Metabolism and energy

Metabolism: chemical reactions in cells

Countless chemical reactions take place in cells and are responsible for all the actions of organisms. Together, these reactions make up an organism's **metabolism**. The chemicals taking part in these reactions are called **metabolites**.

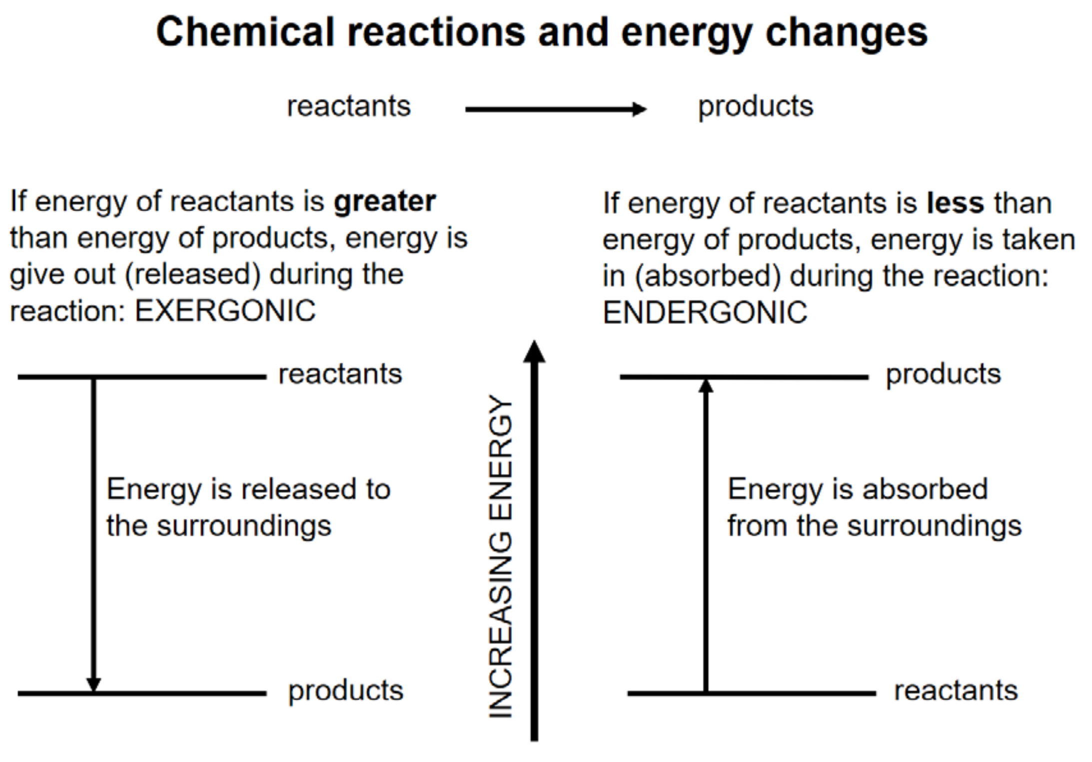
In all reactions:

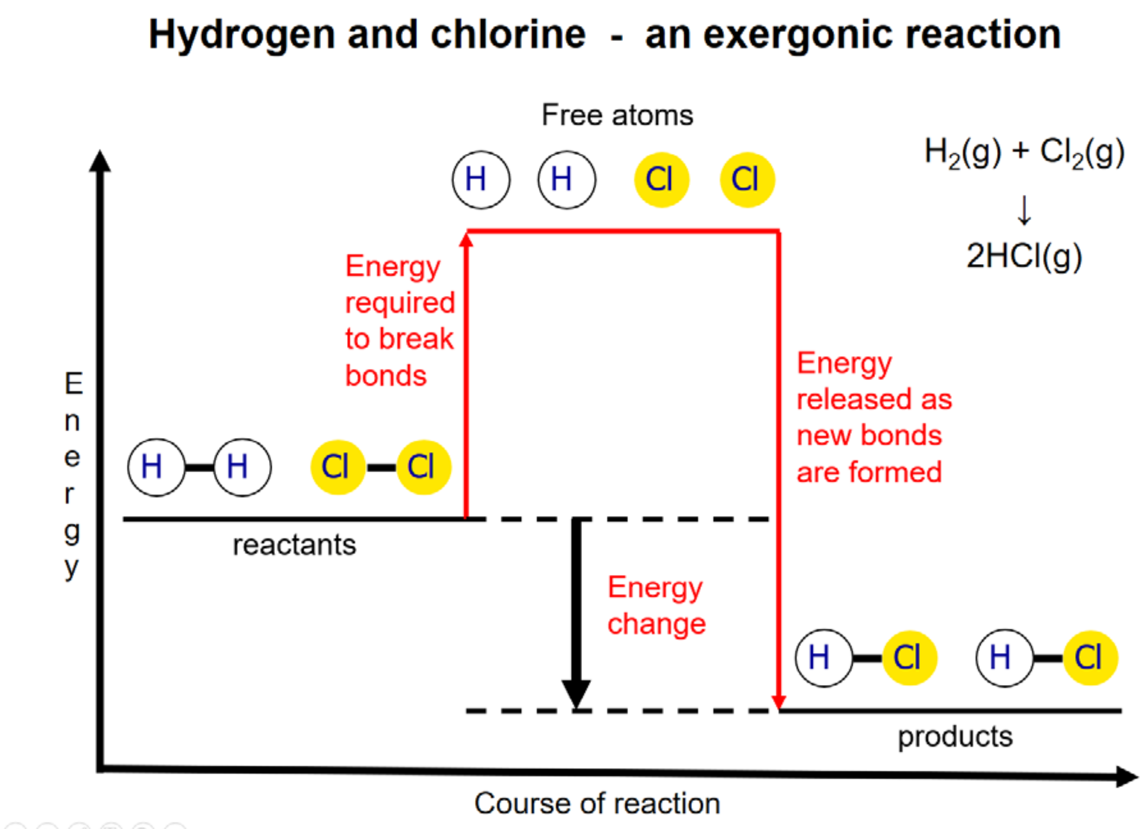
- chemical bonds in the reacting molecules are broken; this takes in energy
- new chemical bonds form to make the products; this gives out energy

When a chemical reaction takes place energy is either taken in or released. This depends on the relative strengths of bonds being broken and bonds being formed.

In an **exergonic** reaction, energy is released to the surroundings. The bonds being formed are stronger than the bonds being broken.

In an **endergonic** reaction, energy is absorbed from the surroundings. The bonds being formed are weaker than the bonds being broken.





You may also come across the terms exothermic and endothermic reactions. These describe exergonic and endergonic reactions when the energy released or absorbed is heat energy. In an exothermic reaction the temperature of the surroundings increases. In an endothermic reaction the temperature of the surroundings decreases.

Anabolism and catabolism

Two types of metabolic reactions take place in the cell: 'building up' (**anabolism**) and 'breaking down' (**catabolism**).

Anabolic reactions use up energy. They are endergonic. In an anabolic reaction small molecules join to make larger ones. For example, the following condensation reactions that occur in cells are anabolic:

- amino acids join together to make dipeptides:

  e.g. $NH_2CHRCOOH + NH_2CHRCOOH \rightarrow NH_2CHRCONHCHRCOOH + H_2O$

  and the process continues as large protein molecules are built up
- small sugar molecules join together to make dissacharides:

  e.g. $C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$

  and the process continues as large polysaccharide molecules are built up
- glycerol reacts with fatty acids to make lipids:

  e.g. $CH_2OHCH(OH)CH_2OH + C_{17}H_{35}COOH \rightarrow CH_2OHCH(OH)CH_2OOCC_{17}H_{35}$

  and the process continues as the trigyleride is produced via similar reactions with the other two hydroxyl groups of the glycerol molecule

- during photosynthesis carbon dioxide and water are used to produce glucose and oxygen:

  e.g. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Catabolic reactions give out energy. They are exergonic. In a catabolic reaction large molecules are broken down into smaller ones. For example, the reverse of the condensation reactions described above, i.e. hydrolysis reactions, are catabolic.

- A simple example of a catabolic reaction that occurs in cells is the decomposition of hydrogen peroxide into water and oxygen:

  $2H_2O_2 \rightarrow 2H_2O + O_2$
- The conversion of glucose during respiration to produce carbon dioxide and water is another common example:

  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

How chemical reactions occur

Chemical reactions that occur during metabolism are affected by temperature. Many animals maintain a constant temperature which results in relatively stable rates of metabolic reactions. Cold-blooded animals are particularly influenced by the temperature of their environment - they are livelier when warm. In the cold their metabolism slows dramatically, and this is why some cold-blooded animals hibernate. Surgery is sometimes carried at low temperatures to slow the patient's metabolic rate, for example, during operations on the heart or brain.

Molecules move and collide

Molecules are constantly moving. Their bonds vibrate and rotate. In gases, liquids and solutions molecules move around, bumping into one another. When molecules collide there is the possibility of a reaction taking place, but only if the colliding molecules:

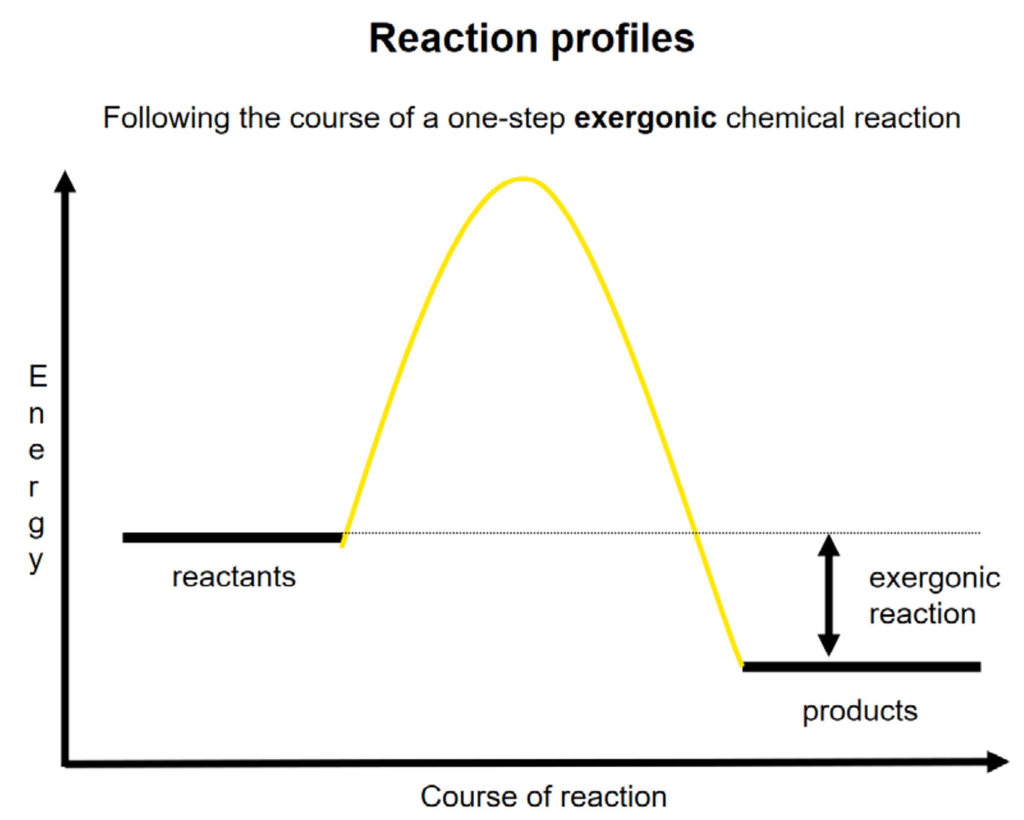
- have enough energy
- are aligned correctly

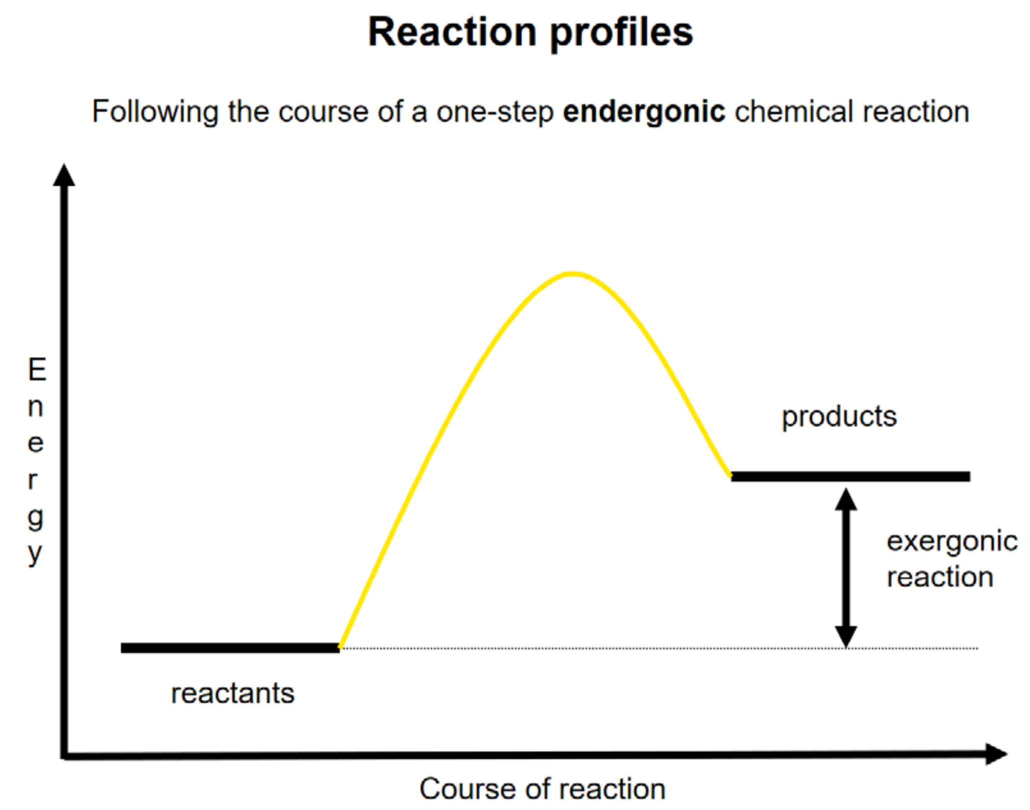
The more collisions there are between molecules with sufficient energy and correct alignment, the faster the reaction takes place. This is called **collision theory**.

- The more molecules present, the faster the reaction. Therefore reactions take place faster in concentrated solutions than in solutions that are more dilute.
- At high temperatures molecules have more energy than at lower temperatures. Therefore collisions are more frequent and the likelihood of the molecules having enough energy is greater. Consequently the rate of chemical reactions increases with increasing temperature.

Activated complexes and activation energy

Some reactions take place in a single step. We can represent this using an **energy profile**.
An **activated complex** (or **transition state**) forms between reactant and product. This is not a 'real' substance in the sense that it can be isolated and put in a test tube. But based on various pieces of experimental evidence it is the chemist's model of how the reaction occurs. The energy 'hump' shows how much energy reacting molecules must have for a 'successful' collision, i.e. one that leads to reaction. The formation of an activated complex requires energy to bring molecules together in the correct orientation. Therefore, it is always an endergonic reaction. The energy required is called the **activation energy** (E_a).

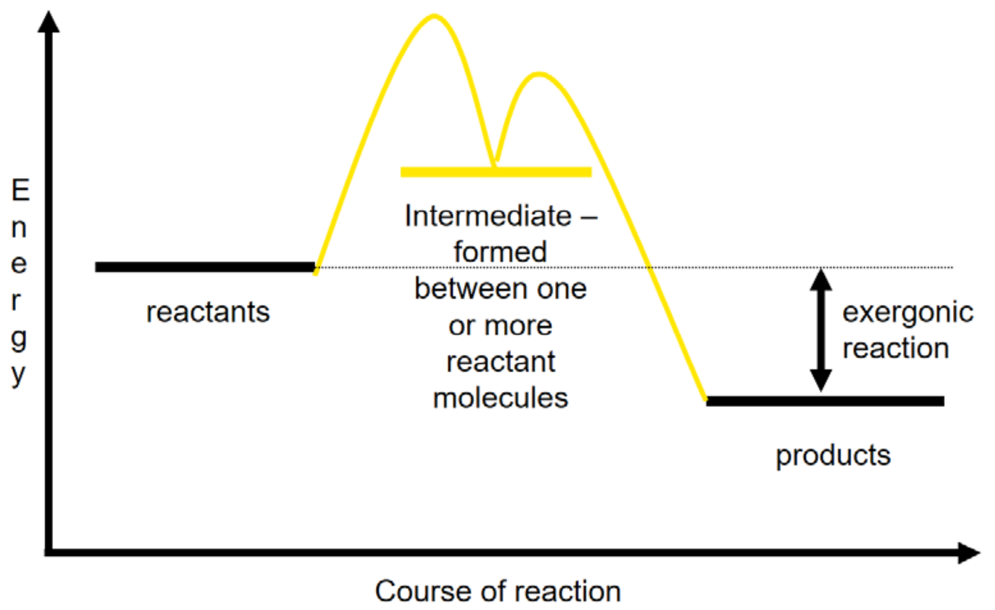




It is more common for reactions between molecules to take place in a series of consecutive steps. After each step a **reaction intermediate** forms. Unlike an activated complex this has a real existence. For each step an activated complex is formed and there is an associated activation energy. The step with the highest activation energy is the **rate-determining step** in the reaction and controls how fast the overall reaction is.

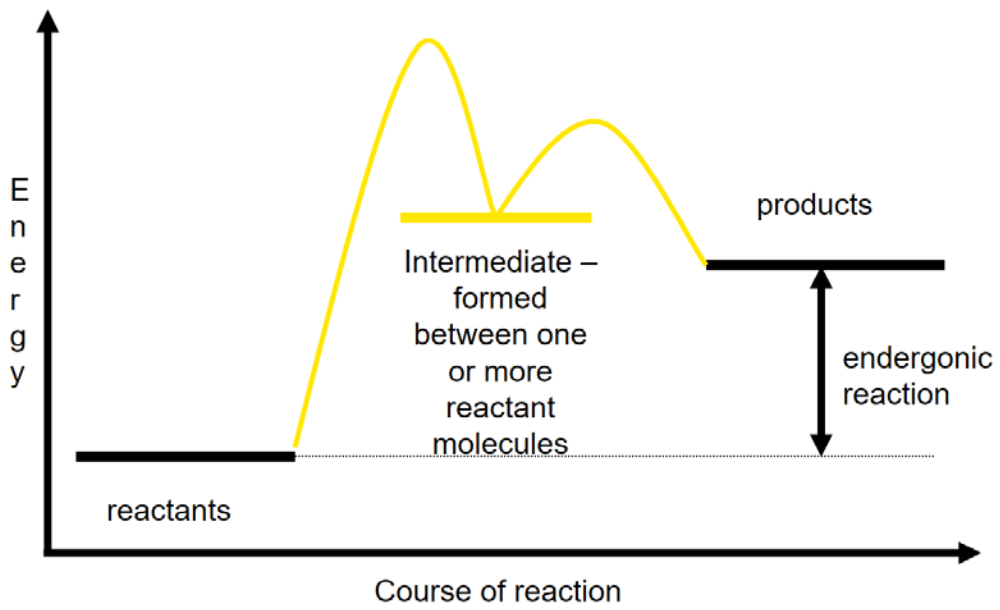
Reaction profiles

Following a the course of a two-step **exergonic** chemical reaction



Reaction profiles

Following a the course of a two-step **endergonic** chemical reaction



Catalysts

In chemical factories high temperatures and pressures are often used. However, this energy costs money. Catalysts make chemical reactions go more quickly and their use in the chemical industry saves time and money.

Cells are extremely sensitive to temperature and pressure. Catalysts are essential to make sure metabolic reactions take place under conditions the cell can withstand. Enzymes are nature's catalysts.

> See the topic about Enzymes

Test your knowledge

Take quiz on *Metabolism and energy*