Variables

A **variable** is something that can change

Match up the type of variable to the description

<table>
<thead>
<tr>
<th>Control Variable</th>
<th>The variable that changes as a result of changing the independent variable. This is the one you measure.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Independent variable</strong></td>
<td>A variable that is kept constant (ie not changed) during an experiment.</td>
</tr>
<tr>
<td><strong>Dependent variable</strong></td>
<td>The one thing that you decide to change.</td>
</tr>
</tbody>
</table>

Below are descriptions of some investigations, for each investigation write down:

- The independent variable
- The dependant variable
- At least two control variables
- Are the independent and dependant variables categoric or continuous

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Independent variable</th>
<th>Dependent variable</th>
<th>Control variable(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>John wants to find out which ball bounces highest, a football, a netball and a basket ball.</td>
<td>The ball</td>
<td>How high it bounces</td>
<td>The height dropped from and the surface</td>
</tr>
<tr>
<td>Michelle wants to find out if at what temperature salt dissolves easiest in water.</td>
<td>The temperature</td>
<td>The time taken to dissolve</td>
<td>The mass of salt The amount of stirring</td>
</tr>
<tr>
<td>Tyler is investigating what concentration of acid reacts quickest when dissolving calcium carbonate. To do this he is going to measure the amount of gas given off</td>
<td>The concentration of acid</td>
<td>The volume of gas</td>
<td>The time the gas is measured for. The amount of acid The size of the marble chips</td>
</tr>
</tbody>
</table>

**Categoric variable**

A variable than can be described by a label i.e. a **word** such as blue or brown for eye colour.

**Continuous variable**

A variable that can be measured and can therefore have any value. Eg Temperature can be measured and can have any value.
Hypothesis

A **hypothesis** is a scientific statement that explains certain observations.

It has the form:

“If I change the **independent variable** this will cause a change in **dependent variable**.”

Can you use this format to write a hypothesis for each of the investigations we have already considered?

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Independent variable</th>
<th>Dependent variable</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>John wants to find out which ball bounces highest, a football, a netball and a basket-ball.</td>
<td></td>
<td></td>
<td>If I change the type of ball this will change the height it bounces to.</td>
</tr>
<tr>
<td>Michelle wants to find out if at what temperature salt dissolves easiest in water.</td>
<td></td>
<td></td>
<td>If I change the temperature this will change the time taken for the salt to dissolve</td>
</tr>
<tr>
<td>Tyler is investigating what concentration of acid reacts quickest when dissolving calcium carbonate. To do this he is going to measure the amount of gas given off</td>
<td></td>
<td></td>
<td>If I change the concentration of acid this will change the amount of gas that is given off when reacting with calcium carbonate.</td>
</tr>
</tbody>
</table>
Research
During your ISA we will give you a description of the context of the experiment AND a hypothesis.

Your first task will be to research the science behind the context and hypothesis and to find additional information about the hypothesis that would explain it in terms of the science.

Websites such as GCSE bitesize, wikipedia,
Text books
Kerboodle text book
GCSE revision guides
Other books or articles
Journal articles
Classbook
Teachers

What is scientific research and what sources could you use?
What is a good source?

Which of these sources would you expect to get more accurate information from AND why?

I would expect the New Scientist to give me more accurate information because it is peer reviewed by other scientists. Peer review means it is more likely that a story is based on fact and evidence.

The Daily Mail has a main aim of trying to sell newspapers so the editor will not investigate the story in the same way.

What information would you need to give to identify a source?

For a book you would need to give the title, author and page number.
For a website you would need to give a URL (full).
For a Journal or article then you would need to give the name of the magazine, date and page number.
For your class book you would need to give the date and a quotation.
Preliminary investigations
Your source could give you some good ideas about what method to use.

How will we tell whether this experiment can actually work?

We have to do a preliminary investigation.

In a dictionary look up what preliminary means and write your answer below:

*Preceding or done in preparation for something fuller and more important*

Often the preliminary investigation will help us to decide how to control our controlled variables.

I want to measure speed of reaction at different concentrations. How could I control the temperature of a reaction to make sure this does not affect the results?

*I could use a water bath*

How will your preliminary investigation help you to decide on the best value for the temperature?

*I need to test a range of temperatures from 20 degrees till 40 degrees until I find a value which gives the best spread of the dependent variable, the time taken to react measured with a stop watch. It is not suitable if it is too fast to measure or if it is too slow to measure in the time I have available. I will then carry out my real experiment at a fixed temperature determined by my preliminary investigation.*
Preliminary investigations

This is a popular ISA test 1 question for 3 marks

“Describe briefly how you would carry out a preliminary investigation to find a suitable value to use for this variable. You should also explain how the results of this preliminary investigation will help you to decide on the best value for this variable”

A perfect answer is

I will need to keep the temperature the same so it does not affect the speed of the reaction. I will test a lower and upper range of 20-35°C using a waterbath.

I will measure the time taken for the reaction at both temperatures and pick a value where the speed is not too slow or too fast.

Common mistakes include:

Not mentioning a suitable control variable
Not mentioning a range
Not saying how that you will measure the dependent variable.
Method - you are always asked to write one of these

When we describe a method in an ISA we need to include:

1. A list of equipment
2. Measurements you would take
3. How you would take the measurements
4. What you will do to make it a fair test
5. Risk assessment

Can you write an equipment list for this equipment?

A 100mL measuring cylinder
A 200 mL beaker
A 2.d.p. electronic balance
An alcohol thermometer
A 50 mL conical flask
A dropping pipette
Method writing... ISA Test 1 – 9 mark question
Tyler is investigating what concentration of acid reacts quickest when dissolving calcium carbonate. To do this he is going to measure the amount of gas given off in 10 seconds with different concentrations of acid.

What measurements is Tyler going to make?
Tyler is going to measure the amount of gas given off in 10 seconds for each of the concentrations of acid.

Identify the variables (IV and DV)
Independent variable is the concentration of acid
Dependent variable is the volume of gas

How will Tyler make sure it is a fair test – control variables
Tyler will keep the volume of acid the same so that this does not affect the amount of gas given off by using a measuring cylinder
Tyler will use the same size of marble chips so this does not affect the rate of the reaction
Tyler will use the same temperature by using a water bath as higher temperature would increase the rate. Tyler is going to take the measurement of gas after 10 seconds each time.

Can you write a risk assessment in the form

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Risk</th>
<th>Precaution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Corrosive and irritant</td>
<td>Use gloves or wash hands if spilled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wear goggles to protect eyes</td>
</tr>
</tbody>
</table>

Step by step method
1. Set up a water bath at 25 degrees C. Clamp a 100ml conical flask in the water bath.
2. Add 50mL of 0.1 M HCl to the conical flask and measure when the temperature reaches 25 degrees.
3. Attach a delivery tube and gas syringe to the conical flask
4. Remove the bung and add 2.00g of small marble chips weighed using a 2.d.p. electronic balance. Immediately replace the bung and start the timer.
5. Read the volume of gas that has been evolved after 10 seconds.
6. Repeat the experiment 3 times and calculate an average. Then repeat for further concentrations of acid from 0.1 to 1.0M as shown in the table.
Table of results
Tables of results must include titles and units and they should be headed with the dependent variable and independent variable.

Can you fill in the headings for Tyler’s experiment?

<table>
<thead>
<tr>
<th>Concentration of acid (M)</th>
<th>Volume of gas evolved (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>5.0</td>
</tr>
<tr>
<td>0.2</td>
<td>10.0</td>
</tr>
<tr>
<td>0.3</td>
<td>13.0</td>
</tr>
<tr>
<td>0.4</td>
<td>16.0</td>
</tr>
<tr>
<td>0.5</td>
<td>18.0</td>
</tr>
<tr>
<td>0.6</td>
<td>19.0</td>
</tr>
<tr>
<td>0.7</td>
<td>20.0</td>
</tr>
<tr>
<td>0.8</td>
<td>20.0</td>
</tr>
<tr>
<td>0.9</td>
<td>20.0</td>
</tr>
<tr>
<td>1.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Drawing a graph
You need to include
1) Axes titles and units
2) All points plotted to within +/- 1mm
3) Line of best fit (could be curved or straight)
4) Appropriate scale (fill at least 1/3 of your axes)

Tip: Use a sharp pencil and ruler. Try and keep your scale simple and use a cross to mark each point.
graph showing the amount of gas evolved in 10sec for different concentrations of acid
Spot the difference
The definitions for repeatable and reproducible are very similar.

Repeatable
A measurement is repeatable if the original experimenter repeats the investigation using the same method and equipment and gets the same results.

Reproducible
A measurement is reproducible if the investigation is repeated by another person or by using different equipment or techniques and the same results are obtained.

Can you spot the difference?

It is only repeatable if YOU do your experiment again with the same equipment and get the same or similar results.
If you do the experiment with different equipment OR someone else does the experiment and gets similar results this is reproducible.

Which is which?

I repeat my results three times and each time I get similar results. All my results follow the same pattern. Does this make my results:

Repeatable or Reproducible

People in my class do a similar experiment and obtain the similar values and the same pattern as me. Does this make my results:

Repeatable or Reproducible
Sharing results
When you have completed your experimental work you will be asked to share your results with others.

When we share our results with others are we can see whether there are similarities and differences. When comparing results with others are we showing:

Reproducibility OR Repeatability?

When we have more data points what effect will this have on our mean?

We can identify anomalous results and remove them
Our mean will be closer to the true value (more accurate)
What type of error is reduced when a mean is calculated?

Random error is reduced when a mean is calculated.

Use these ideas to explain the advantages of sharing your results with others.

If I compare my results with others in my class I can see if they are similar. I can remove anomalous results. I can use their results to calculate a more accurate mean, this minimises the effect of random errors. If I have similar results then my experiment is reproducible.

Model Answer

Enables you to compare your results with those of others to see if there are any similarities or differences.

With more data you are able to calculate a more accurate mean and minimise the effect of random errors.

Enables reproducibility to be confirmed.
ISA test 2

You need to get familiar with all the words on your glossary. Let's practice with some here...

**Accuracy**
A measurement is accurate if it is close to the real value.

**Resolution**
This is the smallest change that a measuring instrument can measure.

Instruments with a higher resolution are more likely to give a value close to the true value. In other words they would give you a more accurate measurement

**Test your understanding:**

I want to measure out 25cm$^3$ of water. Which piece of equipment do you think would get me a volume closest to 25cm$^3$ (circle your answer)?

A measuring cylinder which measures to +/- 0.1cm$^3$

A 25cm$^3$ pipette which measures to +/- 0.005cm$^3$

A pipette would be more accurate because it has a higher resolution. So it will measure closer to the true value.
Do your results support your hypothesis?

This is a popular test 2 question for three marks.

You need to look at your graph and table and see whether there is a pattern or trend.

Look at this graph.

![Graph of mass lost against time taken when burning propanol](image)

Does it support the hypothesis that a fuel loses mass when it is burned?

Yes it does because there is a pattern that shows a positive correlation between the time and the mass of fuel burned. This is supported by my data which shows that at 15 seconds 0.14g has been lost but at 60 seconds 0.52g has been lost.

It is ALWAYS really important to give some values from your table. In my table it shows that at 15 seconds 0.14g has been lost but at 60 seconds 0.52 g has been lost. This supports my hypothesis.
If your results show a clear pattern why do you think this could be?

1) Discuss your range
2) Discuss your repeats
3) Discuss your equipment

For example my results show a clear pattern because:

I chose a suitable range (0-120s) of my independent variable, time in seconds and a suitable interval (every 30s) to record the change in mass.

I repeated my results three times and calculated a mean. This also meant I could remove anomalous results.

I used a balance that had a high resolution (measured to 3dp).
Anomalous results

Look at another version of my graph:

![Graph of lost against time taken when burning propanol](image)

Use your glossary to answer the following questions

What is an anomalous result?

An anomalous result is one which does not follow the expected pattern

How does my graph show me that I have an anomalous result?

There is a point on the graph which lies above the line of best fit and does not follow the trend. It is at 60 sec where the value for mass lost is 0.75g and should be 0.58g.

You should also give the value for any anomalous results. Here my anomalous result is at 60 seconds and is 0.75g which is well above the line of best fit.
Sketching a graph

You will need to sketch a graph

1) Write axes titles
2) Sketch a suitable shape as a line

Can you use the following data to sketch the graph for methanol

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Mass lost (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>15</td>
<td>0.2</td>
</tr>
<tr>
<td>30</td>
<td>0.3</td>
</tr>
<tr>
<td>45</td>
<td>0.4</td>
</tr>
<tr>
<td>60</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Case Studies

You will need to look at four case studies provided on a separate sheet.

As you are looking at the case studies try and spot:

1) Does the data show the same trend?
2) Are the IV and DV the same?
3) Are there any anomalous results?
4) Have the anomalous results been included in the calculations.

**ALWAYS GIVE NUMERICAL EXAMPLES FROM EVERY CASE STUDY**

Take a look at the case studies on the following pages.

The hypothesis is:

It is suggested that there is a link between the mass of mustard powder added and the time it takes for an oil/water emulsion to separate.

Does the data in case study 1 support the hypothesis?

Yes it does because it shows a pattern where increasing mass of mustard powder added means it takes longer for the emulsion to separate. For example when 0.1 g of mustard powder is added it takes 24 s. But when 0.3 g of mustard powder is added it takes 116 s.

Does the data in case study 2 support the hypothesis?

Case study 2 does support the hypothesis because increasing the mass of mustard powder follows the same pattern and takes longer for the emulsion to separate. For example when 0.1 g of mustard powder is added it takes 12 s and when 0.3 g is added it takes 62 s. However there is an anomalous result at 0.2 s which has been used to calculate the mean. The value 32 s should be removed when calculating the mean.

Does the data in case study 3 support the hypothesis?

Test three does not support the hypothesis as the mass of mustard powder has not been varied. The dependent variable in this study is the emulsifier used. This study cannot therefore be related to our hypothesis.
Remember to ALWAYS include numerical examples.
Look at Case study 4

What is the relationship between the percentage of emulsifier used and the time taken for the ice cream to separate?

Explain how well the data supports your answer.

As the percentage of emulsifier increases the time taken for the ice cream to separate increases. For example for 0.2% egg yolk the time is 15 seconds but for 0.4% egg yolk the time is 37 seconds. The same trend is repeated for the additive E433 where at 0.2 emulsifier the time is 40 seconds and at 0.4% E433 the time taken is 92 seconds. Problems with the data include an anomalous result at 0.4% egg yolk which is 22 seconds, however this has not been calculated into the mean. There also seems to be a mistake at what is presumed to be 0.6% E433 which is recorded on the table as a second set of data at 0.4%). To be certain that the results support our hypothesis we would need to clarify this with the experimenter.
Data sheet

Case Study 1

A group of students carried out an investigation similar to the one you have done to test the hypothesis that there is a link between the mass of mustard powder added and the time it takes for oil and water to separate.

They carried out the investigation three times. In each test they used the same volumes of oil and water and shook the mixture 20 times.

These are their results:

<table>
<thead>
<tr>
<th>Mass of mustard powder added to oil (g)</th>
<th>Time for mixture to separate (s)</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Mean time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td></td>
<td>22</td>
<td>26</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>0.15</td>
<td></td>
<td>64</td>
<td>65</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>0.20</td>
<td></td>
<td>87</td>
<td>85</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>0.25</td>
<td></td>
<td>104</td>
<td>104</td>
<td>105</td>
<td>104</td>
</tr>
<tr>
<td>0.30</td>
<td></td>
<td>117</td>
<td>116</td>
<td>115</td>
<td>116</td>
</tr>
</tbody>
</table>

Case Study 2

A group of students carried out an investigation similar to the one you have done to test the hypothesis that there is a link between the mass of mustard powder added and the time it takes for oil and water to separate.

They carried out the investigation three times. In each test they used the same volumes of oil and water and shook the mixture 20 times.

These are their results:

<table>
<thead>
<tr>
<th>Mass of mustard powder added to oil (g)</th>
<th>Time for mixture to separate (s)</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Mean time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td></td>
<td>10</td>
<td>12</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>0.15</td>
<td></td>
<td>32</td>
<td>33</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>0.20</td>
<td></td>
<td>46</td>
<td>32</td>
<td>45</td>
<td>41</td>
</tr>
<tr>
<td>0.25</td>
<td></td>
<td>56</td>
<td>55</td>
<td>57</td>
<td>56</td>
</tr>
<tr>
<td>0.30</td>
<td></td>
<td>62</td>
<td>63</td>
<td>62</td>
<td>62</td>
</tr>
</tbody>
</table>
Case Study 3

Students in a laboratory carried out tests to find the time it took for an oil/water emulsion to separate when 1 g of an emulsifier was added to it. In each test they used the same volumes of oil and water and shook the mixture 20 times.

These are their results:

<table>
<thead>
<tr>
<th>Emulsifier</th>
<th>Time for mixture to separate (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test 1</td>
</tr>
<tr>
<td>Chilli powder</td>
<td>67</td>
</tr>
<tr>
<td>Egg white</td>
<td>4</td>
</tr>
<tr>
<td>Egg yolk</td>
<td>94</td>
</tr>
<tr>
<td>Mustard</td>
<td>76</td>
</tr>
</tbody>
</table>

Case Study 4

An ice-cream company is testing different amounts of two emulsifiers.

The company will use the results to find out which emulsifier and percentage might be best to use in the ice cream.

They added the emulsifier to the same volume of ice cream mix and shook the mixture for the same length of time. They timed how long it took for the ice cream to separate.

These are their results:

<table>
<thead>
<tr>
<th>Emulsifier</th>
<th>Time for mixture to separate (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test 1</td>
</tr>
<tr>
<td>0.2% egg yolk</td>
<td>13</td>
</tr>
<tr>
<td>0.4% egg yolk</td>
<td>36</td>
</tr>
<tr>
<td>0.6% egg yolk</td>
<td>51</td>
</tr>
<tr>
<td>0.2% emulsifier E433</td>
<td>39</td>
</tr>
<tr>
<td>0.4% emulsifier E433</td>
<td>92</td>
</tr>
<tr>
<td>0.4% emulsifier E433</td>
<td>122</td>
</tr>
</tbody>
</table>
Context

The point of the final question on the ISA test paper 2 is to see whether you can link your results to the initial context of the investigation. You must give as much detail as you can how you can solve the original problem.

Here is an example context:

A mayonnaise producer wants to add mustard powder to his mayonnaise to increase shelf life and stop the mustard from separating out. However, he does not want the mayonnaise to taste strongly of mustard or it will put customers off.

In your investigation (see case studies) you have investigated how the effect of mustard on the time taken to separate.

Explain how this will help the producer of mustard to determine how much to add to his product:

My results have supported the hypothesis that increasing the mass of mustard added to an emulsion means it will not separate out as quickly. This is useful to the manufacturer as it means that mustard can be used to stop the product from separating out.

However our results do not tell us how much mustard a customer will be able to taste and our results also suggest that 0.3g will still separate out after 116 seconds, which does not mean the shelf life will be increased by much.

A little bit of mustard may improve the shelf life but it is more likely that the manufacturer will need to use other emulsifiers as well as mustard, for example E433 or egg yolk.

The advantage of these other emulsifiers is that they will not taste as strong as mustard.