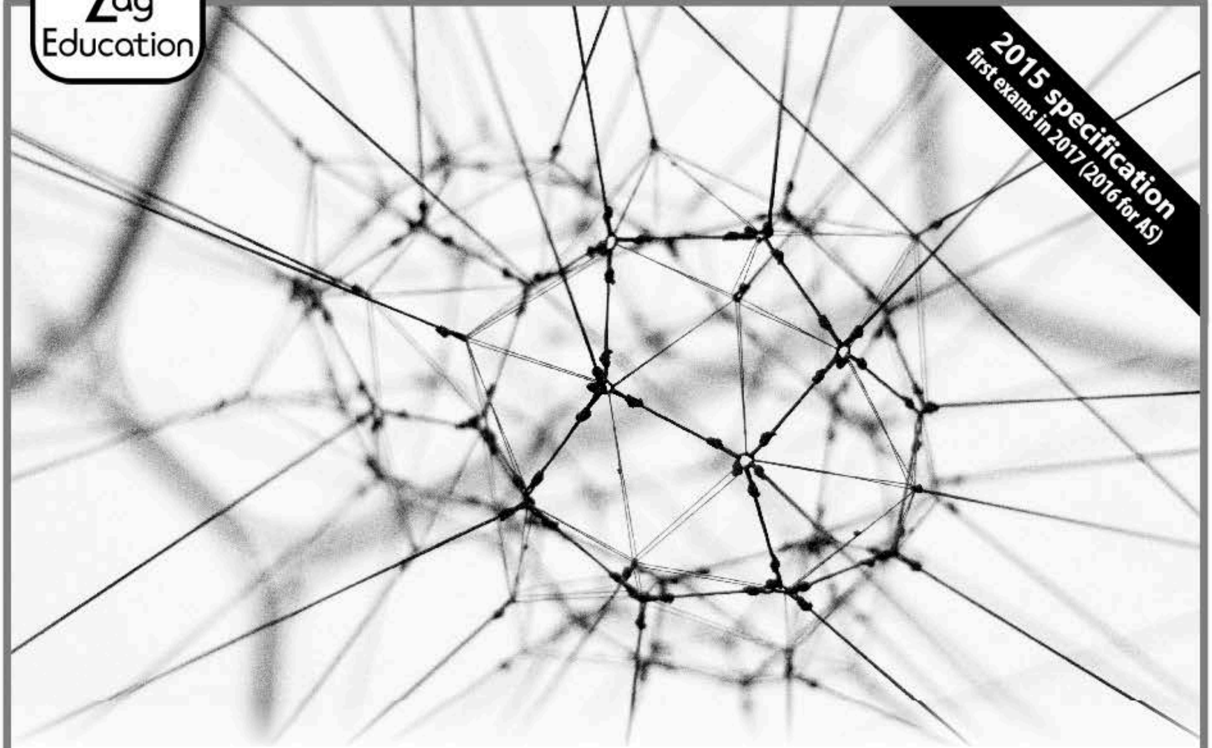
Zig Zag Education

Chemistry

A Level | AQA | 7402/7405



Mastering Maths

for A Level AQA Chemistry

Update v1.1, January 2024

zigzageducation.co.uk

POD 8115

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- Greater than (>) and
- Much greater or less
- Approximately equal
- Directly proportional
- Directly proportional

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Teacher's Introduction

Chemistry students sometimes find the mathematical skills required for success at A Level a challenge, especially when expected to apply them to the context of Chemistry. The new A Level exams have set a much higher bar for the level of maths skills required, and have, therefore, provided an increased level of challenge. The key aim of this resource is to allow students to master the core mathematical skills **so you can focus on the Chemistry!**

Some sections are relatively basic, and serve to boost confidence and eradicate any bad habits. Others will provide even the brightest students with the opportunity to practise the more challenging mathematical skills. All chemical contexts are explained, so that these sheets may be used at any time in the course. Some will be beneficial right at the start of Year 12, while others will provide support for Year 13 students who are dropping maths marks in the run-up to the final exams.

The resource includes a table mapping each basic maths skill outlined in the exam board's published list to each specification point where the skill is found. The required mathematical skills are driven by the Department for Education. The assessment marks of quantitative skills in both AS and A Level papers will comprise a minimum of 20% of the required mathematical skills for Chemistry (Level 2 or above).

Skills Sections

Each section covers all the core mathematical skills mentioned in the exam board's published requirements list. Some skills are treated relatively briefly (e.g. mathematical symbols), while others are given several sections (e.g. rearranging equations).

Each section contains:

- mathematical guidance on the skill
- worked examples, including examples in a chemical context
- a mix of simple questions and in-context questions to practise the relevant skill

Diagnostic Test

This section includes a diagnostic test that is designed to give an assessment of students' comfort with different mathematical skills. This could be used at the start of Year 12 to gain a flavour of different students' background knowledge and ability.

The test indicates the mathematical skills tested in each question, and, therefore, specific skills with which the students are still struggling can be identified.

December 2017

Update v1.1, January 2024:

- Page 13 – 2.605 in solution for b) corrected to 3.605
- Page 64 – 35.9 corrected to 35.7 in first line of answer to Uncertainty I question 3

MATHS SKILLS LIS

Maths skill (skills in bold are tested at A Level only)		Chapter / Diagnostic test number	
Arithmetic and numerical computation			
0.0	Recognise and make use of appropriate units in calculation	2 & 3	**Units**
0.1	Recognise and use expressions in decimal and ordinary form	1	**Decin**
0.2	Use ratios, fractions and percentages	5, 6 & 7	**Fracti** **Perce** **Scalin**
0.3	Estimate results		*Test*
0.4	Use calculators to find and use power, **exponential and logarithmic functions**	Appendix 1	**Using**
Handling data			
1.1	Use an appropriate number of significant figures	4	**Signif**
1.2	Find arithmetic means	8	**Calcu**
1.3	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	9 & 10	**Uncer**
Algebra			
2.1	Understand and use the symbols: $=$, $<$, $\ll$, $\gg$, $>$, $\propto$, $\sim$, equilibrium sign	11	**Math**
2.2	Change the subject of an equation	12, 13, 14	**Using**
2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities		
2.4	Solve algebraic equations		
2.5	**Use logarithms in relation to quantities that range over several orders of magnitude**	15	**Logar**
Graphs			
3.1	Translate information between graphical, numerical and algebraic forms	16	**Cons**
3.2	Plot two variables from experimental or other data		
3.3	**Determine the slope and intercept of a linear graph**	17, 18	**Analy** **Equat**
3.4	**Calculate rate of change from a graph showing a linear relationship**		
3.5	**Draw and use the slope of a tangent to a curve as a measure of rate of change**		
Geometry and trigonometry			
4.1	Use angles and shapes in regular 2D and 3D structures	19	**Shap**
4.2	Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects		
4.3	Understand the symmetry of 2D and 3D shapes		

SPECIFICATION LINKS

Chapter in this resource	MS	Specificatio
Units I Units II	0.0	3.1.2.3 The ideal gas equatio 3.1.4.2 Calorimetry 3.1.9.1 Rate equations
Decimals and Standard Form	0.1	3.1.2.2 The mole and the Avo 3.1.12.3 The ionic product of w
Fractions, Percentages and Ratios Percentage Mass, Purity and Yield Scaling Quantities	0.2	3.1.2.5 Balanced equations a
Using a Calculator	0.4	3.1.2.2 The mole and the Avo 3.1.12.2 Definition and determi
Significant Figures	1.1	3.1.1.2 Mass number and isot 3.1.2.3 The ideal gas equatio 3.1.6.2 Equilibrium constant, K
Calculating Means	1.2	3.1.1.2 Mass number and isot 3.1.2.5 Balanced equations a 3.1.4.4 Bond enthalpies
Uncertainty I Uncertainty II	1.3	3.1.2.5 Balanced equations a Required Practical 1: Make up out a simple acid–base titratio
Mathematical Symbols	2.1	3.1.6.2 Equilibrium constant K
Using Equations I Using Equations II Using Equations III	2.2 2.3 2.4	3.1.2.3 The ideal gas equatio 3.1.6.2 Equilibrium constant, K 3.1.8.2 Gibbs free-energy ch ΔS (A Level only) 3.1.12.4 Weak acids and base 3.1.4.3 Applications of Hess's
Logarithms	2.5	3.1.12.2 Definition and determi 3.1.12.5 pH curves, titrations a
Constructing Graphs	3.1 3.2	3.1.1.2 Mass number and isot 3.1.9.2 Determination of rate 3.2.5.4 Formation of coloured
Rearranging Equations to the Form y = mx + c	3.3	3.1.2.3 The ideal gas equatio 3.1.8.2 Gibbs free-energy ch ΔS (A Level only) 3.1.9.1 Rate equations (A Leve
Analysing Graphs	3.4 3.5	3.1.2.3 The ideal gas equatio 3.1.8.2 Gibbs free-energy ch ΔS (A Level only) 3.1.9.1 Rate equations (A Leve
Shapes in Chemistry	4.1 4.2 4.3	3.1.3.5 Shapes of simple mole 3.2.5.3 Shapes of complex io 3.3.1.3 Isomerism 3.3.7 Optical isomerism

DECIMALS AND STANDA

LEARNING OUTCOME

Be comfortable with using both decimals and standard form, and converting betwe

THEORETICAL OVERVIEW

Chemists need to be able to manage large and small numbers. Sometimes the size make them difficult to use in calculations.

e.g.	a H atom has a mass of…	0.000000000000000000000001661 grar
	there are…	78862000000000000000000 molecule

Standard form

When doing calculations, it is a lot easier to write these numbers in standard form. decimal point, and gives the size of the number as a power of 10.

Converting numbers into standard form
Numbers in standard form are written as:

$$a \times 10^{x}$$

where a is a number from 1 to 9, and x is the number of decimal places the decima

If the decimal point moves to the **left** then x is a **positive number**. If the decimal po **negative number**.

For example:

$$156000000.0 = 1.56 \times 10^{8}$$

8

The d
move
so x

$$0.000429 = 4.29 \times 10^{-4}$$

4

The d
move
so x

Converting numbers back into decimals
To convert from standard form to a decimal, you move the decimal x times in the op above.

For example:

$$3.78 \times 10^{-5} = 000003.78 = 0.0000378$$

5

Rounding

Rounding a number is a way of shortening numbers so they are easier to use in calc rounded to different numbers of decimal places (d.p.).

4.563	
3 d.p.	4.563
2 d.p.	4.56
1 d.p.	4.6
0 d.p.	5

4.56 is closer to 4
4.5, so it is rounde
when rounding to

Standard form on your calculator

To be able to make calculations involving standard form, you will need to know how to use standard form on your calculator.

Standard form button [$\times 10^x$]

Here are some examples of how to use this button:

[3] [•] [5] [$\times 10^x$] [4]
which inputs 3.5×10^4

[4] [$\times 10^x$] [3] [×] [6] [$\times 10^x$] [5]
which inputs the calculation $4 \times 10^3 \times 6 \times 10^5$

WORKED EXAMPLE

A nanotube has a radius of 5×10^{-8} m and is 2.693×10^{-3} m long.

a) Write the length of the nanotube as a decimal to 4 decimal places.

b) The formula for the volume of the nanotube is $\pi \times r^2 \times l$, where r is the rad
the following calculation on your calculator to find the volume in standard

$$\pi \times (5 \times 10^{-8})^2 \times 2.693 \times 10^{-3}$$

Solution

a) $2.693 \times 10^{-3} = 0.002693$ (move the decimal place 3 places to the right)
0.0027 (round up to 2 significant figures)

b) $2.115077254 \times 10^{-17}$ (in standard form)
$= 2.12 \times 10^{-17}$ (rounded down to 3 significant figures)

PRACTICE QUESTIONS

1. Write the following in standard form:
   a) 4 250 000 J
   b) 0.012 m
   c) 623 000 000 000 s
   d) 0.0000007896 kg

2. Write the following numbers out in full:
   a) 6.72×10^{-6} mol
   b) 7.59×10^{4} atoms
   c) 9.91×10^{-4} mol dm^{-3}
   d) 8.143×10^{2} cm^3

3. Round the following to the given number of decimal places (d.p.):
   a) 2.465 g to 2 d.p.
   b) 7.9623 g to 3 d.p.
   c) 3.14159 g to 3 d.p.
   d) 0.956 g to 1 d.p.

4. A drug developer dissolves a mass of 1.6289 g of a new drug in a volume of
   a) Write down the mass in grams of the new drug dissolved in the water to 2
   b) Calculate the concentration of the drug solution in g m^{-3}, by dividing the m
   Give your answer in standard form.

5. A reaction has a percentage yield of 13 % and a theoretical yield of 0.20 g.
   reaction in g using the formula.

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

   Give your answer in standard form.

UNITS I – COMMON UNITS AN

LEARNING OUTCOME

Understand different units, convert between them, and understand why it is importa

THEORETICAL OVERVIEW

Types of unit

In Chemistry, common measurements include length, volume and mass. You will also eventually come across other measurements, such as energy and momentum. The table on the right shows some common units for different types of measurement.

Type of measurement	
length	c
mass	g
volume	c d
temperature	d
time	s

Converting between units

To do a calculation, you might need to convert the values you are given into other units, like converting volumes given in cm^3 into dm^3, or masses from kg to g. In Chemistry, converting between units often involves multiplying or dividing by power of 10.

The different prefixes represent different powers of 10.

To convert to prefixes which are **larger** / higher powers of 10, you need to **divide** by 10 for every difference in the power.

To convert to numbers which are **smaller** / negative powers of 10, you need to **multiply** by 10 for every difference in the power.

For example, **centi**metres (10^{-2}) are 100 times smaller than a metre.

1 cm = 0.01 m

100 cm = 1 m

To convert centimetres to metres, divide the value in centimetres by 100 (10^2).
To convert metres to centimetres, multiply by 100.

÷ 100

1.3 cm = 0.013 m

× 100

Whether it's metres, grams or litres, converting between the different prefixes work
For example, a **kilo**gram is 1000 times (or 10^3 times) bigger than a gram.

1 kg = 1000 g

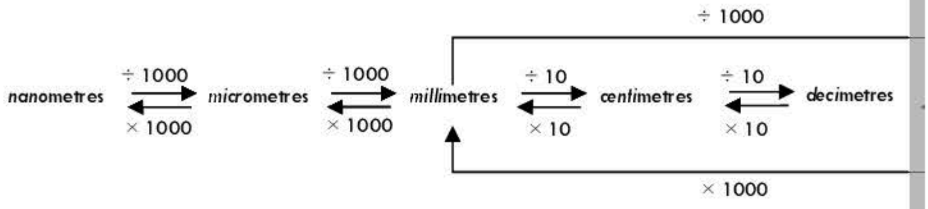
1 g = 0.001 kg

÷ 1000

4.8 g = 0.0048 kg

× 1000

Here is a summary of some common conversions for metres, which are identical fo



WORKED EXAMPLES

'Convert 149 kiloseconds to milliseconds.'

ms (10^{-3}) are 10^6 tim

$149 \times 10^6 = 149\ 000\ 000$

'Convert 289 nanometers to millimeters.'

mm are 10^6 tim

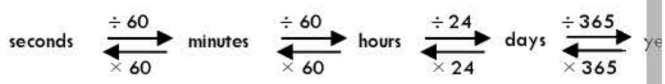
$289 \div 10^6 = 0.000289$ mm

Time and temperature

You may be more used to temperature in °C, but temperature can also be measure
To convert between temperatures in °C and K, add 273.

Time is usually measured in seconds in Chemistry. You can multiply or divide to con
units of time.

Here is a summary of some common conversions for time:



Units in equations

To use equations, it may be necessary to convert values into suitable units for the e
equations should use values in SI units, i.e. moles (mol), pascals (Pa), metres cubed (
kelvin (K).

WORKED EXAMPLE

A student is recording how temperature changes during an experiment, and records th
Draw a second table which has values in SI units.

Temperature (°C)	Time (min)
21	3:20
29	2:50
38	2:10
47	1:50

Solution

Temperature (K)	Time (s)
21 + 273 = 294	3 × 60 + 20 = 200
29 + 273 = 302	2 × 60 + 50 = 170
38 + 273 = 311	2 × 60 + 10 = 130
47 + 273 = 320	1 × 60 + 50 = 110

PRACTICE QUESTIONS

1. Convert the following quantities:
   a) 40 m into km
   b) 0.025 kg into mg
   c) 180 s in min
   d) a temperature of 25 °C into K
   e) 2.45×10^{-7} m into nm
   f) 0.26×10^{12} J into GJ
   g) 4.65×10^{22} nm into km
   h) 684 000 pm in nm

2. Convert the values to the correct base SI units for the ideal gas equation pV =
   a) p = 20 kPa, n = 120 mmol, T = 0 °C
   b) p = 100 kPa, n = 20 mmol, T = 20 °C
   c) p = 40 MPa, n = 1 450 µmol, T = 40 °C

3. The heat generated by a reaction, q, is calculated from mass, heat capacity a

   m = mass in g, c = specific heat capacity in $J\ g^{-1}\ K^{-1}$, *T = chang*

   Convert the values to the correct units for the following data:
   a) m = 0.250 kg
   b) $m = 4.50 \times 10^{6}$ mg
   c) $c = 0.142\ kJ\ g^{-1}K^{-1}$
   d) T = 320 °C
   e) m = 30.0 mg
   f) $c = 129\ J\ kg^{-1}K^{-1}$

UNITS II – UNITS WITH P

LEARNING OUTCOME

Understand units with powers, and convert between them.

Converting units with powers

Units for area (e.g. m^2) and volume (e.g. m^3) have powers (i.e. ^{2} and ^{3}). It is more c with multiple dimensions. It may surprise you that 1 m^3 is 1 000 000 times larger than 1 cm^3.

Areas

Square 2 has 10 times the width and height of square 1.
However, square 2 does **not** have 10 times the area of square 1.
Square 2 has **100 times the area** of square 1.

1 dm^2

square 1

This is 10 squared (10^2) which is 10×10.
(height ↑ width ↑)

Volumes

Cube 2 has 10 times the width, height and depth of cube 1.

However, cube 2 does **not** have 10 times the volume of cube 1.

Cube 2 has **1000 times the volume** of cube 1.

This is 10 cubed (10^3) which is $10 \times 10 \times 10$.
(height ↑ width ↑ length ↑)

1 dm^3

cube 1

> To convert a value in m^3 to a value in dm^3, you have to multiply by 1000, and divide for the reverse calculation.

e.g.

$3\ m^3 = 3000\ dm^3$

÷ 1000

mm^3 ⇄

× 1000

WORKED EXAMPLES

1 **'Convert 400 cm^3 to dm^3.'**
This is going from a smaller unit to a larger unit, so we need to divide.
$400 \div 10^3 = 0.4\ dm^3$

2 **'Convert $8.2 \times 10^{-17}\ m^2$ to nm^2'**
This is going from a larger unit to a smaller unit, so we need to multiply.
$8.2 \times 10^{-17} \times (10^9)^2 = 8.2 \times 10^{-17} \times 10^{18} = 82\ nm^2$

Inverse units

Inverse units include units such as 'per gram' and 'per mole'. These are represented '/ g' or '/ mol', or more commonly at A Level, 'g^{-1}' and 'mol^{-1}'.

These are important for working with compound units, which are made up of two or more different units, like metres per second ($m\ s^{-1}$), or grams per mole ($g\ mol^{-1}$).

When converting between inverse units, the conversion works the other way round t

> To go from a **smaller** unit to a **larger** unit you need to **multiply.**
> To go from a **larger** unit to a **smaller** unit you need to **divide.**

For example, to go from grams to kilograms, you multiply by 1000. But to convert *per* gram to *per* kilogram, you divide by 1000.

WORKED EXAMPLE

'Convert 950 s^{-1} to ms^{-1}.'

This is going from a smaller unit to a larger unit so we need to divide.

$950 \div 10^3 = 0.950\ ms^{-1}$

Converting concentrations

Concentrations can be given in either mol dm^{-3} or g dm^{-3}. To convert between them of the mole equation (which you will meet in your course if you don't know it alread

moles = $\frac{mass}{M_r}$, so

$$\text{mole concentration (mol dm}^{-3}\text{)} = \frac{\text{mass concentration (g dm}^{-3}\text{)}}{M_r}$$

WORKED EXAMPLE

'Convert 0.20 g dm^{-3} into mol dm^{-3} for H_2SO_4'

Solution

M_r of H_2SO_4 $= 2\times1 + 32.1 + 4\times16 = 98.1$

Concentration (mol dm^{-3}) $= \frac{0.20}{98.1}$

$= 0.00204$ mol dm^{-3}

WORKED EXAMPLE

'Convert 0.320 mol dm^{-3} into g dm^{-3} for NaCl.'

Solution

M_r of NaCl $= 23.0 + 35.5 = 58.5$

Concentration (g dm^{-3}) $=$ Concentration (mol dm^{-3}) $\times M_r$

$= 0.320 \times 58.5$

$= 18.72$ g dm^{-3}

PRACTICE QUESTIONS

1. How many times bigger is:
   a) 1 m^3 than 1 dm^3?
   b) 10 m^3 than 1 dm^3?
   c) a cube with sides 2 cm long than a cube with sides 1 cm long?
   d) 2 m^2 than 1 m^2?
   e) 5 m^2 than 10 cm^2?

2. Convert the following quantities:
   a) 5 m^3 into mm^3
   b) 3 cm^3 into m^3
   c) 20 m^2 into dm^2
   d) 100 m^2 into mm^2
   e) 8.8×10^{-17} mm^3 into km^3
   f) 24.55 cm^3 in dm^3
   g) 0.250 dm^3 in cm^3
   h) 3.0 J g^{-1} into J kg^{-1}
   i) 18 mol cm^{-3} into mol dm^{-3}

3. Convert the following concentrations:
   a) 4.60 g dm^{-3} into mol dm^{-3} for KNO_3
   b) 0.500 mol dm^{-3} into g dm^{-3} for NaOH
   c) 11.3 g dm^{-3} into mol dm^{-3} for $MgSO_4$
   d) 0.350 mol dm^{-3} into g dm^{-3} for Na_2CO_3

4. In a titration experiment, the mean titre was recorded as 23.38 cm^3. Convert t

5. 'A gas at 25 °C and a pressure of 150 kPa occupies a volume of 30 dm^3.

   Convert all of these values into suitable units for use in the ideal gas equation.'

   The ideal gas equation is:

$$pV = nRT$$

where: p = pressure in Pa (Pascals)
V = volume in m^3
n = amount of gas in moles
R = 8.31 J K^{-1} mol^{-1}
T = temperature in K

SIGNIFICANT FIGUR

LEARNING OUTCOME

Use and understand significant figures, and give an appropriate number of signific

THEORETICAL OVERVIEW

'Long numbers'

1 ÷ 7 = 0.142857142857142857142…

This number is so long that it would be impractical to try to use it in a calculation. W can use *significant figures* to shorten long numbers.

Significant figures

A significant figure is a digit in a number that gives you information about its value. The first significant figure is the first **non-zero** digit.

Rounding

You can **round** a value to a number of significant figures. To round to 2 significant figures, you look at the 3rd significant figure: if it is larger than 5, round up; if it is smaller than 5, round down.

WORKED EXAMPLE

For example, the two numbers on the right above rounded to 2 significant figures a

34 000 (2 s.f.) *0.0*

Significant figures in the answer

Rounding values to a number of significant figures makes calculations simpler, but it potentially less accurate answer if the rounding is done too early.

Two key points to remember when using significant figures in calculations are:

1. Don't round any numbers until **the very end** of the calculation
2. Give your final answer to the **smallest number** of significant figures used in

You cannot give your final answer to more significant figures than you have used in would mean giving a **more accurate** answer than the values you have used to calcu

Example:

1.0 g + 1.0 g = 2.0 g (2 s.f., 2 s.f., 2 s.f.)

1 g + 1.0 g = 2 g (1 s.f., 2 s.f., 1

The answers have the **same number of significant figures** as the values with the sm **figures.**

WORKED EXAMPLE

The equation for the thermal decomposition of calcium carbonate into calcium o is the following:

$$CaCO_3 \rightarrow CaO + CO_2$$

In an experiment, 4.36758 g of $CaCO_3$ decomposes into 3.605 g of CaO.

a) Give the mass of $CaCO_3$ used to 3 significant figures.

b) All of the mass lost is due to CO_2 leaving the flask.
Calculate the mass of CO_2 produced, using the *unrounded* numbers and ther appropriate number of significant figures.

Solution

a) *The first 3 significant figures are 4.36, but the next digit is a 7 (above 5) so yo = 4.37 (to 3 significant figures).*

b) *The mass of CO_2 evolved = 4.36758 − 3.605 = 1.76258 g. Remember that th until the end.*

The smallest number of significant figures used in the calculation is 4, so the fir significant figures.

= 1.763 g

PRACTICE QUESTIONS

1. Round the following numbers to the given number of significant figures:
   a) 76 489 to 2 s.f.
   b) 0.0061283 to 3 s.f.
   c) 18 990 to 3 s.f.
   d) 0.010034 to 2 s.f.
   e) 0.0034067 to 4 s.f.
   f) 1.9999 to 4 s.f.

2. The number of moles of a substance can be calculated using:

$$\textit{number of moles} = \frac{\textit{mass}}{\textit{molar mass}}$$

   Calculate the number of moles of the following substances, giving your answers significant figures:
   a) Mass of $MgCO_3$ = 16.35 g, molar mass of $MgCO_3$ = 84.3 g mol^{-1}
   b) Mass of $CoCl_2$ = 77 g, molar mass of $CoCl_2$ = 129.9 g mol^{-1}
   c) Mass of $CaCO_3$ = 160.0 g, molar mass of $CaCO_3$ = 100.1 g mol^{-1}

FRACTIONS, PERCENTAGES A

LEARNING OUTCOME

Use and convert between fractions, percentages and ratios.

THEORETICAL OVERVIEW

Fractions, percentages and ratios

Fractions, percentages and ratios are different ways of representing proportions.

Fractions

$$\frac{\text{number}}{\text{total number}}$$

Percentages

$$\frac{\text{number}}{\text{total number}} \times 100$$

WORKED EXAMPLE

A water molecule has the chemical formula H_2O, so it consists of two hydrogen atoms and one oxygen atom. There are three atoms in the molecule overall. You can express this information using fractions, percentages or ratios.

Fractions

The fraction of atoms which are hydrogen atoms is:

$$\frac{\text{number of hydrogen atoms}}{\text{total number of atoms}} = \frac{2}{3}$$

Percentages

The fraction of atoms which are hydrogen atoms is:

$$\frac{\text{number of hydrogen atoms}}{\text{total number of atoms}} \times 100 = 66.7\ \%$$

Each of these representations contains all of the relevant information to describe the

Converting between fractions, percentages and ratios

As well as being able to calculate fractions, percentages and ratios, it is useful to be able to convert between them.

Fractions and percentages

To convert $\frac{3}{4}$ into a percentage, multiply the fraction by 100:

$$\frac{3}{4} \times 100 = 75\ \%$$

It is not always easy to convert from a percentage to a fraction, but some percentages that are useful to recognise are:

5 %	10 %	20 %	25 %	33.33… %	50 %
$\frac{1}{20}$	$\frac{1}{10}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$

Ratios and fractions

Imagine grains of salt and sand in the ratio 2:3. There are 2 grains of salt for ever

The fraction of salt is:

$$\frac{2}{2+3} = \frac{2}{5}$$

Ratios and percentages

To convert a ratio into a percentage, do both of the conversions above, i.e.

1. Convert the ratio to a fraction
2. Multiply by 100.

WORKED EXAMPLE

For a glass that contains ice and water in the ratio of 5:3:

1. Use the ratio to find the fraction of the glass that contains water: $\frac{wat}{water}$
2. Multiply the fraction of water by 100 to get the percentage of the glass t

$$\frac{3}{8} \times 100 = \frac{300}{8} = 37.5\%$$

So the glass is 37.5 % water.

Simplifying

There are different ways of writing the same fraction or ratio, and some fractions a example, $\frac{3}{6}$ and $\frac{1}{2}$ are equal (they are both 50 %). $\frac{1}{2}$ is a simplified version of $\frac{3}{6}$.

Fractions and ratios are normally written in their *simplest form*. To simplify a fracti numbers are divisible by the same number, e.g. 9 and 6 are both divisible by 3. I are no more common divisors.

For example:

- a fraction of $\frac{4}{6}$ (divide top and bottom by 2) is written as $\frac{2}{3}$
- a ratio of 3:6:12, (divide all numbers by 3) is written as 1:2:4

WORKED EXAMPLE

'Aspirin is a molecule derived from the bark of the willow tree, commonly used It has the chemical formula $C_9H_8O_4$.

a) What fraction of the atoms in an aspirin molecule is oxygen atoms?

b) What is this as a percentage?

c) What is the ratio of carbon atoms to other atoms?'

a) *The fraction of oxygen atoms in aspirin is the number of oxygen atoms (4) divi (21).*

$$\frac{\text{number of oxygen atoms}}{\text{total number of atoms}} = \frac{4}{9+8+4} = \frac{4}{21}$$

b) *Then to get a percentage you need to multiply the fraction of oxygen atoms by* $\frac{4}{21} \times 100 = 19.0476... = 19\%$ *oxygen (to the nearest whole number).*

c) *To calculate the number of atoms that aren't carbon, you subtract the number number of atoms:*

number of carbon atoms = 9

number of atoms that aren't carbon = 21 − 9 = 12

ratio of carbon atoms to other atoms = 9:12

= 3:4 ← *simplify (divide both*

PRACTICE QUESTIONS

1. Write the following as decimals:
   a) 45 %
   b) 1/5
   c) 0.3 %
   d) 0.7/3.5
   e) 5/12

2. Write the following as percentages to 1 d.p.:
   a) 5/7
   b) 6/23
   c) 9/10
   d) 7/9
   e) 42/100

3. Write the following as their simplest fractions:
   a) 25 %
   b) 125 %
   c) 30 %
   d) 60 %
   e) 55 %

4. There are two isotopes of chlorine, ^{35}Cl and ^{37}C, which exist in the ratio 3:1.
   a) What fraction of chlorine isotopes are ^{37}Cl?
   b) What percentage of chlorine isotopes are ^{37}Cl?

5. Simplify each of the following formulae to give its empirical formula:
   a) C_2H_4
   b) $C_6H_{12}O_6$

6. In the chemical SO_3, 60 % of the mass is due to the three oxygen atoms, and 4 one S atom. Express the mass of SO_3 as a ratio of 'mass due to S : mass due t

PERCENTAGE MASS, PURITY

LEARNING OUTCOME

Calculate purity and yield as percentages.

THEORETICAL OVERVIEW

Purity

In Chemistry, pure materials are substances which only contain one element or comp only contain the element gold. However, many gold rings also contain **impurities**, s copper, to make the ring more durable.

The purity of a gold ring could be expressed by mass.
For example, a gold ring with a mass of 3.0 g might have:

Mass (g)

From this data, you can calculate the **purity** of each element.

$$\text{Purity (\%)} = \frac{\text{mass of element}}{\text{total mass of ring}} \times 100$$

WORKED EXAMPLE

'What is the percentage purity of gold in the ring described above?'

Percentage purity of gold $= \frac{1.5\ g}{3.0\ g} \times 100 = 50\ \%$

Answer is g
the values

WORKED EXAMPLE

'A chemist dissolved 60 g of a lump of metal ore containing different metals in acid solution was filtered to leave the only metal which didn't react with the aci were obtained, what is the percentage of the rock which is gold?'

Percentage purity of gold $= \frac{0.70\ g}{60\ g} \times 100 = 1.2\ \%$

Answer is g
the values

Percentage by mass

Percentage by mass tells you how much of a compound is one type of element. It us one above:

$$\text{Percentage by mass (\%)} = \frac{\text{relative formula mass of element} \times \text{number of elem}}{\text{relative formula mass of compound}}$$

WORKED EXAMPLE

'What is the percentage by mass of O in $CaSO_4$?'

Relative formula mass of O = 16.0 and there are 4 in the formula

Relative formula mass of $CaSO_4 = 40.1 + 32.1 + 4 \times 16.0 = 136.1$

Percentage by mass (%) $= \frac{16.0 \times 4}{136.2} \times 100 = 47.0\ \%$

WORKED EXAMPLE

'What is the percentage by mass of Mg in $Mg(OH)_2$?'

Relative formula mass of Mg = 24.3

Relative formula mass of $Mg(OH)_2 = 24.3 + (16 + 1) \times 2 = 58.3$

Percentage by mass (%) $= \frac{24.3}{58.3} \times 100 = 41.7\ \%$

Yield

Percentages are also used in Chemistry to represent the yield of a reaction. In a re
form desired products. However, some reactants will form side-products or won't re

reactants → desired products
↓
side-products

If some of the reactants form side-products, this decreases the yield.

To calculate percentage yield:

$$\text{percentage yield} = \frac{\text{actual yield (g)}}{\text{theoretical yield (g)}} \times 100$$

- The actual yield is the mass of product **actually made** in the reaction.
- The theoretical yield is the mass of the product which **could have been mad**
reacted to form the desired products.

WORKED EXAMPLE

'A student performs a reaction and forms 3.4 g of $MgSO_4$. The theoretical mass
been formed from the reactants is 6.5 g. Find the percentage yield of this reacti

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

$$= \frac{3.4}{6.5} \times 100$$

$$= 52\ \%$$

PRACTICE QUESTIONS

1. Calculate the following as percentages:
   a) The purity of copper in 40 g of wire containing 36 g of copper
   b) The purity of iron in 20 g of steel containing 15 g of iron

2. Calculate the following percentage yields:
   a) Actual yield of HNO_3: 1.2 g
      Theoretical yield of HNO_3 3.0 g
   b) Actual yield of $BaCl_2$: 28 g
      Theoretical yield of $BaCl_2$: 56 g
   c) Actual yield of NH_3: 4.1 g
      Theoretical yield of NH_3: 6.7 g

3. Calculate the following percentages by mass:
   a) Ca in $CaCO_3$
   b) Mg in $MgSO_4$
   c) Na in NaOH
   d) H in $Ca(OH)_2$
   e) Fe in $Fe_2(SO_4)_3$

SCALING QUANTIT

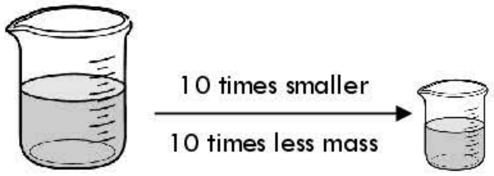
LEARNING OUTCOME

Scale up and down when doing extended calculations.

THEORETICAL OVERVIEW

Scaling up and down

In Chemistry it can be important to scale a quantity up or down in proportion to anc



The trick is to a) divide by the original amount so you know how much there is in, e.g the new amount to find out how much there is at the end.

WORKED EXAMPLE 1

'5.0 g of a substance is dissolved in 200 cm³. 15 cm³ samples are taken. What in each sample?'

200 cm³ contains 5.0 g

1 cm³ contains $\frac{5}{200}$ = 0.025 g

15 cm³ contains 0.375 g

The mass of substance in the samples is: $\frac{5}{200} \times 15 = 0.375$ g — *divide multi*

WORKED EXAMPLE 2: MASS

'30% of a sample weighs 0.48 g. How much does 100% weigh?'

The mass of the whole sample is: $\frac{0.48}{30} \times 100 = 1.6$ g — *divid then*

WORKED EXAMPLE 3: MASS IN A SOLUTION

'0.4 dm³ of a solution contains 3.6 g of a substance. What mass is found in 0.9

The number of grams in 0.9 dm³ is: $\frac{3.6}{0.4} \times 0.9 = 8.1$ g — *divid multi*

WORKED EXAMPLE 4: SCALING DOWN

You can use the exact same method to scale down and work out the value of a sma

'If 90% of the mass of a substance is 27 g, find the mass of 80 % of the substa

The mass of 80 % of the substance is: $\frac{27}{90} \times 80 = 24$ g — *divid multi*

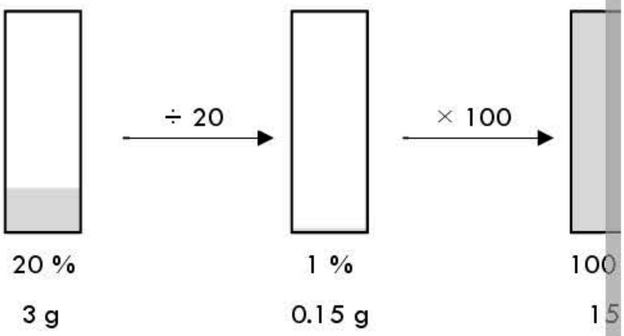
Scaling purity and yields

If you know the percentage purity or yield, you can use it to scale up to find the tot

Imagine a reaction with an actual yield of 3 g, and a percentage yield of 20 %.

$$\text{percentage yield} = \frac{\textit{actual yield}}{\textit{theoretical yield}} \times 100$$

You can find out the theoretical yield by dividing the mass by 20 (to find the mass c 100 (to find the mass of 100 %). This diagram might help visualise the process:



The theoretical yield is, therefore, 15 g.

This concept can also be shown by rearranging the equation for percentage yield:

$$\text{percentage yield} = \frac{\textit{actual yield}}{\textit{theoretical yield}} \times 100$$

multiply b

$$\text{theoretical yield} \times \text{percentage yield} = \text{actual yield} \times 100$$

divide by

$$\text{theoretical yield} = \frac{\textit{actual yield}}{\textit{percentage yield}} \times 100$$

Adding numbers to the calculation:

$$\text{theoretical yield} = \frac{\textit{actual yield}}{\textit{percentage yield}} \times 100$$

$$= \frac{3}{20} \times 100$$

$$= 15 \text{ g}$$

In
by
10

Identifying 'x'

It is possible to find the value of 'x' in a chemical formula given the relative formula percentage by mass of the element.

To do this, find the relative formula mass of the compound by scaling the relative

WORKED EXAMPLE

'A salt with formula $FeCl_x$ contains 44.0 % Fe by mass. Find the value of x.'

Relative formula mass = $\frac{55.8}{44} \times 100 = 126.8$

Relative formula mass of Cl_x = 128.8 − 55.8 = 71.0

Relative formula mass of Cl = 35.5

Value of x = $\frac{71.0}{35.5}$ = 2, so the salt is $FeCl_2$

scaling up the relative form

taking away the mass of Fe relative formula mass; the must be due to Cl

each Cl has a mass of 35.5

$FeCl_2$ has a RFM of 71.0 (x

WORKED EXAMPLE

'A salt contains manganese ions and oxide ions. 53.4 % of the formula mass i has a relative atomic mass of 54.9 . The formula of the salt is MnO_x, where x is What is x?'

The formula can be determined by finding the relative formula mass of the salt, so

a) Calculate the relative formula mass of the salt
b) Determine the value of x from your answer to a)

Solution

a) *Relative formula mass of $MnO_x = \frac{54.9}{53.4} \times 100 = 102.8$*

b) *Relative mass of $O_x = 102.8 - 54.9 = 47.9$.*

Relative mass of O = 16

value of $x = \frac{47.9}{16} = 2.99$

x must be a whole number, so round up to x = 3

scaling up the rela

taking away the r relative formula m must be due to O

each O has a mass

MnO_3 has a M_r of

PRACTICE QUESTIONS

1. 14 % of a sample has a mass of 0.56 g. Work out the mass of the following t
   a) 60 % of the sample
   b) 85 % of the sample
   c) 3 % of the sample

2. 1.36 dm^3 of a solution contains 0.17 g of a substance. Work out how many dr the following. Give your answers to 2 significant figures.
   a) 1 gram of the substance
   b) 1.75 grams of the substance
   c) 34 g of the substance
   d) 0.1 grams of the substance

3. A reaction has a predicted percentage yield of 26.0 % and produces 18.0 g yield of ammonia.

4. A sample of a rock is found to contain 25 % aluminium by mass. The total mas total mass of the rock in g.

5. A reaction with a percentage yield of 75 % produces 3.3 g of a desired prod the reaction in g.

6. A salt has the formula MCl. The metal ion is unknown but can be determined b mass of the salt. Cl^- ions have a relative formula mass of 35.5 and make up 4 mass.
   a) Find the relative formula mass of the salt, MCl.
   b) Using a periodic table, determine the identity of the metal, M.

7. A salt has the formula M_2O_3. O^{2-} ions have a relative formula mass of 16.0 a relative formula mass.
   a) Find the relative formula mass of the salt, M_2O_3.
   b) Using a periodic table, determine the identity of the metal, M.

CALCULATING MEA

LEARNING OUTCOME

Calculate mean averages and weighted means by selecting appropriate values from giv

THEORETICAL OVERVIEW

Repeating experiments

It is common in Chemistry to repeat an experiment and take an average of the resu of the results of multiple experiments, the result will be more **accurate.**

Means

To calculate the mean average, you add up the numbers and divide by the numb

The mean of the numbers 1–4 is:

$$\frac{1+2+3+4}{4} = 2.5$$

Outliers (anomalies)

You might repeat an experiment to find a more accurate value. However, sometim the data you have collected might have an outlier.

Repeat number 2 is an outlier and should be removed when calculating the mean:

$$\text{mean} = \frac{2.3 + 2.3 + 2.4 + 2.2}{4} = 2.3\ \text{s}$$

Titrations

Titrations are a common example of a repeated experiment in Chemistry. There ar titration data.

1. Only include 'concordant' results in the mean calculation. These are results whic other.
2. You sometimes see a 'rough' result. This isn't included in the mean as it is used required, and often is a lot higher than the results that follow.
3. The mean for a titration may be required to 1 or 2 decimal places.

WORKED EXAMPLE

	Rough	Titration 1	Titra
Volume of acid used (cm^3)	19.00	18.10	18

The rough is not used in the mean, and titration 2 is discarded as it is not concord 1 and 3). Concordant titres are titration 1 and 3.

The mean of these results is: $\frac{18.10 + 18.20}{2} = 18.15\ cm^3$

Weighted means

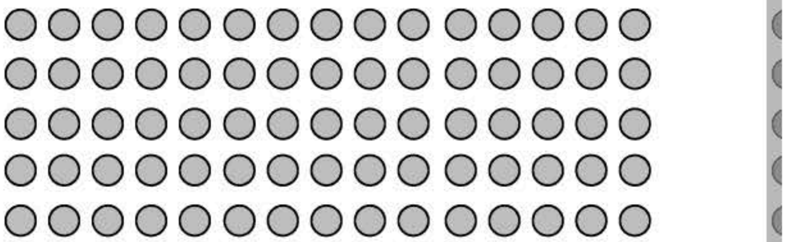
Isotopes are atoms which [cut off]
but different numbers of n[cut off]

The data in the table shows the mass of different isotopes and what percentage of chlorine atoms are in each isotope.

Isot[cut off]
^{35}C[cut off]
^{37}C[cut off]

For the data in the table, it isn't correct to say the average mass is $\frac{35+37}{2} = 36$, because there are three times as many atoms of ^{35}Cl as there are atoms of ^{37}Cl.

Instead, you have to calculate the **weighted mean.** Imagine you had 100 chlorine [cut off] ^{37}Cl.



To find the weighted mean, calculate the mean of the 100 atoms [cut off]

$$\frac{(75 \times 35) + (25 \times 37)}{100} = 35.5$$

The weighted average mass of different isotopes of an element is called the **relativ**[cut off] periodic table – this is the correct relative atomic mass of chlorine to 1 d.p.

WORKED EXAMPLE

'A sample of a meteorite contains three different isotopes of iron, with the abun[cut off]

Use a weighted mean calculation to find the relative atomic mass of iron in the sample.'

Solution

Calculate the weighted mean by multiplying the mass number of each isotope of iron by its 'weight', then dividing by 100 %:

$$\frac{(7 \times 54) + (90 \times 56) + (3 \times 57)}{100} = 55.9$$

PRACTICE QUESTIONS

1. Calculate the mean of the following sets of data:
   a) The whole numbers 1–10
   b) 5, 4, 2, 8
   c) 6.5, 6.2, 6.6, 6.9
   d) 250, 300, 280, 310, 260
   e) 0.06, 0.02, 0.05, 0.02

2. Calculate the mean volume titrated from the following titration data to the giv
   Remember that in titrations you only use concordant results to calculate the me

   a) To 1 d.p.

Titration	Rough	1	2
Volume titrated (cm^3)	16.10	14.60	14.20

   b) To 2 d.p.

Titration	Rough	1	2
Volume titrated (cm^3)	21.05	19.15	19.40

   c) To 1 d.p.

Titration	Rough	1	2
Volume titrated (cm^3)	14.45	13.20	13.50

3. Calculate the relative atomic mass for each of the following samples to 1 d.p.,
   in the worked example.
   a)

Isotope	Mass	Abundance (%)
^{234}U	234	2.00
^{235}U	235	2.00
^{238}U	238	96.00

   b)

Isotope	Mass	Abundance (%)
^{35}Cl	35.0	75.00
^{37}Cl	37.0	25.00

   c)

Isotope	Mass	Abundance (%)
^{6}Li	6.00	8.00
^{7}Li	7.00	92.00

   d)

Isotope	Mass	Abundance (%)
^{50}Cr	50.0	9.00
^{52}Cr	52.0	84.00
^{53}Cr	53.0	7.00

UNCERTAINTY I

LEARNING OUTCOME

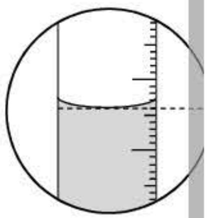
Understand the concept of uncertainty, and be able to calculate uncertainty for diff
measurements, and for experiments, such as titrations.

THEORETICAL OVERVIEW

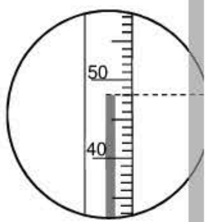
In an experiment, the readings made can never be exact. The true amount can alw
lower than the value given. The amount of 'inexactness' is called the uncertainty.

Readings

A reading is one value recorded in an experiment. The value from a thermometer, on a balance or on a burette are all readings.



The uncertainty in a reading from many pieces of apparatus is half the distance between the lines. For example, if a thermometer has a reading every 1 °C (the distance between lines is 1 °C), then the uncertainty in a reading is 0.5 °C.



This means that for a temperature of 48 °C, the temperature could be as high as 48.5 °C or as low as 47.5 °C.

Writing uncertainties

Uncertainties can be written in the form 'reading ± uncertainty'.
This is called the **absolute uncertainty.**

For a temperature of 48 °C with an uncertainty of 0.5 °C, you would write:

48 ±0.5 °C

NB Th
lines i

Measurements

A measurement is the combination of two readings.

For example, you can measure a temperature change by taking two **readings** and t

Reading 1	**Reading 2**	**Mea**
Start temperature	End temperature	Temper
18 °C	25 °C	

The actual values for readings 1 and 2 are 0.5 °C above or below the written valu

This table shows the maximum and minimum temperature change that could have oc

	Start temperature	**End temperature**
Maximum change	17.5 °C	25.5 °C
Minimum change	18.5 °C	24.5 °C

Another way to show the result is like this:

Start temperature	**End temperature**
18 ±0.5 °C	25 ±0.5 °C

The absolute uncertainty in the measurement (the temperature change) is ±1. It is th
added up.

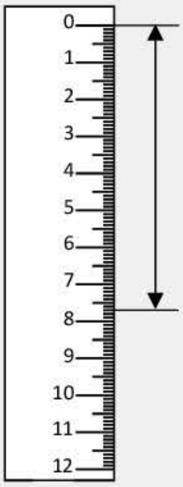
WORKED EXAMPLE

A value from a ruler is actually a measurement, not a reading, because there are two readings: one at the value, and one at zero.

7.7 ±0.1 cm

or

77 ±1 mm



When taking a m
- the **smallest**
- the **uncertai**
- the **uncertai** 0.5 + 0.5 =

WORKED EXAMPLE

'Two chemicals are needed for a reaction and are weighed out.

What is the uncertainty in their combined mass?'

The uncertainty in a digital balance is <u>written on the balance</u>. For the readings shown

- *The value for the combined mass in the reaction is 2.93 + 1.67 = 4.60*
- *The uncertainty for the total mass is 2 × 0.01 = 0.02 g*
- *The value for the mass used in the reaction is written as 4.60 ±0.02 g*

Repeated measurements

Repeating an experiment multiple times and finding the mean result is a method us
Uncertainty is calculated differently for repeated experiments.

When finding the uncertainty from repeat experiments, you find the value of **half** range is the difference between the highest and the lowest value.

WORKED EXAMPLE

'Find the mean of the following volumes, giving the uncertainty in your answer

Reading	1	2	3
Volume (cm^3)	21.2	21.3	21.3

The result for this data is:

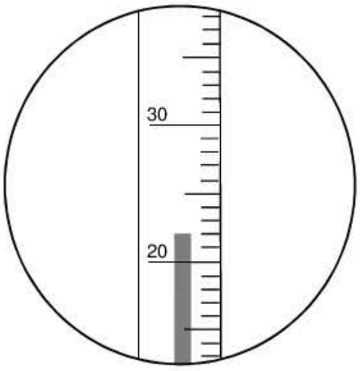
$$\text{Mean} = \frac{21.2 + 21.3 + 21.3 + 21.2}{4}$$

$$\text{Half the range} = \frac{21.3 - 21.2}{2}$$

$$\text{Mean} = 21.25 \pm 0.05 \text{ cm}^3$$

PRACTICE QUESTIONS

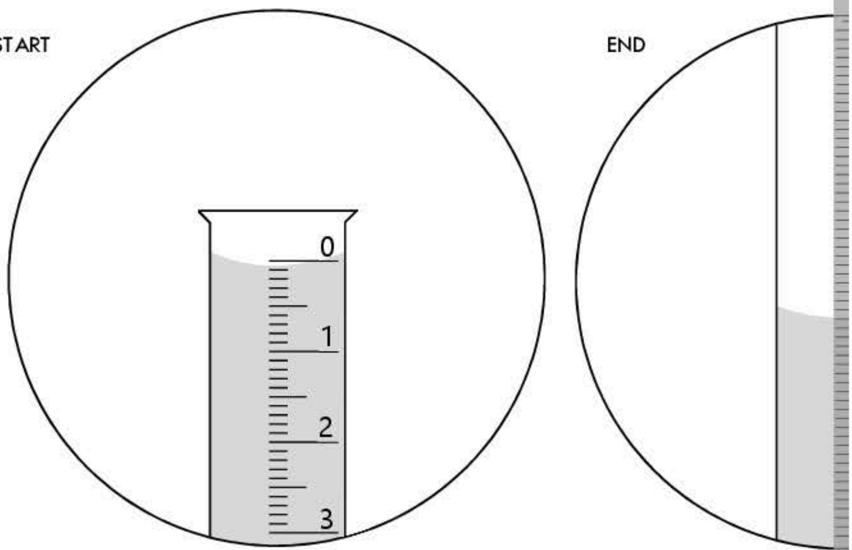
1. Write down the value with the absolute uncertainty of the following measurem
   a) A volume of 23.0 cm^3 measured in a measuring cylinder with 1 cm^3 markir
   b) A 12.0 cm object measured with a ruler with 0.1 cm markings
   c) A temperature change of 16 °C measured with a thermometer with 1 °C r
   d) A volume change of 19.50 cm^3 measured in a burette with markings every
   e) A mass change given by a digital balance with an uncertainty of 0.01 g v
   3.25 g and end mass as 4.50 g
   f) The temperature from the following thermometer:



   g) The measurement from the following burette readings:

START

END



2. a) Calculate the mean result from the following data:

Reading	1	2	3
Temperature (°C)	25.2	24.8	26.2

   b) Calculate the absolute uncertainty of the mean result using the repeated r

3. Calculate the mean value with absolute uncertainty to 1 decimal place for the

Reading	1	2	3	
Mass (g)	34.3	38.1	33.2	3

UNCERTAINTY I

LEARNING OUTCOME
Calculate percentage uncertainty and handle uncertainty in data from titrations.

THEORETICAL OVERVIEW

Percentage uncertainty

An uncertainty of ± 0.1 m is low for a value of a kilometre, but high for a value of
percentage uncertainty in a measurement is useful, as it compares the uncertainty to

The percentage uncertainty of a measurement is calculated using:

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{value}} \times 100\%$$

WORKED EXAMPLE

For this value: 21.25 ±0.05 cm^3

The percentage uncertainty is: $\frac{0.05}{21.25} \times 100\% = 0.235\%$

Overall uncertainty

Here is some titration data:

Titration	Rough	1	2
Final reading (cm^3)	24.50	49.10	25.20
Initial reading (cm^3)	0.05	24.50	0.25
Titre (cm^3)	25.45	24.60	24.95

There are two main sources of error in a titration experiment.

Divisions	Volu
Burettes have 0.1 cm^3 divisions. • The uncertainty in the initial reading is ±0.05 cm^3. • The uncertainty in the final reading is ±0.05 cm^3. The uncertainty of each measurement is 0.10 cm^3.	Another factor adds to • The uncertainty in ju the volume of a dro

So the overall uncertainty in the mean titre is the uncertainties added up: **±0.15 cm**

WORKED EXAMPLE

'A student conducts a titration and obtains the following results:

Titration	Rough	1	2
Final reading (cm^3)	22.00	42.85	21.25
Initial reading (cm^3)	0.10	22.00	0.05
Titre (cm^3)	22.00	20.85	21.20

Calculate the percentage uncertainty in the average titre value.'

Solution

The first two values within 0.1 cm^3 of each other are averaged to find the average t

$$\frac{21.20 + 21.10}{2} = 21.15\ cm^3$$

Then, to calculate the percentage uncertainty in this value:

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{value}} \times 100\ \%$$

$$= \frac{0.15\ (\text{uncertainty in the mean titre})}{21.15} \times 100$$

$$= 0.709\ \%\ (3\ s.f.)$$

PRACTICE QUESTIONS

1. Calculate the percentage uncertainty of the following readings.
   a) 12.50 ± 0.50 mm
   b) 42.60 ± 0.10 °C
   c) 28.50 ± 0.15 cm^3
   d) 49.4 ± 1.0 g
   e) 1542 ± 5 mL
   f) 0.130 ± 0.050 dm^3

2. Calculate the percentage uncertainty in the average titre values for the followi factors from judging each reading and from the uncertainty in judging the end
   a)

Titration	Rough	1	2	3
Initial reading (cm^3)	0.00	0.00	0.00	0.10
Final reading (cm^3)	27.00	26.05	26.15	26.85
Titre (cm^3)				

   b)

Titration	Rough	1	2	3
Initial reading (cm^3)	0.10	0.55	0.25	0.20
Final reading (cm^3)	27.10	26.05	26.05	26.05
Titre (cm^3)				

   c)

Titration	Rough	1	2	3
Initial reading (cm^3)	0.05	0.20	0.30	0.25
Final reading (cm^3)	23.95	22.80	22.70	22.75
Titre (cm^3)				

MATHEMATICAL SYM

LEARNING OUTCOME

Be able to use the symbols <, <<, >, >>, ∝ and ~.

THEORETICAL OVERVIEW

Greater than (>) and less than (<)

The symbol points towards the smaller number: $2 < 5$

These symbols can be rearranged in a similar way to an equals sign =.

For example: $x - 3 < 5$

You can solve this as if it was an equation: $x < 8$

Add 3 to bo

The only difference is when reversing equations. You have to swap the symbol aro

$x < 2$
$2 > x$

WORKED EXAMPLE

'A chemist started with 5 g of impure material containing calcium carbonate, wh hydrochloric acid. The material also contained impurities, some of which also r

The chemist dissolved the material in hydrochloric acid, and found that 0.5 g of

Write an expression for the mass of calcium carbonate (X).'

X + 0.5 < 5 because the 5 g included 0.5 g of impurity
X < 4.5 g

Much greater or less than: << and >>

<< means much less than >> means much greater than

For example: 5 000 000 000 000 000 >> 5

Approximately equal: ~

For example: $5.001 \sim 5$

A quantity called K_c tells us whether there are more reactants or more products left in

reactants ⇌ products

$K_c >> 1$ means that the amount of the products is much greater than the amount o
$K_c << 1$ means that the amount of the reactants is much greater than the amount o
$K_c \sim 1$ means that the amounts of reactants and products are about equal.

Directly proportional: ∝

This symbol means that as the value of one side of an equation increases, so does th

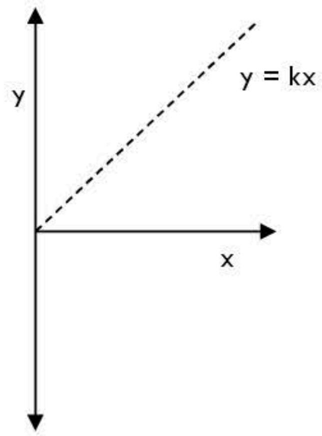
$y \propto x$

Therefore, if y is doubled, x is also doubled. If x is divided by 10, y is also divide

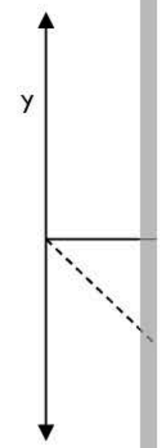
Another way of writing this is using an equals symbol, using 'k' which is a constant (c when x and y change):

$y = kx$

If k is positive
x increases proportionally as y increases



If k i
x decreases prop



A Chemistry example is the ideal gas equation, where, in a constant volume of gas:

$$\text{pressure} \times \text{volume} \propto \text{temperature}$$

$$pV \propto T$$

which can also be rearranged to: $p \propto \frac{T}{V}$

From this, you can tell that:
- doubling the temperature doubles the volume (if pressure is constant)
- doubling the volume halves the pressure (if temperature is constant)

Directly proportional to x^2

y can also be proportional to x^2: $y = kx^2$

which means that when x is multiplied by a factor (e.g. x doubles), y is multiplied by quadruples).

change in x	change in y
$\times 2$	$\times 2^2 = \times 4$
$\times 3$	$\times 3^2 = \times 9$
$\times 4$	$\times 4^2 = \times 16$
$\times \frac{1}{2}$	$\times (\frac{1}{2})^2 = \times \frac{1}{4}$

PRACTICE QUESTIONS

1. Write the following statements using the correct symbols:
   a) 2 cm^3 is greater than 1 cm^3
   b) 4000 mg is less than 4300 mg
   c) A K_c of 4000 is much greater than 0.003
   d) The number of moles is proportional to pressure

2. For the expression $pV \propto nT$:
   a) What happens to V as n doubles, assuming that p and T stay the same?
   b) What happens to V as T halves, assuming p and n stay the same?
   c) What happens to T as n doubles, assuming p and V stay the same?
   d) What happens to n if p is doubled and V and T stay the same?
   e) What happens to T if p and V are both halved and n stays the same?
   f) What happens to V if p, n and T are all tripled?

3. Sketch a graph of the following expressions:
   a) a vs b for ‘$a \propto b$’
   b) pV vs T for $pV \propto T$
   c) Rate vs [Y] for Rate $\propto$ [X][Y]^2[Z]

USING EQUATIONS
REARRANGING SIMPLE E

LEARNING OUTCOME
Use and rearrange simple equations to calculate values for physical quantities.

THEORETICAL OVERVIEW

Substituting values

In Chemistry, equations are used to calculate values from other values. The followin situation 'y is 5 times bigger than x':

$$y = 5x$$

When x = 3, the equation can be used to calculate that y = 15:

$$y = 5 \times 3 = 15$$

Rearranging equations

If you know the value of y and want to find x.

The equation can be rearranged:

$$y = 5x$$

divide both side

$$\frac{y}{5} = x$$

> The key to rearranging equations is that if you do something to one side of the e other side.

Rearranging and substituting

Some equations are more complex because they contain more variables (letters). C ideal gas law, which describes the relationships between pressure, volume and tem ideal gas using the following equation:

$$pV = nRT$$

Though there are more variables in the ideal gas equation, you can rearrange and same way.

So if you know that $p = 1 \times 10^5$ Pa, n = 1 mol, R = 8.31 J mol^{-1} K^{-1}, and T = 273 equation, and then substitute in this information to find V:

$$pV = nRT$$

divide b

$$V = \frac{nRT}{p}$$

substitut

$$V = \frac{1 \times 8.31 \times 273}{1 \times 10^5}$$

perform

$$V = 0.023 \text{ m}^3$$

WORKED EXAMPLE

'The ideal gas equation is:

$$pV = nRT$$

where: **p = pressure in Pa (Pascals)**
V = volume in m^3
n = amount of gas in moles
R = 8.31 J K^{-1} mol^{-1}
T = temperature in K

3.00 moles of a gas are stored in a 0.250 m^3 container at 273 K. Calculate the the walls of the container.'

Solution

$pV = nRT$ —rearrange by dividing by V→ $p = \frac{nRT}{V}$ —substitute in→ $p = \frac{3 \times 8.31 \times 273}{0.25}$

$= 27223.56$ Pa

$(= 27.2$ kPa$)$

PRACTICE QUESTIONS

1. The rate of a reaction can be calculated using the equation:

$$rate = \frac{concentration\ of\ reactant\ used}{reaction\ time}$$

Rearrange the equation to show how the concentration of reactant used depe

2. Rearrange the following equations to make x the subject of the equation:
   a) d = 2x
   b) wA = yx
   c) 24 = 6x

3. Rearrange the following equations to make moles the subject of the equation:
   a) moles × M_r = mass
   b) 24,000 × moles = volume
   c) concentration = $\frac{moles}{volume}$

4. The ideal gas equation is:

$$pV = nRT$$

   a) Rearrange the equation to make p the subject.
   b) Rearrange the equation to make T the subject.
   c) Rearrange the equation to make n the subject.

5. Find the volume in cm^3 of 0.75 moles of gas using the equation: moles = $\frac{V\ (in\ cm}{24\ 00}$

6. Find the value of ΔT for q = mcΔT where: m = 150 g, c = 4.18 J g^{-1} K^{-1} and

USING EQUATIONS II – EQ
WITH +, –, × AND

LEARNING OUTCOME

Make variables the subject of an equation in equations involving multiplications, divisio

THEORETICAL OVERVIEW

Equations are a really useful way of looking at the relationships between quantities. For example, this equation tells you how the quantity y depends on the quantity x.

$$y = 5x + 3$$

But what if you want to know how x depends on y? To see this, you have to **rearrange** the equation to make x the subject:

$$y = 5x + 3$$

$$y - 3 = 5x$$

The second step is to then get the x completely on its own. At the moment, you have $5x$ on the right-hand side of the equation, so divide both sides by 5.

$$\frac{y-3}{5} = x$$

This equation can be written the other way around:

$$x = \frac{y-3}{5}$$

Now that you have rearranged the equation, you can substitute a value of y straight into the equation for x, e.g. when $y = 13$:

$$x = \frac{13-3}{5} = \frac{10}{5} = 2$$

WORKED EXAMPLE

'An experiment measuring the volume of gas produced gave the following data

Repeat	1	2	3	
Gas produced (cm^3)	214	216	211	

A student calculated the mean value as 212 cm^3. Find the value of x.'

Solution

The mean value is given by:

$$\frac{214 + 216 + 211 + x}{4} = 212$$ *which we can simplify to* $\frac{641}{4}$

Rearrange the formula to make x the subject, and calculate the value.

$\frac{641 + x}{4} = 212$

multiply both sides by 4

$641 + x = 212 \times 4$

subtract 641 from both sides

$x = 212 \times 4 - (641)$

perform the calculation

$= 207\ cm^3$

PRACTICE QUESTIONS

1. Make x the subject of the following equations:
   a) $y = \frac{x+5}{3}$
   b) $y = 6x - 9$
   c) $y = mx + c$
   d) $y = \frac{4}{x}$
   e) $9x + 2 = 7x + 2y$
   f) $4y + 2x + 3 = 2y + 6x - 1$
   g) $3yx = 1$
   h) $4xy + 8 = 4y - 4$

2. For the following data, a student calculated the mean to be 8 cm^3:

Repeat	1	2	3	4
Volume (cm^3)	x	10	8	7

   Find the value of x (repeat 1).

3. For the following data, a student calculated the mean to be 29.4 g:

Repeat	1	2	3	4
Mass (g)	30.2	x	28.7	30.0

   Find the value of x (repeat 2).

4. The relative atomic mass of an element can be calculated using:

$$\text{relative atomic mass} = \frac{\text{total of (mass of an isotope} \times \text{abundance}}{100}$$

   A sample of neon was calculated to have a relative atomic mass of 20.2 using

Mass of isotope	Abundance of isotope
20	90
Y	10

   Calculate the mass of the second isotope 'y' using the equation above.

5. The energy change of a reaction can be estimated using the formula:

   energy change = bonds broken – bonds formed

Bond	Energy / kJ mol^{-1}
H–H	436
O=O	498
H–O	?
H–Cl	?
Cl–Cl	242

   a) Find the energy of the H–Cl bond given that the following reaction has an

   BONDS BROKEN 2×H–H + 2×Cl–Cl → 2×H–Cl

   b) Find the energy of the H–O bond given that the following reaction has an

   BONDS BROKEN 2×H–H + O=O → 2×H–O–H

USING EQUATIONS III – EQ
WITH POWERS AND R

LEARNING OUTCOME

Rearrange equations containing powers and roots.

THEORETICAL OVERVIEW

Some equations in Chemistry are quite complex, and can be hard to rearrange. Fo
sphere is given by:

$$V = \frac{4\pi r^3}{3}$$

The
mul
(r³

where r is the radius of, for instance, a spherical nanoparticle.

To make r the subject of the equation:

$$V = \frac{4\pi r^3}{3}$$

multiply bot

$$3V = 4\pi r^3$$

divide both

$$\frac{3V}{4\pi} = r^3$$

take the cu

$$\sqrt[3]{\frac{3V}{4\pi}} = r$$

Now r is the subject of the equation, so the equation can be used to easily calculate

*The cube root finds the number which, multiplied by itself three times, gives that nu
For example $\sqrt[3]{27} = 3$ because $3 \times 3 \times 3 = 27$.

WORKED EXAMPLE

'The kinetic energy of an ion in a mass spectrometer is given by:

$$KE = \frac{1}{2}mv^2$$

Rearrange the formula to make v the subject.'

Solution

$$KE = \frac{1}{2}mv^2$$

multiply both

$$2KE = mv^2$$

divide both si

$$\frac{2KE}{m} = v^2$$

take the squar

$$\sqrt{\frac{2KE}{m}} = v$$

PRACTICE QUESTIONS

1. Given that a = 2 and b = 3, find c for each of the following equations:
   a) $c = a^b + b^2$
   b) $cb = b^a$
   c) $c^2 = b^a$
   d) $abc = \frac{b^2}{a}$
   e) $a^2b^2 = 5 + b^3 + c^2$
   f) $a^2c^3 = b^3 + a^2 + 1$

2. Make x the subject of the following equations:
   a) $y = \frac{1}{2}x^2$
   b) $y = \frac{4\pi}{x^2}$
   c) $y = \sqrt{\frac{x}{4}}$
   d) $y = z(3x)^3$

3. Square brackets are used to represent concentration in equations, e.g. $[Cl^-]$ me
   K_c is a way of measuring how much of the reactants has been converted to pro
   a) Make $[H^+]$ the subject of the equation: $K_c = \frac{[CH_2(COO)_2{}^{2-}][H^+]^2}{[CH_2(COOH)_2]}$ and then cal

      $[CH_2(COO)_2{}^{2-}]$ = 1.200 mol dm^{-3}
      $[CH_2(COOH)_2]$ = 0.500 mol dm^{-3}
      K_c = 2.04 × 10^{-6} mol^2 dm^{-6}

   b) Make $[H_2]$ the subject of the equation: $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$ and then calculate [H

      $[NH_3]$ = 0.040 mol dm^{-3}
      $[N_2]$ = 0.12 mol dm^{-3}
      K_c = 1.45 × 10^{-4} mol^{-2} dm^6

4. The kinetic energy, KE, of an ion in a mass spectrometer is given by KE = ½m
   a) Find the value of m in kg when v = 45 100 m s^{-1} and KE = 6.77 × 10^{-16}
   b) Find the value of v in m s^{-1} when m = 9.27 × 10^{-26} kg and KE = 1.00 ×

5. The rate of the reaction between NO and H_2 is given by Rate = $k[NO]^2[H_2]$,
   a) Calculate the value of k given that:
      Rate = 1.95 × 10^{-8} mol dm^{-3} s^{-1} when [NO] = 8.1 × 10^{-3} mol dm^{-3} and
   b) Calculate the value of [NO] for the same reaction when:
      Rate = 3.52 × 10^{-7} mol dm^{-3} s^{-1} and $[H_2]$ = 3.1 × 10^{-3} mol dm^{-3}

LOGARITHMS

LEARNING OUTCOME
Understand how and why logarithms are used, and use them in calculations.

THEORETICAL OVERVIEW

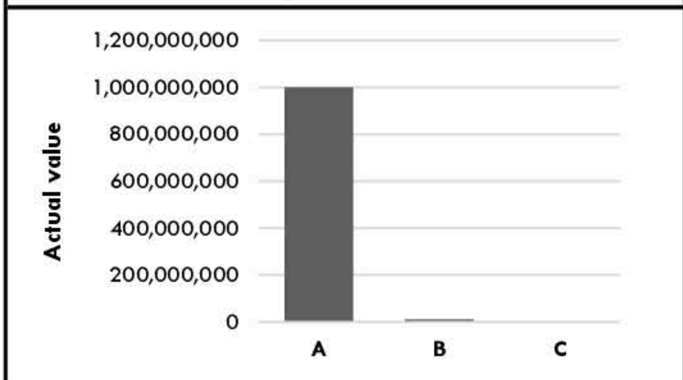
Why logarithms are useful

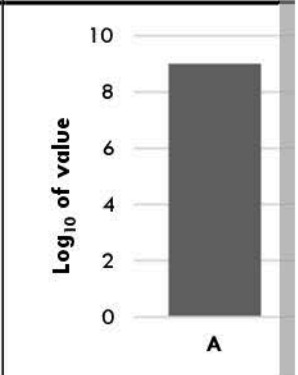
Numbers can get very big or very small in Chemistry. Sometimes this makes it diffic

This data is plotted on the graphs below. These two graphs are plotting the same d
logarithms to make comparing the numbers easier.

Number	Value	$\log_{10}$ of the valu
A	1 000 000 000	9
B	1 000 000	6
C	1 000	3

Using actual values	Using the





As you can see, the left-hand graph is not useful for comparing the size of B and C,
A. This means it isn't possible to see any patterns. By 'taking logs' of each of the v
values we can see that A is much bigger than B and C, **and that C is smaller than B**

Mathematics of $\log_{10}$

Rule 1
The $\log_{10}$ of a number is the power you need to raise 10 to get that number.

$$\log_{10}(10^x) = x$$

For example:

$$\log_{10}(1000) = \log_{10}(10^3) = 3$$
$$\log_{10}(10000) = \log_{10}(10^4) = 4$$

Rule 2
This is also related. Raising 10 to the power of a log gives the number that is 'logg
log, put 10 to the power of the logged number.

$$10^{\log(a)} = a$$

For example:

$$10^{\log(9)} = 9$$

Chemistry example: pH

A Chemistry example where numbers are hard to compare is in acidity.

	Very acidic solution	**Very non–acidic (**
H^+ concentration:	1 mol dm^{-3}	0.000 000 000 (

The pH scale is a way of representing these concentrations in a way that makes the

concentration of H^+ (mol dm^{-3})		**log(concentratio**
decimal	**standard form**	
0.1	10^{-1}	−1
0.001	10^{-3}	−3
0.000 000 1	10^{-7}	−7
0.000 000 001	10^{-9}	−9
0.000 000 000 000 01	10^{-14}	−14

From this table, you can see how pH relates to the concentration. The equation for

$$\text{pH} = -\log(\text{concentration of } H^+)$$

To work out the concentration from the pH:

$$\text{concentration} = 10^{-\text{pH}}$$

WORKED EXAMPLES

1. **'Find the pH of a solution with concentration of 0.00469 mol dm^{-3}.'**

   Solution

   $pH = -\log(\text{concentration of } H^+)$

   $= -\log(0.00469)$

   $= -(-2.33)$

   $= 2.33$

2. **'Find the concentration of H^+ for a solution with a pH of 6.3.'**

   Solution

   $pH = -\log(\text{concentration})$

   $6.3 = -\log(\text{concentration})$

   $-6.3 = \log(\text{concentration})$

   difficult step: both sides are put to the

   $10^{-6.3} = 10^{\log(\text{concentration})}$

   difficult step: see rule 2 above if this do

   $10^{-6.3} = \text{concentration}$

   $= 5.01 \times 10^{-7}$ mol dm^{-3}

Mathematics of natural logs, ln

Many relationships in nature, including Chemistry, have an **exponential** pattern. Thi
as e^x.

ln, or $\log_e$, is an important type of logarithm because of the relationship:

$$\ln(e^x) = x$$

Chemistry example: Arrhenius equation
The only equation in A Level Chemistry which includes e is the Arrhenius equation:

$$k = A \times e^{\frac{-E_a}{RT}}$$

This equation links the activation energy (E_a) and the temperature (T) to the rate con
constant called the Arrhenius constant (A).

Using log rules, the equation can also be expressed as:

$$\ln k = \ln A - \frac{E_a}{RT}$$

This can be used to find values for E_a and A using a graph when the value of k is kn
(see separate section).

WORKED EXAMPLE

'The value of lnA in a reaction was found by a graphical method to be 14.9.

Find the value of A for this reaction.'

Solution

$A = e^{\ln A}$

$= e^{14.9}$

$= 2.96 \times 10^6$

PRACTICE QUESTIONS

1. Use a calculator to find the following values to 4 significant figures:
   a) $10^{3.2}$
   b) log(120 000)
   c) log(0.0005)
   d) $10^{-0.038}$
   e) $\log(10^{-4})$
   f) $10^{\log(3)}$

2. Calculate the value of x to 4 significant figures.
   a) log(x) = 3
   b) log(x) = 8.4
   c) $10^x = 0.002$
   d) $10^x = 7.43$
   e) $10^{(x+3)} = 0.00567$

3. The table shows the values of the first eight ionisation energies of aluminium.
   a) Use log rules to calculate the missing values.

ionisation energy number	.5	2	3	4	
ionisation energy ($kJ\ mol^{-1}$)	577	1816	2744		8
$\log_{10}$(ionisation energy)	2.7612			4.0636	

   b) Explain why using logs is useful in this situation.

4. By rearranging the equation $k = A \times e^{\frac{-E_a}{RT}}$, find the value of k for a reaction wh

CONSTRUCTING GRA

LEARNING OUTCOME

Use experimental data to plot representative graphs and draw a line of best fit.

THEORETICAL OVERVIEW

The following example will walk you through the steps of constructing a graph. Thi
which a solid is heated and decomposes, losing mass.

independent variable the variable chosen by the person doing the experiment

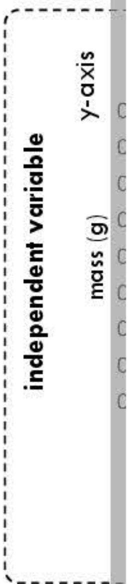
Time (s)	Mass (g)
10	0.88
20	0.79
30	0.70
40	0.63
50	0.49
60	0.37

depe
the m
whos
the in

1. Choosing the axes

The independent variable goes on the *x*-axis, which in this case is time, as you have **chosen** the times at which to measure the mass. As the mass measured **depends** on the time at which it is measured, mass is the **dependent variable**, and so goes on the *y*-axis.

When labelling your axes, always make sure you write the **units** of each variable.



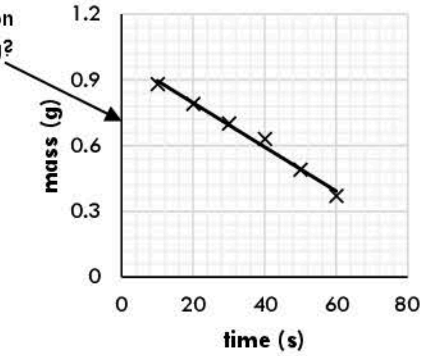
2. Choose a scale for each axis

- The scale must be regular.
- The data must cover at least half the page.
- The data must all fit on the scale!
- Each large square should be a round number.

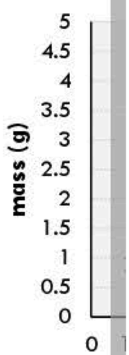
Bad examples:

Divisions are difficult to judge because the major grid lines are every 0.3 g on the y-axis.

e.g. where on here is 0.7 g?

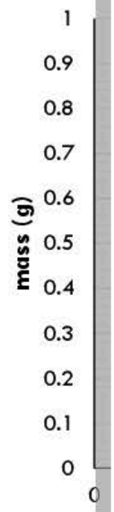


Poor use
the



3. Plot the points

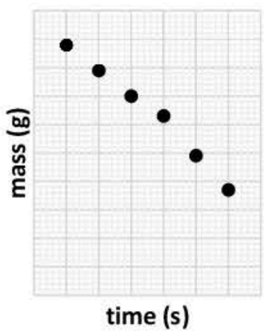
To plot a point, imagine two lines coming from the x- and y-axes at the correct values. The point where these two imaginary lines cross is where you plot your data point.



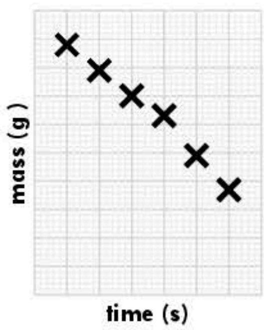
Use a small × to represent each data point.

Examples of bad points plotted:

dots are unclear



crosses too big

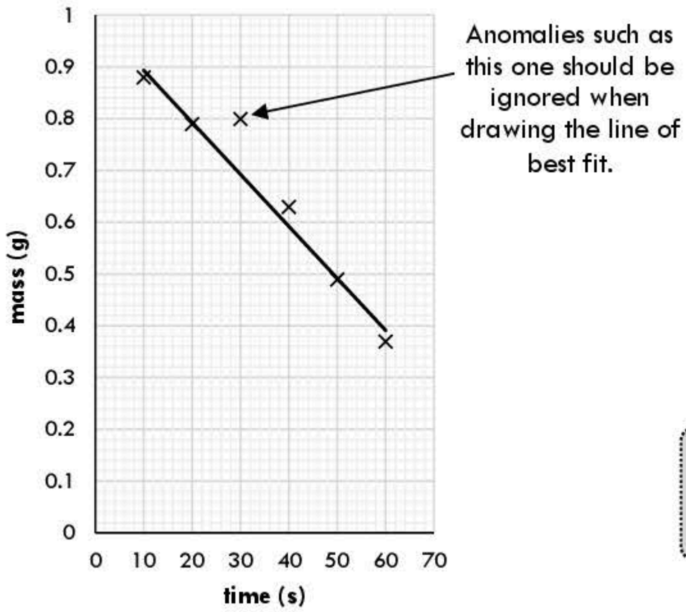


4. Draw a line or curve of best fit

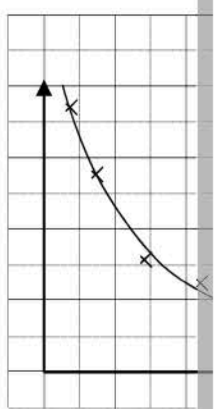
Depending on the data being plotted, a curved or straight best-fit line is used to sh should look at the data to judge which is appropriate. Sometimes two straight lines case, **do not do dot-to-dot.**

You should aim to have an equal number of data points on each side of the line.

Straight lines – use a ruler to draw through the points



Curved lines – smooth fr



Curves can be tricky to temptation to go back 'sketchy' double lines. I

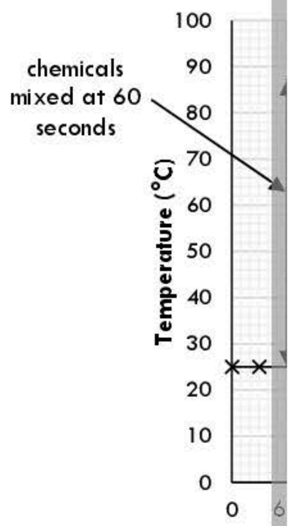
Lines do not have to go through the origin (0,0) but sometimes it makes sense for the timing how far something travels in a given time, you know it hasn't travelled anywh

Two lines of best fit (temperature change)

To find the temperature change of a reaction, a specific method is used. The temperature is recorded before and after the reaction occurs. Two straight lines of best fit are drawn and **extrapolated** to the time at which mixing occurred.

A vertical line is drawn at the time the chemicals are mixed, and the temperature change is recorded as the place where the two lines cross.

The temperature change is 87 – 25 = 62 °C.



PRACTICE QUESTIONS

1. Using graph paper, plot graphs for the data and draw an accurate line of be

a) An experiment monitoring the decrease in mass of calcium carbonate as it thermally decomposes over time.

Time (s)	Mass of $CaCO_3$ (g)
0	5.00
10	4.25
20	3.79
30	3.00
40	2.16
43	1.87

b) An experiment monitoring the amount of CO_2 produced by a reaction over time.

Time (s)	Volume of CO_2 (cm^3)
0	0.0
10	46.5
20	62.3
30	66.3
40	77.2
50	79.3

c) An exper measured hydrochl 90 s. Us temperat lines of b t = 90.

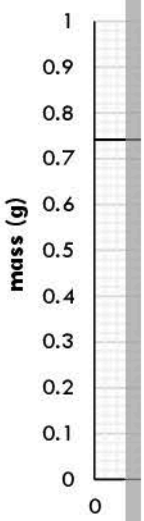
Time (
0
30
60
90
120
150
180
210
240
270

ANALYSING GRAP

LEARNING OUTCOME

Read data values from graphs, calculate the gradient and y-intercept of the line of
rate of change at a given point on a curved line of best fit.

THEORETICAL OVERVIEW



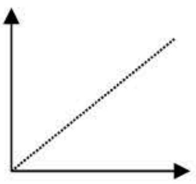
Reading data from a graph

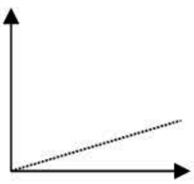
Reading data from a graph is very similar to plotting data on a graph. To find the mass at a certain time, imagine lines going directly up from the time (x-axis), and directly across from the line of best fit. The place where the imaginary line crosses the y-axis gives the mass.

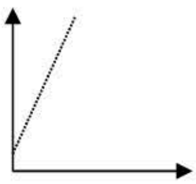
For example, to find the mass at 25 s, draw an imaginary line up from 25 s, and across to the y-axis. The mass at 25 s is 0.74 g.

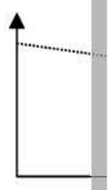
Slopes of graphs

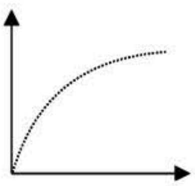
The slope of the line can tell you how quickly the concentration changes. In other words, it tells you the **rate** at which the concentration is changing. A steeper slope shows a higher rate.

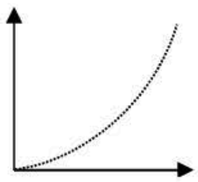

positive, starts at the origin


positive, low rate


positive, high rate


negati... ra...


curved, tending to a gradient of 0


curved with increasing gradient (e.g. exponential)

Calculating the gradient

To obtain a value for this rate of change, you have to calculate the gradient of the
choose two points on the line, and find the difference between the two y–values an

$$\text{gradient} = \frac{\text{difference in y}}{\text{difference in x}}$$

The two points should be far apart, but within the data range.

WORKED EXAMPLE

The gradient of the graph in the top right of the page is:

$$\text{gradient} = \frac{\text{change in mass}}{\text{change in time}} = \frac{\text{mass}_2 - \text{mass}_1}{\text{time}_2 - \text{time}_1}$$

$$= \frac{0.50 - 0.79}{49 - 20}$$

$$= -0.010\ g\ s^{-1}$$

When you have
gradient, **think**
positive or nega

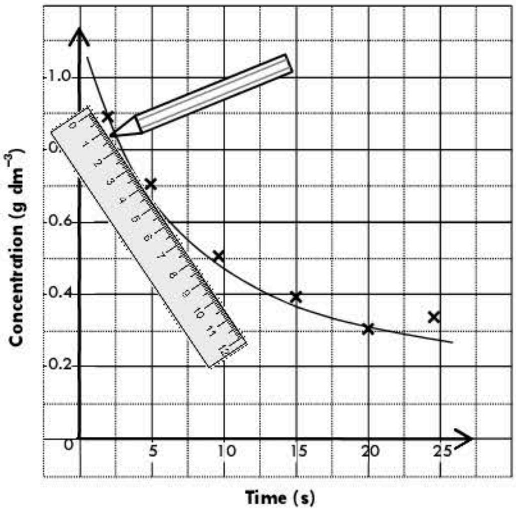
Upwards slope =
Downwards slope

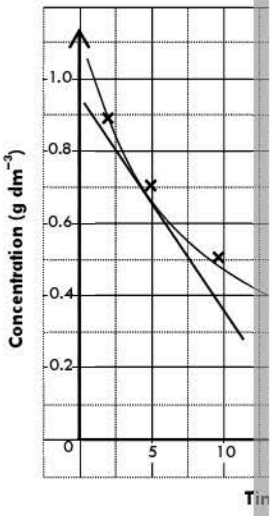
Calculating rate of change from a curved graph

If you have a curved line of best fit, the gradient is different at different points on t

To calculate the gradient at a point on the curve, you can draw a tangent to the c touches the curve only once. To do this, position a ruler on the curve so that it only

The tangent has the same gradient as the curve at the point where the tangent touc the gradient of the line as normal.



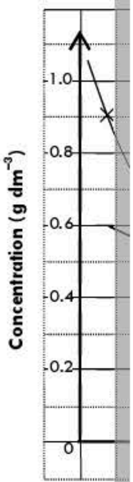


Changing gradients

In many graphs, the steepness of the gradient tells you how fast the reaction is occurring.

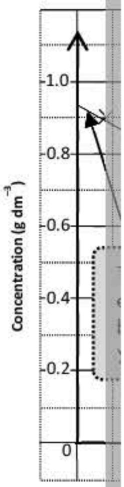
As the reaction slows down, the gradient changes. Later in the experiment, the slope is less steep.

For this graph, we can compare the two gradients to see how much the reaction has slowed down.



y-intercept

The ***y*-intercept** of a line is the point where the line crosses the *y*–axis. In order to work this out, you need to **extrapolate** back from the line of best fit to the axis.



The y-intercept gives you the y-value when the x-value is 0. In this graph, the y-axis tells you the concentration (y-value) at the beginning of the experiment (x = 0). In other words, it will tell you the **initial concentration.**

Sometimes, it is possible to read the *y*-intercept straight from the graph. In this case you can see that the line of best fit crosses the *y*-axis at approximately 0.92 g dm^{-3}.

This means that the concentration was 0.92 g dm^{-3} before the experiment started.

Calculating the y-intercept

Sometimes the *y*-intercept won't be visible on the graph, so you will need to calculat formula of a straight line:

any y-value → $y = mx + c$ ← any x-v

Choose any point on the line of best fit. From the graph above, we can choose the gradient of the line, so m = -0.020 (which we calculated on the previous page). c i trying to calculate).

Rearrange the equation and substitute in the values to calculate c :

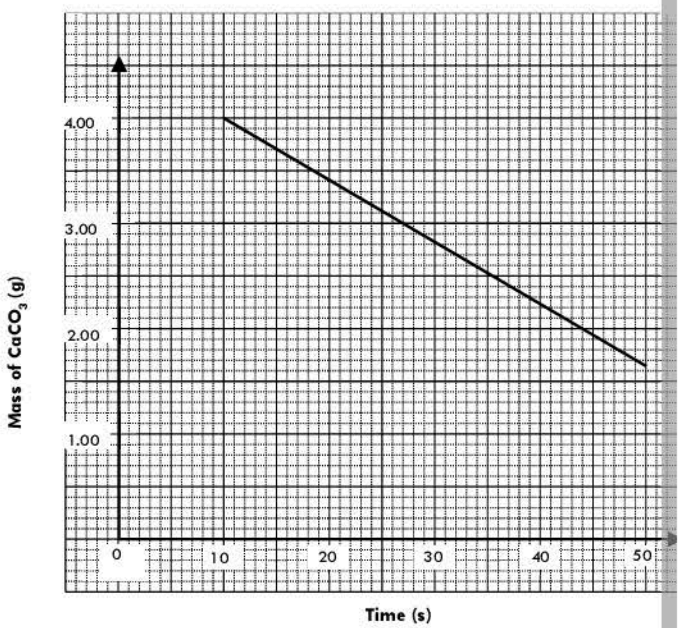
$c = y - mx$

$c = 0.45 - (-0.020 \times 23)$

$= 0.91$ g dm^{-3}

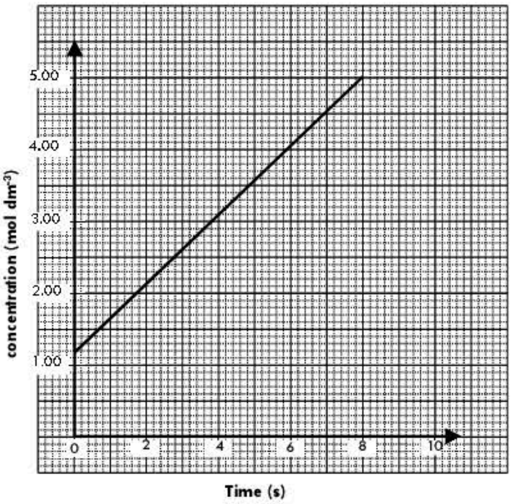
PRACTICE QUESTIONS

1. For the following graph, find:
   a) The mass at 20 s
   b) The mass at 35 s
   c) The time when the mass is 3.00 g
   d) The change in mass between 10 and 40 s

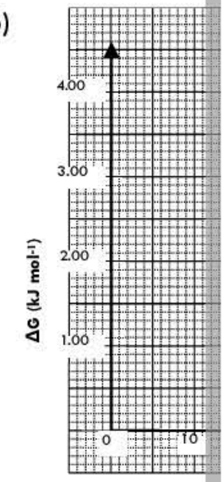


2. For each of the following graphs, calculate the gradient and y-intercept:

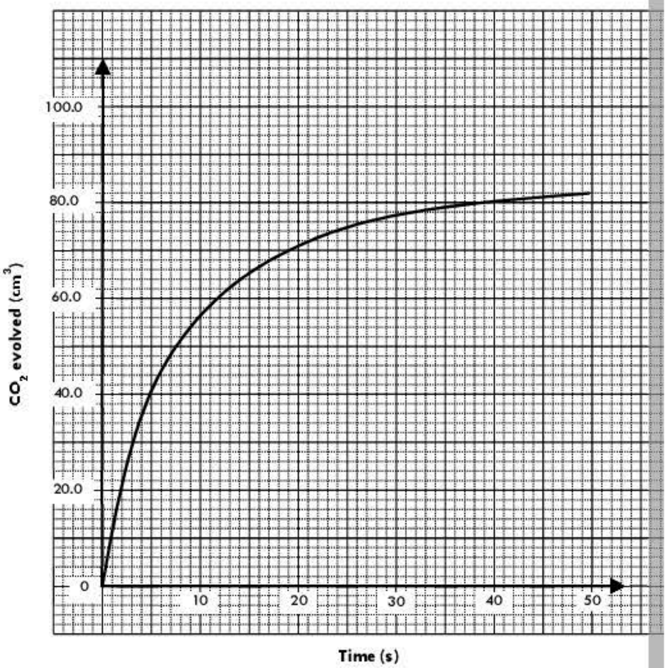
a)



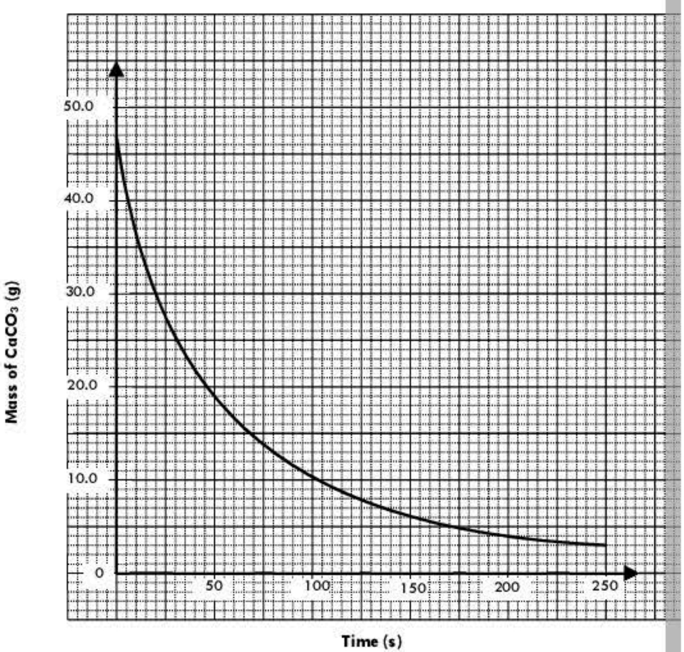
b)



3. Calculate the gradient of the tangent for the following graph:
   a) at 30 s
   b) at 10 s



4. Calculate the gradient of the tangent for the following graph:
   a) at 100 s
   b) at 50 s



REARRANGING EQUATION[cut] FORM $y = mx + c$

LEARNING OUTCOME

Rearrange equations to the form $y = mx + c$, and then use graphs to find gradient [cut]

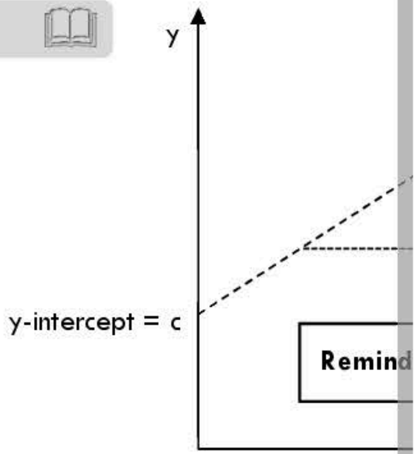
THEORETICAL OVERVIEW

Equations in the form $y = mx + c$ give straight-line graphs.

The equation $\Delta G = \Delta H - T\Delta S$ is called the Gibbs equation. The equation can be rearranged easily to the form $y = mx + c$:

$$y = mx + c$$

$$\Delta G = (-\Delta S)T + \Delta H$$



If a graph of ΔG vs T is plotted, then you can find from the graph the values of:

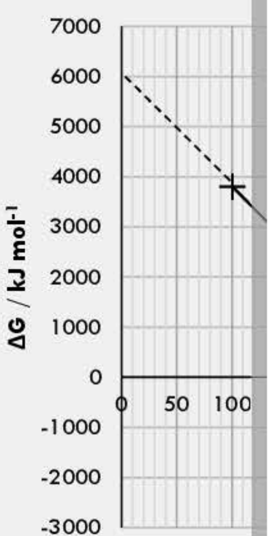
- gradient = m = $-\Delta S$
- y-intercept = c = ΔH

ΔH is the enthalpy change (the energy change due to bond breaking and forming). Unit = k[cut]
ΔS is the entropy change which can be + or –, so the slope could be positive or negative. Un[cut]
ΔG is the free energy change. A negative ΔG means the reaction is feasible. Unit = kJ mol^{-1}

WORKED EXAMPLE: GIBBS FREE ENERGY

Plot the following data and use the graph to find the values of ΔS and ΔH.

T / K	G / kJ mol^{-1}
100	3810
150	2710
200	1610
250	510
300	-590
350	-1690



Calculating the gradient:

$$-\Delta S = \frac{(0)-(3000)}{(275)-(135)} = -21.4$$

$\Delta S = 21.4\ kJ\ mol^{-1}\ K^{-1} = 21400\ J\ mol^{-1}\ K^{-1}$

Extrapolate the line back to the y-axis to find the y-intercept:

$\Delta H = 6000\ kJ\ mol^{-1}$

Altern[cut]
y-interc[cut]
and c =[cut]

WORKED EXAMPLE: IDEAL GAS LAW

'A gas with an unknown number of moles (n) is compressed in a container. As the pressure increases. The temperature is held constant at 298 K.

a) Use the data given to calculate T / V for each volume.

b) Then rearrange the equation pV = nRT, and plot p against $\frac{T}{V}$, to find the val R is 8.314 J K^{-1} mol^{-1}.'

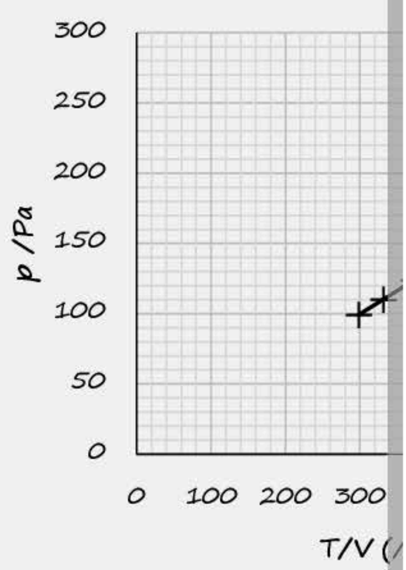
Rearrange the equation to the form y = mx + c:

$$y = mx\ (+c)$$

$$pV = nRT \rightarrow p = nR\frac{T}{V}\ (+0)$$

This equation doesn't have a 'c' part, so the y-intercept will be at 0. The gradient against T/V. Don't forget that T is 298 K.

V / m³	T/V	p / Pa
1.000	298	99.1
0.900	331	110
0.800	373	124
0.700	426	142
0.600	497	165
0.500	596	198
0.400	745	248



Gradient (m) = $\frac{200-100}{600-300}$ = 0.333

Gradient = nR, so n = $\frac{Gradient}{R}$

n = $\frac{0.333}{8.314}$ = 0.0401 mol

Rearranging with exponentials and logs: Arrhenius equation

The Arrhenius equation is $k = Ae^{\frac{-E_A}{RT}}$.

Log rules can be used to rearrange this equation into the form y = mx + c.

$k = Ae^{\frac{-E_A}{RT}}$ — take the natural log of both sides

$\ln k = \ln(A \times e^{\frac{-E_A}{RT}})$ — Use ln(J × K) = ln J + ln K

$\ln k = \ln A + \ln e^{\frac{-E_A}{RT}}$ — Use ln(e^x) = x

$\ln k = \frac{-E_A}{RT} + \ln A$

This is now in the form:

$$y = mx + c$$

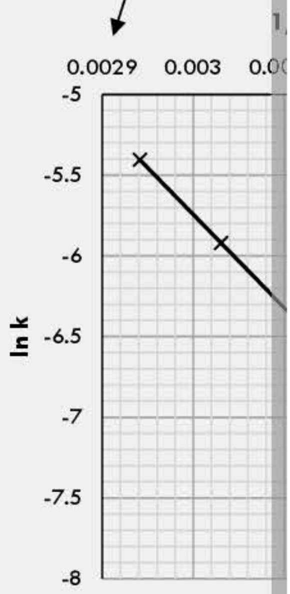
$$\ln k = \frac{-E_A}{R} \times \frac{1}{T} + \ln A$$

WORKED EXAMPLE

'Use the data below to find the missing data, and then plot ln k against $\frac{1}{T}$ to find
R = 8.314 kJ mol⁻¹ K⁻¹.'

T / K	k / s⁻¹	1/T	ln k
300	4.67×10^{-4}	0.00333	-7.67
310	8.69×10^{-4}	0.00323	-7.05
320	1.55×10^{-4}	0.00313	-6.47
330	2.69×10^{-3}	0.00303	-5.92
340	4.49×10^{-3}	0.00294	-5.41

Tip: We can't just e
axis to find the y int
level with x = 0.



Solution

Gradient

$$\text{gradient} = \frac{(-7.5)-(-5.5)}{0.0033 - 0.00296} = -5882$$

$$\text{gradient} = -\frac{E_A}{R}, \text{ so } E_A = -\text{gradient} \times R$$

$$E_A = 5882 \times 8.314 = 49\,000 \text{ kJ mol}^{-1}$$

y-intercept

$$\ln k = \frac{-E_A}{RT} + \ln A$$

$$\text{so } \ln A = \ln k + \frac{E_A}{RT}$$

$$= -7.67 + \frac{49\,000}{8.314 \times 300}$$

$$= 11.9$$

$$A = e^{11.9} = 1.53 \times 10^5$$

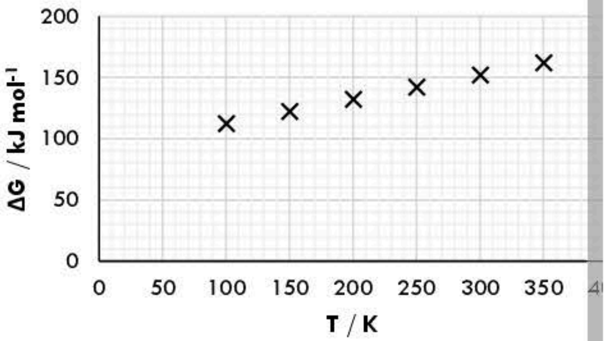
INSPECTION COPY

PRACTICE QUESTIONS

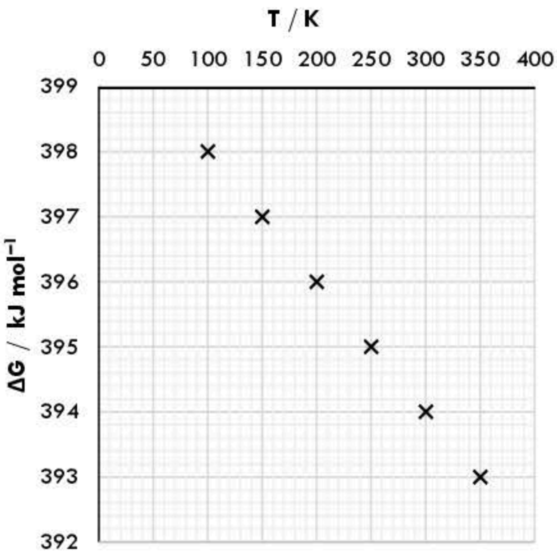
1. Use the following graphs of ΔG vs T to find the values of ΔH and ΔS.

$$\Delta G = \Delta H - T\Delta S$$

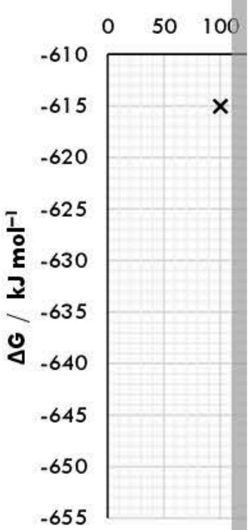
a)



b)



c)



2. Draw a graph of the following to find the stated values:
   a) p vs T/V to find n (pV = nRT). T = 298 K.

V / m^3	p / Pa	T/V K m^{-3}
50.0	15.0	
40.0	19.0	
30.0	25.0	
20.0	37.0	
10.0	74.0	
5.0	149.0	

   b) ln k against 1/T to find E_a and A, using a rearranged version of the equat

T / K	k / s^{-1}	1/T / K^{-1}	ln k
300	1.70×10^{-8}		
400	4.23×10^{-5}		
500	4.61×10^{-3}		
600	1.05×10^{-1}		
700	9.82×10^{-1}		

SHAPES IN CHEMIS

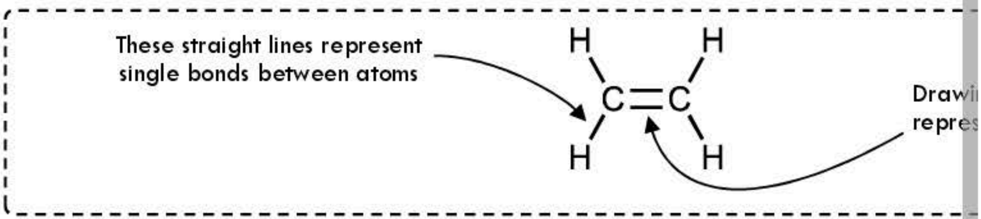
LEARNING OUTCOME

Draw the structures of molecules with different shapes, bond angles and orders of s

THEORETICAL OVERVIEW

2D molecules

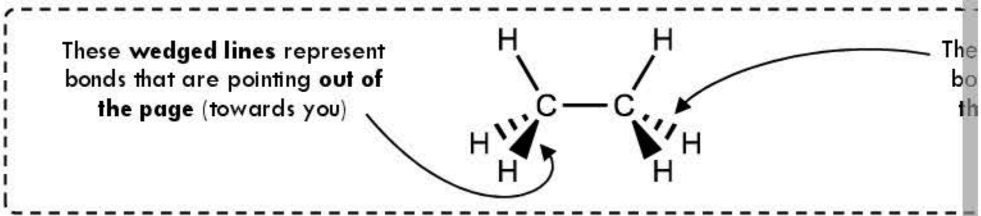
Here is an example of a 2D diagram of a molecule.



This is the simplest way of representing molecules. Each line between atoms represe

Wedge-and-dash diagrams

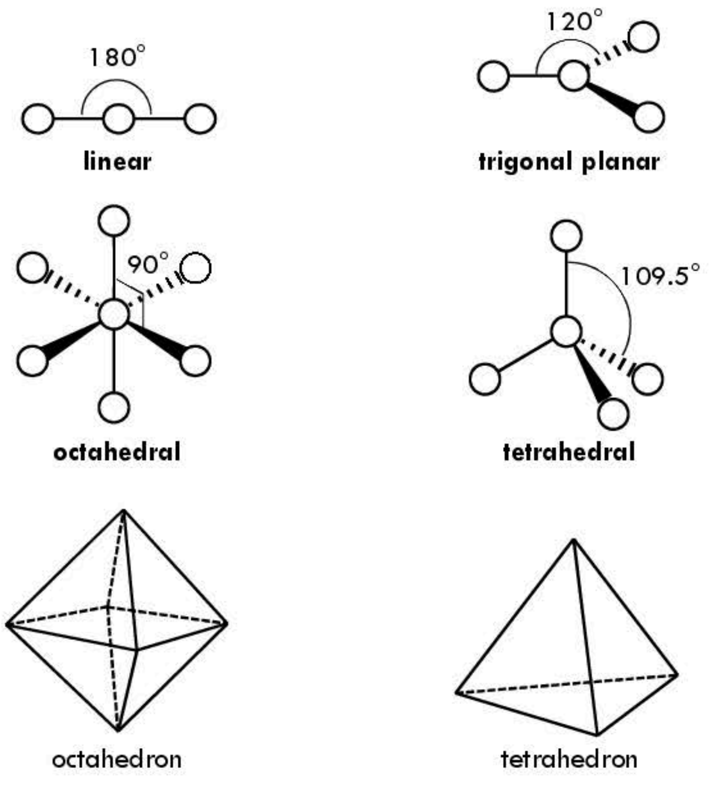
In reality, molecules are not 2D – they are 3D. It is possible to draw the 3D layout **dashed** lines:



Using wedged and dashed lines, you can represent the structures of many basic mo models of these molecules. You can use molecular modelling kits, or even just cockt

Bond angles

Different molecular structures have different **bond angles** (the angle between bond angles in these basic molecular structures.



Symmetry

As well as bond angles, another important feature of molecular structure is **symmetry**. Using a 3D representation of a molecule, you can work out whether it is **symmetrical**.

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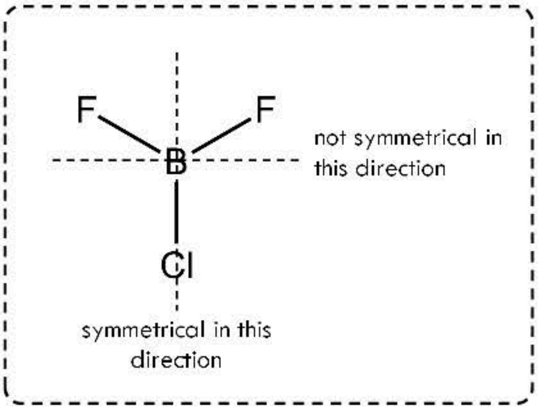
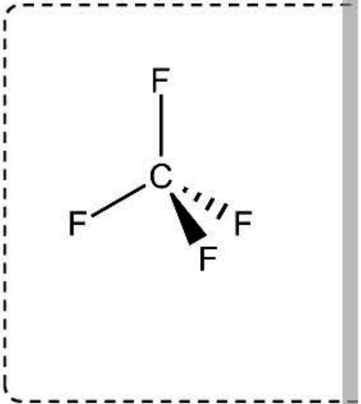
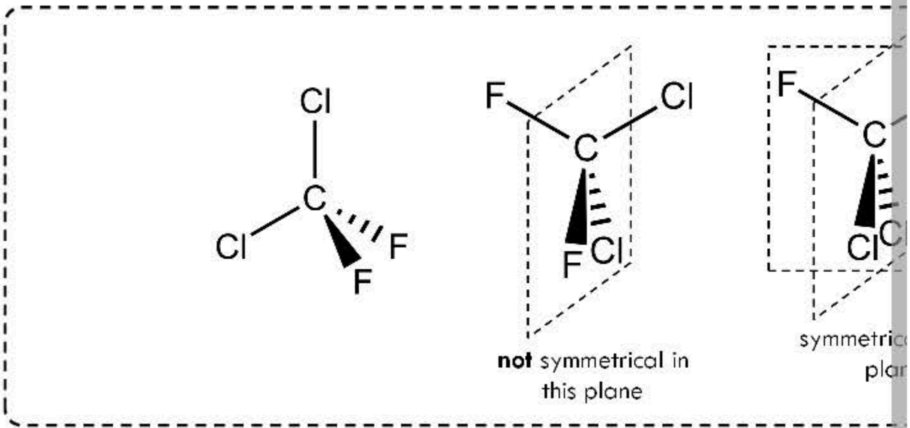
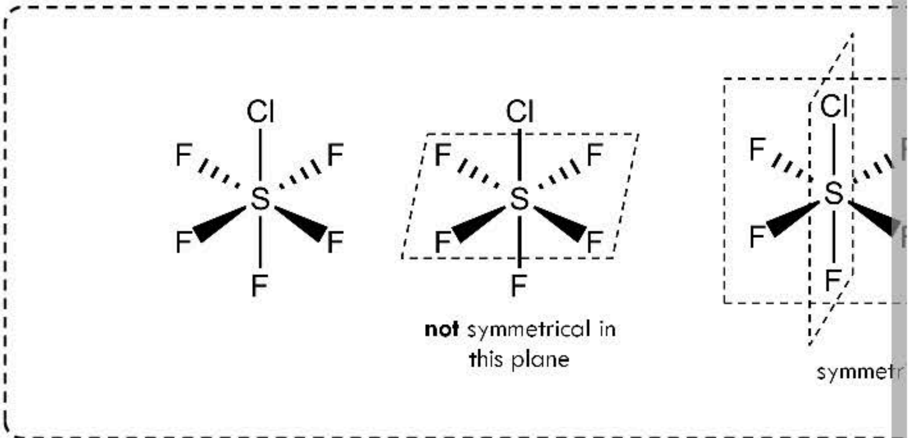




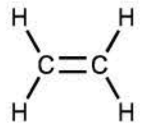




PRACTICE QUESTIONS

1. Methane has the formula CH_4. It contains a central carbon with four hydrogens geometry.
   a) Draw methane in 3D.
   b) Identify the bond angle in methane from its geometry.

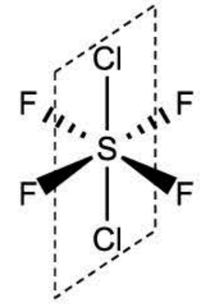
2. This molecule is ethene:



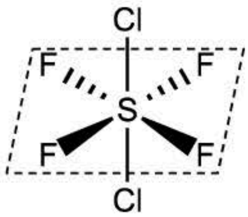
   Represent ethene as a 3D diagram, with the carbon–hydrogen bonds in and o

3. State whether the following molecules are symmetrical in the planes shown.

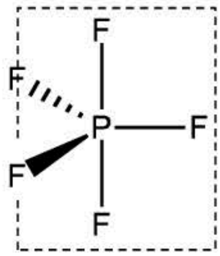
a)



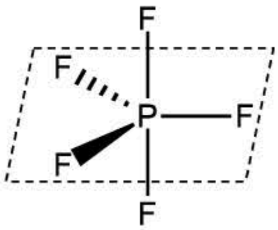
b)



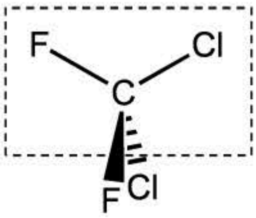
c)



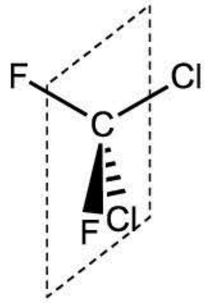
d)



e)



f)

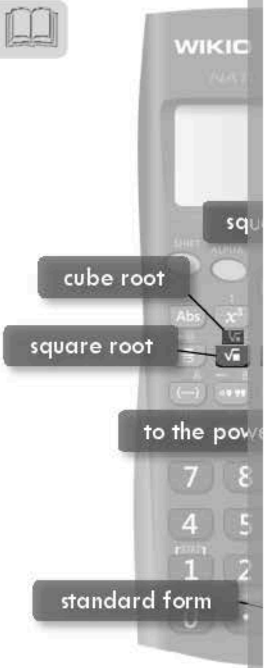


APPENDIX – USING A CAL

LEARNING OUTCOME

Use your calculator to make calculations involving powers, standard form, exponent

THEORETICAL OVERVIEW



Powers

Powers mean that a number is multiplied by itself.

For example:

$3^3 = 3 \times 3 \times 3 = 27$
$10^5 = 10 \times 10 \times 10 \times 10 \times 10 = 100\ 000$

To calculate 2^5, write:

[2] [y^x] [5] [=]

Roots

Roots are the opposite of powers.

$\sqrt[3]{64} = 4$, because $3 \times 3 \times 3 \times 3 = 64$

To calculate $\sqrt[3]{64}$, write:

[3] [$\sqrt[x]{\ }$] [sin] [6] [4] [=]

Logarithms

A logarithm is the opposite of '10 to the power of'. It tells you how many times you
itself to get a certain number.

$\log 1000 = 3$

This is because $10^3 = 10 \times 10 \times 10 = 1000$

To find the log of 1000 on a calculator, type:

[log] [1] [0] [0] [0] [=]

e

e is a number which comes up in a few equations in Chemistry. It is a number, simil
2.7183 to 4 decimal places.

The [e^x] button works in the same way as the power button, so to calculate e^2, you

[e^x] [2] [=]

Natural logarithms

Some equations will include ln, which is called the natural logarithm. To find the nat

[ln] [8] [=]

Standard form

Standard form is a way of representing numbers, especially very large or very sm

To write 5×10^7, type:

[5] [10^x] [7] [=]

WORKED EXAMPLE

'The rate constant, k, can be calculated from the Arrhenius equation:

$$k = Ae^{\frac{-E_a}{RT}}$$

Where: **k is the rate constant**
A is a constant,
E_a is the activation energy,
R is the universal gas constant, which has the value 8.314×10^{-3} kJ m
T is the temperature (in kelvin).

Calculate k when
$A = 2.13 \times 10^9$
$E_a = 111000$
T = 300 K'

Solution

To calculate this, type:

(2 • 1 3 10^x 9) × (e^x (– 1 1 1 0 0 0 ÷ (8 • 3

which should give an answer of 2.04×10^{-10}.

PRACTICE QUESTIONS

1. Calculate the following:
   a) $4^5 - 5^4$
   b) log 10 000 000
   c) $8.95 \times 10^7 \div 1.41 \times 10^9$
   d) $\ln(e^{5^2})$
   e) $e^{4^2-3^2}$
   f) log 63
   g) 6^{8-3^2}
   h) $(9.49 \times 10^{-6}) \div (3.23 \times 10^{-7})$
   i) $\log(4.5) - e^7$
   j) $3^2 + e^2 + (\log(3))^2$

2. Using the Arrhenius equation from the worked example, calculate k for the foll
   a) E_a = 52,100 J mol^{-1}
      T = 313 K
      A = 15.6
      R = 8.314 J K^{-1} mol^{-1}
   b) E_a = 35 600 J mol^{-1}
      T = 612 K
      A = 9.40
      R = 8.314 J K^{-1} mol^{-1}

APPENDIX – DIAGNOST

1. a) Write 0.000432 in standard form.
   b) Write the number 9.045×10^2 out in full.
   c) Round 7.5654 to 3 significant figures.
   d) A reaction starts at 12 °C and ends at 23.7 °C. Write the temperature c significant figures.

2. a) Convert 3 minutes 45 seconds into seconds.
   b) Convert 0.24 km into m.

3. a) Convert 0.20 dm^3 into mm^3.
   b) Convert 200 cm^3 into dm^3.
   c) Convert 32 s^{-1} into ms^{-1}.
   d) Convert 3 kg mol^{-1} into g mol^{-1}.

4. a) How many significant figures does the number 0.00693 have?
   b) Write 45.298 to 4 significant figures.

5. a) Write the ratio 12:42 as a fraction in its simplest form.
   b) Write the fraction $\frac{4}{5}$ as a decimal.
   c) Write the percentage 60 % as a fraction in its simplest form.

6. a) A 87.2 g piece of rock contains 34.5 g aluminium by mass. Calculate the
   b) Find the percentage by mass of C in CO_2.
   c) Calculate the percentage yield of a reaction with actual yield 4.80 g and

7. a) A 120 cm^3 solution contains 3.40 g. How much mass is in 77.0 cm^3 of the
   b) A salt with the formula VO_x contains 61.4 % vanadium. Determine the fo

8. a) Calculate the mean of the following values: 5.5, 5.6, 5.7, 5.6
   b) Calculate the mean titre from the following titres:

	Titre			
	Rough	1	2	3
start volume / cm^3	0.00	0.45	0.05	0.5
end volume / cm^3	30.70	29.45	29.45	29.
volume of acid / cm^3				

   c) Sulfur has the following composition of isotopes: ^{32}S 95.00 %, ^{33}S 00.75 % relative atomic mass of sulfur.

9. Calculate the percentage uncertainty in a reading of 12.45 g on an analogue bal

10. Calculate the uncertainty in a titre of 23.35 cm^3 measured on a burette with 0. errors due to the volume of a drop.

11. a) Sketch a graph to show the relationship between Rate and $[H^+]$ for the ex
    b) For the expression Rate ∝ $[H^+]^2$, describe the effect on the rate if $[H^+]$ is t

12. a) Rearrange the equation $pV = nRT$ to make R the subject of the formula.
    b) Rearrange the equation $y = \frac{x+9}{3}$ to make x the subject of the formula.
    c) Find the value of T when p = 100,000 Pa, V = 0.0430 m^3, n = 2.50 mol

13. a) In the equation $\Delta G = \Delta H - T\Delta S$. Find the value of ΔS when ΔG = -120 k T = 150 K.
    b) An experiment with three measurements has a mean result of 23.45 cm^3. Measurement 1 = 23.40 and measurement 2 = 23.60. Determine the value of measurement 3.

14. a) Find the value of [A] in mol dm^{-3} for the equation Rate = k[A]^3[B] when R
k = 0.0400 dm^9 mol^{-3} s^{-1} and [B] = 0.100 mol dm^{-3}.

b) Rearrange the formula $V = \frac{4\pi r^3}{3}$ to find the value of r when V = 32.0 m^3.

15. a) Use a calculator to find the value of log(13000).

b) Given that pH = -log[H$^+$], find the pH of a solution with [H$^+$] = 0.000320

16. a) Plot a graph of the following data. Add a trend line.

time / s	rate / mol dm^{-3} s^{-1}
0	0.521
60	0.452
120	0.401
180	0.345
240	0.201

b) Plot a graph of the following data. Add a trend line.

time / s	concentration / mol dm^{-3}
60	0.0533
120	0.0487
180	0.115
240	0.161
300	0.146
360	0.293
420	0.344
480	0.557
540	0.936
600	1.58

17. a) Find the gradient of the line of best fit for the graph in 16 a.

b) Find the gradient of the tangent at 400 s for the graph in 16b.

18. Plot a graph of the following data to find the value of E$_a$, given that ln k = ln

T / K	k / s^{-1}	1/T / K^{-1}	ln k
300	7.63×10^2		
400	2.81×10^3		
500	6.14×10^3		
600	1.03×10^4		
700	1.50×10^4		

19. a) Draw the molecule SF_6 in 3D using wedge-and-dash lines. It has octahed

b) Identify the bond angle in SF_6.

DIAGNOSTIC TEST ANS

1. a) 4.32×10^{-4}

   b) 904.5

   c) 7.57

   d) $23.7 - 22 = 11.7$
   $= 12\ ^\circ C$ (2 s.f.)

2. a) 225 s

   b) $0.24 \times 10^3 = 240$ m

3. a) $0.20 \times (10^2)^3 = 200\ 000\ mm^3$

   b) $200 \div 10^3 = 0.2\ dm^3$

   c) $32 \div 10^3 = 0.032\ ms^{-1}$

   d) $3 \times 10^3 = 3000\ g\ mol^{-1}$

4. a) 3

   b) 45.30

5. a) $\frac{2}{7}$

   b) 0.8

   c) $\frac{3}{5}$

6. a) $\frac{34.5}{87.2} \times 100 = 39.6\ \%$

   b) $\frac{12}{12 + 16 \times 2} \times 100 = 27.\ 3\%$

   c) $\frac{4.8}{9.3} \times 100 = 51.\ 6\%$

7. a) $\frac{3.4}{120} \times 77 = 2.18$ g

   b) relative formula mass of V = 50.9
   relative formula mass of $VO_x = \frac{50.9}{61.4} \times 100 = 82.9$
   relative formula mass of $O_x = 82.9 - 50.9 = 32$
   $x = \frac{32}{16} = 2$
   Salt is VO_2

8. a) $\frac{5.5 + 5.6 + 5.7 + 5.6}{4} = 5.6$

   b)

	Titre			
	Rough	1	2	3
start volume / cm^3	0.00	0.45	0.05	0.55
end volume / cm^3	30.70	29.45	29.45	29.45
volume of acid / cm^3	30.70	29.00	29.40	28.90

   Mean titre $= \frac{29.00 + 28.90}{2} = 28.95\ cm^3$

   c) $\frac{(32 \times 9.5) + (33 \times 0.75) + (34 \times 4.25)}{100} = 32.09$

9. Percentage uncertainty $= \frac{0.01}{12.45} \times 100 = 0.08\ \%$

10. Uncertainty in a reading = $0.05\ cm^3$
    Uncertainty in a titre (measurement) $= 0.05 \times 2 = 0.1$

    $\frac{0.1}{23.35} \times 100 = 0.43\ \%$

11. a)

    Ra

    b) multi

12. a) R =

    b) x =

    c) T

13. a) ΔS

    b) 23.4

    23.4
    x =

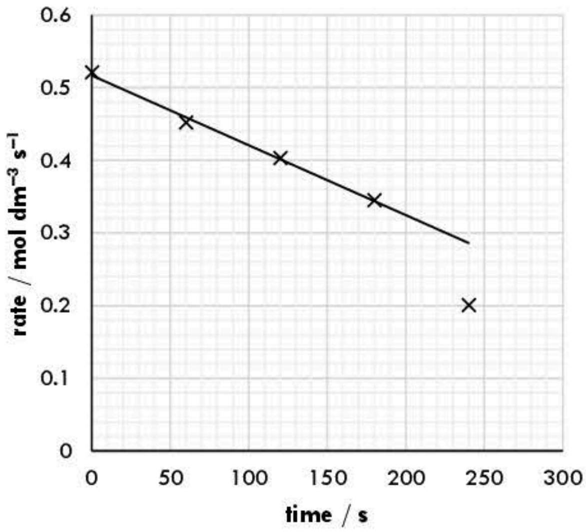
14. a) [A]

    b) r

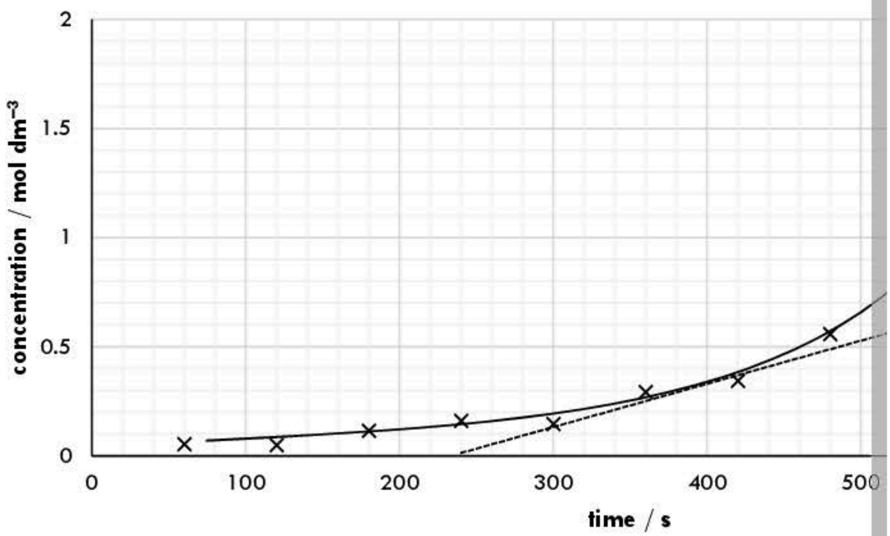
15. a) 4.1

    b) -log

16. a)



b)



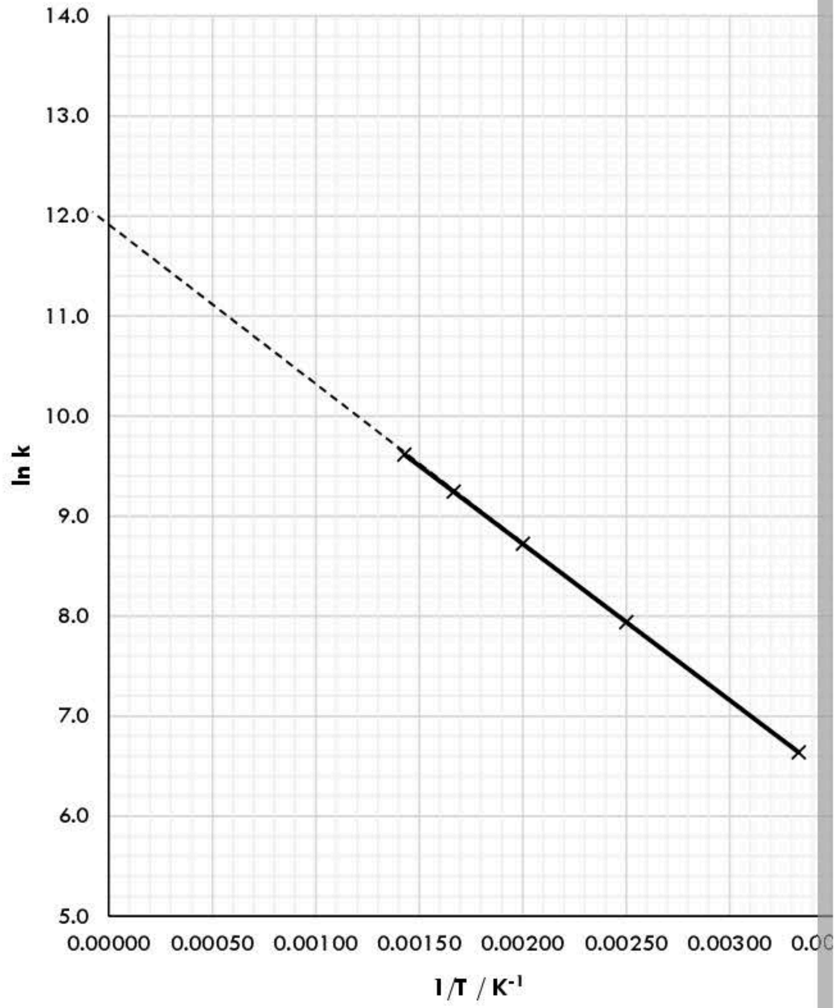
17. a) gradient $= \frac{0.29 - 0.52}{240 - 0}$

$= -9.58 \times 10^{-4}$ mol dm^{-3} s^{-1}

b) Gradient $= \frac{0.9 - 0.1}{680 - 300} = 0.00211$ mol dm^{-3} s^{-1} (allow between 0.00191 and 0.002

18.

T / K	k / s^{-1}	1/T / K^{-1}	lnk
300	7.63×10^2	0.00333	6.64
400	2.81×10^3	0.00250	7.94
500	6.14×10^3	0.00200	8.72
600	1.03×10^4	0.00167	9.24
700	1.50×10^4	0.00143	9.62



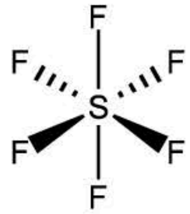
y-intercept = lnA = 11.9

$A = e^{11.9} = 147\,000$

$\text{Gradient} = \frac{9-7}{0.0018-0.0031} = -1538 = \frac{-E_a}{R}$

$E_a = 1538 \times 8.314 = 13\,000 \text{ J mol}^{-1}$

19. a)



b) 90°

PRACTICE QUESTIONS A

Decimals and Standard Form

1. a) 4.25×10^6 J
   b) 1.2×10^{-2} m
   c) 6.23×10^{11} s
   d) 7.896×10^{-7} kg

2. a) 0.00000672 mol
   b) 75900 atoms
   c) 0.000991 mol dm^{-3}
   d) 814.3 cm^3

3. a) 2.47 g
   b) 7.962 g
   c) 3.142 g
   d) 1.0 g

4. a) 1.63 g
   b) 3.26×10^{-1} g

5. $\frac{13 \times 0.2}{100} = 0.026 = 2.$

Units I – Common Units and Prefixes

1. a) $\frac{40}{1000} = 0.04$ km
   b) $0.025 \times 10^6 = 25\ 000$ mg
   c) $\frac{180}{60} = 3$ min
   d) $25 + 273 = 298$ K
   e) $2.45 \times 10^{-7} \times 10^9 = 245$ nm
   f) $\frac{0.26 \times 10^{12}}{10^9} = 260$ GJ
   g) $\frac{4.65 \times 10^{22}}{10^{12}} = 4.65 \times 10^{10}$ km
   h) $\frac{684\ 000}{1\ 000} = 684$ nm

2. a) $p = 20 \times 10^3 = 20\ 000$ Pa
   $n = 120 \div 1000 = 0.120$ mol
   $T = 0 + 273 = 273$ K
   b) $p = 100 \times 10^3$
   $n = 20 \div 1000$
   $T = 20 + 273 =$
   c) $p = 40 \times 10^6 =$
   $n = 1450 \div 1$
   $T = 40 + 273 =$

3. a) $m = 0.250 \times 1$
   b) $m = \frac{4.50 \times 10^6}{10^3} =$
   c) $c = 0.142 \times 10$
   d) $T = 320 + 273$
   e) $m = \frac{30}{1000} = 0.0$
   f) $c = 129 \div 10^3$

Units II – Units with Powers

1. a) 1000 times
   b) 10 000 times
   c) 8 ($2 \times 2 \times 2$)
   d) 2 times
   e) 5000 times

2. a) $5 \times (10^3)^3 = 5\ 000\ 000\ 000$ mm^3
   b) $3 \div (10^{-3})^3 = 3 \times 10^{-6}$ m^3
   c) $20 \times (10)^2 = 2000$ dm^2
   d) $100 \times (10^3)^2 = 100\ 000\ 000$ mm^2
   e) $8.8 \times 10^{-17} \times (10^6)^3 = 88$ km^3
   f) 0.02455 dm^3
   g) 250 cm^3
   h) $3 \times 10^3 = 3000$ J kg^{-1}
   i) $18 \times 10^3 = 18\ 000$ mol dm^{-3}

3. a) $4.6 \div (39.1 + 1$
   b) $0.5 \times (23 + 16$
   c) $11.3 \div (24.3 +$
   d) $0.35 \times (23 \times 2$

4. $23.38 \div 1000 = 0.0$

5. $p = 150$ kPa $= 150$
   $V = 30\ dm^3 = 30 \div$
   $T = 25\ °C = 25 + 2$

Significant Figures

1. a) 76 000
   b) 0.00613
   c) 19000
   d) 0.010
   e) 0.003407
   f) 2.000

2. a) 0.194 mol (3 s.f
   b) 0.59 mol (2 s.f.)
   c) 1.598 mol (4 s.f

Fractions, Percentages and Ratios

1. a) 45 ÷ 100 = 0.45
   b) 1 ÷ 5 = 0.2
   c) 0.3 ÷ 100 = 0.003
   d) 0.7 ÷ 3.5 = 0.2
   e) 5 ÷ 12 = 0.417

2. a) 5 ÷ 7 × 100 = 71.4 %
   b) 6 ÷ 23 × 100 = 26.1 %
   c) 9 ÷ 10 × 100 = 90.0 %
   d) 7 ÷ 9 × 100 = 77.8 %
   e) 42 ÷ 100 × 100 = 42.0 %

3. a) 1/4
   b) 5/4
   c) 3/10
   d) 3/5
   e) 11/20

4. a) 1 ÷ (1 + 3) = 1
   b) 1 ÷ 4 × 100 =

5. a) CH_2 (divide all r
   b) CH_2O (divide a

6. 40:60 = 2:3

Percentage Mass, Purity and Yield

1. a) $\frac{36}{40} \times 100 = 90\ \%$
   b) $\frac{15}{20} \times 100 = 75\ \%$

2. a) $\frac{1.2}{3.0} \times 100 = 40\ \%$
   b) $\frac{28}{56} \times 100 = 50\ \%$
   c) $\frac{4.1}{6.7} \times 100 = 61\ \%$

3. a) $\frac{40.1}{40.1 + 12 + 3 \times 16}$ ×
   b) $\frac{24.3}{24.3 + 32.1 + 4 \times 16}$
   c) $\frac{23.0}{23 + 16 + 1} \times 100$
   d) $\frac{2 \times 1}{40.1 + 2 \times (16 + 1)}$ ×
   e) $\frac{2 \times 55.8}{2 \times 55.8 + 3 \times (32.1}$

Scaling Quantities

1. a) (0.56 ÷ 14) × 60 = 2.4 g
   b) (0.56 ÷ 14) × 85 = 3.4 g
   c) (0.56 ÷ 14) × 3 = 0.12 g

2. a) (1.36 ÷ 0.17) × 1 = 8.0 dm^3
   b) (1.36 ÷ 0.17) × 1.74 = 14 dm^3
   c) (1.36 ÷ 0.17) × 34 = 270 dm^3
   d) (1.36 ÷ 0.17) × 0.1 = 0.80 dm^3

3. percentage yield $= \frac{\textit{actual yield}}{\textit{theoretical yield}} \times 100$

   theoretical yield $= \frac{\textit{actual yield}}{\textit{percentage yield}} \times 100$

   $= \frac{18}{26} \times 100$

   = 69.2 g

4. (40 ÷ 25) × 100 = 1

5. theoretical yield

6. a) (35.5 ÷ 47.6) ×
   b) 74.6 – 35.5 =
   formula mass of
   M is K

7. a) 16 × 3 = 48
   (48 ÷ 47.1) × 1
   101.9 – 48 = 5
   53.9 ÷ 2 = 27.
   b) M is Al as Al ha

Calculating Means

1. a) $\frac{1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10}{10} = 5.5$

   b) $\frac{5 + 4 + 2 + 8}{4} = 4.75$

   c) $\frac{6.5 + 6.2 + 6.6 + 6.9}{4} = 6.55$

   d) $\frac{250 + 300 + 280 + 310 + 260}{5} = 280$

   e) $\frac{0.06 + 0.02 + 0.05 + 0.02}{4} = 0.0375$

2. a) $\frac{14.60 + 14.50}{2} = 14.6\ cm^3$

   b) $\frac{19.40 + 19.45}{2} = 19.43\ cm^3$

   c) $\frac{13.20 + 13.30}{2} = 13.3\ cm^3$

3. a) $\frac{(234 \times 2) + (235 \times 2}{100}$

   b) $\frac{(35 \times 75) + (37 \times 2}{100}$

   c) $\frac{(6 \times 8) + (7 \times 92)}{100}$

   d) $\frac{(50 \times 9) + (52 \times 8}{100}$

Uncertainty I

1. a) $23.0 \pm 0.5\ cm^3$

   b) 12.0 ± 0.1 cm (uncertainty is 0.05×2 as two readings are taken)

   c) 16 ± 1 °C

   d) $19.50 \pm 0.10\ cm^3$

   e) 2×0.01 g $= 0.02$ g
   $4.50 - 3.25 = 1.25$ g
   1.25 ± 0.02 g

   f) 22.0 ± 0.5 °C

   g) $45.60 - 0.05 = 45.55$
   $0.05 \times 2 = 0.10$
   $45.55 \pm 0.10\ cm^3$

2. a) $\frac{25.2 + 24.8 + 26.2 +}{4}$

   b) ± 0.7 °C

3. $\frac{34.3 + 38.1 + 33.2 + 37.1}{4} =$
   $(38.1 - 33.2) \div 2 =$
   35.7 ± 2.5 g

Uncertainty II

1. a) $\frac{0.5}{12.5} \times 100 = 4.0\ \%$

   b) $\frac{0.1}{42.6} \times 100 = 0.23\ \%$

   c) $\frac{0.15}{28.5} \times 100 = 0.53\ \%$

   d) $\frac{1}{49.4} \times 100 = 2.0\ \%$

   e) $\frac{5}{1542} \times 100 = 0.3\ \%$

   f) $\frac{0.05}{0.13} \times 100 = 38\ \%$

2. a)

Titration	Rough	1	2	3
Initial reading (cm^3)	0.00	0.00	0.00	0.10
Final reading (cm^3)	27.00	26.05	26.15	26.85
Titre (cm^3)	27.00	26.05	26.15	26.75

Mean titre $= \frac{26.05 + 26.15}{2} = 26.10$

$\frac{0.15}{26.1} \times 100 = 0.56\ \%$

b)

Titration
Initial reading (cm^3)
Final reading (cm^3)
Titre (cm^3)

Mean titre = 25.

Uncertainty = 0. / 25

c)

Titration
Initial reading (cm^3)
Final reading (cm^3)
Titre (cm^3)

Mean titre = 22.

Uncertainty = 0. / 22

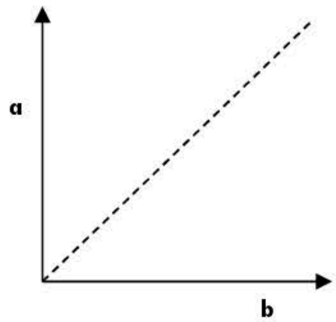
Mathematical Symbols

1. a) $2\ cm^3 > 1\ cm^3$
   b) $4000\ mg < 4300\ mg$
   c) $4000 >> 0.003$
   d) moles $\propto$ pressure

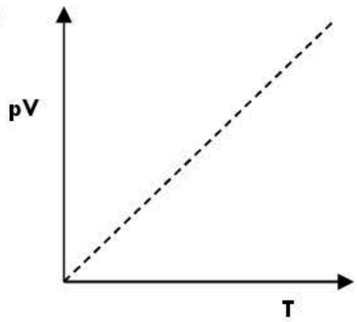
2. a) Doubles (both sides increase proportionally)
   b) Halves (both sides decrease proportionally)

2. c) Halves (pV doe
   cancel out the c
   d) Doubles (both si
   e) Quarters (if p a
   must quarter. n
   decrease propo
   f) Triples (n triplin
   V must triple to

3. a)



b)



c)

Rat

Using Equations I – Rearranging Simple Equations

1. concentration of reactant used = rate × reaction time

2. a) $x = d/2$
   b) $x = wA/y$
   c) $x = 4$

3. moles $= \frac{mass}{M_r}$

   moles $= \frac{volume}{24\ 000}$

   moles = concentration × volume

4. a) $p = \frac{nRT}{V}$
   b) $T = \frac{pV}{nR}$
   c) $n = \frac{pV}{RT}$

5. V = moles × 24 000
   = 0.75 × 24 000
   $= 18\ 000\ cm^3$

6. $\Delta T = \frac{Q}{mc}$
   $= \frac{2000}{150 \times 4.18}$
   $= 3.19\ K$

Using Equations II – Equations with +, –, × and ÷

1. a) $x = 3y - 5$
   b) $x = \frac{y+9}{6}$
   c) $x = \frac{y-c}{m}$
   d) $x = \frac{4}{y}$
   e) $x = y - 1$
   f) $x = \frac{y+2}{2}$ or $x = \frac{y}{2} + 1$
   g) $x = \frac{1}{3y}$
   h) $x = \frac{y-3}{y}$ or $x = 1 - \frac{3}{y}$

2. Mean $= \frac{x + 10 + 8 + 7}{4} = 8$
   $x + 10 + 8 + 7 = 8 \times 4 = 32$
   $x = 32 - (10 + 8 + 7)$
   $x = 7\ cm^3$

3. Mean $= \frac{30.2 + x + 28.7 + 30.0}{4} = 29.4$
   $x + 30.2 + 28.7 + 30.0 = 29.4 \times 4 = 117.6$
   $x = 117.6 - (30.2 + 28.7 + 30.0)$
   $x = 28.7\ g$

4. $20.2 = \frac{(20 \times 90) + (Y \times}{100}$
   20.2 × 100 = (20 ×
   2020 – 1800 = (Y ×
   $\frac{220}{10} = Y$
   Y = 22

5. a) 492 = 2×436 -
   2×H–Cl = 2×4
   H–Cl = 2×
   = 43
   b) -482 = 2×436
   4×H–O = 2×4
   H–O = 2×436 + 4 / 4
   = 46

Using Equations III – Equations with Powers and Roots

1. a) $2^3 + 3^2 = 17$

   b) $c = 3^2 \div 3$
   $= 3$

   c) $c^2 = 3^2$
   $c = 3$ (or -3)

   d) $c = \frac{b}{a^2}$
   $= \frac{3}{2^2} = \frac{3}{4}$
   $= 0.75$

   e) $c = \sqrt{a^2b^2 - b^3 - 5}$
   $= \sqrt{2^2 3^2 - 3^3 - 5}$
   $= \sqrt{4}$
   $= 2$ (or -2)

   f) $c = \sqrt[3]{\frac{b^3 + a^2 + 1}{a^2}}$
   $= \sqrt[3]{\frac{3^3 + 2^2 + 1}{2^2}}$
   $= \sqrt[3]{8}$
   $= 2$

2. a) $x = \sqrt{2y}$

   b) $x = \sqrt{\frac{4\pi}{y}}$

   c) $x = 4y^2$

   d) $x = \sqrt[3]{\frac{y}{27z}}$ or $x = \frac{\sqrt[3]{\frac{y}{z}}}{3}$

3. a) $[H^+] = \sqrt[2]{\frac{[CH_3(COC}{[CH_3(CC}}$
   $= \sqrt[2]{\frac{0.5 \times 2.}{1}}$
   $= 9.22 \times$

   b) $[H_2] = \sqrt[3]{\frac{[NH_3]^2}{[N_2] \times K}}$
   $= \sqrt[3]{\frac{0}{0.12 \times 1}}$
   $= 4.5$ mol

4. a) $m = 2 \times \frac{K.E}{v^2}$
   $= 2 \times \frac{6.77}{45}$
   $= 6.66 \times$

   b) $v = \sqrt{\frac{2\ K.E}{m}}$
   $= \sqrt{\frac{2 \times 1.00}{9.27 \times}}$
   $= 46\ 400$

5. a) $k = \frac{Rate}{[NO]^2[H_2]}$
   $= 0.048$ s

   b) $[NO] = \sqrt{\frac{Rate}{k[H_2]}}$
   $= \sqrt{\frac{3.52}{0.048 \times}}$
   $= 0.049$ m

Logarithms

1. a) 1585
   b) 5.079
   c) -3.301
   d) 0.9162
   e) -4.000
   f) 3.000

2. a) 1000
   b) 2.512×10^8
   c) -2.699
   d) 0.8710
   e) -5.246

3. a)

ionisation energy number	1	2	3	4	5
ionisation energy (kJ mol^{-1})	577	1816	2744	11 577	14 84
log(ionisation energy)	2.7612	3.2591	3.4384	4.0636	4.171

   b) Values span a large range
   It makes the values easier to compare / plot on a graph

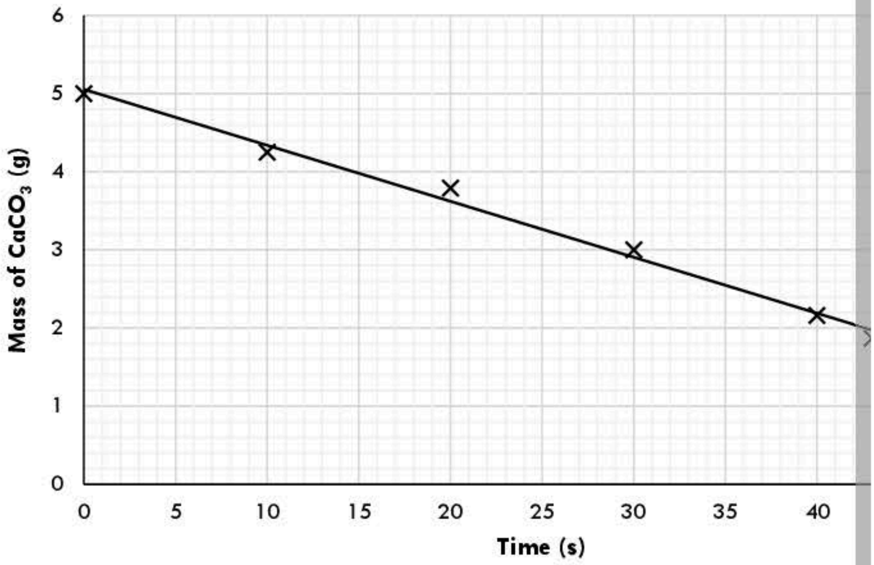
4. $k = Ae^{\frac{-E_a}{RT}}$

   $\ln k = \ln A - \frac{-E_a}{RT}$
   $= 7.65 - 16.4$
   $= -8.75$

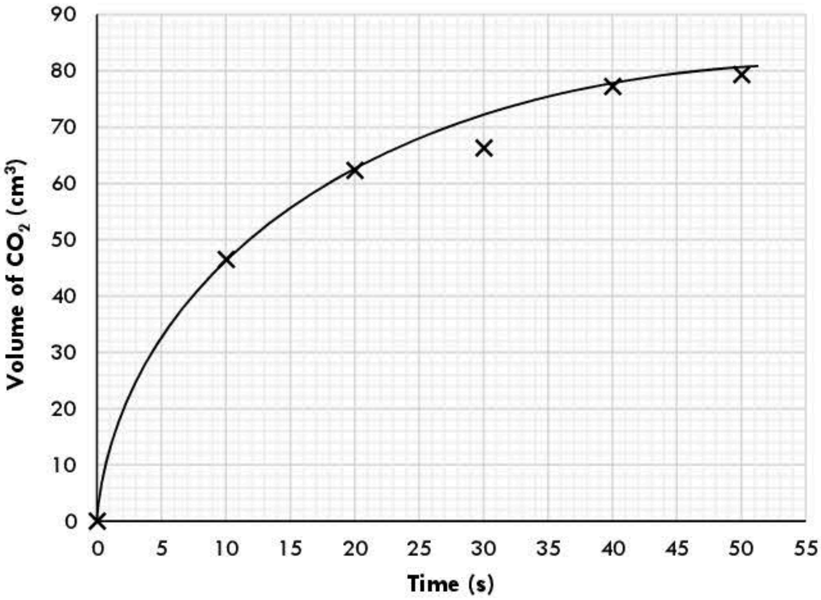
   $k = e^{-8.75}$
   $= 1.58 \times 10^{-4}$

Constructing Graphs

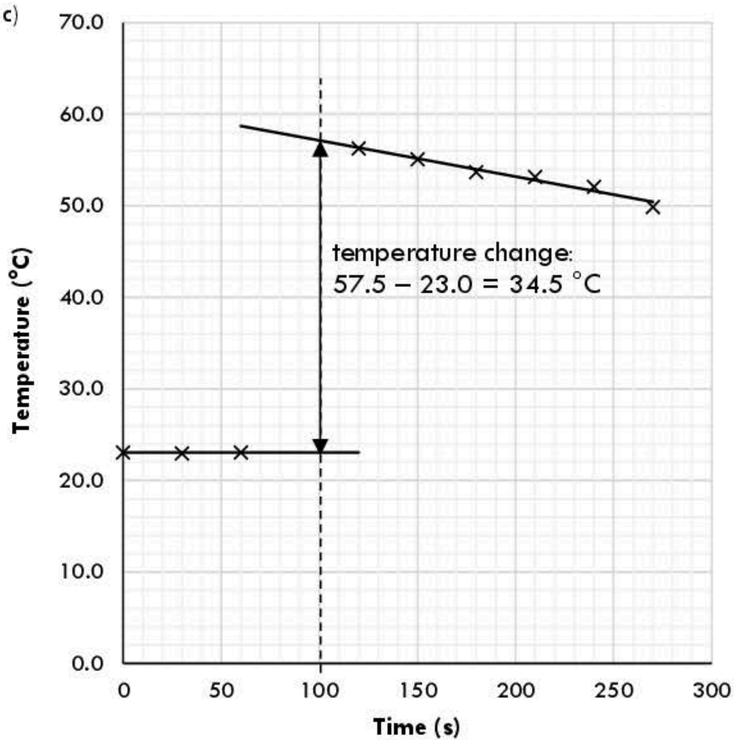
1. a)



b)



c)



Analysing Graphs

1. a) 3.40 g
   b) 2.50 g
   c) 27 s
   d) 4.00 – 2.25 = 1.75 g

2. a) Gradient $= \frac{5.0-1.2}{8-0} = 0.48$ mol dm^{-3} s^{-1}

   y–intercept = 1.2 mol dm^{-3}

   b) Gradient $= \frac{2-3.5}{35-25} = -0.15$ kJ mol^{-1} K^{-1}

   $y = -0.15x + c$, so $c = y + 0.15x$

   When $y = 2$, $x = 35$

   $c = 2 + 0.15 \times 35 = 7.25$ kJ mol^{-1}

3. a) $\frac{80-34}{20-0} = 2.3$ cm

   b) $\frac{84-65}{45-0} = 0.42$ c

4. a) $\frac{0-22}{190-0} = -0.12$

   b) $\frac{0-30}{125-5} = -0.25$

Rearranging Equations to the Form y = mx + c

1. a) $-\Delta S = \frac{(200)-(150)}{350-100} = 0.200$

   $\Delta S = -0.200$ kJ mol^{-1} K^{-1} (= 200 J mol^{-1} K^{-1})

   $\Delta H = \Delta G + T\Delta S$
   $= 110 + 100 \times (-0.2)$
   $= 90$ kJ mol^{-1}

   b) $-\Delta S = \frac{(393)-(398)}{350-100} = *0.020$

   $\Delta S = 0.020$ kJ mol^{-1} K^{-1} (= 20 J mol^{-1} K^{-1})

   $\Delta H = \Delta G + T\Delta S$
   $= 398 + 100 \times 0.020$
   $= 400$ kJ mol^{-1}

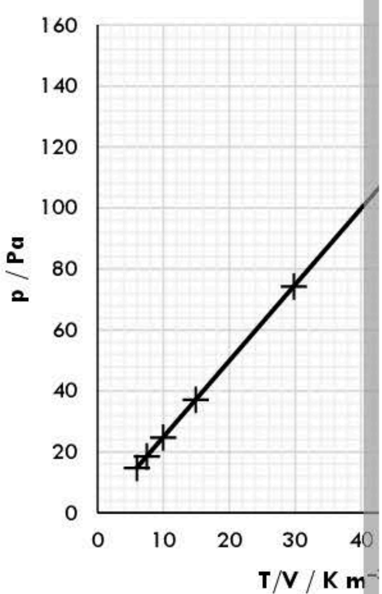
   c) $-\Delta S = \frac{(-645)-(-}{300-10}$

   $\Delta S = 0.150$ kJ

   $\Delta H = \Delta G + T\Delta$
   $= -615 +$
   $= -600$ kJ

2. a)

V / m^3	p / Pa	T/V K m^{-3}
50.0	15.0	5.96
40.0	19.0	7.45
30.0	25.0	9.93
20.0	37.0	14.9
10.0	74.0	29.8
5.00	149.0	59.6

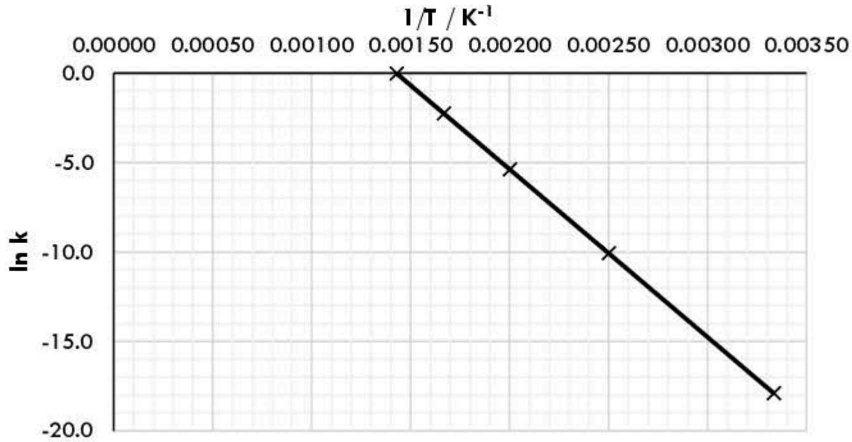


$nR = \frac{(150)-(17)}{60-6} = 2.46$

$n = \frac{2.46}{8.314} = 0.296$ mol

b)

T / K	k / s^{-1}	1/T / K^{-1}	ln k
300	1.70×10^{-8}	0.00333	-17.9
400	4.23×10^{-5}	0.00250	-10.1
500	4.61×10^{-3}	0.00200	-5.38
600	1.05×10^{-1}	0.00167	-2.25
700	9.82×10^{-1}	0.00143	-0.0178



$-E_a/R = \frac{-18 - 0}{0.00332 - 0.00143} = -9523$

$E_a = 9523 \times 8.314 = 79\ 180\ J\ mol^{-1}$

$\ln k = \frac{-E_A}{RT} + \ln A$

so $\ln A = \ln k + \frac{E_A}{RT}$

$= -10 + \frac{79\ 180}{8.314 \times 400}$

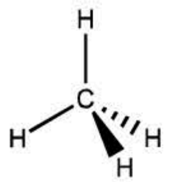
$= 13.8$

$A = e^{13.8} = 994\ 000\ (= 9.94 \times 10^5)$

***Note**: calculating A requires raisi*
in gradient will lead to large diff

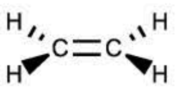
Shapes in Chemistry

1. a)



b) 109.5°

2.



3. a) yes
b) yes
c) yes
d) yes
e) no
f) no

Using a Calculator

1. a) 399
b) 7
c) 0.0635
d) 25
e) 1096.6
f) 1.799
g) 0.16667
h) 29.381
i) −1096.0
j) 16.617

2. a) k = 15.6 ×
= 3.15 ×
b) k = 9.40 ×
= 8.60 ×