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978-1-108-72813-3 — Cambridge IGCSE® Chemistry Maths Skills Workbook
Helen Harden
Excerpt
More Information

Chapter 1:
Representing values

Why do you need to represent values in chemistry?

- If you want to communicate measurements in chemistry, you will need to record values that you measure. You must make sure that another person will be able to understand your measurements, so how you represent them is important. As well as the numerical value, you must also include the correct **unit**.
- In chemistry, you will need to understand numbers that are much larger or much smaller than numbers you may be used to working with. Writing these numbers in different ways will make them easier to understand and compare.

Maths focus 1: Using units

All units of measure in general use are based upon *Standard International (SI) units.*

Table 1.1 shows some SI units that you may meet in chemistry.

Quantity	Unit	SI abbreviation
length	metre	m
mass	kilogram	kg
time	second	s
amount of substance	*mole**	*mol*

Table 1.1: SI units for common quantities
**Supplement only.*

TIP
Remember that a temperature can take a negative value on the Celsius scale.

In chemistry the SI unit for temperature is the kelvin, but it may be easier to use the Celsius **scale**, on which the freezing point of water is 0 °C and the boiling point of water (at 1 atmosphere pressure) is 100 °C. This is more useful for many laboratory measurements, although the kelvin scale is used in more advanced chemistry studies. Note that a temperature difference in kelvin, such as 30 kelvin, is the same as a temperature difference of 30 degrees on the Celsius scale.

What maths skills do you need to be able to use units?

1 Choosing the correct unit	• Identify the type of quantity that the apparatus measures • Select an appropriate unit for that quantity
2 Writing the unit symbol	• Recall or look up the unit symbol • Check whether the unit requires index notation, for example, cm^2, cm^3
3 Writing symbols for derived units	• Work out how the quantity is calculated • Write the derived units to be consistent with the calculation

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Maths skills practice

How does using units help to communicate values measured during chemical reactions?

When you are carrying out experimental work in chemistry, it is essential that you use the appropriate units to record and communicate any measurements you take.

For example, it is meaningless to state the volume of gas produced during a chemical reaction simply as ‘16’. Using units clearly specifies the volume measured. For example, a volume of $16\,cm^3$ is completely different from a volume of 16 litres. Similarly, recording the mass of product formed in an experiment as ‘3’ means nothing unless you add the correct units, such as grams. Remember that an amount of 3 g is a thousand times smaller than 3 kg, so it is essential to use the correct prefix as well as the correct unit.

Most values used in chemistry require units as they are measures of particular quantities, such as length, mass, temperature, time, volume or the amount of a substance.

WATCH OUT

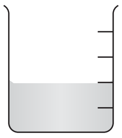
Not all values require units. Relative atomic mass gives the average mass of naturally occurring atoms of an element, based on a scale in which the carbon-12 atom has a mass of exactly 12 units. For example, the relative atomic mass of hydrogen is 1, meaning that, on average, atoms of hydrogen have a mass that is $\frac{1}{12}$ the mass of a carbon atom. This is a **ratio** and therefore it needs no units.

Maths skill 1: Choosing the correct unit

It is important that you can name the units commonly used in chemistry measurements.

WORKED EXAMPLE 1

Choose the correct unit of measurement associated with this small beaker.



A centimetres **B** litres **C** square centimetres **D** cubic centimetres

Step 1 Identify the type of quantity that the apparatus measures.

A beaker measures volume.

Step 2 Select an appropriate unit for that quantity.

KEY QUESTIONS TO ASK YOURSELF:

- What units are used to measure this type of quantity?
  Volume may be measured in a variety of units including litres (l) or cubic centimetres (cm^3).
- Which units are appropriate for the scale on the measuring equipment?
  A small beaker will not measure litres. The scale is likely to be in cubic centimetres (cm^3).

So appropriate units in this case are cubic centimetres.

LINK

See Chapter 5 for more on ratios.

TIP

Make sure that the units are also appropriate to the scale on the measuring apparatus. A small beaker will not measure litres.

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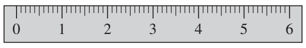
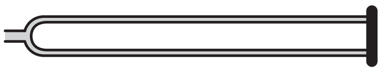
Practice question 1

Draw lines to match each item of measuring apparatus with the appropriate unit of measurement.

balance 	cubic centimetres (cm^3)
measuring cylinder 	grams (g)
thermometer 	cubic centimetres (cm^3)
ruler 	degrees Celsius (°C)
gas syringe 	centimetres (cm)

WATCH OUT

Some unit symbols (abbreviated units) start with a capital letter. This occurs when they are named after a person who invented them; for example, the Celsius temperature is named after the Swedish astronomer Anders Celsius, who developed a similar temperature scale. Most unit symbols start with a lower case letter.

Maths skill 2: Writing the unit symbol

Units are not usually written out in full. Each unit has a short form, or abbreviation, comprising 1–3 letters.

Quantity	Unit	Abbreviation
length	metres	m
mass	kilograms	kg
time	seconds	s
temperature	degrees Celsius	°C
*amount of substance**	*mole*	*mol*

Table 1.2 Abbreviations for some SI units
**Supplement only.*

TIP

Some units are derived (worked out by calculation) from SI units.

LINK

See Chapter 5.

LINK

See Maths focus 2, Maths skills 3 'Understanding unit prefixes'.

TIP

Always remember to include the correct index or **power** when necessary. It is incorrect to write a volume of liquid as 10 cm because centimetres measure length.

Other units are created by inserting a prefix in front of the SI unit. Centimetres are used for measuring shorter distances than metres, for example: 1 cm is $\frac{1}{100}$ or 0.01 m.

Some units require **index** notation. For example:

- **Area** is always measured in *square* units (such as m^2 or cm^2), since it is obtained by multiplying two lengths, for example, m × m or cm × cm (think about counting squares on a grid to find areas).
- **Volume** is always measured in *cubic* units (such as m^3 or cm^3), since it is obtained by multiplying three lengths, for example, m × m × m, or cm × cm × cm (think about counting cubes in a cuboid made from unit cubes).

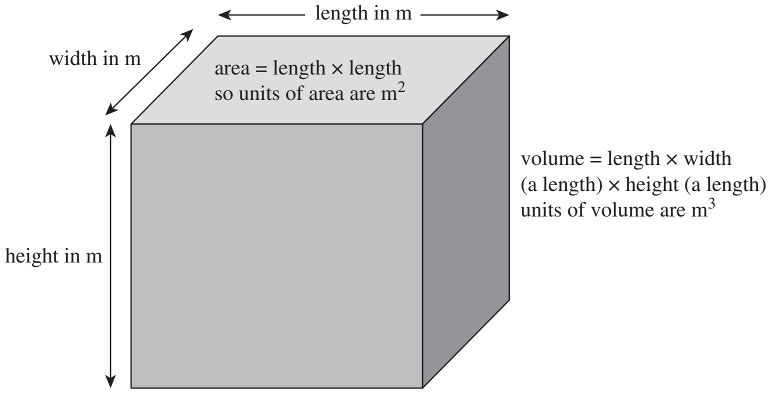


Figure 1.1 Comparing area of a face and volume of a cuboid

WORKED EXAMPLE 2

The length and width of a piece of paper have been measured in centimetres. Write down the correct unit symbol for its area.

Step 1 Recall or look up the unit symbol.

In this case it is centimetres (cm).

Step 2 Check whether the unit requires index notation.

Area is found by multiplying length by width so it must be measured in square units.

The unit is square centimetres (cm^2).

Practice question 2

Write down the correct unit symbol for each measurement.

a Mass of copper sulfate, measured on a digital balance that measures in grams ....

b Temperature of water, measured using a thermometer marked in degrees Celsius ....

c Time taken for a reaction to take place, measured using a stopwatch that displays seconds ....

d Length of magnesium ribbon, measured using a ruler marked in centimetres ....

e Area of floor in a laboratory, where the length and width are measured in metres ....

f Volume of liquid in a beaker that measures in cubic centimetres ....

TIP

The solidus (/) symbol indicates 'per', or division.

WATCH OUT

The symbol / is also used as a separator between a variable name and its unit, in tables and on graphs. Here, you read the / sign as 'in', so 'Temperature / °C' means 'temperature in degrees Celsius'.

Maths skill 3: Writing symbols for derived units

The units for some quantities are derived (based on a calculation) from other units. For example, you can calculate the **rate** of a reaction by dividing the volume of gas produced by the time taken, rather like calculating the speed of a car by dividing the distance travelled by time taken. If the volume is measured in cubic centimetres and the time in seconds, the units of rate of reaction are cm^3/s (cubic centimetres per second).

WORKED EXAMPLE 3

You can work out the density of an aluminium cube by dividing its mass (in grams) by its volume (in cubic centimetres).

Write down the correct derived unit for density.

Step 1 Work out how the quantity is calculated.

The calculation for density is: $\frac{\text{mass}}{\text{volume}}$

Step 2 Write the derived units to be consistent with the calculation.

The derived units are grams per cubic centimetre (g/cm^3).

Practice question 3

Write down the correct derived unit for each calculated quantity:

a The rate of a reaction (how fast a reaction takes place), calculated by dividing the mass of product made (in grams) by the time taken (in seconds) ....

b The density of a bronze statue, calculated by dividing the mass of the statue (in kilograms) by its volume (in cubic metres) ....

c The rate of a reaction, calculated by dividing the volume of gas produced (in cubic centimetres) by the time taken (in seconds) ....

Maths focus 2: Understanding very large and very small numbers

In chemistry you need to understand very large numbers.

In 12 g of carbon there are about 602 000 000 000 000 000 000 000 atoms.

You also need to understand very small numbers.

A single carbon atom has a **diameter** of about 0.000 000 000 17 m.

It is very important to use the correct number of zeros. The value of the number depends upon the place value of the digits. If you use the wrong number of zeros, the value of the number will change.

However, writing out this many zeros takes a lot of time so very large and very small numbers are often written using **powers of ten** instead.

The number of atoms in 12 g of carbon can also be written as 6.02×10^{23}.

The diameter of a carbon atom can be written as 1.7×10^{-10} m.

Sometimes in chemistry the units are changed for very large and very small numbers by adding a **prefix** such as kilo (k) or nano (n). These prefixes replace the power of ten.

So 3 kg = 3×10^3 g or 3000 g

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What maths skills do you need to be able to understand very large and very small numbers?

1 Understanding place value	• Compare digits with the highest place value • Compare digits with the next highest place values
2 Understanding powers of ten	• Write out the multiplication • Calculate the number as it would be written in full
3 Understanding unit prefixes	• Write the measurement in terms of a power of ten • Calculate the number as it would be written in full

Maths skills practice

How does understanding very large and very small numbers help to improve your understanding of the size and number of different particles?

Some numbers used in chemistry are so large, or so small, that they are difficult to imagine. Writing these in a clearer way, such as using powers of ten or prefixes, helps to understand how the size of different particles compare. A particle of PM2.5 'particulate' air pollution has a diameter of about 2.5×10^{-6} m or 2.5 µm, whereas a PM10 particle is about 10×10^{-6} m or 10 µm in diameter.

Understanding powers of ten and **unit prefixes** means that you will instantly know that these are much larger than a typical atom, which is about 1×10^{-10} m in diameter.

Before you can do this, though, it is important that you have a good understanding of place value in numbers that are written out in full.

Maths skill 1: Understanding place value

The position of a digit in a number determines its place value. The left-most digit in a number has the highest place value.

For example, the number in Table 1.3 (reading from left to right) is:

three hundred and twenty-three billion, four hundred and fifty-six million, three hundred and forty-five thousand, six hundred and forty-seven

Hundreds of billions, 10^{11}	Tens of billions, 10^{10}	Billions, 10^9	Hundreds of millions, 10^8	Tens of millions, 10^7	Millions, 10^6	Hundreds of thousands, 10^5	Tens of thousands, 10^4	Thousands, 10^3	Hundreds, 10^2	Tens, 10^1	Units, 10^0
3	2	3	4	5	6	3	4	5	6	4	7

Table 1.3 Place values for large numbers

The decimal fraction in Table 1.4 is one billionth.

		Tenths	Hundredths	Thousandths	Ten-thousandths	Hundred-thousandths	Millionths	Ten-millionths	Hundred-millionths	Billionths
0	.	0	0	0	0	0	0	0	0	1

Table 1.4 Place values for small numbers

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TIP
Read the number from left to right. The place value of the first non-zero number helps you decide how big the number is.

WORKED EXAMPLE 4

Find the largest number in the following list.

A 7 242 519 **B** 8 143 921 **C** 8 349 321 **D** 924 107

Step 1 Compare digits with the highest place value.

A, B and C all have millions as the highest place value. B and C both have digits showing 8 million, so are larger than A, which has 7 million.

Step 2 Compare digits with the next highest place values.

The next highest place value is hundreds of thousands. B has 1 hundred thousand but C has 3 hundred thousand. So the largest number is C.

Practice question 4

Circle the *largest* number in each list.

a	674 591	92 342	141 294	692 381
b	1 943 986	1 949 789	1 942 987	1 944 098
c	0.09	0.12	0.17	0.06
d	0.09	0.015	0.026	0.07
e	0.000 007 2	0.000 008 5	0.000 000 1	0.000 000 165

TIP
Look for the first non-zero digit and use place value to compare numbers.

Practice question 5

Circle the *smallest* number in each list.

a	1 232 452	123 532	723 453	115 362
b	0.123 451	0.345 984	0.135 034	0.124 093
c	0.000 002 234	0.000 002	0.000 002 4	0.000 002 34
d	234.56	234.25	232.12	232.013 4
e	104 985.99	110 374.12	104 895.99	104 895.82

Maths skill 2: Understanding powers of ten

Powers of 10 are the result of multiplying 10 by itself.

A negative power of any number is the **reciprocal** of the corresponding positive power. This means, for example, that $10^{-1} = \frac{1}{10}$, or 1 ÷ 10 (the reciprocal of 10).

$10^1 = 10$	$10^{-1} = \frac{1}{10}$ or 0.1
$10^2 = 10 \times 10 = 100$	$10^{-2} = \frac{1}{10 \times 10} = \frac{1}{100}$ or $1 \div 10 \div 10 = 0.01$
$10^5 = 10 \times 10 \times 10 \times 10 \times 10 = 100\,000$	$10^{-5} = \frac{1}{10 \times 10 \times 10 \times 10 \times 10} = \frac{1}{100\,000}$ $= 1 \div 10 \div 10 \div 10 \div 10 \div 10$ or 0.00001

Table 1.5 Powers of ten

Very large and very small numbers are often recorded as multiples of powers of ten. This saves having to write out lots of zeros.

For example: $4 \times 10^3 = 4 \times 10 \times 10 \times 10 = 4000$

So multiplying by 10^3 means that you need to multiply by 10 three times.

In general 4×10^n means that 4 is multiplied by 10 n times.

4×10^1	4×10	40
4×10^2	$4 \times 10 \times 10$	400
4×10^3	$4 \times 10 \times 10 \times 10$	4000
4×10^4	$4 \times 10 \times 10 \times 10 \times 10$	40 000
4×10^5	$4 \times 10 \times 10 \times 10 \times 10 \times 10$	400 000
4×10^6	$4 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10$	4 000 000

Table 1.6 Multiplying by powers of ten

Multiplying a number by a negative power of ten tells you how many times to divide it by ten.

For example: $4 \times 10^{-3} = 4 \times \frac{1}{10 \times 10 \times 10} = 4 \div 10 \div 10 \div 10$

WORKED EXAMPLE 5 (POSITIVE POWERS OF TEN)

Write 5×10^5 in full.

Step 1 Write out the multiplication.

$5 \times 10^5 = 5 \times 10 \times 10 \times 10 \times 10 \times 10$

Step 2 Calculate the number as it would be written in full.

$= 5 \times 100\,000$

$= 500\,000$

Practice question 6

These numbers are expressed as multiples of powers of ten. Write them in full.

a 3×10^3 ………………………………………..

b 45×10^6 ………………………………………..

c 4×10^1 ………………………………………..

d 123×10^{10} ………………………………………..

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WORKED EXAMPLE 6 (NEGATIVE POWERS OF TEN)

Write 3×10^{-4} as a decimal.

Step 1 Write out the multiplication.

$$3 \times 10^{-4} = 3 \times \frac{1}{10 \times 10 \times 10 \times 10} = 3 \div 10 \div 10 \div 10 \div 10$$

Step 2 Calculate the number as it would be written in full.

$$= 3 \times 0.0001 = 0.0003$$

Practice question 7

Write each of these negative powers of ten as a decimal.

a 2×10^{-2} …………………………………………..

b 34×10^{-6} …………………………………………..

c 9×10^{-9} …………………………………………..

d 43×10^{-5} …………………………………………..

Maths skill 3: Understanding unit prefixes

Very often in science rather than writing a number either in full or using powers of ten, you can just change the unit by using a prefix.

The prefix tells you the power of ten by which to multiply the measurement to find the full number.

For example: 7 kg means $7 \times 10^3 = 7000$ g

Table 1.7 shows some prefixes you should know.

Unit prefix	Unit prefix symbol	Multiplying factor	Example unit names	Example unit symbols
kilo-	k	10^3	kilogram	kg
deci-	d	10^{-1}	cubic decimetre	dm^3
centi-	c	10^{-2}	cubic centimetre	cm^3
milli-	m	10^{-3}	milligram millimetre	mg mm
micro-	µ	10^{-6}	microgram	µg
nano-	n	10^{-9}	nanometre	nm

Table 1.7 Prefixes used with common measures

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LINK
See Maths skill 2 'Understanding powers of ten'.

WORKED EXAMPLE 7

Write 8 mg without using the prefix.

Step 1 Write the measurement in terms of a power of ten.

$8\,\text{mg} = 8 \times 10^{-3}\,\text{g}$

Step 2 Calculate the number as it would be written in full.

$$8 \times 10^{-3} = 8 \times \frac{1}{10 \times 10 \times 10} = 8 \div 10 \div 10 \div 10 = 0.008$$

So $8\,\text{mg} = 8 \times 10^{-3}\,\text{g} = 0.008\,\text{g}$

Practice question 8

Write each measurement without the prefix.

a **i** 3 mg ....

ii 4 µg ....

iii 3 kg ....

b **i** 4 mm ....

ii 2 cm ....

iii 7 nm ....

c **i** 4 cm ....

ii 2 dm ....

Practice question 9

Write each measurement without the prefix.

a **i** 42 mg ....

ii 402 µg ....

iii 345 kg ....

b **i** 74 nm ....

ii 7.4 nm ....

iii 704 nm ....

Maths focus 3: Writing numbers in a required form

Sometimes in chemistry you are required to write a number in a particular form.

When very large or very small numbers are expressed in terms of a power of ten, the convention is to use a system called **standard form** or **standard index form.**

A number in standard form is expressed as a number greater than or equal to 1 but less than 10 multiplied by a power of ten. For example, 54 000 can be written as 5.4×10^4. However, 54×10^3 is *not* in standard form because 54 is not between 1 and 10.

The results of calculations should be rounded to an appropriate number of **significant figures**, based upon the lowest number of significant figures of the numbers used in the calculation.

