Calculating Bond Energies Notes

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Questions on bond energies come up every year (every year since 2018 be exact).
They're lovely questions to get and the standard ones can involve just division, multiplication, addition and subtraction. The slightly more difficult questions involve a little bit of algebra but nothing too much at all.

First of all, what is a bond energy?

A bond energy: the amount of energy required to break one mole of a particular covalent bond. Think of it as the energy that we need to put in to break a bond. It is measured in kilojoules per mole, written as kJ/mol.

To break chemical bonds, we have to put in energy. That makes sense, if we wanted to break some chopsticks for example, we would have to use energy from our body to break them. The energy would move from us into the chopsticks. We always write this energy as a positive value as energy is taken into the bond, this indicates that bond breaking is endothermic.

To make new chemical bonds, the opposite is true of course and energy is given out. So, making new chemical bonds is exothermic. We always write this energy as a negative value as energy is going out from the new bond being made.

Calculating an energy change for a reaction

Step 1: add together the bond energies for all the bonds **broken** in the reactants - this is the 'energy in'.

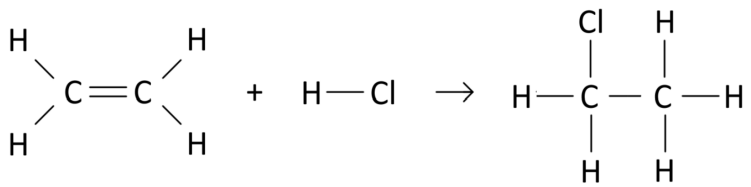
Step 2: add together the bond energies for all the bonds **formed** in the products - this is the 'energy out'.

Step 3: use the following formula to calculate ΔH.

Energy change (ΔH) = energy in – energy out

Let's have a look at an example of one 😊

Example 1: Ethene gas reacts with hydrogen chloride to produce chloroethane.
The figure below shows the displayed formula equation for the reaction.



The table below shows the bond energies we need.

Bond	C – H	C = C	C – C	H – Cl	C – Cl
Bond energy in kJ/mol	412	612	348	431	338

Calculate the energy change for this reaction.

Energy change (ΔH) = energy in – energy out

$$\Delta H = (4(412) + 612 + 431) - (5(412) + 348 + 338)$$

$$\Delta H = 2691 - 2746$$

$$\Delta H = -55 \text{ kJ/mol}$$

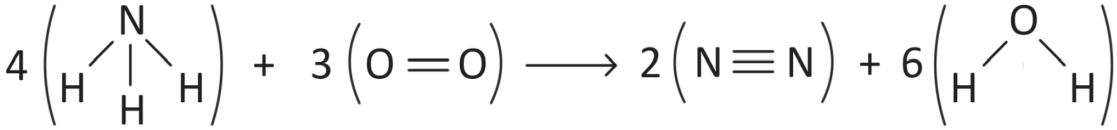
As more energy has been given out, rather than taken in, we say this reaction is an exothermic reaction.

A few points to mention:

1. We will be given the displayed formula equation for the question. All questions in the GCSE exams have included them. Though your teacher may get you to write them from scratch as an extension task.
2. We will be given all of the relevant bond energies for the question. We never have to learn these. One of them may be missing, in which case we have to find it using a bit of algebra.

Let's have a look at another example.

Example 2: Ammonia reacts with oxygen in the presence of a metal oxide catalyst to produce nitrogen and water. The figure below shows the displayed formula equation for the reaction.



The table below shows the bond energies we need.

Bond	N – H	O = O	N ≡ N	O – H
Bond energy in kJ/mol	391	498	945	464

Calculate the overall energy change for the reaction.

Energy change (ΔH) = energy in – energy out

$$\Delta H = \big(12(391) + 3(498)\big) - \big(2(945) + 12(464)\big)$$

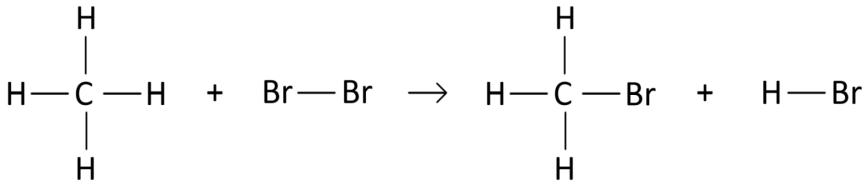
$$\Delta H = 6186 - 7458$$

$$\Delta H = -1272 \text{ kJ/mol}$$

As more energy has been given out, rather than taken in, we say this reaction is an <u>exothermic reaction</u>.

Finally let's have a look at an example where we are given the total energy change and asked to calculate an unknown bond energy. This type of question is the one where we'll need to use a bit of algebra.

Example 3: Bromine gas reacts with methane in the presence of ultraviolet light.
The figure below shows the displayed formula equation for the reaction.



The table below shows the bond energies we need.

Bond	C – H	Br – Br	H – Br	C – Br
Bond energy in kJ/mol	412	193	366	$\boldsymbol{x}$

The total energy change for the reaction is – 51 kJ/mol. Calculate the bond energy $\boldsymbol{x}$ for the C – Br bond.

Step 1: we notice that we are told the total energy change in the question. So, ΔH is equal to – 51.

Step 2: we substitute the values into the equation and solve for $\boldsymbol{x}$.

ΔH = energy in – energy out

$$-51 = \big(4(412) + 193\big) - \big(3(412) + x + 366\big)$$

$$-51 = 1841 - (1602 + x)$$

$$-51 = 239 - x$$

$$x = 290 \text{ kJ/mol}$$