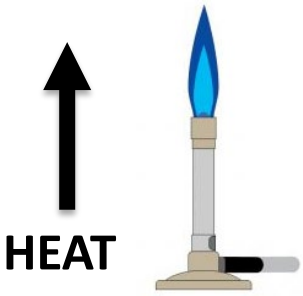
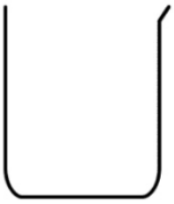
Scientific Skills

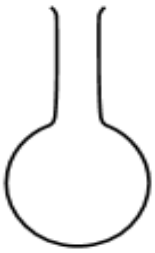
Match up the key word and its definition:

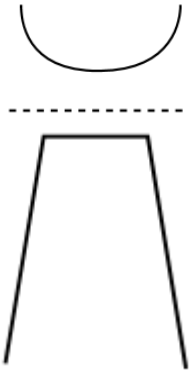
Hypothesis	The variable that is changed or selected by the investigator
Independent variable	The variable that is measured to see the effect of the independent variable
Dependent variable	Measurements that cluster closely together
Control variables	An idea or explanation for something that is based on known facts but has not yet been proven
Accurate	A value which is outside of the range of expected variation
Precise	Measurements which, when repeated under the same conditions by the same investigator, give similar results
Repeatable	A measurement that is close to the true value
Reproducible	Measurements which, when repeated by different investigators with different equipment, give similar results
Anomaly	The variables that are kept the same in an investigation in order to establish the effect of the independent variable

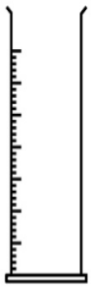
Name the scientific apparatus from its diagram:

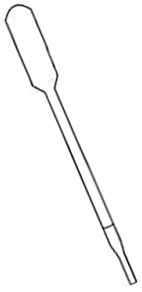


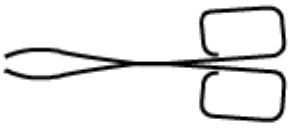


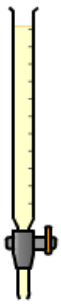










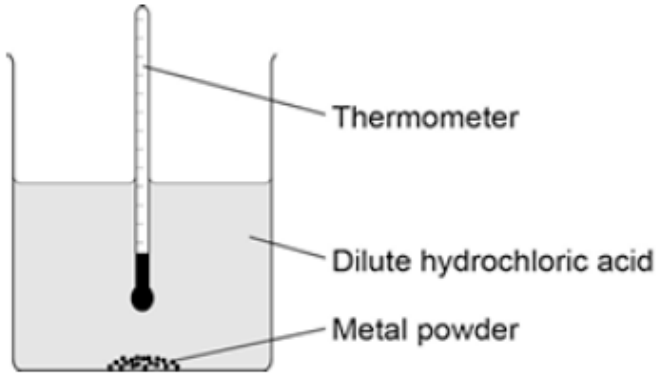


Identifying variables

Investigation	Independent variable (what was changed)	Dependent variable (what was measured)	Control variables
Jack investigated the reaction between hydrochloric acid and marble chips. He completed 4 experiments and used four different concentrations of acids. He collected the volume of gas produced in 30s and recorded his results.			
Sarah ran 5 chromatograms of 5 different felt tips pens that she had in her pencil case. She calculated the Rf values of each solute in the mixtures of dyes.			
Eve completed this method: 1. Weigh 1g of an ionic salt 2. Place in polystyrene cup 3. Add 20ml water 4. Measure the maximum temperature change 5. Repeat with different salts			

A student investigated the reactivity of different metals.

The student used the apparatus shown in the figure below.



The student used four different metals.

The student measured the temperature rise for each metal three times.

The student's results are shown in the table below.

Metal	Temperature rise in °C			Mean temperature rise in °C
	Test 1	Test 2	Test 3	
Calcium	17.8	16.9	17.5	
Iron	6.2	6.0	6.1	6.1
Magnesium	12.5	4.2	12.3	12.4
Zinc	7.8	8.0	7.6	7.8

(a) Give **two** variables the student should control so that the investigation is a fair test.

1 .....

.....

2 .....

.....

(2)

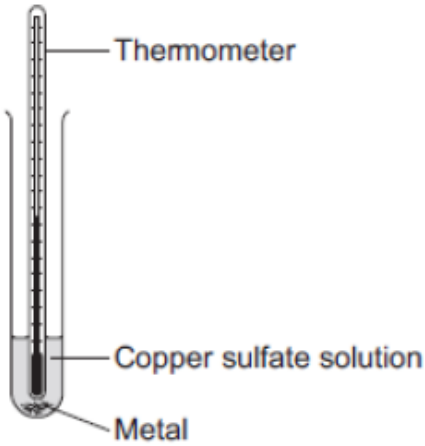
A student investigated displacement reactions of metals.

The student added different metals to copper sulfate solution and measured the temperature change.

The more reactive the metal is compared with copper, the bigger the temperature change.

The apparatus the student used is shown in **Figure 1**.

Figure 1



(a) State **three** variables that the student must control to make his investigation a fair test.

1 .....

2 .....

3 .....

(3)

(c) The student repeated the experiment three times with each metal.

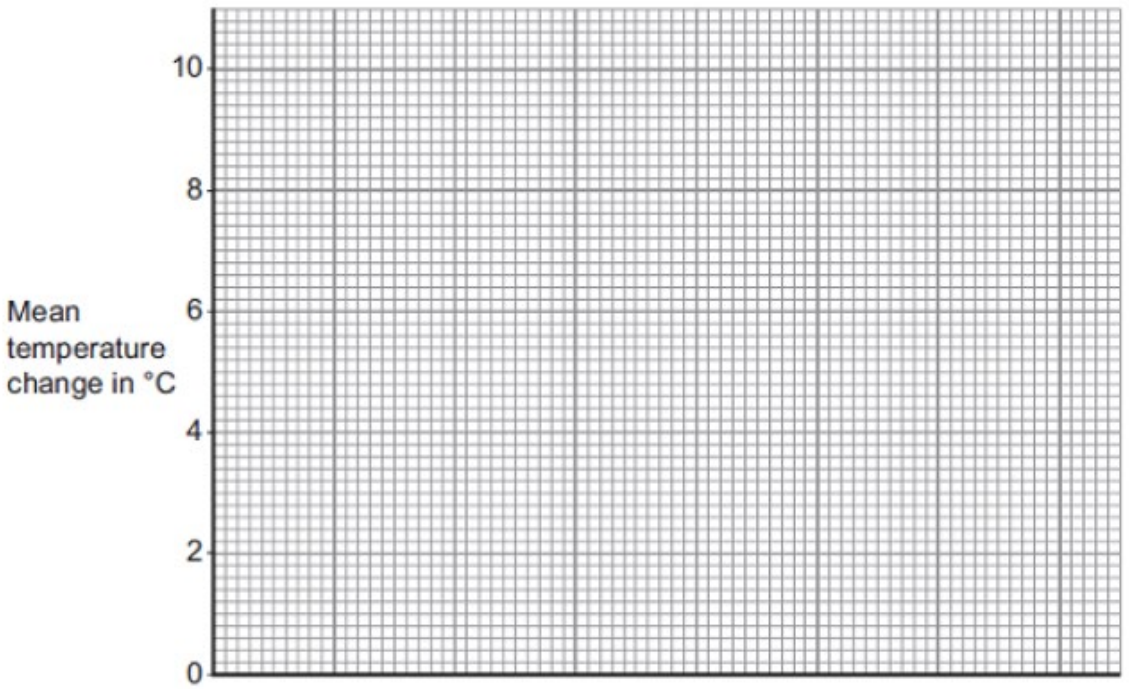
Table 2 shows the mean temperature change for each metal.

Table 2

Metal	**Mean temperature change in °C**
Cobalt	4.5
Gold	0.0
Magnesium	10.0
Nickel	3.0
Silver	0.0
Tin	1.5

(i) On **Figure 3**, draw a bar chart to show the results.

Figure 3



(3)

(ii) Why is a line graph **not** a suitable way of showing the results?

.....

.....

(1)

Random error

- A mistake when measuring
- Carrying out the method inconsistently each time
- Human error

This is why we do repeats, eliminate single anomalies and calculate mean averages!

Systematic error

- An error that was being repeated…e.g. a balance that is not set to zero
- These will produce errors in each measurement made
- These errors will be consistently above, or below, the accurate value

The only way to eliminate these errors is to change method, equipment or environment

Complete the exam question:

Dilute nitric acid reacts with potassium hydroxide solution.

The equation for the reaction is:

$$HNO_3 + KOH \longrightarrow KNO_3 + H_2O$$

A student investigated the temperature change in this reaction.

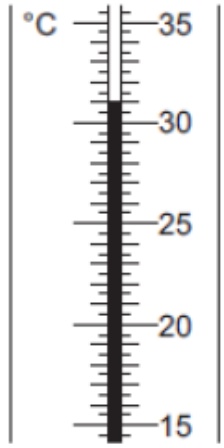
This is the method the student used.

Step 1 Put 25 cm^3 of dilute nitric acid in a polystyrene cup.
Step 2 Use a thermometer to measure the temperature of the dilute nitric acid.
Step 3 Use a burette to add 4 cm^3 of potassium hydroxide solution to the dilute nitric acid and stir the mixture.
Step 4 Use a thermometer to measure the highest temperature of the mixture.
Step 5 Repeat steps 3 and 4 until 40 cm^3 of potassium hydroxide solution have been added.

The dilute nitric acid and the potassium hydroxide solution were both at room temperature.

(a) **Figure 1** shows part of the thermometer after some potassium hydroxide solution had been added to the dilute nitric acid.

Figure 1



What is the temperature shown on the thermometer?

The temperature shown is ..... °C

(1)

(b) Errors are possible in this experiment.

(i) Suggest **two** causes of random error in the experiment.

.....

.....

.....

.....

(2)

(ii) Another student used a glass beaker instead of a polystyrene cup.

This caused a systematic error.

Why does using a glass beaker instead of a polystyrene cup cause a systematic error?

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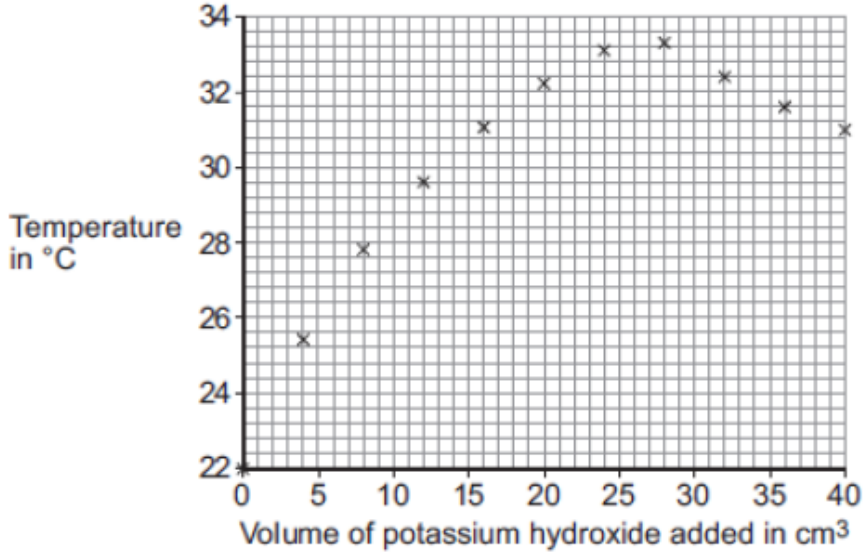
(1)

(c) The results of the student using the polystyrene cup are shown in **Figure 2**.

Figure 2



(i) How do the results in **Figure 2** show that the reaction between dilute nitric acid and potassium hydroxide solution is exothermic?

.....

.....

(1)

(ii) Explain why the temperature readings decrease between 28 cm^3 and 40 cm^3 of potassium hydroxide solution added.

.....

.....

.....

(2)

(iii) It is difficult to use the data in **Figure 2** to find the exact volume of potassium hydroxide solution that would give the maximum temperature.

Suggest further experimental work that the student should do to make it easier to find the exact volume of potassium hydroxide solution that would give the maximum temperature

.....

.....

.....

(2)

(d) The student did further experimental work and found that 31.0 cm^3 of potassium hydroxide solution neutralised 25.0 cm^3 of dilute nitric acid.

The concentration of the dilute nitric acid was 2.0 moles per dm^3.

$$HNO_3 + KOH \longrightarrow KNO_3 + H_2O$$

Calculate the concentration of the potassium hydroxide solution in moles per dm^3.

.....

.....

.....

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.....

.....

Concentration = ... moles per dm^3

(3)

(e) The student repeated the original experiment using 25 cm^3 of dilute nitric acid in a polystyrene cup and potassium hydroxide solution that was twice the original concentration.

She found that:

- a smaller volume of potassium hydroxide solution was required to reach the maximum temperature
- the maximum temperature recorded was higher.

Explain why the maximum temperature recorded was higher.

.....

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.....

.....

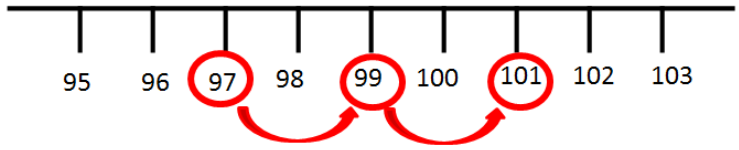
(2)

Analysing results

Temp-erature (°C)	Time taken for reaction to finish (s)			Mean average time (s)	Range (s)	Estimated uncertainty	Percentage uncertainty (%)
	1	2	3				
10	99	101	97				
20	72	73	75				
30	49	39	51				
40	34	33	31				
50	9	11	17				

1. Identify anomalies

1. Write a number scale...



2. Highlight numbers on the scale
3. Compare how far apart the numbers are
4. Identify 'anomalous' results that are clearly out of line with other results

2. Calculate mean averages

$$\text{Mean} = \frac{\text{Add up all values}}{\text{Total number of values}}$$

3. Identify ranges

Range = highest measurement – lowest measurement

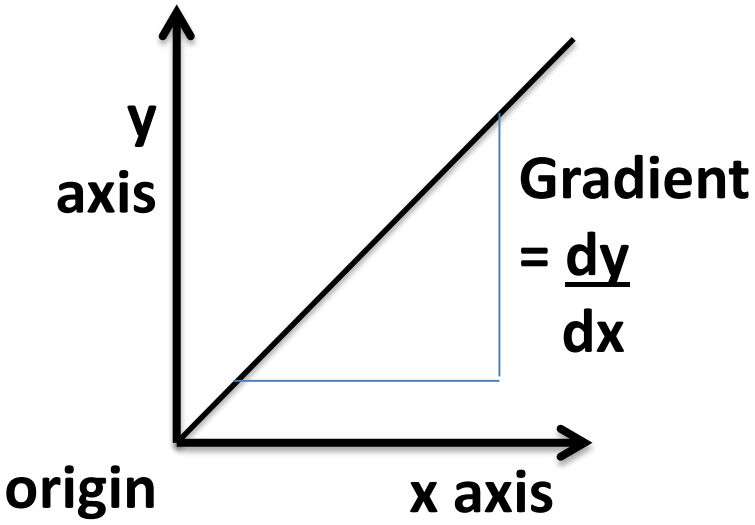
4. Calculate estimated uncertainty

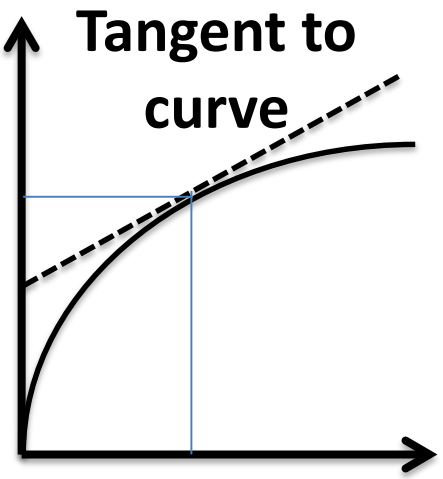
$$\text{Estimated uncertainty} = \frac{\text{range}}{2}$$

5. Calculate percentage uncertainty

$$\text{Percentage uncertainty} = \frac{\text{range}}{\text{mean}} \times 100$$

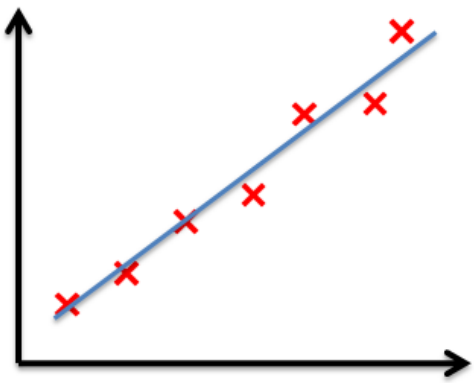
Graphing results





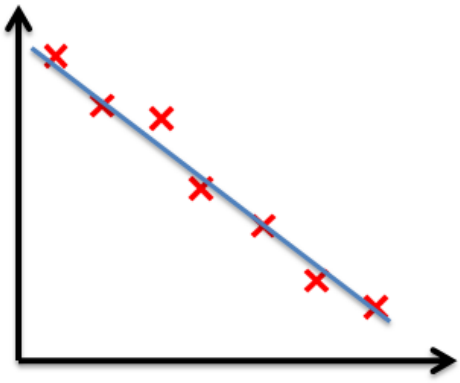
Interpreting graphs

"as the variable on the x axis increases, the variable on the y axis…"



Positive correlation

As the independent variable **increases**, so does the dependent variable

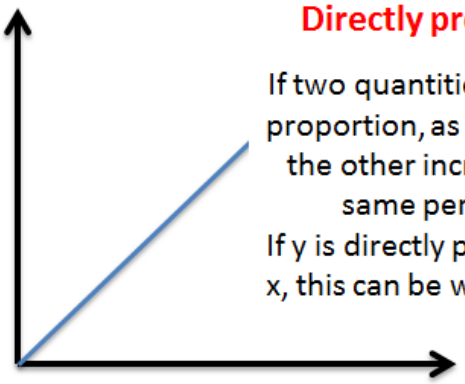


Negative correlation

As the independent variable **increases**, the dependent variable **decreases**

No correlation

Changing the independent variable has no effect on the dependent variable



Directly proportional

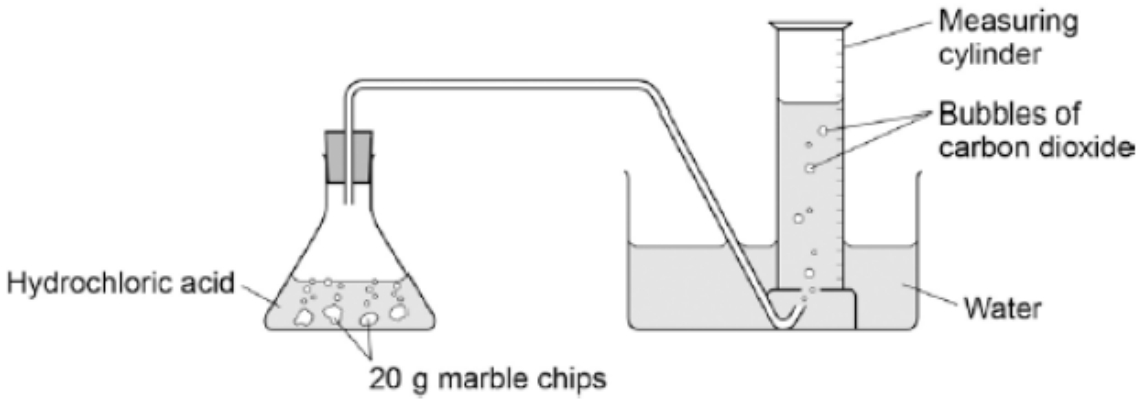
If two quantities are in direct proportion, as one increases, the other increases by the same percentage.
If y is directly proportional to x, this can be written as $y \propto x$

Marble chips are mainly calcium carbonate ($CaCO_3$).

A student investigated the rate of reaction between marble chips and hydrochloric acid (HCl).

Figure 1 shows the apparatus the student used.

Figure 1



(a) Complete and balance the equation for the reaction between marble chips and hydrochloric acid.

..... + ... → $CaCl_2$ + ... + ...

(2)

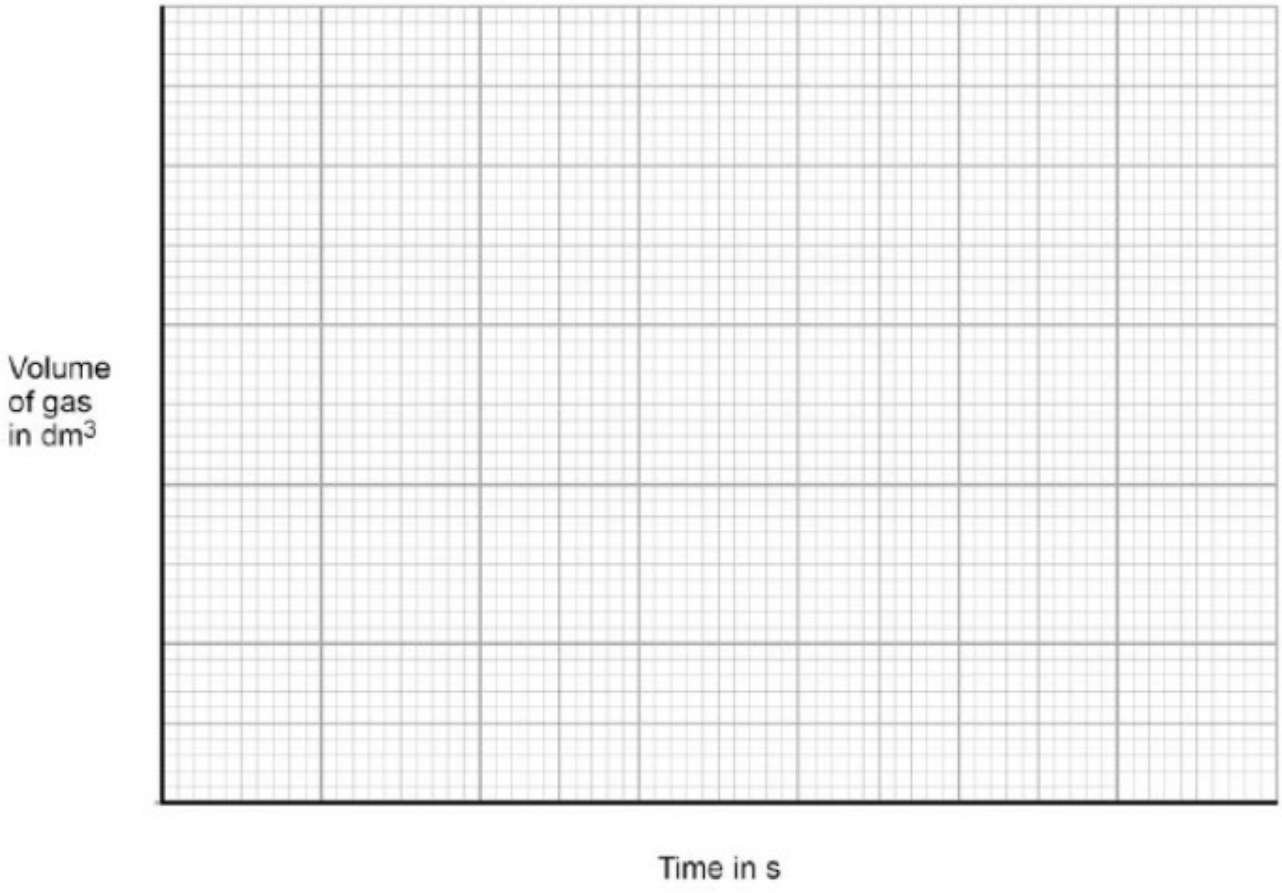
(b) The table below shows the student's results.

Time in s	0	30	60	90	120	150	180	210	240	270
Volume of gas in dm^3	0.000	0.030	0.046	0.052	0.065	0.070	0.076	0.079	0.080	0.080

On **Figure 2**:

- Plot these results on the grid.
- Draw a line of best fit.

Figure 2



(4)

(c) Sketch a line on the grid in **Figure 2** to show the results you would expect if the experiment was repeated using 20 g of smaller marble chips.

Label this line **A**.

(2)

(d) Explain, in terms of particles, how and why the rate of reaction changes during the reaction of calcium carbonate with hydrochloric acid.

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.....

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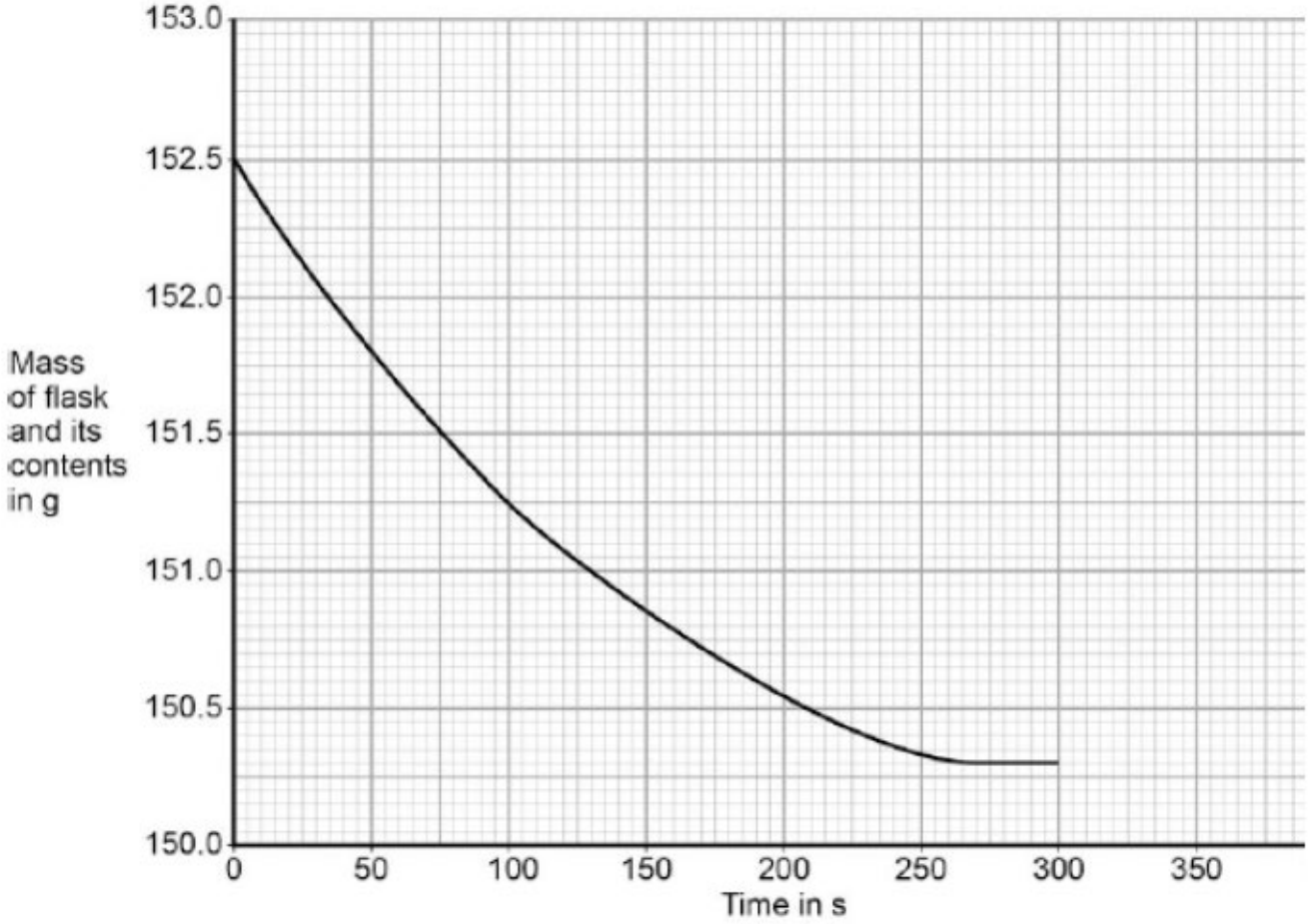
(4)

(e) Another student investigated the rate of reaction by measuring the change in mass.

Figure 3 shows the graph plotted from this student's results.

Figure 3



Use **Figure 3** to calculate the mean rate of the reaction up to the time the reaction is complete.

Give your answer to three significant figures.

.....

.....

.....

.....

.....

.....

Mean rate of reaction = ... g / s

(4)

(f) Use **Figure 3** to determine the rate of reaction at 150 seconds.

Show your working on **Figure 3**.

Give your answer in standard form.

.....

.....

.....

.....

.....

Rate of reaction at 150 s = ... g / s

(4)

Convert these numbers from standard form to ordinary form:

a) 5×10^{2}

b) 6×10^{-3}

c) 4×10^{-4}

d) 4.5×10^{4}

e) 8.4×10^{-3}

f) 2.87×10^{6}

g) 9.7×10^{5}

h) 5.55×10^{-5}

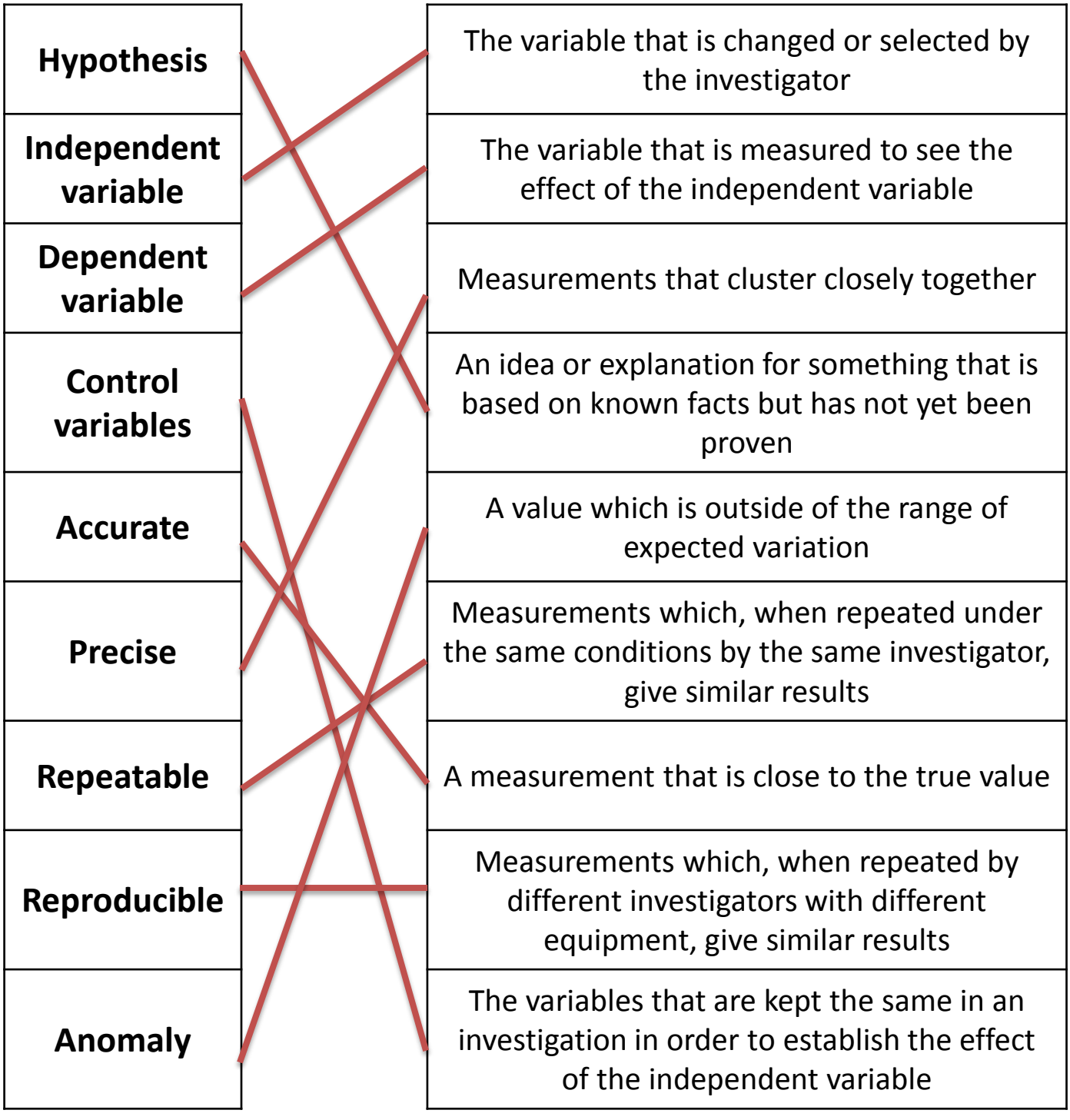
i) 2.41×10^{-8}

Standard Form	Ordinary Form
1×10^{4}	10000
1×10^{3}	1000
1×10^{2}	100
1×10^{1}	10
1×10^{0}	1
1×10^{-1}	0.1
1×10^{-2}	0.01
1×10^{-3}	0.001
1×10^{-4}	0.0001

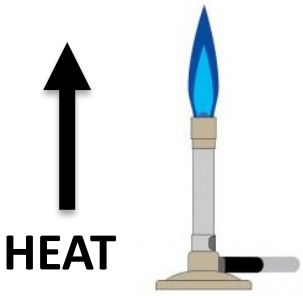
Answers

Scientific Skills

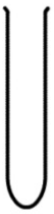
Match up the key word and its definition:



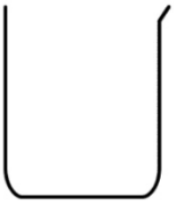
Name the scientific apparatus from its diagram:



Bunsen burner



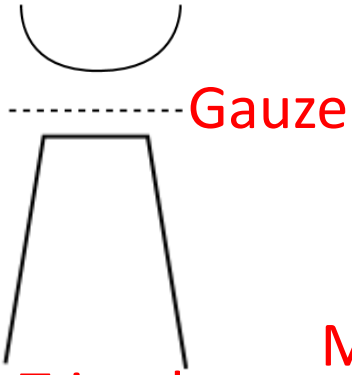
Test tube or boiling tube



Beaker

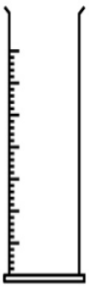
Round-bottomed flask

Crucible or evaporating basin



Tripod

Conical flask

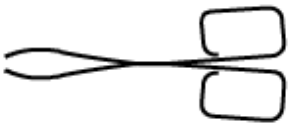


Measuring cylinder

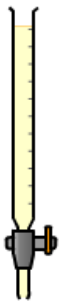
Pipette

Filter paper

Funnel



Tongs



Burette

Clamp

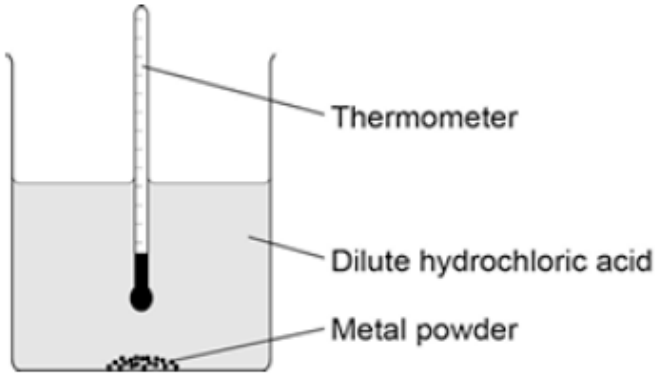
Stand

Identifying variables

Investigation	Independent variable (what was changed)	Dependent variable (what was measured)	Control variables
Jack investigated the reaction between hydrochloric acid and marble chips. He completed 4 experiments and used four different concentrations of acids. He collected the volume of gas produced in 30s and recorded his results.	**Concentration of acid**	**Volume of gas produced in 30s**	**Volume of acid used, mass of marble chips, surface area of marble chips, temperature, amount of stirring, time**
Sarah ran 5 chromatograms of 5 different felt tips pens that she had in her pencil case. She calculated the Rf values of each solute in the mixtures of dyes.	**Felt tip pens**	**Distance each solute travelled**	**Same solvent (mobile phase), same filter paper (stationary phase)**
Eve completed this method: 1. Weigh 1g of an ionic salt 2. Place in polystyrene cup 3. Add 20ml water 4. Measure the maximum temperature change 5. Repeat with different salts	**Ionic salt**	**Maximum temperature change**	**Mass of salt, volume of water, level of insulation, temperature, surface area of salt, amount of stirring**

A student investigated the reactivity of different metals.

The student used the apparatus shown in the figure below.



The student used four different metals.

The student measured the temperature rise for each metal three times.

The student's results are shown in the table below.

Metal	**Temperature rise in °C**			**Mean temperature rise in °C**
	Test 1	Test 2	Test 3	
Calcium	17.8	16.9	17.5	
Iron	6.2	6.0	6.1	6.1
Magnesium	12.5	4.2	12.3	12.4
Zinc	7.8	8.0	7.6	7.8

(a) any **two** from:

- concentration / volume of dilute hydrochloric acid
- mass of metal powder
- surface area of metal powder
- stirring (of any) / rate of stirring

allow reacted for the same length of time

2

(a) any **three** from:

- concentration of (salt) solution
- volume of (salt) solution

  ignore amount of solution
- **initial** temperature (of the solution)

  ignore room temperature
- surface area / form of metal
- moles of metal

  allow mass / amount

  ignore time

  ignore size of tube

3

(c) (i) four bars of correct height

tolerance is + / - half square

*3 correct for **1** mark*

2

bars labelled

1

(ii) *one variable* is non-continuous / categoric

accept qualitative or discrete

accept no values between the metals

1

Random error

- A mistake when measuring
- Carrying out the method inconsistently each time
- Human error

This is why we do repeats, eliminate single anomalies and calculate mean averages!

Systematic error

- An error that was being repeated…e.g. a balance that is not set to zero
- These will produce errors in each measurement made
- These errors will be consistently above, or below, the accurate value

The only way to eliminate these errors is to change method, equipment or environment

Complete the exam question:

Mark schemes

1 (a) 31 **1**

(b) (i) any **two** from:
- incorrect reading of thermometer / temperature
- incorrect measurement of volume of acid
- incorrect measurement of volume of alkali (burette).

2

(ii) glass is a (heat) conductor **or** polystyrene is a (heat) insulator

*answer needs to convey idea that heat lost using glass **or** not lost using polystyrene*

accept answers based on greater thermal capacity of glass (such as "glass absorbs more heat than polystyrene")

1

(c) (i) temperature increases

1

(ii) no reaction takes place **or** all acid used up **or** potassium hydroxide in excess

1

cool / colder potassium hydroxide absorbs energy **or** lowers temperature

ignore idea of heat energy being lost to surroundings

1

(iii) take more readings

ignore just "repeat"

1

around the turning point **or** between 20 cm^3 and 32 cm^3

accept smaller ranges as long as no lower than 20 cm^3 and no higher than 32 cm^3

1

(d) 1.61 **or** 1.6(12903)

*correct answer with or without working scores **3***

*if answer incorrect, allow a maximum of **two** from:*

*moles nitric acid = (2 × 25 / 1000) = 0.05 for **1** mark*

*moles KOH = (moles nitric acid) = 0.05 for **1** mark*

concentration KOH = 0.05 / 0.031

answer must be correctly rounded (1.62 is incorrect)

3

(e) same amount of energy given out

1

which is used to heat a smaller total volume **or** mixture has lower thermal capacity

or

number of moles reacting is the same

but the total volume / thermal capacity is less

*if no other marks awarded award **1** mark for idea of reacting faster*

1

[14]

2 (a) $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

2

*allow **1** mark for correct formulae*

(b) sensible scales, using at least half the grid for the points

1

all points correct

± ½ small square

*allow **1** mark if 8 or 9 of the points are correct*

2

best fit line

1

(c) steeper line to left of original

1

line finishes at same overall volume of gas collected

1

(d) acid particles used up

allow marble / reactant used up

1

so concentration decreases

allow surface area of marble decreases

1

so less frequent collisions / fewer collisions per second

*do **not** accept fewer collisions unqualified*

1

so rate decreases / reaction slows down

1

(e) mass lost of 2.2 (g)

1

time taken of
270 s

allow values in range 265 – 270

1

$\frac{2.2}{270} = 0.00814814$

allow ecf for values given for mass and time

1

0.00815 (g / s)

or

8.15×10^{-3}

*allow **1** mark for correct calculation of value to 3 sig figs*

*accept 0.00815 or 8.15×10^{-3} with no working shown for **4** marks*

1

(f) correct tangent

1

eg 0.35 / 50

1

0.007

allow values in range of 0.0065 – 0.0075

1

7×10^{-3}

1

*accept 7×10^{-3} with no working shown for **4** marks*

a) 5×10^{2} 500

b) 6×10^{-3} 0.006

c) 4×10^{-4} 0.0004

d) 4.5×10^{4} 45000

e) 8.4×10^{-3} 0.0084

f) 2.87×10^{6} 2870000

g) 9.7×10^{5} 970000

h) 5.55×10^{-5} 0.0000555

i) 2.41×10^{-8} 0.0000000241