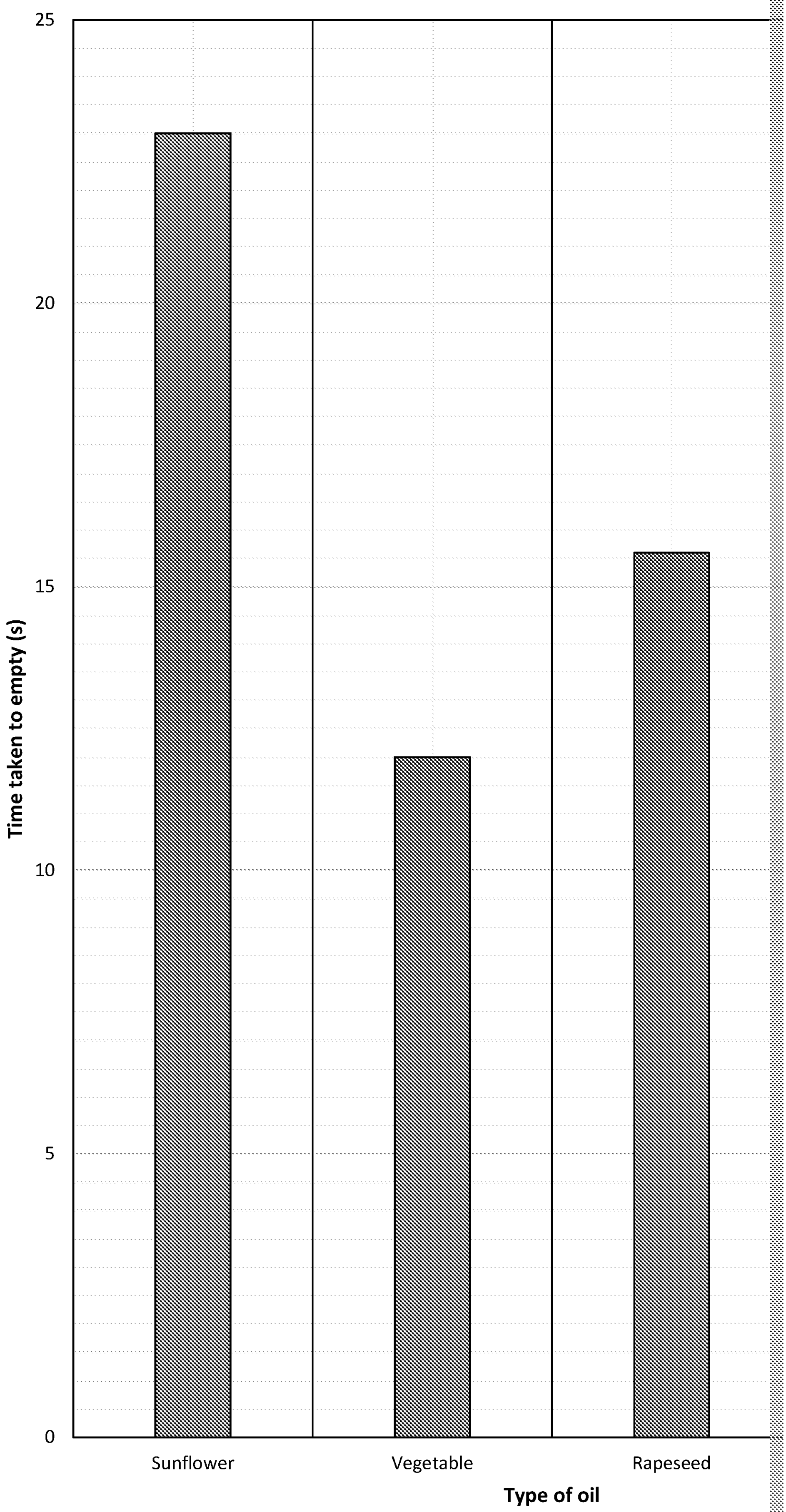
3. Explain which type of oil gave the least reliable set of data.

4. The investigation which produced results C was carried out with a thermom
nearest degree, a stopwatch which measured to the nearest second and a r
10 cm distance the glass bead dropped to the nearest 0.1 cm. Calculate the
device at 80 °C.

5. Explain which piece of equipment would have the biggest impact on the acc

6. Explain, using the concepts of repeatability and reproducibility, how you co
your data.

Appendix 2



25
20
15
10
5
0
Time taken to empty (s)
Sunflower
Vegetable
Rapeseed
Type of oil

Answer Sheets

Pre-lab Tasks

1. (a) – methanol, (b) – butan-1-ol, (c) – propan-1-ol, (d) – ethanol, (e) – pentan-1-ol
2. (a) Flammability – the flammability of a substance is a measure of its ability to be
   (b) Toxicity – a measure of the level of poison of a substance
   (c) Incomplete combustion – the burning of a fuel in limited oxygen, producing ca
   (d) Viscosity – a measure of how thick and sticky a substance is
3. **Method A**
   - ☑ 250 cm^3 beaker
   - ☑ Bunsen burner
   - ☑ Tripod
   - ☑ Gauze
   - ☑ Stopwatch
   - ☑ Thermometer
   - ☑ Boiling tubes filled
   - ☑ Marker pen
   - ☑ Ruler
   - ☑ Glass beads

   Method B
   - ☑ 250 cm^3 beaker
   - ☑ Bunsen burner
   - ☑ Tripod
   - ☑ Gauze
   - ☑ Stopwatch
   - ☑ Measuring cylinder
   - ☑ Thermometer
   - ☑ Oils to be tested
   - ☑ 2 plastic cups
   - ☑ Pipe clay triangle
   - ☑ Funnel
4. As temperature increases, the viscosity of an oil will decrease due to the extra kine move over each other more.
5. Independent variable: temperature of oil (°C)
   Dependent variable: time taken for glass bead to drop (s) / time taken for cup visco
6. **Method A**
   Distance bead travels: distance marked on using a ruler and marker pen
   Surface area of glass bead: beads from the same production batch used

   Method B
   Volume of oil which drains: measured using a measuring cylinder
   Size of hole in viscometer: use of same viscometer throughout
   Any other sensible suggestion
7.

Hazard	Risk	
Oil	Flammable	Only heat using a w
Hot oil	Can cause serious burns	Do not heat higher
Glassware	Can smash and cause cuts	Keep your workspa with equipment an

Data Analysis

As temperature of oil increases, viscosity decreases. This should be accompanied by a de relationship is proportional or not.
The final graph should be a bar chart rather than a line graph. This is because categorical being plotted.

Evaluation

Comments should include:
Method A:

- Time for bead to drop is very short and can be impacted by poor human reaction ti
- Glass bead does not always drop straight down and, therefore, distance is not cons
- Very little variation in some results as precision was not high enough

Method B:

- Volume of oil changed each repeat due to being unable to transfer all from cup to v
- End point hard to judge consistently
- Due to length of time taken, the temperature of the oil changed throughout each re

Comprehension Questions

1. Results A – do support the hypothesis (1) as the hotter the oil, the faster the viscom lower the viscosity. However, the lack of repeats makes it hard to trust the reliabili
   Results B – do not support the hypothesis (1) as the independent variable is not ten
   Results C – do support the hypothesis (1) but also suggest that past 90 °C the tempe viscosity (1)
2. Use the standard deviations given below and the scale on the graph to check accura

Type of oil	s.d.
Sunflower	0.816 (1 mark)
Vegetable	0 (1 mark)
Rapeseed	0.471 (1 mark)
Linseed	0.816 (1 mark)

   4 error bars correctly drawn (2) OR 2/3 error bars correctly drawn (1)
3. Sunflower and linseed (1) as they have the largest standard deviation (1)
4.
   - thermometer – % error = (0.5 ÷ 80) × 100 = 0.625 % (1)
   - stopwatch – % error = (0.5 ÷ 2.6) × 100 = 19.2 % (1)
   - ruler – % error = (0.05 ÷ 10) × 100 = 0.5 % (1)
5. The stopwatch (1) as it has the largest percentage error (1)
6. Repeatability: repeat the experiment (1) while using the same equipment (1)
   Reproducibility: other students should carry out the experiment (1) and compare re

Experiment 8 – Investigating the energ

Teacher's Notes

Purpose
This investigation has been set in the Unit 3 exam in both the food and alcohol fu well-tested experiment which students will probably have had the opportunity to educational journey. This practical also allows students the opportunity to incre of data loggers. This could allow them to increase the level of detail in their plan

Prior Learning
Students will be required to use E = mcΔT in order to calculate energy changes a equations and calculate relative formula masses for alcohols.

Suggested Starter Questions
- What is the general equation for the combustion of a fuel?
  - ✓ *Fuel + oxygen → Carbon dioxide + water*
- What possible observations could you make during this experiment?
  - ✓ *Heat given off, colour of flame, size of flame, sootiness of flame, how w appearance of foodstuff after burning*
- What are the areas in this experiment that are most likely to cause inaccura
  - ✓ *Loss of heat to the environment, inconsistent heating of the liquid*
- What are the different variables in this investigation?
  - ✓ *Independent = type of food, dependent = temperature change of water, distance of food from the water*

Brief Outline of Method
Students burn a mass of foodstuff, capturing the energy given off in a test tube o temperature change and the mass of food burnt, students can calculate an energ

Required Equipment
In addition to standard laboratory apparatus students will need access to:
- Balance
- Selection of foodstuff (crisps, crackers, marshmallows, popcorn, bread)
- Mounted need
- Data logger wi sensor / therm

Time Requirements
Suggested lab time: 1.5 hours

Health and Safety Considerations
- Check in advance for any known allergies among the students

Practical Considerations
If the foodstuffs provided are unable to burn efficiently on a mounted needle, i.e alternative method can be carried out supporting the food on a teaspoon.

Foods high in protein can cause strong odours when burnt.

Sample Data

Type of food	Start temp of water (°C)			End temp of water (°C)			Initial mass o	
Marshmallow	19	19	19	73	49	52	4.2	4.7
Maize crisp	19	19	19	67	68	65	3.7	4.0
Cream cracker	19	19	19	62	66	64	3.2	3.3

NB An anomaly has been included for marshmallow, trial 1

Pre-lab Tasks

1. Match the keyword to its meaning:

1. Combustion	**a) The unit for m**
2. Joule	**b) A chemical change w**
3. Exothermic	**c) A chemical that usable**
4. Oxidation	**d) The scientific**
5. Fuel	**e) A chemical change t oxidation, or loss of**

2. In this practical, you will be burning food items and calculating the energy p
   (a) State the general equation for combustion of a fuel.
   (b) Use this equation to write a balanced symbol equation for the complet
      i. ethanol
      ii. pentan-1-ol

3. Read the 'Student instructions' sheet and write a list of the equipment requ Ensure you select the most suitable piece of apparatus for each procedure a your selection.

4. Produce an annotated diagram of the equipment set-up, including any mod to ensure accuracy. Explain how these modifications will ensure accurate re

5. The results you obtain for this experiment will not match those given in the foodstuffs. Describe how your value will differ and give two reasons for this

6. Identify the independent and dependent variables for the investigation. Us results table to be used to record **all** data required to determine the energy

7. Construct a risk assessment which considers all possible risks in this investig you will take to avoid them.

Student Instructions

You are expected to ensure you are working safely and observing good laborat

NB The following is an outline for the experiment you should carry out. It does detail, so ensure you have read it thoroughly before beginning and have a clea method you will follow.

1. Place 10 cm^3 of water in a boiling tube and record the temperature.
   How will you measure this water to ensure the volume is as accurate as poss

2. Weigh a small amount of food and then position it underneath the boiling tu
   How precisely will you record the mass of the food? How will you ensure rep the foodstuff?

3. Ignite the foodstuff and heat the water. If the flame goes out, immediately

4. Once the food is completely burnt, stir the water and retake the temperatu
   What is the benefit of stirring the water before taking the temperature?

5. Reweigh any unburnt food.
   Why is this stage necessary?

6. Empty the boiling tube and then repeat the experiment.
   How many foods will you test? How many repeats will you carry out, and w

SAFETY INFORMATION!

- *Food allergies are increasingly common. Be aware of the needs of those food items.*
- *Food used in a lab is not to be tasted or consumed.*

Data Analysis and Evaluation

Data Analysis

Other than change in temperature, state two observations you made regarding th

Use the equation:

heat energy = mass of water × specific heat capacity of water ×

specific heat capacity of water = 4.2 $Jg^{-1}\,°C^{-1}$, 100 cm^3 of water h

to calculate the average heat energy in joules supplied to the water by each burn food burnt to convert this value to energy provided per gram and show this infor

Evaluation

Explain, using the concepts of repeatability and reproducibility, how you could te
Explain two ways you could extend this investigation in order to improve the qua

Comprehension Questions

1. State two control variables in this investigation and explain how you contro

2. Identify one other variable in this experiment that was difficult to control. G

3. Focus on one of the food items you investigated. State the equipment used error for the equipment you used to:

   (a) measure the volume of water
   (b) record the temperature
   (c) determine the mass of food burnt

   State which piece of equipment would have the biggest impact on the accur

Your colleague carried out a similar investigation involving burning organic alc supplied to heat 100 cm^3 of water. Each time the water was heated by 30 °C be resulting in a heat transfer of 12.54 kJ.

4. Your colleague's results are shown in the table below. Complete the missin

Heat of combustion (kJ mol^{-1}) = heat energy supplied × m / Mass of fuel burnt

Name of alcohol	Mass of fuel burnt (g)	Formula of alcohol	Molar
Ethanol	0.47		
Propan-1-ol	0.38		
Butan-1-ol	0.36		
Pentan-1-ol	0.32		

5. Information regarding the price of each fuel is given below.

Name of alcohol	Price per litre (£)
Ethanol	2.47
Propan-1-ol	12.59
Butan-1-ol	8.64
Pentan-1-ol	64.53

Evaluate the statement:

'Ethanol is the best alternative fuel to use in a c

Answer Sheets

Pre-lab Tasks

1. Match the keyword to its meaning:

1. Combustion	d) The scientific
2. Joule	a) The unit for
3. Exothermic	b) A chemical change
4. Oxidation	e) A chemical change oxidation, or loss of
5. Fuel	c) A chemical that is burn

2. (a) fuel + oxygen → carbon dioxide + water
   (b) i. $C_2H_5OH + 3.5\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$ (allow multiples)
   ii. $C_5H_{11}OH + 8\ O_2 \rightarrow 5\ CO_2 + 6\ H_2O$
3.

Equipment needed	Justification
Boiling tube	More suitable than a beaker due to the small v
Clam and clamp stand	To ensure the boiling tube remains in the same the experiment
10 cm^3 pipette	Most accurate way to measure the water to be
Thermometer / data logger and temperature probe	This will vary depending on the resources avail Best way to determine the temperature of the
Balance which records to 2 d.p.	The change in mass of food will be very small, a is needed
Ruler	To ensure the food is placed the same distance each repeat
Mounted needle	To secure the food item while it is burning
Heat shield	To prevent heat loss to the surroundings

4. Diagram should show:
   - A specified height for foodstuff from boiling tube – as a control variable to ens reaching the foodstuff in each experiment
   - A heat shield around the outside of the apparatus – to prevent any heat loss t
5. The obtained value will be lower than that published in a data book. This could be and equipment and the fact that all foodstuff will not burn fully / complete combus
6. Independent variable: foodstuff burnt
   Dependent variable: temperature change of water (°C)

Type of food	Start temp of water (°C)	End temp of water (°C)	Temperature change of water (°C)	Initial mas food (g)

7.

Hazard	Risk	
Mounted needle	Can cause cuts	Keep sharp end of when placing food
Items of food	Potential for allergies within the room	Check for any aller with practical work foodstuffs provided
Glassware	Can smash and cause cuts	Keep your workspa with equipment an

Data Analysis

Allow comments on:

- Colour of the flame
- Size of the flame
- The fluctuation of the flame itself

Evaluation

Repeat the experiment using the same equipment

Other learners should carry out the same experiment and the results should be compare

Any two linked statements from:

- Repeat the experiment more times until results become concordant – this will help
- Extend the range of the results by repeating the experiment with further foodstuffs
- Repeat the experiment with liquid food sources such as oils to see if there are any p

Comprehension Questions

1. - The volume of water used (1) measured using a pipette (1)
   - Distance of food away from boiling tube (1) measured using a ruler (1)
2. Distance of flame from the boiling tube (1) the flame itself fluctuated in size throug
3. State the equipment used and calculate the percentage error for the equipment yo
   (a) pipette – % error = (0.2 ÷ 10) × 100 = 2 % (1)
   (b) thermometer – % error = ((0.5 × 2) ÷ average temp change) × 100 (2: additional m
   (c) determine the mass of food burnt – % error = ((0.005 × 2) ÷ average mass cha available due to doubling the error)
   The piece of equipment with the largest % error would have the biggest effect on t
4.

Name of alcohol	Mass of fuel burnt (g)	Formula of alcohol	Molar m
Ethanol	0.47	C_2H_5OH	46.0
Propan-1-ol	0.38	C_3H_7OH	60.1
Butan-1-ol	0.36	C_4H_9OH	74.1
Pentan-1-ol	0.32	$C_5H_{11}OH$	88.1

Formula of alcohol: all four correct (2 marks), three or two correct (1 mark)
Molar mass: all four correct (2 marks), three or two correct (1 mark)
Heat of combustion: all four correct (3 marks), three or two correct (2 marks), one c

5. Any 3 marks from the following:
   - In a litre of fuel for ethanol you would have more moles of chemical than for t
   - Ethanol is the cheapest fuel per litre, but it has the lowest heat of combustion
   - The other three fuels have a larger heat of combustion, but are also more exp
   - Any correct manipulation of the numbers (1)

Experiment 9 – Investigating the resist

Teacher's Notes

Purpose
This is a well-known experiment which students should have covered as part of t allow them the opportunity to practise further processing of data before plotting

Prior Learning
While the majority of this task is very straightforward, students will need to be fa voltage = current × resistance equation in order to process their data.

Suggested Starter Questions
- How are voltmeters and ammeters connected in circuits, and what is the pu
  - ✓ *Voltmeters record voltage and are added in parallel, ammeters record c*
- What is your hypothesis for this investigation?
  - ✓ *The longer the length of wire, the higher the resistance. This is due to t collisions between the current-carrying electrons and the atoms within*
- Suggest two control variables for this experiment and how they will be cont
  - ✓ *Temperature – the circuit will be disconnected between measurements up. Material / cross-section area of the wire – use the same wire each t*
- Suggest why the meters in this experiment may not record a zero value, eve
  - ✓ *It is very difficult to connect the crocodile clips at 0 cm of wire without t resistance within themselves.*

Brief Outline of Method
Students will record current and voltage readings for the varying lengths of resis process these to discover the link between length of wire and resistance.

Required Equipment
In addition to standard laboratory apparatus students will need access to:
- A suitable power supply
- Ammeter
- Voltmeter
- 2 crocodile clips
- Resistance wire
- Metre rule
- Connecting leads

Time Requirements
Suggested lab time: 1 hour

Health and Safety Considerations
The resistance wire can get very hot during the practical. Ensure the power pack repeats and use low values of voltage.

Practical Considerations
The resistance wire can be created by using a metre of 22 swg constantan which rule. Two crocodile clips can be attached, one at a value of 0 mm, and the other wire to create wires of different length.

Sample Data

Length of wire (cm)	Current (A)	Vol
10	1.29	
20	0.81	
30	0.60	
40	0.48	
50	0.40	
60	0.33	
70	0.29	
80	0.26	
90	0.23	
100	0.21	

NB An anomaly has been included for 90 cm wire

Pre-lab Tasks

1. Draw out the circuit symbols for the following electrical components:
   - Bulb
   - Cell
   - Battery
   - Ammeter
   - Voltmeter
   - Resistor

2. Draw out electrical circuits which show:
   (a) two bulbs placed in series powered by two cells
   (b) two bulbs, each controlled by a switch placed in parallel and powered b

3. State the equation used to calculate resistance if you know the voltage and

4. Draw the circuit required to measure the resistance of a wire of varying len

5. Complete the following table:

Reading on voltmeter (V)	Reading on ammeter (A)	R
	1.5	
24		
9	3	
3	6	
12		
	2	

6. Identify the independent and dependent variables for the investigation. Us results table for your practical which will allow you to record all data.

7. Suggest two control variables and how they will be controlled.

8. Construct a risk assessment which considers all possible risks in this investig you will take to avoid them.

Student Instructions

You are expected to ensure you are working safely and observing good laborat

In this experiment you are investigating the hypothesis:

> 'The longer the length of wire, the higher the resistance. This is due to the in
> collisions between the current-carrying electrons and the atoms

NB The following is an outline for the experiment you should carry out. It does detail so ensure you have read it thoroughly before beginning and have a clear method you will follow.

1. Collect the following equipment:
   - ☑ A power supply
   - ☑ Voltmeter
   - ☑ Connecting wires
   - ☑ Resistance wire
   - ☑ Ammeter
   - ☑ 2 crocodile clips
   - ☑ Metre stick
   - ☑ Tape
2. Decide on the number of wire lengths to investigate.
3. Connect the apparatus together to form the circuit you have drawn during t
4. Ensuring you disconnect the circuit in between measurements, record the c length of wire you have chosen to investigate.
5. Repeat this process until you have obtained a suitable number of repeats.

SAFETY INFORMATION!

The resistance wire can get very hot during the practical. Ensure the power p repeats and use low values of voltage.

Data Analysis and Evaluation

Data Analysis

Calculate the average resistance for each length of wire and plot a graph of resis in mm.

Use the equation:

voltage (V) = current (A) × resistance (Ω)

Use your graph to describe the relationship between the two variables.

Evaluation

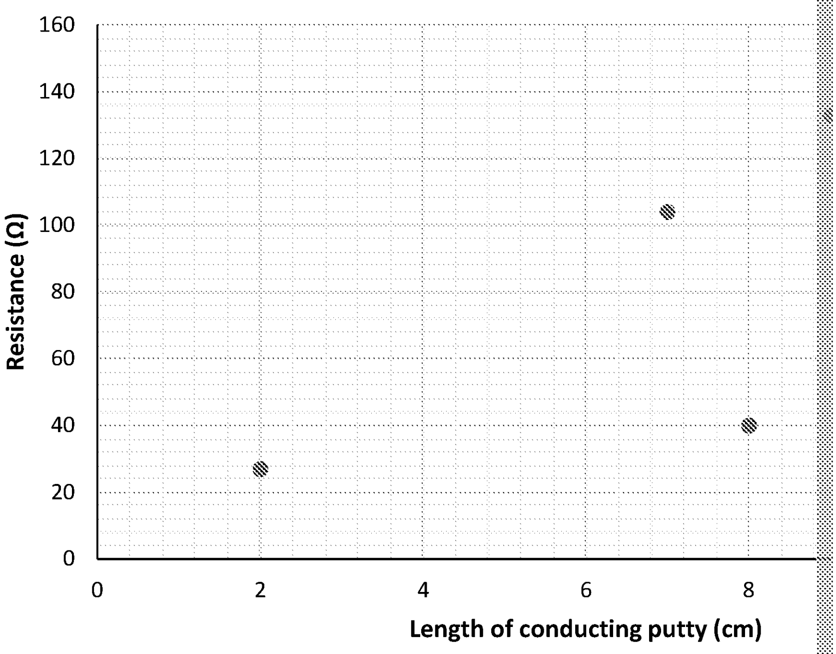
There are two benefits of disconnecting the circuit in between measurements. S
For each length of wire, calculate the standard deviation for the set of results an
to the points on your graph. Use this information to decide which length was th

Comprehension Questions

1. A similar experiment is carried out by one of your peers. Instead of using re
a material known as conducting putty. This material can be cut to any lengt
electric current.

   Using an identical circuit to yours with the resistance wire substituted for th
method was used to obtain a set of results:

   - Measure how long the conducting putty is
   - Connect the putty into the circuit
   - Record the values for current and voltage
   - Change the length of the conducting putty
   - Write down the new readings



   The student concludes that the relationship between length of putty and re

   Evaluate the learner's investigation. You should comment on the method fo
the conclusion formed.

2. Your peer then extended the investigation to see the effect on the voltage o
circuits previously experimented on. It was recorded that when the resistan
voltage across the lamp was 1.47 V and the current was 0.54 A. Show the p

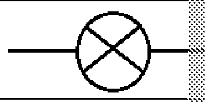
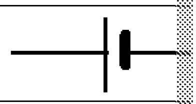
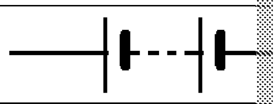
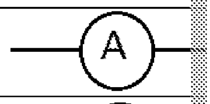
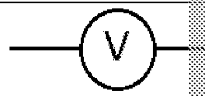
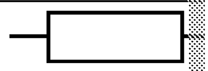
3. The above information can then be used to determine how long a lamp wou
placed in a torch. The average energy stored by a cell is 10 000 J. Assume t
lamp is 0.8 W. Calculate the time, in hours, that the lamp would remain pow

4. The voltmeter used by your peer had an uncertainty (maximum error) of 0.0
error in the measurement taken in Q2.

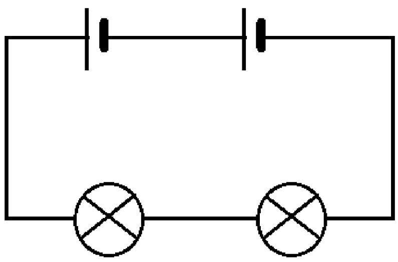
Answer Sheets

Pre-lab Tasks

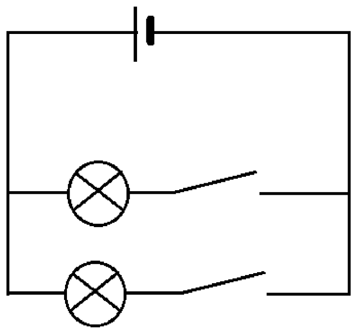
1.

Component	Circuit Symbo
Bulb	
Cell	
Battery	
Ammeter	
Voltmeter	
Resistor	

2. (a)

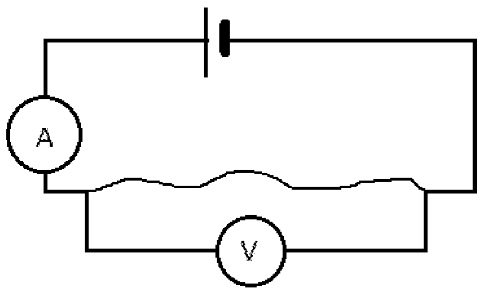


(b)



3. Resistance (R) = $\frac{\text{Voltage (V)}}{\text{Current (I)}}$

4.



5.

Reading on Voltmeter (V)	Reading on Ammeter (A)	Res
3	1.5	
24	**4**	
9	3	
3	6	
12	**6**	
10	2	

6. Independent variable: Length of wire (mm)
Dependent variable: Resistance of wire (Ω)

Length of wire (cm)	Current (A)				Voltage (V)			
	1	2	3	Mean	1	2	3	M
10								
20								
30								
40								
50								
60								
70								
80								
90								
100								

7. Any two from:
Temperature of wire, cross-sectional area of wire, material of wire. These are contr
between readings and using the same wire for each measurement.

8.

Hazard	Risk	
Wires	Fraying causing risk of electric shock	Check the conditi
Resistance wire	Can get hot and cause minor burns	Use low-voltage p between readings

Evaluation

1. By switching off the circuit in between readings you allow the resistance wire to coo
chance of being burnt during the investigation.
2. By switching off the circuit in between readings you allow the resistance wire to coo
temperature, which will secure more accurate results as temperature can also affec

Comprehension Questions

1. Any three from:
Method:
- No specific mention of specific lengths for the putty (1)
- Putty should be measured in mm rather than cm (1)
- No discussion of keeping the cross section of the putty the same (1)
- No mention of switching off the current in between readings to ensure consta

Any three from:
Results:
- No repeat readings evident for each length (1)
- The obtained data is not evenly spread out across the range (1)
- Result at 8 cm appears to be an anomaly (1)
- Readings required for 3 cm, 4 cm, 5 cm and 6 cm (1)
- There is no line of best fit drawn on the graph (1)

Conclusion
- The data does not support the conclusion (1)
- As length increases, the resistance increases (1)

2. power = voltage × current (1)
= 1.47 × 0.54 (1)
= 0.79 W (1)
3. power = energy ÷ time (1) → time = energy ÷ power (1)
= 10,000 ÷ 0.8 (1)
= 12,500 seconds (1) → 3.5 hours (1)
4. percentage error = (uncertainty ÷ reading) × 100 (1)
= (0.005 ÷ 1.47) × 100 (1)
= 0.34 % (1)

Experiment 10 – Investigating

Teacher's Notes

Purpose
This practical involves students developing a multicircuit set-up alongside using c
measurements to calculate power. They are expected to plan the practical them

Prior Learning
Students need to be aware of the power equation and how current and voltage c

Suggested Starter Questions
- What is an LDR? Suggest some everyday uses.
  - ✓ *A light-dependent resistor. A component whose resistance changes as t As light intensity increases, resistance decreases. It can be used to auto the light gets to a certain level.*
- What equation is used to determine power of electric appliances and how w required to calculate it?
  - ✓ *power = voltage × current. An ammeter measures current and a voltme*

Brief Outline of Method
Students will vary the voltage to a lamp, ensuring current and voltage are recorde being supplied. This lamp in turn will affect the resistance of an LDR which will ha

The pre-lab tasks given for this task require students to plan a method for this in guidance. A student instruction sheet has been provided that could help suppor method as described in the pre-lab tasks or could be used for the class to follow i methods which are not feasible to conduct in the lab environment.

Required Equipment
In addition to standard laboratory apparatus students will need access to:
- A suitable power supply
- Ammeter
- Voltmeter
- Ohmmeter
- Connecting leads
- LDR
- Bulb
- Variable resistor

Time Requirements
Suggested lab time: 1 hour

Health and Safety Considerations
- Do not allow the voltage to get so high that it will damage the equipment. T during the investigation; avoid touching it.

Practical Considerations
This practical should be trialled before attempting with students in order to give on the power supply and best distance to set the bulb at from the LDR.

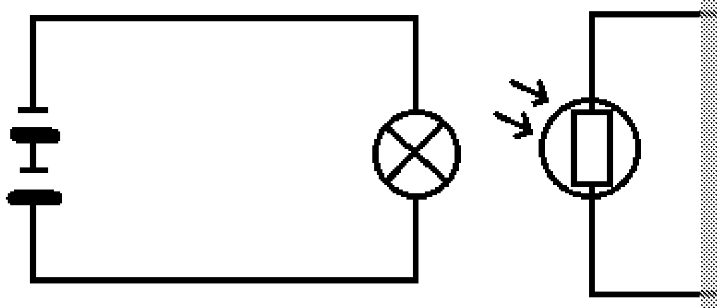
Sample Data

Current (A)	Voltage (V)	Resis
1.40	0.89	
0.90	1.14	
0.76	1.23	
0.54	1.29	
0.47	1.34	
0.39	1.39	
0.35	1.42	
0.29	1.46	
0.27	1.47	
0.24	1.47	

Pre-lab Tasks

- **The resistance of an LDR changes based on the intensity of the light shini**
- **The brightness of a bulb can be affected by the power supplied to it.**

These two statements can be linked together by setting up the following circuits



You will be provided with the following equipment:

☑	A power supply	☑	Voltmeter
☑	Ammeter	☑	Ohmmeter
☑	LDR	☑	Connecting lea
☑	Bulb	☑	Variable resist

Write a plan which details how you can investigate how the resistance of an LDR to a lamp which is shining on it. You are expected to make modifications to the c fully investigate this problem.

You should include the following:

(a) A hypothesis which states what you believe the outcome of this investigatio to support your reasoning

(b) A description of the purpose of each piece of equipment

(c) A logical list of instructions, highlighting any stages you believe will ensure a

(d) Identification of the variables in your investigation: independent/dependen control/measure these and are there any variables you believe will be diffic

(e) What range and interval will you select for your independent variable, and why

(f) How will you record your data? Draft a version of the results table you can experimental observations.

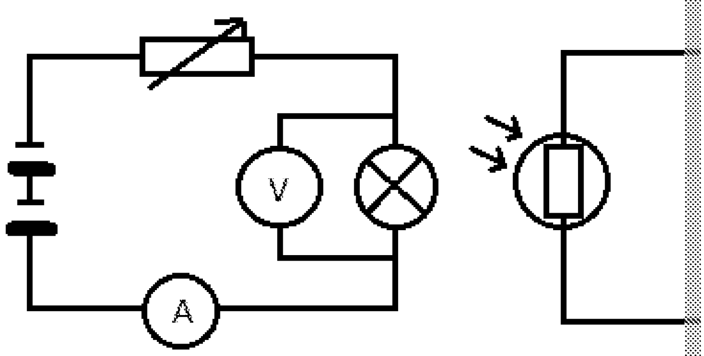
(g) What are the inherent risks within this experiment and how will you minimi

Student Instructions

You are expected to ensure you are working safely and observing good laborat

The following method can be used to aid you in the planning process. Conside the instructions to ensure that the practical you design shows good scientific p

1. Collect the following equipment:
   - ☑ A power supply
   - ☑ Ammeter
   - ☑ LDR
   - ☑ Bulb
   - ☑ Voltmeter
   - ☑ Ohmmeter
   - ☑ Connecting leads
   - ☑ Variable resistor
2. Connect the apparatus together to form the circuits shown below:



   State and explain any modifications to these circuits from those shown in th

3. Ensure the room is in a suitable condition and that the lamp is in an approp
   What does this mean? Where will you place the lamp, and why?
4. Set the power supply to a suitable voltage and then record the values show
   What is a 'suitable' voltage? Ensure you consider health and safety as well as
5. Use the variable resistor to change the voltage supplied to the bulb and rec
   What will you do in between each reading? How many different voltages w
6. Repeat this process until you are satisfied with the data you have collected.

SAFETY INFORMATION!

Do not allow the voltage to get so high that it will damage the equipment. The the investigation; avoid touching it.

Data Analysis and Evaluation

Data Analysis
Use the equation:

power (W) = current (A) × voltage (V)

to determine the average power supplied to the bulb for each set of resistance r against resistance. Use your graph to describe the relationship between the two

Evaluation
Suggest stages in your method which may have introduced error into your invest potentially be improved in future repeats.

Comprehension Questions

1. State two observations you made during this investigation other than the va meters changing.

2. You used the same ammeter throughout your investigation. Explain how one

3. Explain, using the concepts of repeatability and reproducibility, how you could

4. The conditions within the room were very important in this investigation. S the biggest impact on your results and explain how you ensured this remain

5. A student has carried out an experiment similar to yours using an LED in pla investigation are shown in the table below.

Power (W)	Resistance (Ω
1	24.4
1.5	19.9
2	22.3
2.5	12.8
3	9.1
3.5	4.9
4	

Explain which result is an anomaly.

6. Explain how you would deal with this anomaly to ensure the results obtaine

7. Use the table to predict the resistance of the LDR when the LED is supplied w

8. During this investigation, the student recorded the percentage error for eac The ammeter had a percentage error of 0.5 %. The voltmeter had a percent The ohmmeter recorded resistance to the nearest 0.1 Ω. Explain which piec the greatest effect on accuracy at a power of 2.5 W.

Answer Sheet

Pre-lab Tasks

Hypothesis: as the power supplied to the bulb increases, the resistance of the LDR will de
in light energy producing more free electrons, and, therefore, increasing the current for
See 'Student instructions' Sheet for suggested method.

Current (A)				Voltage (V)				Power (W)
1	2	3	Mean	1	2	3	Mean	

Hazard	Risk	
Wires	Fraying causing risk of electric shock	Check the conditi
Bulb	Can get hot and cause minor burns	Use low-voltage p current between

Comprehension Questions

1. The brightness of the light bulb changed (1), the bulb became warm (1)
2. Any one point from (2 marks):
   - Light conditions in the environment (1) – all light sources were switched off ar
   - Distance of lamp from LDR (1) – measured with a ruler (1)

   Any other sensible suggestion
3. Repeatability: repeat the experiment (1) while using the same equipment (1)
   Reproducibility: other students should carry out the experiment (1) and compare re
4. External light sources (1) all lights other than the bulb were switched off (1) any ext
   blacked out (1)
5. The result at 1.5 W (1) it does not fit the pattern (1)
6. Any two from:
   - Ignore it when calculating the average (1)
   - Repeat the result again (1)
   - Plot a graph and use the line of best fit to interpolate the true value (1)
7. Any value between 3.5 and 0 (1)
8. Percentage error = (uncertainty ÷ reading) × 100 (1)
   Ohmmeter = 0.05 uncertainty (1)
   = (0.05 ÷ 12.8) × 100 = 0.02 % (1)
   The voltmeter had the biggest effect as it has the highest percentage error (1)