Bond Energy

Average Bond Energy

Bonds between **different atoms** require different amounts of **energy** to break them. When the **same two atoms** bond in the same way, the amount of energy needed is always about the same. The average bond energy values for some common bonds are given below:

C–H 413	C–O 360	C=C 612
O=O 498	H–H 436	C=O 743
C–C 348	O–H 463	

All these values are in kJ mol^{-1}.

The values tell you that:

e.g. It takes 413 kJ of energy to break 1 mole of C–H bonds.

It takes $463 \times 2 = 926$ kJ to break 1 mole of water (which has 2 O–H bonds per molecule) into oxygen and hydrogen atoms.

$743 \times 2 = 1486$ kJ are released when 1 mole of CO_2 (which has 2 C=O bonds) forms.

Calculating the *Change* in Energy

When a reaction takes place, the change in energy is simply:

sum of energy required to break old bonds – sum of energy released by new bonds formed

EXAMPLE: Calculate the energy change involved when 1 mole of methane burns in oxygen.

The equation for the reaction is: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

This tells you that 1 mole of methane reacts with 2 moles of oxygen to form 1 mole of carbon dioxide and 2 moles of water.

Step 1: Calculate the energy required to break all of the bonds between the reactant atoms:

4 C–H bonds $= 4 \times 413 = 1652$ kJ

2 O=O bonds $= 2 \times 498 = 996$ kJ

Total = 2648 kJ

Step 2: Calculate the energy released by all the new bonds formed in the products:

2 C=O bonds $= 2 \times 743 = 1486$ kJ

4 O–H bonds $= 4 \times 463 = 1852$ kJ

Total = 3338 kJ

Step 3: Combine the two values to give the overall value for the energy change:

The overall energy change is: $2648 - 3338 =$ **–690 kJ mol^{-1}**.

The negative sign shows that energy is being released to the surroundings, indicating that this is an **exothermic** reaction. This is expected, since this is a combustion reaction.

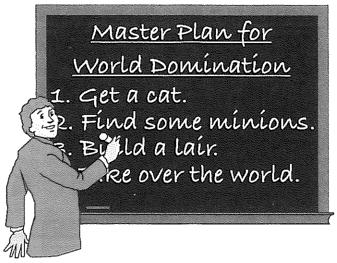
Ian Fleming was like an exothermic reaction — he made lots of Bonds...

1) Calculate the energy change of the following reactions:
(Use the values for the average bond energies given at the top of the page).
 a) burning 1 mole of propane $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
 b) burning 1 mole of ethanol $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$
 c) hydrogenation of 1 mole of ethene $C_2H_4 + H_2 \rightarrow C_2H_6$

Planning Experiments

Make Sure You **Plan** *Your* **Experiment Carefully**

To get accurate and precise results from your experiments, you first need to plan them carefully...



1) Work out the **aim** of the experiment.
2) Identify the **variables** (see below).
3) Decide what **data** to collect.
4) Decide the right **equipment** to use.
5) Plan how to reduce any **risks** in your experiment.
6) Write out a **detailed method**.
7) Carry out **tests** to address the aim of your experiment.

You Need to Control All the **Variables**

A **variable** is a quantity that might **change** during an experiment, for example temperature. There are two types of variables to know about when carrying out an experiment:

- The **independent variable** is the quantity that you **change**.
- The **dependent variable** is the thing that you measure.

When you plan an experiment you need to work out how you will **control** the variables so that the only one that changes is the one you're investigating — all the others are kept **constant**.

EXAMPLE: Measuring the effect of surface area on reaction rate.

In this experiment, the **independent variable** is the **surface area**, and the **dependent variable** is the **rate** of reaction.

Everything else, such as temperature and concentration, has to stay exactly the same between different experiments. Surface area is the only variable that you change.

Choose the Right **Equipment**

You need to think carefully about selecting the right **equipment** for your experiment...

1) The equipment has to be **appropriate** for the specific experiment — for example, in an experiment where you're collecting a **gas** the equipment you use needs to be properly **sealed** so that the gas can't **escape**.
2) The equipment needs to be the right **size**.
3) The equipment needs to be the right level of **sensitivity** — for example, if you want to measure out 4.2 g of a compound, you'll need a balance that measures to at least the nearest 0.1 g, not the nearest gram.

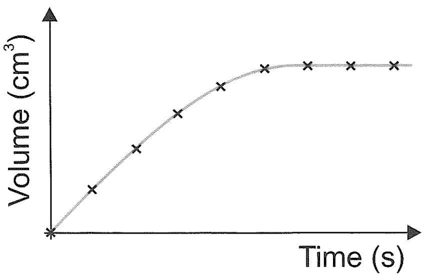
Reduce Risk — and play poker instead...

1) A student is measuring the effect of temperature on the time taken for a lump of magnesium to react completely in a sample of concentrated hydrochloric acid.
   a) What is the dependent variable in the student's experiment?
   b) Name two variables that the student should control to make the experiment a fair test.

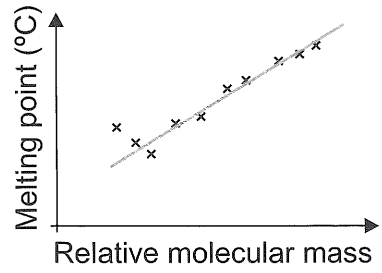
Presenting and Interpreting Data

You Can Represent Your Data in a **Table** or on a **Graph**

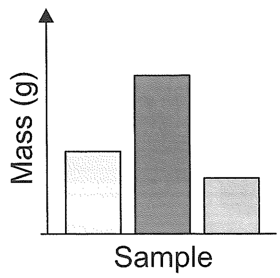
When you do an experiment, it's a good idea to set up a table to **record** your **results** in. Make sure you **include** enough **rows** and **columns** to **record all of the data** you need. Tables are good for **recording** data, but it can be easier to interpret your results if you **plot** them on a **graph**. Depending on the **type** of experiment, the **graph** you plot will vary:



Line graphs show how two sets of data are related.



Scatter plots show **trends** in data. Don't join all the points — just draw a **line of best fit**.



If one of your sets of data can be split into **groups**, draw a **bar graph**.

Repeating an Experiment Makes Your Results More **Reliable**

1) If you **repeat** an experiment, your results will usually **differ slightly** each time you do it. You can use the **mean** (or average) of the measurements to represent all these values. The more times you repeat the experiment the **more reliable** the average will be. To find the mean:

Add together all the data values then **divide** by the total number of values in the sample.

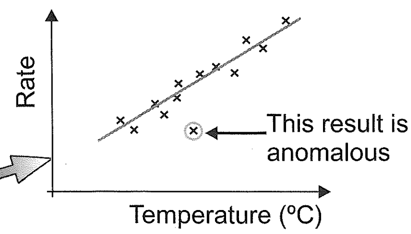
EXAMPLE: Calculate the mean result for the volume of hydrogen gas produced after 30 seconds in the reaction between hydrochloric acid and magnesium.

Run 1	Run 2	Run 3
23 cm^3	22 cm^3	25 cm^3

There are **three** values in this sample, so to find the mean result, just add together the results and divide by three:

$(23 + 22 + 25) \div 3 = \mathbf{23.3\ cm^3}$

2) Repeating experiments also lets you spot any **weird results** that stick out like a hedgehog in a tea cup. These are called **anomalous** results. For example — if one of the results above was only 5 cm^3, then something probably went wrong. You should **ignore** the anomalous result when you calculate the mean.
3) Anomalous results are really easy to spot on **scatter plots** and **line graphs** as they sit miles away from the line of best fit.



I was hoping for a nice result, but it ended up being mean...

1) Kay measured the volume of gas given off in a reaction. Her results were 22.0 cm^3, 23.0 cm^3, 22.0 cm^3, 19.0 cm^3 and 24.0 cm^3. Identify any anomalous results and calculate the mean.

Conclusions and Error

Measurements Always Have **Uncertainty** in Them

1) You saw on the last page that if you **repeat** an experiment then the results normally **vary** slightly, even if you do everything **exactly the same** each time. This is partly to do with the fact that there will always be a degree of **error** in any measurements you make.
   For example, if you use **measuring scales** that measure to the nearest **gram**, then whenever you weigh something, you might have **up to 0.5 g** more or less than the measured mass.
2) The **uncertainty** of a measurement is just the **maximum error** there could be — so in the example above it's **0.5 g**.
3) The **percentage error** of a measurement is just another way of showing the uncertainty. You calculate it using the following formula:

$$\text{percentage error} = \frac{\text{uncertainty}}{\text{measurement}} \times 100$$

EXAMPLE: Nikhil measures out 6.0 cm^3 of water in a measuring cylinder that has markings every 0.5 cm^3. Calculate the percentage error of his measurement.

The measuring cylinder can be read to the nearest 0.5 cm^3, so any measurement could be up to 0.25 cm^3 more than or less than the reading. So the uncertainty is 0.25 cm^3.

$$\text{Percentage error} = \frac{\text{uncertainty}}{\text{measurement}} \times 100 = \frac{0.25\ \text{cm}^3}{6.0\ \text{cm}^3} \times 100 = \mathbf{4.2\%}$$

Don't **Jump to Conclusions**

1) Collecting reliable data is important, but if the data doesn't answer the aim, it's not much use.
2) The **data** should **support** the conclusion. This may sound obvious, but it's easy to **jump** to conclusions. Conclusions should be **specific** — not make sweeping generalisations.
3) Conclusions often try to link changes in one variable with another. For your conclusion to be valid, you have to make sure all the other variables in the experiment were **controlled**.
4) And remember — **correlation doesn't** always mean **cause**.

EXAMPLE: Investigating whether chlorinated drinking water increases cancer risk.

Some studies claim that drinking chlorinated tap water increases the risk of some cancers. But it's hard to **control** all the **variables** between people who drink tap water and people who don't, so designing a fair test is very tricky.
But, even if some studies show a group of people who drink more chlorinated water are slightly more likely to get certain cancers, it doesn't mean that drinking chlorinated water **causes** cancer. There will be heaps of other differences between the groups of people. It could be due to any of them.

You've reached the conclusion. Please travel safely and mind the gap...

1) Calculate the percentage error in each of the following measurements:
   a) A mass of 1.4 g on a weighing scale that can measure to the nearest 0.1 g.
   b) A time of 23 seconds on a clock that times to the nearest second.
   c) A temperature of 10.6 °C on a thermometer that has markings every 0.2 °C.