Chem Factsheet

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Maths for Chemists 1

This Factsheet concentrates on reviewing the basic mathematical techniques required for AS/A2 Chemistry. You will have already met the ideas involved in GCSE Maths, but this Factsheet aims to provide some fool-proof methods for applying them in chemical contexts. The topics covered are:

- Ratios
- Percentages
- Standard form
- Significant figures

Later Factsheets will cover work on rearranging formulae, graphs, and exponentials and logarithms.

Ratios

Ratios are used in **mole calculations**. There are two stages in this part of the calculation:

1. Using a chemical equation to find the **reacting ratio**
2. Using the reacting ratio to work out moles.

Stage 1 just involves looking at the numbers in the equation!

eg: $4Al + 3O_2 \rightarrow 2Al_2O_3$

Reacting ratio of Al to O_2 is 4:3

$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

Reacting ratio of NaOH to H_2SO_4 is 2:1

You do have to be careful if you are looking for the reacting ratio for a particular **ion** rather than the entire compound. For example, 1 mole of H_2SO_4 contains 2 moles of hydrogen ions (because of the "H_2" in the "H_2SO_4"). So in the equation $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$, the reacting ratio of OH^- ions to H^+ ions is 2:2 (the same as 1:1)

Stage 2 involves the actual calculation. There are several ways to do this – if you are confident and accurate with another method, you probably do not need this one! But if you ever make mistakes, it's worth taking a look.

Example 1.
0.316 moles of aluminium react with oxygen to form aluminium oxide. Find the number of moles of oxygen gas used.

> ***Exam Hint:*** *We need the number of moles of O_2, not moles of O, because oxygen normally exists as O_2.*

Step 1: Write down your reacting ratio from the equation

Al: O_2
4 : 3

Step 2: Underneath the ratio, in the right order, write down the moles you know and a ? for the moles you don't. Line up the : to avoid mix ups

4 : 3
0.316 : ?

Step 3: Draw a cross:

4 : 3
0.316 : ?

Step 4: Multiply the two joined numbers and divide by the other one to find ?

? = 3 × 0.316 ÷ 4 = 0.237 moles of O_2

> ***Exam Hint****: Make sure at the end of this part of your calculation that the substance corresponding to the larger "ratio number" has the larger number of moles*

Example 2. $5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

Find the number of moles of Fe^{2+} required to react with 0.123 moles of MnO_4^-

Step 1: Fe^{2+} : MnO_4^-
5 : 1

Steps 2 & 3: ? : 0.123

Step 4: Moles of Fe^{2+} = 5 × 0.123 ÷ 1 = 0.615

The questions at the end of the Factsheet gives more practice on ratio calculations

NB: This is only part of the entire mole calculation! The rest of it will involve converting between moles, masses, concentrations, volumes etc. For more details on moles calculations, see Factsheets 2, 3, 7 ,23 and 59.

Percentages

Percentages are used in:

- **Yield Calculations**
  This relates to experiments involving preparing a particular substance. You never actually get as much of the substance as you'd theoretically predict. The % yield is the amount you actually get as a percentage of what you'd get theoretically
- **% purity (or % by mass) calculations**
  This relates to doing an experiment on a sample that's only partly the substance that's reacting (eg a commercial "iron pill" is certainly not pure iron!) The % purity is the mass of the substance you're interested in as a percentage of the total mass of the sample

Note that all these types of calculation will involve other parts as well as finding the percentage!

> ***Exam Hint****: You will see percentages in empirical formula calculations too - but you just use them like masses - rather than calculating them.*

Percentage calculations can be done in a similar way to ratio calculations, using the cross method shown above. You draw a table, with one column for % and one for actual amounts (masses,moles etc). You can use the same method whether you are trying to find a percentage or an actual amount.

Example
In an experiment, 1.062g of compound X were produced. The theoretical maximum yield was 1.231g. Find the percentage yield.

Step 1: Draw a table, with one column for % and one for mass, and put in the data you know. The theoretical maximum is 100%

%	mass
100	1.231
?	1.062

Step 2: Draw a cross

Step 3: Multiply the two joined numbers and divide by the other one to find ?

? = 100 × 1.062 ÷ 1.231 = 86.3%

Standard Form

Standard form is a way of writing very large or very small numbers. You need to be able to

- be confident with **manipulating** standard form numbers in a variety of contexts - e.g. when using data to determine the order of a reaction, or when plotting a graph
- enter these numbers into your **calculator**, and write the answer correctly

Working with standard form

Numbers in standard form look like this:

This number is between 1 and 9.999...

The power can be positive (large numbers) or negative (small numbers)

$$6.02 \times 10^{23}$$

This is always 10

In GCSE maths, you will have done work on changing numbers in and out of standard form. Now it is more important to be able to **compare** two numbers in standard form - without having to convert them both to "normal" numbers.

Comparing numbers is easy if they both have the same power of 10. For example, it's easy to see that

$6 \times 10^{-5} = 2\times (3\times10^{-5})$

But it's harder to compare, say, 1.2×10^{-5} and 3×10^{-6}.

> To compare numbers in standard form, convert them all to the same power

This is how to convert standard form numbers to the same power:

Method	**Example:** 1.2×10^{-5} and 3×10^{-6}.
Choose the **smaller** power.	The smaller power is 10^{-6}
Write: no. in big power = no. in small power + something	$10^{-5} = 10^{-6+1}$
Use the **laws of powers** (adding powers means multiply)	$10^{-5} = 10^{-6}\times10^{1}$
Substitute back	$1.2 \times 10^{-5} = 1.2 \times10^{-6}\times10^{1}$ $= 1.2 \times10^{1} \times10^{-6}$ $= 1.2 \times10 \times10^{-6}$ $= 12 \times10^{-6}$
Do the comparison	We can see that: $12 \times10^{-6} = 4 \times (3 \times 10^{-6})$

This sort of calculation might be required to compare rates of reaction when the concentration of a reactant is doubled, for example.

To draw a **graph** using numbers in standard form, first convert them all to the same power, following the procedure above. For example, you might end up with 1×10^{-6}, 2×10^{-6} ....., 14×10^{-6}, 15×10^{-6}. You'd work out a scale for these just like you would for the numbers 1 - 15. You must remember to put the "$\times10^{-6}$" in; it can either be written with the actual numbers in the scale itself, or as part of the labelling (eg $[H^{+1}]/10^{-6}$).

Standard form on your calculator

Entering numbers in standard form

There is a special key used for entering standard form; it's usually labelled EE or EXP.

You enter a number in standard form by typing in the first part of the number, then hitting the EE or EXP key, then typing in the power

eg: 6.02 EXP 23 gives 6.02×10^{23}

Take care with minus signs:
if you enter them **before** pressing the EE/EXP key, they'll be attached to the **number** (eg -2×10^{5})
if you enter them **after** pressing the EE/EXP key, they'll be attached to the **power** (eg 2×10^{-5})

Reading off the answer

Most calculators display standard form numbers like this:

6.02 ^{23}

The two small digits high up to the right show the power - so this display means (and should be written as) 6.02×10^{23}.

Significant figures

Specifications require that students quote their answers "to an appropriate number of significant figures". This section reviews what is meant by significant figures, and explains the rules for using them.

What are significant figures?

Significant figures (SF) refer to the most "important" figures in a number – the ones that represent the largest amounts.
For example, in the number 1425:

- 1 is the most important – the 1st **SF** - it represents 1000
- 4 is the 2nd most important – the **2nd SF** - it represents 400

Similarly, in the number 0.00423:

- 4 is the 1st SF, because it represents 0.004
- 2 is the 2nd SF because it represents 0.0002

So you count from the **left** to find significant figures, ignoring initial zeros.
NB: It is **only** the initial zeros you ignore, not ones in the middle of the number - eg in 9806, 0 is the third significant figure.

Rounding to a number of significant figures

To round to a particular number of SF:

- Count to that number of SF (eg for 4SF, find the 4th SF)
- Look at the next figure – if it's 5 or above, round up, otherwise round down

Working with significant figures

When doing a calculation, you will often need to decide how many significant figures. You will need to consider:-

- **The data given in the question** (eg from a table, a graph…)
  - o eg 2.10 is correct to 3SF but 2.1 is correct to 2SF
  - o be realistic about how accurately you can read a graph – usually to the nearest small square on graph paper.
- **What is required in the answer**.
  - o you may be asked for a specific number of DP or SF
  - o if not, give your answer to the same accuracy as the data in the question, and state the number of SF you are using

Then, you should:

- Work to a greater accuracy than is required in the answer, to avoid rounding errors (eg if 2SF is needed, you work to at least 3SF)
- Keep intermediate answers in your calculator as far as possible
- Give the final answer to no greater accuracy than is given in the question (eg if all data in the question are to 2SF, it would be silly to give the answer to 3SF)

Questions

1. 0.53 moles of sodium react with oxygen to form sodium peroxide (Na_2O_2)

   (a) Write an equation for this reaction

   (b) Calculate the number of moles of oxygen required

2. Iodide ions (I^-) react with iodate V ions (IO_3^-) in the presence of acid to produce iodine.

   $5I^- + IO_3^- + 6H^+ \rightarrow 3I_2 + 6H_2O$

   0.821 moles of iodine are produced.

   Calculate the moles required of
   (i) iodide ions
   (ii) iodate ions

3. Iron II ions are oxidised by dichromate ions to form iron III ions in the presence of acid

   $6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$

   Calculate the moles of dichromate ions required to fully oxidise 0.0174 moles of iron II ions

4. Dichromate ions oxidise iodide ions to iodine:

   $6I^- + Cr_2O_7^{2-} + 14H^+ \rightarrow 3I_2 + 2Cr^{3+} + 7H_2O$

   The iodine liberated is titrated with sodium thiosulphate solution:

   $2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$

   0.105 moles of sodium thiosulphate are required.
   Calculate the moles of dichromate ions used.

5. In an experiment, 0.813g of a compound are produced. The theoretical mass expected was 1.02g. Calculate the percentage yield

6. A commercial iron pill of mass 0.87 g is found to contain 5.6% of iron by mass. Calculate the mass of iron in one pill.

7. Write the following pairs of numbers to the same power of 10
   (i) 2.3×10^{-5} and 3.68×10^{-4}

   (ii) 1.08×10^{-3} and 5.4×10^{-4}

   (iii) 9.1×10^{-6} and 2.43×10^{-4}

8. Use your calculator to find the following. Give your answers in standard form

   (i) $(2.91 \times 10^{-5}) \times (5.81 \times 10^{2})$
   (ii) $(7.03 \times 10^{4}) \div (2.03 \times 10^{-1})$

9. Write the following correct to the number of significant figures given

   (i) 290300 3 significant figures
   (ii) 0.9998 3 significant figures
   (iii) 0.0368 2 significant figures

10. The following data are given in a question:

Time (s)	0.0	5.0	10	15	20
Concentration (mol dm^{-3})	2.00	1.21	0.736	0.446	0.271

   (a) How many significant figures are
   (i) the times
   (ii) the concentrations
   given to?

   (b) A graph is to be plotted from this data. Suggest a suitable level of accuracy to use for any measurements taken from this graph.

Answers

1. (a) $2Na + O_2 \rightarrow Na_2O_2$
   (b) $0.53 \times 1 \div 2 = 0.265$ moles of O_2

2. (i) $0.821 \times 5 \div 3 = 1.37$ moles of I^-
   (ii) $0.821 \times 1 \div 3 = 0.274$ moles of IO_3^-

3. $0.0174 \times 1 \div 6 = 0.0029$ moles of $Cr_2O_7^{2-}$

4. Moles of iodine = $0.105 \times 1 \div 2$
   Moles of dichromate = moles of iodine $\times 1 \div 3$
   $= 0.105 \times 1 \div 2 \times 1 \div 3$
   $= 0.0175$

5. $0.813 \times 100 \div 1.02 = 79.7\%$

6. $5.6 \times 0.87 \div 100 = 0.049$g

7. (i) 2.3×10^{-5} and 36.8×10^{-5}
   (ii) 10.8×10^{-4} and 5.4×10^{-4}
   (iii) 9.1×10^{-6} and 243×10^{-6}

8. (i) 1.69×10^{-2} (ii) 3.46×10^{5}

9. (i) 290000 (ii) 1.00 (iii) 0.037

10. (a) (i) 2 (ii) 3
    (b) 2 SF

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