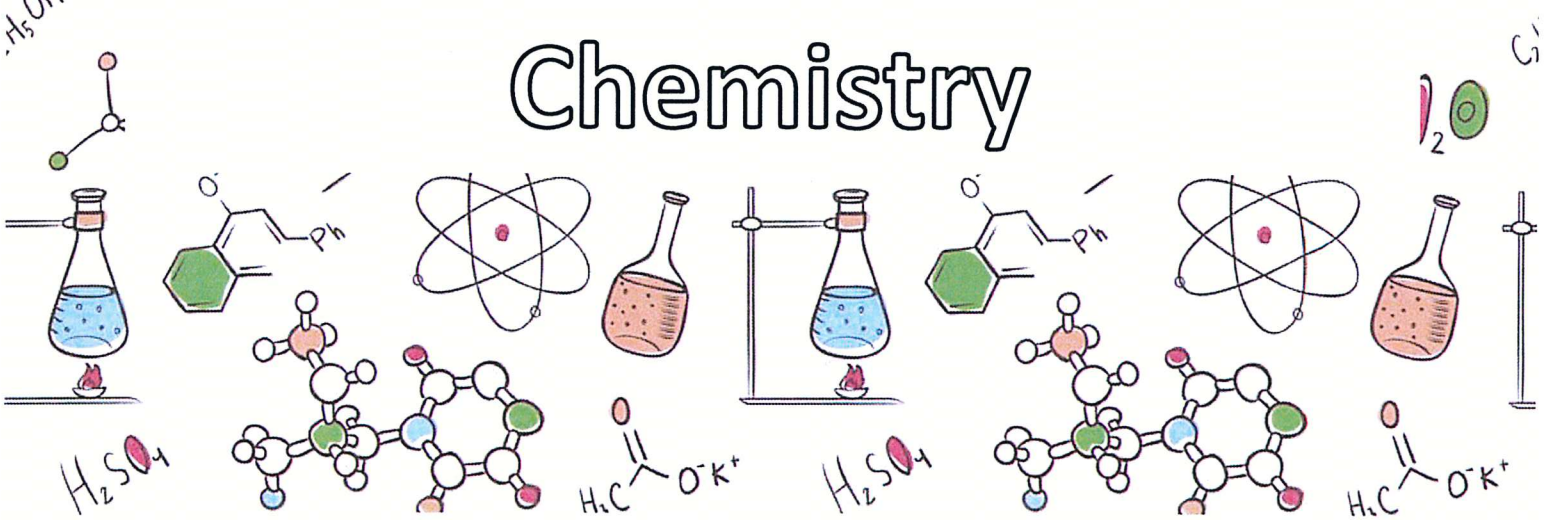
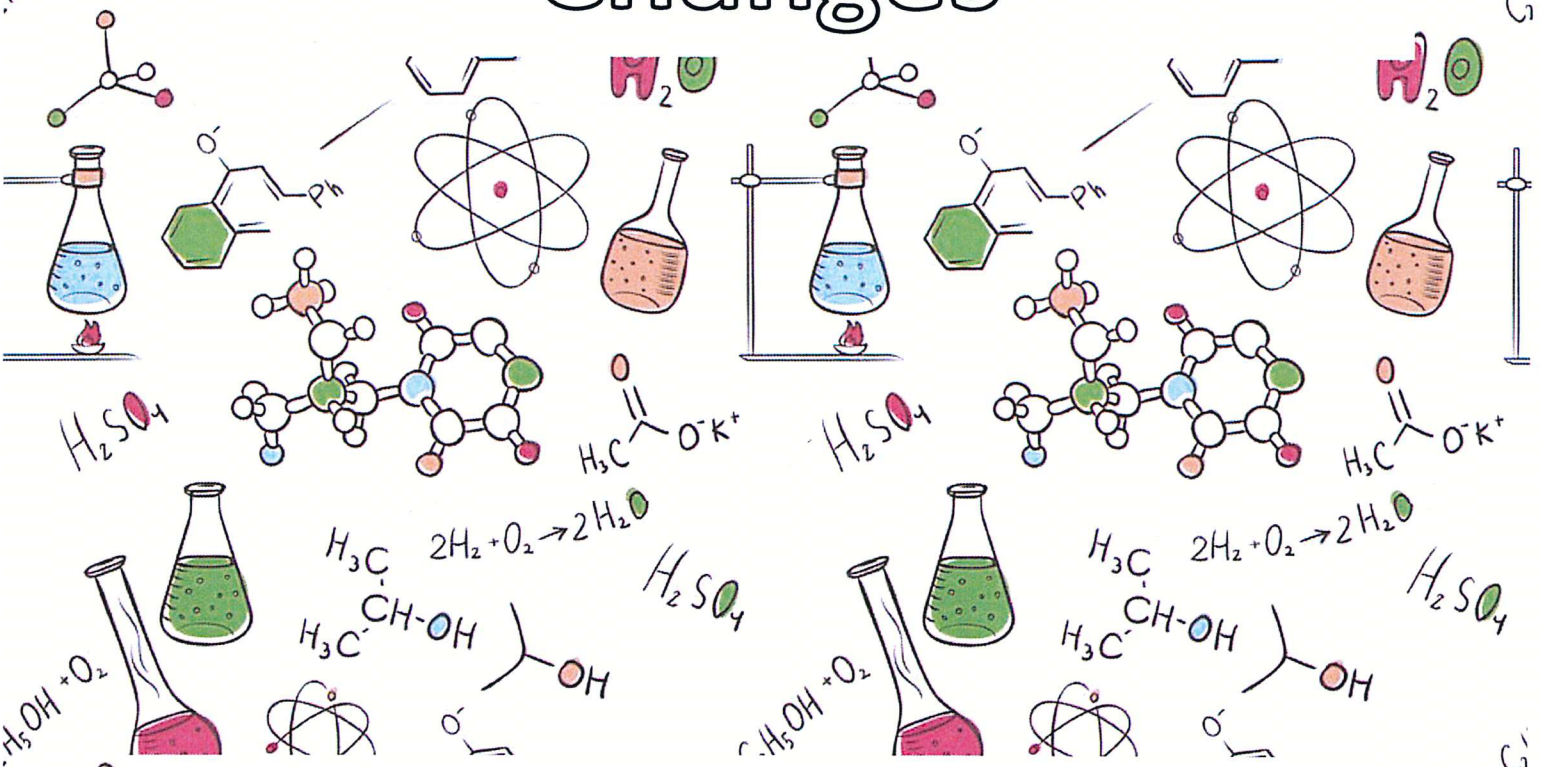
GCSE Combined Science

Chemistry



Topic 5 – Energy Changes



Name: _____

C5 Energy Changes

Can you...?	☺	😐	☹
5.1.1 Energy transfer during exothermic and endothermic reactions			
Recall that Energy is conserved in chemical reactions. The amount of energy in the universe at the end of a chemical reaction is the same as before the reaction takes place. If a reaction transfers energy to the surroundings the product molecules must have less energy than the reactants, by the amount transferred.			
Describe what an exothermic reaction is and give examples.			
Describe what an endothermic reaction is and give examples.			
State every day uses of exothermic reactions.			
State every day uses of endothermic reactions.			
Distinguish between exothermic and endothermic reactions on the basis of the temperature change of the surroundings.			
Evaluate uses and applications of exothermic and endothermic reactions given appropriate information.			
5.1.2 Reaction profiles			
State what must occur for particles to react.			
Explain what the activation energy is.			
Recall that reaction profiles can be used to show the relative energies of reactants and products, the activation energy and the overall energy change of a reaction.			
Draw simple reaction profiles (energy level diagrams) for exothermic and endothermic reactions showing the relative energies of reactants and products, the activation energy and the overall energy change, with a curved line to show the energy as the reaction proceeds.			
Use reaction profiles to identify reactions as exothermic or endothermic.			
5.1.3 The energy change of reactions (HT only)			
Recall that during a chemical reaction energy must be supplied to break bonds in the reactants and energy is released when bonds in the products are formed.			
Recall that the energy needed to break bonds and the energy released when bonds are formed can be calculated from bond energies.			
State how the energy needed to break bonds and the energy released when bonds are formed differ in endothermic and exothermic reactions.			
Calculate the energy transferred in chemical reactions using bond energies supplied.			

Topic 5 - Energy changes

Chemical reactions involve energy transfers. Many chemical reactions involve the release of energy however, some chemical reactions require energy to be supplied.

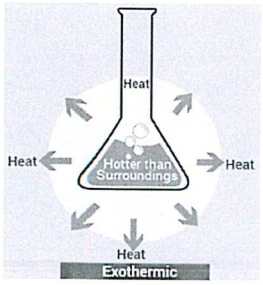
During a chemical reaction bonds in the reactants are broken and new bonds are made in the products

- Energy is absorbed to break bonds. **Bond-breaking** is an **endothermic** process.
- Energy is released when new bonds form. **Bond-making** is an **exothermic** process.

Whether a reaction is endothermic or exothermic depends on the difference between the energy needed to break bonds and the energy released when new bonds form.

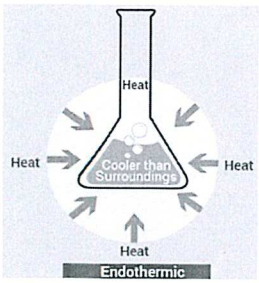
Exothermic reactions

Energy is released from the reaction and transferred to the surroundings – the reaction gets hotter (temperature increases).
This is because more energy is released making new bonds than absorbed to break old bonds.



Endothermic reactions

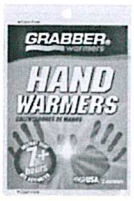
Energy is absorbed from the surroundings and transferred to the reaction – the reaction gets colder (temperature decreases).
This is because more energy is absorbed breaking old bonds than absorbed to making new bonds.



Energy transfer during exothermic and endothermic reactions

Energy is conserved in chemical reactions. The amount of energy at the end of a chemical reaction is the same as before the reaction takes place. If a reaction transfers energy to the surroundings the product molecules must have less energy than the reactants, by the amount transferred.

An exothermic reaction is one that transfers energy to the surroundings so the temperature of the surroundings increases. Exothermic reactions include combustion, many oxidation reactions and neutralisation.
Everyday uses of exothermic reactions include self-heating cans and hand warmers.



An endothermic reaction is one that takes in energy from the surroundings so the temperature of the surroundings decreases. Endothermic reactions include thermal decompositions and the reaction of citric acid and sodium hydrogencarbonate. Some sports injury packs are based on endothermic reactions.

Exothermic and endothermic reactions

1. Use the words in the box to complete the sentences.

exothermic, endothermic, temperature, increases, decreases, energy, created, destroyed, conserved, more, less

Synoptic In a chemical reaction energy is _____. An _____ reaction is one that transfers _____ to the surroundings so that the temperature of the surroundings _____. The product particles have _____ energy than the reactant's particles. [5 marks]

2. Which everyday item depends upon an endothermic reaction?

Tick **one** box.

Hand warmers ☐ Self-heating cans ☐

Sports injury packs ☐ Fireworks ☐ [1 mark]

3. The results of Jethro's energy change experiments are listed in Table 1.

Worked Example

Table 1

Sample	Start temperature (°C)	End temperature (°C)	Temperature change (°C)
Ammonium chloride	15	9	−6
Potassium hydroxide	15	30	+13
Ammonium nitrate	15	1	14
Sodium hydroxide	15	32	17

Worked Example **a** Complete Table 1. [2 marks]

Worked Example **b** Which of the solids had the largest exothermic reaction? Explain your answer. [3 marks]

Comment

To find the temperature change the end temperature is subtracted from the start temperature so the answer for ammonium nitrate should be 1−15 = −14°C. The sign is important because it tells you if the temperature went up or down.

Literacy

During an exothermic reaction the temperature does go up as heat energy is given out to the surroundings. So all the reactions are exothermic apart from the reaction with ammonium chloride. The reaction with sodium hydroxide is the most exothermic as it has greatest the temperature change.

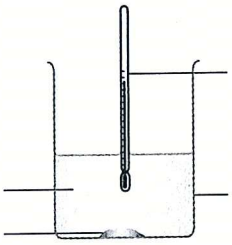
Marks gained: [3 marks]

Comment
The final answer is correct but an error has been carried through from part **a**. Ammonium nitrate is actually endothermic. If this happened in an exam you would only lose marks for this error in part **a**.

4. Sarah wants to investigate the temperature changes that take place when different metals are added to copper sulfate solution.

Practical

a On the diagram, label the apparatus Sarah will use.



[4 marks]

b Give **two** variables that Sarah should control so the investigation is a fair test.

What variables must she keep the same?

_____ [2 marks]

c Name **two** other pieces of apparatus Sarah will also need.

How will Sarah measure out the volume of copper sulfate and the mass of metal?

_____ [2 marks]

Practical

d Sarah's results are shown in the table below.

Metal	Temperature (°C)			Mean temperature (°C)
	First test	Second test	Thid test	
Magnesium	15.2	4.3	15.8	15.5
Zinc	9.9	9.5	9.6	9.7
Calcium	20.0	20.4	19.9	20.1
Iron	4.1	3.9	4.0	

i One of the results for magnesium is anomalous.

State the anomalous result. _____ [1 mark]

Suggest a reason why it could be anomalous.

_____ [1 mark]

Maths
To find the mean; add up all the results for that metal and then divide by the number of results.

Reaction profiles

Chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the activation energy.

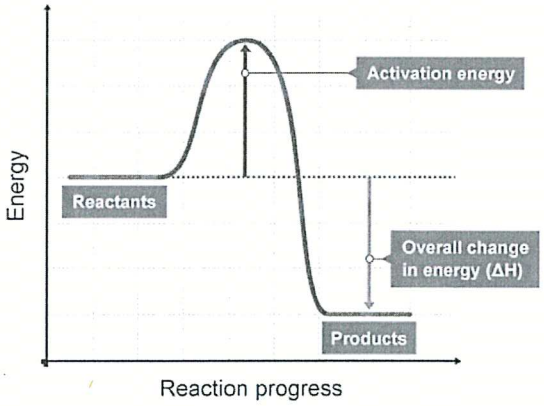
A reaction profile (aka an energy profile) is a visual way of representing the energy changes during a reaction.

These diagrams show the relative amounts of energy contained within the reactant and products, measured in kilojoules per mole (kJ/mol).

Reaction profiles tell you information about specific chemical reactions:

- How much energy is required for the reaction to start (activation energy)
- How much energy is released/absorbed during the reaction.

Reaction profiles also allow us to identify exothermic and endothermic reactions.



In an exothermic reaction, the reactants are at a higher energy level than the products.

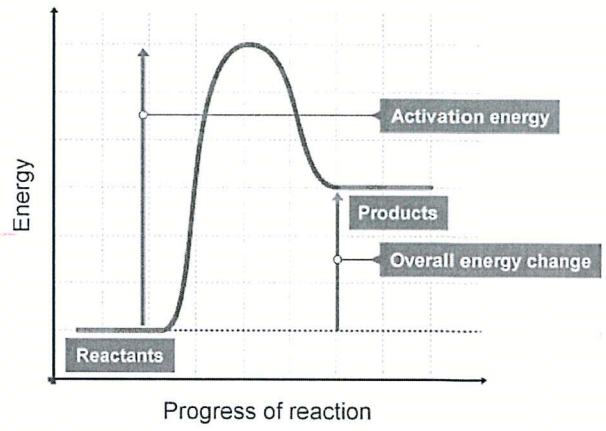
When the reactants form the products, energy is transferred from the reaction to the surroundings (it gets hotter).

An amount equal to the difference in energy between the reactants and products is released.

In an endothermic reaction, the reactants are at a lower energy level than the products. The activation energy is much larger.

As the reactants react to form the products, energy is transferred from the surroundings to the reaction (it gets colder).

An amount equal to the difference in energy between the reactants and products is absorbed.



Bond energy calculations (HT only)

During a chemical reaction:

- Energy must be supplied to break bonds in the reactants
- Energy is released when bonds in the products are formed.

The energy needed to break bonds and the energy released when bonds are formed can be calculated from bond energies.

Maths

ii Calculate the mean result for iron and write it in the table. [1 mark]

iii Use the data in the results table to put the metals into order of reactivity.

The first one has been done for you. [2 marks]

Increasing reactivity ↓ iron

Literacy

iv Describe and explain what Sarah could do to improve her results.

_____

_____

_____

_____ [4 marks]

Command

Describe means that you should 'recall' a point and explain means that you should give 'a reason for the point made in the answer'. Marks will only be awarded if the correct reason is given for the point being made.

Reaction profiles

1. For a chemical reaction to occur...

Tick **two** boxes to complete the sentence correctly.

The reacting particles must collide. ☐

The reacting particles must have energy. ☐

The reacting particles bounce off each other. ☐

The reacting particles must have enough energy to activate the reaction. ☐ [2 marks]

2. **Figure 1** shows the reaction profile for a chemical reaction.

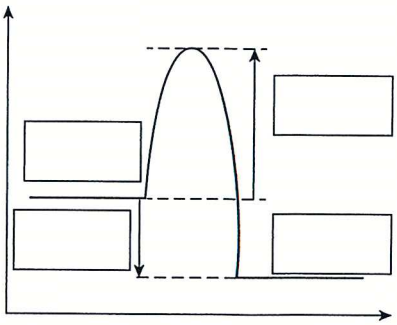


Figure 1

a Add the correct labels to the diagram. [4 marks]

b Describe how you can tell from the diagram that the reaction is exothermic.

_____ [1 mark]

c Explain how the profile would change if the reaction was endothermic.

_____

_____ [2 marks]

Remember

The changes taking place in an endothermic reaction are opposite to those taking place in an exothermic reaction.

The difference between the sum of the energy needed to break bonds in the reactants and the sum of the energy released when bonds in the products are formed is the overall energy change of the reaction.
In an exothermic reaction, the energy released from forming new bonds is greater than the energy needed to break existing bonds. In an endothermic reaction, the energy needed to break existing bonds is greater than the energy released from forming new bonds

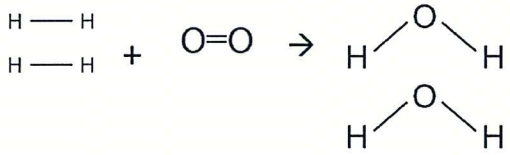
To calculate the energy change of the reaction using bond energies use the following formula:

Energy change	=	Energy absorbed from reactant bonds breaking	-	Energy released from product bonds forming

Worked example:

When hydrogen and oxygen react they produce water. The balanced symbol equation for this reaction is:

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$$



Bond	Bond Energy (kJ/mol)
H-H	436
O=O	496
O-H	463

Calculate the energy change for this reaction using the bond energies given.

Step 1: Total the type of bonds on each side of the reaction arrow:	
Reactants	**Products**
2 x H – H 1 x O = O	4 x O – H
Step 2: Use the bond energy table to calculate the amount of energy in the bonds on either side of the reaction arrow:	
2 x 436 = 872 1 x 496 = 496 (+) 1368	4 x 463 = 1852
Step 3: Calculate energy change by subtracting the total energy in the product bonds from the total energy in the reactant bonds:	
Energy change = energy in reactant bonds – energy in product bonds = 1368 – 1852 = - 484 kJ/mol	

If the number is negative it is an exothermic reaction, if it is positive it is an endothermic reaction.

3. Jack and John were on a camping trip. They wanted to boil some water using their propane gas stove. Explain what provides the activation energy for the reaction.

Literacy

What do they need to do to light a gas stove?

[3 marks]

Energy change of reactions

1. **Figure 2** shows a reaction profile.

Higher Tier only

The reaction profile represents the reaction

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

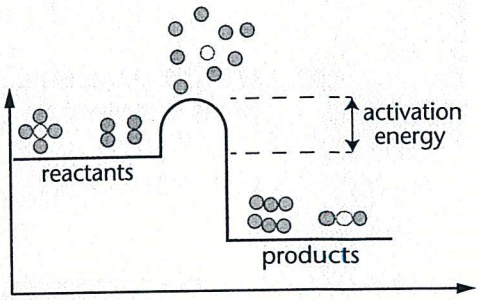


Figure 2

a Describe what happens during the reaction in terms of bond breaking and bond making.

[3 marks]

b Use the bond energies in the table to calculate the overall energy change for the reaction:

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

[5 marks]

Marks gained: [5 marks]

Worked Example

Bond	C–H	O=O	C=O	H–O
Bond energy (kJ/mol)	412	498	532	465

Work out the bond energies of the reactants.

4 × C–H = 4 × 412 = 1648

2 × O=O = 2 × 498 = 996

Total = 1648 + 996 = 2644 kJ/mol [2 marks for working this out correctly]

Work out the bond energies of the products.

$2 \times C{=}O = 2 \times 532 = 1064$

$2(2 \times O{-}H) = 2(2 \times 465) = 2 \times 930 = 1860$

Total = 1064 + 1860 = 2924 kJ/mol [2 marks for working this out correctly]

Now work out the difference between the bond energies of the reactants and products.

2924 - 2644 = 280

The difference is 280 kJ/mol. More energy is released than taken in, so the reaction is exothermic. [1 mark for working this difference out correctly]

c Use the bond energies in the table to determine whether propane, C_3H_8 gives out more or less energy than methane when it burns in air.

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

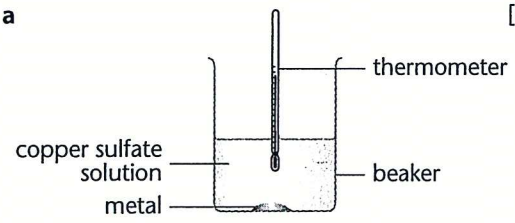
[6 marks]

Bond	C–H	O=O	C=O	H–O	C–C
Bond energy (kJ/mol)	412	498	532	465	346

Follow the method given in the worked example above to work out how much energy is given out when propane burns in air. Then compare your answer to that given in part **b**.

Exothermic and endothermic reactions

1. Answers in order: conserved [1 mark], exothermic [1 mark], energy [1 mark]. increases [1 mark], more [1 mark]
2. Sports injury packs [1 mark]
3. **a** and **b**: Worked example – full answers given in workbook.
4. **a** [4 marks]



b Any two from: concentration of copper sulfate, volume of copper sulfate, mass of metal, size of metal particles [2 marks]

c Any two from: measuring cylinder, balance, also accept lid [2 marks]

d **i** Result: 4.3 [1 mark]

Reason: any one from: misread the thermometer; didn't wait long enough before taking the reading; used very cold copper sulfate [1 mark]

ii 4.0 [1 mark]

iii In order of increasing reactivity: zinc, magnesium, calcium [2 marks]

iv Use a lid to stop heat energy escaping from the top of the beaker. [1 mark]

Wrap cotton wool around the beaker to insulate it and reduce heat loss. [1 mark]

Use a polystyrene cup to improve insulation and reduce heat loss. [1 mark]

Use a temperature sensor to record the temperature. This should lead to a more accurate result as lots more data points will be collected. [1 mark]

Allow any other reasonable answer.

Reaction profiles

1. The reacting particles must collide. [1 mark]

   The reacting particles must have enough energy to activate the reaction. [1 mark]

2. **a** reactants [1 mark], products [1 mark], activation energy [1 mark], energy change during the reaction [1 mark]

   b The energy of the products is lower than that of the reactants. [1 mark]

   c The line drawn showing the energy level of the products would be higher than that of the reactants. [1 mark] The arrow showing the overall energy change would go up. [1 mark]

3. The activation energy is the energy needed to start the reaction between propane gas and oxygen. [1 mark] They could turn on the gas, strike a match [1 mark] and hold it in the gas. The energy given out from the burning match is transferred to the reacting particles of propane and oxygen. [1 mark]

Energy change of reactions

1. **a** Bonds break C–H and O=O. (1 mark)

   Atoms rearrange. [1 mark]

   Bonds made C=O and H–O [1 mark]

   Accept if answer is given in terms of correct coloured particles e.g. bonds break between yellow and purple particle, etc.

   b Worked example – full answer given in workbook.

   c Bond energies of reactants = $(8 \times C–H) + (2 \times C–C) + (5 \times O=O) = 3296 + 692 + 2490 = 6478$ kJ/mol. [2 marks]

   Bond energies of products = $3(2 \times C=O) + 4(2 \times O–H) = 3192 + 3720 = 6912$ kJ/mol. [2 marks]

   Energy given out during the reaction is $6912 – 6478 =$ 434 kJ/mol. [1 mark]

   Therefore, propane gives out more energy than methane when it burns in oxygen. [1 mark]

Topic 5 – Energy Changes Glossary

Key Word	Definition
Activation energy	The minimum amount of energy required that reactant particles must have to react.
Bond energy	The amount of energy stored in a chemical bond, this energy is released when the bond is formed and absorbed when the bond is made.
Conservation of energy	The amount of energy at the start of a chemical reaction must equal the amount of energy at the end.
Displayed formula	A formula that shows all the atoms and bonds in a molecule.
Endothermic	A reaction that absorbs energy from its surroundings, the reaction gets colder.
Energy change	The difference in energy between the reactants and products.
Exothermic	A reaction that releases energy to its surroundings, the reaction gets hotter.
Product	The substance formed in a chemical reaction (on the right hand side of the reaction arrow).
Reactant	The substance that reacts in a chemical reaction (on the left hand side of the reaction arrow).
Reaction profile	A visual representation of the energy changes during a chemical reaction.

AQA

The Periodic Table of Elements

1	2											3	4	5	6	7	0
							1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4											11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[97] **Tc** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Tl** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[267] **Rf** rutherfordium 104	[270] **Db** dubnium 105	[269] **Sg** seaborgium 106	[270] **Bh** bohrium 107	[270] **Hs** hassium 108	[278] **Mt** meitnerium 109	[281] **Ds** darmstadtium 110	[281] **Rg** roentgenium 111	[285] **Cn** copernicium 112	[286] **Nh** nihonium 113	[289] **Fl** flerovium 114	[289] **Mc** moscovium 115	[293] **Lv** livermorium 116	[293] **Ts** tennessine 117	[294] **Og** oganesson 118

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for **Cu** and **Cl** have not been rounded to the nearest whole number.