Energy changes

Model answers and marking points

GCSE science 6-mark questions

This topic online

1 A pharmacy in Bristol sells two kinds of single-use pack. A hand warmer gets hot when a seal is broken. An instant cold pack for sports injuries gets cold when it is squeezed.

Compare the reactions in the two packs. Include energy transfers, temperature changes and what a reaction profile would show for each.

(6 marks)

Model answer

The hand warmer uses an exothermic reaction, whereas the cold pack uses an endothermic reaction.

In the exothermic reaction, energy is transferred from the chemicals to the surroundings, so the temperature of the surroundings, including your hands, rises. In the endothermic reaction, energy is taken in from the surroundings, so the temperature of the surroundings falls and the injury is cooled.

On a reaction profile for the hand warmer, the products would be at a lower energy level than the reactants, because energy has been given out. For the cold pack, the products would be at a higher energy level than the reactants, because energy has been taken in. Both profiles would show a hump at the start, the activation energy, which is the minimum energy the particles need to react.

In terms of bonds, in the exothermic reaction more energy is released making new bonds than is needed to break the old bonds. In the endothermic reaction, more energy is needed to break bonds than is released when new bonds form.

Both packs can only be used once, because once the reactants are used up the reaction stops.

Marking points (credit any 6 relevant points, linked in a sensible order)

- The hand warmer uses an exothermic reaction; the cold pack uses an endothermic reaction
- Exothermic: energy is transferred to the surroundings, so the temperature of the surroundings rises
- Endothermic: energy is taken in from the surroundings, so the temperature of the surroundings falls
- Exothermic profile: products are at a lower energy level than reactants
- Endothermic profile: products are at a higher energy level than reactants
- Both profiles show an activation energy hump, the minimum energy needed for particles to react
- Exothermic: more energy released making new bonds than taken in breaking bonds
- Endothermic: more energy taken in breaking bonds than released making bonds
- Both packs are single use because the reactants are used up; other examples: combustion is exothermic, thermal decomposition is endothermic

How it is marked

- 5-6 marks: compares both reactions point by point for energy transfer, temperature change and reaction profile, and links the difference to bond breaking and making.
- 3-4 marks: correctly names each reaction type and compares energy transfer or temperature, with a partly correct description of the profiles.
- 1-2 marks: states that one gets hot and one gets cold, or names one reaction type correctly.

What loses marks

- Saying the cold pack 'gives out cold' instead of taking in energy
- Drawing or describing the endothermic profile with products lower than reactants
- Saying making bonds takes in energy

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2 **Higher tier**

Hydrogen peroxide slowly decomposes into water and oxygen. This is why some bottles of hair bleach have caps that let gas escape.

2 H-O-O-H → 2 H-O-H + O=O

Bond	Bond energy in kJ/mol
O-H	464
O-O	146
O=O	498

Use the data to calculate the overall energy change for the reaction. Explain whether the reaction is exothermic or endothermic, and what this means in terms of bonds. (6 marks)

Model answer

First I work out the energy needed to break the bonds in the reactants. Each hydrogen peroxide molecule has two O-H bonds and one O-O bond, so two molecules have four O-H bonds and two O-O bonds:

(4 × 464) + (2 × 146) = 1856 + 292 = 2148 kJ/mol

Next I work out the energy released when the new bonds form. Two water molecules have four O-H bonds, and there is one O=O bond in the oxygen molecule:

(4 × 464) + 498 = 1856 + 498 = 2354 kJ/mol

The overall energy change is the energy taken in to break bonds minus the energy released making bonds:

2148 - 2354 = -206 kJ/mol

The answer is negative, so the reaction is exothermic. Breaking bonds is endothermic because energy must be taken in, and making bonds is exothermic because energy is released. In this reaction more energy is released forming the new bonds than is needed to break the old ones, so overall energy is transferred to the surroundings and they warm up. On a reaction profile, the products would be at a lower energy level than the reactants.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Bonds broken: each H-O-O-H has two O-H bonds and one O-O bond, so two molecules have four O-H and two O-O
- Energy to break bonds = (4 × 464) + (2 × 146) = 1856 + 292 = 2148 kJ/mol
- Bonds made: two water molecules have four O-H bonds, plus one O=O bond in the oxygen molecule
- Energy released making bonds = (4 × 464) + 498 = 1856 + 498 = 2354 kJ/mol
- Overall energy change = energy in breaking bonds - energy out making bonds
- = 2148 - 2354 = -206 kJ/mol
- Negative sign means the reaction is exothermic
- More energy is released forming new bonds than is needed to break the old bonds
- Breaking bonds is endothermic and making bonds is exothermic
- Products are at a lower energy level than reactants; the surroundings warm up

How it is marked

- 5-6 marks: correct working for both bonds broken and bonds made, correct answer of -206 kJ/mol with sign, and a correct explanation of exothermic in terms of bond energies.
- 3-4 marks: one error in counting bonds or in the subtraction, but a correct method and a conclusion consistent with the answer.

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- 1-2 marks: some correct steps, such as the energy to break bonds, or a correct statement that bond breaking takes in energy.

What loses marks

- Counting the bonds in only one hydrogen peroxide molecule instead of two
- Forgetting the O-O bond in hydrogen peroxide or the O=O bond in oxygen
- Subtracting the wrong way round and getting +206 kJ/mol
- Saying breaking bonds releases energy

3 Zara makes a simple cell by putting a strip of zinc and a strip of copper into a beaker of salt solution and connecting them to a voltmeter. The voltmeter reads 0.9 V.

Describe how a chemical cell produces a voltage and the factors that affect the size of the voltage. Then describe the difference between non-rechargeable and rechargeable cells.

Separate science only

(6 marks)

Model answer

A chemical cell contains chemicals that react to produce electricity. Zara's cell is made from two different metals dipped in an electrolyte, the salt solution. Zinc is more reactive than copper, so it loses electrons more readily. This sets up a potential difference between the two metals, which the voltmeter measures.

The size of the voltage depends on which metals are used. The bigger the difference in reactivity between the two metals, the bigger the voltage. For example, magnesium and copper would give a bigger voltage than zinc and copper. The voltage also depends on which electrolyte is used. To get a bigger voltage, two or more cells can be connected in series to make a battery.

In a non-rechargeable cell, such as an alkaline battery, the chemical reactions stop when one of the reactants has been used up, and the cell has to be thrown away or recycled. In a rechargeable cell, the chemical reactions can be reversed by supplying an external electrical current, so the reactants are made again and the cell can be used many times.

Marking points (credit any 6 relevant points, linked in a sensible order)

- A cell contains chemicals that react to produce electricity
- A simple cell is made from two different metals in contact with an electrolyte
- The more reactive metal (zinc) loses electrons more readily, so a potential difference is set up
- The voltage depends on the two metals used
- The bigger the difference in reactivity between the metals, the bigger the voltage
- The voltage also depends on the electrolyte used
- A battery is two or more cells connected in series to give a bigger voltage
- Non-rechargeable cells (e.g. alkaline) stop when one of the reactants has been used up
- Rechargeable cells can be recharged because the reactions are reversed when an external current is supplied

How it is marked

- 5-6 marks: describes how the cell works using reactivity, gives both factors (metals and electrolyte) with the reactivity difference idea, and clearly distinguishes rechargeable from non-rechargeable cells using reactions being reversed or reactants used up.
- 3-4 marks: describes the cell and one factor, with a basic distinction between the two types of cell.
- 1-2 marks: states that the cell needs two metals or that some batteries can be recharged, with little detail.

What loses marks

- Using two pieces of the same metal, which gives no voltage
- Saying non-rechargeable cells run out of electricity rather than a reactant
- Mixing up a cell and a battery

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4 A delivery firm in Glasgow is choosing between hydrogen fuel cell vans and vans with rechargeable lithium-ion batteries.

Feature	Hydrogen fuel cell van	Battery van
Time to refuel or recharge	5 minutes	6 hours (or 1 hour on a fast charger)
Range on a full tank or charge	480 km	250 km
Refuelling or charging points near the depot	1	14
Waste product while driving	water	none

In a hydrogen fuel cell, hydrogen reacts with oxygen from the air to produce electricity.

Evaluate the two types of van for the firm. Use the information and your own knowledge.

Separate science only

(6 marks)

Model answer

In the fuel cell, hydrogen reacts with oxygen and the only product is water, so the van causes no pollution while driving. It refuels in 5 minutes and can travel 480 km, almost twice as far as the battery van, so drivers would lose less time stopping. However, there is only one hydrogen station near the depot, so if it closed the vans could not refuel. Hydrogen is a flammable gas that must be stored in strong, bulky tanks at high pressure, which is a safety risk. Also, hydrogen is often made from fossil fuels or by electrolysis that may use electricity from fossil fuels, so it is not always low carbon.

The battery vans have 14 charging points nearby and could be charged at the depot overnight. Their drawbacks are a range of only 250 km and charging that takes 1 to 6 hours. Batteries contain toxic chemicals, are difficult to dispose of and can only be recharged a limited number of times. Their electricity may also come from fossil fuels.

Overall, I would choose battery vans for local deliveries because charging is easy and safer, but fuel cell vans would suit long routes better.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Fuel cell overall reaction: hydrogen + oxygen → water; the only product is water, so no pollution while driving
- Fuel cell vans refuel in 5 minutes and travel almost twice as far (480 km vs 250 km), so less time off the road
- Hydrogen is a flammable gas that must be stored under high pressure, which is a safety risk and needs bulky tanks
- Hydrogen is often made from fossil fuels or by electrolysis, which may use electricity from fossil fuels
- Only one hydrogen station near the depot: a risk if it closes
- Battery vans have 14 charging points nearby and can be charged at the depot overnight
- Batteries take hours to charge and have a shorter range
- Batteries contain toxic chemicals, are hard to dispose of, and can only be recharged a limited number of times
- Battery electricity may also come from fossil fuel power stations
- Justified conclusion depends on routes: battery vans for shorter local routes, fuel cells for long routes

How it is marked

- 5-6 marks: uses the data to give advantages and disadvantages of both vans, adds scientific knowledge about hydrogen storage, production and battery disposal, and reaches a justified conclusion.

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- 3-4 marks: gives advantages and disadvantages of both from the table, with little of their own knowledge, or no clear conclusion.
- 1-2 marks: makes one or two simple points about one van, often copied from the table.

What loses marks

- Saying fuel cells produce no waste at all or are completely carbon-free
- Repeating the table without adding any chemistry
- Giving no conclusion or a conclusion with no reason

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5 The gas in a camping stove does not burn when it is turned on. It only starts burning when a spark is made. Once it is burning, it keeps burning without any more sparks.

A different reaction, the decomposition of hydrogen peroxide, is very slow on its own but becomes fast when a small amount of manganese dioxide is added.

Explain both observations using ideas about energy and reaction profiles. (6 marks)

Model answer

For particles to react, they must collide with at least a minimum amount of energy, called the activation energy. At room temperature very few of the gas and oxygen particles have this much energy, so the gas does not burn when the stove is turned on.

The spark supplies energy to some of the particles so they reach the activation energy and start to react. Combustion is exothermic, so it releases energy to the surroundings. This energy heats the nearby particles so they also reach the activation energy, which is why the flame keeps going without another spark. On a reaction profile, the reactants start higher than the products, with a hump in between showing the activation energy.

Manganese dioxide is a catalyst. It speeds up the decomposition of hydrogen peroxide without being used up itself. It works by providing a different reaction pathway with a lower activation energy. This means a greater proportion of collisions have enough energy to react, so the reaction is much faster. On the reaction profile, the hump for the catalysed reaction is lower, but the energy levels of the reactants and products stay the same.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Particles must collide with at least a minimum energy to react: the activation energy
- At room temperature few gas and oxygen particles have enough energy, so no reaction
- The spark supplies energy so some particles reach the activation energy and start to react
- Combustion is exothermic: it releases energy to the surroundings
- The energy released heats nearby particles so they reach the activation energy, so the reaction keeps going
- Reaction profile for combustion: a hump for activation energy, products lower than reactants
- Manganese dioxide is a catalyst: it speeds up the reaction without being used up
- A catalyst provides a different pathway with a lower activation energy
- So more collisions have enough energy to react, and the reaction is faster
- On the profile, the catalysed hump is lower; the energy levels of reactants and products are unchanged

How it is marked

- 5-6 marks: explains both observations using activation energy, includes why burning keeps going once started, and explains the catalyst using a lower activation energy and an alternative pathway, with correct profile features.
- 3-4 marks: explains one observation well and the other partly, for example says the catalyst speeds up the reaction without explaining activation energy.
- 1-2 marks: states the spark starts the reaction or the catalyst speeds it up, with no use of activation energy.

What loses marks

- Saying the catalyst gives the particles more energy
- Saying the catalyst changes the overall energy change of the reaction
- Not explaining why the flame keeps burning after the spark

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