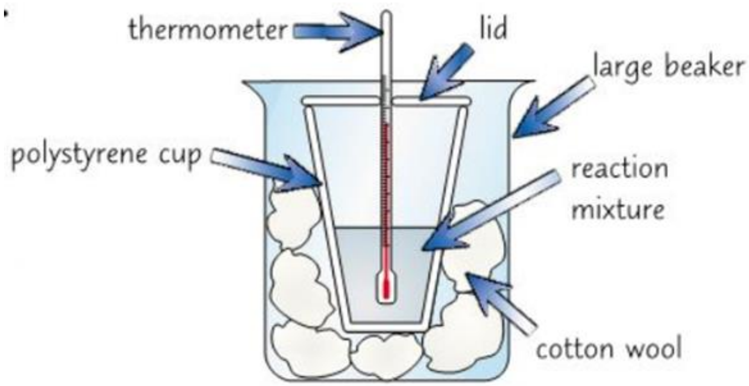
Energy Changes – Exothermic and Endothermic Reactions

During chemical reactions there is always an energy change. This means that some reactions give out energy to the surroundings (exothermic) and some reactions absorb energy from the surroundings (endothermic). Energy can be in the form of heat or light.

How can exothermic or endothermic reactions be investigated?



Part of Equipment	Function in the Experiment
Thermomete r	The thermometer is used to measure the temperature at the start of the reaction and the temperature at the end of the reaction. The temperature change can then be calculated.
Polystyrene Cup	Polystyrene is a thermal insulator. It will stop heat energy getting in and out of the cup. This makes the experiment more accurate so the thermometer measure the true temperature change.
Cotton Wool	Cotton wool is also a thermal insulator. It stops heat energy warming the air surrounding the polystyrene cup and prevents heat loss.
Large Beaker	To stand the polystyrene cup in and hold the cotton wool.
Lid	Stops heat escaping through the top of the plastic cup.

Examples of Exothermic and Endothermic Reactions

Exothermic	Endothermic
Burning Fuels	Decomposition Reactions (Chemicals splitting up because they have been heated)
Displacement Reactions (a more reactive metal reacting with a less reactive metal compound)	Acid + Hydrogen Carbonate
Metal + Acid	Dissolving
Neutralisation (acid and a alkali/base reacting)	

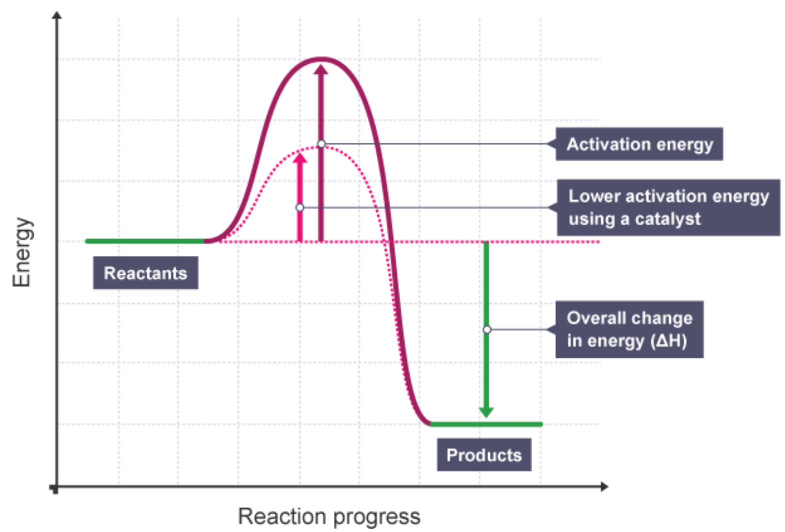
Investigation: How does the mass of magnesium effect the temperature rise when reacted with hydrochloric acid?

Independent Variable	You are changing the mass of magnesium. Measure out different masses of magnesium using a balanced. E.g. 1g, 2g, 3g 4g 5g
Dependant Variable	You are choosing to measuring temperature change. You will measure the temperature before and after and calculate the temperature change.
Control Variables	To make the investigation a fair test you will need to control all other factors. Volume of hydrochloric acid using a measuring cylinder, concentration of hydrochloric acid .
Repeats	Each mass of magnesium will be repeated three times. Any anomalies (results that are far away from the others) ignored and then the mean (average) calculated.
Analysis	The results will then be plotted on a scatter graph and a line of best fit drawn. A scatter graph is used as the data is continuous (many possible values could be measured). The graph can be used to predict the temperature rise of 2.5g of magnesium by reading off the line of best fit.

When chemical reactions happen energy is needed (endothermic) to **break** bonds between atoms in the reactants and energy is released (exothermic) to **form** bonds between atoms to make the products.

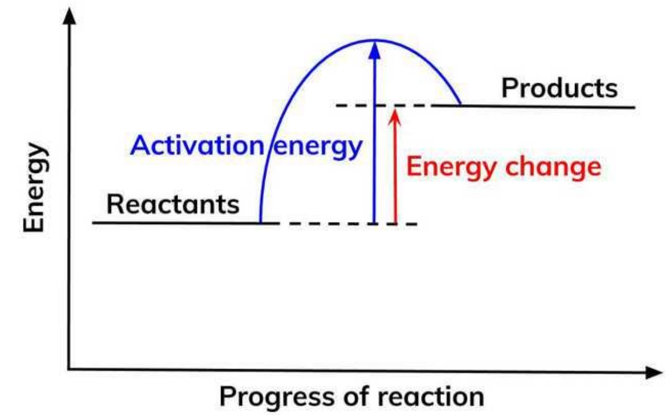
Reaction Profiles

- A reaction profile is a type of graph. It shows the amount of energy in the reactants (the starting chemicals in a reaction) and the products (the end chemicals).
- The difference between their energies is the energy change in the reaction.
- The graphs have parts you need to identify and the shape of them is different for exothermic and endothermic reactions.



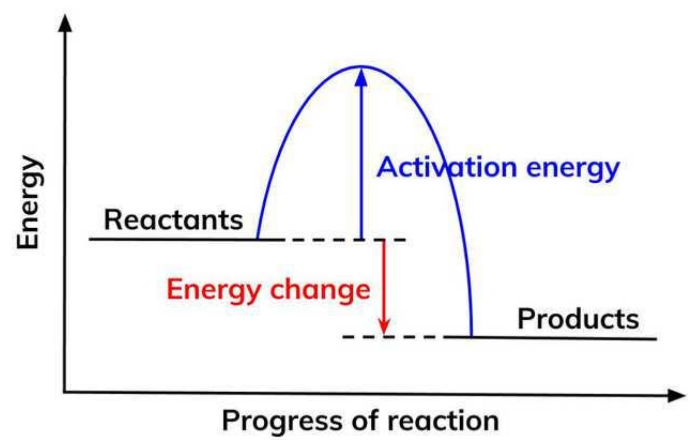
- This reaction profile shows that the reactants had greater energy than the products.
- The rise represents energy being put in to break bonds – this is an endothermic process.
- The 'hill' is the amount of energy that needs to be put in to start the reaction. This is called activation energy.
- The fall represents energy being released to the surrounds when bonds are made – this is an exothermic process.
- Catalysts are chemicals (often transition metals) that lower the activation energy. They allow the reaction to progress by an alternative route – less energy is needed for the reaction to get started.

Endothermic Reaction



- The products have higher energy than the reactants therefore energy has gone in – endothermic.
- Less energy was released when bonds were formed to make the products than was absorbed to break the bonds in the reactants – **overall** the reaction is endothermic.

Exothermic Reaction



- The products have lower energy than the reactants therefore energy has exited - exothermic.
- More energy was released when bonds were formed to make the products than was absorbed to break the bonds in the reactants – **overall** the reaction is exothermic.

When chemical reactions happen energy is needed (endothermic) to **break** bonds between atoms in the reactants and energy is released (exothermic) to **form** bonds between atoms to make the products.

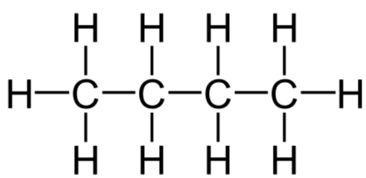
Bond Energies

Different types of chemical bond require or release different amounts of energy when broken or made. In the table you can see different combinations of atoms and the amount of energy needed to break one bond in kJ/mol.

Bond	Bond energy (kJ/mol)	Bond	Bond energy (kJ/mol)
C—C	347	H—Cl	432
C—O	358	H—O	464
C—H	413	H—N	391
C—N	286	H—H	436
C—Cl	346	O=O	498
Cl—Cl	243	N≡N	945

To work out the amount of energy needed to break all the bonds OR form all the bonds between the atoms in a compound you add up all the values for all the bonds.
E.g.

C-H 10 x 413 = 4130
C-C 4 x 347 = 1388
Total = 4130 + 1388
Total = 5518



- *A reaction is exothermic if: More energy is released when the bonds were formed than was needed to break the bonds (energy change is negative because energy has gone out).*
- *A reaction is endothermic if: More energy is absorbed when the bonds were broken than was released when bonds were formed (energy change is positive because energy has gone in).*

Calculating Energy Changes Using Bond Energies

Step 1: Calculate the bond energies for the reactants and the products from the balanced equation.
Step 2: Energy change = bonds broken – bonds made
Step 3: Include the correct sign (+/-) and units (kJ/mol)

H—H + Br—Br ⟶ 2 H—Br

BREAK

H-H = 436
Br-Br = 193
BREAK = 629

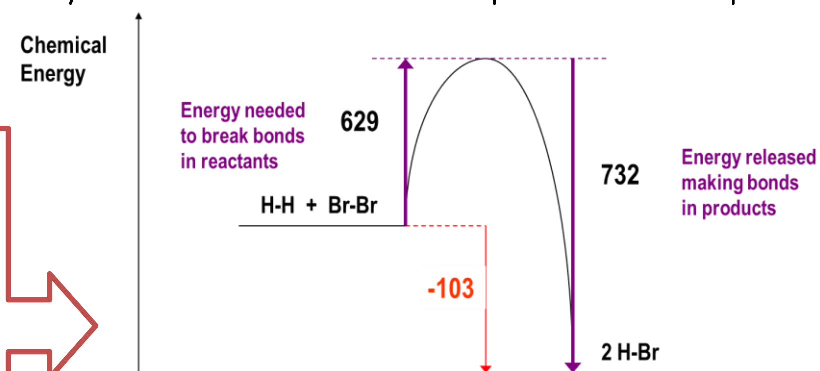
MAKE

2 (H-Br) = 2(366)
MAKE = 732

ENERGY CHANGE = BREAK – MAKE

Energy change = 629 – 732
= –103 kJ/mol

Below is a reaction profile of the bond energy calculation above. Can you see how the values match up to the reaction profile?



Reaction is EXOTHERMIC because
more energy is released making bonds than is needed to break bonds

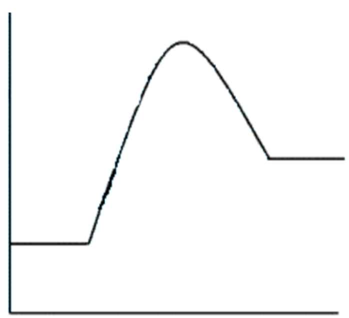
QUESTIONS

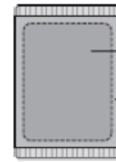
Are these reactions exothermic or endothermic?

Reaction	Starting Temp (^{o}C)	End Temp (^{o}C)	Temp Change (^{o}C)	Exothermic or Endothermic?
A	12	24		
B	16	15		
C	-12	-42		
D	-6	3		
E	-9	-2		
F	106	144		
G	37	39		
H	21	9		
I	43	-1		

This reaction profile is for an endothermic reaction. Label the reaction profiles with the following:

- Energy In
- Energy Out
- Activation Energy
- Energy Changes
- Bonds Broken
- Bonds Made
- Endothermic
- Exothermic



Disposable hand warmer	Reusable hand warmer
	
The hand warmer stays warm for 10 hours.	The hand warmer stays warm for 30 minutes.
The maximum temperature reached is 45°C.	The maximum temperature reached is 54°C.
The contents are: • Iron filings (small pieces of iron) • Water • Salt (catalyst) • Vermiculite (a mineral that holds water)	The contents are: • Sodium ethanoate • Water • Metal disc (to start crystallisation) Reusable hand warmers are regenerated by putting into boiling water, then cooling.

Write an evaluation of these hand warmers. Which would be most suitable for a walker?

What's wrong with these answers?

Question: the reaction was exothermic. Explain in terms of bonds broken and bonds made.

The reaction is exothermic because there is more energy in the reactants than in the products.

The reaction was exothermic because more energy was needed to make the bonds than was needed to break the bonds.

The reaction was exothermic because more bonds were made than broken.

What's the correct answer?