CHAPTER 12

Energy And Chemical Change

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You have probably seen a fire burning or burnt fuel for warmth or cooking or light. A fire burning is one of the most noticeable examples of a chemical reaction that produces a lot of energy.

All chemical reactions involve energy changes. In some reactions, we are able to observe these energy changes as either an increase or a decrease in the overall energy of the system. In some reactions we see this as a change in the temperature. In other reactions we can observe this change when a reaction starts to give off light or when a reaction will only work after light is shone on it.

The study of energy changes (particularly heat) in chemical reactions is known as chemical thermodynamics. This is also sometimes called thermochemistry.

KEY CONCEPTS

- Graphs - Mathematics, Grade 10, Functions and graphs
- Equations - Mathematics, Grade 10, Equations and inequalities
- Units and unit conversions - Physical Sciences, Grade 10, Science skills

1 ENERGY CHANGES IN CHEMICAL REACTIONS

1.1 What causes the energy changes in chemical reactions?

When a chemical reaction occurs, bonds in the reactants *break*, while new bonds form in the product. The following example explains this. Hydrogen reacts with oxygen to *form* water, according to the following equation:

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

In this reaction, the bond between the two hydrogen atoms in the H_2 molecule will *break*, as will the bond between the oxygen atoms in the O_2 molecule. New bonds will *form* between the two hydrogen atoms and the single oxygen atom in the water molecule that is formed as the product.

For bonds to *break*, energy must be *absorbed*. When new bonds *form*, energy is *released*. The energy that is needed to break a bond is called the **bond energy** or **bond dissociation energy**. Bond energies are measured in units of $kJ{\cdot}mol^{-1}$.

DEFINITION

Bond energy

Bond energy is a measure of bond strength in a chemical bond. It is the amount of energy (in $kJ{\cdot}mol^{-1}$) that is needed to break the chemical bond between two atoms.

Remember when we discussed bonding (Chapter 3) we used the following energy diagram:

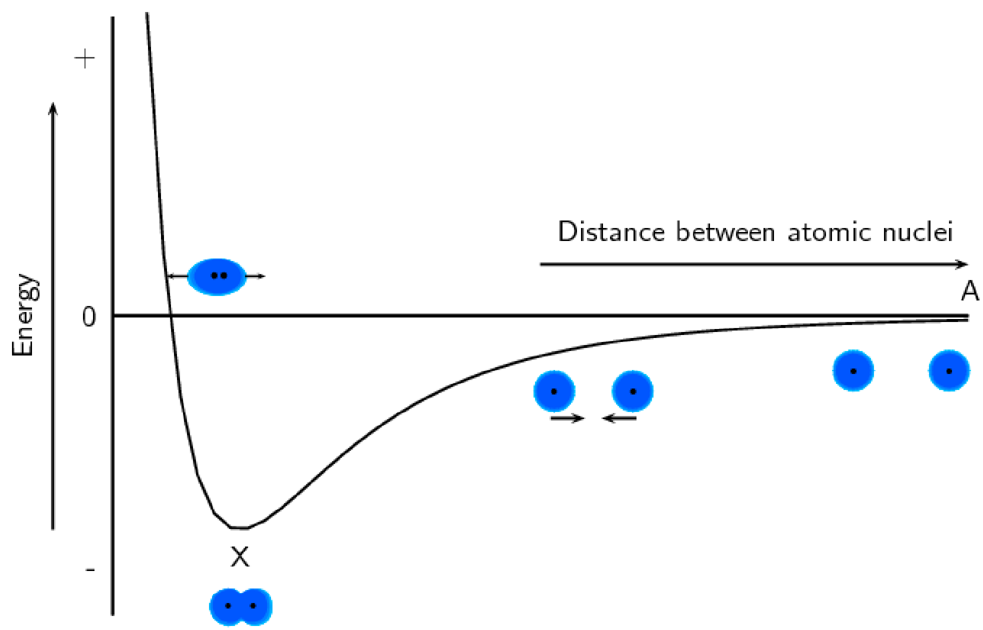


Figure 1: Graph showing the changes in energy that take place as the distance between two atoms changes.

We can use this diagram to understand why bond breaking requires energy and bond making releases energy. Point X on the diagram is at the lowest energy. When a bond breaks, the atoms move apart and the distance between them increases (i.e. the atom moves to the right on the x-axis or from point X to point A). Looking at the diagram we see that when this happens, the energy increases (i.e. the energy at point A is greater than the energy at point X). So when a bond breaks energy is needed.

When a bond forms the atoms move closer together and the distance between them decreases (i.e. the atom moves to the left on the x-axis or from point A to point X). Looking at the diagram we see that when this happens, the energy decreases (i.e. the energy at point X is less than the energy at point A). So when a bond forms energy is released.

Looking at the example of hydrogen reacting with oxygen to form water:

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

We see that energy is needed to break the bonds in the hydrogen molecule and to break the bonds in the oxygen molecule). And we also see that energy is released when hydrogen and oxygen bond to form water). When we look at the entire reaction and consider both bond breaking and bond forming we need to look at the **enthalpy** of the system.

DEFINITION

Enthalpy

Enthalpy is a measure of the total energy of a chemical system for a given pressure, and is given the symbol H.

TIP

A chemical system is a closed system that contains only the reactants and products involved in the reaction.

As we learn about exothermic and endothermic reactions we will see more on the concept of enthalpy.

1.2 Exothermic and endothermic reactions

In some reactions, the energy that must be absorbed to break the bonds in the reactants, is less than the energy that is released when the new bonds of the products are formed. This means that in the overall reaction, energy is released as either heat or light. This type of reaction is called an exothermic reaction.

DEFINITION

Exothermic reaction

An exothermic reaction is one that releases energy in the form of heat or light.

Another way of describing an exothermic reaction is that it is one in which the energy of the products is less than the energy of the reactants, because energy has been released during the reaction. We can represent this using the following general formula:

$$\text{Reactants} \rightarrow \text{Products} + \text{Energy}$$

In other reactions, the energy that must be *absorbed* to break the bonds in the reactants, is more than the energy that is *released* when the new bonds in the products are formed. This means that in the overall reaction, energy must be *absorbed* from the surroundings. This type of reaction is known as an **endothermic** reaction.

DEFINITION

Endothermic reaction

An endothermic reaction is one that absorbs energy in the form of heat or light.

Another way of describing an endothermic reaction is that it is one in which the energy of the products is greater than the energy of the reactants, because energy has been absorbed during the reaction. This can be represented by the following general formula:

$$\text{Reactants} + \text{Energy} \rightarrow \text{Products}$$

The difference in energy (E) between the reactants and the products is known as the **heat of the reaction**. It is also sometimes referred to as the **enthalpy change** of the system. This is represented using ΔH

TIP

Δ is read as delta and means a change in. You may recall this symbol from physics.

FORMAL EXPERIMENT

Endothermic and exothermic reactions - Part 1

Apparatus and materials

- citric acid
- bicarbonate
- a polystyrene cup
- a lid for the cup
- thermometer
- glass stirring rod
- scissors

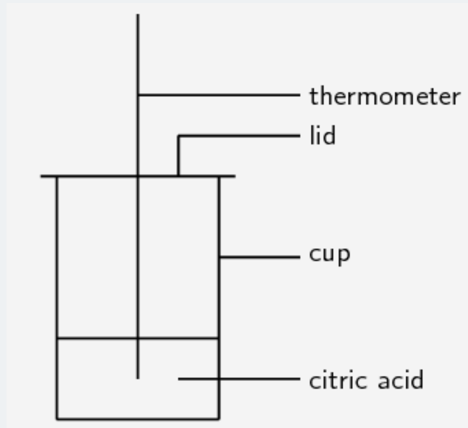
TIP

You can get polystyrene cups with lids from coffee shops or fast food stores. Cardboard cups will also work fine. Some of the lids will have a hole for a straw, which is useful for this experiment.

Note that citric acid is found in citrus fruits such as lemons. Sodium bicarbonate is actually bicarbonate of soda (baking soda), the baking ingredient that helps cakes to rise.

FORMAL EXPERIMENT (continued)

Method



1. If your lid does not have a hole for a straw, then cut a small hole into the lid.
2. Pour some citric acid (($C_6H_8O_7$)) into the polystyrene cup, cover the cup with its lid and record the temperature of the solution.
3. Stir in the sodium bicarbonate (($NaHCO_3$)), then cover the cup again.
4. Immediately record the temperature, and then take a temperature reading every two minutes after that. Record your results.

The equation for the reaction that takes place is:

$$C_6H_8O_7(aq) + 3NaHCO_3(s) \rightarrow 3CO_2(g) + 3H_2O() + Na_3C_6H_5O_7(aq)$$

Results

Time (mins)	0	2	4	6
Temperature (°C)				

Plot your temperature results on a graph of time (x-axis) against temperature (y-axis).

Discussion and conclusion

- What happens to the temperature during this reaction?
- Is this an exothermic or an endothermic reaction? (Was energy taken in or given out? Did the temperature increase or decrease?)
- Why was it important to keep the cup covered with a lid?

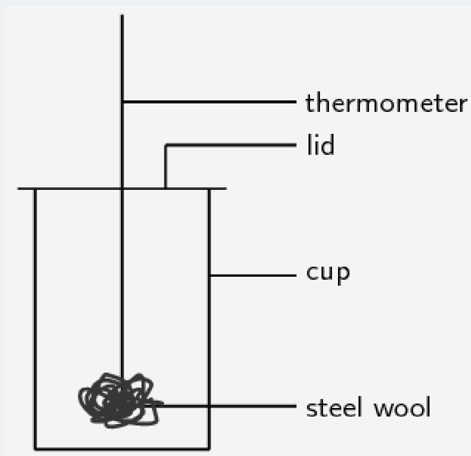
FORMAL EXPERIMENT

Endothermic and exothermic reactions - Part 2

Apparatus and materials

- Vinegar
- steel wool
- thermometer
- polystyrene cup and plastic lid (from previous experiment)

Method



1. Put the thermometer through the plastic lid, cover the cup and record the temperature in the empty cup. You will need to leave the thermometer in the cup for about 5 minutes in order to get an accurate reading.
2. Soak a piece of steel wool in vinegar for about a minute. The vinegar removes the protective coating from the steel wool so that the metal is exposed to oxygen.
3. Take the thermometer out of the cup. Keep the thermometer through the hole of the lid.
4. After the steel wool has been in the vinegar, remove it and squeeze out any vinegar that is still on the wool. Wrap the steel wool around the thermometer and place it (still wrapped round the thermometer) back into the cup. The cup is automatically sealed when you do this because the thermometer is through the top of the lid.
5. Leave the steel wool in the cup for about 5 minutes and then record the temperature. Record your observations.

FORMAL EXPERIMENT (continued)

Results

You should notice that the temperature increases when the steel wool is wrapped around the thermometer.

Conclusion

The reaction between oxygen and the exposed metal in the steel wool is **exothermic**, which means that energy is released and the temperature increases.

1.3 Examples of endothermic and exothermic reactions

There are many examples of endothermic and exothermic reactions that occur around us all the time. The following are just a few examples.

TIP

Note that we are only discussing chemical changes (recall from grade 10 about physical and chemical changes). Physical changes can also be classified as exothermic or endothermic. When we are referring to physical change then we talk about exothermic or endothermic processes. Evaporation is an endothermic process while condensation is an exothermic process.

1. **Endothermic reactions**

   - **Photosynthesis**

     Photosynthesis is the chemical reaction that takes place in green plants, which uses energy from the sun to change carbon dioxide and water into food that the plant needs to survive, and which other organisms (such as humans and other animals) can eat so that they too can survive. The equation for this reaction is:

     $$6CO_2(g) + 6H_2O\ (l) + \text{energy} \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$$

     Photosynthesis is an endothermic reaction. Energy in the form of sunlight is absorbed during the reaction.

   - **The thermal decomposition of limestone**

     In industry, the breakdown of limestone into quicklime and carbon dioxide is very important. Quicklime can be used to make steel from iron and also to neutralise soils that are too acid. However, the limestone must be heated in a kiln (oven) at a temperature of over 900 ℃ before the decomposition reaction will take place. The equation for the reaction is shown below:

$$CaCO_3(s) \rightarrow CaO\ (s) + CO_2(g)$$

2. **Exothermic reactions**

- **Combustion reactions**

  The burning of fuel is an example of a combustion reaction, and we as humans rely heavily on this process for our energy requirements. The following equations describe the combustion of a hydrocarbon such as *petrol* (C_8H_{18}):

  fuel + oxygen $\rightarrow$ heat + water + carbon dioxide

  $$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O\ (g) + \text{heat}$$

  This is why we burn fuels (such as paraffin, coal, propane and butane) for energy, because the chemical changes that take place during the reaction release huge amounts of energy, which we then use for things like power and electricity. You should also note that *carbon dioxide* is produced during this reaction. The chemical reaction that takes place when fuels burn has both positive and negative consequences. Although we benefit from heat, power and electricity the carbon dioxide that is produced has a negative impact on the environment.

- **Respiration**

  Respiration is the chemical reaction that happens in our bodies to produce energy for our cells. The equation below describes what happens during this reaction:

  $$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) + \text{energy}$$

  In the reaction above, glucose (a type of carbohydrate in the food we eat) reacts with oxygen from the air that we breathe in, to form carbon dioxide (which we breathe out), water and energy. The energy that is produced allows the cell to carry out its functions efficiently. Can you see now why you must eat food to get energy? It is not the food itself that provides you with energy, but the exothermic reaction that takes place when compounds within the food react with the oxygen you have breathed in!

FACT

Lightsticks or glowsticks are used by divers, campers, and for decoration and fun. A lightstick is a plastic tube with a glass vial inside it. To activate a lightstick, you bend the plastic stick, which breaks the glass vial. This allows the chemicals that are inside the glass to mix with the chemicals in the plastic tube. These two chemicals react and release energy. Another part of a lightstick is a fluorescent dye which

FACT (continued)

changes this energy into light, causing the lightstick to glow! This is known as phosphorescence or chemiluminescence.

2 EXOTHERMIC AND ENDOTHERMIC REACTIONS

2.1 The heat of reaction

The **heat of the reaction** is represented by the symbol ΔH, where:

$$\Delta H = E_{prod} - E_{react}$$

- In an *exothermic* reaction, ΔH is less than zero because the energy of the reactants is greater than the energy of the products. Energy is released in the reaction. For example:

$$H_2(g) + Cl_2(g) \rightarrow 2HCl\ (g) \qquad \Delta H < 0$$

- In an *endothermic* reaction, ΔH is greater than zero because the energy of the reactants is less than the energy of the products. Energy is absorbed in the reaction. For example:

$$C\ (s) + H_2O\ (l) \rightarrow CO\ (g) + H_2(g) \qquad \Delta H > 0$$

Some of the information relating to exothermic and endothermic reactions is summarised in Table 1.

Type of reaction	**Exothermic**	**Endothermic**
Energy absorbed or released	Released	Absorbed
Relative energy of reactants and products	Energy of reactants greater than energy of product	Energy of reactants less than energy of product
Sign of ΔH	Negative (i.e. < 0)	Positive (i.e. > 0)

Table 1: A comparison of exothermic and endothermic reactions.

Writing equations using ΔH

TIP

ΔH has been calculated for many different reactions and so instead of saying that ΔH is positive or negative, we can look up the value of ΔH for the reaction and use that value instead.

There are two ways to write the heat of the reaction in an equation.

For the exothermic reaction $C(s) + O_2(g) \rightarrow CO_2(g)$, we can write:

$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -393\ kJ{\cdot}mol^{-1}$

or

$C(s) + O_2(g) \rightarrow CO_2(g) + 393\ kJ{\cdot}mol^{-1}$

For the endothermic reaction, $C(s) + H_2O(g) \rightarrow H_2(g) + CO(g)$, we can write:

$C(s) + H_2O(g) \rightarrow H_2(g) + CO(g) \qquad \Delta H = +131\ kJ{\cdot}mol^{-1}$

or

$C(s) + H_2O(g) + +131\ kJ{\cdot}mol^{-1} \rightarrow H_2(g) + CO(g)$

The **units** for ΔH are $kJ{\cdot}mol^{-1}$. In other words, the ΔH value gives the amount of energy that is absorbed or released per mole of product that is formed. Units can also be written as **kJ**, which then gives the total amount of energy that is released or absorbed when the product forms.

The energy changes during exothermic and endothermic reactions can be plotted on a graph:

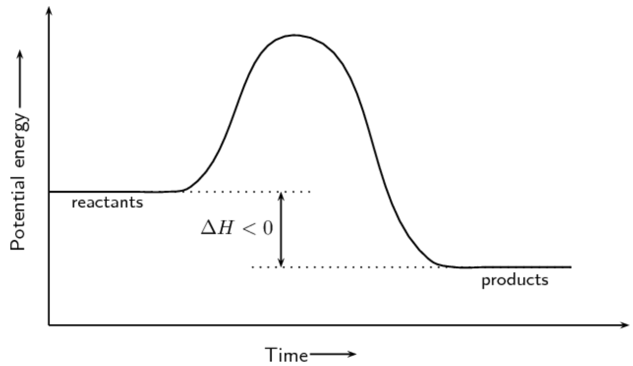


Figure 2: The energy changes that take place during an exothermic reaction.

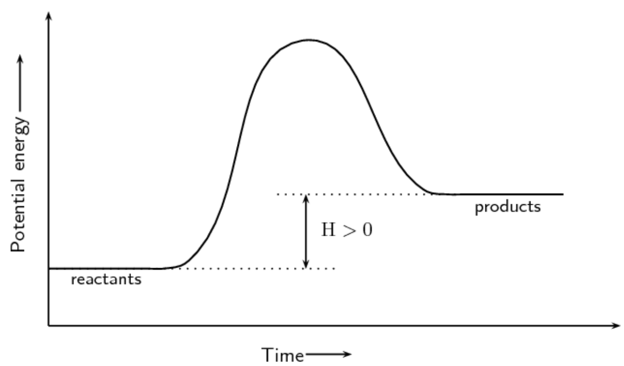


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Figure 3: The energy changes that take place during an endothermic reaction.

We will explain shortly why we draw these graphs with a curve rather than simply drawing a straight line from the reactants energy to the products energy.

INVESTIGATION

Endothermic and exothermic reactions

Aim

To investigate exothermic and endothermic reactions.

Apparatus and materials

- Approximately 2 g of calcium chloride ($CaCl_2$)
- Approximately 2 g of sodium hydroxide ($NaOH$)

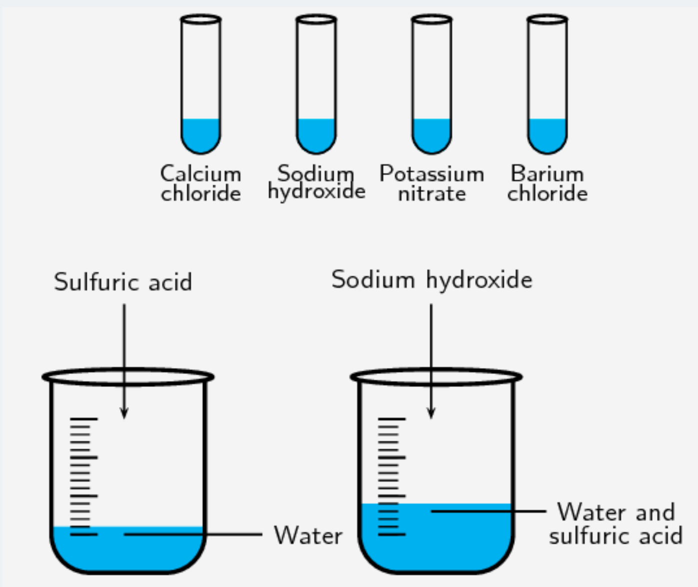
INVESTIGATION (continued)

- Approximately 2 g of potassium nitrate (KNO_3)
- Approximately 2 g of barium chloride $(BaCl_2)$
- concentrated sulphuric acid (H_2SO_4) (Be careful, this can cause serious burns)
- 5 test tubes
- thermometer

WARNING

When working with concentrated sulfuric acid always wear gloves and safety glasses. Always work in a well ventilated room or in a fume cupboard.

Method



1. Dissolve about 1 g of each of the following substances in 5-10 cm^3 of water in a test tube: $CaCl_2$, NaOH, KNO_3 and $BaCl_2$.
2. Observe whether the reaction is endothermic or exothermic, either by feeling whether the side of the test tube gets hot or cold, or using a thermometer.
3. Dilute 3 cm^3 of concentrated H_2SO_4 in 10 cm^3 of water in the fifth test tube and observe whether the temperature changes.

INVESTIGATION (continued)

WARNING

Remember to always add the acid to the water.

4. Wait a few minutes and then carefully add NaOH to the diluted H_2SO_4. Observe any temperature (energy) changes.

Results

Record which of the above reactions are endothermic and which are exothermic.

Exothermic reactions	Endothermic reactions

- When $BaCl_2$ and KNO_3 dissolve in water, they take in heat from the surroundings. The dissolution of these salts is **endothermic**.
- When $CaCl_2$ and NaOH dissolve in water, heat is released. The process is **exothermic**.
- The reaction of H_2SO_4 and NaOH is also **exothermic**.

3 ACTIVATION ENERGY AND THE ACTIVATED COMPLEX

If you take a match and just hold it or wave it around in the air, the match will not light. You have to strike the match against the side of the box. All chemical reactions need something that makes them start going.

Chemical reactions will not take place until the system has some minimum amount of energy added to it. This energy is called the **activation energy**.

DEFINITION

Activation energy

Activation energy is the minimum amount of energy that is needed to start a chemical reaction.

> **TIP**
>
> It is important to realise that even though exothermic reactions release energy they still need a small amount of energy to start the reaction.

Recall from earlier that we drew graphs for the energy changes in exothermic and endothermic reactions. We can now add some information to these graphs. This will also explain why we draw these graphs with a curve rather than using a straight line from the reactants energy to the products energy.

We will start by looking at exothermic reactions. We will use:

$$H_2(g) + F_2(g) \rightarrow 2HF\ (g)$$

as an example of an exothermic reaction.

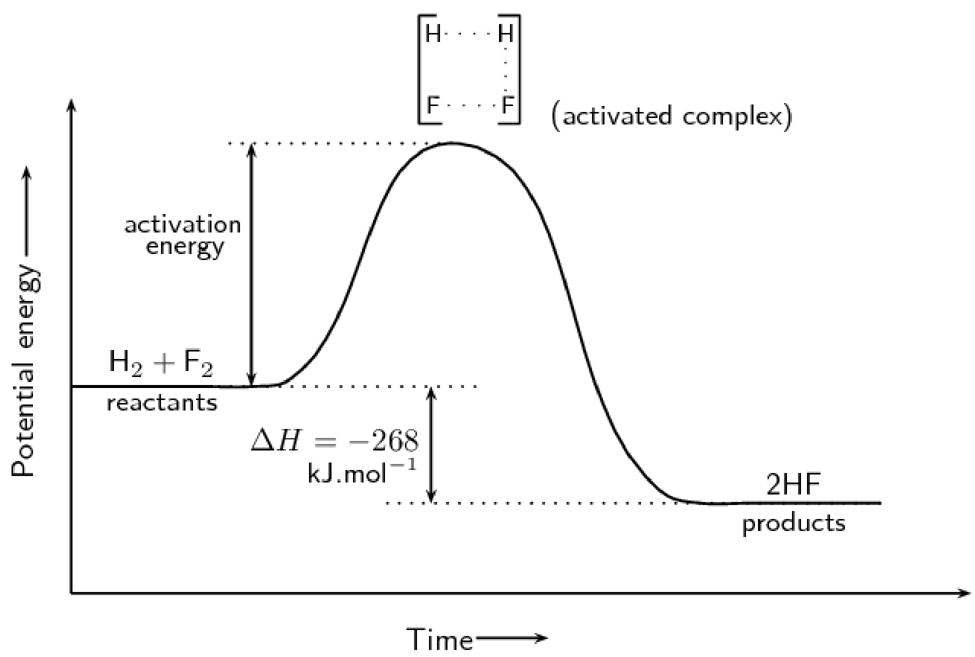
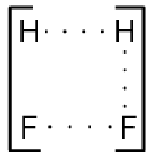


Figure 4: The energy changes that take place during an exothermic reaction.

> **TIP**
>
> The activation energy is the difference between the energy of the **reactants** and the maximum energy (i.e. the energy of the activated complex).

The reaction between $H_2(g)$ and $F_2(g)$ (Figure 4) needs energy in order to proceed, and this is the activation energy. To form the product the bond between H and H in H_2 must break. The bond between F and F in F_2 must also break. A new bond between H and F must also form to make HF. The reactant bonds break at the same time that the product bonds form.

We can show this as:



This is called the **activated complex** or transition state. The activated complex lasts for only a *very short time*. After this short time one of two things will happen: the original bonds will reform, or the bonds are broken and a new product forms. In this example, the final product is HF and it has a lower energy than the reactants. The reaction is exothermic and ΔH is negative.

FACT

The reaction between H_2 and F_2 was considered by NASA (National Aeronautics and Space Administration) as a fuel system for rocket boosters because of the energy that is released during this exothermic reaction.

The activated complex is the complex that exists as the bonds in the products are forming and the bonds in the reactants are breaking. This complex exists for a very short period of time and is found when the energy of the system is at its maximum.

TIP

Enzymes and activation energy

An enzyme is a catalyst that helps to speed up the rate of a reaction by lowering the activation energy of a reaction. There are many enzymes in the human body, without which lots of important reactions would never take place. Cellular respiration is one example of a reaction that is catalysed by enzymes. You will learn more about catalysts in Grade 12.

In endothermic reactions, the final products have a higher energy than the reactants. An energy diagram is shown below (Figure 12.5) for the endothermic reaction:

$$O_2(g) + N_2(g) \rightarrow 2NO\ (g)$$

Notice that the activation energy for the endothermic reaction is much greater than for the exothermic reaction.

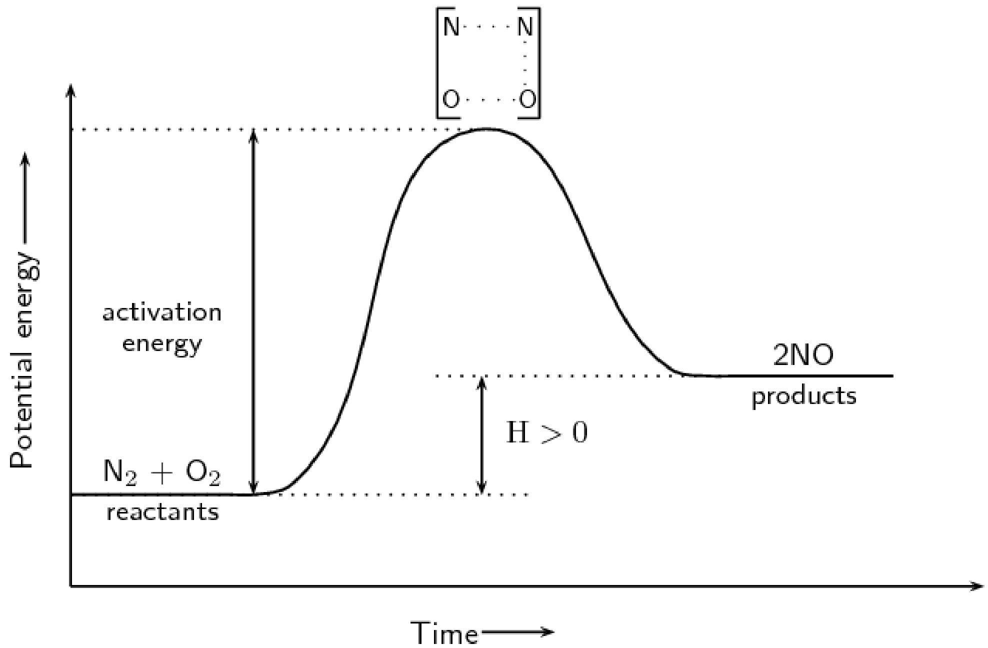


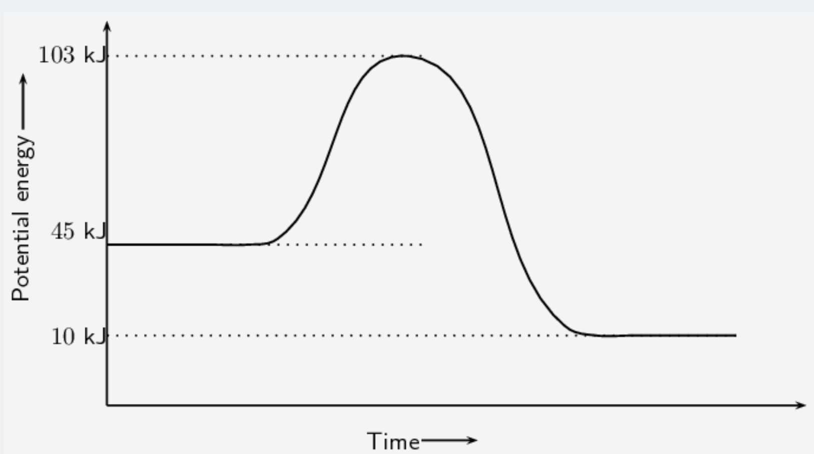
Figure 5: The energy changes that take place during an endothermic reaction.

It is because of this activation energy that we first need to show an increase in energy from the reactant to the activated complex and then a decrease in energy from the activated complex to the product. We show this on the energy graphs by drawing a curve from the energy of the reactants to the energy of the products.

WORKED EXAMPLE 1: ACTIVATION ENERGY

QUESTION

Refer to the graph below and then answer the questions that follow:



WORKED EXAMPLE 1: ACTIVATION ENERGY (continued)

1. Calculate ΔH.
2. Is the reaction endothermic or exothermic and why?
3. Calculate the activation energy for this reaction.

SOLUTION

Step 1: Calculate ΔH

ΔH is found by subtracting the energy of the **reactants** from the energy of the **products**. We find the energy of the reactants and the products from the graph.

$$\begin{aligned}\Delta \text{H} &= \text{energy of products} - \text{energy of reactants}\\ &= 10 \text{ kJ} - 45 \text{ kJ}\\ &= -35 \text{ kJ}\end{aligned}$$

Step 2: Determine if this is exothermic or endothermic.

The reaction is exothermic since $\Delta \text{H} < 0$. We also note that the energy of the reactants is greater than the energy of the products.

Step 3: Calculate the activation energy

The activation energy is found by subtracting the energy of the reactants from the energy of the activated complex. Again we can read the energy of the reactants and activated complex off the graph.

$$\begin{aligned}\text{activation energy} &= \text{energy of activated complex} - \text{energy of reactants}\\ &= 103 \text{ kJ} - 45 \text{ kJ}\\ &= 58 \text{ kJ}\end{aligned}$$

4 CHAPTER SUMMARY

- When a reaction occurs, bonds in the reactants break and new bonds in the products form. These changes involve **energy**.
- When bonds break, energy is **absorbed** and when new bonds form, energy is **released**.
- The **bond energy** is a measure of bond strength in a chemical bond. It is the amount of energy (in kJ·mol^{-1}) that is needed to break the chemical bond between two atoms.
- **Enthalpy** is a measure of the total energy of a chemical system for a given pressure and is given the

symbol H.

- If the energy that is needed to *break* the bonds is less than the energy that is released when new bonds *form*, then the reaction is **exothermic**. The energy of the products is less than the energy of the reactants.
- An **exothermic** reaction is one that **releases energy** in the form of heat or light.
- If the energy that is needed to **break** the bonds is more than the energy that is released when new bonds **form**, then the reaction is **endothermic**. The energy of the products is greater than the energy of the reactants.
- An **endothermic** reaction is one that **absorbs energy** in the form of heat or light.
- Photosynthesis and the thermal decomposition of limestone are both examples of endothermic reactions.
- Combustion reactions and respiration are both examples of exothermic reactions.
- The difference in energy between the reactants and the product is called the **heat of reaction** and has the symbol ΔH.
- ΔH is calculated using: $H = E_{\text{prod}} - E_{\text{react}}$
- In an endothermic reaction, **ΔH is a positive number** (greater than 0). In an exothermic reaction, **ΔH will be negative** (less than 0).
- Chemical reactions will not take place until the system has some minimum amount of energy added to it.
- The **activation energy** is the minimum amount of energy that is needed to start a chemical reaction.
- The **activated complex** (or transition state) is the complex that exists as the bonds in the products are forming and the bonds in the reactants are breaking. This complex exists for a very short period of time and is found when the energy of the system is at its maximum.

5 EXERCISES

5.1 Exercise 1

1. State whether energy is taken in or released in each of the following situations
   1.1 The bond between hydrogen and chlorine in a molecule of hydrogen chloride breaks
   1.2 A bond is formed between hydrogen and fluorine
   1.3 A molecule pf nitrogen N_2 is formed
   1.4 A molecule of carbon monoxide breaks apart
2. State whether the following descriptions are used to describe an exothermic or endothermic reaction

2.1 Reactants react to give products and energy

2.2 The energy must be absorbed to break the bonds in the reactants is greater than the energy that is released when products form

2.3 The energy of the products is found to be greater than the energy of the reactants for this type of reaction

2.4 Heat or light must be absorbed from the surroundings before this type of reaction takes place

5.2 Exercise 2

1. In each of these reactions, say whether the reaction is endothermic or exothermic and give a reason for your answer

   1.1 $H_2(g) + I_2(g) \rightarrow 2HI(g) + 21 kg \cdot mol^{-1}$

   1.2 $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \qquad \Delta H = -802 kg \cdot mol^{-1}$

   1.3 The following reaction takes place in a flask

   $$Ba(OH)_2.8H_2O(s) + 2NH_4NO_3(aq) \rightarrow Ba(NO_3)_2(aq) + 2NH_3(aq) + 10H_2O(l)$$

   Within a few minutes, the temperature of the flask drops by approximately $20°C$

   1.4 $2Na(aq) + Cl_2(aq) \rightarrow 2NaCl(aq) \quad \Delta H = -411 kJ \cdot mol^{-1}$

   1.5 $C(s) + O_2(g) \rightarrow CO_2(g)$

2. For each of the following descriptions, say whether the process is endothermic or exothermic and give a reason for your answer.

   2.1 evaporation

   2.2 the combustion reaction in a car engine

   2.3 bomb explosions

   2.4 melting ice

   2.5 digestion of food

   2.6 condensation

3. When you add water to acid the resulting solution splashes up. The beaker also gets very hot. Explain why.

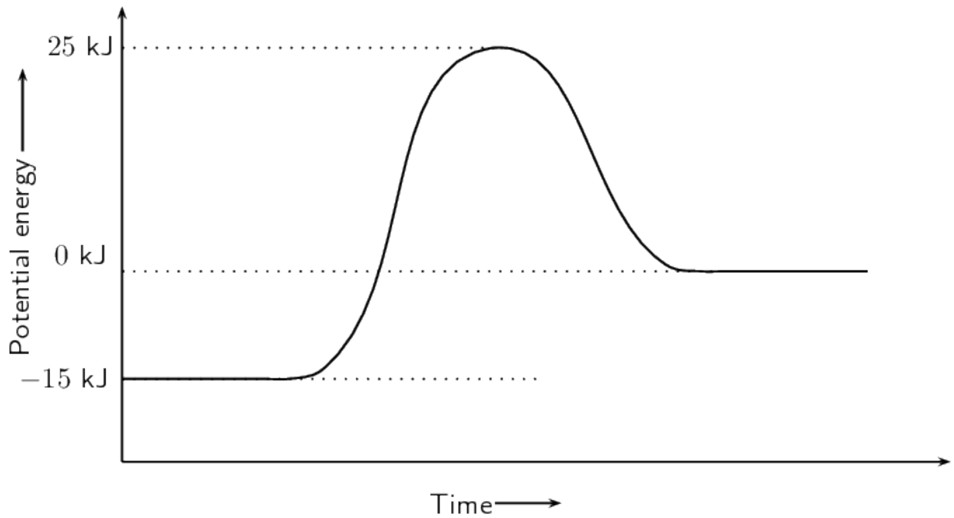
5.3 Exercise 3

1. Carbon reacts with water according to the following equation:

$$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g) \quad \Delta H > 0$$

Is this reaction endothermic or exothermic? Give a reason for your answer

2. Refer to the graph below and then answer the questions that follow:



2.1 What is the energy of the reactants?

2.2 What is the energy of the products?

2.3 Calculate ΔH.

2.4 What is the activation energy for this reaction?

6 SOLUTIONS TO EXERCISES

6.1 Exercise 1

1.1 This is bond breaking and so energy is taken in.

1.2 This is bond forming and so energy is released.

1.3 A bond is formed and so energy is released.

1.4 A bond is broken and so energy is taken in.

2.1 Exothermic

2.2 Endothermic

2.3 Exothermic

2.4 Endothermic

6.2 Exercise 2

1.1 Exothermic, energy is released

1.2 Exothermic , enthalpy is negative

1.3 Endothermic, energy is absorbed

1.4 Exothermic , enthalpy is negative

1.5 Exothermic, combustion reaction occurs

2.1 Endothermic. Energy is needed to break the intermolecular forces.

2.2 Exothermic. Energy is released.

2.3 Exothermic. In an explosion a large amount of energy is released.

2.4 Endothermic. Energy is needed to break the intermolecular forces.

2.5 Exothermic. Digestion of food involves the release of energy that your body can then use

2.6 Exothermic. Energy is given off as the particles are going from a higher energy state to a lower energy state.

3. The reaction between acid and water is an exothermic reaction.This reaction produces a lot of heat and energy which causes the resulting solution to splash

6.3 Exercise 3

1. Endothermic $\Delta H > 0$

2.1 -15 kJ

2.2 0 kJ

2.3 15 kJ

2.4 40 kJ