SAPS STUDY SUPPORT

Concentrations and Dilutions

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Concentrations and Dilutions:
A survival guide

In your science experiments, often you need to know how much material to use or how much of a solute is present in a solution. This applies particularly to biology and chemistry experiments. Almost certainly you will need to do some calculations!

This survival guide should help you to do these calculations. It looks closely at how to handle numbers correctly, how to express concentrations and how to calculate dilutions. There are plenty of worked examples to guide you, then lots of questions (with answers) for you to practise your skills.

The five sections in the guide are listed below:

You may decide to work through step by step from the beginning or you may prefer to jump to the section that will help you with your problem.

Look for red to find the questions you are encouraged to attempt.
Look for green to find the answers just click on check answer.

At the end of the guide, we hope you will have developed greater confidence with handling numbers, concentrations and dilutions. You might even be more enthusiastic!

1. Numbers in standard form

It is important that you are able to handle, with confidence, calculations that deal with numbers in so-called standard form. Sometimes standard form is called scientific or index notation but they mean the same thing.

Invariably concentrations are expressed in standard form and so this is an important skill that you must develop. At first it may seem daunting but stick with it! In our experience the use of standard form is a very common area where students have problems and so it will be good practice for you to try out the calculations in the examples that follow later. You might also find it worth looking at the additional explanations and examples given in Appendix 1.

Let's answer this by looking at an example. Suppose we wish to convert the number 512 to standard form – how would we do it? Well a number in standard form is expressed as a value between 1 and 10 multiplied by a power of 10. Let's look at the number 512. We can say that

$512 = 5.12 \times 100$

Now $100 = 1.0 \times 10^2$

(If you have not come across this way of writing numbers before don't worry! We have included an appendix that gives a more detailed explanation. Common powers of 10 are also given in the Table below).

If we combine the two equations above we obtain

$512 = 5.12 \times 1.0 \times 10^2 = 5.12 \times 10^2$

Table 1. Some common powers of 10

Number	*Standard Form*
100 000 000	1.0×10^8
10 000 000	1.0×10^7
1 000 000	1.0×10^6
100 000	1.0×10^5
10 000	1.0×10^4
1 000	1.0×10^3
100	1.0×10^2
10	1.0×10^1
1	1.0×10^0

Given that 512 is simpler to write than 5.12×10^2 you might ask the question:- 'Why do we use standard form?' One answer is that the repeating of zeros in both large and small numbers can lead to errors. Stating the numbers in standard form often avoids these errors. You need to realise that the number 2 in 10^2 is 'superscripted' (i.e. above the line) – you need to be careful so that the number is not confused with 102. The number 2 in 10^2 is given a special name – the power (sometimes this is also called the index).

This may sound trivial but how would you do it?

The most common way would be to say 'five point one two times ten to the two'.

Alternatively you might say 'five point one two times ten to the power of two'

You might also want to find out how you enter superscripts and subscripts on your word processor!

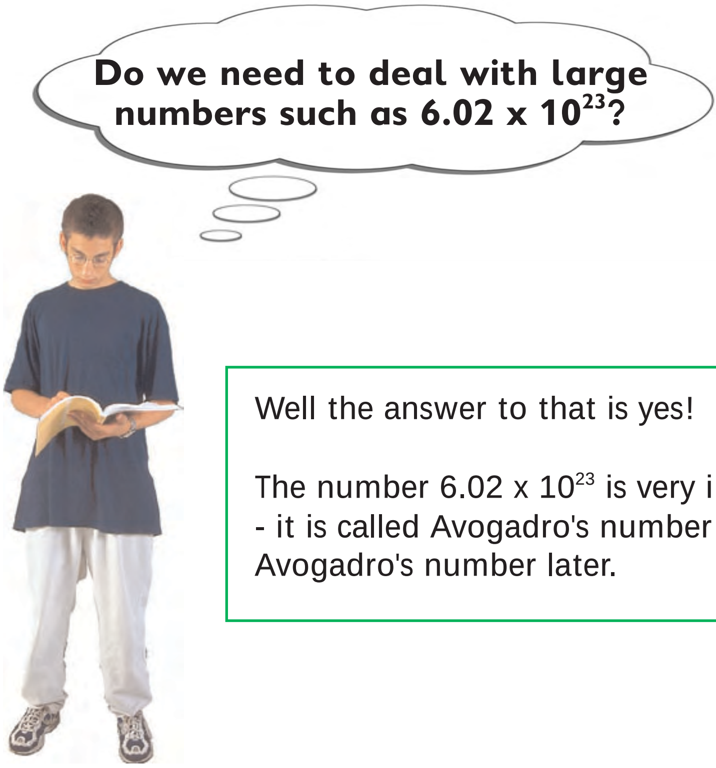
Let's look at some examples of converting numbers to and from standard form.

Self-Assessment Questions 1

Convert the following numbers to standard form:

(i) 385
(ii) 385.3
(iii) 321
(iv) 31
(v) 43000
(vi) 152000
(vii) 32000000
(viii) 24.3
(ix) 2321
(x) 8
(xi) 14100
(xii) 385000
(xiii) 602000000000000000000000

Check answers



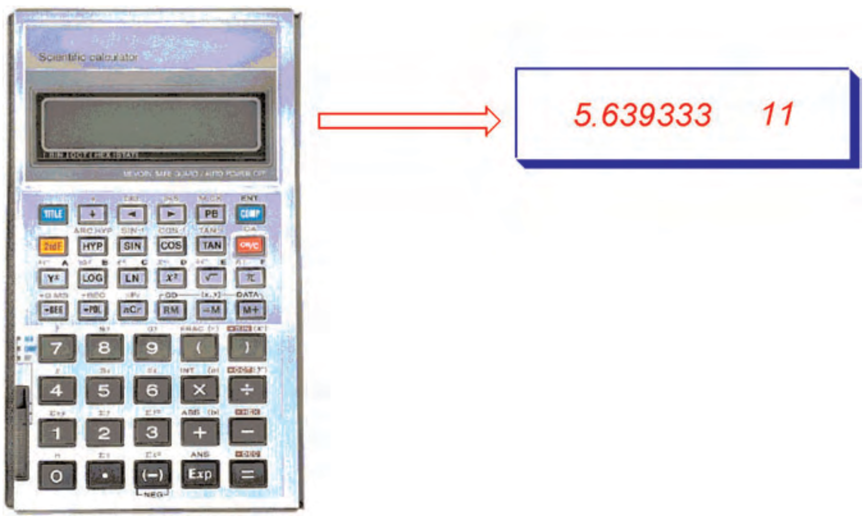
Well the answer to that is yes!

The number 6.02×10^{23} is very important in science - it is called Avogadro's number - we shall return to Avogadro's number later.

The easiest way to deal with numbers in standard form is, of course, to use a scientific calculator that will do the conversions for you. Most calculators automatically convert numbers to standard form once they get bigger than 100 000 000 (100 million) – although this statement is meant to be a rough guide only! Most calculators have a 'mode' key that allows you to have all numbers presented in scientific format (a term often used to describe standard form).

Try the following calculation (using your calculator): 123456 x 4567890

(Ignoring a few of the decimal places) the calculator display will look something like



It is important that you realise the meaning of the number 11 which is separated from the rest of the digits.

In fact $123456 \times 4567890 = 5.63933 \times 10^{11}$

and so the number 11 represents the index of the power of 10 of the number. We would normally state verbally that the calculator reads as "5.639 times ten to the eleven".

We said before that most calculators will automatically convert numbers bigger than 10^8 into standard form. You should try and find out whether you can convert numbers lower than this to standard form using your calculator (you might need to read the instruction booklet that accompanies your calculator!)

Try the following calculation (use your calculator): 5 ÷ 555

The chances are that your calculator display will look similar to one of the following:

In a similar way to the multiplication above, the -03 represents a power of 10 that is less than zero. In this case the number can be written as:

0.009009009 or $\frac{9.009009}{1000}$

Now, 1 ÷ 1000 can be written as 1×10^{-3} and so 0.009009009 can be written as 9.009009×10^{-3}

In fact some (often older) calculators convert numbers smaller than 0.01 to standard form automatically. Try and type in the number 0.0032. Once you have typed in the final digit press the '=' button. Some calculators will automatically change the display to 3.2^{-03}, i.e. 3.2×10^{-3}. Other calculators will convert numbers to scientific notation only when you set them to do so (check the instruction booklet). We would normally state verbally that the calculator reads as '3.2 times ten to the minus three'. It might be useful to look at the following table which lists some numbers and their equivalents in standard form.

Table 2. Some powers of 10 and their decimal equivalent

Number	*Standard Form*
0.1	1.0×10^{-1}
0.01	1.0×10^{-2}
0.001	1.0×10^{-3}
0.0001	1.0×10^{-4}
0.00001	1.0×10^{-5}
0.000001	1.0×10^{-6}
0.0000001	1.0×10^{-7}
0.00000001	1.0×10^{-8}
0.000000001	1.0×10^{-9}

So how do we go from a number that is smaller than 1 to standard form?

The best way to answer that is by looking at an example. Let's suppose we wish to convert the number 0.0064 to standard form – how do we do it?

Most people would initially convert the number so that there is a single digit in front of the decimal point. So we would convert 0.0064 to 6.4. To do this we would have to multiply by 1000. Of course, to go back from 6.4 to 0.0064 we would have to divide by 1000 or multiply by 1×10^{-3}.

So $0.0064 = 6.4 \times 10^{-3}$

Some more examples for you to have a go at!

Self-Assessment Questions 2

Write the following numbers in standard form:

(i) 0.013
(ii) 0.000698
(iii) 0.00000546
(iv) 0.23
(v) 0.694
(vi) 0.00385
(vii) 0.00000000048

Check answers

How do I enter numbers in standard form into my calculator?

Suppose that you wish to enter the number 3.46×10^{12} into your calculator - what do you do?

Each calculator is slightly different but in general you would type in 3.46 followed by the key marked 'EXP' followed by 12. The 'EXP' key takes the place of 'times 10 to the power of'.

When dealing with numbers less than 1, for example 0.00346, you would type 3.46 'EXP' ± 3. The button marked ± changes the sign of the number. On some calculators it looks like +/-.

You need to be careful that you follow these instructions in the correct order and you also need to check how your calculator works.

2. Relative atomic mass and molar mass

Atoms are very small particles! This means that their masses give us figures that are difficult to work with. The table below lists the average mass of an atom of some common elements in grams.

Element	***Symbol***	***Average mass of an atom / g***
Hydrogen	H	1.67355×10^{-24}
Helium	He	6.64605×10^{-24}
Lithium	Li	1.15217×10^{-23}
Carbon	C	1.99436×10^{-23}
Oxygen	O	2.65659×10^{-23}
Sodium	Na	3.81730×10^{-23}
Argon	Ar	6.63310×10^{-23}
Uranium	U	3.95233×10^{-22}

To overcome the difficulty of working with such small amounts of material it is usual to work with a relative scale for the atomic mass. The scale used is known as the carbon-12 scale. This was adopted by IUPAC (the International Union of Pure and Applied Chemistry) in 1961 as its standard. In this carbon-12 scale, the mass of a carbon atom of isotope number 12 (symbol ^{12}C) is 1.99252×10^{-23} g and the relative mass of all atoms is compared to $1/12^{th}$ of the mass of ^{12}C. The relative mass is, therefore calculated as:

Relative mass = *Average mass* $\div$ *$1/12^{th}$ of mass of ^{12}C*

We can now re-write the above table to give relative masses. You can see that relative masses numbers are much easier to handle than average masses.

Symbol	***Average mass of an atom / g***	***Relative mass***
H	1.67355×10^{-24}	1.0079
He	6.64605×10^{-24}	4.0026
Li	1.15217×10^{-23}	6.9390
C	1.99436×10^{-23}	12.0111
O	2.65659×10^{-23}	15.9993
Na	3.81730×10^{-23}	22.9898
Ar	6.63310×10^{-23}	39.9480
U	3.95233×10^{-22}	238.0300

When we come on to looking at the concentrations of materials we will need to be able to express the amount of a substance that is contained in a given volume of solution. The SI unit for quantity of material is called the mole (abbreviation mol). The mol is defined as the amount of substance that contains as many elementary particles as there are atoms in 12 g of ^{12}C. This definition of a mole is important.

How many atoms are there in 12 g of ^{12}C?

We can work out this figure in the following way:

The mass of a single ^{12}C atom is 1.99252×10^{-23} g

So, in 1 g of ^{12}C there are:

$1 \div 1.99252 \times 10^{-23}$ *atoms* $= 5.0188 \times 10^{22}$ *atoms.*

In 12 g of ^{12}C there will be 12 times as many atoms as there are in 1 g. So, in 12 g of ^{12}C atoms there are:

$12 \times 5.0188 \times 10^{22}$ *atoms* $= 6.02 \times 10^{23}$ *atoms.*

You may remember that we have already mentioned the number 6.02×10^{23} and we called this Avogadro's number. Avogadro's number relates the number of particles to the amount. Avogadro's number has units of mol^{-1}.

Worked examples

You will need to be able to calculate (with confidence!!) the molar mass of a range of materials during your studies. To help you in this task a number of examples follow.

(i) Calculate the mass of one mole of carbon dioxide.

Answer:

A carbon dioxide molecule has the formula CO_2. So:

1 mol of CO_2 has a mass of 12 + (2 x 16) g = 12 + 32 = 44 g

The molar mass (i.e. the mass of one mole) of CO_2 is 44 g.

(ii) Calculate the mass of 1 mol of sodium carbonate molecules.

Answer:

A sodium carbonate molecule has the formula Na_2CO_3. So:

1 mol of Na_2CO_3 has a mass of (2 x 23) + 12 + (3 x 16) g = 46 + 12 + 48 = 106 g

The molar mass of (i.e. the mass of one mol) of Na_2CO_3 is 106 g.

(iii) Calculate the mass of 0.2 mol of sodium carbonate molecules.

Answer:

A sodium carbonate molecule has the formula Na_2CO_3. So:

1 mol of Na_2CO_3 = (2 x 23) + 12 + (3 x 16) g = 46 + 12 + 48 = 106 g

The mass of 0.2 mol of Na_2CO_3 is 106 x 0.2 = 21.2 g

You should now attempt the sample questions in SAQ3 - answers are given. You will probably need to refer to the table of relative atomic masses of a range of elements. You may also need to consult a suitable textbook that gives the molecular formulae for the compounds listed.

Self-Assessment Questions 3

Calculate the molar masses (the mass of 1 mol) of the following molecules:

(i) water (H_2O)
(ii) carbon dioxide (CO_2)
(iii) oxygen (O_2)
(iv) nitrogen (N_2)
(v) ammonia (NH_3)
(vi) glucose ($C_6H_{12}O_6$)
(vii) sucrose ($C_{12}H_{22}O_{11}$)

Check answers

Hopefully (!) once you have completed SAQ3 you will feel more confident about how to calculate the molar masses of substances.

It is often necessary to calculate how many moles of a substance there are in a given mass of material. This can be done using the following expression:

Number of moles = mass present ÷ molar mass

Worked examples

(i) Calculate the number of moles of material present in 6.3 g of carbon dioxide.

Answer:

Number of moles = mass present ÷ molar mass

= 6.3 ÷ 44 = 0.143 mol carbon dioxide

(ii) Calculate the number of moles of material present in 12.5 g of glucose.

Answer:

Number of moles = mass present ÷ molar mass

= 12.5 ÷ 180 = 0.069 mol glucose

During practical work you may come across occasions when you need to do calculations such as these and so it is important that you are able to handle them accurately and confidently. To help you further, we recommend that you try the examples in SAQ4.

Self-Assessment Questions 4

Calculate the number of moles of material present in each of the following:

(i) 0.5 g of glycine (molecular formula $C_2H_5NO_2$)
(ii) 10 g of urea (molecular formula CN_2H_4O)
(iii) 25 g of disodium hydrogen phosphate (molecular formula Na_2HPO_4)
(iv) 250 g of fructose
(v) 0.0028 g of ribose (molecular formula = $C_5H_{10}O_5$)
(vi) 12 g of sodium hydroxide
(vii) 15.8 g of glucose

Check answers

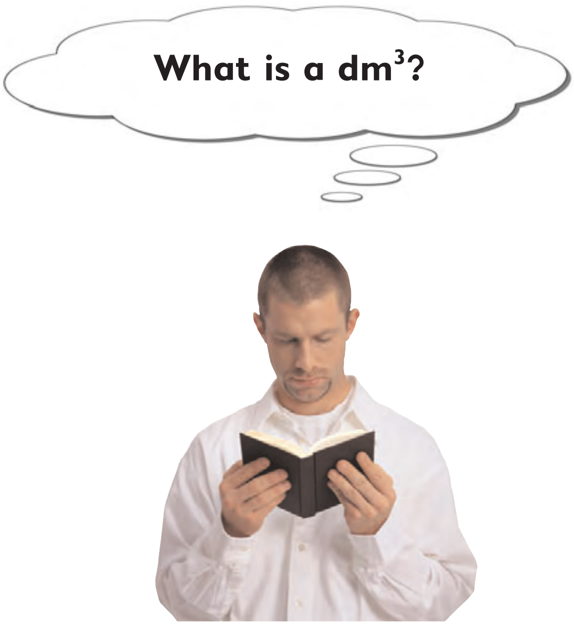
3. Amounts in solution

The concentration of a solution is the amount of a substance present in a given volume of solvent.

So

concentration = amount ÷ volume

Normally we measure the amount in moles and the volume in dm^3. So the concentration of a substance is usually expressed in mol dm^{-3}.



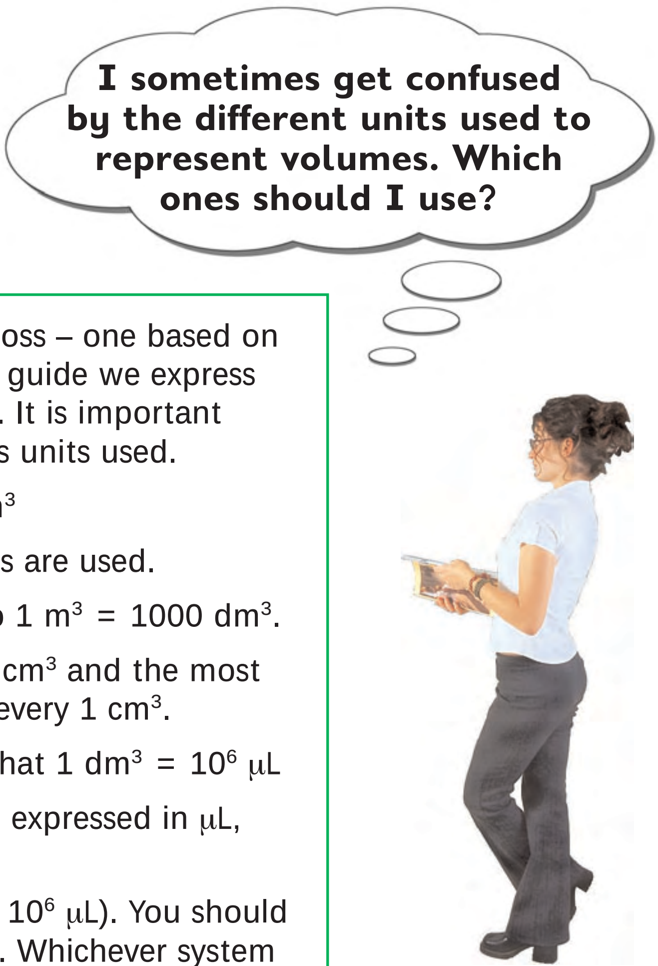
Well, 1 decimetre is one-tenth of a metre. So,

1 dm = 0.1 m = 10 cm

So 1 dm^3 = 10 cm x 10 cm x 10 cm = 1000 cm^3

or 1 dm^3 is 1000 cm^3.

That means 1 dm^3 is also equal to 1 litre.



There are two main systems that you will come across – one based on the m^3 and the other based on the litre (L). In this guide we express volumes in μL (pronounced microlitre), cm^3 or dm^3. It is important that you know how to convert between the various units used.

Now, 1 m^3 = 100 cm x 100 cm x 100 cm = 10^6 cm^3

and so 1 m^3 is a very large unit and so smaller units are used.

As we have already seen 1 dm^3 = 1000 cm^3 and so 1 m^3 = 1000 dm^3.

Occasionally we might use volumes smaller than 1 cm^3 and the most common unit used is the μL. There are 1000 μL in every 1 cm^3.

Since 1000 μL = 1 cm^3 you should be able to see that 1 dm^3 = 10^6 μL

In the other system, commonly in use, volumes are expressed in μL, mL or L.

Now 1 L = 1000 mL and 1 mL = 1000 μL (or 1L = 10^6 μL). You should be able to see that 1 dm^3 = 1 L and 1 cm^3 = 1 mL. Whichever system you use is a matter of personal choice. Just be sure to be consistent with your choice.

The concentration of a substance is defined as the number of moles of the substance in 1 dm^3 of solution. So the concentration of a substance is measured in mol dm^{-3} (verbally stated as moles per decimetre cubed or moles per cubic decimetre). You will occasionally see the symbol **M** or the term **molarity** both of which are used as alternatives to mol dm^{-3}. The use of both these terms is discouraged and we recommend that you adopt mol dm^{-3}.

Worked example

A solution of sodium chloride in water is prepared by dissolving 11.7 g of solid in water giving a total volume of 1.0 dm^3. What is the concentration of the sodium chloride in mol dm^{-3}?

Answer:

The mass of one mole of NaCl may be calculated as 23 + 35.5 g = 58.5 g

So, 11.7 g of NaCl represents 11.7 ÷ 58.5 mol NcCl = 0.2 mol

The solution contains 0.2 mole NaCl made up to a volume of 1 dm^3 with water

So, the concentration of the solution is:

$0.2 \div 1$ mol dm^{-3} = 0.2 mol dm^{-3}

Worked example

A solution of sodium chloride in water is prepared by dissolving 6.5 g of solid in water giving a total volume of 250 cm^3. What is the concentration of the sodium chloride in mol dm^{-3}?

Answer:

The mass of one mole of NaCl may be calculated as 23 + 35.5 g = 58.5 g

So, 6.5 g represents 6.5 ÷ 58.5 mol NaCl = 0.111 mol

The solution contains 0.111 mol NaCl made up to a volume of 250 cm^3 with water.

Now 250 cm^3 represents 250/1000 dm^3 = 0.25 dm^3.

So, the concentration of the solution is:

$0.111 \div 0.25$ mol dm^{-3} = 0.444 mol dm^{-3}

It is important that you practise calculations such as these since they form an integral part of any advanced course in biology and related areas.

Why don't you try the following examples!

Self-Assessment Questions 5

(i) A solution of disodium hydrogen phosphate (Na_2HPO_4) is prepared. If the solution contained 71.0 g of Na_2HPO_4 in 1 dm^3 of water, what is the concentration in mol dm^{-3}?

(ii) A solution is made containing 2.38 g of magnesium chloride ($MgCl_2$) in 500 cm^3 of water. What is the concentration of $MgCl_2$ in this solution?

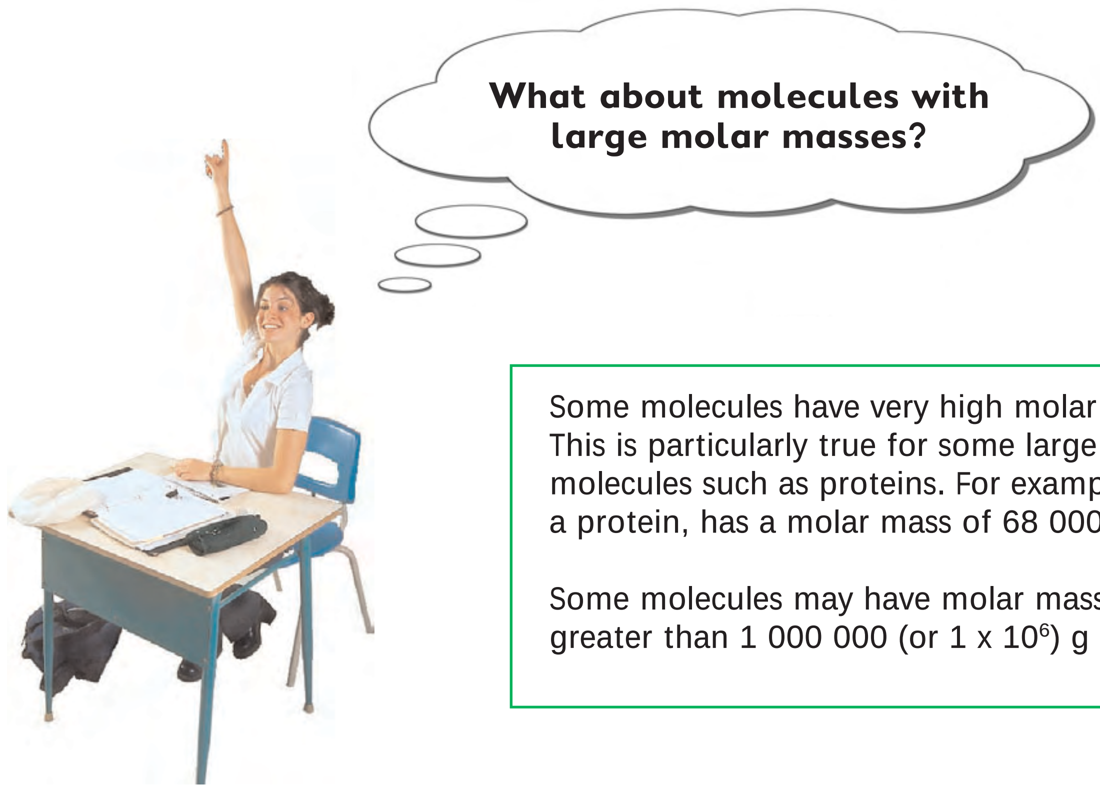
(iii) The table below indicates the masses of various compounds that were used to prepare solutions of the stated volumes. Calculate the concentrations of these solutions.

	Compound	*Molecular formula*	*Mass / g*	*Volume water / cm³*
(a)	Glucose	$C_6H_{12}O_6$	8.5	1000
(b)	Ribose	$C_5H_{10}O_5$	10.7	500
(c)	Glycine	$C_2H_5NO_2$	25.7	2000
(d)	Sucrose	$C_{12}H_{22}O_{11}$	18.5	375

(iv) You are asked to prepare a 100 cm^3 of a solution of ribose (molecular formula, $C_5H_{10}O_5$) at a concentration of 1.0×10^{-4} mol dm^{-3}. How much ribose would you need?

(v) How much disodium hydrogen phosphate (Na_2HPO_4) is needed to prepare 5 dm^3 of solution with a concentration of 1.8×10^{-2} mol dm^{-3}?

Check answers



Some molecules have very high molar masses. This is particularly true for some large biological molecules such as proteins. For example, albumin, a protein, has a molar mass of 68 000 g mol^{-3}!

Some molecules may have molar masses that are greater than 1 000 000 (or 1×10^6) g mol^{-3}!

Worked example

Let's have a look at an example of a calculation involving a molecule with a large molar mass. Suppose that we have prepared a solution of albumin by dissolving 0.0068 g of albumin in 100 cm^3 of water. What is the concentration of this solution?

Answer

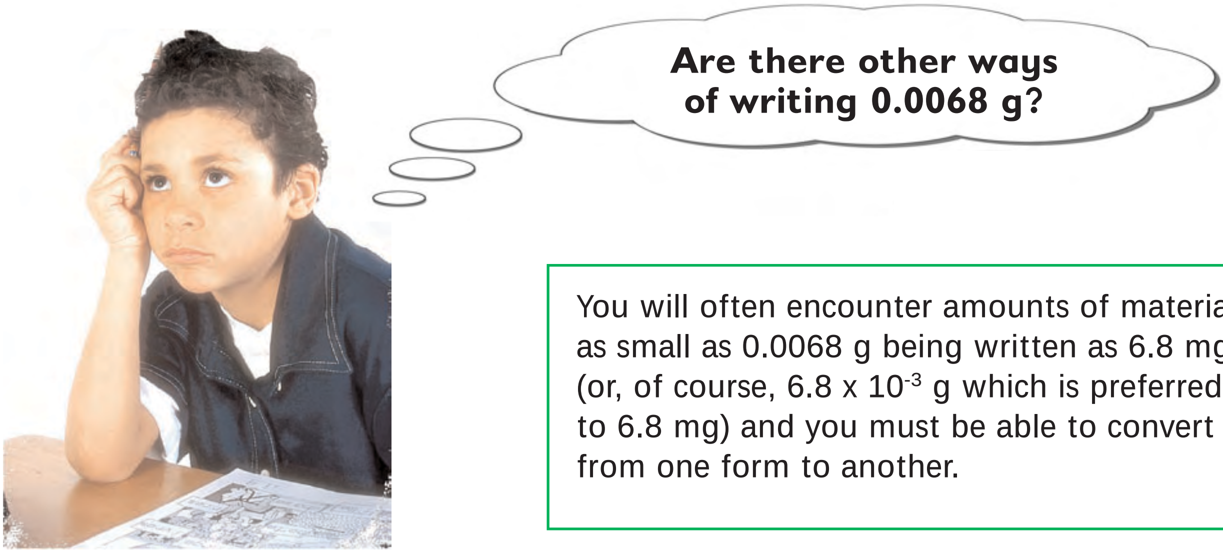
One mole of albumin has a molar mass of 68 000 g mol^{-1}

So the 0.0068 g represents 0.0068 ÷ 68 000 = 0.0000001 (or 1.0×10^{-7}) mol of albumin

The concentration is given by:

Concentration = amount of material ÷ volume

= 1.0×10^{-7} ÷ 0.1 = 1.0×10^{-6} mol dm^{-3} (remember 100 cm^3 = 0.1 dm^3)



You will often encounter amounts of materials as small as 0.0068 g being written as 6.8 mg (or, of course, 6.8×10^{-3} g which is preferred to 6.8 mg) and you must be able to convert from one form to another.

Self-Assessment Questions 6

(i) The molar mass of a protein is 32000 g mol^{-1}. A student takes 0.003 g of the protein and dissolves it in 500 cm^3 of water. What is the concentration of the solution that has been prepared?

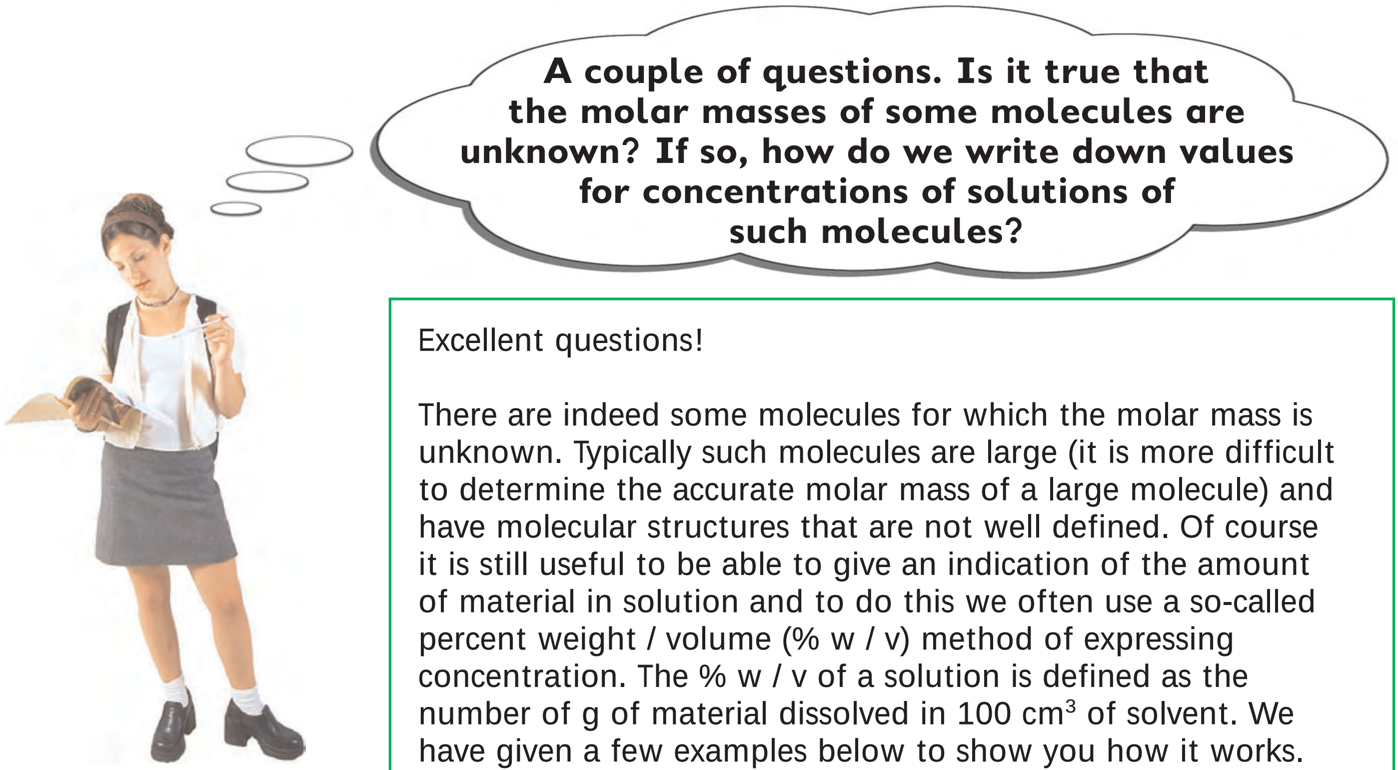
(ii) Suppose that instead of dissolving the protein in 500 cm^3 of water only 25.8 cm^3 of water had been used. What would the concentration have been in that case?

(iii) A solution of a carbohydrate whose molar mass is 1.8×10^5 g mol^{-1} is prepared by dissolving 0.14 g of the carbohydrate in 150 cm^3 of water. What is the concentration of the solution?

(iv) A solution of the protein catalase is needed for an experiment. Given that the molar mass of catalase is 250 000 g mol^{-1} how much catalase is needed to prepare 150 cm^3 of solution with a concentration of 3.5×10^{-7} mol dm^{-3}?

Check answers

4. Percentage weight/volume



Excellent questions!

There are indeed some molecules for which the molar mass is unknown. Typically such molecules are large (it is more difficult to determine the accurate molar mass of a large molecule) and have molecular structures that are not well defined. Of course it is still useful to be able to give an indication of the amount of material in solution and to do this we often use a so-called percent weight / volume (% w / v) method of expressing concentration. The % w / v of a solution is defined as the number of g of material dissolved in 100 cm^3 of solvent. We have given a few examples below to show you how it works.

Worked examples

(i) A solution containing 1 g of starch dissolved in 100 cm^3 of water is prepared. What is its concentration?

Answer:

Starch is a polymer made up of glucose molecules. The molar mass of starch varies according to its source and method of extraction. In order to give an indication of the concentration we can express it in terms of percentage weight / volume (often abbreviated to % w / v). We have 1 g of starch dissolved in 100 cm^3 of solvent and so the concentration is 1% w / v.

(ii) A small quantity (0.005 g) protein of unknown molar mass was dissolved in 10 cm^3 of water. What is the protein concentration in terms of % w / v?

Answer:

In this case we have 0.005 g of the protein in 10 cm^3 of water – this is equivalent to 0.05 g of protein in 100 cm^3 of water. Thus the concentration of the protein solution is 0.05% w / v.

Self-Assessment Questions 7

Express the following solutions in terms of % w / v

(i) 0.5 g of DNA in 100 cm^3 water
(ii) 0.013 g of RNA in 10 cm^3 of water
(iii) 0.02 g of starch in 500 cm^3 of water
(iv) 0.007 g of DNA in 12.5 cm^3 of buffer

Check answers

5. Dilutions

OK, I have this solution and I need to make a series of weaker solutions. How do I work out what I need to do?

Students often have problems in calculating the effect of diluting solutions. You may be given a solution (the 'stock' solution) and asked to prepare from it a range of solutions of different concentrations.

In this section we will look at how to calculate the effect of diluting solutions.

Suppose that you are given 500 cm^3 of a stock solution of sodium chloride. The concentration of the stock solution is 0.5 mol dm^{-3}. You are asked to use the stock solution to prepare new solutions (to have a final volume of 50 cm^3) of each of the following concentrations:

0.1 mol dm^{-3}; 0.2 mol dm^{-3}; 0.3 mol dm^{-3}; 0.4 mol dm^{-3}.

How do you calculate what is needed? Well, there are a number of ways you could do this calculation.

Method 1 Let's start by thinking how much of the solution you wish to prepare. The final volume of each sample that we require is 50 cm^3.

If we took 1 cm^3 of the stock solution and added 49 cm^3 of water we would produce a solution whose concentration was 1/50th of the original (remember the concentration of the stock solution is 0.5 mol dm^{-3} and so 1/50th of that is 0.01 mol dm^{-3}). Similarly if we took 2 cm^3 of the stock solution and added 48 cm^3 of water we would produce a solution whose concentration was 2/50th (or 1/25th) of the original and so on . . .

You could build up a table:

Volume of stock taken / cm^3	Volume of water taken / cm^3	Dilution Factor (= 50 ÷ volume taken)	Final concentration / mol dm^3
1	49	50.000	0.01
2	48	25.000	0.02
4	46	12.500	0.04
6	44	8.333	0.06
8	42	6.250	0.08
10	40	5.000	0.10
15	35	3.333	0.15
20	30	2.500	0.20
24	26	2.083	0.24
28	22	1.786	0.28
30	20	1.667	0.30
36	24	1.389	0.36
40	10	1.250	0.40
44	6	1.136	0.44
48	2	1.042	0.48

Using the data above it is fairly easy to see that the volumes required are 10, 20, 30 and 40 cm^3 to prepare 50 cm^3 of solutions with concentrations of 0.1 mol dm^{-3}, 0.2 mol dm^{-3}, 0.3 mol dm^{-3} and 0.4 mol dm^{-3} respectively.

The approach above yielded the right answers although the construction of the table was somewhat arbitrary. If we had needed to make a solution whose concentration was 0.37 mol dm^{-3} then all we could say is that the volume required lies somewhere between 36 and 40 cm^3.

Method 2 An approach that does not use quite such a hit-and-miss method is to work out how much volume is required to make a small (approximately 1% change) and use this as the basis for calculating the amount required.

Let us see how this works.

Suppose we take 0.5 cm^3 of stock (0.5 mol dm^{-3}) and make it up to 50 cm^3 with water then the concentration of the resulting solution will be 0.005 mol dm^{-3}. So:

Each 0.5 cm^3 in 50 cm^3 $\longrightarrow$ 0.005 mol dm^{-3}
Each 0.1 cm^3 in 50 cm^3 $\longrightarrow$ 0.001 mol dm^{-3}

Therefore, each 0.1 cm^3 in 50 cm^3 leads to a final concentration of 0.001 mol dm^{-3}.

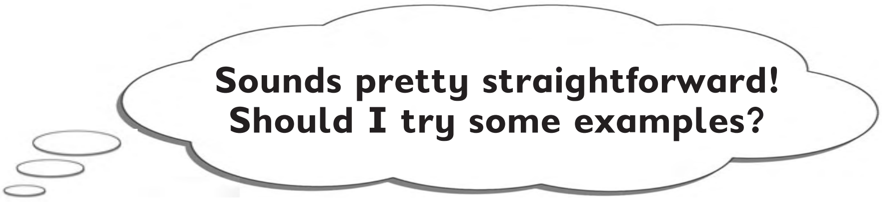
So to calculate how much is required to make a solution of 0.37 mol dm^{-3}, we need to know the ratio of 0.37 to 0.001 (= 370) and, therefore, we need 370 times as much stock as was required to make a solution of 0.001 mol dm^{-3}. Hence we need 370 x 0.1 cm^3 = 37 cm^3 of stock made up to 50 cm^3 with solvent (water in this case).

In general one of the following equations can be used in dilution calculations:

$$A = \frac{C \times V}{S} \quad \textit{or} \quad C = \frac{A \times S}{V}$$

Where:

A is the amount of stock solution to be added (cm^3)
V is the final volume of solution required (cm^3)
C is the final concentration (mol dm^{-3})
S is the stock solution concentration (mol dm^{-3})



Self-Assessment Questions 8

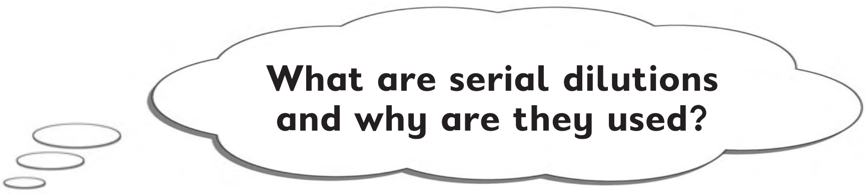
Methylene blue is an intensely coloured dye molecule used for staining nucleic acids. A stock solution of methylene blue was prepared in water with the concentration of the methylene blue being 5 x 10^{-5} mol dm^{-3}.

(i) 4 volumetric flasks (25 cm^3) were taken. Different volumes of the methylene blue stock were placed in the flasks such that the first contained 1 cm^3, the second contained 2 cm^3, the third contained 3 cm^3, and the fourth contained 4 cm^3. Each flask was made up to the mark with distilled water. What are the final concentrations of methylene blue in each of the four volumetric flasks?

(ii) How much methylene blue stock solution would need to be placed in a flask (25 cm^3) in order to achieve a final concentration of 2.4 x 10^{-6} mol dm^{-3} when the flask is made up to the mark with distilled water?

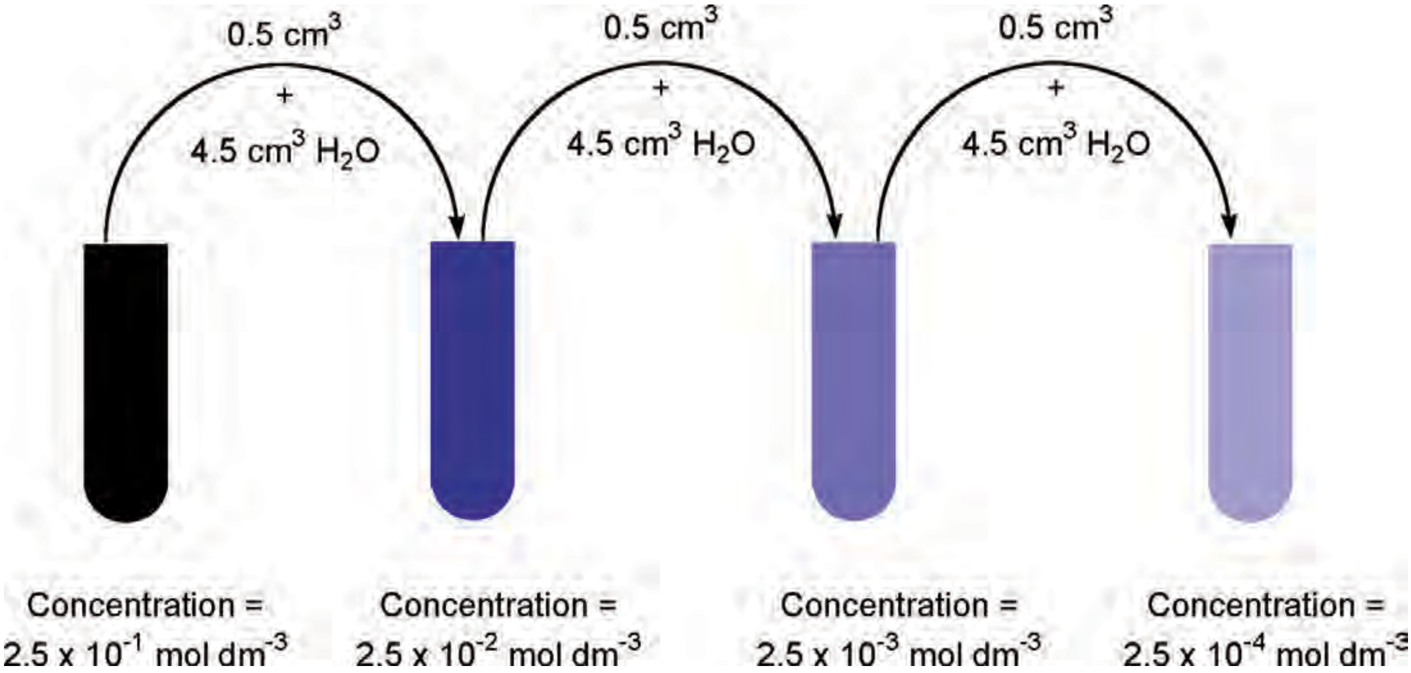
Check answers

During your science studies when you might have to do some calculations involving so-called serial dilutions. Students often find such calculations challenging and so this section has been written to help give you confidence in dealing with such problems.



There are occasions when you are given a stock solution (for example a concentrated dye solution or a suspension of bacteria) and you need to measure the concentration. The device you use to measure the concentration may only be accurate over a certain concentration range and so you may need to dilute your stock solution to ensure that you can work in this range. Often the best way to approach this is to prepare a range of dilutions from the stock and a common approach is to use a method called *serial dilution*.

Let's work through an example. Suppose we are given a solution (the stock solution) of a dye that is occasionally used to stain DNA. We are told that the concentration of the stock solution is 2.5 x 10^{-1} mol dm^{-3}. For use as a DNA stain, the dye needs to be present in solution in the concentration range 1.0 – 4.0 x 10^{-4} mol dm^{-3}. How could we prepare a sample (5 cm^3) of the dye from the stock solution that falls inside this range? A reliable method to use would be to create a series of serial dilutions as shown in the diagram below.



Starting with the stock solution you would take 0.5 cm^3 and add 4.5 cm^3 of water. This would give you a solution of concentration 2.5×10^{-2} mol dm^{-3}. You could then repeat this process until you have a solution that lies in the correct concentration range.

The above case is an example where the serial dilutions differ by an order of magnitude from one to the other. You could of course change the concentration by any suitable factor you wished.

6. Acknowledgements

I am grateful to those individuals who have read early drafts of this guide and given freely of their time, advice and expertise. Particular thanks go to John Adds (Abbey Tutorial College), Jaquie Burt (Portobello High School, Edinburgh), Erica Clark (SAPS), Kath Crawford (Scottish Schools Equipment Research Centre (SSERC) and SAPS Biotechnology Scotland Project), Debbie Eldridge (King Ecgbert School, Sheffield), John Gray (University of Cambridge) and Stephen Tomkins (University of Cambridge). Any errors or omissions that remain are, of course, the sole responsibility of the author.

It is our intention to issue updates to this Guide on a regular basis and so further comments on content and other areas that might be covered are welcomed. Please send your comments and suggestions to SAPS@homerton.cam.ac.uk.

Appendix 1 Laws of Indices

In many areas of science it is important for you to be able to express numbers in so-called standard form (also called scientific notation). When dealing with numbers in standard form it is worth recalling (or possibly learning for the first time?!) how numbers are written using index notation. In all the examples that follow the letter x means 'multiplied by' or 'times' – **it does not represent an unknown number**.

Let us start by looking at an example of a calculation.

Worked example

(i) Let a number be represented by the letter y (it doesn't matter, at this stage, what the number is). What do we obtain if we multiply y by itself?

Well,

y x y = y^2

The number 2 in the answer is called an index (plural indices) and is superscripted (i.e. written above the line). You would state the answer to y x y as '*y to the power 2*' or '*y to the 2' or 'y squared*'. Each of these answers is correct although we would recommend you use '*y to the 2*'.

(ii) How would we write y x y x y x y x y in index notation?

Well,

y x y x y x y x y = y^5

You would state the answer to y x y x y x y x y as '*y to the 5'* (preferred) or '*y to the power 5*'.

Well, why not try out some examples just to make sure!

Have a go at the questions that follow. You can always check your answers by clicking on the link.

Self-Assessment Questions 9

Try the following examples leaving your answer in index notation:

(i) y x y x y
(ii) q x q x q x q
(iii) w x w x w x w x w
(iv) s x s x s x s x s x s x s x s x s

Check answers

A good question . . .

Suppose you want to multiply y^2 by y^5.
How would you work out the answer?

Well,

$y^2 = y \times y$ and
$y^5 = y \times y \times y \times y \times y$

So,

$y^2 \times y^5 = y \times y \times y \times y \times y \times y \times y = y^7$

This leads us to the First Law of Indices:

Add the indices together when multiplying powers of the same number

You can see that the index in the answer of the example is 7 and that equals (2+5) which is the sum of the indices of the two original numbers.

As a general rule then, we might write that:

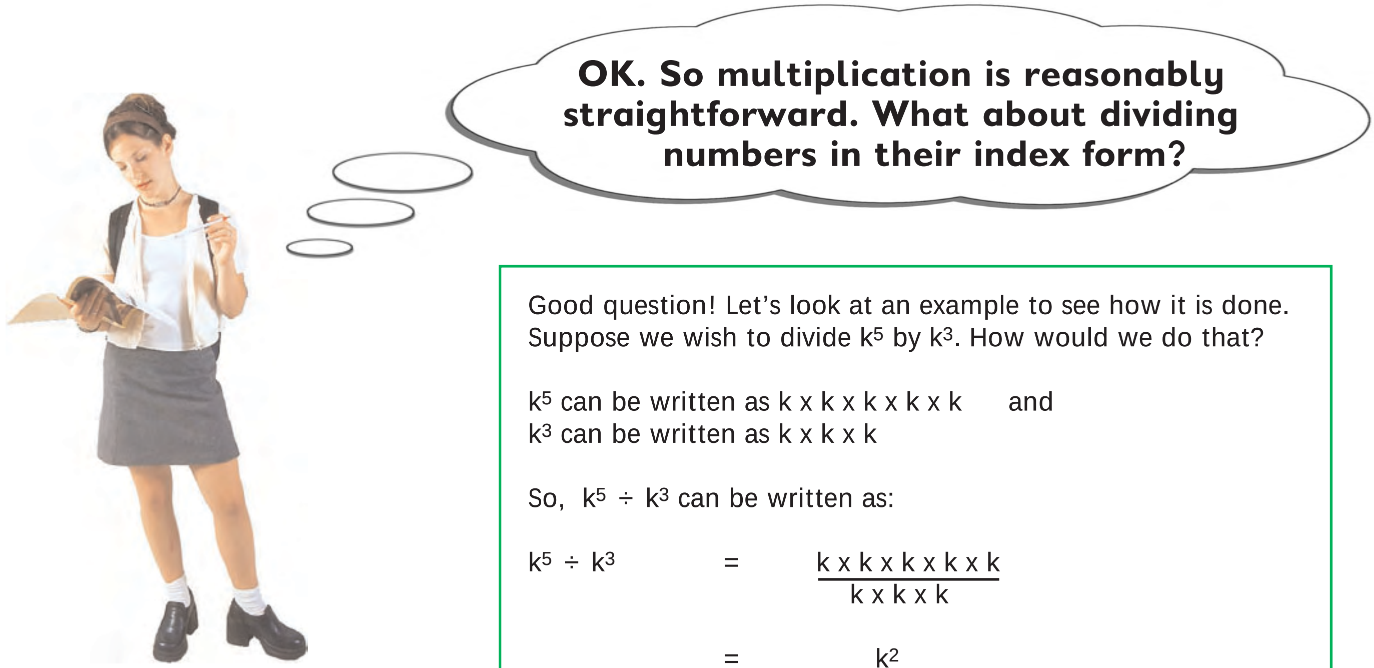
$$y^m \times y^n = y^{(m+n)}$$

Self-Assessment Questions 10

Try the following examples leaving your answer in index notation:

(i) $y^2 \times y^4$
(ii) $q^4 \times q^4$
(iii) $z^{12} \times z^3$
(iv) $10^6 \times 10^4$

Check answers



Good question! Let's look at an example to see how it is done. Suppose we wish to divide k^5 by k^3. How would we do that?

k^5 can be written as k x k x k x k x k and
k^3 can be written as k x k x k

So, $k^5 \div k^3$ can be written as:

$$k^5 \div k^3 = \frac{k \times k \times k \times k \times k}{k \times k \times k}$$

$$= k^2$$

This leads us to the Second Law of Indices:

When dividing powers of the same number subtract the index of the denominator from the numerator

Let us calculate $y^6 \div y^2$

This may be written as:

$$y^6 \div y^2 = \frac{y \times y \times y \times y \times y \times y}{y \times y} = y \times y \times y \times y = y^4$$

You can see that we have subtracted the index of the second number from the first.

$$y^6 \div y^2 = y^{(6-2)} = y^4$$

As a general rule then, we might write that:

$$y^m \div y^n = y^{(m-n)}$$

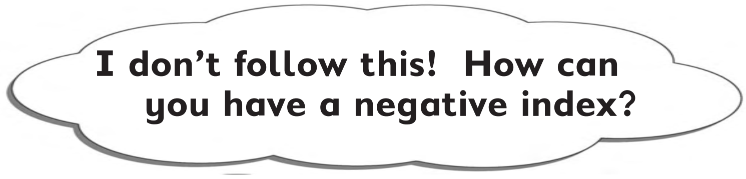
Self-Assessment Questions 11

Try the following examples - leave your answer in the index notation:

(i) $y^6 \div y^4$
(ii) $q^7 \div q^5$
(iii) $w^{12} \div w^7$
(iv) $t^3 \div t^2$
(v) $p^6 \div p^8$

Check answers

You should have noticed that the answer to the last example in SAQ11 gives a negative number for the index. Don't panic - that is quite correct!



Negative indices can arise when using both of the Laws that we have covered. As an example we might ask what is $a^3 \div a^5$? We can calculate the answer in two ways:

Firstly, we can write:

$$a^3 \div a^5 = \frac{a \times a \times a}{a \times a \times a \times a \times a} = \frac{1}{a \times a} = \frac{1}{a^2}$$

An alternative way to write the answer (see Law 2) is:

$$a^3 \div a^5 = a^{(3-5)} = a^{-2}$$

So, a^{-2} is the same as $\frac{1}{a^2}$

This leads us to the Third Law of Indices:

A negative index indicates the reciprocal of the quantity

At this point you should attempt some further examples which incorporate the three laws that we have covered. Try out the following questions and compare your answers with those given.

Self-Assessment Questions 12

Try the following examples - leave your answers in index notation.

(i) $y^6 \times y^4$

(ii) $q^4 \div q^7$

(iii) $y^6 \times y^4 \times y^4$

(iv) $2^3 \times 2^5$

(v) $10^{-2} \times 10^{-4}$

(vi) $(10^3)^2$

(vii) $m^{12} \div m^{14}$

(viii) $10^{-2} \div 10^{-4}$

(ix) $(ab^2)^3$

(x) $10^{-2} \times 10^4$

Check answers

Any number can be written in the index form. We have looked at examples where the index has been a whole number ≥ 1 or ≤ 1. Other possibilities exist and the two most common ones are when the index is 0 or 1.

So, how does that work then?

Suppose we try the calculation $y^3 \div y^2$.

We know (2nd Law of Indices) that:

$y^3 \div y^2 = y^{(3-2)} = y^1$

We also know that:

$$y^3 \div y^2 = \frac{y \times y \times y}{y \times y} = y$$

So $y^1 = y$

This is true for all numbers – it is just that we don't normally write in the number 1. So we could write the number 10 as 10^1 etc.

OK. I can see how the index might be 1 but how can it be zero?!

Suppose we try the calculation $q^4 \div q^4$.

We know (2nd Law of Indices) that:

$q^4 \div q^4 = q^{(4-4)} = q^0$

We also know that:

$$q^4 \div q^4 = \frac{q \times q \times q \times q}{q \times q \times q \times q} = 1$$

So $q^0 = 1$

This is true for all numbers. So we could write the number 1 as 10^0, q^0, y^0 etc.

SAQ1 answers:

(i)	385	= 3.85 x 100	= 3.85 x 10^2
(ii)	385.3	= 3.853 x 100	= 3.853 x 10^2
(iii)	321	= 3.21 x 100	= 3.21 x 10^2
(iv)	31	= 3.1 x 10	= 3.1 x 10^1
(v)	43000	= 4.3 x 10000	= 4.3 x 10^4
(vi)	152000	= 1.52 x 100000	= 1.52 x 10^5
(vii)	32000000	= 3.2 x 10000000	= 3.2 x 10^7
(viii)	24.3	= 2.43 x 10	= 2.43 x 10^1
(ix)	2321	= 2.321 x 1000	= 2.321 x 10^3
(x)	8	= 8 x 1	= 8 x 10^0
(xi)	14100	= 1.41 x 10000	= 1.41 x 10^4
(xii)	385000	= 3.85 x 100000	= 3.85 x 10^5

(xiii) 602 000 000 000 000 000 000 000 = 6.02 x 100 000 000 000 000 000 000 000
= 6.02 x 10^{23}

So, 6.02 x 100 000 000 000 000 000 000 000 can be written as 6.02 x 10^{23}. This latter number (6.02 x 10^{23}) is much easier to handle than when it is written in its full form.
(You would state this as ‘six point zero two times ten to the twenty-three’)

Return

SAQ2 answers:

(i)	0.013	= 1.3 ÷ 100	= 1.3 x 10^{-2}
(ii)	0.000698	= 6.98 ÷ 10000	= 6.98 x 10^{-4}
(iii)	0.00000546	= 5.46 ÷ 1000000	= 5.46 x 10^{-6}
(iv)	0.23	= 2.3 ÷ 10	= 2.3 x 10^{-1}
(v)	0.694	= 6.94 ÷ 10	= 6.94 x 10^{-1}
(vi)	0.00385	= 3.85 ÷ 1000	= 3.85 x 10^{-3}
(vii)	0.00000000048	= 4.8 ÷ 10000000000	= 4.8 x 10^{-10}

Return

SAQ3 answers:

(i)	water	=	(1 x 2) + 16	=	18 g mol^{-1}
(ii)	carbon dioxide	=	12 + (16 x 2)	=	44 g mol^{-1}
(iii)	oxygen	=	16 x 2	=	32 g mol^{-1}
(iv)	nitrogen	=	14 x 2	=	28 g mol^{-1}
(v)	ammonia (NH3)	=	14 + (3 x 1)	=	17 g mol^{-1}
(vi)	glucose	=	(12 x 6) + (1 x 12) + (16 x 6)	=	180 g mol^{-1}
(vii)	sucrose	=	(12 x 12) + (1 x 22) + (16 x 11)	=	342 g mol^{-1}

Return

SAQ4 answers:

(i)	Molar mass of glycine = (12 x 2) + (1 x 5) + 14 + (16 x 2)	=	75 g mol^{-1}
	Number of moles of glycine = 0.5 ÷ 75	=	0.0067 mol
(ii)	Molar mass of urea = 12 + 16 + (14 x 2) + (4 x 1)	=	60 g mol^{-1}
	Number of moles of urea = 10 ÷ 60	=	0.167 mol
(iii)	Molar mass of Na_2HPO_4 = (23 x 2) + 1 + 31 + (16 x 4)	=	142 g mol^{-1}
	Number of moles of Na_2HPO_4 = 25 ÷ 142	=	0.176 mol
(iv)	Molar mass of fructose = (12 x 6) + (1 x 12) + (16 x 6)	=	180 g mol^{-1}
	Number of moles of fructose = 250 ÷ 180	=	1.39 mol
(v)	Molar mass of ribose = (12 x 5) + (1 x 10) + (16 x 5)	=	150 g mol^{-1}
	Number of moles of ribose = 0.0028 ÷ 150	=	1.87 x 10^{-5} mol
(vi)	Molar mass of sodium hydroxide = 23 + 16 + 1	=	40 g mol^{-1}
	Number of moles of sodium hydroxide = 12 ÷ 40	=	0.30 mol
(vii)	Molar mass of glucose = (12 x 6) + (1 x 12) + (16 x 6)	=	180 g mol^{-1}
	Number of moles of glucose = 15.8 ÷ 180	=	0.088 mol

Return

SAQ5 answers:

(i) Molar mass of Na_2HPO_4 = (23 x 2) + 1 + 31 + (16 x 4) = 142 g mol^{-1}
Number of moles of Na_2HPO_4 = 71.0 ÷ 142 = 0.50 mol

Concentration = amount of material ÷ volume
= 0.50 ÷ 1.0 = 0.50 mol dm^{-3}

(ii) Molar mass of $MgCl_2$ = 24.3 + (35.5 x 2) = 95.3 g mol^{-1}
Number of moles of $MgCl_2$ = 2.38 ÷ 95.3 = 0.025 mol

Concentration = amount of material ÷ volume
= 0.025 ÷ 0.5 = 0.050 mol dm^{-3} (remember 500 cm^3 = 0.5 dm^3!)

(iii) (a) Molar mass of glucose = (12 x 6) + (1 x 12) + (16 x 6) = 180 g mol^{-1}
Number of moles of glucose = 8.5 ÷ 180 = 0.047 mol

Concentration = amount of material ÷ volume
= 0.047 ÷ 1.0 = 0.047 mol dm^{-3}

(b) Molar mass of ribose = (12 x 5) + (1 x 10) + (16 x 5) = 150 g mol^{-1}
Number of moles of ribose = 10.7 ÷ 150 = 0.071 mol

Concentration = amount of material ÷ volume
= 0.071 ÷ 0.5 = 0.142 mol dm^{-3}

(c) Molar mass of glycine = (12 x 2) + (1 x 5) + 14 + (16 x 2) = 75 g mol^{-1}
Number of moles of glycine = 25.7 ÷ 75 = 0.343 mol

Concentration = amount of material ÷ volume
= 0.343 ÷ 2.0 = 0.172 mol dm^{-3}

(d) Molar mass of sucrose = (12 x 12) + (1 x 22) + (16 x 11) = 342 g mol^{-1}
Number of moles of sucrose = 18.5 ÷ 342 = 0.054 mol

Concentration = amount of material ÷ volume
= 0.054 ÷ 0.375 = 0.144 mol dm^{-3}

(iv) Molar mass of ribose = (12 x 5) + (1 x 10) + (16 x 5) = 150 g mol^{-1}

Amount of material = concentration x volume
= 1.0 x 10^{-4} x 0.1 = 1.0 x 10^{-5} mol
Mass of material = molar mass x amount of material (in moles)
= 150 x 1.0 x 10^{-5} = 1.5 x 10^{-3} g or 0.0015 g

(v) Molar mass of Na_2HPO_4 = (23 x 2) + 1 + 31 + (16 x 4) = 142 g mol^{-1}

Amount of material = concentration x volume
= 1.8 x 10^{-2} x 5.0 = 9.0 x 10^{-2} mol
Mass of material = molar mass x amount of material (in moles)
= 142 x 9.0 x 10^{-2} = 12.78 g

Return

SAQ6 answers:

(i) The molar mass of a protein is 32000 g mol^{-1}. A student takes 0.003 g of the protein and dissolves it in 500 cm^3 of water. What is the concentration of the solution that has been prepared?

Concentration = amount of material (in moles) ÷ volume
Amount of material = 0.003 ÷ 32000 = 9.4×10^{-8} mol

So, concentration = 9.4×10^{-8} ÷ 0.5 = 1.9×10^{-7} mol dm^{-3}

(ii) Suppose that instead of dissolving the protein in 500 cm^3 of water only 25.8 cm^3 of water had been used. What would the concentration have been in that case?

Concentration = amount of material (in moles) ÷ volume
Amount of material = 0.003 ÷ 32000 = 9.4×10^{-8} mol

So, concentration = 9.4×10^{-8} ÷ 0.0258 = 3.64×10^{-6} mol dm^{-3}

(iii) A solution of a carbohydrate whose molar mass is 1.8×10^5 g mol^{-1} is prepared by dissolving 0.14 g of the carbohydrate in 150 cm^3 of water. What is the concentration of the solution?

Concentration = amount of material (in moles) ÷ volume
Amount of material = 0.14 ÷ 1.8×10^5 = 7.78×10^{-7} mol

So, concentration = 7.78×10^{-7} ÷ 0.15 = 5.19×10^{-6} mol dm^{-3}

(iv) A solution of the protein catalase is needed for an experiment. Given that the molar mass of catalase is 250 000 g mol^{-1} how much catalase is needed to prepare 150 cm^3 of solution with a concentration of 3.5×10^{-7} mol dm^{-3}?

Amount of material = concentration x volume
Amount of material = $3.5 \times 10^{-7} \times 0.15$ = 5.25×10^{-8} mol

So, mass of catalase needed = $5.25 \times 10^{-8} \times 250\,000$ = 0.013 g catalase

Return

SAQ7 answers:

(i) 0.5 g of DNA in 100 cm^3 water = 0.5% w/v

(ii) 0.013 g of RNA in 10 cm^3 of water = 0.13 % w/v (remember 0.013 g in 10 cm^3 is equivalent to 0.13 g in 100 cm^3)

(iii) 0.02 g of starch in 500 cm^3 of water = 0.004 % w/v (remember 0.02 g in 500 cm^3 is equivalent to 0.004 g in 100 cm^3)

(iv) 0.007 g of DNA in 12.5 cm^3 of buffer = 0.056 % w/v (remember 0.007 in 12.5 cm^3 is equivalent to 0.056 g in 100 cm^3)

Return

SAQ8 answers:

The concentration of the methylene blue stock solution was 5 x 10^{-5} mol dm^{-3}.

(i) 4 volumetric flasks (25 cm^3) were taken. Different volumes of the methylene blue stock were placed in the flasks such that the first contained 1 cm^3, the second 2 cm^3, the third 3 cm^3, and the fourth 4 cm^3. Each flask was made to the mark with distilled water. What are the final concentrations of methylene blue in each of the four volumetric flasks?

$$C = \frac{A \times S}{V}$$

Using the above expression we can calculate that the final concentration in each flask is:

	(1 x 5 x 10^{-5}) ÷ 25	(2 x 5 x 10^{-5}) ÷ 25;	(3 x 5 x 10^{-5}) ÷ 25	(4 x 5 x 10^{-5}) ÷ 25
=	2.0 x 10^{-6} mol dm^{-3}	4.0 x 10^{-6} mol dm^{-3}	6.0 x 10^{-6} mol dm^{-3}	8.0 x 10^{-6} mol dm^{-3}

(ii) How much methylene blue stock solution would need to be placed in a flask (25 cm^3) in order to achieve a final concentration of 2.4 x 10^{-6} mol dm^{-3} when the flask is made up to the mark with dis tilled water?

$$A = \frac{C \times V}{S}$$

Using the above expression we can calculate that the amount needed will be:

Amount = (2.4 x 10^{-6} x 25) ÷ 5 x 10^{-5} = 1.2 cm^3 of stock solution

Return

SAQ9 answers:

(i) y x y x y = y^3

(ii) q x q x q x q = q^4

(iii) w x w x w x w x w = w^5

(iv) s x s x s x s x s x s x s x s x s = s^9

Return

SAQ10 answers:

(i) $y^2 \times y^4$ = y^6

(ii) $q^4 \times q^4$ = q^8

(iii) $z^{12} \times z^3$ = z^{15}

(iv) $10^6 \times 10^4$ = 10^{10}

Return

SAQ11 answers:

(i) $y^6 \div y^4$ = y^2

(ii) $q^7 \div q^5$ = q^2

(iii) $w^{12} \div w^7$ = w^5

(iv) $t^3 \div t^2$ = t^1

(v) $p^6 \div p^8$ = p^{-2}

Return

SAQ12 answers:

(i)	$y^6 \times y^4$	$= y^{10}$		
(ii)	$q^4 \div q^7$	$= q^{-3}$		
(iii)	$y^6 \times y^4 \times y^4$	$= y^{14}$		
(iv)	$2^3 \times 2^5$	$= 2^8$		
(v)	$10^{-2} \times 10^{-4}$	$= 10^{-6}$		
(vi)	$(10^3)^2$	$= 10^3 \times 10^3$	$= 10^6$	
(vii)	$m^{12} \div m^{14}$	$= m^{-2}$		
(viii)	$10^{-2} \div 10^{-4}$	$= 10^{(-2-(-4))}$	$= 10^{(-2+4)}$	$= 10^2$
(ix)	$(ab^2)^3$	$= ab^2 \times ab^2$	$= a^3b^6$	
(x)	$10^{-2} \times 10^4$	$= 10^2$		

Return

Table 1 Relative atomic masses of elements 1 - 100

Element	Symbol	Atomic Number	Relative Atomic Mass (g mol-1)	Element	Symbol	Atomic Number	Relative Atomic Mass (g mol-1)
Actinium	Ac	89	227.0	Mercury	Hg	80	200.6
Aluminium	Al	13	26.9	Molybdenum	Mo	42	95.9
Americium	Am	95	243.0	Neodymium	Nd	60	144.2
Antimony	Sb	51	121.8	Neon	Ne	10	20.2
Argon	Ar	18	39.9	Neptunium	Np	93	237.0
Arsenic	As	33	74.9	Nickel	Ni	28	58.7
Astatine	At	85	210.0	Niobium	Nb	41	92.9
Barium	Ba	56	137.3	Nitrogen	N	7	14.0
Berkelium	Bk	97	249.0	Osmium	Os	76	190.2
Beryllium	Be	4	9.0	Oxygen	O	8	16.0
Bismuth	Bi	83	209.0	Palladium	Pd	46	106.4
Boron	B	5	10.8	Phosphorous	P	15	31.0
Bromine	Br	35	79.9	Platinum	Pt	78	195.1
Cadmium	Cd	48	112.4	Plutonium	Pu	94	242.0
Caesium	Cs	55	132.9	Polonium	Po	84	210.0
Calcium	Ca	20	40.1	Potassium	K	19	39.1
Californium	Cf	98	251.0	Praesodymium	Pr	59	140.9
Carbon	C	6	12.0	Promethium	Pm	61	145.0
Cerium	Ce	58	140.1	Protactinium	Pa	91	231.0
Chlorine	Cl	17	35.5	Radium	Ra	88	226.1
Chromium	Cr	24	52.0	Radon	Rn	86	222.0
Cobalt	Co	27	58.9	Rhenium	Re	75	186.2
Copper	Cu	29	63.5	Rhodium	Rh	45	102.9
Curium	Cm	96	247.0	Rubidium	Rb	37	85.5
Dysprosium	Dy	66	162.5	Ruthenium	Ru	44	101.1
Einsteinium	Es	99	254.0	Samarium	Sm	62	150.4
Erbium	Er	68	167.3	Scandium	Sc	21	45.0
Europium	Eu	63	152.0	Selenium	Se	34	79.0
Fermium	Fm	100	253.0	Silicon	Si	14	28.1
Fluorine	F	9	19.0	Silver	Ag	47	107.9
Francium	Fr	87	223.0	Sodium	Na	11	23.0
Gadolinium	Gd	64	157.3	Strontium	Sr	38	87.6
Gallium	Ga	31	69.7	Sulfur	S	16	32.1
Germanium	Ge	32	72.6	Tantalum	Ta	73	180.9
Gold	Au	79	197.0	Technetium	Tc	43	99.0
Hafnium	Hf	72	178.5	Tellurium	Te	52	127.6
Helium	He	2	4.0	Terbium	Tb	65	158.9
Holmium	Ho	67	164.9	Thallium	Tl	81	204.4
Hydrogen	H	1	1.0	Thorium	Th	90	232.0
Indium	In	49	114.8	Thulium	Tm	69	168.9
Iodine	I	53	126.9	Tin	Sn	50	118.7
Iridium	Ir	77	192.2	Titanium	Ti	22	47.9
Iron	Fe	26	55.8	Tungsten	W	74	183.9
Krypton	Kr	36	83.8	Uranium	U	92	238.0
Lanthanum	La	57	138.9	Vanadium	V	23	50.9
Lead	Pb	82	207.2	Xenon	Xe	54	131.3
Lithium	Li	3	6.9	Ytterbium	Yb	70	173.0
Lutetium	Lu	71	175.0	Yttrium	Y	39	88.9
Magnesium	Mg	12	24.3	Zinc	Zn	30	65.4
Manganese	Mn	25	54.9	Zirconium	Zr	40	91.2