

2017 Specification
First exams in 2019

Maths Skills

for GCSE CCEA Chemistry

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Teacher's Introduction

This GCSE Maths Skills pack will help students to develop the key mathematical skills needed in studying GCSE Chemistry. The pack has been written to cover mathematical skills required by the CCEA specification.

Mathematical skills pose a challenge for many students, with some finding it difficult to see how a skill learned in a Maths lesson is applied in a Chemistry lesson. This resource has been designed to support students in making this connection. It gives a gentle, conversational review of the skill, with worked examples, and offers students the opportunity to practise the skill in isolation and then also in the context of an examination-style question.

By using this resource, students can ensure they have the skills they need for each section of the Chemistry course. They can work through the chapters proactively, or they can be directed to them as support for skills identified in class as in need of some improvement.

There are five chapters covering all the key maths skills needed for GCSE Chemistry. Each chapter contains the following elements:

- **Specification overview** – this provides an overview of the skills and explains what the exam board requires students to demonstrate in the exam with the skills.
- **Theoretical overview** – a brief summary recapping the skills and demonstrating how to apply the skills.
- **Worked examples** – shows one or more fully worked questions which use the relevant skill, to demonstrate how students should approach them.
- **Practice questions** – each skill is concluded with practice questions that increase in difficulty. All the chemistry knowledge needed to complete the question will be provided, and the question focuses on testing students' understanding of the maths skill itself.

The chapters cover:

1. Arithmetic and numerical computation
2. Handling data
3. Algebra
4. Graphs
5. Geometry and trigonometry

There are two diagnostic tests for each chapter. The first is designed to be used before you work through each chapter and is provided at the start of the resource. The second is designed to be used after reviewing the chapter's content and is provided after the main content of the resource, just before the answers. The tests will allow you to identify areas for particular focus before undertaking the work, and then afterwards, should further focus on particular areas be necessary.

Graph paper is required for Diagnostic Tests for D2.

July 2024

Students' Introduction

Mathematical skills pose a challenge for many students, with some finding it difficult to see how a Maths lesson is applied in a Chemistry lesson. This resource has been designed to bridge this connection. It gives a gentle, conversational review of the skill, with worked examples and an opportunity to practise the skill in isolation and then also in the context of an exam question.

By using these resources, you can ensure you have the skills you need for each section of your course. You can work through the chapters proactively, or your teacher will direct you to the skills that you need to improve.

There are five chapters. There are also two sets of diagnostic tests to help identify areas for improvement. These are linked to the relevant chapters. Within each chapter, there are four elements:

- **Specification overview** – this provides an overview of the skills and explains how you can demonstrate in the exam with the skills.
- **Theoretical overview** – a brief summary recapping the skills and demonstrating how they are used.
- **Worked examples** – shows one or more fully worked questions which use the skill, explaining how you should approach them.
- **Practice questions** – each skill is concluded with practice questions that increase your chemistry knowledge needed to complete the question will be provided, and your understanding of the maths skill itself.

The chapters cover:

1. Arithmetic and numerical computation
2. Handling data
3. Algebra
4. Graphs
5. Geometry and trigonometry

There are two diagnostic tests for each chapter. The first is designed to be used before you start the chapter. The second is designed to be used after reviewing the chapter's content to identify areas for particular focus before undertaking the work, and then afterwards to see if any particular areas be necessary.

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DIAGNOSTIC TEST

A1 Arithmetic and numerical computation

1. Write the fraction $\frac{3}{8}$ as a decimal.
.....
2. Write the fraction $\frac{4}{9}$ as a decimal to three decimal places.
.....
3. Which of the following is the correct way to write the number 21 368 in standard form?
A. 21.368×10^3 ☐
B. 2.1368×10^4 ☐
C. 21.368×10^{-3} ☐
D. 2.1368×10^{-4} ☐
4. 12 moles of iron react with 18 moles of oxygen. Express the ratio 12:18 in its simplest terms (as a ratio of whole numbers).
.....
.....
5. Two gases are mixed in the ratio 3:1. If the total volume of gases is 8 dm³, what is the volume of each gas?
.....
.....
6. Convert the decimal 0.25 to the following:
a. a percentage:
b. a fraction in its simplest terms:
7. A chemical weighing 1.20 g is heated, which causes its mass to reduce to 0.84 g.
a. How much mass has been lost?
.....
b. Express the mass lost as a percentage of the original mass.
.....
8. The term 'PM_{2.5}' refers to particles that have a maximum diameter of 2.5 µm. A particle with a maximum diameter of 0.1 µm. Use this information to estimate how many times larger a PM_{2.5} particle is than a nanoparticle.
.....
9. Every time the pH of a solution increases by one unit, the concentration of H⁺ ions decreases by a factor of 10. Estimate how many times the concentration of H⁺ ions decreases when a solution's pH increases by 3 units.
.....
.....

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DIAGNOSTIC TEST

B1 Handling data

1. How many significant figures are in the following numbers?
 - a. 234.202
 - b. 0.001304
 - c. 0.070050
2. Give the answers to these calculations. Make sure that you give the answer to places, rounding if necessary.
 - a. $1.479 + 0.3421$
 - b. $12.323 - 0.85$
 - c. $0.003 + 0.012$
3. Give the answers to these calculations. Make sure that you give the answer to figures, rounding if necessary.
 - a. $14.9 \div 3.0$
 - b. 147×0.025
 - c. 3.87×1.575
4. The pH of a buffer solution was measured three times. The results were: 8.4, 8.5, 8.6. What is the mean average pH?
.....
.....
5. A class is asked to measure the rate of a reaction by counting the number of bubbles produced in a one minute period. Twenty-five students each measured the number of bubbles, and the results (in order) are shown below.
Put this data into a frequency table and from that calculate the arithmetic mean.
98, 98, 98, 99, 99, 99, 99, 100, 100, 100, 100, 100, 100, 101, 101, 101, 101, 101, 101, 102, 103, 103

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DIAGNOSTIC TEST

C1 Algebra

1. The rate of a chemical reaction can be defined as: $\text{rate} = \frac{\text{mass of product formed}}{\text{time}}$

The rate of a reaction is found to be **0.85 g/s**. Use this value and the equation to calculate the mass of product that would be formed in **15 s**.

.....

.....

.....

.....

2. Rearrange the equation $y = 4x + 7$ to make x the subject.

.....

3. The concentration of a solution can be calculated using the formula:

$$\text{concentration (mol/dm}^3\text{)} = \frac{\text{number of moles of substance}}{\text{volume of solution (dm}^3\text{)}}$$

Calculate the concentration of a solution with a volume of 250 cm^3 that contains 0.05 mol of substance.

You will need to pay careful attention to the units.

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DIAGNOSTIC TEST

D1 Graphs

1. Plot the data shown in the table below on graph paper. Draw a line of best fit

x	y
1	6.8
2	13.4
5	30.8
8	53.0
10	61.6

2. Use the graph that you drew in question 1 to work out the following:
- what the y value would be when $x = 6.5$
 - what the x value would be when $y = 55$
 - what the value for y would be when $x = 0$ (you may need to extend your
.....)
3. A reaction is monitored by weighing the mass of the reaction flask every 2 min
graph below. Use this to predict what the mass of the flask would be at these

- a. 1 minute

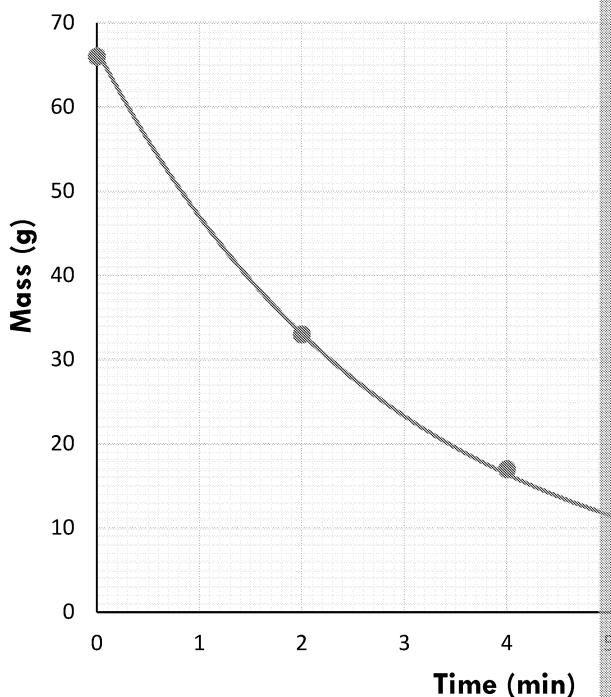
.....

- b. 3 minutes

.....

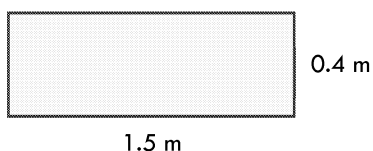
- c. 7 minutes

.....



E1 Geometry and trigonometry

1. A cube has six faces. If all the sides of the cube are 15 mm long, calculate:
- The volume of the cube
 - The surface area of the cube
2. Calculate the area of the following shape.



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1 ARITHMETIC AND NUM COMPUTATION

SPECIFICATION OVERVIEW

Recognise and use expressions in decimal form
Recognise and use expressions in standard form
Use ratios, fractions and percentages
Make estimates of the results of simple calculations

THEORETICAL OVERVIEW

In this section you will learn how to perform some calculations that are important in d fractions, ratios and percentages. You will also learn how to work with numbers that

Fractions and decimals

A fraction is written as one number on top of the other. The value of a fraction is th divided by the bottom number (the *denominator*). For example: $\frac{2}{4}$ is equal to 2 divid written as a **decimal**: 0.5.

Some common fractions and decimals			
Fraction	Decimal (to 3 decimal places)	Fraction	Deci
$\frac{4}{5}$	0.800 (0.8 exactly)	$\frac{1}{3}$	0.333
$\frac{3}{4}$	0.750 (0.75 exactly)	$\frac{1}{4}$	
$\frac{2}{3}$	0.667 (the '6' repeats infinitely)	$\frac{1}{5}$	
$\frac{1}{2}$	0.500 (0.5 exactly)	$\frac{1}{6}$	0.167
$\frac{2}{5}$	0.400 (0.4 exactly)	$\frac{1}{8}$	

Not all fractions have exact values. If you try to write $\frac{1}{3}$ as a decimal (you could try calculator) you get a string of '3's after the decimal point that only ends because th a decimal like this you will have to decide how many digits to include after the deci **places** to write the number to. For example, $\frac{1}{3} = 0.33$ to two decimal places or 0.3

WORKED EXAMPLE 1

Write the fraction $\frac{4}{7}$ as a decimal. Give the answer to three decimal places.

Solution

$4 \div 7 = 0.571$ (you should work this out using a calculator)

More digits are possible in the answer, but the question specifies that only three d should be given. You should look at the fourth decimal place (one more than aske this number. In this case the number is 0.5714. Because 4 is less than 5 you do r

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WORKED EXAMPLE 2

Write the fraction $\frac{7}{11}$ as a decimal. Give the answer to two decimal places.

Solution

$$7 \div 11 = 0.64$$

In this case, you have been asked to give the number to two decimal places, so you need to look at the third decimal place to decide how to round. The number is 0.636. You must round the 3 to 4 (always round up when the digit after the one you are rounding is 5 or bigger).

Fractions can sometimes be simplified, i.e. written using smaller numbers. You do this by dividing both the numerator and the denominator by the same number. This only works if you get whole numbers when you divide both the numerator and the denominator by this number.

WORKED EXAMPLE 3

The number of moles of atoms in an element is calculated using the formula:
number of moles = mass/ A_r

How many moles of beryllium are there in 6 g? (A_r for beryllium = 9)
 Give the answer as a fraction in its simplest form.

Solution

Number of moles = $\frac{6}{9}$. This fraction can be simplified because both the numerator and the denominator are divisible by 3.

divided by 3: number of moles = $\frac{2}{3}$.

Standard form

Sometimes the numbers used in chemistry can be very large (e.g. the number of atoms in a mole) or very small (e.g. the length of the bond between two atoms in a molecule). When studying chemistry, it is often easier to write such numbers without using very long strings of digits – many of which would be zeros.

This is where **standard form** is helpful. Numbers are written in standard form as a number between 1 and 10 multiplied by 10 to a power. For example:

Decimal must be at least 1 but less than 10 $\rightarrow 9.8 \times 10^x$ \rightarrow x can be positive or negative

For very large numbers, a positive value of x is used. For example, in a strip of magnesium (0.001 g) there are about 24.8 billion billion atoms. You could write this as 24 800 000 000 000 000 000. A shorter way is to write it as 2.48×10^{19} . The power to which 10 is raised (+19) tells you how many places you need to move the decimal point to the **right** (adding zeros if necessary) to convert from standard form to a decimal.

For very small numbers, a negative value of x is used. The distance between the oxygen atoms in a molecule of oxygen is 0.000000000097 m. You could write this as 9.7×10^{-11} m. The power to which 10 is raised (-11) tells you how many places you need to move the decimal point to the **left** (adding zeros if necessary) to convert from standard form to a decimal.

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WORKED EXAMPLE 1

Write 2437.8 in standard form.

Solution

Move the decimal point until you get a number that is at least 1 but less than 10. The decimal point moves 3 places. Multiply this decimal by 10^x where x is how many times the decimal point moves. The sign of x is positive since the original number is bigger than 10 (and you move the decimal point to the left).

$$\begin{array}{c} \curvearrowright \curvearrowright \curvearrowright \\ 2437.8 \end{array} = 2.4378 \times 10^3$$

WORKED EXAMPLE 2

Write 0.0631 in standard form.

Solution

Move the decimal point until you get a number that is at least 1 but less than 10. The decimal point moves 2 places. Multiply this decimal by 10^x where x is how many times the decimal point moves. The sign of x is negative since the original number is less than 10 (and you move the decimal point to the right).

$$\begin{array}{c} \curvearrowright \\ 0.0631 \end{array} = 6.31 \times 10^{-2}$$

Using standard form with a calculator

When you enter a number in standard form into a calculator you do not use the normal multiply button and the '1' and '0' buttons to enter ' $\times 10^x$ '. There is a special button that enters ' $\times 10^x$ ' in one go. On some calculators it is written as ' $\times 10^x$ '; on others (usually older models) it is written as 'exp'. Look at the bottom of your calculator on the right-hand side.

**Ratio**

A ratio tells you how big a set of numbers are relative to one another, but not the actual numbers.

For example, if a box of pens contains black and blue pens in the ratio 2:1 this tells us that there are 2 black pens for every 1 blue pen. It does not tell us how many pens there are of either colour.

If we knew the total number of pens, we could work out how many of each there were using the given ratio. One way of doing this is to convert the ratio number into fractions by dividing each number by the sum of the numbers and using this total as the denominator, with each ratio number as the numerator. So for a ratio of 2:1, the fractions are $\frac{2}{3}$ and $\frac{1}{3}$ because $2 + 1 = 3$.

If there are 45 pens in the box, the number of black pens is $\frac{2}{3} \times 45 = 30$ and the number of blue pens is $\frac{1}{3} \times 45 = 15$.

Ratios can sometimes be simplified – you divide all the numbers in the ratio by the same number. For example, 6 moles of hydrogen react with 3 moles of oxygen to produce 6 moles of water, the ratio is 6:3:6. Since 3 can be divided into all of these numbers, the ratio can be simplified to 2:1:2.

A **balanced chemical equation** is written using the simplest reacting ratio of reactants. The balanced chemical equation for the reaction of hydrogen and oxygen is written as $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ (the number '1' is never written).

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WORKED EXAMPLE 1

A dilute acid is prepared by mixing concentrated acid and water in the ratio 1:9.

To prepare a total volume of 100 ml of the diluted acid, what volume of concentrated acid should be used?

Solution

Since $1 + 9 = 10$, the ratio can be written as fractions. Ratio acid:water = $\frac{1}{10} : \frac{9}{10}$

The volume of acid required is $\frac{1}{10} \times 100 = 10$ ml

The volume of water required is $\frac{9}{10} \times 100 = 90$ ml

(You can check the answer by making sure the two volumes add up to the total: $10 + 90 = 100$ ml)

WORKED EXAMPLE 2

The balanced equation for the reaction of nitrogen (N_2) and hydrogen (H_2) to form ammonia is:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

To produce 0.6 moles of NH_3 , how many moles of N_2 and H_2 should be reacted?

Solution

The balanced equation gives you the reacting ratio $N_2:H_2:NH_3 = 1:3:2$

It may be easier to think of these in two pairs. Firstly, $N_2:NH_3 = 1:2$, so to make 0.6 moles of NH_3 (since $0.3:0.6 = 1:2$).

Then, $N_2:H_2 = 1:3$. We now know that 0.3 moles of N_2 is needed, so we can work out the volume of H_2 needed (because $0.3:0.9 = 1:3$).

Finally, check all three amounts are in the right ratio. $N_2:H_2:NH_3 = 0.3:0.9:0.6 = 1:3:2$

Percentages

A percentage can be thought of as a fraction where the denominator is always 100. It is often written as a fraction with 100 on the bottom though. Instead, the symbol '%' is written after the number. The number before the symbol is the numerator, the top number, if it was written as a fraction).

Thinking about percentages as fractions can sometimes help to simplify them.

For example, 25% is the same as $\frac{25}{100}$. Since we know how to simplify fractions by dividing both the top and bottom by the same thing (in this case they can both be divided by 25) we can say $25\% = \frac{1}{4}$.

If you need to express a fraction as a percentage, you simply multiply it by 100. For example, $\frac{7}{20} \times 100 = 35\%$.

WORKED EXAMPLE 1

A mixture of H_2 , I_2 and HI has a total volume of 15 ml. If the mixture contains 20% H_2 and 20% I_2 (by volume), what is the volume of each of the three components of the mixture?

Solution

If 20% of the mixture is H_2 and 20% of the mixture is I_2 , then 60% must be HI (because $20 + 20 + 60 = 100$).

These can be written as fractions and simplified: $20\% = \frac{20}{100} = \frac{1}{5}$ and $\frac{60}{100} = \frac{3}{5}$

So the volume of H_2 in the mixture is $\frac{1}{5} \times 15$ ml = 3 ml

The volume of I_2 in the mixture is also $\frac{1}{5} \times 15$ ml = 3 ml

The volume of HI in the mixture is also $\frac{3}{5} \times 15$ ml = 9 ml

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WORKED EXAMPLE 2

The theoretical yield (the maximum possible mass) of a reaction is 0.45 g. A reaction and gets 0.33 g of product.

What is the percentage yield? Give your answer to one decimal place.

Solution

The question is asking what the amount of product that was actually made (0.33 g) is as a percentage of the theoretical yield (0.45 g).

You can write these numbers as a fraction and multiply by 100 (you will need to use 0.45 on a calculator and then multiply this by 100): $\frac{0.33}{0.45} \times 100 = 73.33\%$, which rounds to one decimal place to give 73.3%.

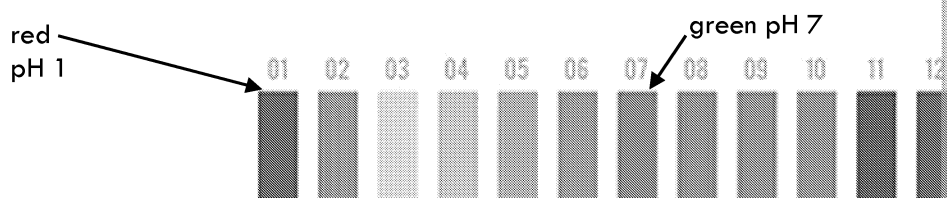
Estimating answers

It is not always possible or necessary to calculate exact answers. It may be that you do not have the data that you are using in a calculation, or it may be that you do not need to know the exact answer so can estimate the answer to make the calculation easier and faster.

For example, when you are trying to understand the structure of atoms it is useful to know the relative sizes of the proton, neutron and electron, but you do not need to know the actual sizes. A proton, a neutron and an electron is thought to be about 0.84, 0.80 and 0.001 fm in size.

You could get your calculator out and work out exactly how much bigger one particle is than another. You need to know this? If you are just trying to get a feel for what an atom is like, you can recognise that protons and neutrons are about the same size (and electrons are about 1000 times smaller).

An example of where we do not have very precise data is working out the concentration of an acid using universal indicator. The indicator colour tells you the pH – but only to the nearest whole number. You need to get your calculator out and use the inverse log function to work out the concentration – you can make an estimate like this: pH 1 is a concentration of 0.1 M, pH 2 is 0.01 M. You can estimate because you do not know the pH value exactly.

**WORKED EXAMPLE 1**

A carbon atom has a radius of 77 pm, a nitrogen atom has a radius of 74 pm and a gallium atom has a radius of 153 pm. Estimate the ratio of sizes of the atoms.

Solution

Because we only need to estimate an approximate answer, we can say that carbon (77 pm) and nitrogen (74 pm) are almost the same size. The gallium atom (153 pm) is close to double the size of the carbon and nitrogen atoms. So, the ratio of the sizes of the atoms can be written as: carbon:nitrogen:gallium = 1:1:2.

WORKED EXAMPLE 2

The rate of a reaction is estimated by timing how long it takes for a colour change. In a reaction, the reaction is set up, it takes 84 s for the colour to change. The reaction is repeated with twice as much of one of the chemicals in the solution. This time it takes 20 s for the colour to change.

Estimate how many times faster the reaction becomes when the amount of the chemical is doubled.

Solution

Since 20 is approximately one quarter of 84, we can say that the reaction was four times faster when performed the second time (with twice as much chemical in the solution).

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PRACTICE QUESTIONS

- Write the number 0.4 as a fraction in its simplest terms.
- In a sample of 0.40 moles of a mixture of gases there are 0.15 moles of hydrogen. The rest of the mixture is oxygen.
 - What is the ratio of hydrogen to oxygen in this mixture? Give the answer in its simplest terms.
 - What fraction of the total number of moles of gas is hydrogen? Write this as a fraction.
 - Convert the answer to part b to a decimal. Round the answer to 2 decimal places.
- Write these numbers in standard form.
 - 0.006423
 - 970854
 - 0.0000582
- The number of atoms or molecules in one mole is called the Avogadro number. Use a calculator to work out how many atoms are in 1.275×10^{-5} moles.
(**HINT:** You need to multiply these two numbers together and give the final answer in standard form.)
- A solution is made by dissolving 41 g of solid in 1.9 dm^3 of water. Estimate the concentration of the solution in g/dm^3 . Give your answer to the nearest 10 g/dm^3 . Do **not** use a calculator.
- The theoretical yield for a reaction is 3.6 g. If a student produces 2.9 g, what percentage of the theoretical yield?
- A sample of an organic compound is analysed and found to contain 0.15 moles of carbon atoms and 0.35 moles of hydrogen atoms.
 - Give the ratio of moles of carbon atoms to moles of hydrogen atoms in the compound. Give the answer in its simplest terms.
 - What fraction of the total number of atoms are carbon atoms? Give the fraction in its simplest terms.
 - Express the answer to part b as a percentage.
- When the concentration of a strong acid increases ten times, the pH decreases by 1. A solution of a strong acid is made by dissolving 5.1 g of acid in 1 dm^3 of solution. Using indicator paper, the pH is approximately 3. Estimate the mass of strong acid that would be needed to make 1 dm^3 of solution with a pH of approximately 2.
- 21% of the volume of air is oxygen. Estimate the volume of oxygen in 250 cm^3 of air. Do **not** use a calculator.
- In an equilibrium mixture of gases, there are 0.84 moles of NO_2 and 0.28 moles of N_2O_4 .
 - What is the ratio of moles of NO_2 to moles of N_2O_4 in its simplest terms?
 - What fraction of the total number of moles is N_2O_4 ?
 - Write the fraction from part b as a decimal.

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2 HANDLING DATA

SPECIFICATION OVERVIEW

Use an appropriate number of significant figures
Find arithmetic means
Make order of magnitude calculations
(Frequency tables are also covered)

THEORETICAL OVERVIEW

In this section you will learn some important statistical processes such as how to work out how to display data in graphical forms, such as frequency tables. You will also learn how to perform calculations to the correct number of decimal places or significant figures.

Significant figures and decimal places

The number of decimal places is how many digits (including zeros) are after the decimal point. To work out how many significant figures are in a number, count all the digits except any zeros at the beginning of the number (as soon as you count the first non-zero digit, count any zeros after that, including zeros at the end).

e.g. The number 0.02030 has five decimal places (five digits after the decimal point) and four significant figures (the first two '0's do not count, but you do count the '0' in the middle of the number (a **contained** or **trapped zero**) and the final '0').

When you are **adding** or **subtracting** numbers, you should give the answer to the same number of decimal places as the numbers you are adding or subtracting. If the numbers do not all have the same number of decimal places, give your answer to the same number of decimal places as the one with the fewest decimal places.

When you are multiplying or dividing, you should give the answer to the same number of significant figures as the numbers you are multiplying or dividing. If the numbers do not all have the same number of significant figures, give your answer to the same number of significant figures as the one with the fewest significant figures.

If the answer that you work out has more significant figures or decimal places than you need, then you need to **round** your answer. Decide how many significant figures or decimal places you need, then look at the next digit to the right of the last one that you are going to include. If it is 5 or more, then you need to 'round up' – increase the last digit by 1. If it is less than 5, do not round up.

WORKED EXAMPLE 1

Give the answer to this calculation: $1.457 + 3.92$

Be careful to give your answer to the correct number of decimal places.

Solution

$1.457 + 3.92 = 5.377$ (if you put it into the calculator this is what you will see)
However, you should give the answer as **5.38** because the number '3.92' has only two decimal places. Since the digit in the third decimal place is 7, you must give your answer to two decimal places. Since the digit in the third decimal place is 7, you must round up.

WORKED EXAMPLE 2

Give the answer to this calculation: 10.9×1.105

Be careful to give your answer to the correct number of significant figures.

Solution

$10.9 \times 1.105 = 12.0445$ (if you put it into the calculator this is what you will see)
However, you should give the answer as **12.0** because the number '10.9' has only three significant figures. Since the fourth significant digit is 4, you must give your answer to three significant figures. Since the fourth significant digit is 4, you must round up – but you must include the last zero (because '12' is only two significant figures).

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The arithmetic mean

The arithmetic mean (sometimes just called 'the mean') is a type of **average** that you calculate for a set of values. You do this by adding the numbers together and dividing by how many numbers there are.

For example, if you take the temperature in your house four times during the day, you can find the average temperature for that day by adding the four temperatures together and dividing by 4.

Say the temperatures that you recorded were 18 °C, 19 °C, 22 °C and 21 °C. The average temperature would be calculated like this:

$$\text{average temperature} = \frac{18 + 19 + 22 + 21}{4} = \frac{80}{4} = 20$$

The rules about how many decimal places or significant figures to give in an arithmetic mean depend on the data that you are working out the mean for. However, a useful guide is that if the data has a certain number of significant figures to include (e.g. 20) then you should give the arithmetic mean to one more significant figure than is in the data.

Imagine you measure the temperature three times and get these values: 19 °C, 20 °C and 19 °C. The average temperature would be calculated like this:

$$\text{average temperature} = \frac{19 + 20 + 19}{3} = \frac{58}{3} = 19.333333$$

There is no justification (or need) for all those '3's in the answer, so applying the rule about significant figures, figure than the data, you should give the answer as **19.3 °C**.

WORKED EXAMPLE 1

A titration is repeated until 3 concordant titres (volumes added from the buret) are obtained. 0.1 cm³ of one another) are obtained. These are:

Titre 1 (cm ³)	Titre 2 (cm ³)	Titre 3 (cm ³)
12.40	12.45	12.40

Calculate the average titre. Give your answer to 2 decimal places.

Solution:

$$\text{average titre} = \frac{12.40 + 12.45 + 12.40}{3} = \frac{37.25}{3} = 12.416666$$

Since the question specifies that the answer must be given to 2 decimal places you should round the answer to 12.42 cm³.

WORKED EXAMPLE 2

A group of five students each measures the volume of gas produced by a chemical reaction in the first 30 seconds. Their results are shown below. Work out the average volume of gas produced.

Student 1 (cm ³)	Student 2 (cm ³)	Student 3 (cm ³)	Student 4 (cm ³)	Student 5 (cm ³)
43.4	40.5	39.8	42.9	41.1

Solution:

$$\text{average volume} = \frac{43.4 + 40.5 + 39.8 + 42.9 + 41.1}{5} = \frac{207.7}{5} = 41.54$$

Applying the rule of using one more significant figure than the data, you should give the answer to 41.5 cm³ (and not round it to 41.5 cm³).

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Frequency tables

A frequency table lists measurements and tells you how often each one occurs in a neater way of displaying the data, but it can also make the process of calculating an example demonstrates how to make a frequency table from a set of data.

WORKED EXAMPLE

You are investigating the masses of 100 cm³ beakers in a laboratory. There are 30 beakers and you weigh all of them and record the masses. You write out the masses from smallest to largest, like this:

33.4 g; 33.4 g; 33.4 g; 33.4 g; 33.4 g; 33.5 g; 33.5 g; 33.6 g; 33.6 g; 33.6 g;
33.6 g; 33.6 g; 33.6 g; 33.6 g; 33.7 g; 33.7 g; 33.7 g; 33.7 g; 33.7 g; 33.7 g;
33.7 g; 33.8 g; 33.8 g; 33.8 g; 33.8 g; 33.8 g; 33.8 g; 33.8 g; 33.9 g; 33.9 g; 33.9 g

Display this data in a frequency table.

Solution:

To produce a frequency table, list all the values for the masses in one column and the frequency of each value in the next column.

Mass (g)	Frequency
33.4	5
33.5	2
33.6	7
33.7	7
33.8	6
33.9	3

Calculating averages from frequency tables

To calculate the mean using a frequency table, add an extra column that shows the mass \times frequency and find the total of all the numbers in this column. The mean is this total divided by the number of beakers (30) to get the mean.

WORKED EXAMPLE 1

Using the frequency table (masses of 100 cm³ beakers) from the previous section, calculate the mean average mass.

Solution:

Add the mass \times frequency column to the table and work out the total of the numbers in this column. This gives the total mass of all 30 beakers (and you avoided having to add up all 30 numbers!). Divide this total by the number of beakers (30) to get the mean.

Mass (g)	Frequency	Mass \times frequency (g)
33.4	5	167
33.5	2	67
33.6	7	235.2
33.7	7	235.9
33.8	6	202.8
33.9	3	101.7
Total		1009.6

$$1009.6 / 30 = 33.65333333$$

Applying the rule of using one more significant figure than the data, you should give the mean as 33.7 g.

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Calculating orders of magnitude

An order of magnitude calculation is a special type of estimation where you are trying to find the nearest multiple of ten, i.e., 1, 10, 100, 1000, etc. You could also write these numbers as 10^0 , 10^1 , 10^2 , 10^3 , etc.

WORKED EXAMPLE

The mass of a proton is 1.67×10^{-27} kg. The mass of an electron is 9.11×10^{-31} kg. How many orders of magnitude bigger is the mass of the proton compared to the electron?

Solution:

Since we are only working with orders of magnitude, we can round both numbers to the nearest power of ten.

$$1.67 \times 10^{-27} \approx 10^{-27} \text{ and } 9.11 \times 10^{-31} \approx 10^{-30}$$

Divide the mass of the proton by that of the electron using just the orders of magnitude.

$$10^{-27} / 10^{-30} = 10^3 \text{ (1000 or 'three orders of magnitude')}$$

PRACTICE QUESTIONS

- Calculate $119.4 \div 3.21$, giving your answer to the appropriate number of significant figures.
- The mass of a solid was recorded using four different balances. The results were: 12.423 g; 12.5 g; 12.46 g and 12.4 g.
 - Calculate the total of these masses. Give your answer to an appropriate number of significant figures.
 - What is the arithmetic mean of these masses? Give your answer to two decimal places.
- Five students measure the time taken for a colour change in a chemical reaction. The results are shown in the table below.

Student	1	2	3	4	5
Time taken (s)	97	89	92	99	95

What is the arithmetic mean average time for the reaction?

- A class of 25 students each drops a lump of limestone into some dilute acid and measures the volume of gas produced over a period of 30 seconds. Their results are shown below.

Number of bubbles =

25; 26; 26; 27; 27; 27; 27; 28; 28; 28; 28; 29; 29; 29; 29; 29; 29; 30; 30; 30; 30; 30; 30; 30; 30; 30

 - Produce a frequency table from this data including a column with **number of bubbles**.
 - Use the frequency table to calculate the arithmetic mean average for the 30 seconds.
- The pH of saliva samples from a group of people was measured. The results are shown below.

pH = 6.5; 7.0; 6.9; 6.8; 7.1; 6.6; 7.3; 7.0; 6.9; 7.2; 6.4; 6.3; 6.9; 6.2; 7.0; 7.1

Produce a frequency table from this data.
- One indicator of air quality is the amount of 'PM_{2.5}' particles in the air. These are particles with a diameter of no more than 2.5×10^{-6} m. These particles often get into the air as soot from the burning of fossil fuels, mainly carbon. A carbon atom has a diameter of approximately 1.5×10^{-10} m. How many orders of magnitude bigger is a 'PM_{2.5}' particle compared to a single carbon atom?

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3 ALGEBRA

SPECIFICATION OVERVIEW

Change the subject of an equation

Substitute numerical values into algebraic equations using appropriate units for p

THEORETICAL OVERVIEW

In this section you will learn how to use equations in calculations, including how to rearrange equations to calculate different things.

Rearranging equations

Many equations are used in chemistry to work out quantities. For example, you can calculate the mass of a substance using the equation: $\text{mass} = \text{number of moles} \times M_r$. To calculate mass you need to multiply the number of moles by M_r (the relative formula mass). What if you know the mass and want to calculate the number of moles? To do this you need to rearrange the equation to make the number of moles the **subject** of the equation (the variable that you are solving for, the '=' sign).

To rearrange an equation, you perform an operation on **both** sides of the equation. The operation involved with a term (a part of the equation) that you want to move (it must be the same operation on both sides).

In simple terms, if a term is being **multiplied** in an equation you can move it by **dividing** by that term (because dividing is the inverse of multiplying). If a term is being **added** to an equation you can move it by **subtracting** it from both sides of the equation (because subtracting is the inverse of adding).

WORKED EXAMPLE 1

Rearrange the equation $\text{mass} = \text{number of moles} \times M_r$ so that it could be used to calculate number of moles from mass and M_r .

Solution:

The equation has mass as its subject, so it needs rearranging to make number of moles the subject (what we want to find).

We need to get the term 'number of moles' on its own. We can move the term ' M_r ' by dividing both sides of the equation by it like this:

$$\frac{\text{mass}}{M_r} = \frac{\text{number of moles} \times M_r}{M_r}$$

The term ' M_r ' on the right side of the equation vanishes since it is divided by itself.

$$\frac{\text{mass}}{M_r} = \text{number of moles} \text{ or: } \text{number of moles} = \frac{\text{mass}}{M_r}$$

WORKED EXAMPLE 2

Rearrange the equation $\text{mass number} = \text{number of protons} + \text{number of neutrons}$ so that it could be used to calculate number of protons when the mass number and number of neutrons are known.

Solution:

The equation has mass number as its subject, so it needs rearranging to make number of protons the subject (since this is what we want to find).

We need to get the term 'number of protons' on its own. We can move the term 'number of neutrons' by subtracting it from both sides of the equation by it like this:

$$\text{mass number} - \text{number of neutrons} = \text{number of protons} + \text{number of neutrons} - \text{number of neutrons}$$

The term 'number of neutrons' on the right side of the equation vanishes since it is subtracted from itself.

$$\text{mass number} - \text{number of neutrons} = \text{number of protons}$$

$$\text{or: } \text{number of protons} = \text{mass number} - \text{number of neutrons}$$

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Solving equations by substitution

'Solving an equation by substitution' simply means replacing all but one of the variables with values, and then working out the value of the remaining variable.

For example, if $y = 2x$ and you are told that $x = 7$, then substituting 7 for x gives $y = 14$.

If the variable that you want to find a value for is not the subject of the equation then you must rearrange the equation first, then make the substitutions.

WORKED EXAMPLE 1

A solution is made by dissolving 0.095 moles of substance in 0.50 dm³ of solution. To work out the concentration of the solution, the equation $\text{concentration} = \frac{\text{number of moles}}{\text{volume}}$ is used.

Solution:

Since number of moles = 0.095 and volume = 0.5 dm³, we can substitute these values into the equation to calculate the concentration: $\text{concentration} = \frac{0.095}{0.50} = 0.19 \text{ mol/dm}^3$

WORKED EXAMPLE 2

Use the equation $\text{concentration} = \frac{\text{number of moles}}{\text{volume}}$ to work out how many moles of substance are needed to make 0.25 dm³ of solution with a concentration of 1.5 mol/dm³.

Solution:

First, we need to rearrange the equation to make the number of moles the subject of the equation. To do this, multiply both sides by volume you get: $\text{number of moles} = \text{concentration} \times \text{volume}$.

Then you can substitute in the values: $\text{number of moles} = 1.5 \times 0.25 = 0.375$ (since the units in the values of number of moles and volume, we could round the answer to 0.38 moles).

Dealing with units in equations

When you work out a value by substituting numbers into an equation, you need to make sure that the units match with the value. These should match the units in the numbers you have used in the equation. If the units do not match, then the answer will be wrong.

For example, the density of a substance can be calculated from the formula $\text{density} = \frac{\text{mass}}{\text{volume}}$.

If you are told a substance has a mass of 142 g and a volume of 200 cm³, you would calculate the density as follows:

$$\text{density} = \frac{142 \text{ g}}{200 \text{ cm}^3} = 0.710 \text{ g/cm}^3$$

WORKED EXAMPLE 1

1.26 g of a solid is dissolved in water and made up to a total volume of 30 cm³. To work out the concentration of the solution, the equation $\text{concentration} = \frac{\text{mass}}{\text{volume}}$ is used.

Solution:

$\text{concentration} = \frac{1.26 \text{ g}}{30 \text{ cm}^3} = 0.042 \text{ g/cm}^3$. The units for the answer must be g/cm³ (or mol/dm³) because the units in the numbers that were substituted into the equation are g and cm³.

When you are substituting numbers into equations, you need to be careful about the units. If the units for different variables do not match, you will not get the correct answer. Sometimes you need to convert some numbers to make sure that they all match before carrying out the calculation.

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Here are a few unit conversions that are common in chemistry:

Quantity	Units	How to convert
Mass	1 kg = 1000 g	Divide by 1000 to go from kg to g Multiply by 1000 to go from g to kg
Volume	1 dm ³ = 1000 cm ³	Divide by 1000 to go from dm ³ to cm ³ Multiply by 1000 to go from cm ³ to dm ³
Concentration	1 mol/cm ³ = 1000 mol/dm ³ 1 g/cm ³ = 1000 g/dm ³	Divide by 1000 to go from cm ³ to dm ³ Multiply by 1000 to go from dm ³ to cm ³ (do the same for g/cm ³)
Energy	1 kJ = 1000 J	Divide by 1000 to go from kJ to J Multiply by 1000 to go from J to kJ

WORKED EXAMPLE 2

Use the equation **number of moles = concentration × volume** to work out how much substance would be needed to make 50 cm³ of solution with a concentration of 0.25 mol/dm³.

Solution:

First, we need to do a unit conversion because the concentration is in a different unit to the volume.
 $50 \text{ cm}^3 = 50 / 1000 \text{ dm}^3 = 0.050 \text{ dm}^3$

Then we can make the substitutions: $\text{number of moles} = 0.25 \text{ mol/dm}^3 \times 0.050 \text{ dm}^3$

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PRACTICE QUESTIONS

1. In a chemical reaction, the percentage yield can be calculated using this equation:

$$\text{percentage yield} = \frac{\text{actual mass of product}}{\text{theoretical mass of product}} \times 100$$

- Rearrange the equation to make actual mass of product the subject.
 - In a reaction where the theoretical mass of product is **2.5 g** and the percentage yield is **80%**, what would the actual yield be?
2. The relative formula mass of a metal chloride salt (where the metal is from group 1) is calculated by adding together the relative atomic masses of the metal and chlorine shown by this equation:

$$M_r = A_r(\text{metal}) + A_r(\text{chlorine})$$

- Rearrange the equation to make $A_r(\text{metal})$ the subject.
 - The relative formula mass of the compound, M_r , is **74.5**, and the relative atomic mass of chlorine, $A_r(\text{chlorine})$, is **35.5**. Use this information and your answer to part a to calculate the relative atomic mass of the group 1 metal. Which metal is it?
3. The number of moles of a gas can be calculated from this equation:

$$\text{moles} = \frac{\text{volume (dm}^3\text{)}}{24 \text{ dm}^3/\text{mol}}$$

A reaction produces 420 cm^3 of gas.

- Convert the volume (420 cm^3) into dm^3 . (**HINT:** there are 1000 cm^3 in 1 dm^3)
 - How many moles of gas were produced?
4. In a titration, 24.55 cm^3 of a solution with a concentration of 0.150 mol/dm^3 was used in a burette. How many moles of chemical were dispensed?

$$\text{moles} = \text{concentration (mol/dm}^3\text{)} \times \text{volume (dm}^3\text{)}$$

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4 GRAPHS

SPECIFICATION OVERVIEW

Translate information between graphical and numeric form
Plot two variables from experimental or other data
Determine the slope and intercept of a linear graph

THEORETICAL OVERVIEW

In this section you will learn how to create graphs from data by plotting two variables (one on the x-axis and one on the y-axis). Graphs will be used to see data in a visual form but also to analyse data.

Plotting and reading graphs

A graph consists of a set of points that are plotted in specific positions described by the coordinates of the axes of the graph. Often the horizontal axis is referred to as the x-axis and the vertical axis as the y-axis. The numbers on the x-axis are values of an *independent* variable, i.e. something that has been deliberately changed by the person collecting the data (or allowed to change naturally, e.g. time progressing). The numbers on the y-axis are values of a *dependent* variable, i.e. values that have been measured in the experiment – these are called the *dependent* variable.

A **line of best fit** (sometimes called a trend line) is a straight line or a curve that passes through the points on a graph, showing how the two variables are related. It does not have to touch all (or even any) of the points. It is a line running between the points and not a 'dot-to-dot' series of lines joining them up.

WORKED EXAMPLE 1

The data shown was collected by measuring the rate of a series of reactions, each with a different concentration of sodium hydroxide. Plot these on a graph with a line of best fit.

Concentration of sodium hydroxide (mol/dm^3)	Rate of reaction ($\text{mol/dm}^3/\text{min}$)
0.010	0.035
0.020	0.065
0.050	0.150
0.080	0.250
0.100	0.350

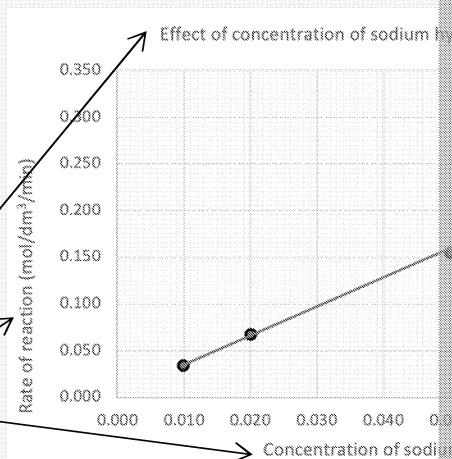
Solution:

The independent variable is the concentration of sodium hydroxide (since this is what has been deliberately changed), so these numbers go on the x-axis with the rate of reaction on the y-axis.

Title describes what the graph is showing

Both axes are labelled with the name of the variable **and** the units

Line of best fit is through the middle of the points (some are above and some below the line)



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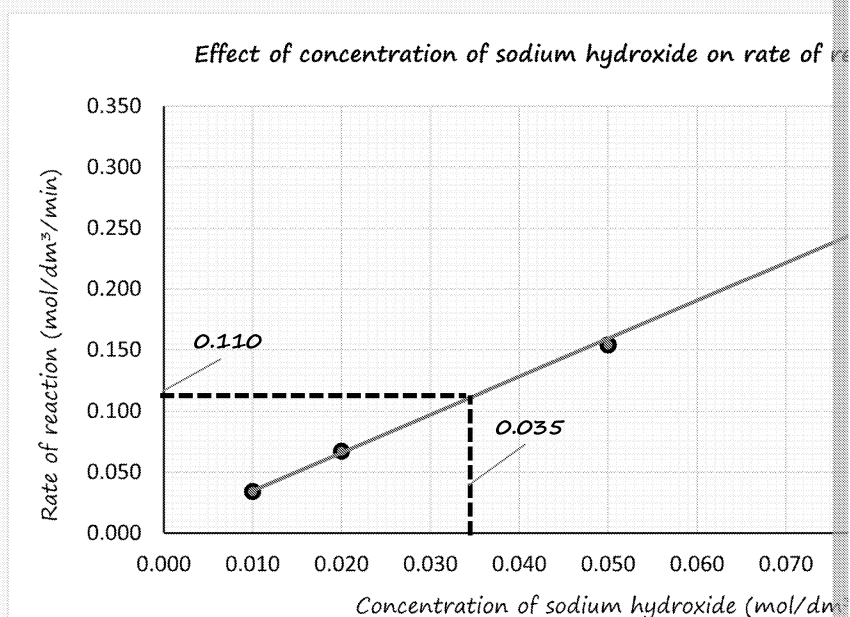
Graphs with a line of best fit can be used to convert the value of one of the variables into the value of the other. To find the value that you know on the axis and drawing a straight line (horizontally from the x-axis) until it meets the line of best fit. Then draw another line from this point to the y-axis and read the value.

WORKED EXAMPLE 2

Using the graph from WORKED EXAMPLE 1, find out what the rate of reaction was when the concentration of sodium hydroxide was 0.035 mol/dm^3 .

Solution:

Find 0.035 on the x-axis, draw a vertical line from this to the line of best fit, then draw a horizontal line to the y-axis and read the rate of reaction: 0.110 mol/dm^3 .



Straight line graphs

The slope (gradient) of a line can be found by dividing the change in y by the change in x (longer sections tend to give more accurate measurements). The y -intercept is found on the y -axis where the line of best fit crosses it (i.e. the value of y when $x = 0$).

It is important to understand what the gradient of a line means. It is a measure of how much the y -axis is affected by changes in the variable on the x -axis. In the worked example, a steeper line (had a larger gradient), it would mean that changing the concentration of sodium hydroxide had a bigger effect on the rate of reaction.

When the variable on the x -axis is **time**, the gradient of the line of best fit tells you how fast the rate of reaction is changing. Steep lines mean a rapid change while lines with a lower gradient indicate a slower change.

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WORKED EXAMPLE

A reaction that releases carbon dioxide gas was set up in an open flask and every minute. Plot the data in the table below and work out the slope and the

Time (min)	0	1	2	3	4
Mass of flask (g)	43	41	39	37	35

Solution:

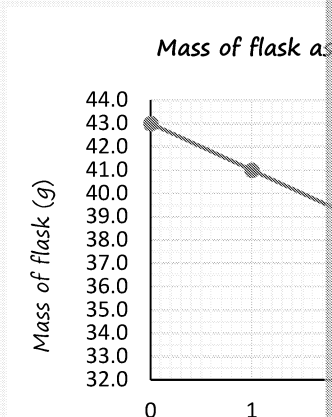
Plot the graph and find the y-intercept: 43.0.

Work out the gradient by dividing the change in y over the whole line

(33.0 g – 43.0 g = –10.0 g – it's a negative number because the mass is decreasing) by the change in x over the whole line

(5 min – 0 min = 5 min):

Gradient = –10.0 g/5 min = –2 g/min

**PRACTICE QUESTIONS**

1. The rate of a chemical reaction between two gases is measured at different pressures. The results are shown in the table below.

Pressure (atms)	1.0	1.5	2.0	2.5
Rate of reaction (mol/min)	0.63	0.94	1.25	1.61

- Plot the data on a graph and add a trend line. Extend the trend line back to read off the intercept on the y-axis (the rate of reaction when pressure = 0).
- Measure the gradient of the trend line.

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5 GEOMETRY AND TRIGONOMETRY

SPECIFICATION OVERVIEW

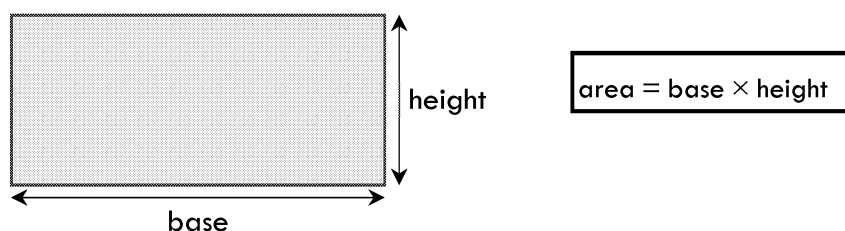
Calculate areas of rectangles and surface areas and volumes of cubes

THEORETICAL OVERVIEW

In this section you will learn how to perform some calculations to work out areas and volumes of shapes such as rectangles and cubes.

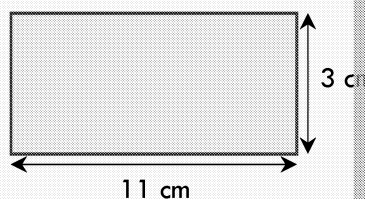
Calculating areas of rectangles

The area of a rectangle is calculated by multiplying the length of its base by its height.



WORKED EXAMPLE 1

Calculate the area of the rectangle shown.



Solution: $\text{area} = \text{base} \times \text{height} = 11 \text{ cm} \times 3 \text{ cm} = 33 \text{ cm}^2$

Note that because you are multiplying cm by cm, the answer is in units of cm^2 .

Calculating the surface area and volume of a cube

The volume of a cube is calculated by multiplying the length, height and width of the cube together. A cube has all sides the same length, so volume of cube = l^3 , where l is the length of all sides.

To work out the surface area of a cube, think about each of the six faces as a square with sides of length l . The area is found by squaring l .

Since there are six faces, surface area of cube = $6l^2$.

WORKED EXAMPLE 1

Calculate the volume and surface area of a cube which has sides of length 5 mm.

Solution:

volume of cube = $l^3 = (5 \text{ mm})^3 = 5 \text{ mm} \times 5 \text{ mm} \times 5 \text{ mm} = 125 \text{ mm}^3$.

Note the units of volume are whichever units of length were used, but cubed.

surface area of cube = $6l^2 = 6 \times (5 \text{ mm})^2 = 6 \times 5 \text{ mm} \times 5 \text{ mm} = 150 \text{ mm}^2$

Note the units of surface area are whichever units of length were used, but squared.

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WORKED EXAMPLE 2

The cube in **WORKED EXAMPLE 1** is cut in half along every side producing eight smaller cubes, each with sides of 2.5 mm.

What is the total volume and total surface area of these eight cubes?

Solution:

The volume of each cube is $(2.5 \text{ mm})^3 = 15.625 \text{ mm}^3$, so the total volume of all eight cubes is $15.625 \text{ mm}^3 \times 8 = 125 \text{ mm}^3$. This is exactly the same as the volume before the cube was cut – because the total volume should be the same since none of the cube is lost and no new material is gained.

The surface area of each cube is $6 \times 2.5 \text{ mm} \times 2.5 \text{ mm} = 37.5 \text{ mm}^2$ so the total surface area of all eight cubes is $37.5 \text{ mm}^2 \times 8 = 300 \text{ mm}^2$. This is double the surface area of the single cube – but when you cut a cube, you have exposed new surfaces. It is always true that when a piece of material is cut into smaller pieces, the total volume remains the same but the total surface area increases.

PRACTICE QUESTIONS

1. A microscope slide is a rectangle with length = 75 mm and width = 26 mm. Calculate its surface area.
2. A cube measuring 2 cm on all sides is cut into eight smaller cubes, each measuring 1 cm on all sides.
 - a. What is the total volume of the eight small cubes?
 - b. What is the surface area of the original, larger cube?
 - c. What is the **total** surface area of all eight smaller cubes?

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DIAGNOSTIC TEST

A2 Arithmetic and numerical computation

1. Write the fraction $\frac{1}{6}$ as a decimal to three decimal places.
.....
2. Write the fraction $\frac{3}{4}$ as a decimal.
.....
3. Which of the following is the correct way to write the number 0.007849 in standard form?
A. 7.849×10^3 ☐
B. 7.849×10^2 ☐
C. 7.849×10^{-3} ☐
D. 7.849×10^{-2} ☐
4. 1.8 moles of calcium react with 3.6 moles of water. Express this molar ratio as a simplified fraction.
.....
5. Two gases are mixed in the ratio 7:2. If the total volume of gases is 45 cm³, what is the volume of each gas?
.....
.....
6. Convert the decimal 0.125 to the following:
a. a percentage
b. a fraction
7. A chemical weighing 0.821 g is heated in air until its mass becomes 1.270 g.
a. How much mass has been gained?
.....
b. Express the mass gained as a percentage of the original mass.
.....
8. A human hair is approximately 7.0×10^{-5} m wide, and a carbon atom is about 0.15 nm wide. Estimate, to the nearest one hundred thousand, how many carbon atoms could fit across the width of a human hair.
.....

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DIAGNOSTIC TEST

B2 Handling data

1. How many significant figures are in the following numbers?
 - a. 0.475
 - b. 12.0089
 - c. 0.004030
2. Give the answers to these calculations. Make sure that you give the answer to places, rounding if necessary.
 - a. $17.925 + 0.1837$
 - b. $1.608 - 0.24$
 - c. $0.032 + 0.0073$
3. Give the answers to these calculations. Make sure that you give the answer to figures, rounding if necessary.
 - a. $9.39 \div 3.0$
 - b. 401×0.125
 - c. 0.264×12.69
4. The temperature of a liquid was measured three times. The results were: 28.9,
.....
.....
mean average temperature?
5. A class is asked to measure the rate of a reaction by timing how long it takes
Twenty students each measured the time in seconds, and their measurements (p
Put this data into a frequency table and from that calculate the arithmetic mea
colour change.
Time (seconds): 66, 66, 67, 67, 67, 67, 68, 68, 68, 68, 69, 69, 69, 69, 69, 69, 69, 69, 69, 69

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DIAGNOSTIC TEST

C2 Algebra

1. The concentration of a solution can be calculated using the formula: concentration

Use this equation to calculate how many moles of solute would be needed to make 1 dm³ of a solution with a concentration of **2.50 mol/dm³**.

.....

.....

.....

2. Rearrange the equation $4p + 2q = 2x + 6$ to make x the subject.

.....

3. The number of moles of a substance can be calculated using the formula:

$$\text{number of moles (mol)} = \frac{\text{mass of substance (g)}}{M_r \text{ (g/mol)}}$$

Calculate the M_r of a substance if 24.0 moles of that substance has a mass of 480 g.

You will need to pay careful attention to the units.

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DIAGNOSTIC TEST

D2 Graphs

1. A wet compound is dried by heating it in a warm oven. The compound is taken out at regular intervals, cooled and weighed. The mass of the compound (plus any remaining water) and the time taken are shown below.

Time (min)	Mass (g)
0	92.4
5	46.2
10	23.8
15	11.2
20	5.6

Plot the data shown in the table below on graph paper and draw a line of best fit.

E2 Geometry and trigonometry

1. a. What is the volume and total surface area of a cube with sides that are 2 cm long?
- i) volume.....
- ii) surface area.....
- b. If the cube was cut into eight cubes by cutting each of the three sides in half, what is the volume and total surface area of the eight cubes?
- i) total volume.....
- ii) total surface area

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SOLUTIONS TO QUESTIONS

DIAGNOSTIC TEST 1

A1 Arithmetic and numerical computation

- 0.375
- 0.444
- B. 2.1368×10^4
- 2:3
- $3 + 1 = 4$
 $8 \text{ dm}^3 / 4 = 2 \text{ dm}^3$
 $3 \times 2 \text{ dm}^3 = 6 \text{ dm}^3$ and $1 \times 2 \text{ dm}^3 = 2 \text{ dm}^3$
- a. 25%
b. $\frac{1}{4}$
- a. $1.20 \text{ g} - 0.84 \text{ g} = 0.36 \text{ g}$
b. $(0.36 \text{ g} / 1.20 \text{ g}) \times 100 = 30\%$
- Approximately $2.5 \mu\text{m} / 0.1 \mu\text{m} = 25$ times bigger
- The difference between 3.2 and 6.1 is close to 3, so the concentration of H^+ is close to $3 \times 10 \times 10 = 1000$ times

B1 Handling data

- a. Six
b. Four
c. Five
- a. 1.821 (three decimal places)
b. 11.47 (two decimal places)
c. 0.015 (three decimal places)
- a. 5.0 (4.966... rounded to two significant figures)
b. 3.7 (3.675 rounded to two significant figures)
c. 6.10 (6.09525 rounded to three significant figures)
- $(8.4 + 8.5 + 8.3) / 3 = 8.4$
-

Rate (no. bubbles)	Frequency	Rate \times frequency
98	3	
99	4	
100	6	
101	7	
102	3	
103	2	
Total		

Mean = $2509 / 25 = 100.36$ (100.4 would be acceptable)

C1 Algebra

- Mass of product formed = rate \times time
Mass of product formed = $0.85 \text{ g/s} \times 15 \text{ s}$
= 12.75 g (13 g to two significant figures)
- $x = \frac{y-7}{4}$
- $250 \text{ cm}^3 = 0.250 \text{ dm}^3$
concentration (mol/dm^3) = $\frac{0.445 \text{ mol}}{0.250 \text{ dm}^3} = 1.78 \text{ mol/dm}^3$

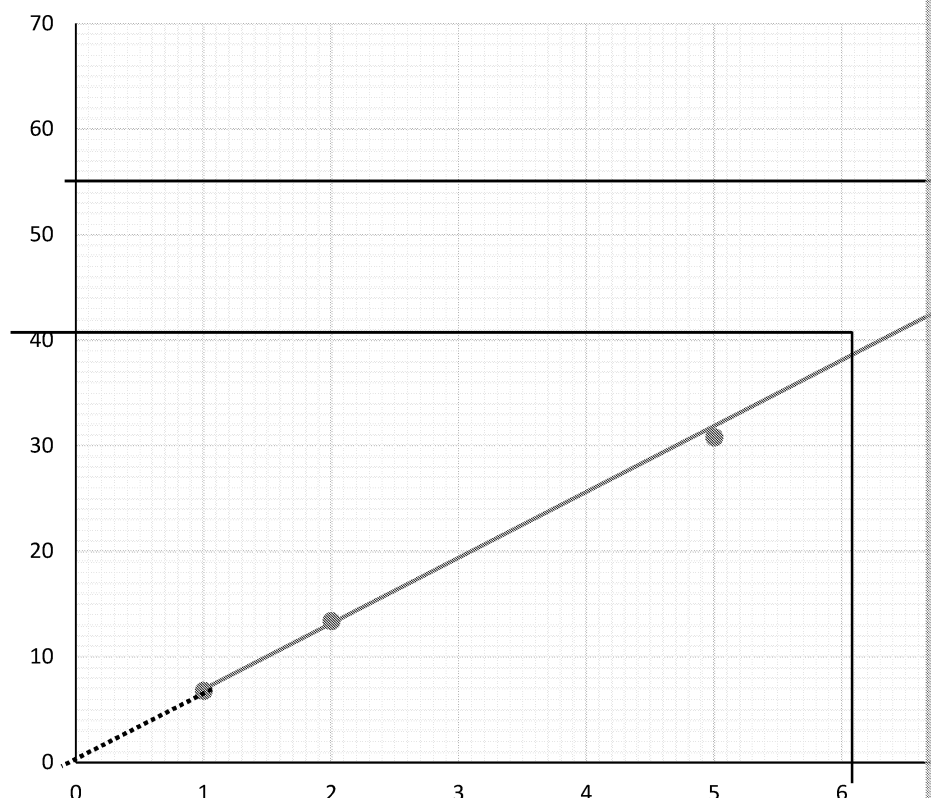
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D1 Graphs

1.



2.
 - a. $y = 41$ (allow 41 to 42)
 - b. $x = 8.7$ (allow 8.5 to 8.7)
 - c. $y = 0.7$ (allow 0 to 1)
3.
 - a. 47 g
 - b. 23.5 g (allow 23–24 g)
 - c. 5.5 g (allow 5–6 g)

E1 Geometry and trigonometry

1.
 - a. Volume of cube = $(15 \text{ mm})^3 = 3375 \text{ mm}^3$
 - b. Surface area of cube = $6 \times 15 \text{ mm} \times 15 \text{ mm} = 1350 \text{ mm}^2$
2. $1.5 \text{ m} \times 0.4 \text{ m} = 0.6 \text{ m}^2$

PRACTICE QUESTIONS

Arithmetic and numerical computation

1. $0.4 = \frac{4}{10} = \frac{2}{5}$ (1)
2.
 - a. Moles of oxygen = $0.40 - 0.15 = 0.25$; ratio hydrogen:oxygen = $0.15:0.25$
 - b. $\frac{0.15}{0.40} = \frac{3}{8}$ (1)
 - c. $\frac{3}{8} = 0.375 = 0.38$ (two decimal places) (1)
3.
 - a. 6.423×10^{-3} (1)
 - b. 9.70854×10^5 (1)
 - c. 5.82×10^{-5} (1)
4. $6.022 \times 10^{23} \times 1.275 \times 10^{-5} = 7.67805 \times 10^{18}$ (7.678×10^{18} is an acceptable answer) (1)
5. This is approximately $40 \text{ g}/2 \text{ dm}^3 = 20 \text{ g}/\text{dm}^3$ (1)
6. $\frac{2.9 \text{ g}}{3.6 \text{ g}} \times 100 = 80.55\% = 81\%$ (to two significant figures) (1)

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7. a. $C:H = 0.15:0.35 = 3:7$ (1)
 b. $\frac{0.15 \text{ moles}}{(0.15 + 0.35) \text{ moles}} = \frac{0.15 \text{ moles}}{0.50 \text{ moles}} = \frac{3}{10}$ (1)
 c. $\frac{3}{10} \times 100 = 30\%$ (1)
8. To decrease the pH by about one unit, you need approximately ten times as much of solution. Since just over 5 g in 1 dm³ makes a solution with pH = 3, about 50 g in 1 dm³ solution with a pH of 2. (1)
9. This is easiest to do using fractions. Since the percentage is very nearly 20% of the volume of air is oxygen. $\frac{1}{5}$ of 250 cm³ = **50 cm³**. (1)
10. a. $NO_2:N_2O_4 = 0.84:0.28 = 3:1$ (1)
 b. You could work it out without the ratio like this: $\frac{0.28}{(0.84 + 0.28)} = \frac{0.28}{1.12} = \frac{1}{4}$ but it is easier to use the ratio: 3 + 1 = 4 so $\frac{1}{4}$ of the total number of moles is N₂O₄ (1)
 c. $\frac{1}{4} = 0.25$ (1)

Handling data

1. **37.2** (37.196... rounded to three significant figures) (1)
2. a. $12.423 + 12.5 + 12.46 + 12.4 = \mathbf{49.8 \text{ g}}$ (49.783 rounded to one decimal place) (1)
 b. $\frac{49.783}{4} = 12.44575 = \mathbf{12.45}$ to two decimal places (1)
3. $\frac{(97 + 89 + 92 + 99 + 95)}{5} = 94.4$ seconds (1)
4. a.

Number of bubbles	Frequency
25	1
26	2
27	4
28	4
29	6
30	3
31	2
32	2
33	1
Total	

(2 – 1)

- b. Arithmetic mean = $\frac{720}{25} = 28.8$ (1)

5.

pH	Frequency	pH
6.2	1	6.9
6.3	1	7.0
6.4	1	7.1
6.5	1	7.2
6.6	2	7.3
6.7	0	7.4
6.8	2	

6. $\frac{10^{-6}}{10^{-10}} = 10^4$ (10 000) (1)

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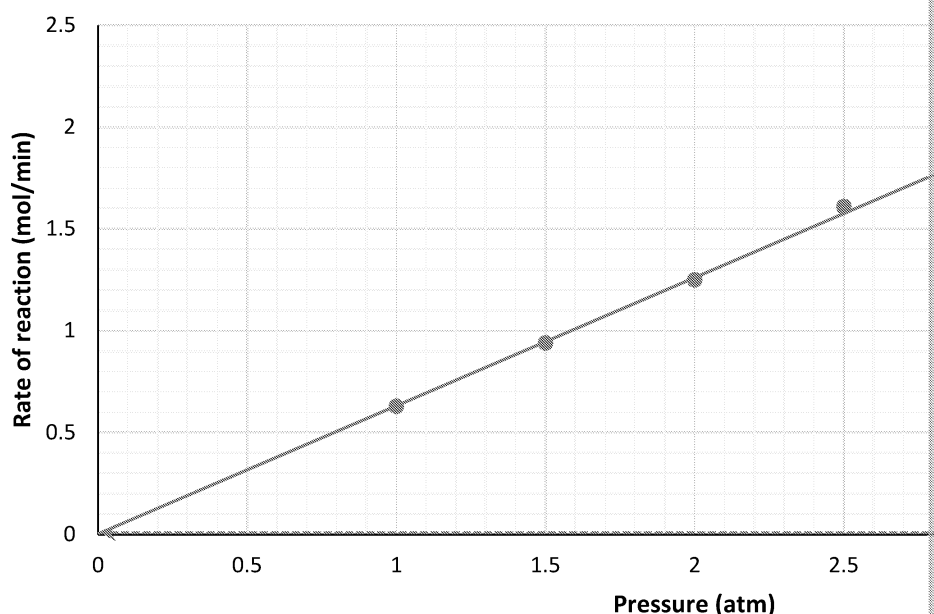
Algebra

- actual mass of product = $\frac{\text{percentage yield} \times \text{theoretical mass of product}}{100}$ (1)
 - actual mass of product = $\frac{59 \times 2.5 \text{ g}}{100} = 1.475 \text{ g}$ (1.5 g to two significant figures) (1)
- $A_r(\text{metal}) = M_r - A_r(\text{chlorine})$ (1)
 - $A_r(\text{metal}) = 74.5 - 35.5 = 39$ (1) The metal is **potassium** (1)
- $420 \text{ cm}^3 = 0.420 \text{ dm}^3$ (1)
 - moles = $\frac{0.420}{24} = 0.0175$ (1)
- $24.55 \text{ cm}^3 = 0.02455 \text{ dm}^3$ (1)
 moles = $0.150 \times 0.02455 = 0.0036825 = 3.68 \times 10^{-3}$ (three significant figures) (1)

Graphs

- Correct plotting (1), trend line drawn correctly (1) Intercept at y-axis = 0 (1)

Rate of reaction at different pressures



- Gradient = $2.2 / 3.5 = 0.63 \text{ mol/min/atm}$ (to two significant figures) (1)

Geometry and trigonometry

- area = $75 \text{ mm} \times 26 \text{ mm} = 1950 \text{ mm}^2$ (1) (allow rounding to two significant figures) (1)
- You can calculate the volume of the original, larger cube since the volume of the smaller cube is divided into smaller cubes. volume of cube = $(2 \text{ cm})^3 = 8 \text{ cm}^3$ (1) (It could also be done as total volume = $8 \times (1 \text{ cm})^3 = 8 \text{ cm}^3$) (1)
 - surface area of cube = $6 \times 2 \text{ cm} \times 2 \text{ cm} = 24 \text{ cm}^2$ (1)
 - surface area of eight cubes = $8 \times 6 \times 1 \text{ cm} \times 1 \text{ cm} = 48 \text{ cm}^2$ (1)

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DIAGNOSTIC TEST 2**A2 Arithmetic and numerical computation**

- 0.167
- 0.75
- C. 7.849×10^{-3}
- 1:2
- 35 cm^3 and 10 cm^3
- 12.5%
 - $\frac{1}{8}$
- 0.449 g
 - 54.7% (to three significant figures)
- 200 000

B2 Handling data

- Three
 - Six
 - Four
- 18.109
 - 1.37
 - 0.039
- 3.1
 - 50.1
 - 3.35
- 28.93 (to four significant figures)
-

Time (s)	Frequency	
66	2	
67	4	
68	4	
69	6	
70	3	
71	1	
Total		

$$\text{Mean} = 1367 / 20 = 68.35$$

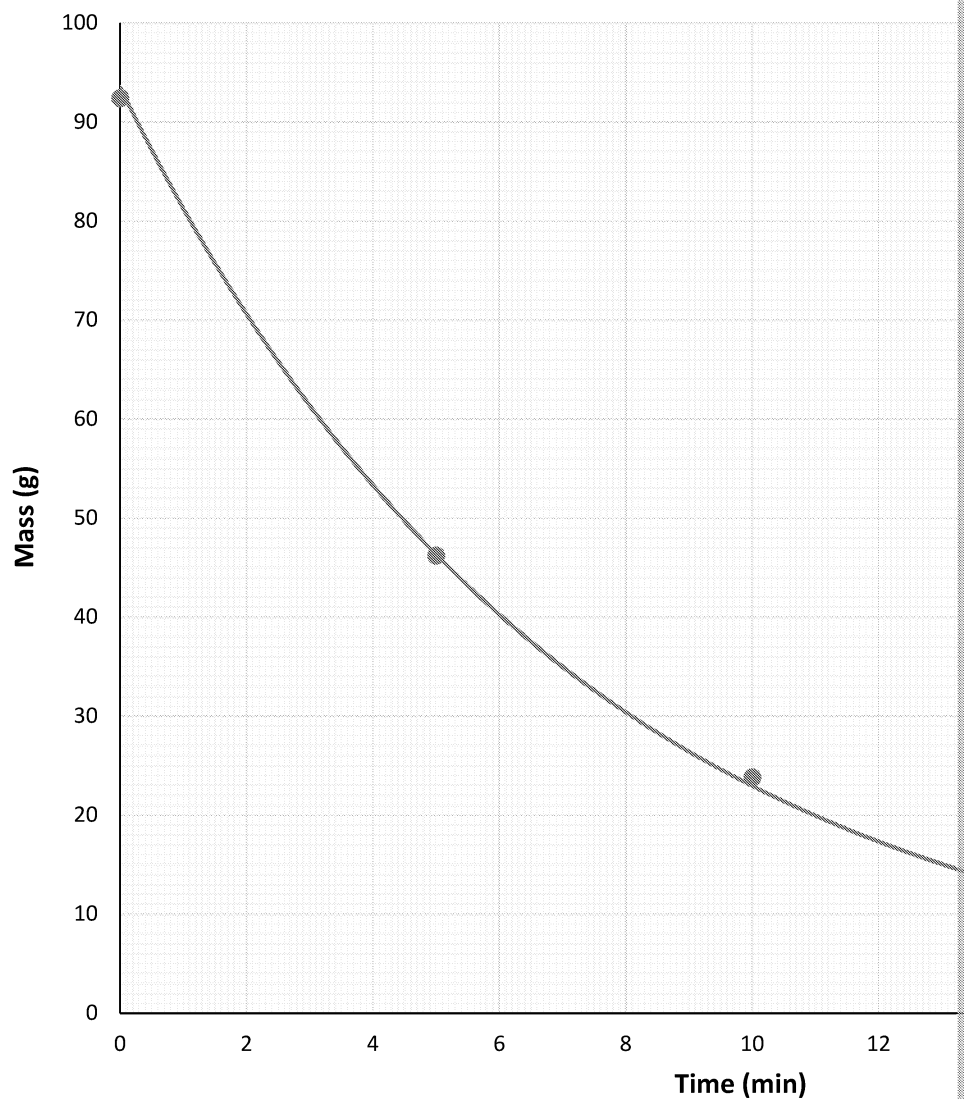
C2 Algebra

- 1.25 moles
- $x = 2p + q - 3$
- 180 g/mol (or 0.180 kg/mol)

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D2 Graphs

1.



E2 Geometry and trigonometry

1. a. i) $\text{volume} = 2.40 \text{ cm} \times 2.40 \text{ cm} \times 2.40 \text{ cm} = 13.8 \text{ cm}^3$ (13.824 to three significant figures)
ii) $\text{surface area} = 6 \times 2.40 \text{ cm} \times 2.40 \text{ cm} = 34.6 \text{ cm}^2$ (three significant figures)
b. i) $\text{volume} = 13.8 \text{ cm}^3$ (unchanged)
ii) $\text{surface area} = 8 \times 6 \times 1.20 \text{ cm} \times 1.20 \text{ cm} = 69.1 \text{ cm}^2$ (two significant figures)

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