Rewarding Learning

# GCSE

# Sciences

## Guidance for Teachers on Internal Assessment

For use with Specification for first examination in 2003
(These materials replace the *Notes for Guidance for GCSE Sciences* up to 2002)

Issued: January 2002

## Introduction

**These materials replace the *Notes for Guidance for GCSE Sciences up to 2002.***

The new specifications for GCSE Science subjects for first examination in 2003 include some changes to the requirements for the assessment of Experimental and Investigative Skills.

The main changes are as follows.

1 There are minor changes to the wording of some of the assessment criteria. Some of these, for example, P.6a, P.8a, reflect the increased emphasis on quality of written communication within the assessment criteria. There are no longer separate additional marks for the assessment of spelling, punctuation and grammar. Other changes, for example, the use of "evidence" to replace "observation and measurement" reflect a desire to allow for the possibility of investigations which might involve the researching of evidence from secondary sources such as the internet.

2 The evidence required by CCEA for moderation purposes has changed and there are new limits to the number of pieces which can be submitted for moderation.

In general, the changes are not major and any investigation or piece of practical work which has been used successfully for internal assessment of practical skills in GCSE Sciences up to 2002 will be appropriate for the new specifications and should attract an equivalent overall mark. Teachers need to be sure, however that they are applying the revised assessment criteria and not the previous criteria.

**Contact Information**

To find out more about CCEA GCSE *Sciences*, please contact:

**Gerry Garvey**
- tel. (028) 9026 1200 ext. 2270
- e-mail: ggarvey@ccea.org.uk

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# 1. Science Coursework

## 1.1 Contexts to be used for assessment

Contexts derived from **Living organisms and life processes and** (AT2), **Materials and their uses** (AT3) and **Physical processes** (AT4) should be used to teach students about experimental and investigative methods.

On at least one occasion, students should carry out a practically based whole investigation.

## 1.2 The scheme of assessment

Although the scheme of assessment is the same for all GCSE science specifications conforming to the Science Criteria, it should be noted that the requirements for evidence to support the arrival at the final mark submitted are different for each of Science: Double Award, Science: Single Award and the separate sciences (Section 3.1).

## 1.3 The Programmes of Study

The three skill areas and associated statements from the Programmes of Study for Experimental and Investigative Science constitute a framework for the coursework and its assessment. Details of the Programmes of Study for each skill area precede the mark descriptions (Section 2.3).

Teachers should refer frequently to the Programmes of Study in order to:

- ensure that appropriate experimental and investigative activities are used;
- assist in the interpretation of the statements contained within the mark descriptions.

The four skill areas, within the context of Investigative Skills, which students should be taught are:

- Skill Area P   Planning Experimental Procedures
- Skill Area O   Obtaining evidence
- Skill Area I   Interpreting and Evaluating

## 1.4 Mark Descriptions

Whenever assessments are made, the mark descriptions should be used hierarchically to judge which mark should be awarded.

### 1.4.1 The statements within the mark descriptions

The mark descriptions consist of a number of statements in each skill area.

It should be noted that some of the statements in a mark description contain a phrase such as 'where appropriate' and therefore may not apply to a particular activity. However, coursework activities chosen for assessment should, wherever possible, provide opportunities for all the statements in a mark description to be addressed.

### 1.4.2 The hierarchical nature of the mark descriptions

The mark descriptions within a skill area have been written to be hierarchical.

For example, if a teacher is considering awarding 8 marks to a piece of work, the student must demonstrate achievements corresponding to the mark description statements for 2, 4 and 6 marks in the same piece of work.

There may be occasions where this would not be evident to a moderator from what is written in the report. In such cases, the teacher must annotate the work in such a way as to make clear the justification for awarding the mark given (Section 4.4).

## 1.5 Experimental and investigative activities

The scheme of internal assessment is designed to encourage a wide variety of activities. These include those based on the collection of first-hand evidence and those which depend on secondary evidence. The term ‘evidence’ has been used consistently throughout the assessment scheme to mean observations, measurements or other data.

An activity can take the form of a whole investigation or an experimental task.

- A whole investigation is defined as a piece of work, carried out by the student, in which all three skill areas are attempted;
- An experimental task consists of an activity in which only two or fewer skill areas are attempted.

Students should be provided with several opportunities to develop their investigative skills to allow them to achieve their highest potential in such work.

Students should be encouraged to participate in practical work wherever possible (Section 3).

## 1.6 Explanation of terminology

### A practically based investigation

A practically based investigation is one in which some first hand evidence is gathered by the student through observation or measurement. Evidence from books, simulations or the Internet is not considered to be first hand evidence.

### Demand of an activity

The demand of an activity is an important feature of the assessment. Over the mark range in a skill area, the activity should involve increasing demands of associated scientific knowledge and understanding, manipulation skills, precision, and accuracy or complexity. The assessed mark should reflect those features of the activity.

On the right-hand side of each mark description table (Section 2.3), is a vertical arrow under the heading 'increasing demand of activity'. The purpose of this arrow is to remind teachers that, when they are considering awarding the higher marks in any skill area, the demand of the activity should require a sophisticated approach and/or complex treatment. Teachers should not award the higher marks for work which is simplistic or trivial, even although it may superficially appear to satisfy the mark descriptions.

Credit should be given only on the basis of decisions and judgements made by the student. The use of a highly-structured worksheet will limit the range of marks available, by giving too much guidance.

### Evidence

‘Evidence’ has been used consistently throughout the assessment scheme to mean observations, measurements or other data.

### Reliable evidence

Reliable evidence is that evidence which is likely to be reproduced on repetition of the observation or measurement.

**Valid evidence**

'Valid' implies that the outcome of an activity is not being distorted by extraneous factors, e.g. when investigating cooling, descriptions such as ‘we used the same sort of cup each time, and the same amount of water, but wrapped the cups in different materials' would be acceptable at P.4a. In some experiments, one factor is varied whilst other control factors are kept constant (e.g. rates of reaction). In other cases (e.g. in biology/fieldwork) other techniques (e.g. random sampling) may be used. In all cases, students must show an awareness of the situation and make judgements about the evidence needed.

**Processing of evidence**

Processing of evidence in skill area I involves the manipulation of recorded observations, measurements and/or data in order to derive further information, e.g. grouping or re-ordering results to demonstrate relationships such as a trend or a pattern, making calculations using results, drawing graphs.

**Factor**

'Factor' means 'anything which may influence the outcome of the activity’. Appropriate factors to consider may include: guarding against draughts; avoiding unwanted heating effects; the condition of living material; keeping temperature constant; keeping the mass of a solid reactant constant, keeping the voltage constant.

**Key factors**

These are the most important factors likely to influence the outcome of an activity.

**Variables**

A variable is a factor that is measured and/or controlled. For students to identify and manipulate variables they need to know what to change (independent variable), how many values they will need and what to measure or judge (the dependent variable) for each value of the independent variable.

**Numerical methods**

In skill area I, these involve calculations or simple statistics, e.g. calculation of quantities derived from a formula or equation. In this context, simple calculation of an average of repeat results does not fully satisfy the requirements of the mark description at I.6a.

**Preliminary work**

This is work carried out by a student as part of planning which helps to clarify what they have to do and how to do it. For most investigations, it is appropriate for the student to carry out and report some preliminary work or trial experiments.

**Safety aspects**

Safety aspects are important features of the planning and the carrying out of experimental and investigative work. The assessment of a student's performance should take account of these.

The reference to safety aspects in the mark description at 2 marks in skill area O, and the hierarchical nature of the mark descriptions across the mark range are consistent with the need for teachers to ensure that all practical activities are carried out safely.

As safety aspects vary so much in nature and extent over the range of possible activities, they have not been specifically included in every mark description.

## 2. Use of Mark Descriptions for Investigative Skills

A practically based investigation is one in which some first hand evidence is gathered by the student through observation or measurement. Evidence obtained from books, simulations or the Internet is not considered to be first hand evidence.

### 2.1 Skill area marks

Descriptions are provided for 2, 4, 6 and 8 marks in each skill area.

It is assumed that activities which access higher marks will involve a more sophisticated approach and/or a more complex treatment.

A student who fails to meet the requirements for 2 marks, but who has made a creditworthy-attempt in a skill area should be given 1 mark for that skill.

Zero marks should only be awarded where a student has attempted to address a skill area but has failed to demonstrate any achievement in that skill. Where a skill area has **not** been attempted, a dash should be entered for that skill area on the student's record card.

### 2.2 Awarding intermediate marks

Teachers should make use of the intermediate marks: 1, 3, 5 and 7 in each of skill areas P, O and I.

These intermediate marks should be awarded when the work of a student exceeds the requirements of one mark description, but does not meet the requirements of the next mark description sufficiently to justify its award.

For example, an intermediate mark of 5 in a skill area could be awarded if a student's work fully matches the 4 mark description, and:

- the student's work has fully matched the statement for 6a but contains no evidence to match the statement for 6b, or vice versa;
- the student's work has fully matched the statement for 6a but only partially matched the statement for 6b, or vice versa;
- the student's work has partially matched the statement for 6a and the statement for 6b, showing sufficient progression beyond the requirements for 4 marks.

### 2.3 The mark descriptions

# Skill Area P: Planning

| Programme of Study Requirements |
|---|
| Candidates should be able to:<br>(a) use their scientific knowledge and understanding to turn ideas into a form that can be investigated;<br>(b) make predictions where appropriate to do so;<br>(c) consider the factors which need to be taken into account in investigations;<br>(d) draw up procedures for the investigation taking into account the observations or measurements which need to be made and how these are to be used;<br>(e) select appropriate apparatus, instruments and techniques for the investigation, taking into account criteria, for example, the range and accuracy of the measurements and observations required, and the need for safe working procedures. |

| MARK DESCRIPTIONS | | | |
|---|---|---|---|
| The mark descriptions are designed to be hierarchical.<br>All work should be assessed in the context of the specification content. | | | |
| | | Candidates: | Increasing demand of activity |
| 2 marks | P.2a | outline a simple procedure | ↓ |
| 4 marks | P.4a | plan to collect evidence which will be valid | |
| | P.4b | plan the use of suitable equipment or sources of evidence | |
| 6 marks | P.6a | use scientific knowledge and understanding to plan and communicate a procedure, to identify key factors to vary, control or take into account, and to make a prediction where appropriate | |
| | P.6b | decide a suitable extent and range of evidence to be collected | |
| 8 marks | P.8a | use detailed scientific knowledge and understanding to plan and communicate an appropriate strategy, taking into account the need to produce precise and reliable evidence, and to justify a prediction, when one has been made | |
| | P.8b | include a strategy for dealing with results | |

# Skill Area O: Obtaining evidence

| Programme of Study Requirements |
|---|
| Candidates should be taught to:<br>Candidates should be able to:<br>(a) use apparatus and materials in a safe and competent manner;<br>(b) use apparatus and instruments to make observations and measurements to an appropriate degree of accuracy;<br>(c) understand the need, where appropriate, to repeat measurements;<br>(d) record observations or measurements systematically using methods appropriate to the information collected and to the purpose of the investigation. |

| MARK DESCRIPTIONS | | | |
|---|---|---|---|
| The mark descriptions are designed to be hierarchical.<br>All work should be assessed in the context of the specification content. | | | |
| | | Candidates: | Increasing demand of activity |
| 2 marks | O.2a | collect some evidence using a simple and safe procedure | ↓ |
| 4 marks | O.4a<br><br>O.4b | collect appropriate evidence which is adequate for the activity<br><br>record the evidence | |
| 6 marks | O.6a<br><br>O.6b | collect sufficient systematic and accurate evidence and repeat or check where appropriate<br><br>record clearly and accurately the evidence collected | |
| 8 marks | O.8a | use a procedure with precision and skill to obtain and record an appropriate range of reliable evidence | |

# Skill Area I: Interpreting and Evaluating

| Programme of Study Requirements |
|---|
| Candidates should be able to:<br>(a) present results in ways appropriate to the data collected and the purpose of the investigation, including, where appropriate, the use of graphs;<br>(b) interpret and evaluate results using, where appropriate, mathematical relationships;<br>(c) identify any trends, patterns and conclusions emerging from consideration of the results;<br>(d) draw valid conclusions and decide whether these conclusions agree with the original idea;<br>(e) explain the conclusions in the light of their scientific knowledge and understanding;<br>(f) consider their observations and measurements, including anomalies and sources of error, and suggest, where appropriate, improvements that could be made if they were to repeat their investigation;<br>(g) produce a written report of their investigation, using appropriate scientific vocabulary. |

| MARK DESCRIPTIONS | | | |
|---|---|---|---|
| The mark descriptions are designed to be hierarchical.<br>All work should be assessed in the context of the specification content. | | | |
| | | Candidates: | Increasing demand of activity |
| 2 marks | I.2a | state simply what is shown by the evidence | ↓ |
| 4 marks | I.4a<br><br>I.4b | use simple diagrams, charts or graphs as a basis for explaining the evidence<br><br>identify trends and patterns in the evidence | |
| 6 marks | I.6a<br><br>I.6b<br><br>I.6c | construct and use suitable diagrams, charts, graphs (with lines of best fit, where appropriate), or use numerical methods, to process evidence for a conclusion<br><br>draw a conclusion consistent with the evidence and explain it using scientific knowledge and understanding<br><br>comment on the suitability of the procedure and, where appropriate, suggest changes to improve it | |
| 8 marks | I.8a<br><br>I.8b<br><br>I.8c | use detailed scientific knowledge and understanding to explain a valid conclusion drawn from processed evidence<br><br>explain the extent to which the conclusion supports the prediction, if one has been made<br><br>consider critically the reliability of the evidence and whether it is sufficient to support the conclusion, accounting for any anomalies | |

### 2.4 Quality of Written Communication

In the mark descriptions, the use of terms such as ‘plan’, ‘communicate’, ‘record’, ‘identify’, ‘explain, ‘comment’, ‘consider’ and ‘describe’ ensures that the quality of written communication will form part of the assessment of Investigative Skills.

## 3. Arrival at the Final Mark

### 3.1 The requirements for each science subject

#### 3.1.1 Double Award

Two marks are required for each skill area. Thus six marks are required in total. The marks in skill area P and O are added giving a possible total in each skill area of 16. The marks in skill area I are added and the multiplied by 1.5 to reflect the weighting for skill area I. Where this does not give a whole number round up to the next whole number. The maximum for skill area I is therefore 24. The total possible mark is 16 + 16 + 24 = 56.
To satisfy the GCSE criteria for Science these marks should be drawn from not more than four pieces of work. At least one mark must be from a practically based whole investigation.
At least two of the attainment targets (AT2, AT3 or AT4) must be represented.
The minimum requirement is therefore two practically based whole investigations from each of which all three skill area marks are counted.

#### 3.1.2 Single Award

One mark is required for each skill area. Thus three marks are required in total.
The marks in skill area P and O are multiplied by 2 and the mark in skill area I is multiplied by 3 to reflect the weighting for skill area I. The total maximum mark is 56.
To satisfy the GCSE criteria for Science these marks should be drawn from not more than two pieces of work. At least one mark must be from a practically based whole investigation.
All marks may be drawn from a single attainment target.
The minimum requirement is therefore a single practically based whole investigation from which all three skill area marks are counted.

#### 3.1.3 Separate Sciences

One mark is required for each skill area. Thus three marks are required in total.
The marks in skill area P and O are multiplied by 2 and the mark in skill area I is multiplied by 3 to reflect the weighting for skill area I. The total maximum mark is 56.
To satisfy the GCSE criteria for Science these marks should be drawn from not more than two pieces of work. At least one mark must be from a practically based whole investigation.
The minimum requirement is therefore a single practically based whole investigation from which all three skill area marks are counted.

### 3.2 The final mark submitted

The final mark submitted should represent the best total produced from the evidence referred to in section 3.1.

In cases where the aggregation rules cannot be met, penalties may apply (see the examples that follow in 3.2.2 and 3.2.3).

To assist teachers in arriving at the best total mark the following procedures are suggested.

### 3.2.1 Monitoring and recording of marks

There should be a recording system in centres, common to all Double Award specifications and compatible with those for Single Award and the separate sciences.

The pieces of work contributing to the final mark for each student in each skill area need to be kept and made available for moderation.

### 3.2.2 Partial completion of mark requirements

A coursework mark may still be claimed for a student who has failed to complete the full requirement for the assessment.

**Example**: Student 1, a Double Award specification, a practically based whole investigation and an ICT based skill area assessment

*A student has failed to achieve sufficient skill area marks. The remaining cells in the assessment grid are completed with a dash.*

| **AT** | **Activity** | **Practical Investigation** | **Skill Area** | | |
|---|---|---|---|---|---|
| | | | P | O | I |
| AT2 | | | | | |
| AT3 | Rates | Yes | 6 | 6 | 4 |
| AT4 | Bouncing balls | No | 6 | - | - |
| | | | | | |
| | | Total | 12 | 6 | 4 |
| | | weighting | x1 | x1 | x1.5 |
| | | | 12 | 6 | 6 |
| | | | Overall total | | 24 |

Assessor's action: 4 skill area marks only. All may be used. Overall total is 24 marks out of 56.

### 3.2.3 Difficulties in meeting the aggregation rules

A mark penalty will be applied in each instance when;

- no practically based whole investigation is represented;

In addition, for Double Award specifications, further mark penalties will be applied in each instance when;

- work from two attainment targets is not represented;
- the two marks reported for a skill area are drawn from two contexts which are very similar (e.g. the effect of light intensity on photosynthesis, the effect of wavelength of light on photosynthesis; the effect of temperature on reaction rate, the effect of concentration on reaction rate; the effect of length of wire on resistance, the effect of cross-sectional area on resistance)

**When a mark penalty is applied, it is normally the mark which contributes least to the overall total that is removed.**

**Example**: Student 2, a Single Award specification, no mark from a practically based whole investigation

*The student has more than enough marks for all skill areas but the selection criteria have not been met. If a student has the appropriate number of pieces of work but none of them is a practically based whole investigation, a maximum of two skill area marks may be counted for Single Award/Separate Science, or five skill area marks for Double Award.*

| **AT** | **Activity** | **Practical Investigation** | **Skill Area** | | |
|---|---|---|---|---|---|
| | | | P | O | I |
| Sc2 | Yeast | No | (6) | (7) | |
| Sc3 | Rates | No | | 6 | 4 |
| | | | | | |
| | | weighting | x2 | x2 | x3 |
| | | | 12 | 14 | - |
| | | | Overall total | | 26 |

Assessor's action: mark of 4 for skill area I not used, since it is the skill area mark which contributes least to the overall total. If the mark of 6 for skill area P had not been used the outcome would have been the same.
Reported mark: 26 out of 56

Student 3, a Double Award specification, no mark from a practically based whole investigation

| **AT** | **Activity** | **Practical Investigation** | **Skill Area** | | |
|---|---|---|---|---|---|
| | | | P | O | I |
| AT2 | Yeast | No | - | (7) | (5) |
| AT3 | Rates | No | (6) | (6) | - |
| AT4 | Bouncing balls | No | (6) | - | - |
| AT4 | Resistance | No | - | 6 | 4 |
| | | Total | 12 | 13 | 5 |
| | | weighting | x1 | x1 | x1.5 |
| | | | 12 | 13 | 8 |
| | | | Overall total | | 33 |

Assessor's action: Two marks for each of skill areas P and O but the mark of 4 for skill area I is not used. Not using a mark of 6 from either P or O would have the same effect.
Reported mark: 33 out of 56.

**Example**: Student 4, a Double Award specification,

*A student for Double Award has two whole investigations, both based on contexts in the same attainment target but which are significantly different, a maximum of 5 skill area marks may be counted.*

| AT | Activity | Practical Investigation | Skill Area | | |
|---|---|---|---|---|---|
| | | | P | O | I |
| AT4 | Bouncing balls | Yes | 7 | 8 | 5 |
| AT4 | Resistance | Yes | 5 | 6 | 4 |
| | | | | | |
| | | | | | |
| | | Total | 7 | 14 | 9 |
| | | weighting | x1 | x1 | x1.5 |
| | | | 7 | 14 | 14 |
| | | | Overall total | | 35 |

Assessor's action: Two marks for each of skill areas O and I, but the mark of 5 for skill area P is not used as it is the mark which contributes least to the overall total.
Reported mark: 35 out of 56.

**Example**: Student 5, a Double Award specification,

*A student for Double Award has two whole investigations, but both are based on a single context in the same attainment target. A maximum of three skill area marks may be counted, the three marks which contribute most to the overall total.*

| AT | Activity | Practical Investigation | Skill Area | | |
|---|---|---|---|---|---|
| | | | P | O | I |
| AT4 | Resistance - length | Yes | 7 | 8 | 4 |
| AT4 | Resistance - area | Yes | 6 | 6 | 5 |
| | | | | | |
| | | | | | |
| | | Total | 7 | 8 | 5 |
| | | weighting | x1 | x1 | x1.5 |
| | | | 7 | 8 | 8 |
| | | | Overall total | | 23 |

Assessor's action: One mark is discounted in each skill area for similarity of context. Since only three marks are being counted there is no further penalty for lack of attainment target coverage.
Reported mark: 23 out 56.

**Example**: Student 6, a Double Award specification,

*A student for Double Award has three whole investigations, but two are based on a single context in the same attainment target. It is possible to count 6 skill area marks, provided two marks for the same skill area are not taken from the same context.*

| AT | Activity | Practical Investigation | Skill Area | | |
|---|---|---|---|---|---|
| | | | P | O | I |
| AT4 | Resistance - length | Yes | (7) | (8) | 4 |
| AT4 | Resistance - area | Yes | 6 | 6 | (5) |
| AT3 | Ratea | Yes | (5) | (6) | (4) |
| | | | | | |
| | | Total | 12 | 14 | 9 |
| | | weighting | x1 | x1 | x1.5 |
| | | | 12 | 14 | 15 |
| | | | Overall total | | 41 |

Assessor's action: The mark of 6 in skill area Pis not included as it comes from a similar context to the mark of 7 in the same skill area.

Reported mark: 41 out of 56

## 4. Other Assessment Issues

### 4.1 Predictions

There is no requirement for a student to make a prediction of the outcome in advance of the actual investigation if it is inappropriate to do so.

If a student makes a prediction then it must be justified when awarding the higher marks. Without any scientific knowledge and understanding to back it up, a prediction may be no more than a guess.

If a prediction has been made it does not need to be quantitative in order to qualify for consideration towards the award of marks. However, a quantitative prediction, if appropriate, may reflect the 'increasing demand of the activity' and allow access to the higher marks.

### 4.2 Variables

When carrying out work for science assessments, students do not have to deal with more than one independent variable or more than one aspect in order to qualify for the highest marks.

An investigation dealing with only one factor can qualify for consideration for the award of the highest marks.

### 4.3 Supervision of coursework

The GCSE, GCE, VCE and GNVQ Code of Practice states that:

- 'The awarding body must specify the conditions under which internally assessed work can be undertaken. The specified conditions must facilitate the supervision and authentication of candidates' work by teachers and internal assessors. Where, because of the nature of the subject, the specification requires centre-based candidates to undertake some internally assessed activities outside their school or college, the awarding body must require that sufficient work takes place under direct supervision to allow the internal assessors concerned to authenticate each candidate's work with confidence'. (paragraph 80)

- ‘The awarding body must specify the degree to which candidates are allowed to re-draft their work prior to it being marked by the internal assessor’. (paragraph 81)

- 'The awarding body must require internal assessors to confirm that they have taken steps to satisfy themselves that work produced is solely that of the candidate concerned. The internal assessor must present a written declaration that the candidate's work was conducted under the required conditions as laid down by the specification. Where awarding bodies accept entries from private/external candidates they must ensure that adequate procedures exist for the authentication of internally assessed components. (paragraph 82)

Working 'under supervision' is not the same as ‘working under examination conditions'.

In all cases of group work, the teacher must be able to identify the individual contributions of the students in order to give appropriate credit to each individual student.

### 4.4 Annotation of students' work

The GCSE, GCE, VCE and GNVQ Code of Practice states that:

- ‘The awarding body must require internal assessors to show clearly how credit has been assigned in relation to the criteria defined in the specification. The awarding body must provide guidance on how this is to be done'. (paragraph 84)

Annotation should show fully:

- what guidance has been given;
- ephemeral evidence provided by the student to the teacher in order to justify the awarding of a particular mark;
- those areas of the work that provided the evidence for the award of a particular mark.

Reference to the mark descriptions should be made using the codes, e.g. P.6a, O.4b, etc.

Any information or guidance provided to students must accompany the work when submitted for moderation e.g. data provided for analysis. Where secondary evidence is used, students must quote the appropriate references.

### 4.5 Activities covering only one skill area

For activities which cover only one skill area, the following guidance notes apply.

#### 4.5.1 Skill Area P: Planning

Students must plan a procedure for an activity which is appropriate GCSE work;

Assessment of planning should be limited to techniques and/or equipment which are found normally in centres;

If the planning is then implemented by work done by the student, the plan may be elaborated or modified as a consequence, and this may improve the planning performance.

#### 4.5.2 Skill Area O: Obtaining evidence

In presenting the activity to be undertaken by the students, the teacher must ensure that opportunities exist for students to exercise their own judgement in order that they can fulfil the requirements of the mark descriptions.

For example:

O.4a: collect **appropriate** evidence which is **adequate** for the activity
O.6a: collect **sufficient systematic** and **accurate** evidence and **repeat or check** where appropriate

The students must be given opportunities to make their own individual judgements on the matters in **bold type above**, and in all similar situations. Thus prescriptive plans or highly structured worksheets provided to students will limit the range of marks available by giving them too much guidance.

#### 4.5.3 Skill Area I
**Interpreting and Evaluating**

Where data are provided for students, they will be better able to work effectively if they are aware of how the data were obtained. Data that are provided should be realistic, not idealised. Data which are too carefully structured may limit the demand of the activity and hence limit access to the higher marks.

If teachers present students with sets of results for analysis or for evaluation, then these results must be generated from activities such as:

- individual student work;
- group student work (including pooled results);
- teacher demonstrations;
- videos of practical work;
- computer simulations

i.e. they must be derived from realistic, not idealised, practical situations.

In addition, for skill area I, information must be supplied to the students on the procedures used, including details of the equipment and methods.
Teachers must give careful consideration to the mark descriptions and ensure that opportunities exist for individual students to meet the appropriate requirements.

### 4.6 Allocation of an activity to an attainment target

#### 4.6.1 Single and Double Award

For each student, each piece of work must be assigned to a particular attainment target: e.g. an investigation on photosynthesis which involved features from AT2 and AT3 must be designated as either AT2 or AT3.
The actual designation can vary from student to student within a centre (e.g. AT2 for student X, AT3 for student Y).

#### 4.6.2 Separate sciences

If, in a particular piece of work, the scientific knowledge and understanding is appropriate to more than one separate science specification, then the marks awarded and the piece of work can contribute to the assessment of investigative skills in more than one separate science specification.

### 4.7 Cross-crediting of evidence

**Scientific knowledge and understanding**

Cross-crediting of evidence from one skill area to another, in one piece of work - particularly scientific knowledge and understanding, is possible in some situations i.e. relevant evidence from any part of a written report may be used to assess any skill area, where appropriate.

The mark descriptions for skill area I refer to relating the conclusion to scientific knowledge and understanding and to the use of scientific knowledge and understanding to explain a conclusion. Thus, if relevant scientific knowledge and understanding is presented in skill area P of an investigation, a definite link to the conclusion must be established when the evidence is analysed for skill area A, and the scientific knowledge and understanding must be used in an appropriate way - a mere reference or restatement of the scientific knowledge and understanding in the planning will not be sufficient.

## 4.8 Use of ICT (Simulations, models etc.)

The use of ICT, e.g. for word-processing, data-logging and graphical display (including lines of best-fit) is to be encouraged as recommended in the Programmes of Study.

In addition, through the teaching of Investigative Skills, students should be given opportunities to apply and develop their ICT capability. In particular, students could:

- use data-handling software to analyse data from fieldwork;
- use data-handling software to create, analyse and evaluate charts or graphs;
- use data loggers in investigations;
- use spreadsheets for data analysis
- use the internet or CD-ROM software as sources of secondary evidence.

All sources and references used must be clearly identified by the student.

## 5. Exemplar Material

The portfolio of Exemplar Material that supports this booklet contains work in the form that it would have been sent to the moderator.

The commentaries and marks awarded for each piece of work have been agreed by the Awarding Bodies.

The pieces have been selected to show two pieces of work, of differing standards, in each of the attainment targets.

It is intended that further exemplar work will be added to the portfolio, in order to exemplify as many aspects as possible involved with assessment of coursework.

| **Code** | **Activity** | **Practically based whole investigation** | **AT** | **Skill area marks** | | |
|---|---|---|---|---|---|---|
| | | | | **P** | **O** | **I** |
| CC1 | Light and photosynthesis | Y | 2 | 5 | 6 | 3 |
| CC2 | Light and photosynthesis | Y | 2 | 6 | 6 | 7 |
| CC3 | Sodium Thiosulphate and Hydrochloric Acid | Y | 3 | 5 | 6 | 5 |
| CC4 | Sodium Thiosulphate and Hydrochloric Acid | Y | 3 | 6 | 8 | 7 |
| CC5 | Solar cells | Y | 4 | 6 | 6 | 5 |
| CC6 | Solar Cells | Y | 4 | 8 | 6 | 7 |

**How does light strength affect photosynthesis?**

## Theory

Green plants are called producers because they make their own food. They make their food by photosynthesis. Most photosynthesis takes place in the leaves of a plant. chlorophyll the green colour in the leaves traps light energy from the Sun. The energy is used to change water and carbon dioxide into Sugar and oxygen.

This equation shows what happens.

$$\text{water} + \text{carbon dioxide} \; \frac{\text{sunlight energy}}{\text{chlorophyll}} \; \text{sugar} \blacktriangleright + \text{oxygen}$$

This is another way of wrighting the equation

$$6H_2O + 6CO_2 \; \frac{\text{sunlight energy}}{\text{chlorophyll}} \; \rightarrow C_6H_{12}O_6 + 6O_2$$

prediction

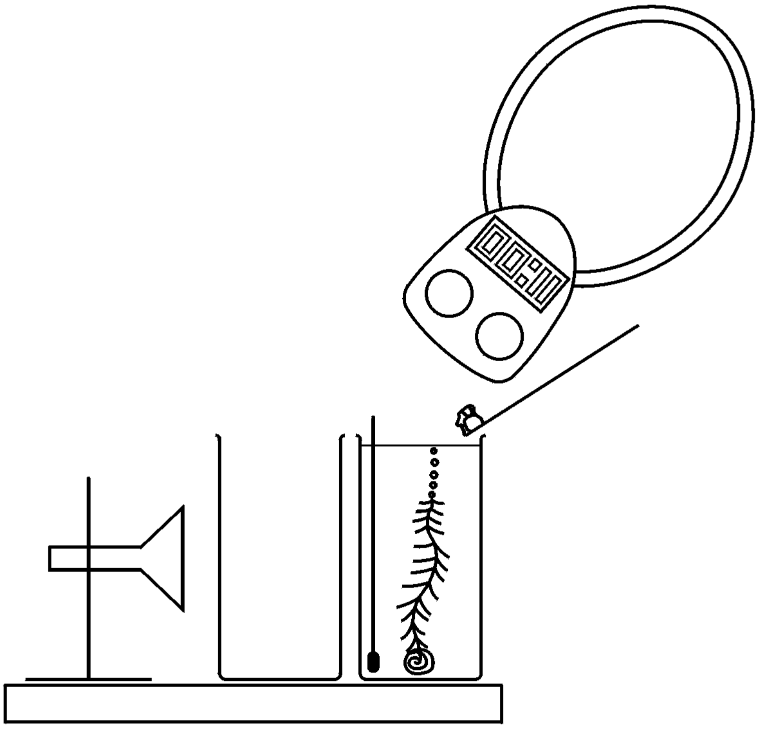
I think that the closer the light is the more bubbles and the thurther the light is the less bubbles.

explaining my prediction

The plant need the light to make photosynthes

How I will test my prediction

1. 2 beakers
2. 1 light
3. 1 plant
4. 1 ruler
5. paper clip
6. sodium bicarbonate
7. stop clock
8. thermometer



| | Number of bubbles per minuite | | | |
|---|---|---|---|---|
| Distance | Go 1 | Go 2 | Go 3 | Average |
| (cm) | | | | |
| 5 | 42 | 43 | 43 | 43 |
| 10 | 32 | 29 | 32 | 31 |
| 15 | 19 | 20 | 21 | 20 |
| 20 | 15 | 14 | 13 | 14 |
| 25 | 10 | 13 | 12 | 12 |

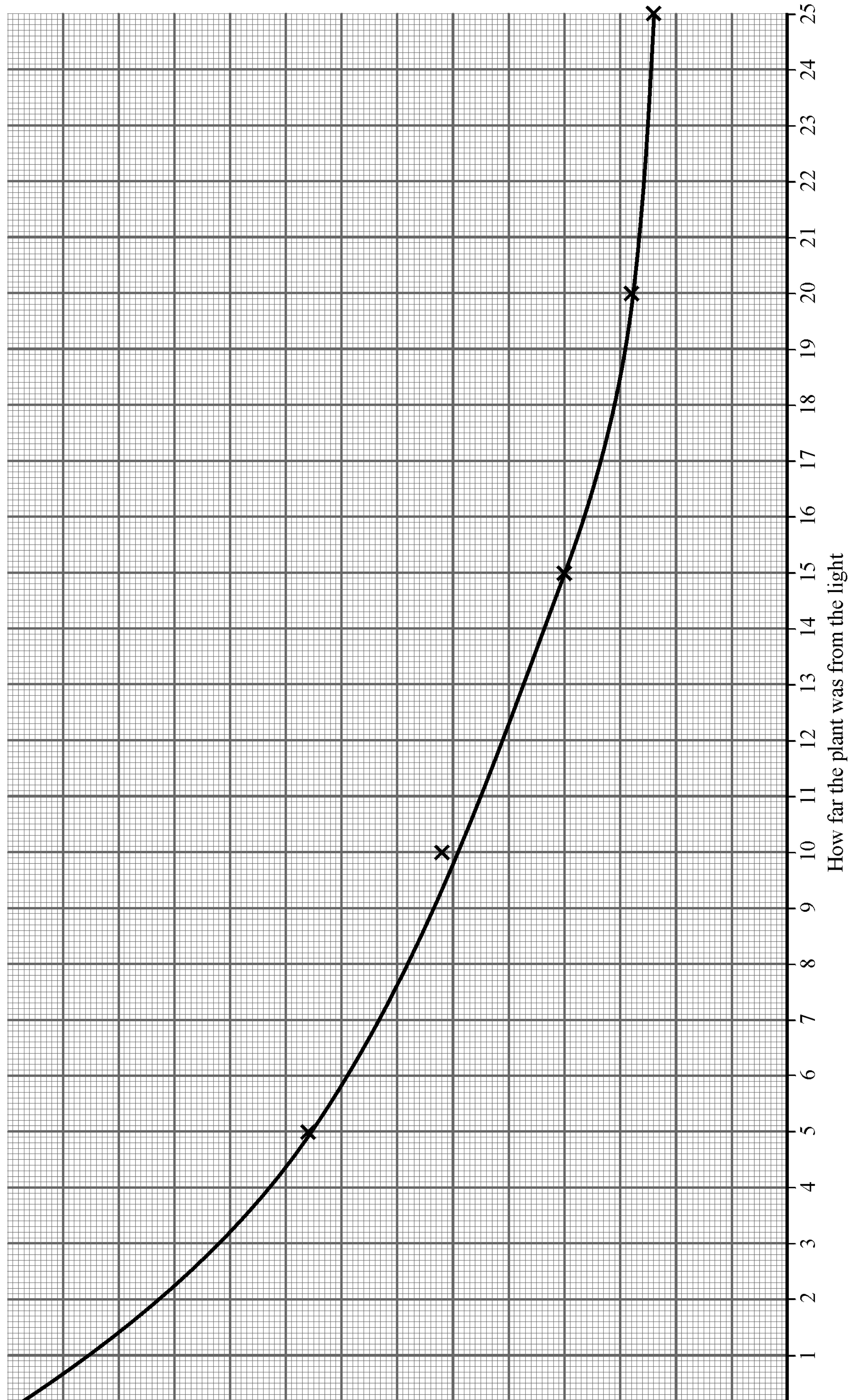
***Teacher Annotation***
*When questioned, the student explained that he would use the same piece of Elodea in the same tube, but move the lamp.*

Conclusion

I found out that a plant needs light for photosizing. It means that it you don't have any light the plant will not be also to do photosynthesis.

Evaluation

My prediction was right from the start.



The number off bubbles
How far the plant was from the light
0
5
10
15
20
25
30
35
40
45
50
55
60
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

# CC1 - Commentary

**Skill Area P**: Planning

**P.2a** A simple procedure has been outlined.

**P.4a** There is an implicit plan to collect evidence by way of counting bubbles, although a written plan would have been preferable. An appropriate prediction has been made. Teacher annotation covering the question of fair testing allows the award of P.4a.

**P.4b** The equipment chosen is suitable.

**P.6a** Although the equation for photosynthesis has been quoted, this has not been used in formulating a plan.

**P.6b** The extent and range of the evidence to be collected is just sufficient to qualify for this mark.

**5 marks awarded**, as P.6b has been matched, but P.6a has not.

**Skill Area O**: Obtaining Evidence

**O.2a** The equipment has been used to make some measurements.

**O.4a** The observations and measurements are adequate for the activity.

**O.4b** The observations have been recorded.

**O.6a** The observations are sufficient and have been repeated. The consistency between the three sets is indicative of accuracy.

**O.6b** The evidence has been recorded clearly.

**O.8a** There is insufficient evidence of precision and skill being used to justify the award of this mark.

**6 marks awarded**, as O.8a has not been matched.

**Skill Area I**: Interpreting and Evaluating

**I.2a** A simple explanation has been given.

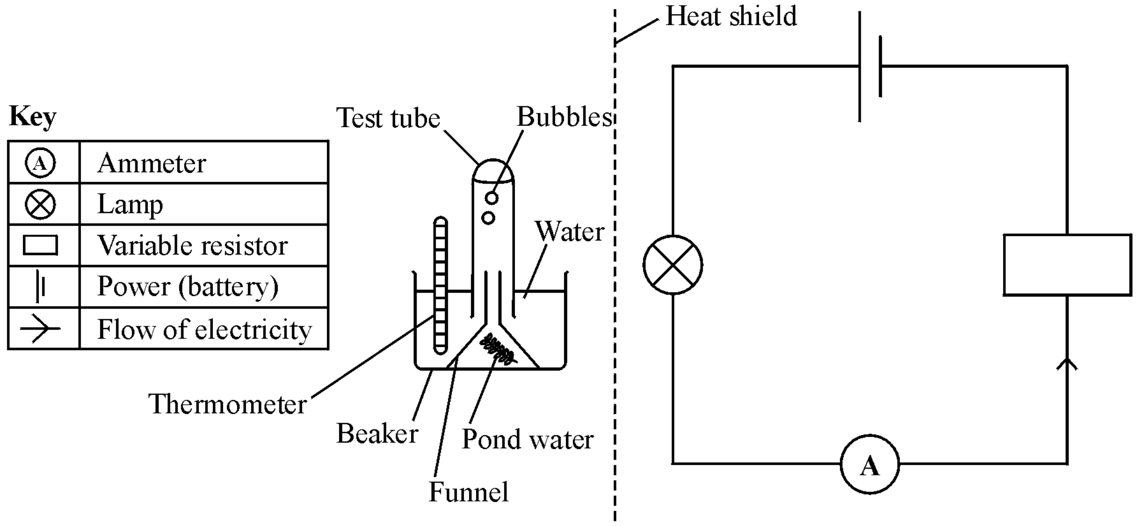
**I.4a** A suitable graph has been drawn.

**I.4b** There is no written evidence, nor is there a teacher annotation, to show that a pattern has been identified.

**3 marks awarded**, as I.4a has been matched but I.4b has not.

**How does light intensity affect the rate of photosynthesis?**

## Diagram




## Method

To test if light intensity affects the rate of photosynthesis we will set up a circuit like the one shown in the diagram above, with a lamp, ammeter, variable resister and power pack. In front of the lamp we will place some pondweed in a beaker of water with a funnel and a test tube. In this experiment we will only change one variable which is the intensity of the light, we will change this with the variable resister which will intern alter the brightness of the lamp. To see what the measurement of the light intensity is, we will read the current in amps from the ammeter. We will choose 5 different settings of light intensity, the highest, the lowest and three spread evenly between. To measure the rate of photosynthesis we will measure the number of bubbles given off in the test tube over a three minutes time span, we will do this for each light intensity. We will measure the number of bubbles because they will be oxygen bubbles as oxygen is a product of photosynthesis; therefore, the more bubbles that there are, the more photosynthesis taking place. However if the speed of photosynthesis is very slow, to distinguish a difference between the affect of the light intensity we may find it necessary to add 1 spatula of sodium hydrogen carbonate to the beaker. Addition of sodium hydrogen carbonate will stimulate photosynthesis if there are no obvious signs of bubbles being produced, increasing the carbon dioxide availability. The addition of carbon dioxide increases the rate of photosynthesis, as it is one of the vital products which are needed for photosynthesis to take place, therefore it will speed up the process and produce more oxygen.
Originally we were going to use a heat shield in between the beaker and the lamp so that any heat given off by the lamp would not heat up the water to affect the experiment, however in practice this was not necessary as the temperature of the water did not rise due to the lamp.
We will choose an average length of pondweed, as it will keep the rate of photosynthesis the same for each time that we do the experiment, keeping it fair.
All other variables will be kept the same to make it a fair test, so will not be changed. These include; the distance between the lamp and the beaker, the amount of water, the 3 minute time span to count the oxygen bubbles, the temperature of the water and the amount of sodium hydrogen carbonate as these can all affect the outcome of the experiment. As this experiment involves electricity and water it is important to take care as these two things are hazardous and can cause electrocutions, so safety is an important issue.

We will do the experiment with each light intensity at lest three times because then we can be sure that the results obtained will be quite fair and accurate to get an average result.

After doing the experiment I predict that the strongest light intensity will create the most oxygen bubbles and therefore will photosynthesise more. I predict this because for a plant to photosynthesise, water, carbondioxide, chlorophyll and light is needed. *(Photosynthesis = carbondioxide + water = (with light and chlorophyll) glucose + oxygen)* In theory as water, carbondioxide and chlorophyll will be kept the same, these factors should not influence photosynthesis, therefore, the deciding factor is the amount of light that the plant receives, thus the more light it receives the more it will photosynthesise. (increasing gradually as the light intensity does) Also, because the light is stronger than with other light intensities the wavelength of the light is shorter giving off a greater amount of energy, which is all, concentrated onto the plant to increase photosynthesis.

## Results

In all three experiments we decided not to use sodium hydrogen carbonate as we felt it was not necessary and the plant was photosynthesising well by itself.
The results of the three experiments are shown below in the tables:

**1.** Temperature = 24°

| Light Intensity (amps) | Number of bubbles produced |
|---|---|
| 0.51 | 3 |
| 0.57 | 5 |
| 0.68 | 8 |
| 0.73 | 9 |
| 0.82 | 12 |

**2.** Temperature = 26°

| Light Intensity (amps) | Number of bubbles produced |
|---|---|
| 0.59 | 6 |
| 0.72 | 12 |
| 0.97 | 14 |
| 1.25 | 24 |
| 1.67 | 36 |

**3.** Temperature = 22°

| Light Intensity (amps) | Number of bubbles produced |
|---|---|
| 0.51 | 2 |
| 0.57 | 3 |
| 0.68 | 7 |
| 0.73 | 7 |
| 0.82 | 10 |

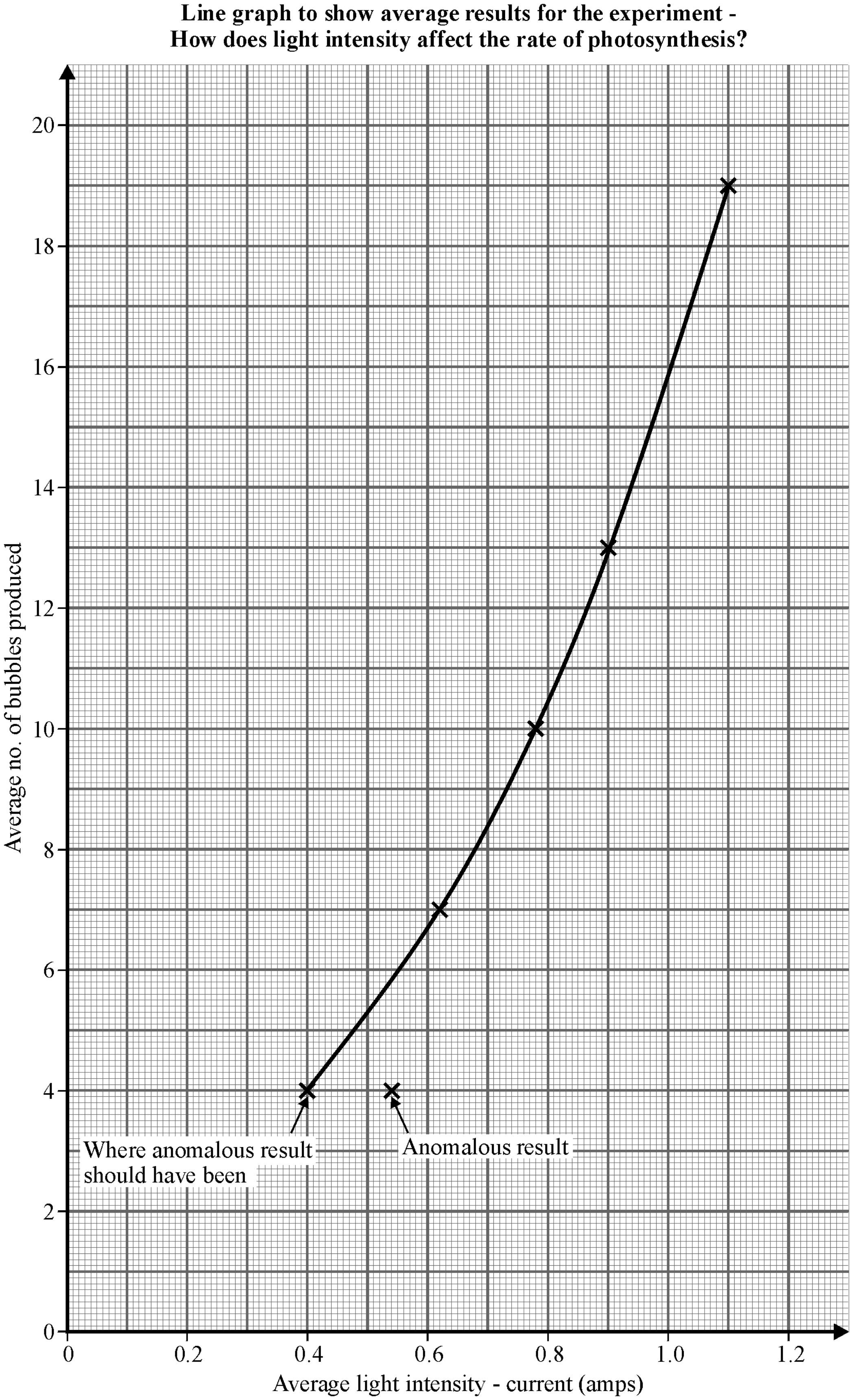
I noticed that each time I did the experiment the speed at which the bubbles floated upwards differed as we used different plants, however this did not affect the nature of the experiment as the results were still the same.
While doing the experiment it was obvious that the size of the bubbles had an impact on the experiment because sometimes although the amount of bubbles changed, as expected, the size of the bubbles also differed. Therefore the amount of oxygen given off altered, affecting the recording process of the experiment because more small bubbles could hold the same amount of oxygen as large bubbles but as it is recorded as having more it is assumed to have photosynthesised more which may not be the case.

We have got three sets of results from the experiment so will now create an average set of results by finding the mean of each light intensity and the mean for the number of bubbles produced from that light intensity.

## Average Results

| Average light intensity (amps) | Average Number of bubbles |
|---|---|
| 0.54 | 4 |
| 0.62 | 7 |
| 0.78 | 10 |
| 0.9 | 13 |
| 1.1 | 19 |

I will now plot these results on to a piece of graph paper to recognise any patterns or unusual readings in the results.



## Conclusion/Evaluation

My results tell us that the stronger the light intensity, the quicker the rate of photosynthesis is. I know this because in all three experiments the strongest light intensity created the most amount of bubbles, and the bubbles are of oxygen, which is a product of photosythesis. This proved that my original prediction before the experiment was correct. Between the light intensities the number of bubbles were spread out quite evenly, as shown in the graph. This was all except for the strongest, which created almost double the amount of bubbles, than between the other light intensities.

I could improve on the practical by using the same equipment for all three experiments, because then the test would be fairer and would not affect the outcome of each experiment. For example, using different variable resisters meant that there were differences between the number of amps for each light intensity. This affected the amount of bubbles for that setting, as it affected the brightness. So more light created more bubbles. Also the water for each experiment was a different temperature, this affected the experiment because the warmer the temperature the more a plant photosynthesises, making it an unfair advantage for those results if the water was warmer at that time. So using the same pieces of equipment would have made the results a lot more accurate and fair between them.
I could improve the accuracy of the results by repeating the experiment not just three times but a number of times as this would make sure that it truly was accurate. Using the same pond weed would also make the results more reliable because different pieces of pond weed photosynthesise at different rates, so using the same piece would give each set of results a greater degree of accuracy. However this was not possible due to the times that we did the experiment.

The size of the oxygen bubbles often differed between the experiments; some were very small and some very big. This was also an unfair advantage because bigger bubbles would contain more oxygen than the smaller ones, however if there were more of the smaller ones it would seem as if that light intensity photosynthesised more, when in fact it could have contained less oxygen than the bigger ones who produced less but photosynthesies more. So this was not a reliable factor, however this could only improve if the same equipment was used each time.

As temperature could affect the rate of photosynthesis it was important too keep it controlled as the brightness of the light was the only variable that we wanted, to affect the rate of photosynthesis and higher temperatures increased that rate. A heat shield would do the job of stopping wasted heat energy from the lamp of transferring to heat the water, as it would prevent this heat from reaching the beaker of water. However we found out that we did not need to use a heat shield because the temperature of the water did not increase due to the lamp.

If carbon dioxide ran out in the water, then the plant would be unable to photosythesise, as carbon dioxide is one of the two products that are needed for this to take place. We would know if carbon dioxide had run out in the water because there would be no bubbles of oxygen released into the test tube. If carbon dioxide had run out, then sodium hydrogen carbonate could be added to the water, this adds carbon dioxide to the water, helping speed up the process, but we found that this was not necessary in our experiments. The amount of water had to be kept the same because water is the other product needed for photosynthesis so the more the plant had the more it would photosynthesise however if it was kept the same them it would not be a variable which affected photosynthesis. Other than this if sodium hydrogen carbonate was added to the water and there was not the same amount of water in each experiment then the concentration of the sodium hydrogen carbonate would differ. This would mean that the amount of carbon dioxide that the plant received would differ, affecting the rate of photosynthesis.

After drawing my graph I realised that my result for the first light intensity did not fit with the general pattern of the rest because the number of amps was too high compared to the rest, as the others were evenly spaced out. On the graph I have drawn a dotted line of where the line should have started, if the amperage was spaced out in the same pattern as the rest, showing what the amperage should be.
The amperage was 0.54 amps however from the graph we can see that in co-ordination with the rest of the points, this should be 0.4 amps.

There are no set of results can be exactly correct because each plant differs at different times of when it photosynthesises and any little factor can affect this.  However they can be fairly accurate and based on scientific knowledge and the results that I got in practice, I found that my results were legitimate as they did show that strongest light intensities speed up the rate of photosynthesis.

If I were to extend the nature of this experiment I could repeat it more times, which would enable me to find out a formula for the pattern between the amount of bubbles and each light intensity.  I could also experiment between how distance of light affects photosynthesis for the same light intensity rather than different light intensities with the same distance.

# CC2 - Commentary

**Skill Area P**: Planning

**P.2a** A procedure has been outlined.

**P.4a** The plan will yield valid data.

**P.4b** Suitable equipment has been chosen.

**P.6a** The candidate displays a good depth of scientific knowledge and understanding, and has been linked to the predictions.

**P.6b** The extent and range of the data to be collected is sufficient to match this mark description.

**P.8a** The depth of scientific understanding shown is not sufficient to justify the award of this mark.

**P.8b** There is no strategy for dealing with results

**6 marks awarded**, as neither P.8a nor P.8b has been matched.

**Skill Area O**: Obtaining Evidence

**O.2a** Observations have been obtained.

**O.4a** The measurements obtained are adequate for the activity.

**O.4b** The measurements have been recorded.

**O.6a** A range of five currents has been used and there is repetition, but no direct measurement of light intensity.

**O.6b** The results have been carefully and clearly recorded.

**O.8a** A candidate operating at this level might be expected to ensure that the lamp current was adjusted to the same value for each measurement repeated. The fact that it was different for the second series of readings suggests that the necessary precision was lacking.

**6 marks awarded**, as O.8a has not been matched.

**Skill Area I**: Interpreting and Evaluating

**I.2a** The candidate has stated what has been found out.

**I.4a** The recorded data has been processed into the form of a line graph.

**I.4b** A pattern has been noted and commented upon.

**I.6a** The graph drawn shows a line of best fit.

**I.6b** The conclusion drawn has been explained by relating it to scientific understanding.

**I.6.c** There are several comments concerning the procedure used, together with suggestions for improvement, e.g. the use of a heat shield.

**I.8a** The level of scientific knowledge and understanding being used to process the conclusion is not as detailed as would be expected at this level.

**I.8b** The candidate has made an attempt to explain how the conclusion supports the prediction but it lacks the detail needed at this level.

**I.8c** There is enough evidence to be able to award this mark, eg the candidate comments on different volumes of the bubbles and offers an explanation of the identified anomalous result.

**7 marks awarded**, as I.8a and I.8b have not been matched but I8.c has.

**The sodium thiosulphate practical**

1. We are trying to find out if you increase the temperature of the sodium thiosulphate the reaction will be faster or slow than when it is a room temperature with the hydrochloric.

2. The variable I am going to change is the temperature of the sodium thiosulphate.

3. The temperatures that I am going to use in the experiment are

   10 $^oC$, 20 $^oC$, 30 $^oC$, 40 $^oC$, 50 $^oC$

4. The other variable I will measure is the rate of the reaction.

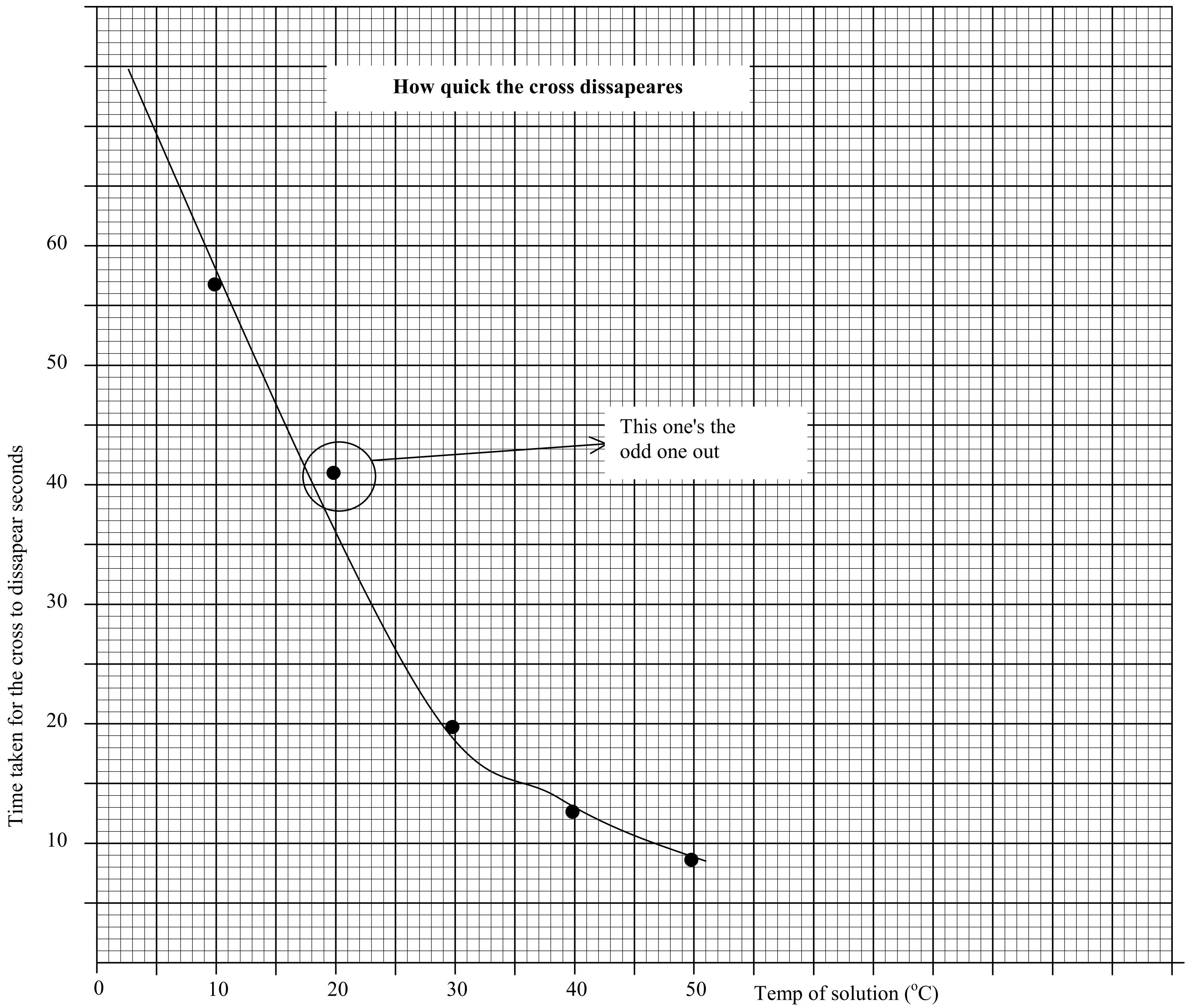
5. I predict that the higher the temperature the quicker the reaction. The reason I think this is because the hotter the liquid - the more energy the particals have to move around so they move a lot quicker, so there are more colitions with the particals from the hydrochloric acid so the reaction is faster.

6. The equipment I am going to use 40ml sodium thiosulphate, 5 ml hydrochloric acid, conical flask, thermometer, measuring cylinders 10ml and 50ml, stop clock, try pod, gauze, heat mat, bunsen berner, gogles, 50ml beaker, paper, pen

7. Method At the beginning of the test you should get out the bunsen berner and get it ready to be used. You should pour 40ml of sodium thiosulphate into the 50ml beasker and then put the thermometer in. you should then heat it up to the given temperature with the bunsen berner or cool it in a bowl of ice. Then draw a cross on a peace of paperand put the conical flask on it. Then add the heated or cooled sodium thiosulphate to the flask, then you put in the 5ml of hydrochloric acid and start the stopclock and record the time in a table. You should do this for all the temperatures and do it twice to ensure you get accurate results and remember that when you are around the bunsen berner always to wear gogles.

**Results**

| **Temperature of solution ($^oC$)** | **Time for the cross to dissapear (s)** | | | |
|---|---|---|---|---|
| | 1st | 2nd | 3rd | Average |
| 10 | 56.67 | 58.74 | 54.13 | 56.51 |
| 20 | 43.13 | 39.67 | 40.00 | 40.94 |
| 30 | 21.00 | 16.76 | 21.01 | 19.59 |
| 40 | 13.02 | 12.84 | 12.54 | 12.83 |
| 50 | 8.95 | 7.58 | 9.75 | 8.76 |




**Conclusion**

I have found out that the hotter the solution is the quicker the rate of reaction. Because when the solution is at room temperature the atoms have some energy so they will react but when you heat the solution the atoms get a lot more energy and get more reactive so the reaction is a lot quicker.

**Evaluation**

The data that I have collected was suficient enufe to prove my prediction. My prediction was that the hotter the solution the faster the reaction would take place. I had one anomobus point that did not fit the pattern. I think the reason for this is that I was not carful enufe to mesure the solution.. I was not quick enufe to press the stop button on the stop clock so my result was not accurate.
There were no weaknesses in my method and it all went as I had planned.

# H9 - Commentary

**Skill Area P**

**P.2a** A simple procedure has been planned.

**P.4a** The use of standard procedures will provide valid evidence

**P.4b** The equipment chosen is suitable for the task.

**P.6a** Reaction rate is linked to more frequent collisions at higher temperature, but with very little detail. There is no plan to measure the temperature of the solutions after mixing, and no explanation of how the end point would be recognised. The general quality of communication is poor and this mark description is only partially matched.

**P.6b** The candidate plans to take a suitable range of five temperatures and to repeat them.

**5 marks awarded**, as P.6a is only partially matched.

**Skill Area O**

**O.2a** Evidence has been collected and one safety precaution has been mentioned.

**O.4a** Appropriate and adequate evidence has been collected to enable the candidate to draw a suitable conclusion.

**O.4b** All the raw data have been recorded.

**O.6a** The student has collected sufficient data systematically, and repeat readings show good agreement.

**O.6b** The data have been clearly recorded in a table with correct use of units and consistent use of decimal places.

**O.8a** Precision and skill are insufficient to ensure reliable evidence. For example the student has failed to measure the temperature of the solutions when mixed.

**6 marks awarded.**

**Skill Area I**

**I.2a** The candidate has given a written conclusion.

**I.4a** The data collected has been displayed graphically. All the points have been plotted correctly.

**I.4b** The candidate clearly identifies the trend in the data.

**I.6a** The quality of the 'best-fit' line is just sufficient to match the mark description.

**I.6b** The candidate comments, briefly, on the link between the scientific background and the trend discovered, but there is not sufficient detail to confirm a match.

**I.6c** The candidate does not comment on either the procedure used or the ways of improving the reliability.

**5 marks awarded**, since I.6a is just sufficiently matched and I.6b is only partially matched.

## CHEMISTRY INVESTIGATION

Sodium thiosulphate has formula $Na_2S_2O_3$. This has an extra sulphur atom which can be driven out by reaction with an acid.

Sodium thiosulphate + hydrochloric acid → sulphur + sulphur dioxide + sodium chloride

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow S(s) + SO_2(g) + 2NaCl(aq).$$

Sulphur is precipitated when this reaction takes place.

INVESTIGATION OF ONE FACTOR AFFECTING THE RATE OF THIS REACTION

There are several different factors that will affect the rate of this reaction. They are:
concentration of sodium thiosulphate,
temperature of the reaction,
pressure.
I have decided to investigate how temperature affects this reaction. I think that the higher the temperature is, the faster the reaction will be i.e. the higher the temperature, the quicker the sulphur will be precipitated- time is inversely proportional to temperature (the higher the temperature, the less time it will take for a given amount of sulphur to be precipitated.

Why?
"The hotter something is, the quicker the particles in it move" (Kinetic Theory). Therefore the hotter the solution is, the quicker the particles in it will move. This means that they will collide more often. This means that they react more quickly because they react as they hit. They move more quickly because they have more energy. This shows that by heating something, you are giving it more energy. Therefore: by increasing the temperature of this reaction, you are increasing its energy and thereby you are increasing the rate of reaction.

e.g. from textbook: "A reaction goes faster when the temperature of it is raised. When the temperature increases by 10°C, the rate approximately doubles". Therefore, I expect that every time this reaction takes place, the same will be true. Therefore, if at 10°C it takes 140 seconds to precipitate the defined amount of sulphur, at 20°C it will take 70 seconds, at 30°C it will take 35 seconds.

**FAIR TEST**

Because various other things affect the rate of reaction, I must keep these things constant.

1. The concentration of the sodium thiosulphate affects it because the more molecules there are of sodium thiosulphate, the more often they will collide with each other. As it is when they collide that they react, the more often they collide, the quicker the rate of reaction will be. A more concentrated solution has more molecules per ml of the substance the so the more concentrated the solution is, the higher the rate of reaction. I know from preliminary work that a 60 % solution of a 40 g/l solution is concentrated enough to show a reaction yet slow enough to measure properly.

2. The concentration of the hydrochloric acid. This is for the same reason as for the sodium thiosulphate i.e. the more concentrated it is, the more molecules there are to collide therefore the quicker the rate of reaction.

3. The volume of the sodium thiosulphate. This is because the more sodium thiosulphate there is, the more often the molecules will collide so the rate of reaction will be quicker. I know form preliminary work that 50 ml is the right amount to use because it shows the reaction but is still a reasonable amount.

4. The volume of the hydrochloric acid. This is for the same reasons as for the volume of the sodium thiosulphate i.e. the more there is, the quicker the rate of reaction. However less is needed to show the reaction so I use 10 ml not 50 ml.

5. I must use the same beaker. This is because we are measuring the amount of precipitated sulphur

by how long it takes for that amount to cover a cross. If the bottom of the beaker has a larger surface area it will take longer to precipitate enough sulphur to cover the cross therefore the beaker must be the same each time.

6. The same person must judge whether the cross has disappeared or not because there is only a very tiny difference and different people will judge it differently.

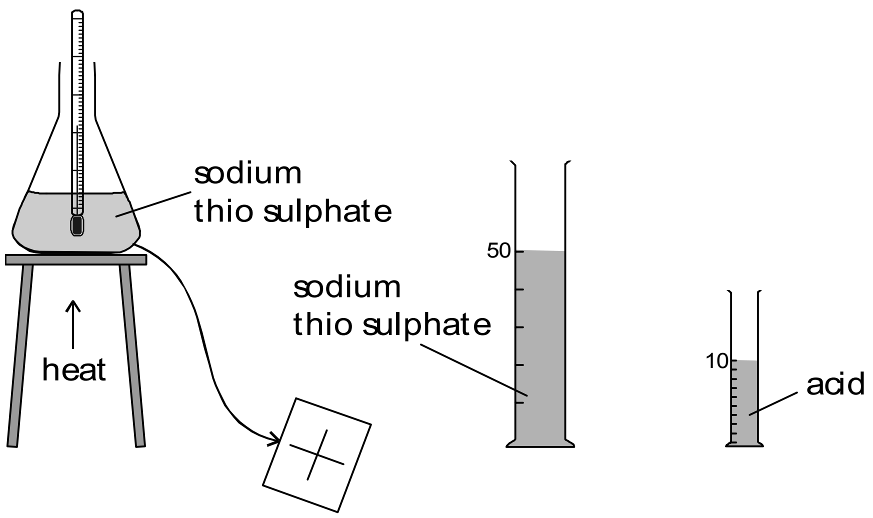
7. I must measure the temperature of the sodium thiosulphate at the same point in the experiment – just before I add the acid.

8. I must use the same cross each time to make sure that it needs the same amount of sulphur to cover it.

I will use temperatures of 10°C, 20°C, 30°C, 40°C, 50°C, 60°C, 70°C, 80°C, 90°C and 100°C but since it will be difficult to get exact temperatures, I will do as near than possible.

**APPARATUS**

2 measuring cylinders, bunsen burner, heat proof mat, gauze, tripod, conical flask, thermometer, cross, goggles, lab coat.




1. Measure out 50 ml of sodium thiosulphate and 10 ml of acid.
2. Wearing goggles and lab coat, heat the sodium thiosulphate over the bunsen burner standing on gauze on a tripod on a heat proof mat over the bunsen.
3. For lower temperatures, it may be necessary to cool it rather than heating it.
4. When it reaches desired temperature, place on top of cross take temperature and note it, then add acid and time how long it takes for the cross to disappear.
5. Do each temperature (every 10°C) 3 times for accuracy.
6. Be careful to keep acid away from bunsen! Turn bunsen down/off in between using it.
7. Wash out flask immediately after each experiment because of $SO_2$ given off.

| Temp °C of $Na_2S_2O_3$ | Time s |
|---|---|
| 16 | 102 |
| 23 | 59 |
| 32 | 40 |
| 41 | 33 |
| 48 | 23 |
| 59 | 10 |
| 69 | 5 |
| 80 | 5 |
| 91 | 4 |
| 97 | 2.5 |

These are the results I got using my original prediction. However I found that:-

a) At the higher temperatures, the results were inaccurate because the cross disappeared too quickly to get accurate results.

b) In between taking the temperature and doing the experiment, there were a few seconds in which the temperatures may have changed a lot.

c) The acid cooled down the sodium thiosulphate. Therefore, I redid my experiment taking the temperature 3 times:

1 the sodium thiosulpohate
2 once the acid was added i.e. at the beginning of the experiment
3 at the end of the experiment

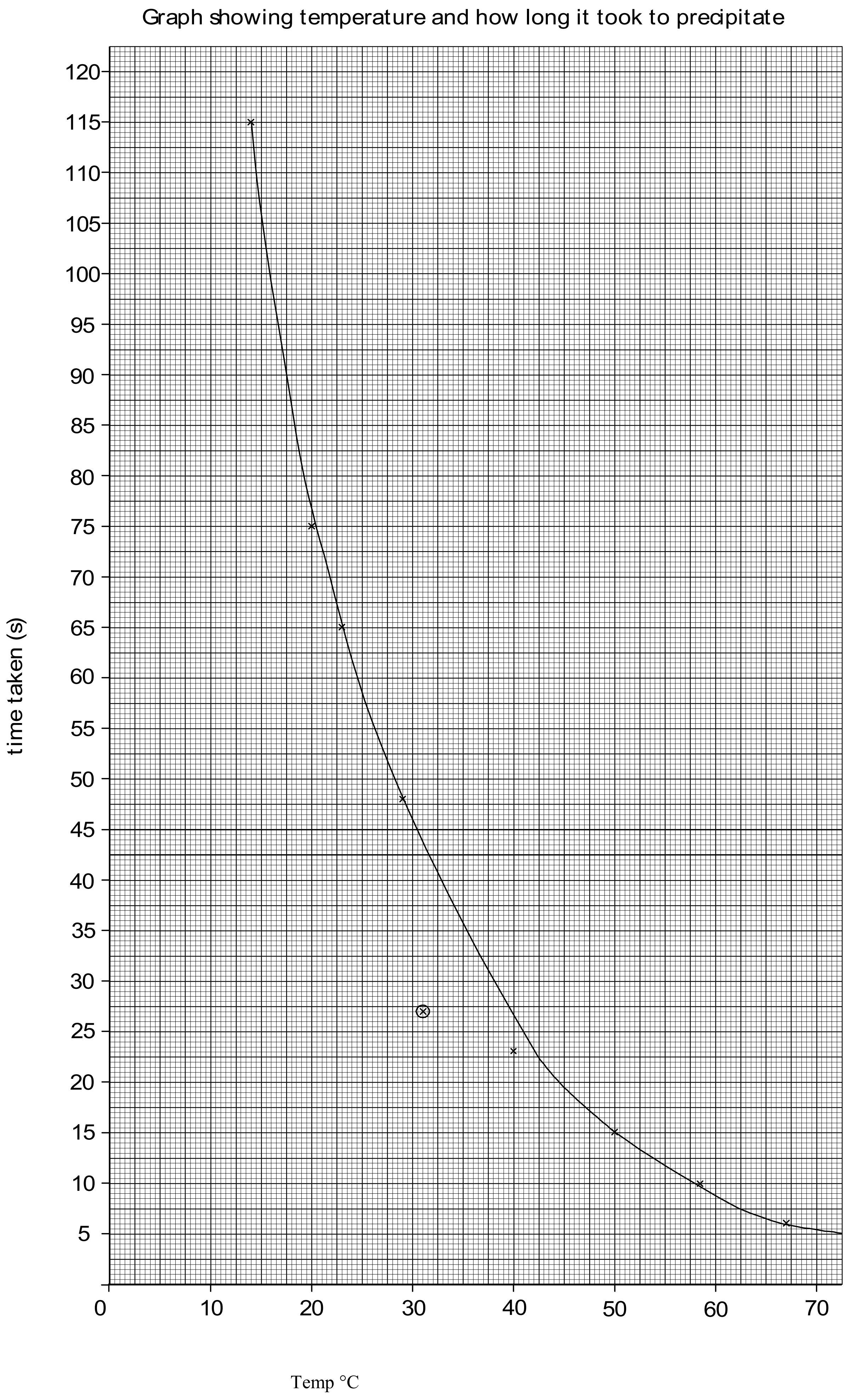
I also only went up to 80°C this time as above that the experiment was too inaccurate to do properly.

| Temp before °C $Na_2S_2O_3$ | Temp with acid °C | Temp °C at end of experiment | Time s |
|---|---|---|---|
| 15 | 15 | 15 | 110 |
| 24 | 24 | 24 | 53 |
| 34 | 34 | 34 | 33 |
| 43 | 43 | 43 | 25 |
| 54 | 50 | 50 | 15 |
| 61 | 55 | 52 | 11 |
| 70 | 64 | 60 | 10 |
| 85 | 80 | 79 | 3 |

I found that the acid was cooling down the sodium thiosulphate considerably at the higher temperatures. I therefore re-did the experiment, heating the acid in a water bath to the required temperature before adding it to the $Na_2S_2O_3$.

| Temp before °C $Na_2S_2O_3$ | Temp °C of HCl | Temp together °C | Time s |
|---|---|---|---|
| 14 | 12 | 14 | 115 |
| 19 | 21 | 20 | 75 |
| 23 | 22 | 23 | 65 |
| 27 | 27 | 28 | 50 |
| 28 | 31 | 29 | 48 |
| 32 | 31 | 31 | 27 |
| 38 | 40 | 40 | 23 |
| 52 | 50 | 50 | 15 |
| 59 | 59 | 59 | 10 |
| 69 | 65 | 67 | 6 |

Instead of doing each temperature 3 times, I did a large number of temperatures. This is because it would have been extremely difficult to reach each temperature exactly the same as it was the first time.


Graph showing temperature and how long it took to precipitate
time taken (s)
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
10
20
30
40
50
60
70
Temp °C

## ANALYSIS

I can see from my graph that although it is true that "the higher the temperature the quicker the rate of reaction", it is not quite so straightforward as that. At the very high temperatures (between 50 °C and 70°C) the graph flattens out. This may be because of the fact that the hotter it is, the quicker it cools down once it is off the flame so that the higher temperatures cooled down the most whereas the lower temperatures stayed at the same point.

At the lower temperatures it also levels out. This may be because the reaction needs a certain amount of activation energy before it can start precipitating so that it takes time to start reacting.

Prediction- "The hotter something is, the quicker its particles move (Kinetic Theory). This means that they collide with each other more often so react quicker. This is because they react as they collide."
"When the temperature increases by 10 °C, the rate approximately doubles."

Is this true?

The higher the temperature, the quicker the rate of reaction is true. However I found that because of the fact that the graph levels out at the higher and lower temperatures, the rate does not double for every 10 °C. However between 20 °C and 50 °C, the rate goes up by approximately 1.6 times the amount for every 10 °C.

| Temperature | × 1.6 of 10°C previous | Actual from graph |
|---|---|---|
| 20 °C | | 75 |
| 30 °C | 45 | 46 |
| 40 °C | 27 | 26 |
| 50 °C | 15 | 15 |

## EVALUATION

My result of 31 °C was not very good. This may be because it was stood too near to a bunsen burner so warmed up or may be because we did not measure accurately or just because it is difficult to tell exactly when the cross disappeared. We redid this at 29 °C and got a much more accurate result i.e. 48s rather than 27s.

All my other results were on the curve of my graph and the 3 times I did the experiment were roughly the same (allowing for differences because of differences in method).

I think that I could check the experiment by measuring the amount of sulphur dioxide given off i.e. making sure it was the same each time.

I also think that I should have insulated the flask to prevent heat/cold from the air surrounding it affecting the experiment.

I could also perhaps have found a more accurate way of watching the cross disappear perhaps by videoing it to take the exact same point each time.

I could maybe have done the temperatures by computerized equipment so that they are more exact. I think I should have done more temperatures to get a more accurate graph. If I were doing this experiment again, I would try to do these things.

# CC4 – Commentary

**Skill Area P: Planning**

**P.2a** A safe procedure has been planned, but it would be preferable to see some attempt to assess hazards

**P.4a** A prediction has been made and there is extensive discussion of the factors needed for fair testing.

**P.4b** Appropriate equipment has been selected.

**P.6a** The student makes use of particle and collision theory to justify the prediction and choice of variable.

**P.6b** A wide range of temperatures is proposed and the intervals are regular and appropriate.

**P.8a** The theory does not consider the effectiveness of collisions in relationship to temperature. The equation is incomplete.

**P.8b** There is no strategy for dealing with results.

**6 marks awarded**

**Skill Area O: Obtaining Evidence**

**O.2a** The equipment has been used safely.

**O.4a** The measurements are clearly adequate for the activity.

**O.4b** The measurements are clearly recorded.

**O.6a** The candidate ahs made the decision to use a large number of temperatures rather than repeat them. The results show that repetition was not needed.

**O.8a** Reliability has been achieved by improvements to the stated method and by accurate measurements of the temperatures. Precision was obtained by the measurement of the hydrochloric acid and sodium thiosulphate solutions independently and when mixed together. The number and range of temperatures is appropriate. The graph showing the pattern of times suggests that the data are reliable. this investigation shows haw sufficient care taken with basic equipment can lead to high quality results.

**8 marks awarded** since O8.8a is sufficiently matched.

**Skill Area I: Interpreting and Evaluating.**

**I.2a** A description of how temperature affects rate of reaction is given.

**I.4a** The results are presented as a graph.

**I.4b** The pattern of resuls is recognised.

**I.6a** A graph has been drawn with a line of best fit and this has been used a s evidence for the conclusion.

**I.6b** Simple collision theory has been used to explain the conclusion.

**I.6c** The candidate has suggested three ways for improving the quality of the data, although all of them lack detail.

**I.8a** The first three paragraphs of the analysis suggest that the candidate is confused about the significance of activation energy.

**I.8b** The data are further processed in an attempt to relate the pattern to the doubling of the rate of reaction every $10^{o}C$

**I.8c** The candidate has commented on the reliability of the results and has attempted a plausible explanation of the correctly identified anomalous result.

**7 marks awarded**, since I.8a is not satisfied.

# Solar panels

**Aim**

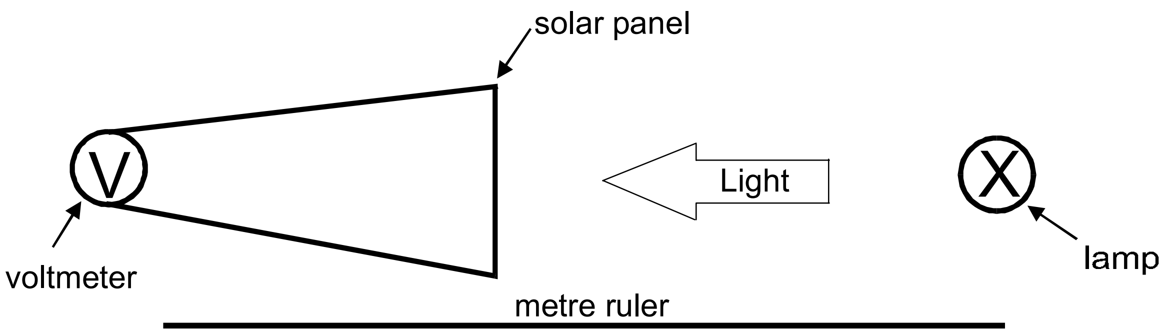
The aim is to investigate two variables that effect the energy output of a solar panel. We were given a solar panel 6 cms. by 9 cms. it was suggested that we might need to consider size, distance and angle of the panels in our experiments.

Solar panels are semiconductors, meaning that they aren't as conductive as a metal-for instance iron or graphite but more conductive than an insulator-for example rubber or plastic. Semiconductor material generates electrical energy when they are exposed to electromagnetic radiation, for example sunlight.

Plan

Variables investigated:
- Distance
- Surface area of the solar panel

The reason that we have chosen to these variables are that they aren't to complex so there isn't that much apart from human era to go wrong with them.




**Distance.**

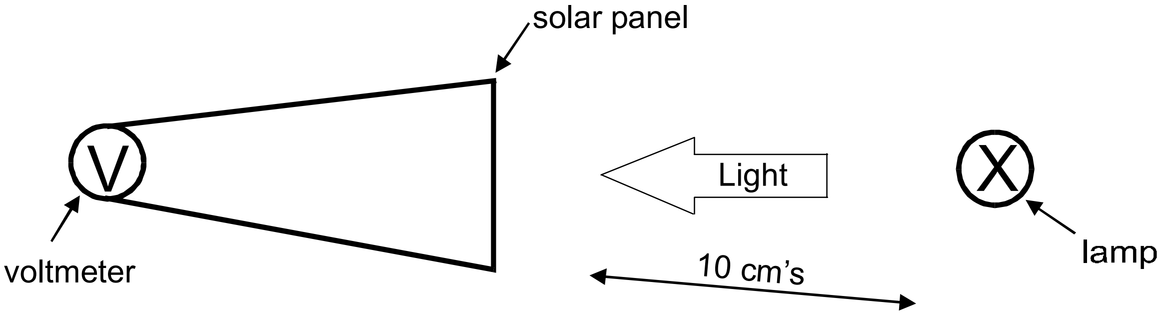
The first variable investigated will be distance. The lamp will be kept in a fixed position and the solar panel; will be moved away at regular intervals. The energy output will be measured at intervals of 10cm's until a maximum distance of 100cm's is reached. We will repeat the experiment twice so that the it helps reduce human era and also verifies are results.

Readings will be taken at:
- 0cm's
- 10cm's
- 20cm's
- 30cm's

  ↓
- 100cm's

For experiment one I predict that the further the solar panel is away from the lamp the less output energy the solar panel will produce. I believe that this will happen because the further the light has to travel the more it disperses so less of it falls on the solar panel therefore the solar panel will produce less energy this is because it has less light falling on it to create an electrical currant.

Surface area.




The second variable investigated will be the surface area of the solar panel. The lamp and the solar panel will be kept at a constant distance of 10cms from each other. The area of the solar panel will be split up into nine equal sections, each section will be 6 cm's by 1 cm. Each section will be uncovered, one at a time, gradually increasing the surface area of the solar panel, and the energy output recorded until the maximum surface area of the solar panel is exposed to the lamp. This experiment will also be done twice, in doing this the results will be as accurate as possible.

For the second experiment I think that the more of the solar panel showing the more output energy there will be because there is more light falling on it to produce energy. If there is no light falling on the solar panel the panel will not be able to convert light energy into electrical energy.

The results achieved will not be completely accurate as, despite the room being blacked out for these experiments there will still be lights from other groups in the room, the solar panel might gather energy from these other sources the results may also be altered by human era.

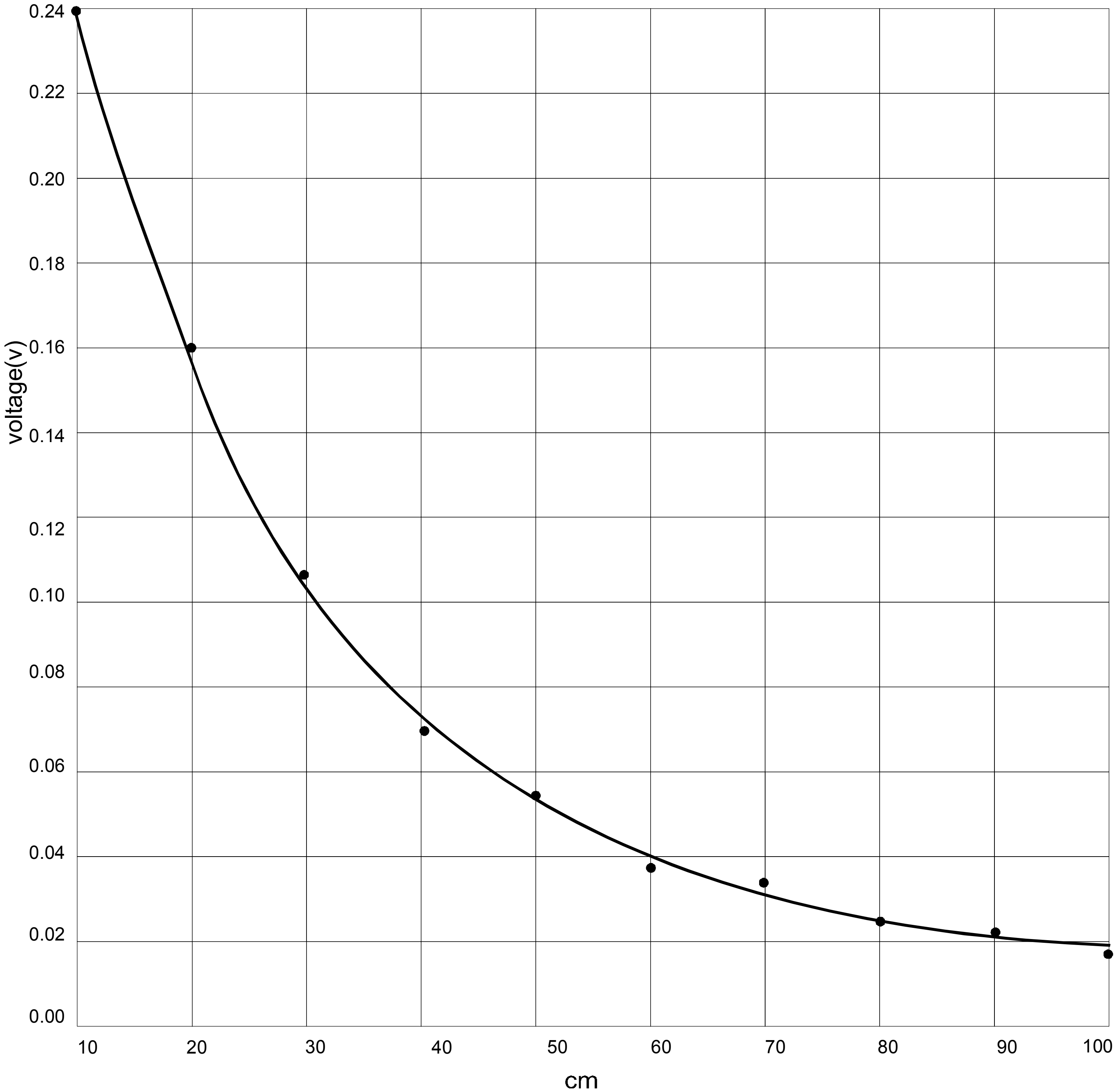
Equipment

A metre ruler, to measure the distances between the lamp and the solar panel.
A lamp, to provide a light source needed in both the experiments.
A volt meter, to detect whether any voltage is being created by the solar panel.
A solar panel, to convert light energy into electrical energy.

| Results measurement | Test 1 Voltage (V) | Test 2 Voltage (V) | Average (V) |
|---|---|---|---|
| 1m | 0.0215 | 0.016 | 0.01875 |
| 90cm | 0.024 | 0.079 | 0.0215 |
| 80cm | 0.030 | 0.024 | 0.027 |
| 70cm | 0.038 | 0.030 | 0.034 |
| 60cm | 0.04 | 0.037 | 0.0385 |
| 50cm | 0.06 | 0.05 | 0.055 |
| 40cm | 0.07 | 0.065 | 0.0675 |
| 30cm | 0.11 | 0.10 | 0.105 |
| 20cm | 0.16 | 0.16 | 0.16 |
| 10cm | 0.24 | 0.24 | 0.24 |

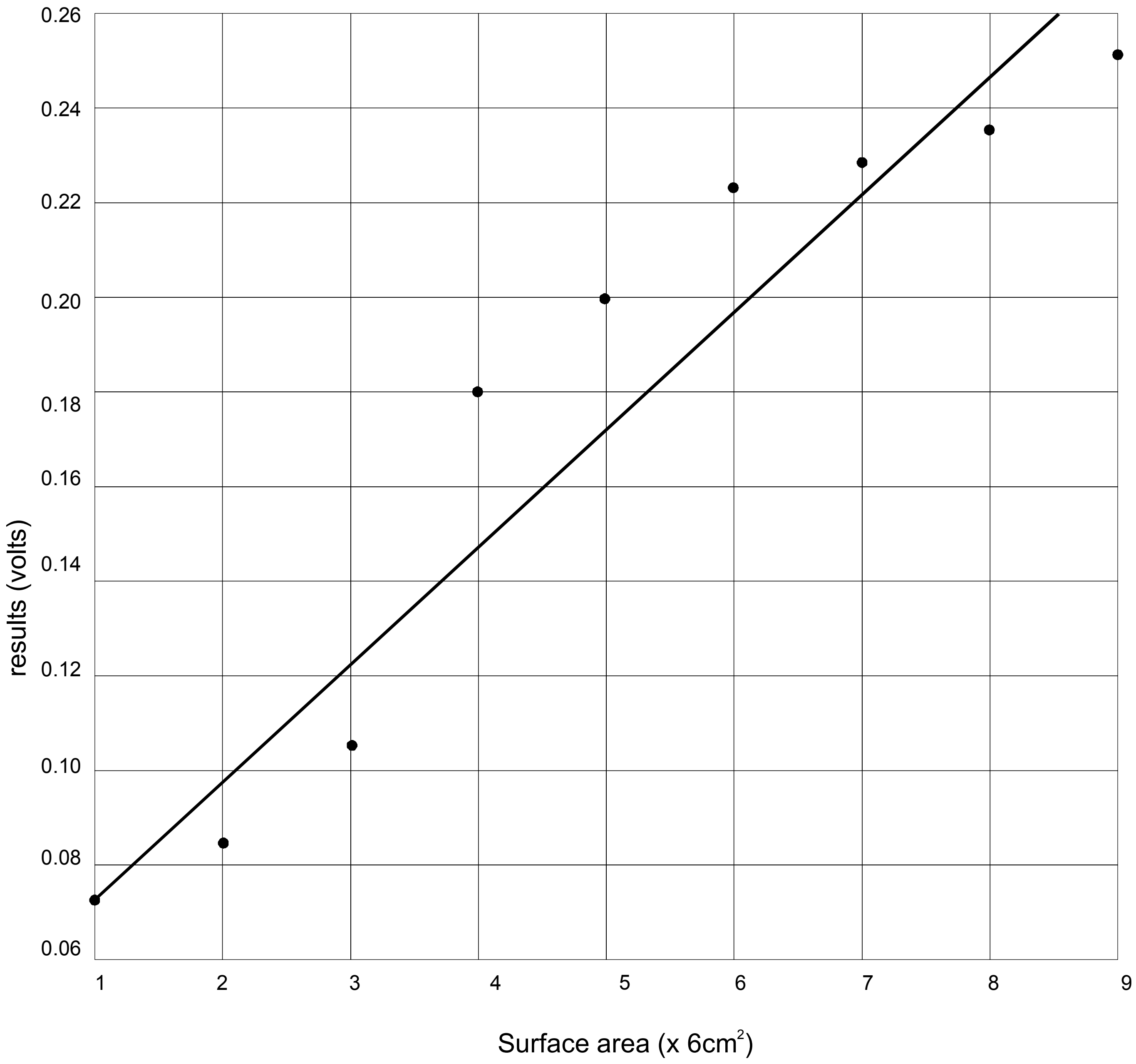
Changing area with distance at 50cm.

## A graph to show the voltage, when the light is at different distances from the solar panel



| The amount of solar panel revealed to the light / 6cm squared | Results one /volts | Results two /volts |
|---|---|---|
| 1 | 0.07 | 0.07 |
| 2 | 0.08 | 0.09 |
| 3 | 0.11 | 0.10 |
| 4 | 0.18 | 0.18 |
| 5 | 0.20 | 0.20 |
| 6 | 0.23 | 0.22 |
| 7 | 0.23 | 0.23 |
| 8 | 0.23 | 0.24 |
| 9 | 0.25 | 0.25 |

**Graph 2: How area effects energy output**



Conclusion One

I conclude that our prediction was correct. The distance between the solar panel and the light source is proportional to the energy output. I conclude that the further away a light source is from a solar panel the less energy is produced by the solar panel this is because less electromagnetic radiation falls on the surface of the solar panel. This is proven in table 1 and also in graph 1. If you look at graph 1, as the distance goes up the voltage produced goes down this is also shown in table 1.

Conclusion Two

For this experiment my prediction was proven correct the more of the solar panel showing the more energy is produced by the solar panel. I have come to this conclusion by looking at table2 and graph2, it starts at a low voltage and as more of it is uncovered the voltage goes up.

Evaluation

I think that both of our methods gave us reliable results to an extent but there could have been improvements. We could have made the results more accurate by excluding external light sources; we could have done this in several ways, her are the two easiest: we could have gone in a room by our selves so there are no other light sources in the room. The other method is before we start the experiments we should measure the background light by setting up the solar panel and measuring the energy produced without the lamp that I was using in my experiments and then I would take the reading away from the results that I received. The results could also be more accurately measured by using a more sensitive voltmeter, I would have used one of these voltmeters but there wasn't one that went high enough.

I think for experiment 1 the results are fairly reliable there doesn't seem to be much of a difference between the two sets of results. Experiment 2 althea the graph looks a bit odd the results on the table seem to be correct, as I did both of these experiments twice I would have spotted any major difference between the two sets of results so I would know that one of my answers was false. I think that because of this the conclusions above are correct.

# CC5 - Commentary

Note: Ttwo factors have been investigated, but there is no indication that this improved performance. The investigation of one factor only, distance or surface area would have achieved the same marks awarded in each skill area.

**Skill Area P: Planning**

**P.2a** A procedure has been described.

**P.4a** A valid plan to collect evidence has been made for both factors investigated.

**P.4b** The use of suitable equipment has been planned in both cases.

**P.6a** Scientific knowledge and understanding has been used to make a prediction for both factors to be investigated and to inform the planned procedure. Key factors have been identified and taken into account in the planning.

**P.6b** A suitable number and range of measurements have been chosen for both cases.

**P.8a** There is a lack of detailed scientific knowledge used in the planning of the procedure and to justify the predictions.

**P.8b** There is no strategy for dealing with results

**6 marks awarded**, as P.8a and P.8b are not satisfied.

**Skill Area O: Obtaining Evidence**

**O.2a** Evidence has been collected for both factors using a safe procedure.

**O.4a** Appropriate measurements have been made in both cases.

**O.4b** The evidence has been recorded.

**O.6a** The range and number of measurements for both aspects is sufficient and they have been repeated. The drawn graphs indicate that the results are reasonably accurate.

**O.6b** The results are recorded clearly and correctly in tables.

**O.8a** The level of demand of both tasks carried out is relatively low and there is no indication that any special measures had been taken to ensure that the measurements are as accurate, precise and reliable as possible.

**6 marks awarded**, as O.6a and O.6b only are satisfied.

**Skill Area I: Interpreting and Evaluating**

**I.2a** The student has stated what the evidence shows.

**I.4a** A graph has been drawn from the results for both factors.

**I.4b** Trends and patterns in the evidence have been identified for both aspects investigated.

**I.6a** In both cases a line of best-fit graph has been drawn, although the straight line of graph 2 (surface area) is somewhat arbitrary.

**I.6b** Insufficient scientific knowledge has used to write and explain conclusions based on the evidence.

**I.6c** The suitability of the procedure is discussed and appropriate changes suggested for improvement.

**5 marks awarded**, as I.6a is just about satisfied, I.6c is satisfied but I.6b is not.

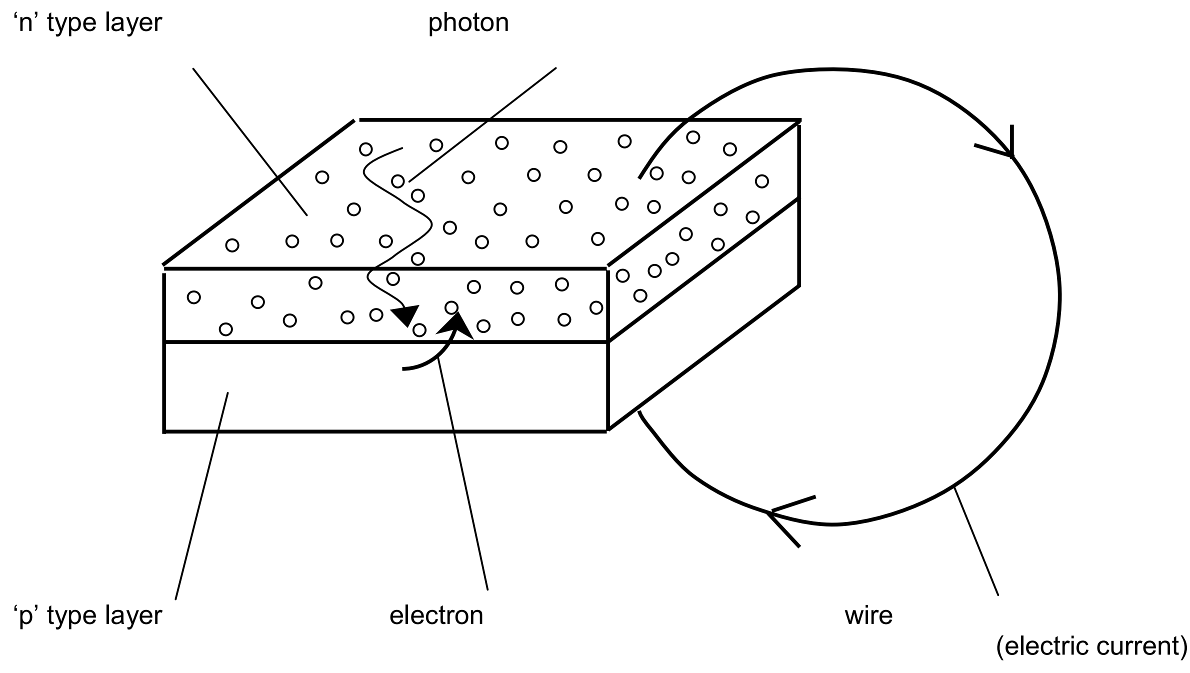
**An investigation to determine the factors that affect the performance of a solar cell**

A solar cell directly converts light energy into electricity. Solar cells do not produce a great amount of electricity, so they are only useful on a smaller scale. Solar panels are used on calculators, to recharge rechargeable batteries and other appliances which only need a small amount of voltage to power them. If the surface area of the solar panel is large enough, they can be used to power satellites because it is the only source of power available, as they are so isolated. This is also the reason why they are used in some remote areas of third world countries to power small water pumps or heaters.

Solar cells work when light particles, called photons strike a semiconductor. Silicon is one main semiconductor which can have impurities added to it to change the material slightly. The flow of electrons can be controlled in silicon. Solar cells contain two different layers of silicon, each containing different amounts of impurities. The ‘n’ type layer contains lots of electrons giving it a negative charge, but the ‘p’ type layer contains a much lower number of electrons, casing it to have a positive charge.

The photons pass through the ‘n’ type layer and strike the ‘p’ type layer underneath. The photon gives its energy to one of the electrons in the ‘p’ type layer. This electron then has enough energy to break lose and jump from the ‘p’ type layer into the ‘n’ type layer. This loss of one electron causes the ‘p’ type layer to become even more positively charged, and the ‘n’ type layer, having gained another electron becomes even more negatively charged. The greater difference in charge is called the potential difference or voltage. To make the action of the jumping of the electron from one layer to the next continuous, a wire can be connected from the ‘n’ type layer to the ‘p’ type layer. This means that the electrons will continuously create the potential difference by moving back to the ‘p’ type layer in the form of an electric current.

A diagram to explain this theory




**Planning the experimental procedure**

**Factors that could be investigated to show the affect of the performance of a solar cell**

* The light intensity of the light source could be varied.
* The distance of the solar cell from the light source could be altered
* The surface area of the solar cell could be varied.
* Objects could be placed between the light source and the solar cell to simulate clouds.

The factor that I will be investigating will be:

* The surface area of the solar cell

The apparatus that I will be using are:

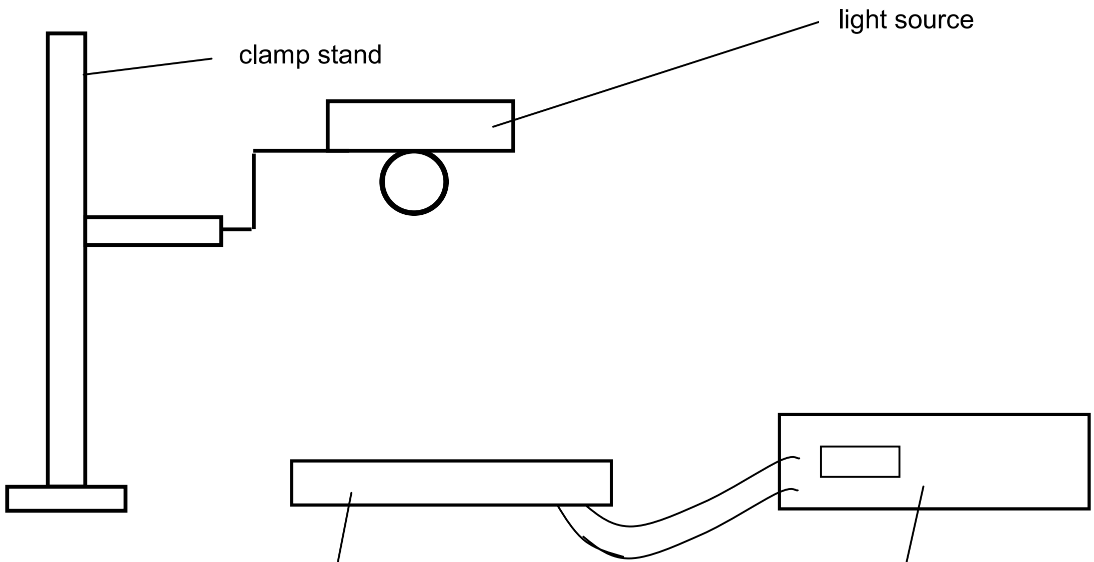
* A solar cell
* A lamp
* A power supply
* A millivoltmeter
* A clamp stand
* Blue tac
* Thick black card

I chose to use a millivoltmeter instead of a normal voltmeter because it is more sensitive to the potential difference produced generated by the solar cell, as this is a relatively small amount of voltage.  This will mean the results will be more accurate.  The blue tac will hold the solar cell in place, to minimise movement as this would alter the results.  The thick black card will not let any light through it, so it will be used to cover up parts of the solar cell to decrease the surface area of the cell that is exposed to the light.

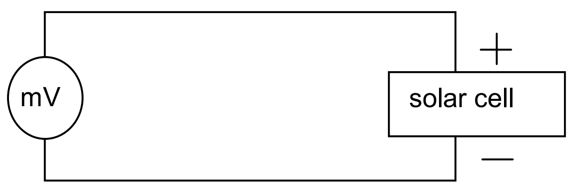
Method of the experiment

1. I will set up the apparatus as shown in the diagram.
2. I will take a reading from the millivoltmeter without any alteration to the solar cell and record it in the table of results.
3. The black card will be marked with a pencil into tenths of the solar cell this is to be able to measure the voltage as the cell is covered each time with one more tenth.
4. I will then cover the solar cell up with the first tenth drawn on the card, and note the voltage into the results table.
5. I will repeat this procedure over, each time covering one more tenth of the solar cell, to decrease the surface area, with the card.

Diagram to show the apparatus




Circuit diagram



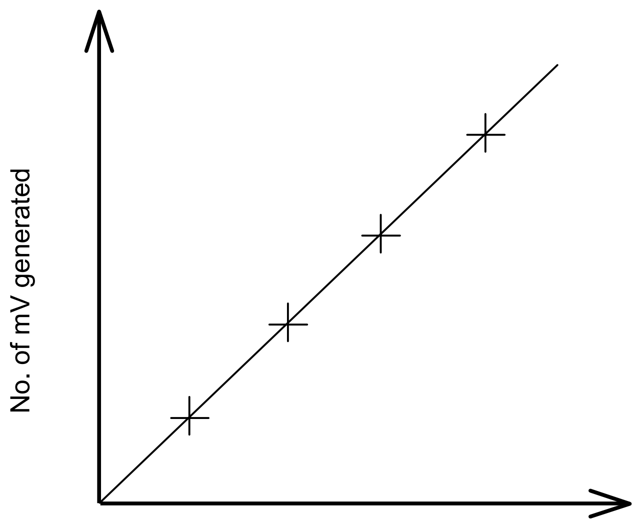
To make the test a fair test, I will conduct the experiment in the same place, not to alter the background light in the area. I will keep the light source the same distance from the solar cell, and I will keep the voltage of the light source the same as well. I will keep the solar cell in a secure position at all times. I will use the same piece of card throughout the experiment, so that the light will not alter when it reaches the solar cell. All these factors will help to make the results more accurate.

Prediction

My prediction is that the larger the surface area that is exposed to the light, the more potential difference will be generated.

This is because the more light that hits the solar cell, the more photons are coming in to transfer their energy to the electrons in the 'p' type layer. This means there will be more electrons jumping to the 'n' type layer in the solar cell, causing more potential difference to be generated. If the surface area of the cell is larger, then the photons have more solar cell to make contact with.

Graph prediction




* The graph is a straight line because the amount of potential difference being generated is directly proportional to the number of photons striking the solar cell.

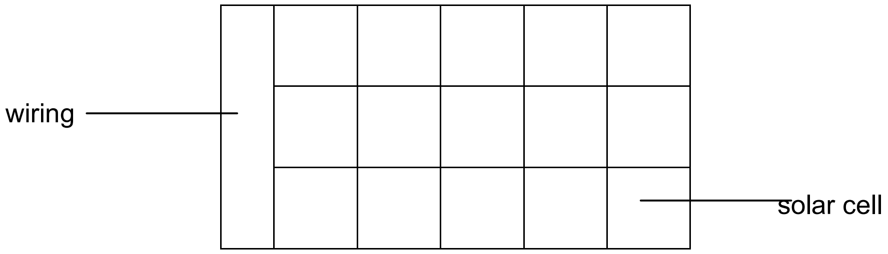
**Pre-testing**

I completed a pre-test because I needed to ensure each aspect of the experiment would be sufficient to gain accurate results. I also found out that background light had a large influence on the results, so I will conduct the experiment in a dark room to limit the amount of background light. I also found out that I needed to use a millivoltmeter instead of a normal voltmeter, as the voltmeter was not sensitive enough to detect the amount of potential difference being generated by the solar cell. Another factor which I found had an influence on the experiment was the number of volts leading to the light source. I will use 12 volts for the maximum range of results. The distance of the light source from the solar cell also needed to be altered for the real experiment, as it was too far away for the maximum results. I will use a shorter distance for the real experiment.

While the pre-test was carried out, it was important that none of the apparatus moved a great deal because it would have altered the number of photons hitting the cell. I needed to test the type of material I needed to cover the cell with in order to decrease the surface area. I tested white paper, sugar paper and a text book cover. All these let the light pass through and didn't stop enough light to be able to carry out the experiment successfully. I then tried thick card and thick black card. Both of these were very opaque and didn't let any light through to the cell.

Also in this test, I realised that the light could pass underneath the material. I need to ensure that the card is close enough to the solar cell that it minimises the amount of light that goes underneath the card. I also realised that there was an area to the left that was not actually part of the cell, but an area for the wiring. I therefore had to measure the cell without including that area.

E.g.

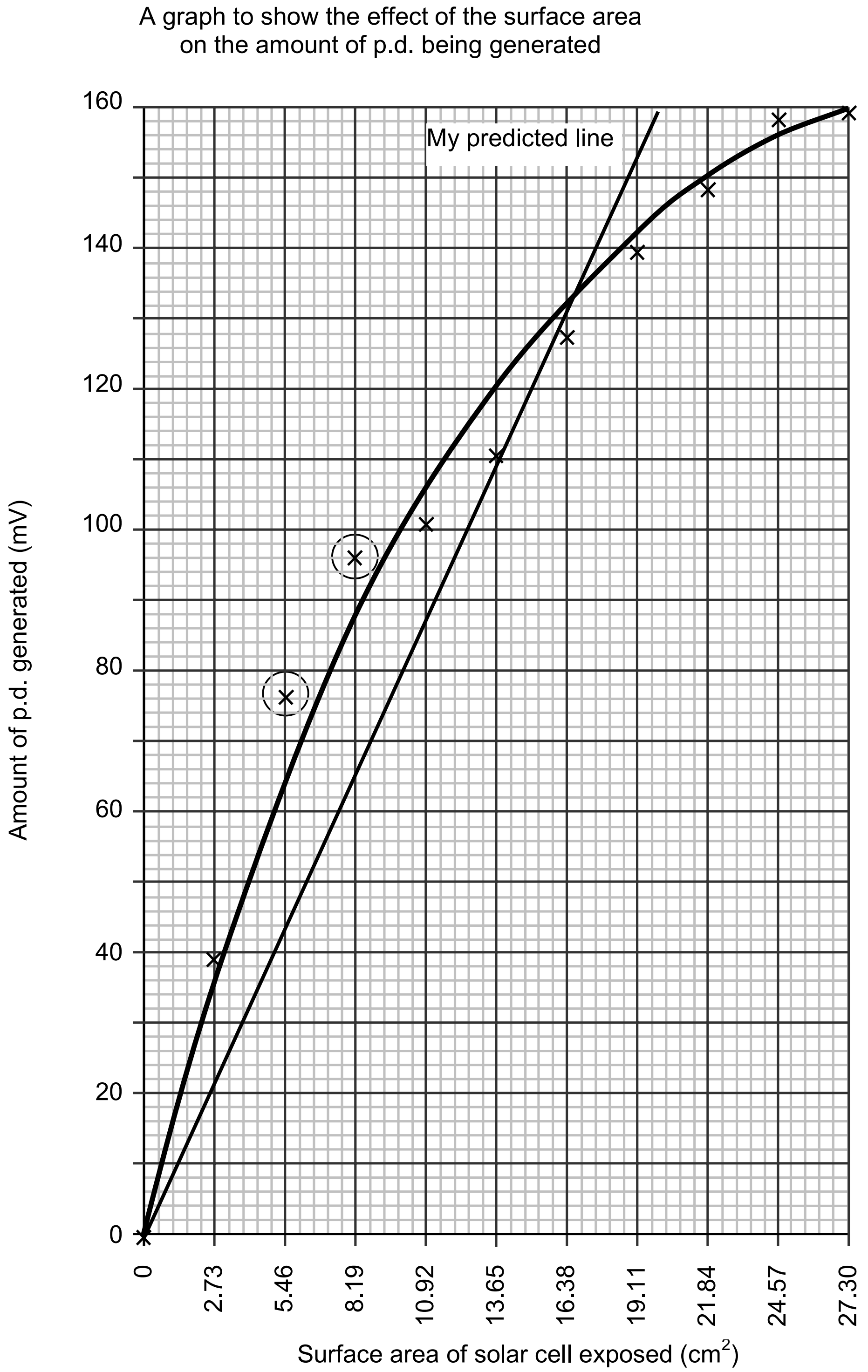



The cell therefore measured 65 mm by 42 mm.

To gain more accurate results, I will conduct the same experiment with the same surface area 3 times and then calculate the average. I will use 10 different surface areas to investigate.

Table of results

| Amount of potential difference generated (mV) | | | | |
|---|---|---|---|---|
| Surface area exposed ($cm^2$) | Test 1 | Test 2 | Test 3 | Average (mV) |
| 0 | 0 | 0 | 0 | 0 |
| 2.73 | 39 | 40 | 40 | 39.7 |
| 5.46 | 77 | 77 | 76 | 76.3 |
| 8.19 | 94 | 99 | 96 | 96.3 |
| 10.92 | 103 | 100 | 102 | 101.7 |
| 13.65 | 108 | 114 | 111 | 111 |
| 16.38 | 128 | 128 | 128 | 128 |
| 19.11 | 137 | 143 | 140 | 140 |
| 21.84 | 149 | 149 | 148 | 148.7 |
| 24.57 | 158 | 157 | 157 | 157.3 |
| 27.3 | 160 | 160 | 160 | 160 |



A graph to show the effect of the surface area
on the amount of p.d. being generated
My predicted line
Amount of p.d. generated (mV)
160
140
120
100
80
60
40
20
0
0
2.73
5.46
8.19
10.92
13.65
16.38
19.11
21.84
24.57
27.30
Surface area of solar cell exposed (cm2)

Conclusion

The graph, which displays the results, begins as a slight curve, and then straightens off towards the area where more surface area is exposed to the light. The line of best fit passes through the origin, which means that when the whole of the solar cell is covered with the card, there is no potential difference being generated. This also shows that the card I used in the experiment was effective as no light was able to pass through. The graph is mostly a straight line because the amount of millivolts being generated is directly proportional to the amount of light striking the solar cell. I stated this in my plan with a graph prediction, which demonstrates the straight line. When the surface area of the cell that is being exposed to the light is at its maximum of 27.3 $cm^2$, 160 mV is being generated, this is the maximum potential difference being generated. When the surface area being exposed to the light is 16.38 $cm^2$, 111 mV is being generated.

My prediction stated that;

"the larger the surface area that is exposed to the light, the more potential difference will be generated."

*My results support my prediction, as the greater the surface area that is exposed to the light, the greater number of mV is being generated. This shows that my prediction was correct. I also said in my plan that I would investigate if the number of mV being generated would double when the surface area exposed to the light was doubled. My results show that this did not happen in this experiment, as when the surface area is 13.65 $cm^2$, the mV is 111, and when the surface area is doubled to 27.3 $cm^2$, the mV is 160, which is not doubled.*

*This potential difference being generated is due to the* photoelectric effect*. This is the arrangement and the ability for electrically charged particles in matter when light is aimed at it. The photovoltaic effect takes place inside a semiconductor, in this case, silicon. There are two layers to the silicon; the 'p' type layer and the 'n' type layer. They both have different amounts of impurities in them. The 'p' type layer has a low number of electrons inside it which is why it is positively charged. The 'n' type layer has many more electrons in it which is why it is negatively charged.*

*In the photovoltaic effect, photons create electron-hole pairs. When the light strikes the solar cell, the photons travel through the 'n' type layer and strike the 'p' type layer underneath. The photon then transfers its energy to an electron of tone of the atoms in the 'p' type layer, this electron then has the energy to liberate itself, and it jumps to the 'n' type layer. The 'n' type layer already has many electrons, and is negatively charged, so the extra electron causes the 'n' type layer to become even more negatively charged and to have one more electron. The more photons that strike the 'p' type layer, the more electrons are able to gain energy from the photons, so the more electron that can jump from the 'p' type layer to the 'n' type layer.*

*The liberating of these electrons form the 'p' type layer to the 'n' type layer is called a potential difference where a voltage is generated. To make the action of the liberating of the electron from the 'p' type layer to the 'n' type layer continuous, a wire can be connected from one layer to the next allowing electrons that jump from the 'p' type layer to the 'n' type layer to be 'carried' back to the 'p' type layer in the form of an electric current. This voltage can then be measured in parallel to the solar cell with a millivoltmeter. (Refer back to the introduction for diagram)*

*Much research has been done into the* photoelectric effect*. In 1900, Max Planck discovered a constant,* h, *which is equal to $6.626*10^{-34}$ joule-second in the meter-kilogram-second system. He discovered that the energy of a photon is equal to the frequency of the light multiplied by a constant.*

*Therefore;*

$E = hf$

*Where E = the energy of a photon*
h = *Planck's constant of $6.626*10^{-34}$*
*f = The frequency of the light*

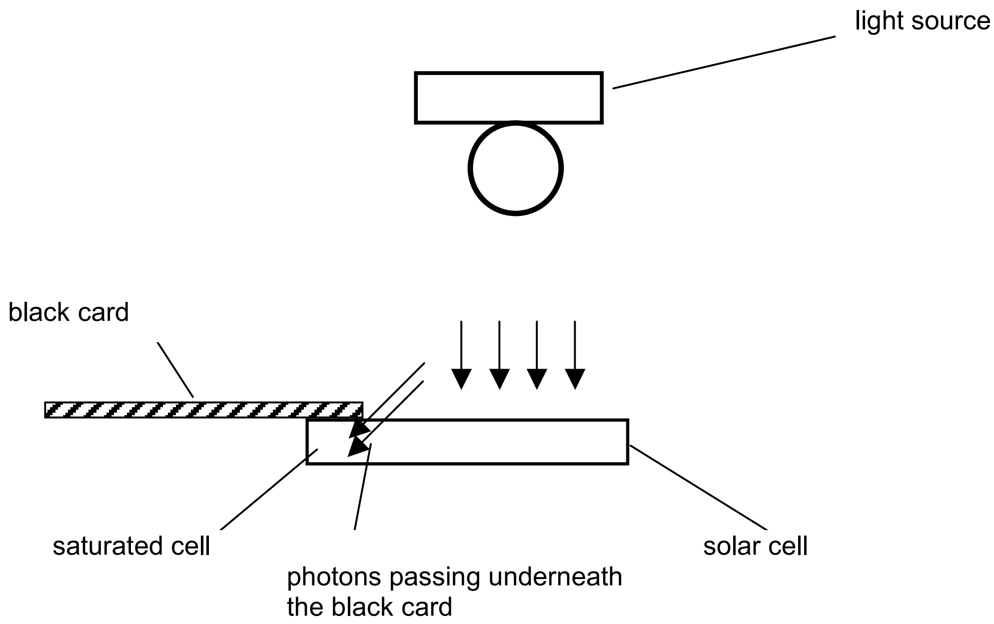
*This has contributed to the development of the quantum theory.*

*Evaluation*

*I am very pleased with this investigation, as my results supported the scientific theory of this investigation. I had also predicted the outcome of this experiment correctly. The results were consistent which shows I took enough readings to be able to gain accurate results, and to enable me to draw a valid conclusion from them. It also shows that the equipment I used was appropriate for this experiment, and that the readings that I took were accurate. I tried to keep the test as fair as possible which is reflected in my results. All these factors allowed me to draw a valid conclusion to the investigation.*

*Along with the positive results, there were 2 anomalous results, circled on the graph, although I tried to eliminate any errors. These may have been due to human error in the recording of the results. When covering up the solar cell with the black card, there could have been a slight movement of the solar cell, as I tried to hold the card as close onto the cell as possible, to try to eliminate any light from entering underneath the card. Therefore the angle of the solar cell may have altered. There is a chance that these errors could have occurred in the experiment.*

*The graph drawn from my results shows a curve towards the area where there is only a small part of the solar cell being covered up by the black card. This is due to the saturation of the cell, as there is only a small area being covered by the card, the photons are able to slip under the card through the large area of silicon that is exposed. Here is a diagram which demonstrates this;*




*Given more time, I could improve the experimental procedure. I could record a wider range of results to find a more accurate average. I could split the solar cell up into different amounts rather than tenths. I could try sixths or fifteenths to compare the results from each. To gain a larger range of results, I could use a larger solar cell, or a larger light source. I could have used more accurate equipment to take measurements from, but there are certain limitations when conducting the experiment in a school laboratory, although I am pleased with the results that I gained with the equipment available to me.*

*I could extend the enquiry further by choosing a different variable to change. I could determine the effect of placing obstacles in the path of the light source to the solar cell to simulate clouds on the amount of mV generated. I would use the same equipment as I did for this experiment, except instead of black card to change the surface area, I would conduct a pre-test to discover the best material to simulate a cloud. I could try tracing paper, or normal white plain paper. I could try different thickness to simulate different amount of cloud cover. I would take 4 readings for each 'cloud' and test about 10 different cloud thicknesses/types. I would conduct a pre-test to make sure I could keep all the other factors such as the surface area of the cell, the intensity of the light source, the distance of the solar cell from the light source, the same.*

*I could then record the results into a table and record them on a graph. I could then compare the results with that of this investigation, and determine which factor effects the performance of the solar cell the most.*

*Bibliography*

*Microsoft (R) Encarta (R) 98 Encyclopaedia. (c) 1993-1997. Microsoft Corporation. All rights reserved*

G.C.S.E. PHYSICS. Tom Duncan.

**Commentary –CC6**

**Skill Area P: Planning**

**P.2a** A procedure has been described in detail

**P.4a** The plan to collect the evidence is valid.

**P.4b** The use of suitable equipment is planned.

**P.6a** Scientific knowledge was used plan a procedure and to make a prediction. Key factors were identified and plans incorporated into the procedure to control them.

**P.6b** A suitable number of measurements and an acceptable range are chosen. Repeat measurements are planned.

**P.8a** Sufficient detailed scientific knowledge and understanding has been used to plan the procedure and to justify the predictions. A lot of attention has been paid to ensuring the evidence obtained is as precise and reliable as possible.

**P.8b** There is a strategy for dealing with results

**8 marks awarded**

**Skill Area O: Obtaining Evidence**

**O.2a** Evidence has been collected using a safe procedure.

**O.4a** The evidence collected is appropriate for the activity.

**O.4b** The measurements were recorded.

**O.6a** The range and number of measurements made is sufficient and they were repeated twice. The drawn graph indicates a high degree of accuracy for the results.

**O.6b** The evidence has been recorded clearly and apparently correctly in a table.

**O.8a** The candidate appears to have made only a single initial measurement of the area exposed and then carried out a simple multiplication exercise. The actual measurements made involve the reading of a millivoltmeter scale, which is a relatively low level skill, but gives precise and accurate results.

**6 marks awarded**

**Skill Area I: Interpreting and Evaluating**

**I.2a** What is shown by the evidence is stated.

**I.4a** A graph has been drawn from the evidence.

**I.4b** Trends and patterns in the evidence have been identified.

**I.6a** A suitable graph with a line of best fit has been constructed, from which a conclusion can be drawn. The scale on the x axis is unusual.

**I.6b** The conclusion is consistent with the evidence and scientific knowledge and understanding has been used to explain what has been found out in general terms.

**I.6c** The suitability of the procedure was discussed and improvements suggested.

**I.8a** Detailed scientific knowledge and understanding has been quoted, but has not been used to explain the conclusion which is drawn from the evidence shown in the graph.

**I.8b** The predictions were discussed and the extent to which the evidence supports them is explained in the conclusion.

**I.8c** The student has attempted to discuss critically the reliability of the evidence, but the discussion is lacking in depth. Nor is there any discussion as to whether the evidence is sufficient to support the conclusion. However there is an attempt to account for the suggested anomalous results.

**7 marks awarded**, as I.8a and I.8c have not been matched.