# Chapter 10
## *Energy in Chemical Reactions*

NCEA Level 3 Chemistry material covered in this chapter is for Achievement Standard 90780 (Chemistry 3.4), ‘Describe properties of particles and thermochemical principles’ through:

- Definition of the terms $\Delta_c H°$, $\Delta_f H°$ and $\Delta_r H°$.
- Transfer of heat between the system and surroundings, and use of specific heat capacity.
- Hess’s Law including application of $\Delta_r H° = \Sigma\Delta_f H°(\text{products}) - \Sigma\Delta_f H°(\text{reactants})$.
- Use of average bond enthalpies in enthalpy change calculations.



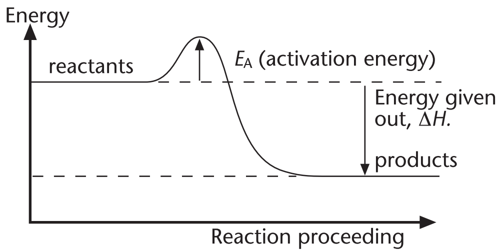
## Change in Enthalpy, $\Delta H$

Chemical reactions involve changes in energy, eg heat energy (**enthalpy**, ***H***). $\Delta H$ refers to a *change* in enthalpy.

## Exothermic and Endothermic Reactions

Negative values for $\Delta H$ signify an **exothermic** reaction:

- Energy is released to the environment.
- More energy is given out by bonds forming (in the products) than is taken in to break the bonds (in the reactants).

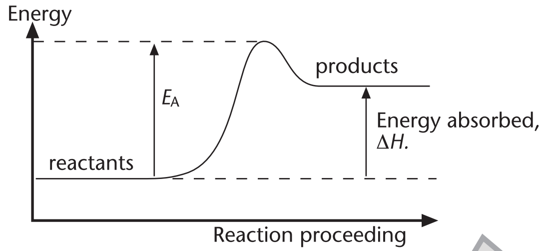



Overall, energy is **released** because more energy is given out by the bonds in the products forming than is taken in by the reactant bonds breaking.

***Fig. 10.1:*** *Reaction profile for an exothermic reaction.*

Positive values for $\Delta H$ signify an **endothermic** reaction:

- Energy is absorbed from the environment.
- More energy is needed to break bonds (in the reactants) than is given out by bonds forming (in the products).




Overall, energy is **absorbed** because more energy is needed to break the bonds in the reactants than is given out by the new bonds forming.

***Fig. 10.2:*** *Reaction profile for an endothermic reaction.*



In catalysed reactions, overall enthalpy changes are the same as for uncatalysed reactions. It is the reaction pathways that are different.

## Catalysts and Activation Energy

Catalysts are substances which change the **rate** of a chemical reaction without themselves being used up.

While catalysts are usually used to increase the rate of a reaction, some catalysts are used to inhibit or slow reactions down. Catalysts work by providing an alternative reaction pathway of lower (or higher) **activation energy**, $E_A$, where $E_A$ is the amount of energy needed to initiate a chemical reaction.

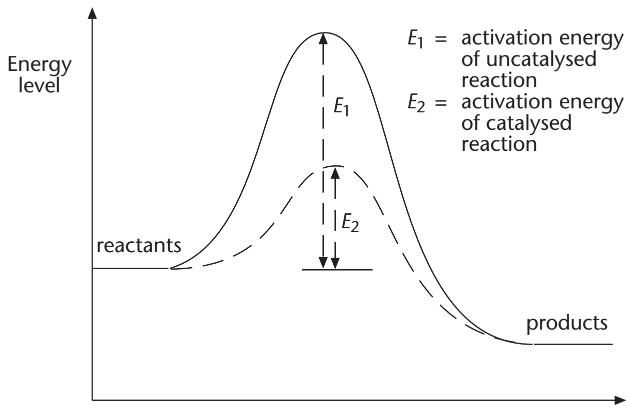



***Fig. 10.3:*** *Effect of catalyst on activation energy.*

When the activation energy is reduced in the presence of a catalyst, a greater proportion of reactant particles will have a higher kinetic energy than the activation energy. This means that more molecules have the energy required to take part in a given reaction. Hence, the reaction will proceed at a faster rate.

## *Activity 17D: Proteins*

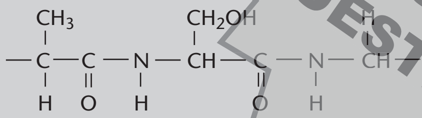


**1**. Describe the relationship between proteins, amino acids, polypeptides and dipeptides.

**2**. Draw the structural formulae for the two possible dipeptides formed from aminoethanoic acid (glycine, $H_2NCH_2COOH$) and 2-aminopropanoic acid (alanine, $CH_3CH(NH_2)COOH$).

**3**. Explain why it is impossible to draw a repeating unit for a protein.

**4**. A portion of a protein molecule is drawn below:



Hydrolysis of the portion shown will yield three amino acids: glycine, alanine and serine.

**a**. Explain what is meant by the term 'hydrolysis'.

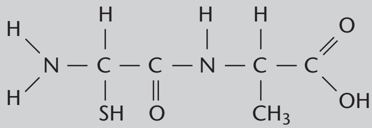
**b**. Give one condition under which hydrolysis of the protein could occur.

**c**. Draw the structure and name the amino acid containing the hydroxyl group.

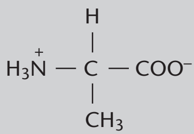
**5**. Draw the structures of the two amino acids formed when the dipeptide drawn below is hydrolysed under:

**a**. Acidic conditions.

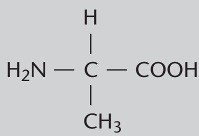
**b**. Basic conditions.



**6**. Explain why the structure of 2-aminopropanoic acid is more correctly drawn as shown below (as a zwitterion).



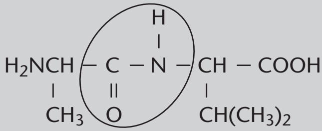
**7**. Alanine has the structure



**a**. Draw a box around the group of atoms that causes the amino acid to behave as a base.

**b**. Electrophoresis is a process by which different amino acids can be separated using an electric field. In acidic conditions, the amino acid forms an ion that will move to the negative electrode. In basic conditions, the amino acid forms another ion that will move toward the positive electrode. Explain how the conditions described above give rise to the two ions that will move towards the two different electrodes.

**c**. Alanine reacts with amino acid B to form the following compound




**i**. Name the link circled in the structure above.

**ii**. Draw the structure of amino acid B.

**8**. Aqueous hydrochloric acid, HCl, and aqueous sodium hydroxide are used to hydrolyse peptide links.

**a**. Acid hydrolysis using HCl(aq) of the peptide link in N-methylethanamide, $CH_3CONHCH_3$, produces a carboxylic acid and methylammonium chloride, $CH_3NH_3Cl$. Give a balanced equation for the reaction.

**b**. Give the balanced equation for the basic hydrolysis of N-methylethanamide, $CH_3CONHCH_3$.

## *Activity 3C: Calculating $E^0_{cell}$ values*

**1**. **a**. **i**. +0.62 V **ii**. +1.17 V **iii**. +1.24 V **iv**. +1.30 V (***A***)

**b**. **i**. $Sn^{2+} + Zn \longrightarrow Sn + Zn^{2+}$

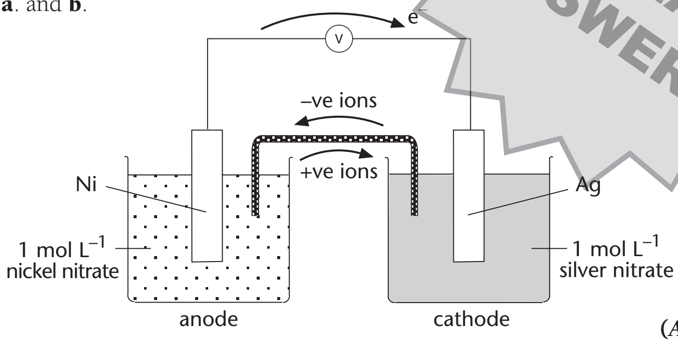
**ii**. $5Cu + 2MnO_4^- + 16H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 5Cu^{2+}$

**iii**. $2Ag^+ + Fe \longrightarrow Fe^{2+} + 2Ag$

**iv**. $Zn + I_2 \longrightarrow Zn^{2+} + 2I^-$ (***A***)

**2**. + 0.81 V (***A***)

**3**. **a**. and **b**.




(***A***)

**c**. $E^0_{cell}$ = +1.04 V (***A***)

**4**. **a**.

| Cell | Strongest oxidant | Strongest reductant |
|---|---|---|
| i. | $Ag^+$ | Zn |
| ii. | $Fe^{3+}$ | Sn |
| iii. | $MnO_4^-$ | $Cl^-$ |

(***A***)

**b**. **i**. $Ag^+ + e^- \longrightarrow Ag$ and $Zn \longrightarrow Zn^{2+} + 2e^-$

**ii**. $Fe^{3+} + e^- \longrightarrow Fe^{2+}$ and $Sn \longrightarrow Sn^{2+} + 2e^-$

**iii**. $2Cl^- \longrightarrow Cl_2 + 2e^-$ and $MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$ (***A***)

**c**. **i**. $2Ag^+ + Zn \longrightarrow Zn^{2+} + 2Ag$

**ii**. $2Fe^{3+} + Sn \longrightarrow Sn^{2+} + 2Fe^{2+}$

**iii**. $10Cl^- + 2MnO_4^- + 16H^+ \longrightarrow 2Mn^{2+} + 8H_2O + 5Cl_2$ (***A***)

**d**. **i**. $E^0_{cell}$ = +0.80 V – (–0.76 V) = +1.56 V

**ii**. $E^0_{cell}$ = +0.77 V – (–0.14 V) = +0.91 V

**iii**. $E^0_{cell}$ = 1.51 V – 1.36 V = +0.15 V (***M***)

**e**. **i**. $Zn(s)Zn^{2+}(aq) \,||\, Ag^+(aq) \,|\, Ag(s)$

**ii**. $Sn(s) \,|\, Sn^{2+}(aq) \,||\, Fe^{3+}(aq),Fe^{2+}(aq) \,|\, Pt(s)$

**iii**. $Pt(s) \,|\, Cl^-(aq),Cl_2(aq) \,||\, MnO_4^-(aq),Mn^{2+}(aq) \,|\, C(s)$ (***A***)

**5**. **a**. In order of decreasing reactivity: B, A, C, D. The most reactive metal will have the most negative reduction potential (strongest reductant). (***M***)

# Glossary/Index



**acetaldehyde** (181): common, non-systematic name for ethanal, $CH_3CHO$.

**acetone** (182): common, non-systematic name for propanone, $CH_3COCH_3$.

**acid** (**Brønsted**) (245): a species that is able to donate a proton (to a base).

**acid dissociation constant, $K_a$** (252): the equilibrium constant for the dissociation of a weak acid in which the concentration of water is considered as constant; also known as dissociation constant and acidity constant.

**acid-base titration** (283): see *titration*.

**acidic** (249): neutralises bases or alkalis.

**acidic oxides** (43): any oxide which reacts with a basic solution but not with an acidic solution.

**acidic salt** (266): salt that contains an ion that reacts with water to form $H_3O^+(aq)$.

**acidity constant** (252): see *acid dissociation constant*.

**activation energy, $E_A$** (88, 116, 228): the minimum amount of energy needed for a reaction to occur; has the symbol, $E_A$.

**addition polymers** (207): polymers formed by addition reactions.

**addition reactions** (151): reactions in which the parts of a small molecule such as hydrogen chloride are added across a double (or triple bond) in an organic compound.

**alcohols** (157): a homologous series with a hydroxyl group, –OH, attached to one of the carbon atoms; systematic IUPAC name, alkanols.

**aldehydes** (163, 181): a homologous series with a terminal –CHO group; systematic IUPAC name, alkanals.

**alkali** (247): a base that is soluble in water.

**alkaline** (247): a solution with pH greater than 7; may also be referred to as a basic solution.

**alkanals** (181): systematic IUPAC name for aldehydes, R–CHO.

**alkanamides** (200): see *amides*.

**alkanes** (138): a homologous series containing only carbon and hydrogen atoms joined by single bonds only.

**alkanols** (157): systematic IUPAC name for alcohols, R–OH.

**alkanoyl chloride** (190): systematic IUPAC name for the acid chlorides, RCOCl.

**alkenes** (147): a homologous series containing at least one carbon-to-carbon double bond (C=C).

**alkyl group** (138, 140): a group of carbon and hydrogen atoms eg methyl $CH_3$– and ethyl $C_2H_5$– that can be represented by R, R' or R".

**alkyl halide** (169): see *haloalkanes*.

**allotrope** (107): different physical forms of the same element.

**amides** (190): a homologous series containing the amide functional group, $–CONH_2$, –CONH– or –CON(R)–; systematic IUPAC name, alkanamides.

**amines** (175): a homologous series containing the amine functional group eg $RNH_2$, RNHR', group, RN(R")R'; systematic IUPAC name, aminoalkanes.

**amino acids** (203): monomer units for proteins containing both a carboxylic acid group, –COOH, and an amine group, $–NH_2$.