Questions matter

# Purposeful questioning in science

## ASE Conference January 2024

Examples and exercises

| Contents | Page |
|---|---|

# Ofqual criteria for AO2

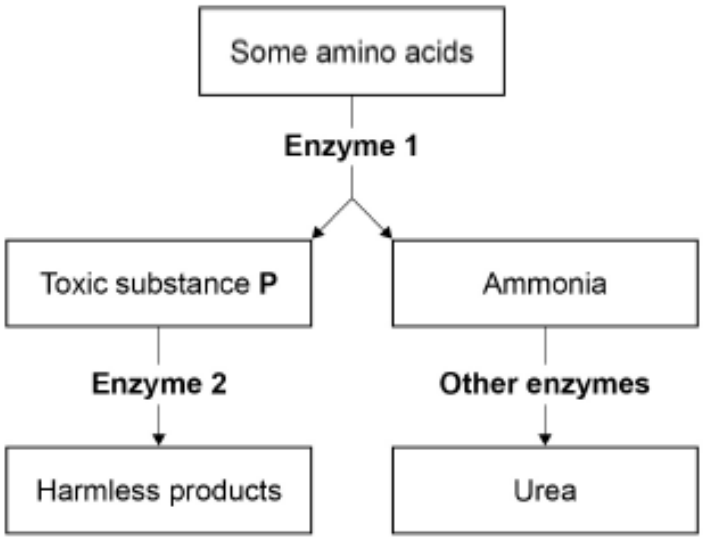
| **AO2: Apply knowledge and understanding of:**<br>▪ **scientific ideas**<br>▪ **scientific enquiry, techniques and procedures.** | | | *40%* |
|---|---|---|---|
| **Strands** | **Elements** | **Coverage** | **Interpretations and definitions** |
| **1 – Apply knowledge and understanding of scientific ideas.** | This strand is a single element. | ▪ Full coverage in each set of assessments (but not in every assessment). | ▪ **Scientific ideas** are aspects of the subject content. They include the subject-specific requirements and the requirements for Working Scientifically as set out in the Content Document – for example, theories, models and the use of relevant mathematics.<br>▪ **Scientific enquiry, techniques and procedures** encompasses, but is broader than, knowledge and understanding of the core practical activities. In the context of this assessment objective, it involves applying such knowledge and understanding to a given context.<br>▪ The emphasis in this assessment objective is on Learners applying their knowledge and understanding to provide meaning or explanation – for instance, to connect theory with particular contexts, stimuli or materials. This application should relate principally to:<br>▫ novel situations that are not clearly indicated in the specification;<br>▫ developing further material that is covered in the specification;<br>▫ making links between such types of material, which are not signalled in the specification.<br>▪ Application of knowledge should also involve determining how to make sense of connections and linkages within data, information and detail – although not to the extent of drawing conclusions or making judgements. |
| **2 – Apply knowledge and understanding of scientific enquiry, techniques and procedures.** | This strand is a single element. | | |

# Questions set in unfamiliar contexts

## Example 1: 2022 GCSE Biology Paper 1H Question 5.4

**Figure 5** shows chemical reactions involved in the normal breakdown of some types of amino acid inside body cells.

**Figure 5**




A person with MSUD **cannot** make **Enzyme 2**.

**0 5 . 4** Explain why the **blood** of a person with MSUD will have a high concentration of toxic substance P.

Use information from **Figure 5**.

**[3 marks]**

**Commentary**

Learners are unlikely to have even heard of MSUD (maple syrup urine disease), so the context might throw them off. But if they look beyond the context, the question tests their knowledge of how digestive enzymes work to break down substances (4.2.2.1), and of diffusion (4.1.3.1) to work out why the substance will build up in the blood without that enzyme.

## Example 2: 2022 GCSE Chemistry Paper 1F Question 3.3

**0 3 . 3** A metal oxide reacts with an acid to produce zinc sulfate and water.

Name the metal oxide and the acid used in this reaction.

**[2 marks]**

Name of metal oxide _____

Name of acid _____

**Commentary**

Learners might not have come across this particular reaction but should know that in acid-base reactions the salt produced depends on the acid and the positive ions (4.4.2.2), so should be able to apply that knowledge to determine the reactants as zinc oxide and sulfuric acid.

## Example 3: 2022 GCSE Physics Paper 1F Question 6.5

The highest point above sea level in England is the top of a mountain called Scafell Pike.

The height above sea level of Scafell Pike is 978 m.

**0 6 . 5** A student climbs Scafell Pike.

Why does the atmospheric pressure decrease as the student climbs higher?

**[2 marks]**

Tick (✓) **two** boxes.

- The air exerts a greater force on the student. ☐
- The density of the air decreases. ☐
- The mass of air above the student decreases. ☐
- The temperature of the air increases. ☐
- The volume of air above the student increases. ☐

**Commentary**

Learners might never have heard of Scafell Pike, but the question is about understanding why atmospheric pressure decreases with an increase in height (4.5.5.2), so they need to look through the context to the science beneath.

## Example 4: 2022 Combined Science Trilogy Chemistry Paper 2H Question 3

**Commentary**

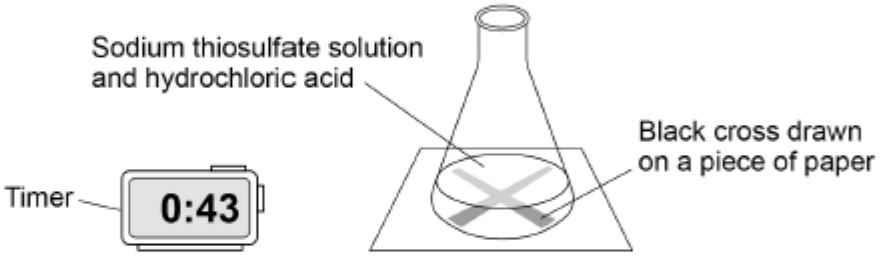
In this question, learners are assessed on subject content, WS, maths and practical skills in the context of a variant on Chemistry RPA5. Here, the investigation is on the effect of temperature on the rate of reaction rather than concentration.

A teacher demonstrated the reaction between sodium thiosulfate solution and hydrochloric acid.

**Figure 3** shows the experiment.

The experiment was done in a fume cupboard.

**Figure 3**




This is the method the teacher used.

1. Pour 50 $cm^3$ of sodium thiosulfate solution into a conical flask.
2. Put the conical flask on a black cross drawn on a piece of paper.
3. Pour 10 $cm^3$ of hydrochloric acid into the conical flask and start a timer.
4. Stop the timer when the cross can no longer be seen.
5. Repeat the experiment at different temperatures.

**0 3 . 2** What type of variable is time in this reaction?

**[1 mark]**

Tick (✓) **one** box.

- Control ☐
- Dependent ☐
- Independent ☐

0 3 . 3 **Table 1** shows the results.

**Table 1**

| Temperature in °C | Time in seconds |
|---|---|
| 19 | 82 |
| 32 | 48 |
| 45 | 43 |
| 52 | 15 |
| 63 | 7 |
| 73 | 3 |

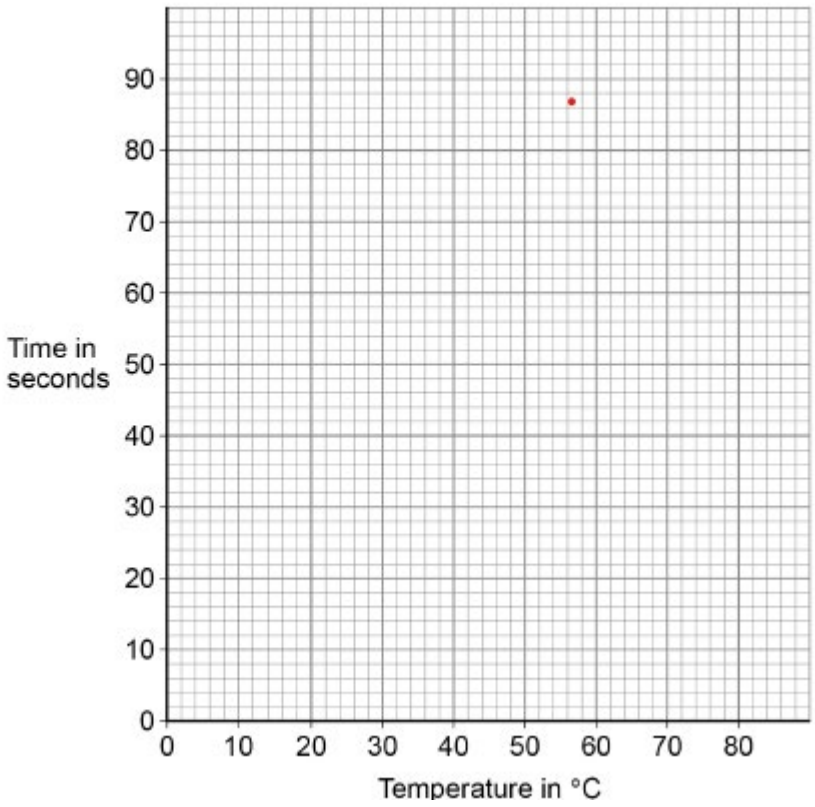
Complete **Figure 4**.

You should:

- plot the data from **Table 1** on **Figure 4**
- draw a line of best fit.

**[3 marks]**

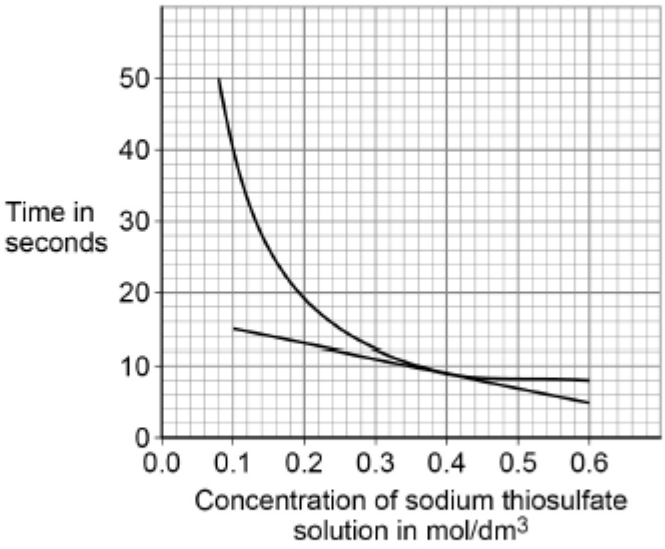
**Figure 4**



**0 3 . 4** A student investigated the effect of concentration of sodium thiosulfate on the time taken for the reaction at room temperature.

**Figure 5** shows the results with a tangent drawn at 0.4 mol/dm$^3$

**Figure 5**




Calculate the gradient (slope) of the tangent at 0.4 mol/dm$^3$

Give the unit.

**[4 marks]**

**0 3 . 5** The student determined the **rate** of the reaction at regular time intervals during an experiment.

Explain why the **rate** decreased during the reaction.

You should give your answer in terms of particles.

**[2 marks]**

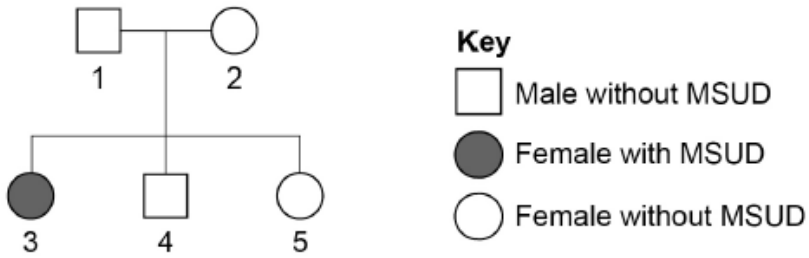
## Example 5: 2022 GCSE Biology Paper 1F Question 1.3

Maple syrup urine disease (MSUD) is a rare inherited human condition.

The allele for MSUD is recessive.

**Figure 1** shows the inheritance of MSUD in one family.

**Figure 1**




Persons **1** and **2** in **Figure 1** have a child with MSUD and some children without MSUD.

**0 1 . 3** Complete **Figure 2** to show the possible genotypes of the children.

Use the following symbols:

**N** = allele for **not** having MSUD
**n** = allele for MSUD

**[2 marks]**

**Figure 2**

| | | **Person 2** | |
|---|---|---|---|
| | | **N** | **n** |
| **Person 1** | **N** | | **Nn** |
| | **n** | | |

## Example 6: 2022 GCSE Chemistry Paper 1F Question 6.7

**0 6 . 7** Calculate the relative formula mass ($M_r$) of carbonic acid ($H_2CO_3$).

Relative atomic masses ($A_r$): H = 1 C = 12 O = 16

**[2 marks]**

**Commentary**

Learners need to use their understanding of relative formula mass and how to calculate it from relative atomic masses. However, they might not have come across carbonic acid, having maybe done calculations with more familiar chemicals. They just need to know that they have done this type of calculation before and that they do know how to do it.

# Using questions to help recognise the science behind the question

The following examples are questions from the 2022 series, set in contexts that learners are very unlikely to have encountered.

Think how you might help a learner look beyond the context and identify the science that is actually being assessed.

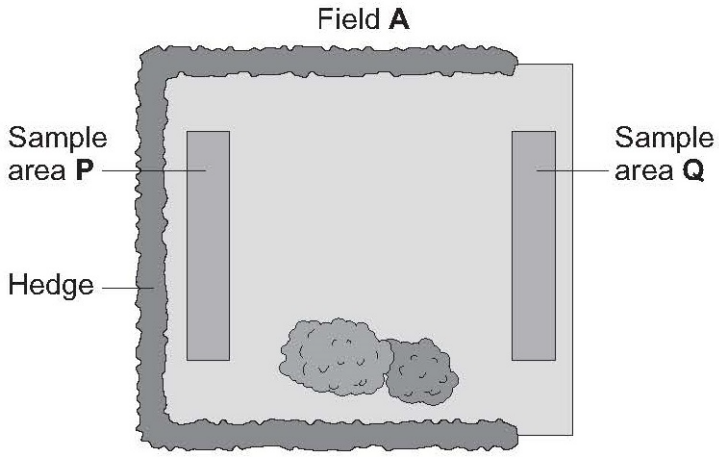
How might you model identifying the science behind the question?

## Example 7: 2022 GCSE Combined Science: Synergy 2F Q5.6

A student did a different investigation in field **A**.

**Figure 13** shows the areas sampled.

**Figure 13**




**0 5 . 6** Suggest **one** way to increase biodiversity in field **A**.

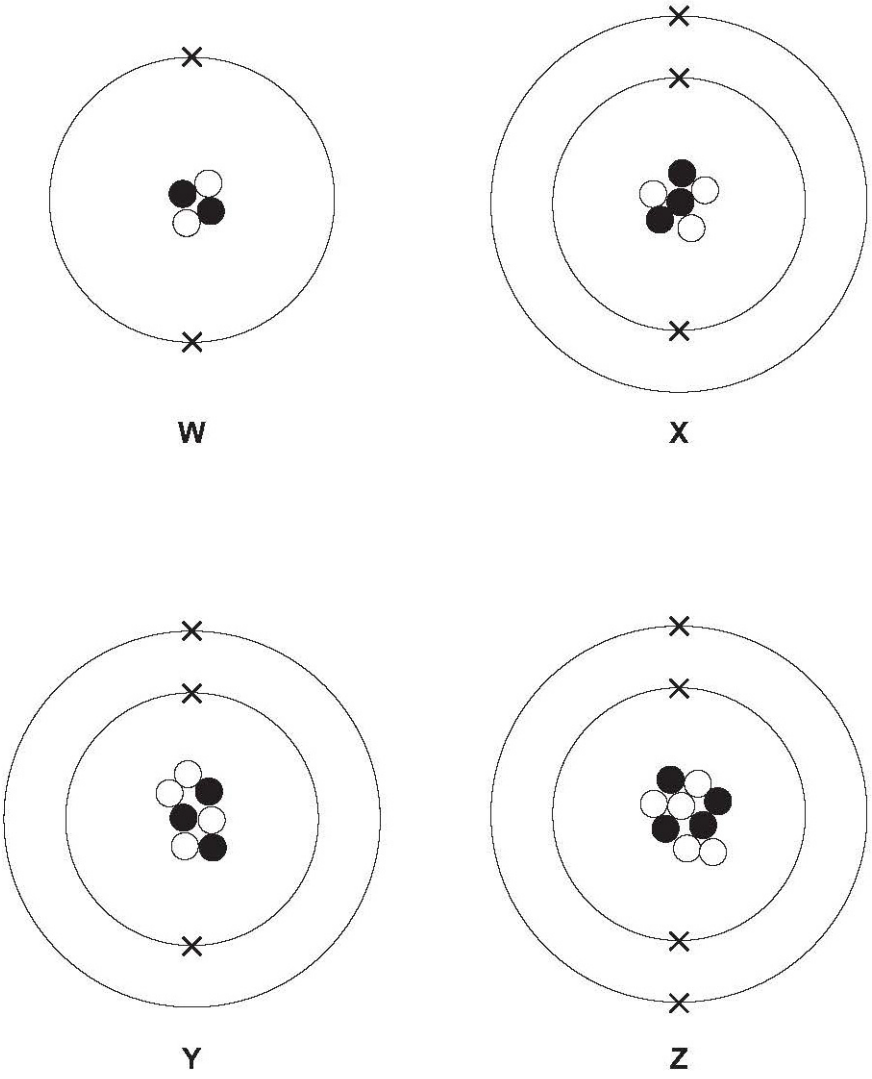
**[1 mark]**

| Question | Answers | Extra information | Mark | AO / Spec. Ref. |
|---|---|---|---|---|
| **05.6** | any **one** from:<br>• plant hedges / flowers / trees<br>• add a pond<br>• add a log pile or compost heap or beehive or bird box<br>• avoid walking on it<br>• avoid using pesticides / herbicides / insecticides<br>• avoid using heavy machinery<br>• avoid mowing (grass)<br>• remove grazing animals<br>• do not plant crops | | 1 | AO2<br>4.4.2.5<br>4.4.2.7 |

## Example 8: 2022 GCSE Combined Science Synergy 1F Q7.8

**Figure 12** represents four atoms.

**Figure 12**



**0 7 . 8** Which two atoms in **Figure 12** represent isotopes of the same element?

**[1 mark]**

Tick (✓) **one** box.

- **W** and **X** ☐
- **W** and **Z** ☐
- **X** and **Y** ☐
- **Y** and **Z** ☐

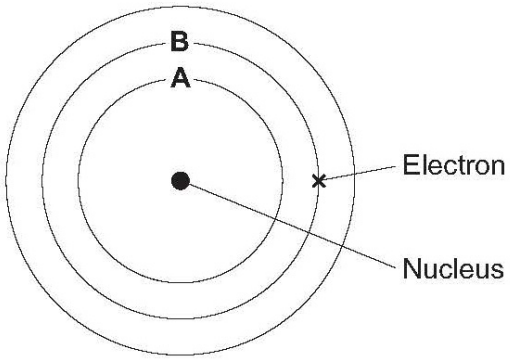
| Question | Answers | Extra information | Mark | AO / Spec. Ref. |
|---|---|---|---|---|
| **07.8** | **X** and **Y** | | 1 | AO2<br>4.1.2.4 |

## Example 9: 2022 GCSE Combined Science Synergy 1F Q9.2

**0 9 . 2** Neon atoms can absorb electromagnetic radiation.

**Figure 13** shows three of the energy levels around the nucleus of a neon atom.

**Figure 13**




The atom in **Figure 13** has absorbed electromagnetic radiation.

What happens as an electron moves from energy level **B** to energy level **A**?

**[1 mark]**

Tick (✓) **one** box.

Light is absorbed ☐

Light is emitted ☐

Light is reflected ☐

| Question | Answers | Extra information | Mark | AO / Spec. Ref. |
|---|---|---|---|---|
| **09.2** | light is emitted | | 1 | AO2<br>4.3.2.1<br>4.1.2.5 |

## Example 10: 2019 GCSE Biology Paper 1F Question 9

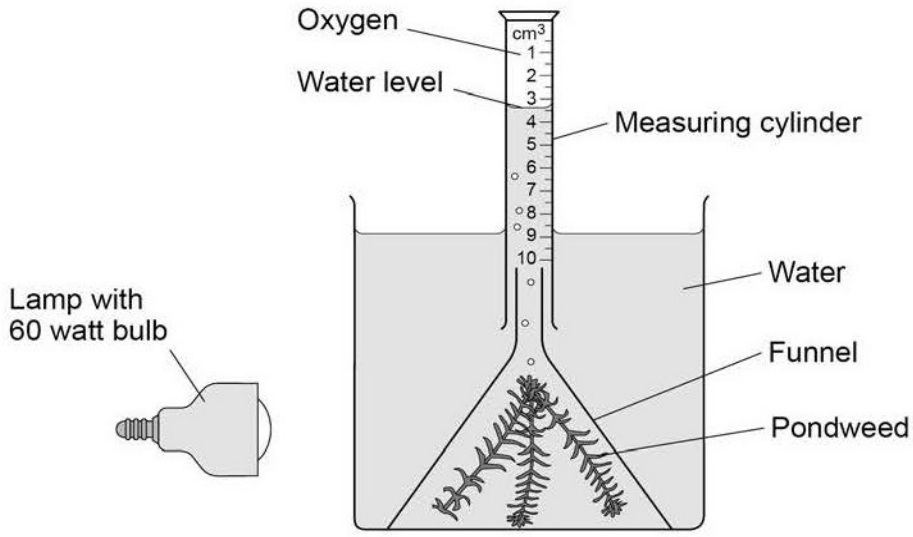
This is an investigation of the effect of light intensity on the rate of photosynthesis. It's a required practical and learners should be familiar with the set-up, or something very close to this.

What questions could you ask learners about this method to help with their understanding?

A student investigated photosynthesis using pondweed.

**Figure 14** shows the apparatus the student used.

**Figure 14**




This is the method used.

1. Set up the apparatus as shown in **Figure 14**.
2. Switch on the lamp.
3. After 20 minutes, record the volume of oxygen collected in the measuring cylinder.
4. Repeat steps 1–3 using bulbs of different power output.

# Practical questions in unfamiliar contexts

The following investigations each relate to a required practical learners should have done, but in a context or investigation different from what they are likely to have done in class.

Consider:

- the required practical to which it relates
- how confident you think your learners would be in answering questions about this investigation
- what experience a learner would need to be able to deal with questions relating to this example.

What extra questions might you add to your framework to help learners with unfamiliar contexts?

## Example 11: 2018 Combined Science Trilogy Chemistry Paper 2F Question 5

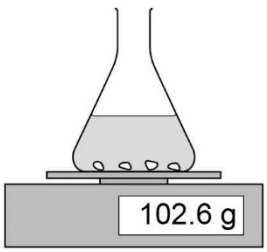
A student investigated the effect of the size of marble chips on the rate of the reaction between marble chips and hydrochloric acid.

This is the method used.

1. Add 10.0 g of marble chips into the flask.
2. Add 50 $cm^3$ of hydrochloric acid and start a timer.
3. Record the mass lost from the flask every 10 seconds.
4. Repeat steps 1 to 3 with different sizes of marble chips.

**Figure 10** shows the apparatus.

**Figure 10**




**Commentary**

Learners will have carried out an experiment in the Chemistry RPA5 to investigate how changing the concentration of one of the reactants affects the rate of reaction (for example in a reaction between different concentrations of hydrochloric acid and magnesium ribbon). They should be familiar with the reaction and know how to measure the volume of gas given off.

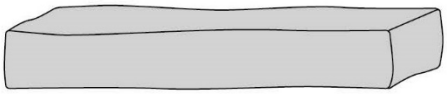
This investigation is related in that it's looking at how a change in a variable affects the rate of reaction – in this case the size of marble chips. In this example, the method makes it clear that mass is lost, and the flask is open, so it's likely a gas is given off, which should point students to the area of content they should be thinking about. They are not being asked to measure the gas being given off, but simply to note the difference in mass as the reaction continues.

## Example 12: 2018 Combined Science Synergy Paper 2F Question 7

A group of students investigated the effect of temperature on the rate of osmosis in potato cells. The students used five potato chips all cut to the same size.

**Figure 9** shows one chip.

**Figure 9**



This is the method used.

1. Half fill a boiling tube with distilled water.
2. Heat the water to 25 °C
3. Place one potato chip in the boiling tube.
4. Keep the boiling tube and potato chip at 25 °C for 30 minutes.
5. Repeat steps 1–4 at four other temperatures.

In Biology RPA3 learners will have carried out some sort of investigation into the effect of concentration of sugar or salt solutions on the mass of plant material (eg the change in mass of pieces of potato in different concentrations of sugar).

The introduction to this investigation clearly states that the learners are studying a factor affecting rate of osmosis, so they should be able to relate this to the specification content. This investigation requires students to understand that what they have learned in their RPA can be applied to this situation, even though it's investigating something completely different that they haven't come across.

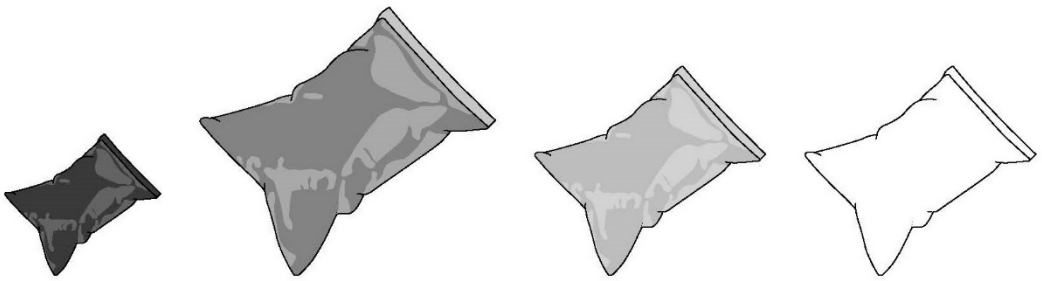
## Example 13: 2018 Combined Science Synergy Paper 2H Question 1

A solar water bag can be used to heat water for an outdoor swimming pool.

A student wanted to find out if the colour of the solar water bag affects the temperature increase of the water inside the bag.

**Figure 1** shows some of the equipment used.

**Figure 1**




This is the method used.

1. Fill each bag with water.
2. Place the four bags on the ground outside.
3. After three hours, measure the temperature of the water inside each bag.
4. Repeat steps 1–3 on the next two days.

**Commentary**

Learners should be familiar with Physics RPA10, in which they investigate infrared radiation (most usually using some sort of Leslie cube), and will know that different surfaces affect the amount of infrared radiation absorbed.

Even though the context of this example will be unfamiliar, learners should be able to recognise that this is what is happening here and apply the learning from the RPA – the different materials of the bags will have different effects on the amount of radiation absorbed and therefore the temperature of the water inside the bag.

# Questions for interrogating an experimental method

Here are some suggestions for questions you could use with any given method (familiar or unfamiliar) and which you could adapt for the specific method or level of demand. You don't have to ask questions about every aspect of the practical – you could just use one or two to focus understanding.

| Category of question | Questions that could be asked |
|---|---|
| Content being covered | • What is being investigated?<br>• What is it in the wording that tells you this?<br>• Does this method relate to a practical you have done?<br>• Is it the same or is it slightly different?<br>• How is it different from what you have done?<br>• What topic you have studied is this practical about? |
| Hypotheses | • Is the student/scientist testing a hypothesis?<br>• What hypothesis are they testing?<br>• Suggest a hypothesis for this investigation.<br>• Do the results support this hypothesis? |
| Variables | • Is the student changing any variables in this investigation?<br>• What variables are they changing?<br>• Why are they changing that variable?<br>• What is the independent variable?<br>• What is the dependent variable?<br>• What variables to they need to keep the same? |
| Sampling/controls | • What would you use as a control sample in this experiment?<br>• What would be a suitable range of measurements to use?<br>• What other things could you measure?<br>• How could you change the method to determine... ? |
| Measurements and types of error | • One of the results is anomalous. What could have caused this anomaly?<br>• Give a reason why the measurement(s) may not be accurate.<br>• The student made a mistake setting up the apparatus. What mistake did they make? What problem could this cause? |
| Accuracy/resolution | • What was the resolution of the [instrument used]?<br>• What could the student do to make their results more accurate? |
| Results | • What results do you predict? Why?<br>• What would getting results that don't match your prediction tell you?<br>• Do the results confirm the hypothesis? If not, what **are** they showing?<br>• Explain the result for [X] |

| | |
|---|---|
| | • One of the results is anomalous. How do you know which result is anomalous? What could have caused the anomalous result? |
| Evaluating methods/validity | • How could the student improve the method to get more valid results?<br>• The method will produce qualitative results. How could you change the method to produce accurate, quantitative results?<br>• How could the method be changed to ensure that results are repeatable?<br>• What mistake did the student make when setting up the apparatus?<br>• The student concludes that the results are valid. Is the student correct? Why? |

# GCSE Sciences command words

Command words are the words and phrases used in exams that tell students how they should answer a question.

## Balance

Students need to balance a chemical equation.

## Calculate

Students should use numbers given in the question to work out the answer.

## Choose

Select from a range of alternatives.

## Compare

This requires the student to describe the similarities and/or differences between things, not just write about one.

## Complete

Answers should be written in the space provided, for example, on a diagram, in spaces in a sentence or in a table.

## Define

Specify the meaning of something.

## Describe

Students may be asked to recall some facts, events or process in an accurate way.

## Design

Set out how something will be done.

## Determine

Use given data or information to obtain and answer.

## Draw

To produce, or add to, a diagram.

## Estimate

Assign an approximate value.

## Evaluate

Students should use the information supplied, as well as their knowledge and understanding, to consider evidence for and against when making a judgement.

## Explain

Students should make something clear, or state the reasons for something happening.

## Give

Only a short answer is required, not an explanation or a description.

## How/What/When/Where/Which/Who/Why

These can be used for more direct questions.

## Identify

Name or otherwise characterise.

## Justify

Use evidence from the information supplied to support an answer.

## Label

Provide appropriate names on a diagram.

## Measure

Find an item of data for a given quantity.

## Name

Only a short answer is required, not an explanation or a description. Often it can be answered with a single word, phrase or sentence.

## Plan

Write a method.

## Plot

Mark on a graph using data given.

## Predict

Give a plausible outcome.

## Show

Provide structured evidence to reach a conclusion.

## Sketch

Draw approximately.

## Suggest

This term is used in questions where students need to apply their knowledge and understanding to a new situation.

## Use

The answer must be based on the information given in the question. Unless the information given in the question is used, no marks can be given. In some cases students might be asked to use their own knowledge and understanding.

## Write

Only a short answer is required, not an explanation or a description

# Example questions using key command words

All examples are taken from the GCSE Combined Science: Trilogy June 2022 papers.

## Describe

Can cover any assessment objective and be worth any number of marks.

Describe how a quadrat can be used to measure the size of the buttercup population on the wet soil area.

**[4 marks]**

Describe how a low blood glucose concentration would lead to a person feeling weak.

**[2 marks]**

Describe how the student would know when all the starch had been digested.

**[1 mark]**

Describe how the boiling points change as the number of carbon atoms in the hydrocarbon increases.

**[1 mark]**

Describe the trend of the melting points of the Group 1 elements in **Figure 2.**

**[3 marks]**

Describe how the student could use the equipment shown in **Figure 10** to determine the specific heat capacity of vegetable oil.

**[6 marks]**

Describe the pattern shown by the data in **Table 1**.

**[2 marks]**

## Explain

Questions cover all assessment objectives. Always worth more than 1 mark.

Microorganisms in the soil recycle carbon from the leaves so that the carbon is used for new plant growth.

Explain how.

**[4 marks]**

Explain how the structure of enzyme molecules is related to the effect of pH on the Activity of amylase.

**[6 marks]**

Explain why the magnesium alloy is harder than magnesium metal.

Use **Figure 9.**

**[3 marks]**

Explain the trend in the melting points of the Group 7 elements.

Use **Figure 4.**

**[3 marks]**

Explain how using step-up transformers makes the network efficient.

**[3 marks]**

Explain why there is a force on the wire when there is a current in the wire.

**[3 marks]**

## Compare

Likely to be mostly AO2 and AO3, although there will often be some element of AO1. Likely to be higher tariff (4–6 marks), although some questions may require a simple comparison and be worth 2 or 3 marks.

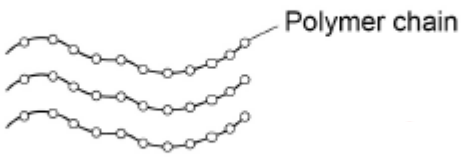
Compare the growth of boys with the growth of girls.

Use data from **Figure 5** in your answer.

**[6 marks]**

**Figure 6** represents part of the structure of a polymer.

**Figure 6**




Compare the bonding within the chains with the forces between the chains in this polymer.

**[3 marks]**

## Evaluate

Evaluate questions almost always assess AO3, with some AO2. They are unlikely to involve much AO1. They will always be higher tariff questions (4 marks or higher).

Farmers add nitrate fertiliser to fields where they grow corn.

Nitrate fertilisers are expensive.

Evaluate the economic and environmental implication of adding fertiliser to soil in nitrate ion concentrations ranging from 0 to 50 ppm

**[4 marks]**

In Question **07.2** it was assumed that the acceleration was a constant 9.8 $m/s^2$

Evaluate this assumption.

**[4 marks]**

Evaluate the sustainability of wooden and plastic window frames.

You should include environmental and economic factors.

**[6 marks]**

# Generic levels descriptors

You might use the top level descriptors in conjunction with the requirements above, to help learners understand what they need to do to fully answer these key command words.

## Describe

| | |
|---|---|
| **Level 2:** Scientifically relevant facts, events or processes are identified and given in detail to form an accurate account. | 3–4<br>or<br>4–6 |
| **Level 1:** Facts, events or processes are identified and simply stated but their relevance is not clear. | 1–2<br>or<br>1–3 |
| **No relevant content.** | 0 |

## Explain

| | |
|---|---|
| **Level 3:** Relevant points (reasons/causes) are identified, given in detail and logically linked to form a clear account. | 5–6 |
| **Level 2:** Relevant points (reasons/causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear. | 3–4 |
| **Level 1:** Points are identified and stated simply, but their relevance is not clear and there's no attempt at logical linking. | 1–2 |
| **No relevant content.** | 0 |

## Compare

| | |
|---|---|
| **Level 2:** Scientifically relevant features are identified; the way(s) in which they are similar/different is made clear and (where appropriate) the magnitude of the similarity/difference is noted. | 3–4<br>or<br>4–6 |
| **Level 1:** Relevant features are identified and differences noted. | 1–2<br>or<br>1–3 |
| **No relevant content.** | 0 |

## Evaluate

| | |
|---|---|
| **Level 3:** A judgement, strongly linked and logically supported by a sufficient range of correct reasons, is given. | 5–6 |
| **Level 2:** Some logically linked reasons are given. There may also be a simple judgement. | 3–4 |
| **Level 1:** Relevant points are made. They aren't logically linked. | 1–2 |
| **No relevant content.** | 0 |

# Notes

# Contact us

Our friendly team will be happy to support you between 8am and 5pm, Monday to Friday.

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