# 4.2 Covalent Bonding

## Single Covalent Bonds

- Involves the sharing of one or more pairs of electrons so that each atom in the molecule achieves an inert gas configuration
- The two electrons in a hydrogen molecule  $(H_2)$  are shared between the two atoms to form a molecule
- When one pair of electrons is shared the resulting bond is known as a single covalent bond

## Lewis Structures

- In the Lewis structure all the valence electrons are shown
- Single Covalent Bonds:
- **Multiple Covalent Bonds:** 
  - In atoms some compounds can share more than one pair of electrons to achieve an 0 inert gas configuration

## Co-Ordinate (Dative) Bonds

The electrons in the shared pair may originate from the same atom \_

## Bond Length and Bond Strength

- CO.UN Reflectrons affects both the The strength of attraction that the two nuclei have for the 👧 length and strength of the bond
- Double bonds are generally much strenge s ne bonds
- Triple bonds are generally much stronger and shorter than thuse bonds

## Bond

- In diatomic molecules containing the same element the electron pair will be shared equally as both atoms exert an identical attraction
- When the atoms are different, the more electronegative atom exerts a greater attraction for the electron pair
- One end of the molecule will thus be more electron rich than the other end, resulting in a polar bond
- The bigger the difference in electronegativity values, the more polar the bond

# 5.2- ∆H Calculations

## Calculation of Enthalpy Changes

- The heat involved in changing the temperature of any substance can be calculated from the equation: Heat energy (Q) = Mass (m) x Specific Heat Capacity (c) x Temperature Change ( $\Delta T$ )
- The specific heat capacity of water is *4.18kJkg*<sup>-1</sup>*K*<sup>-1</sup>, that is, it requires 4.18 kilojoules of energy to raise the temperature of one kilogram one water by one kelvin



# 5.6 Spontaneity of a Reaction

## Possible Combinations for Free Energy Change

Туре	ΔH <sup>ø</sup>	ΔS <sup>ø</sup>	TΔS <sup>ø</sup>	ΔΗ <sup>ø</sup> - ΤΔS <sup>ø</sup>	ΔG <sup>ø</sup>
1	0	+	+	0 - +	-
2	0	-	-	0	+
3	-	+	+	+	-
4	+	-	-	+	+
5	+	+	+	+ - +	-or+
6	-	-	-		+ or -



## 6.1-Rates of Reaction and Collision Theory

## Rate of Reaction

- Chemical kinetics is the study of the factors affecting the rate of a chemical reaction
- Reaction Rate: the increase in the concentration of one of the products per unit time or the decrease in the concentration of one of the reactants per unit time (mol dm<sup>-3</sup> s<sup>-1</sup>)
- The change in concentration can be measured by using any property that differs between the reactants and the products
- When the concentration of the reactant/product is graphed, the rate at any given moment in time is the gradient of the graph at that point in time
- Rates of reaction usually decrease with time as the reactants are used up

## Maxwell-Boltzmann Distribution

- The moving particles in a liquid or gas do not all trave with the same velocity
- The faster they move the more kinetic energy they possess \_
- The Maxwell-Boltzmann Distribution illustrates the distribution of the kinetic energies of \_ particles
- As the temperature increases the area under the curve does not change as the total number of particles remains constant
- However more particles have a higher average kinetic energy which leads to a treat ening of the curve The peak of the curve shifts to the right and decreases innegation

## Collision Theory

- For a reaction to occur th
- iditions must be met 6 The particles must collide they must collic pit the ppropriate geometry or orientation so that the respective parts of the particles come into contact with each other  $\circ$   $\;$  They must collide with sufficient energy to bring about the reaction
- Activation Energy: the minimum amount of energy required for a reaction to occur
- Any factor which either increase the frequency of the collisions or increases the energy with which they collide will make the reaction go faster

# 9.1 Redox Reactions

## Definitions of Oxidation and Reduction

- Oxidation: the loss of one or more electrons from a substance
- Reduction: the gain of one or more electrons
- Since the processes involve the transfer of electrons oxidation and reduction must occur simultaneously
  - Such reactions are known as redox reactions

## Rules for Determining Oxidation Numbers

- Useful tools to identify which species have been oxidised and which reduced
- 1. In an ionic compound between two elements the oxidation number of each element is equal to the charge carried by the ion
  - a. NaCl = 0: Na = +1, Cl = -1
- 2. For covalent compounds assume the compound is ionic with the more electronegative element forming the negative ion
  - a. CCl<sub>4</sub>: C = +4, Cl = -1
- 3. The algebraic sum of all oxidation numbers in a compound is equal to zero
  a. CCl<sub>4</sub> = 0: C = +4, 4 x Cl = -4
- 4. The algebraic sum of all the oxidation numbers in an in  $SO_4^{2-} = -2$ : S = +6, 4 x O = -8
- 5. Elements not combined with other clements have an exidet in number of zero a.  $O_2 = 0$
- 6. Oxygen what combined always has possible number of -2 except in peroxides  $(H_2O_2)$
- 7. Hydrogen when combined always has an oxidation number of +1 except in metal hydrides (NaH) where it is -1
- Many elements show different oxidation numbers in different compounds
- When elements show more than one oxidation state the oxidation number is represented by using Roman numerals when naming the compound

## Oxidation and Reduction in Terms of Oxidation Numbers

- When an element is oxidised its oxidation number increases
- When an element is reduced its oxidation number decreases
- The change in oxidation number will be equal to the number od electrons involved in the half equations
- Reactions where an element is uncombined on one side of the equation and combined on the other side must be redox reactions since there must be a change in oxidation number

## Oxidizing Agents and Reducing Agents

- A substance that readily oxidizes other substances is known as an oxidizing agent

- Oxidizing agents readily accept electrons
- Reducing agents readily donate electrons



# 9.2 Reactivity Series

## Reactivity

- Reactivity with water decreases down group 1
- In all of these reactions the metal is losing electrons
  - It is being oxidized and in the process it is acting as a reducing agent
- A reactivity series of reducing agents can be deduced by considering the reactivity of metals with water and acids
- The more readily the metal losses its outer electrons the more reactive it is
- Metals higher in the series can displace metal ions lower in the series from the solution
- The series can be extended for oxidizing agents, the most reactive oxidising agent will be the species that gains electrons the most readily
- Oxidising agents lower in the series gain electrons from species higher in the series

## Simple Voltaic Cells

- A half-cell is simply a metal in contact with an aqueous solution of its own ions
- Voltaic cells consist of two half-cells, connected together to enable the electrons transferred during the redox reaction to produce energy in the form of electricity
- Connected by an external wire and a salt bridge which allows free movement of iots
- The electrons will flow from the metal which is higher in the reactivity series to the me which is lower
- The voltage produced by a voltaic cell depends on the restrict difference between the two metals in the reactivity series
  - $\circ$  The greater the difference the greater the voltage produced
- In a voltaic cell:

• The arrive V che negative electrode where oxidation occurs • The cathode is the postion electrode where reduction occurs

## 10.2 Properties of Different Functional Groups

## **Boiling Points**

- As the carbon chain gets longer the mass of the molecules increases and the van der Waals forces increase
- The boiling point hence increases as the carbon chain gets longer
- When branching occurs the molecules become more spherical in shape which reduces the contact surface area between them and lowers the boiling point
- Volatility of the compounds follows the same pattern
- -Lower members of the alkanes are all gases as the attractive forces are weak and the next few members are volatile liquids
- As the carbon chain increases in length the alcohols have lower volatility

## Solubility in Water

- Depends on the functional group and on the chain length
- Lower members of alcohols, amines, aldehydes, ketones and carboxylic acids are all water soluble
- As carbon chain length increases solubility in water decreases
- Compounds with non-polar functional groups such as alkanes and alkenes do not dissolve in

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# 10.4 Alkanes

## Low Reactivity of Alkanes

- The relatively strong C-C and C-H bonds and the low polarity of alkanes tends to be quite unreactive
- Only readily undergo combustion reactions with oxygen and substitution reactions in ultraviolet light

## Combustion

- Alkanes are hydrocarbons and only hydrocarbons burn in a plentiful supply of oxygen to give carbon dioxide and water
- $C_XH_Y + (X + Y/4)O_2 \rightarrow XCO_2 + Y/2H_2O$
- This reaction is exothermic and much use is made of the alkanes as fuels
- If there is an insufficient supply of oxygen then incomplete combustion occurs and carbon monoxide and carbon are also produced as products

## Substitution Reactions

- Alkanes can react with chlorine (or other halogens) in the presence of ultraviolet light to Mechanism of Chlorination of Methanetesale.co.uk form hydrogen chlorine and a substituted alkane

- - Heterolytic fission to how the shared electronic go to one of the atoms resulting in a 0 negative and positive ion

chundiyac fission: each and the wo atoms forming the bond retains one of the shared electrons resulting in the cormation of two free radicals

- $Cl_2 \rightarrow Cl + Cl$  This step is called initiation
- Free radicals contain an unpaired electron and are highly reactive
- When the chlorine free radicals come into contact with a methane molecule they combine with a hydrogen atom to produce hydrogen chloride and a methyl radical
- $H_3C-H + CI \rightarrow H_3C + CI$
- Since a new radical is produced this stage is called propagation
- The methyl radical is also highly reactive and reacts with a chlorine molecule to form the product and regenerate another chlorine radical
- This is a further propagation step and enables a chain reaction to occur as the process can repeat itself
- $CH_3 + Cl_2 \rightarrow CH_3 Cl + Cl^2$
- Termination occurs when two radicals react together
- $Cl_1 + Cl_2 \rightarrow Cl_2$
- Further substitution can occur when chlorine radicals react with the substituted products
- The substitution can continue even further to produce trichloromethane and then tetrachloromethane
- The overall mechanism is called free radical substitution

# 10.5 Alkenes

## Addition Reactions

- The C=C bond accounts for the relative reactivity of alkenes compared to alkanes
- Most important reactions are addition reactions
- Reactive molecules are able to add across the double bond
- Double bond is unsaturated and the product is said to be saturated
- $CZ_2CZ_2 + XY \rightarrow CZ_2XCZ_2Y$ \_
- To produce an alcohol from an alkene a sulfuric acid catalyst is required

## Uses of Addition Reactions

### **Bromination**

- Pure bromine is red liquid but has distinct yellow/orange colour in solution \_
- When added to an alkene the product is colourless
- The decolourisation of bromine solution provides a useful test to indicate the presence of an alkene group

#### Hydration

- Ethene is an important product formed during the cracking of oil \_
- Although ethanol can be made from the fermentation of starch and sugar
- ahere Much industrial ethanol is formed from the addition of steam \_

#### Hydrogenation

- 6 dustrially to make The addition of hydrogen to unsa margarine
- bnds in the polyunsaturated vegetable oils Hydrogenation the number of do It to become a solid at room temperature a nargarine

## Addition Polymerisation

- Under certain conditions ethene can undergo addition reactions with itself to form a long chain polymer containing many thousands of carbon atoms
- $N(CH_2CH_2) \rightarrow -(CH_2CH_2)-n$
- These addition reactions can be extended to other substituted alkenes to give a wide variety of different addition polymers

# 10.12- Stereoisomerism

- Structural Isomers: share the same molecular formula but have different structural formulas
  - Stereoisomers: have the same structural formula but differ in their spatial arrangement
    - Two types of stereoisomerism:
      - Geometrical Isomerism
      - Optical Isomerism

## Geometrical Isomerism

- Occurs when rotation about a bond is restricted or prevented
- The classic examples of geometric isomers occur with asymmetric non-cyclic alkenes
- A cis- isomer is one in which the substituents are on the same side of the double bond
- In a trans- isomer the substituents are on opposite sides of the double bond
  - Cis-: H<sub>3</sub>CHC=CHCH<sub>3</sub>
  - Trans-: HH<sub>3</sub>CC=CHCH<sub>3</sub>
- When there is a single bond between two carbon atoms free rotation about the bond is possible
- However, the double bond in an alkene is made up of a  $\sigma$  and a  $\pi$  bond
- The  $\pi$  bond is formed from the combination of two p orbitals, one from each of the carbon atoms
- These two p orbitals must be in the same plane to combine
- Rotating the bond would cause the  $\pi$  bond to break so no rotation is 6550
- *Cis* and *trans* isomerism will always occur in alkenes when the two groups attached to each of the two carbon atoms are different
- Geometrical isomerism can also occurrin discostituted cycloal a es
  - The rotation is restlicted because the 6-C smill bowd is part of a ring system

## Physics had the mical Dog Old of Geometrical Isomers

- The chemical properties of geometric isomers tend to be similar but their physical properties are different
- Sometimes there can be a marked difference in both chemical and physical properties which tends to occur when there is some sort of chemical interaction between the substituents

## **Optical Isomerism**

- Optical isomerism is shown by all compounds that contain at least one asymmetric or chiral carbon atom within the molecule
- A chiral carbon is one that contains four different atoms or groups bonded to it
- The two isomers are known as enantiomers and are mirror images of each other
- The two different isomers are optically active with plane polarised light
- Normal light consists of electromagnetic radiation which vibrates in all planes
- When it is passed through a polarizing filter the waves only vibrate in one plane and the light is said to be plane polarized
- The two enantiomers both rotate the plane of plane polarised light
- One of the enantiomers rotates it to the left and the other rotates it by the same amount to the right
- Enantiomers have identical physical properties