AQA Chemistry
GCSE Student calculation sheet C7.4

Name ..... Class ..... Date .....

Calculating energy changes using bond energies

Specification references

- C5.1.3 The energy change of reactions (H)
- MS 3a, 3c

Aims

This worksheet gives you practice at calculating the theoretical energy change for a reaction using the bond energies for the bonds that are broken and made.

Learning outcomes

After completing this worksheet, you should be able to:

- calculate the energy needed to break the reactants' bonds and the energy released when the product bonds are made
- calculate the energy change for a reaction, including the correct unit
- explain in terms of bond energies how a reaction is either exothermic or endothermic.

Setting the scene

During a chemical reaction, bonds are broken and bonds are formed.

Energy must be supplied to break bonds in reactants (**bond breaking** is an **endothermic** process). Energy is transferred to the surroundings when bonds in products are formed (**bond making** is an **exothermic** process). The difference between the sum of the energy needed to break bonds in reactants and the sum of the energy released when bonds in products are formed is the overall energy change for a reaction. This can be shown in an equation by:

$$\text{overall energy change} = \text{total energy needed to break bonds} - \text{total energy transferred to the surroundings when bonds are formed}$$

If the overall process is **endothermic**, the energy released when new bonds are formed is less than the energy absorbed when bonds are broken. The **overall energy change is positive**.

If the overall process is **exothermic**, the energy released when new bonds are formed is greater than the energy absorbed when bonds are broken. The **overall energy change is negative**.

AQA Chemistry GCSE Student calculation sheet C7.4

Name ..... Class ..... Date .....

The energy needed to break a bond between two atoms is called the **bond energy** for that bond. The amount of energy released when that bond is formed is the same. Bond energies are measured in units of **kilojoules per mole (kJ/mol)**. You do not need to learn the actual values of different bond energies. They will always be provided in a question.

Worked example

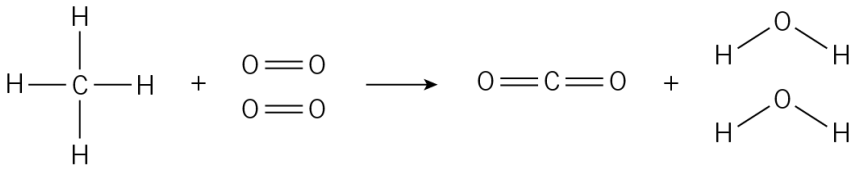
Use the bond energies provided in the table to calculate the energy change for the complete combustion of methane:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Bond	Bond energy in kJ/mol
C–H	413
O=O	498
C=O	804
H–O	464

Step 1

First, draw out the molecules involved in the equation. Show all the bonds and include the correct numbers of each molecule from the balanced symbol equation.



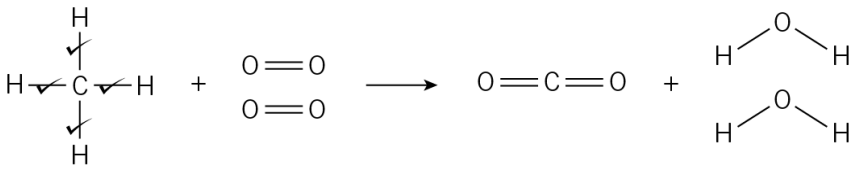
Step 2

Next, draw tables to show the type and number of bonds broken to turn the reactants into individual atoms, and the type and number of bonds made to form the products.

Bond broken	Number
C–H	4
O=O	2

Bond made	Number
C=O	2
H–O	4

Tip – to make sure you don't miss any bonds, it is good practice to tick off the bonds as you make or break them, as shown below:



Name ..... Class ..... Date .....

Step 3

Add up the energy required to break the bonds, and the energy released when the bonds are made, using the values from your tables.

Bond broken	Number	Energy needed in kJ/mol
C–H	4	4 × 413
O=O	2	2 × 498

Bond made	Number	Energy released in kJ/mol
C=O	2	2 × 804
H–O	4	4 × 464

Step 4

Calculate the total energy needed to break the bonds in the reactants and the total energy released when the products are formed.

Bond broken	Number	Energy needed in kJ/mol
C–H	4	4 × 413
O=O	2	2 × 498
Total energy needed		(4 × 413) + (2 × 498) = **2648**

Bond made	Number	Energy released in kJ/mol
C=O	2	2 × 804
H–O	4	4 × 464
Total energy released		(2 × 804) + (4 × 464) = **3464**

Step 5

Calculate the overall energy change for the reaction using the equation:

overall energy change = total energy needed to break bonds – total energy released when bonds are formed

overall energy change = 2648 – 3464

= **–816 kJ/mol**

The overall energy change is negative so the reaction is exothermic. This fits with what we know in practice, as the combustion of any fuel is an exothermic process.

Questions

1 Calculate the overall energy change for each of the following reactions, given the total energy needed to break the bonds in the reactants and the total energy released when the bonds in the products are formed.

State if each reaction is an endothermic or an exothermic process.

a $C_2H_4 + H_2O \rightarrow CH_3CH_2OH$

Total energy needed to break the bonds in the reactants = 3192 kJ/mol

Total energy released when the bonds in the products are made = 3234 kJ/mol

..... (*2 marks*)

Name ..... Class ..... Date .....

b $2HBr \rightarrow H_2 + Br_2$

Total energy needed to break the bonds in the reactants = 732 kJ/mol

Total energy released when the bonds in the products are made = 628 kJ/mol

..... (*2 marks*)

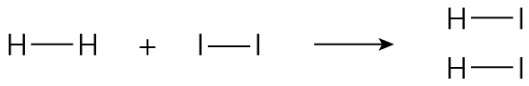
c $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Total energy needed to break the bonds in the reactants = 6488 kJ/mol

Total energy released when the bonds in the products are made = 8542 kJ/mol

..... (*2 marks*)

2 Hydrogen, H_2, reacts with iodine, I_2, to form HI.



Bond	Bond energy in kJ/mol
H–H	436
I–I	148
H–I	295

a State the number and type of bonds broken to turn an H_2 and an I_2 molecule into 2 × H atoms and 2 × I atoms.

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..... (*1 mark*)

b Calculate the energy needed to break the bonds in part **a**.

..... (*1 mark*)

c State the number and type of bonds made when 2 × H atoms and 2 × I atoms are converted into 2 × HI molecules.

..... (*1 mark*)

d Calculate the energy released when the bonds in part **c** are formed.

..... (*1 mark*)

Name ..... Class ..... Date .....

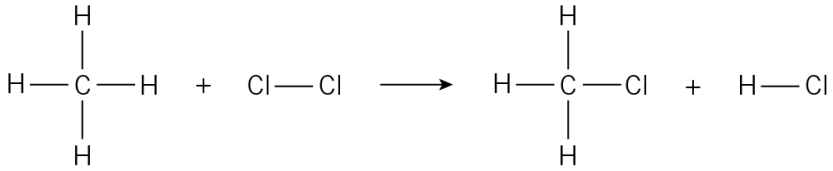
e Calculate the overall energy change for the reaction using your answers to part **b** and **d**.

..... (*1 mark*)

f State if the reaction is endothermic or exothermic.

..... (*1 mark*)

3 Methane, CH_4, reacts with chlorine, Cl_2, to form chloromethane, CH_3Cl, and hydrogen chloride, HCl.



Bond	Bond energy in kJ/mol
C–H	413
Cl–Cl	243
C–Cl	346
H–Cl	432

a Complete the tables below to calculate the total energy needed to turn reactants into atoms and the total energy released to form the products for this reaction. (*2 marks*)

Bond broken	Number	Energy needed in kJ/mol
Total energy needed		

Bond made	Number	Energy released in kJ/mol
Total energy released		

b Calculate the overall energy change for the reaction with units.
State if it is an endothermic or an exothermic process.

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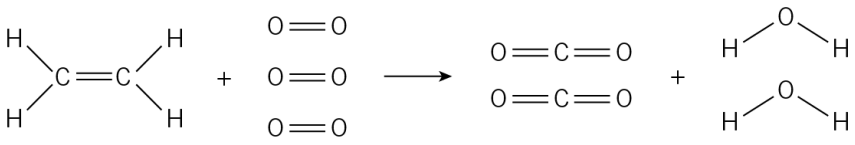
..... (*2 marks*)

Name ..... Class ..... Date .....

4 Use the bond energies given in the table below to calculate the energy change for the complete combustion of **one mole** of ethene.



Bond	Bond energy in kJ/mol
C–H	413
C=C	612
O=O	498
C=O	804
O–H	464

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..... (*3 marks*)

Student follow-up

1 Scientists are developing hydrogen as a fuel.

Hydrogen undergoes combustion in the presence of oxygen to form water.

a Give a balanced symbol equation for the complete combustion of hydrogen.

..... (*2 marks*)

b Use the bond energies given in the table below to calculate the energy change for the combustion of **one mole** of hydrogen.

Bond	Bond energy in kJ/mol
H–H	436
O=O	498
O–H	464

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..... (*2 marks*)

Name ..... Class ..... Date .....

c Draw a labelled diagram to show the reaction profile for the reaction. (*2 marks*)

d State one advantage and one disadvantage of hydrogen as a fuel.

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..... (*2 marks*)

Maths skills links

The maths skills in this topic are simple arithmetic. You will need to apply simple arithmetic throughout your course.