Overview
Energy Changes

Exothermic and endothermic reactions

- Energy changes during exothermic and endothermic reactions
- Reaction profiles
- The energy change of reactions (HT only)

Chemical cells and fuel cells (Chemistry only)

- Cells and batteries
- Fuel cells

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Exothermic and Endothermic reactions

- Exothermic reactions
- Endothermic reactions

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Exothermic and endothermic reactions part 1 – Exothermic reactions

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.

$$H_2\,(g) + Cl_2\,(g) \rightarrow 2HCl\,(g)$$

In the above reaction energy is released, it gets hotter.

An exothermic reaction is one that transfers energy to the surroundings so the temperature of the surroundings increases – "it gets hotter".

The two HCl molecules made will not hold as much energy as the H_2 and Cl_2 molecules at the start, so the spare energy is released as heat.

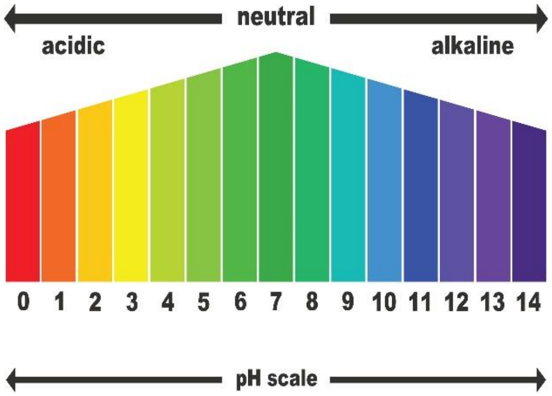
Exothermic and endothermic reactions part 1 – Exothermic reactions

There are a number of common exothermic reactions, they include:

Combustion

Oxidation

Neutralisation



Know all three of these examples of exothermic reactions

Everyday uses of exothermic reactions include –

Self-heating cans

Hand warmers

Know both of these uses for exothermic reactions

Exothermic and endothermic reactions part 1 – Endothermic reactions

We have already learnt that energy is conserved in chemical reactions.

$$2CH_3COOH(aq) + Na_2CO_3(s) \rightarrow 2CH_3COONa(aq) + CO_2(g) + H_2O\ (l)$$

In the above reaction, energy is taken in- it gets colder.
An endothermic reaction is one that takes energy from the surroundings so the temperature of the surroundings decreases – "it gets colder".
The sodium ethanoate, carbon dioxide and water molecules made will hold more energy than the ethanoic acid and sodium carbonate molecules at the start, so the energy needed is taken in as heat.

Other examples of endothermic reactions are

- Thermal decomposition
- Sports injury packs

Know all three of these examples of endothermic reactions

QuestionIT!

Energy Changes
Part 1

- Exothermic reactions
- Endothermic reactions

Energy Changes part 1 – QuestionIT

1. How would you know if an exothermic reaction had occurred?

2. How would you know if an endothermic reaction had occurred?

3. Below is a table of results for four reactions, the temperatures before and after the reactions are also given.

Reaction	Temperature at start ^{O}C	Temperature at end ^{O}C
A	22	28
B	20	20
C	21	12
D	25	25

a/ Which reaction is endothermic? Explain how you know this.

b/ Which reaction is exothermic? Explain how you know this.

AnswerIT!

Energy Changes
Part 1

- Exothermic reactions
- Endothermic reactions

Energy Changes part 1 – AnswerIT

1. How would you know if an exothermic reaction had occurred?

   The reaction would give out heat/get warmer/ temperature increase.

2. How would you know if an endothermic reaction had occurred?

   The reaction would take in heat/get colder/ temperature decrease.

3. Below is a table of results for four reactions, the temperatures before and after the reactions are also given.

Reaction	Temperature at start ^{O}C	Temperature at end ^{O}C
A	22	28
B	20	20
C	21	12
D	25	25

a/ Which reaction is endothermic? Explain how you know this.

Reaction C, it gets colder/temperature falls.

b/ Which reaction is exothermic? Explain how you know this.

Reaction A, it gets warmer/temperature increases.

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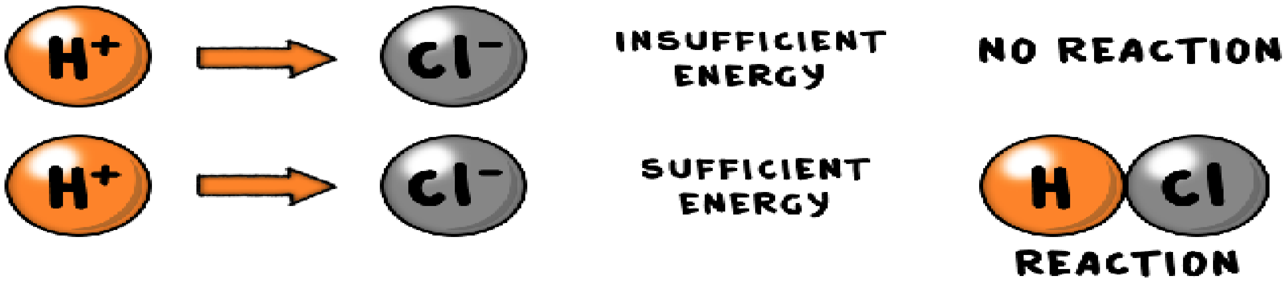
Energy Changes Part 2

- Reaction profiles
- The energy change of reactions (HT only)

Energy Changes part 2 – Reaction profiles

Chemical reactions can only occur when reacting particles collide with each other with sufficient energy.



The minimum amount of energy that particles must have to react is called the activation energy

You have given a reaction its activation energy when you have used a lit spill to light a Bunsen burner. Without the activation energy from the lit spill the methane gas and oxygen in the air will not combust and release the heat energy.

When we look at this reaction we see the following.

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

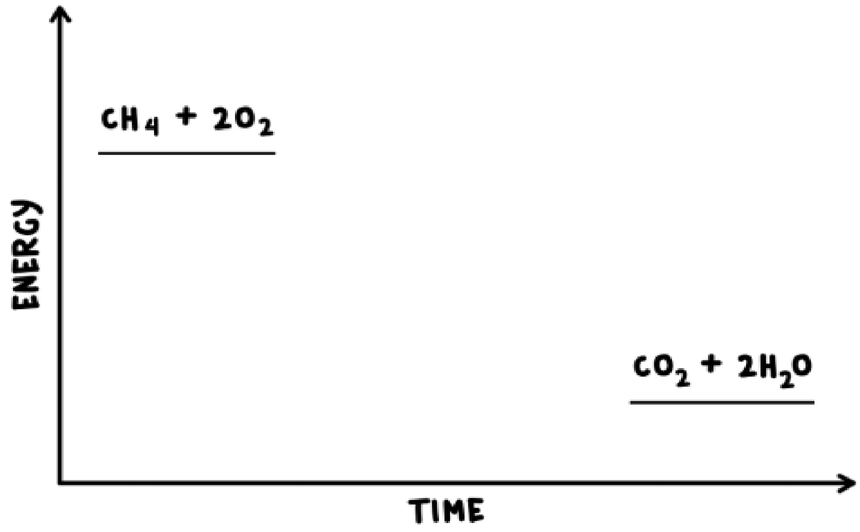
You will be expected to balance this equation.

Energy Changes part 2 – Reaction profiles

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

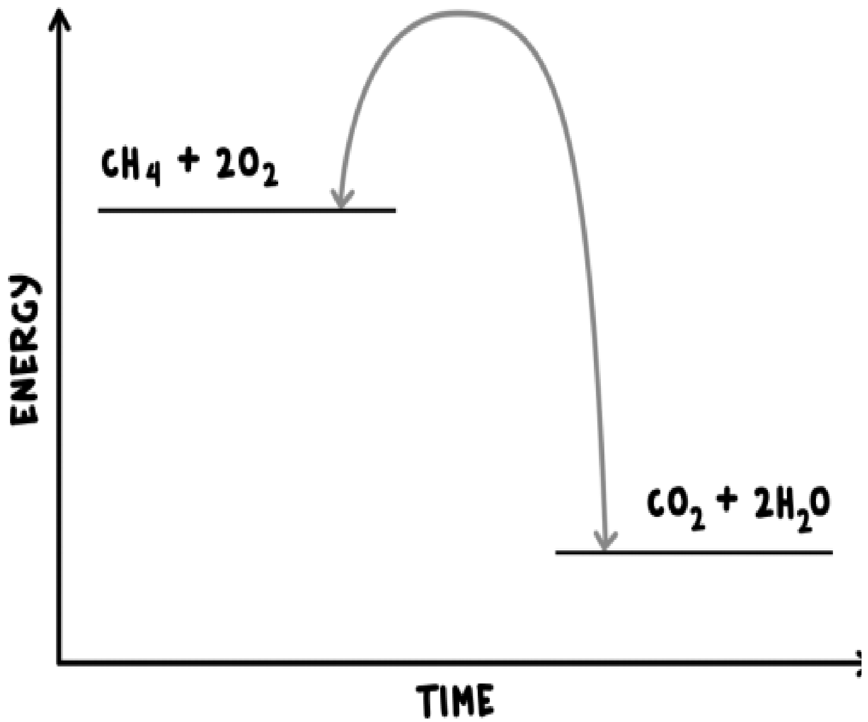
We know this reaction is exothermic, this means energy is released. So the CH_4 and $2O_2$, the reactants, must have more energy than the products, CO_2 and $2H_2O$

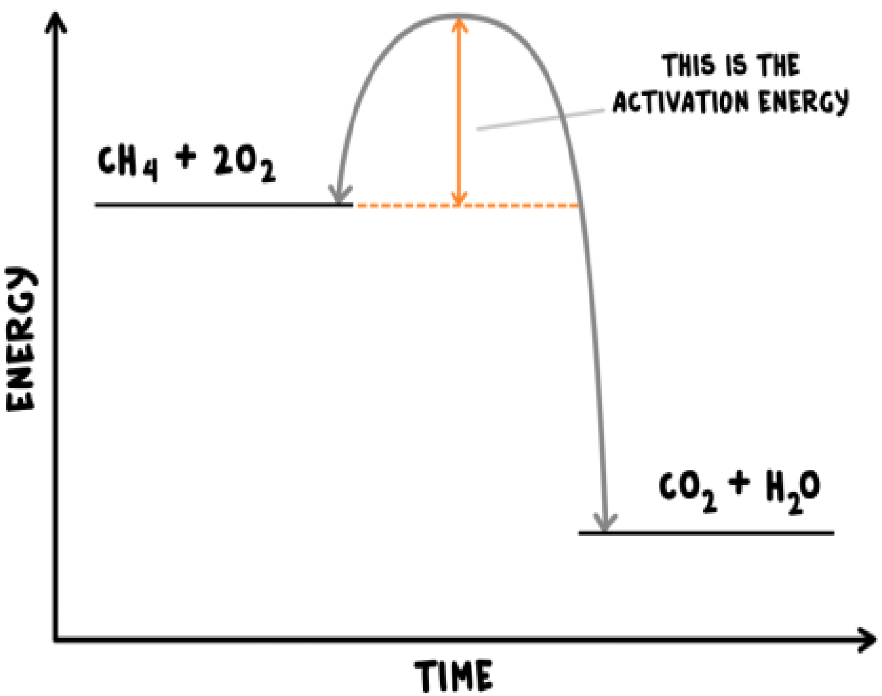
We can show this as a reaction profile. On it we need to include the formulae or names of the products and reactants. We also need to show the relative energies of the reactants and products



Energy Changes part 2 – Reaction profiles

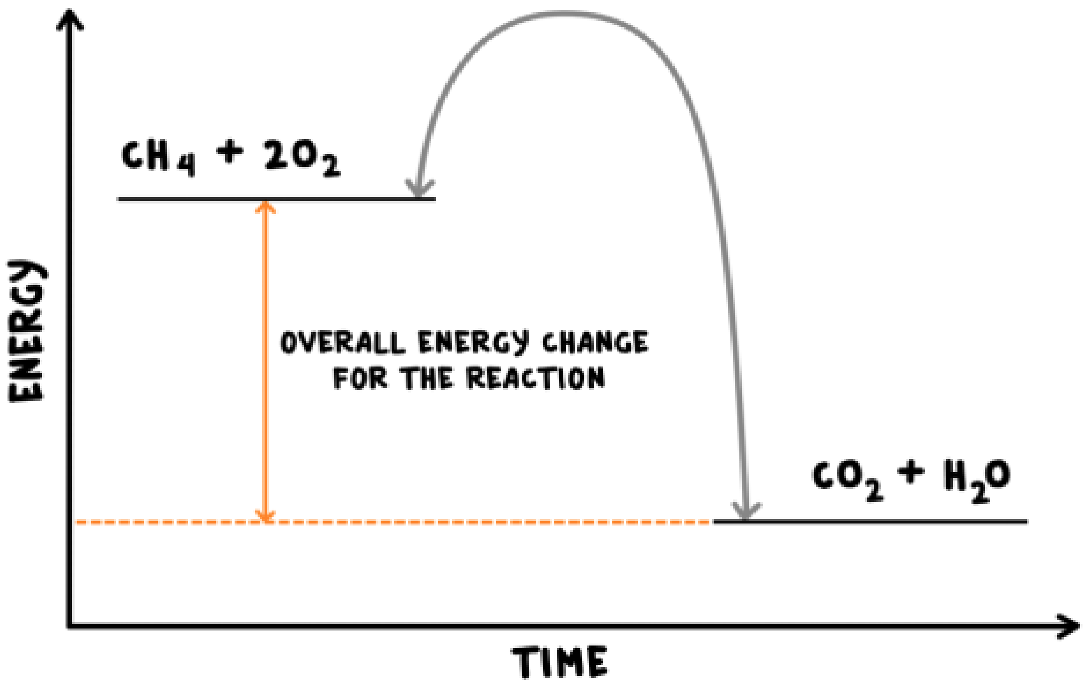
More information needs to be included in the reaction profile. This will show the activation energy of the reaction. It is shown by a curved line rising above the reactants energy.





Energy Changes part 2 – Reaction profiles

We can now see the overall change in energy within the reaction.



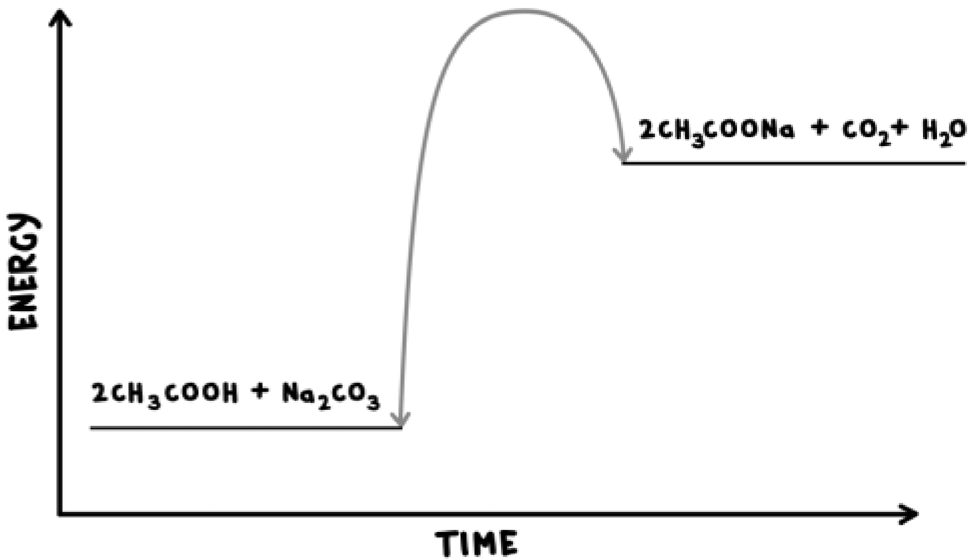
The products have less energy than the reactants. This will have been lost as heat as the reaction is exothermic.

Energy Changes part 2 – Reaction profiles

We saw earlier that the following reaction was endothermic:

$2CH_3COOH(aq) + Na_2CO_3(s) \rightarrow 2CH_3COONa(aq) + CO_2(g) + H_2O\ (l)$

What would the reaction profile look like for this reaction?



We can see that the products have more energy than the reactants. This will have been taken in as heat energy it feels colder.

QuestionIT!

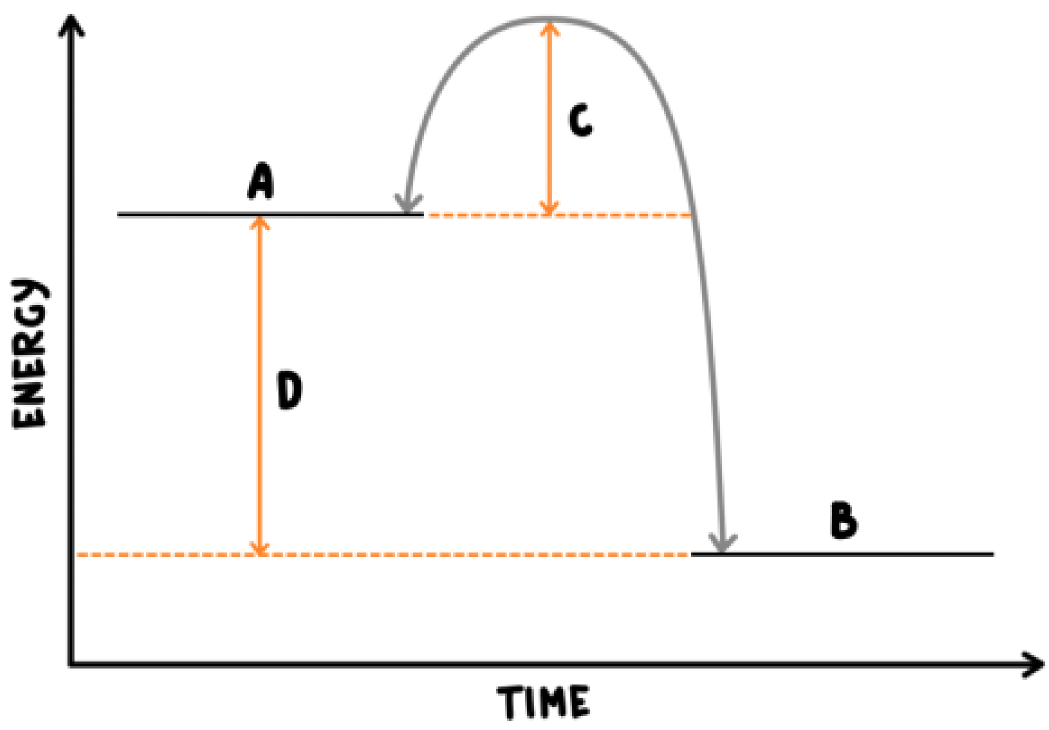
Energy Changes part 2

- Activation energy
- Reaction profiles

1. What is meant by the term activation energy?

2. On the reaction profile below what is shown by the letters?

A
B
C
D



3. What two things are needed for a chemical reaction to occur?

4. What is an exothermic reaction?

5. What is an endothermic reaction?

AnswerIT!

Energy Changes part 2

- Activation energy
- Reaction profiles

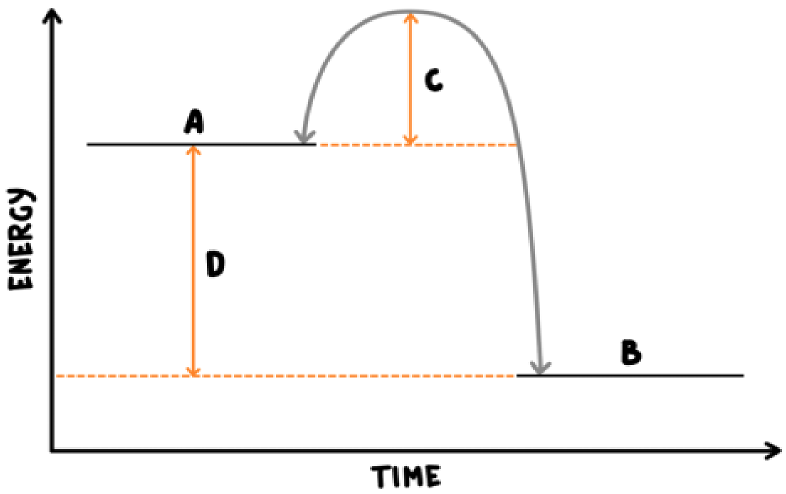
Energy Changes part 2 AnswerIT

1. What is meant by the term activation energy?

The minimum amount of energy that particles must have to react.

2. On the reaction profile below what is shown by the letters?

- A Reactants
- B Products
- C Activation energy
- D Overall energy change/that the reaction is exothermic



3. What two things are needed for a chemical reaction to occur?

Reacting particles collide with each other and with sufficient energy.

4. What is an exothermic reaction?

Heat energy given out/energy lost to the surroundings

5. What is an endothermic reaction?

Heat energy taken in/energy taken in from the surroundings

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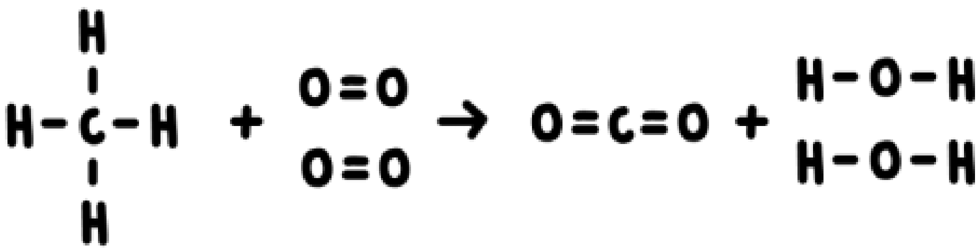
The energy change of reactions (Higher Tier only)

The energy change of reactions (HT only)

For the reaction of methane with oxygen we can write out the balanced symbol equation:

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

We can draw out the bonds between the atoms e.g.



Each line represents a bond, two lines represent a double bond e.g. in the oxygen molecule.

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The energy change of reactions (HT only)

During a chemical reaction:

- **Energy must be supplied to break bonds in the reactants**
- **Energy is released to form bonds in the products.**

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

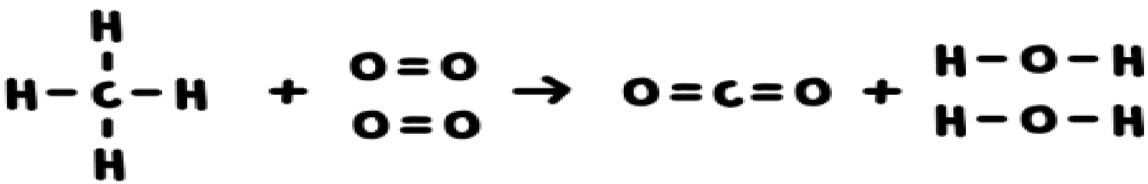
Bond	Bond Energy kJ/mol
C-H	411
O=O	494
C=O	799
O-H	459

This means that 411kJ/mol of energy needs to be put in to break the carbon-hydrogen bond.
It also means that 459 kJ/mol is given out when the oxygen hydrogen bond is made in water.

The energy change of reactions (HT only)

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.

Worked example



For the reactants	For the products
There are four C-H bonds so 4 x 411kJ/mol = 1,644kJ/mol	There are two C=O bonds so 2 x 799kJ/mol = 1,598kJ/mol
There are two O=O bonds so 2 x 494kJ/mol = 988kJ/mol	There are four O-H bonds so 4 x 459kJ/mol = 1,836kJ/mol
The sum of these is the energy supplied to break the bonds in the reactants it is 1,644 + 988 = 2,632kJ/mol	The sum of these is the energy released when bonds in the products are formed it is 1,598 + 1,836 = 3,434kJ/mol

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The energy change of reactions (HT only)

We already know that 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.

This means that

Overall energy change = energy needed to break the bonds – energy released as bonds are made

= 2,632kJ/mol - 3,434kJ/mol

Overall energy change = - 802kJ/mol

This is an exothermic reaction, so the sum of the difference between the calculations is negative. For an endothermic reaction it would be positive.

Students should be able to calculate the energy transferred in chemical reactions using bond energies supplied.

The energy change of reactions (HT only)

Know these two definitions- they are often asked for in the exam.

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 then the energy released from forming new bonds

QuestionIT!

The energy change of reactions (Higher Tier only)

The energy change of reactions (HT only) QuestionIT

1. **Which process is exothermic, bond breaking or bond making?**

2. **Explain your answer to question 1.**

3. **How do we calculate the overall energy change of a reaction?**

The energy change of reactions (HT only) QuestionIT

4. The bond energy between a hydrogen and a nitrogen atom is 386 kJ/mol, the bond energy between two hydrogen atoms is 432 kJ/mol and the bond energy between two nitrogen atoms is 942kJ/mol. Using these bond energies, calculate the overall energy change for the following reaction.

$$2NH_3 \rightarrow N_2 + 3H_2$$

5. Is the reaction exothermic or endothermic? Explain your answer.

AnswerIT!

The energy change of reactions (Higher Tier only)

The energy change of reactions (HT only) AnswerIT

1. **Which process is exothermic, bond breaking or bond making?**

   Bond making

2. **Explain your answer to question 1**

   Energy is released/temperature increases

3. **How do we calculate the overall energy change of a reaction?**

   It is 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.

The energy change of reactions (HT only) AnswerIT

4. The bond energy between a hydrogen and a nitrogen atom is 386 kJ/mol, the bond energy between two hydrogen atoms is 432 kJ/mol and the bond energy between two nitrogen atoms is 942kJ/mol. Using these bond energies calculate the overall energy change for the following reaction.

$$2NH_3 \rightarrow N_2 + 3H_2$$

For the reactants
There are three nitrogen to hydrogen bonds in each molecule and there are two molecules so
386kJ/mol x 6 = **2,316kJ/mol**

For the products
There are three hydrogen to hydrogen bonds (432kJ/mol) and one nitrogen to nitrogen triple bond so
3 x 432kJ/mol + 942kJ/mol
= **2,238kJ/mol**

Overall energy change = energy needed to break the bonds – energy released as bonds are made

2,316kJ/mol - 2,238kJ/mol

Overall energy change = + 78kJ/mol

5. Is the reaction exothermic or endothermic? Explain your answer.

The reaction is endothermic as the overall energy change is positive.

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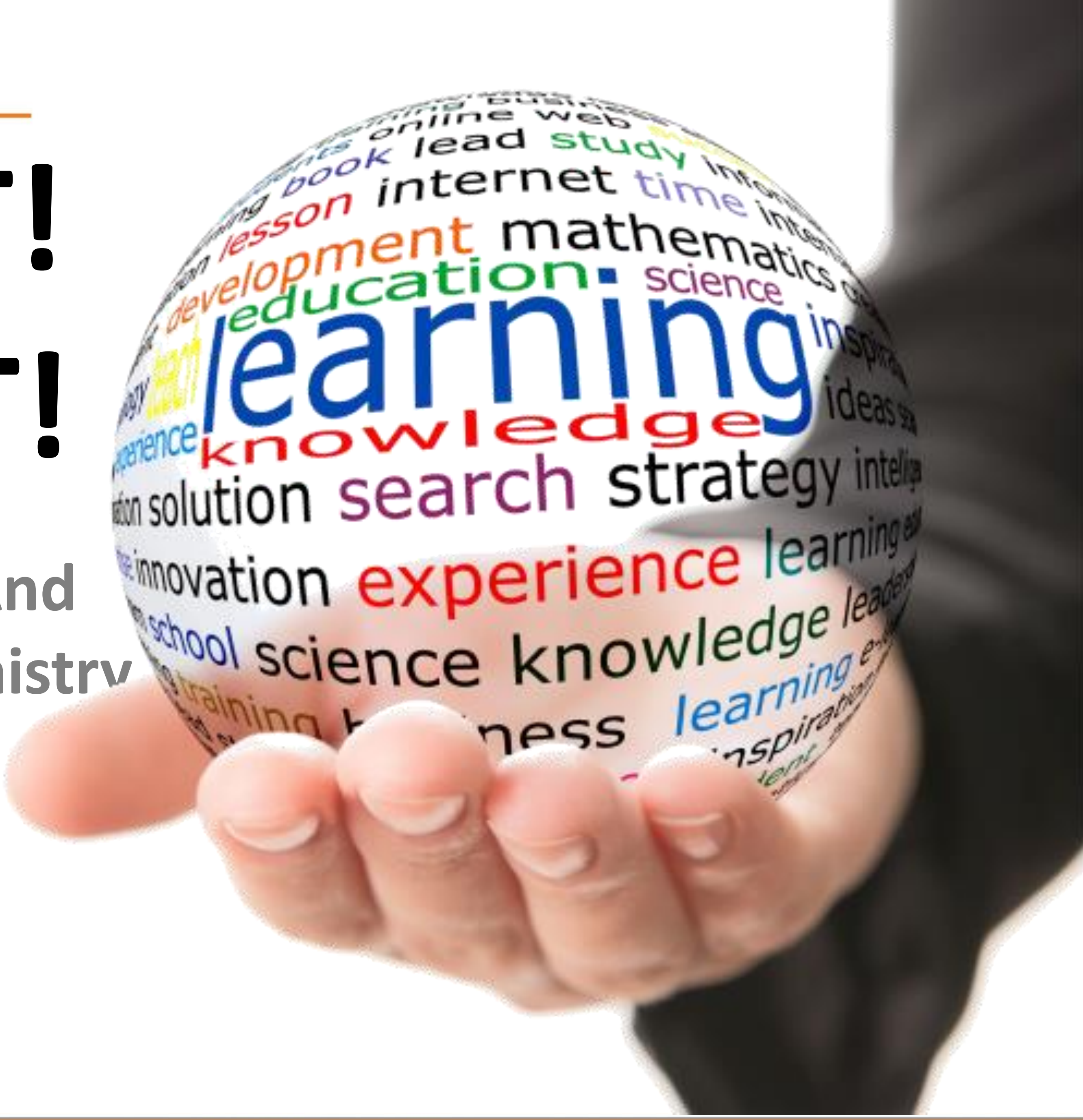
Chemical Cells And Fuel Cells (Chemistry Only)



- Cells And Batteries
- Fuel Cells

Cells and batteries (Chemistry only)

Cells contain chemicals which react to produce electricity.

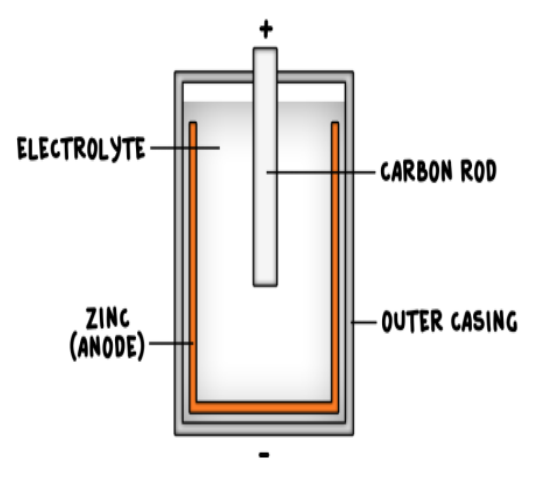
The voltage produced by a cell is dependent upon a number of factors including the type of electrode and electrolyte.

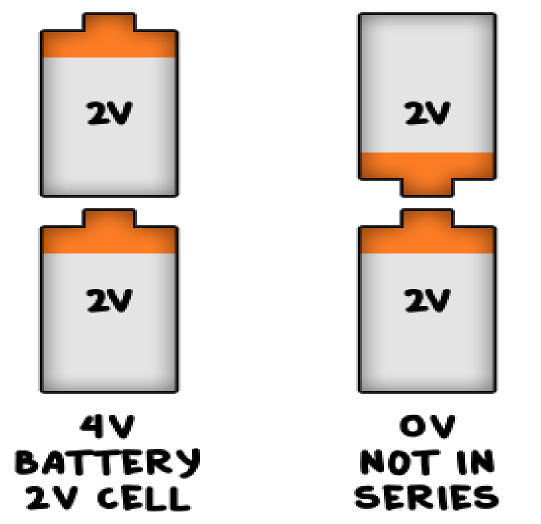
A simple cell can be made by connecting two different metals in contact with an electrolyte.

Batteries consist of two or more cells connected together in series to provide a greater voltage.

In non-rechargeable cells and batteries the chemical reactions stop when one of the reactants has been used up. Alkaline batteries are non-rechargeable.

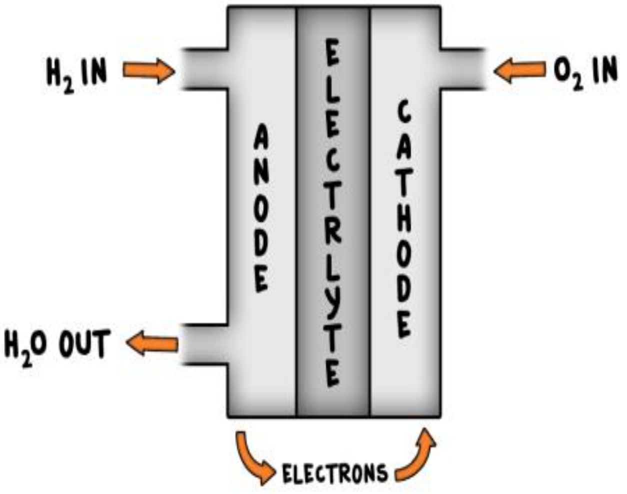
Rechargeable cells and batteries can be recharged because the chemical reactions are reversed when an external electrical current is supplied.





Fuel Cells (Chemistry only)

Fuel cells are supplied by an external source of fuel (e.g. hydrogen) and oxygen or air. The fuel is oxidised electrochemically within the fuel cell to produce a potential difference (a voltage).



The overall reaction in a hydrogen fuel cell involves the oxidation of hydrogen to produce water.

hydrogen + oxygen → water

$$2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(g)$$

(Higher Tier only)

There are two electrodes in the hydrogen fuel cell.

At the cathode (+ charged)

$$2H_2\,(g) \rightarrow 4H^+\,(aq) + 4e^-$$

At the anode (- charged)

$$4H^+\,(aq) + O_2\,(g) + 4e^- \rightarrow 2H_2O\,(g)$$

The half equations are only needed for the higher tier, however they are very important and worth revising carefully

Hydrogen fuel cells offer a potential alternative to rechargeable cells and batteries.

QuestionIT!

Chemical Cells And Fuel Cells (Chemistry Only)

- Cells And Batteries
- Fuel Cells

Cells and batteries (Chemistry only) QuestionIT

1. Give two factors which may affect the voltage given out by a battery.

2. Here is a reactivity series of metals. The most reactive is first, the least reactive is last: Magnesium Zinc Tin Copper

Which two metals would you use to make a battery which had the highest voltage? Explain why.

3. Why do non-renewable batteries stop producing a voltage after a certain time?

4. How are rechargeable batteries recharged?

Fuel Cells (Chemistry only) QuestionIT

1. What chemical is the fuel in a fuel cell ?

2. What happens to this fuel inside the fuel cell to produce a potential difference?

3. Write the overall balanced symbol equation for the reaction in a fuel cell.

4. Write the half equation for the reaction that happens at the cathode in a fuel cell.

5. Write the half equation for the reaction that happens at the anode in a fuel cell.

AnswerIT!

Chemical Cells And Fuel Cells (Chemistry Only)

- Cells And Batteries
- Fuel Cells

Cells and batteries (Chemistry only) AnswerIT

1. Give two factors which may affect the voltage given out by a battery.

The type of electrode and the electrolyte

2. Here is a reactivity series of metals. The most reactive is first, the least reactive is last. Magnesium Zinc Tin Copper

Which two metals would you use to make a battery which gave off the most voltage? Explain why

Magnesium and copper as largest difference in reactivity.

3. Why do non-renewable batteries stop producing a voltage after a certain time?

The chemical reactions stop when one of the reactants has been used up.

4. How are rechargeable batteries recharged?

The chemical reactions are reversed by an external electrical current.

Fuel Cells (Chemistry only) AnswerIT

1. What chemical is the fuel in a fuel cell ?

Hydrogen.

2. What happens to this fuel inside the fuel cell to produce a potential difference?

It is oxidised electrochemically.

3. Write the overall balanced symbol equation for the reaction in a fuel cell.

$$2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(g)$$

4. Write the half equation for the reaction that happens at the cathode in a fuel cell.

$$2H_2\,(g) \rightarrow 4H^+\,(aq) + 4e^-$$

5. Write the half equation for the reaction that happens at the anode in a fuel cell.

$$4H^+\,(aq) + O_2\,(g) + 4e^- \rightarrow 2H_2O\,(g)$$