50 Energy Profile Diagrams

Energy profiles are diagrams that show the changes in energy levels during reactions. They illustrate the chemical energy present in the reactants and in the products at the beginning, during and end of chemical reactions.

The total energy in a chemical system is called its **enthalpy** and the symbol that is used for this is *H*. We cannot measure enthalpy directly, but we can measure how enthalpy changes during a chemical reaction. The symbol for **change in enthalpy** is ΔH. The change in enthalpy (ΔH) is the difference between the energy of the reactants and the products. In other words it is the net energy released to or taken from the environment.

An energy profile diagram is based on the enthalpy before and after a chemical reaction. From an energy profile you can see at a glance how much energy is needed to get the reaction started (its activation energy) and also whether energy has been taken in (an endothermic reaction) or released to the environment (an exothermic reaction).

To illustrate this we will look at a profile for an exothermic chemical reaction and for an endothermic chemical reaction.

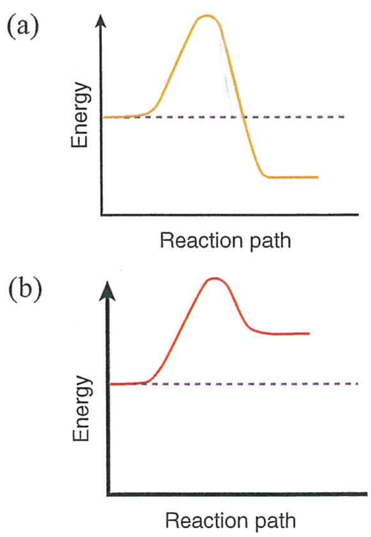


Figure 50.1 Examples of energy profiles

These diagrams illustrate energy changes in two different chemical reactions. In this example, they both start with the same level of energy. They both show increases in energy level of the chemicals during the reaction. But they end differently. In (a) the energy level of the chemicals is lower at the end of the reaction. In (b) the energy level of the chemicals is higher at the end of the reaction. One of these reactions is an exothermic reaction and the other is endothermic. See if you can work out which is which.

Now let's look at an exothermic and an endothermic reaction profile in more detail.

Energy profile for exothermic reaction

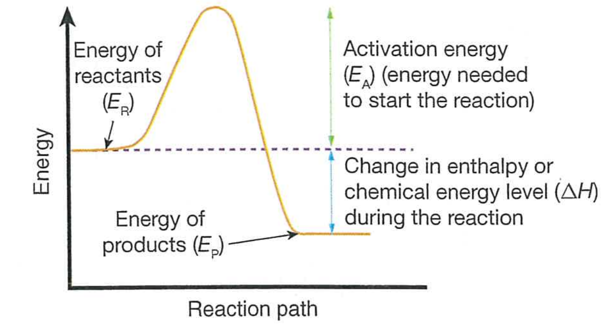


Figure 50.2 Energy profile for an exothermic reaction.

Notice the following for an exothermic reaction.

- The **products have less energy locked inside them than the reactants.** E_P is lower on the graph than E_R.
- The **energy level has dropped** during the reaction, so the change in enthalpy is said to be negative ($-\Delta H$).
- Once the activation energy is overcome, the **reaction will produce energy and maintain itself** without further energy input. For example, once you light a piece of paper with a match, it will then keep burning without the match being there.
- The **ignition temperature for a combustion reaction** is a measure of the **activation energy** (E_A). How high the graph reaches up indicates the energy needed to start the reaction and therefore how high the ignition temperature will be for a combustion reaction.

Most of the reactions you have carried out have been exothermic reactions and they have energy profiles shaped like the one above. **Examples** include all combustion reactions, the reaction of acids with metals and neutralisation reactions.

When exothermic chemical reactions take place, the **container becomes hot**. The reaction has released some of the energy that was formerly locked in the reacting chemicals. The products now have less total energy than the reactants.

Energy profile for endothermic reaction

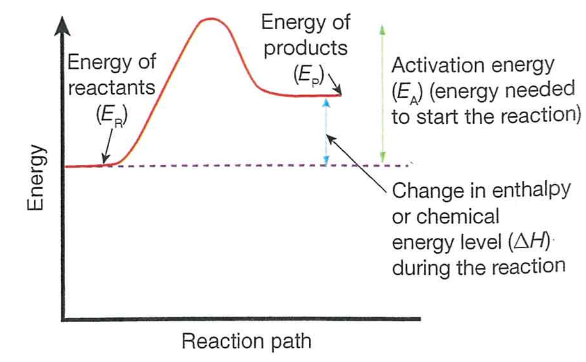


Figure 50.3 Energy profile for an endothermic reaction.

Notice the following for an endothermic reaction.

- The products have more energy than the reactants (E_P is higher on the graph than E_R).
- The energy level has increased, so the change in enthalpy is said to be positive ($+\Delta H$). Energy must have come from the environment and gone into the chemicals to raise the total energy content.
- Constant energy input is needed to maintain these reactions.

Some **examples of endothermic reactions** are:

- The decomposition of water by electrolysis.

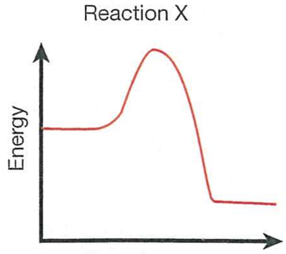
  $2H_2O(l) + \text{energy} \rightarrow 2H_2(g) + O_2(g)$
- The decomposition of molten or aqueous sodium chloride by electrolysis.
- The decomposition of copper carbonate by heat.

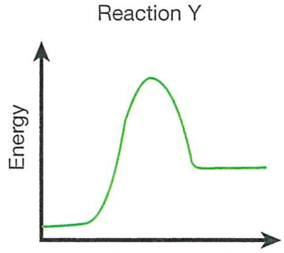
  $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$

Energy has to be constantly supplied for these reactions to take place, so in each case, the energy of the products is greater than the energy of the reactants.

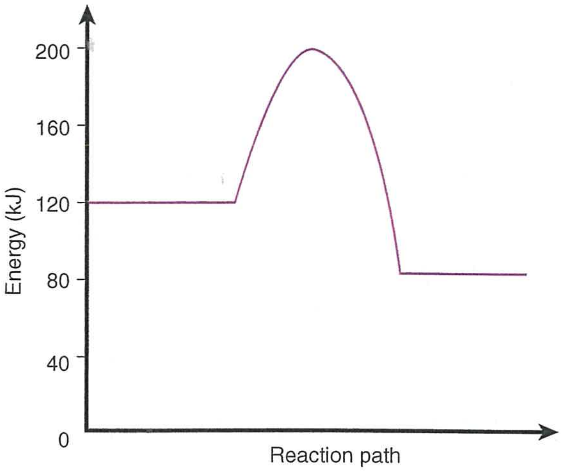
QUESTIONS

1. Explain what is meant by the following symbols and terms related to an energy profile.
   (a) E_P
   (b) E_R
   (c) E_A
   (d) ΔH
   (e) Activation energy.
   (f) Ignition temperature.
2. Two chemical reactions essential for life on Earth are respiration and photosynthesis.
   (a) Write an equation for respiration. Is this reaction exothermic or endothermic? Justify your answer.
   (b) Write an equation for photosynthesis. Is this reaction exothermic or endothermic? Justify your answer.
3. The following diagrams show energy profiles for two reactions, one of which is endothermic and the other exothermic.





   (a) Identify each reaction as exothermic or endothermic. Justify your answers.
   (b) For each of these reactions, label the activation energy and enthalpy change.
   (c) For which reaction, (a) or (b), will ΔH be negative?
4. A few crystals of sodium thiosulfate are placed in a test tube. Water is added and the test tube gently shaken. The test tube feels very cold. Explain.
5. The following diagram represents energy changes during a chemical reaction.

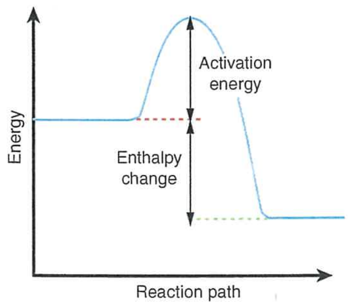


   From this energy profile, determine the following.
   (a) The activation energy for this reaction.
   (b) The change in enthalpy for the reaction.
   (c) Is this reaction endothermic or exothermic?
6. (a) Sketch energy profile diagrams to distinguish between a fuel with a high ignition temperature such as methane (ignition temperature 630°C) and a fuel with a lower ignition temperature such as petrol (ignition temperature 390°C).
   (b) If petrol were combusted in a limited supply of oxygen, how would its energy profile diagram differ?
7. Research the use of an exothermic reaction in commercial cold packs.
8. Check your knowledge with this quick quiz.
   (a) Reactions which release energy to the environment are referred to as .... reactions.
   (b) Combustion reactions are always (endothermic/exothermic).
   (c) Identify the symbol for energy change in a reaction.
   (d) Enthalpy change in an exothermic reaction is always (positive/negative).
   (e) If an equation is followed by the expression $\Delta H = -90$ kJ, what does this mean?

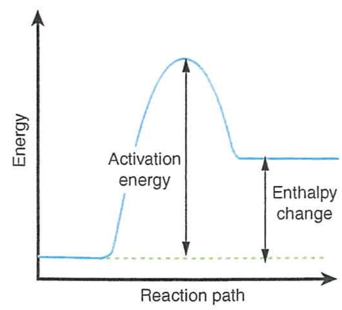
4. Endothermic reactions are ones in which more energy is required to break bonds than is released by bond formation. Energy must be continuously supplied to keep the reaction going.
Exothermic reactions are ones in which more energy is released when bonds form that is needed to break the existing bonds. Once started, the reaction will keep going, without any more energy input being needed and excess energy will be released to the environment.
5. (a) Activation energy.
(b) High.
(c) Does not.
(d) Fewer.

50 Energy Profile Diagrams

1. (a) E_P – The chemical energy present in the products of a chemical reaction.
(b) E_R – The energy present in the reactants of a reaction.
(c) E_A – The activation energy of the reaction, i.e. the energy needed to start a reaction.
(d) ΔH – The enthalpy or energy change during a reaction.
(e) Activation energy of the reaction (same as (c)). This is the enthalpy or energy needed to start a chemical reaction.
(f) Ignition temperature – the temperature at which a substance will start burning without a spark or flame.
2. (a) $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g) + \text{energy}$
Respiration is an exothermic reaction which occurs in the cells of living things. Glucose undergoes slow combustion producing carbon dioxide and water vapour and releasing the chemical energy which was stored in the glucose molecules. The products have less energy than reactants as energy is given out during reaction.
(b) $6CO_2(g) + 6H_2O(g) + \text{energy} \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$
Endothermic – During photosynthesis, solar energy is used to make carbon dioxide and water react. The products formed are glucose and oxygen. The solar energy is not lost; it is changed to chemical energy and stored as part of the glucose molecule. The products have more energy than the reactants because light is absorbed during the reaction.
3. (a) X – exothermic – the products have less energy than the reactants.
Y – endothermic – the products have more energy than the reactants.
(b) Reaction X

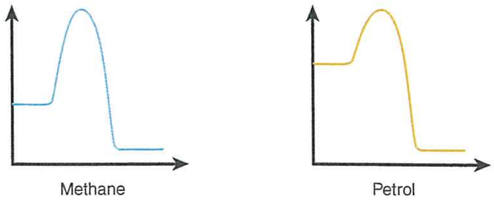


Reaction Y



(c) Reaction X.
4. The dissolution reaction is endothermic; heat is taken from surroundings into the chemicals reacting.
5. (a) 80 kJ
(b) −40 kJ
(c) Exothermic.

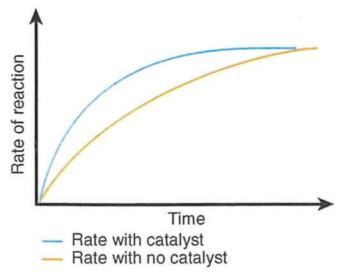
6. (a)



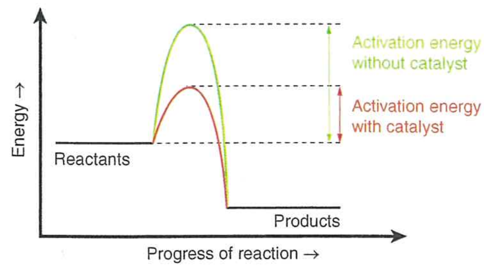
(b) E_R (energy of reactants) and E_A (activation energy) would be the same but the change in enthalpy ΔH would be less.
7. Endothermic reactions also occur in cold packs that you buy from the chemist. When you need a cold pack you squeeze the container. This breaks the bag inside allowing two chemicals to mix, e.g. ammonium nitrate and water. The endothermic reaction between these chemicals absorbs heat from the surroundings and cools the pack.
8. (a) Exothermic.
(b) Exothermic.
(c) ΔH.
(d) Negative.
(e) 90 kJ of energy is released by the equation as written, i.e. it is exothermic.

51 Reaction Rate and Catalysts

1. (a) A catalyst is a substance that changes the rate of a chemical reaction without being used up by the reaction.
(b) A catalyst can speed up a reaction by providing an alternative pathway for the reaction that needs a lower activation energy. This increases the proportion of collisions that have sufficient kinetic energy for reaction to occur – this increases the reaction rate.
(c) The catalyst increases the rate at which product(s) form, producing it more quickly, but it has no effect on the amount of product(s).
2.



3.



4. (a) Catalysts are used in industry to speed up the rate of a chemical reaction and the end point may be reached sooner. They may provide an alternative pathway for the reaction and/or lower the activation energy of the reaction. One example is the use of platinum to catalyse the hydrogenation of vegetable oils to manufacture margarine.
(b) Various. Some people act as a catalyst in a social setting. Their presence seems to encourage others to argue or fight. They do not take part in the fight themselves, but their presence promotes it and makes it more likely to happen. They may be like most catalysts in that they seem to make it easier for many people to argue, or they could be like enzymes in that they only promote fighting between particular people.
You could use a role play to model this.
From your reading about catalysts, see if you can think of other ways to model this process.