Answers

CHECK IT!

Atomic structure and the periodic table

Atoms, elements and compounds

1 Sodium atoms

2 There is only one type of atom present.

3 A compound

4 a Compound b Element

5 a Silver-1 atom; nitrogen-1 atom; oxygen-3 atoms.

b Iron-1 atom; nitrogen-3 atoms; oxygen-9 atoms.

Mixtures and compounds

1 In the mixture, the iron and sulfur are not chemically combined. In iron sulfide, the iron and sulfur are combined chemically.

2 a Add the mixture to water; stir; the salt will dissolve, resulting in a salt solution. The chalk can then be separated from the salt solution by filtration. The solid salt can be separated from the salt solution by crystallisation.

b Add the mixture of Q and R to petrol. Q would dissolve in the petrol but R would not. R can be separated by filtration. Solid Q can be obtained by gentle heating to evaporate off the petrol.

Pure substances and formulations

1 A single element or a single compound.

2 It contains several different compounds.

3 A formulation is a mixture that is designed to improve upon the properties of the pure substance on its own.

4 Example is a drug which may include substances to make it more easily swallowed; substances that will bind it together and substances that prolong its shelf life.

Chromatography

1 Stationary phase = paper

Mobile phase = solvent

2 The pen will separate into its components and interfere with the chromatogram. The graphite in the pencil will not separate, so will not affect the chromatogram.

3 a B and C are pure substances.

b i It gives more than one spot.

ii B and C

c 8.5

7.3 = 0.859

Scientific models of the atom

1 Cannot be split up any further.

2 Electrons, protons and neutrons

3 The nucleus contains the protons and neutrons. Around the nucleus are the electrons, which are arranged in shells.

Atomic structure

1 Oxygen has 8 protons, which means its atomic number is 8. The atomic number is unique to the element.

2 Protons and neutrons are both found in the nucleus and are much heavier than electrons, which are not in the nucleus.

3 $^{31}_{15}P$

4 10. There are 13 electrons in an aluminium atom and therefore there are 3 less in an Al^{3+} ion.

5 The atomic number is 11, therefore there are 11 protons and 11 electrons. There are 12 neutrons because the mass number = 23 and the number of neutrons = mass number − atomic number, or 23 − 11.

Isotopes and relative atomic mass

1 a They have the same atomic number, but different mass numbers

b Protons and electrons = 18; neutrons = 20 and 22.

2 a Let there be 100 atoms, the mass of the atoms with atomic number 63 = 63 × 69 = 4347 atomic mass units (amu). The mass of the atoms with atomic number 65 = 65 × 31 = 2015 amu. This means: Total mass of 100 atoms copper = 4347 + 2015 = 63.6 amu.

b There are 29 protons and 29 electrons. In the isotope with atomic mass 63 there are 34 neutrons. In the isotope with atomic mass 65 there are 36 neutrons.

The development of the periodic table and the noble gases

1 Groups and periods.

2 Aluminium

3 Because he believed that some elements had not yet been discovered.

4 Because iodine would have been placed in group 6 and tellurium in group 7 which is the halogens, and this would be wrong. Similarly potassium would have been placed in the noble gases and argon in the alkali metals.

Electronic structure and the periodic table

1 In shells around the nucleus.

2 8

3 The electron arrangement is 2,8,8,1. It is in group 1 and period 4.

Metals and non-metals

1 On the left-hand side.

2 Sulfur is a non-metal. It is a dull solid that is a poor electrical and thermal conductor, and it is brittle. Sodium is a metal. It is a shiny solid, a good electrical and thermal conductor.

3 Sodium is a metal and forms a positive ion.

4 Phosphorus is placed on the right-hand side the periodic table. It is a non-metal and would therefore be expected to be a poor conductor of electricity.

Group 1 – the alkali metals

1 a Lithium 2,1, potassium 2,8,8,1

b Both have one electron in their outermost electron shell, therefore they are placed in group 1.

2 Any of soft, malleable and ductile, less dense than water, good electrical and thermal conductor and is a shiny silver-white solid at room temperature.

3 Potassium(s) + water(l) → potassium hydroxide(aq) + hydrogen(g)

$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

4 When sodium and lithium react they both lose their outermost electrons to form +1 ions. The outermost electron of sodium is further from the positively charged nucleus and feels less of an attractive force; it also has more shielding electrons between it and the nucleus.

5 a Rubidium is lower in the group than potassium and would therefore react more violently. When added to water it would melt, burst into flame more violently than potassium as the hydrogen formed is ignited by the reaction.

b $2Rb(s) + 2H_2O(l) \rightarrow 2RbOH(aq) + H_2(g)$

6 The alkali metals are extremely reactive and in the presence of non-metals would react immediately.

Group 7 – the halogens

1 7 2 Cl^- 3 2,8,8

Displacement reactions in group 7

1 F_2

2 The solution would go brown or a purple solid would form.

3 a Bromine(l) + sodium iodide(aq) → iodine(s) + sodium bromide(aq)

$Br_2(l) + 2NaI(aq) \rightarrow I_2(s) + 2NaBr(aq)$

b Bromine is above iodine in the group and is more reactive than iodine. Therefore bromine will displace iodine from a solution of its salt to give iodine and sodium bromide.

c $Br_2(l) + 2I^-(aq) \rightarrow 2Br^-(aq) + I_2(s)$

4 a You would also add the same volume of bromine to an equal volume of water. If there is no reaction you would still get an orange coloured solution.

b Chlorine is more reactive than bromine, when bromine is added to sodium chloride the bromine does not displace the chlorine from its salt, therefore no change is observed.

The transition metals

1 It forms coloured compounds. It can be a catalyst. It is hard and dense. It forms ions with different charges.

2 Calcium is a non-transition metal; Nickel and iron are transition metals.

3 The sodium chloride is white because sodium is a non-transition metal. The copper chloride will be coloured (green) because copper is a transition metal.

Bonding, structure and the properties of matter

Bonding and structure

1 Liquid

2 There are weak forces between the particles.

3 In the solid state the particles vibrate about fixed positions. When the substance melts the particles are free to move around and are randomly arranged.

4 a i Liquid ii Gas

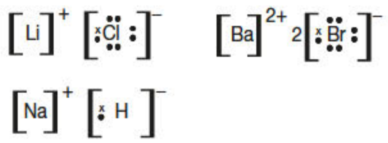
b (l)

5 There are several particles that are not spherically shaped. For example, polymers are linear. Particles are not solid. Atoms are mostly empty space.

Ions and ionic bonding

1 LiCl; $BaBr_2$; NaH

2



3 When group 1 elements react they lose their outer electron in order to form a stable full outer electron shell. The particle formed has one fewer electron and is therefore a 1+ ion.

4 S^{2-}

5 The electrostatic attraction between the oppositely charged ions holds the ions together.

6 K_2S and MgI_2

The structure and properties of ionic compounds

1 The electrostatic attraction between the oppositely charged ions.

2 Because it is a giant structure all the strong ionic bonds have to be broken for melting to take place.

3 In the solid the ions are not free to move and cannot carry the current so does not conduct electricity. In the liquid the ions are free to move and can carry the current, making it a good conductor.

4 There are twice as many fluoride as magnesium ions.

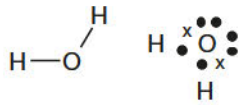
5 In CaO the ions present are Ca^{2+} and O^{2-} and in KBr they are K^+ and Br^-. Because of their higher charge the attractions between Ca^{2+} and O^{2-} are greater than between K^+ and Br^-. This means that CaO has the higher melting point.

Covalent bonds and simple molecules

1 A covalent bond is the sharing of a pair of electrons between two atoms, 1 electron coming from each atom.

2 Non-metallic

3



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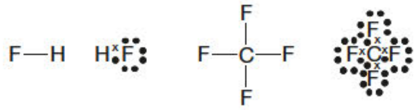


5 Low melting and boiling point; poor electrical conductor both as a solid and as a liquid.

Diamond, graphite and graphene

1 Giant covalent

2 All the atoms are joined by strong covalent bonds, all of these bonds have to be broken so lots of energy is required and the melting points are high.

3 The carbon atoms are arranged in layers of hexagonal rings. The layers are held together by weak intermolecular forces which are easily broken, this allows the layers to slide over each other and means that graphite is soft.

4 There are no charged particles or free electrons in diamond so it cannot conduct electricity in either the solid or liquid state. In the layers in graphite each carbon atom has a spare electron and these electrons are free to move, this means that graphite can conduct electricity.

5 The carbons are arranged in hexagonal rings and each carbon is joined to three others by strong covalent bonds.

6 Crystalline, very hard, high melting/boiling points; does not conduct electricity.

Fullerenes and polymers

1 a 60

b It has low melting and boiling points; it does not conduct electricity in either the solid or liquid state.

2 They are cylindrical fullerenes. They have a high length-to-diameter ratio.

3 The strong covalent bonds mean that they have a high tensile strength.

4 As a lubricant or to deliver drugs to their required sites within the body.

Giant metallic structures and alloys

1 Giant lattice of positive metal ions (cations) in a sea of delocalised electrons.

2 The delocalised electrons are free to move and carry the current in both liquid and solid states.

3 An alloy is a mixture of metals.

4 In the pure metal the layers of positive ions can slide over each other without disrupting the structure. This makes a pure metal soft and easily deformed. In alloys the ions of the other metal are of a different size to the main metal and make it harder for the layers to slide which means the alloy is harder.

Nanoparticles

1 1 nm to 100 nm in size. A nm = 1×10^{-9} m

2 Examples: titanium dioxide nanoparticles in sunscreens, silver nanoparticles used in antibacterial preparations, fullerenes used to deliver drugs and as lubricants.

3 Surface area to volume ratio $= \frac{96}{94} = 1.5$

For the cube with 2 nm sides; surface to volume ratio $= \frac{24}{8} = 3$.

Quantitative chemistry

Conservation of mass and balancing equations

1 a The reactants are magnesium and aluminium oxide; the products are magnesium oxide and aluminium.

b 72 + 103 = 175 g.

2 a Hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide

b $2\,HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

c See chemical equation above

d The carbon dioxide gas has a mass and is released from the reaction, therefore the mass decreases.

Relative formula masses

1 a 56 b 95 c 101 d 342

2 a 432 g

b The law of conservation of mass

The mole

1 Avogadro's number = $\mathbf{6.02 \times 10^{23}}$

2 It is the relative formula mass expressed in grams.

3 a $M_r = 32 + 2 \times 16 = \mathbf{64}$

b Number of moles $= \frac{m}{M_r} = \frac{1.6}{64} =$ **0.025 (2.5 × 10^{-2})mol**

c No. of molecules $= 0.025 \times 6.02 \times 10^{23}$ $= \mathbf{1.51 \times 10^{22}}$

Reacting masses and using moles to balance equations

1 1 mol of copper gives 2 mol silver

63.5 g of copper gives 2 × 108 g of silver = **216 g**

1 g of copper gives $\frac{1}{63.5} \times 216$ g of silver

6.35 g of copper gives $\frac{6.35}{63.5} \times 216$ g of silver = **21.6 g**

2 M_r ($AgNO_3$) = 108 + 14 + 3 × 16 = 170; A_r(Ag) = **108**

$M_r(NO_2)$ = 14 + 2 × 16 = 46; $M_r(O_2)$ = **32**

68 g of $AgNO_3$ = $\frac{68}{170}$ = **0.4 mol;**

43.2 g of Ag = $\frac{43.2}{108}$ = **0.4 mol**

18.4 g of NO_2 = $\frac{18.4}{46}$ mol = 0.4 mol; 6.4 g O_2 = **0.2 mol**

Therefore 0.4 mol $AgNO_3$ gives 0.4 mol Ag + 0.4 mol NO_2 and 0.2 mol of O_2;

Divide through by 0.2;

2 mol $AgNO_3$ gives 2 mol Ag + 2 mol NO_2 + 1 mol O_2;

The equation is $2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$

Limiting reactant

1 a The sulfuric acid.

b From the equation 1 mol of magnesium reacts with 1 mol of sulfuric acid. The limiting reactant is the sulfuric acid because it is the smaller amount.

c From the equation the number of moles of H_2 are the same as the magnesium and sulfuric acid but the limiting reactant is the sulfuric; therefore 0.9 mol are formed.

Concentrations in solutions

1 a 500 cm³ = $\frac{500}{1000}$ = **0.5 dm³**

Concentration = $\frac{0.1}{0.5}$ = **2 mol/dm³**

b 1 mol of HCl weighs 36.5 g; Therefore, concentration = 2 × 36.5 g/dm³ = **71 g/dm³**

2 n = C × V = 0.2 × 0.25 = **0.05 mol**

Moles in solution

1 Volume of KOH = $\frac{20}{1000}$ = **0.02 dm³;**

Volume of HNO_3 = $\frac{30}{1000}$ dm³ = **0.03 dm³**

No. of mol of KOH = C × V = 0.2 × 0.02 =**4 × 10⁻³ mol**

No. of mol of HNO_3 = No. of mol of KOH =**4 × 10⁻³ mol;**

Concentration of HNO_3 = $\frac{n}{V}$ = 4 × $\frac{10^{-3}}{0.03}$ = **0.133 mol/dm³**

2 Volume of Na_2CO_3 = $\frac{20}{1000}$ dm³ = **0.02 dm³**

No. of mol of Na_2CO_3 = C × V = 0.500 × 0.02 = **0.01 mol**

No. of mol of HCl = 2 × No. of mol of Na_2CO_3 = **0.02 mol**

Volume of acid = $\frac{n}{C}$ = $\frac{0.02}{1.00}$ = **0.02 dm³ (20 cm³)**

Moles and gas volumes

1 n = $\frac{V}{24}$ (V is in dm³) = $\frac{\mathbf{V}}{\mathbf{24000}}$ **(V is in cm³)**

2 n = $\frac{120}{24000}$ = **5 × 10⁻³ mol**

3 No. of mol of O_2 = $\frac{480}{24000}$ = **2 × 10⁻² mol**

Mass = n × M_r = 2 × 10⁻² × (16 × 2) = **0.64 g**

4 a $M_r(Ag_2O)$ = 2 × 108 + 16 = **232**

No. of mol of Ag_2O = $\frac{11.6}{232}$ = **5 × 10⁻² mol**

b 2 mol of Ag_2O give 1 mol of oxygen

1 mol of Ag_2O give 0.5 mol of oxygen

This means that 5 × 10⁻² mol of Ag_2O gives 0.5 × 5 × 10⁻² = **2.5 × 10⁻² mol of oxygen**

Volume of oxygen = n × 24 dm³ = 2.5 × 10⁻² × 24 dm³ = **0.6 dm³**

c Mass = n × M_r = 2.5 × 10⁻² × 32 = **0.8 g**

d Mass of reactants = mass of products

Mass of products = 11.6 g; mass of silver = 11.6 – 0.8 g = **10.8 g**

Percentage yield and atom economy

1 Yield = 25%

- Products are lost during the purification process.
- The reaction is reversible and therefore does not go to completion.
- The reaction is incomplete because other reactions are taking place.

2 a Atom economy = $\frac{17}{53.5}$ × 100% = 31.8%

b Atom economy = $\frac{34}{34}$ × 100% = 100%

Chemical changes

Metal oxides and the reactivity series

1 A positive metal ion (cation).

2 Carbon

3 Lithium hydroxide and hydrogen.

4 Hydrogen(g) + copper(II) oxide(s) → water(l) + copper(s)

$H_2(g) + CuO(s) \rightarrow H_2O(l) + Cu(s)$

5 Magnesium(s) + copper(II) sulfate → magnesium sulfate(aq) + copper(s)

$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s)$

6 a Zinc chloride and hydrogen

b No reaction

Extraction of metals and reduction

1 a Oxidation b Reduction

2 Aluminium is oxidised, iron is reduced.

3 a By heating its oxide with carbon. Carbon reduces the lead oxide to lead.

b By electrolysis of an ionic compound of barium.

Blast furnace

1 The temperature of the furnace is high enough to melt the iron.

2 The nitrogen is in the hot air blown into the furnace and does not take part in any of the reactions; Therefore it leaves the furnace unchanged.

3 The first function is as a fuel; The second is as a source of carbon monoxide, the main reducing agent in the furnace.

The reactions of acids

1 a An alkali is a soluble metal hydroxide.

b A base is an insoluble metal oxide or hydroxide.

2 a Sodium chloride b Sodium nitrate

3 The gas carbon dioxide is formed, and this produces effervescence.

4 a NO_3^-

b $Mg(NO_3)_2$

5 a $MgO(s) + H_2SO_4(aq) \rightarrow H_2O(l) + MgSO_4(aq)$

b $MgCO_3(s) + H_2SO_4(aq) \rightarrow H_2O(l) + MgSO_4(aq) + CO_2(g)$

c $Mg(OH)_2 + H_2SO_4(aq) \rightarrow H_2O(l) + MgSO_4(aq)$

6 a $2H^+ (aq) + Mg(s) \rightarrow H_2(g) + Mg^{2+} (aq)$

b The hydrogen ions gain electrons and are reduced. The magnesium loses electrons and is oxidised.

The preparation of a soluble salt

1 a Either copper(II) oxide or copper(II) carbonate and sulfuric acid.

b Either zinc oxide, zinc hydroxide or zinc carbonate and nitric acid.

c Either magnesium, magnesium oxide, magnesium hydroxide or magnesium carbonate and hydrochloric acid.

2 a By filtration

b The excess base is insoluble and forms the residue on the filter paper and the soluble salt solution is the filtrate.

3 Yield = actual yield/theoretic yield × 100% = $\frac{4.5}{5}$ × 100% = 90%

4 a The insoluble magnesium carbonate would stop dissolving and the mixture would stop fizzing as no more carbon dioxide would be produced.

b Method A

Atom economy = $\frac{148}{166}$ × 100% = 89.2%

Method B

Atom economy= $\frac{148}{166}$ × 100% = 70.5%

Oxidation and reduction in terms of electrons

1 Oxidation is loss of electrons and reduction is gain of electrons.

2 a $Mg(s) + Zn^{2+}(aq) \rightarrow Mg^{2+}(aq) + Zn(s)$

b The magnesium has been oxidised.

The pH scale and neutralisation

1 H^+ ions

2 OH^- ions

3 $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

4 The hydrochloric acid is a strong acid and the ethanoic acid is a weak acid.

Strong and weak acids

1 A strong acid is fully ionised in water whilst a weak acid is only partially ionised.

2 A concentrated solution has a greater amount in moles of the solute dissolved in the same volume of water than a dilute solution.

3 The pH decreasing by 3 means that the hydrogen ion concentration has increased by 3 orders of magnitude, 10^3 times or 1000 times.

The basics of electrolysis and the electrolysis of molten ionic compounds

1 a The electrolyte
  b The cathode
  c The anode

2 a Chlorine
  b Magnesium

3 a At the anode (+) $2Cl^- \rightarrow Cl_2 + 2e^-$
  At the cathode (–) $Mg^{2+} + 2e^- \rightarrow Mg$
  b The chloride ions lose electrons and loss of electrons is oxidation.

The electrolysis of copper(II) sulfate and electroplating

1 The cathode would increase in mass by exactly the same amount as the loss in mass of the anode; The cathode would therefore increase in mass by 0.200 g.

2 The electrolyte would be silver nitrate solution; The silver anode would decrease in mass and the spoon would increase in mass and be coated with silver.

The electrolysis of aqueous solutions

1 a Na^+, Cl^-, H^+, OH^-
  b Chlorine at the anode (+) and hydrogen at the cathode (–)
  c Sodium hydroxide solution
  d At the anode(+) $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ Oxidation
  At the cathode (–) $2H^+(aq) + 2e^- \rightarrow H_2(g)$ Reduction

Extraction of metals by electrolysis

1 Aluminium, magnesium, calcium, lithium, sodium and potassium.

2 Because it is more reactive than carbon and this means that carbon cannot reduce aluminium oxide to aluminium.

3 Aluminium is extracted from its ore bauxite (aluminium oxide). The melting point of aluminium oxide is very high so to reduce the operating temperature the aluminium oxide is dissolved in cryolite. The aluminium ions are discharged at the negative cathode to give molten aluminium metal which is run off at the bottom of the cell. Oxygen is given off at the anode, because the anodes are made of carbon, the temperature is very high so the anodes burn away and have to be replaced at regular intervals.

4 At anode(+) $2O^{2-} \rightarrow O_2 + 4e^-$
  At cathode $Al^{3+} + 3e^- \rightarrow Al$

Investigation of the electrolysis of aqueous solutions

1 At cathode is hydrogen; at anode is oxygen.

2 Because the product at the anode is bromine, and a weak solution of bromine water is yellow-orange in colour.

3 Hydrogen will give loud popping sound with a lighted splint; The sodium hydroxide will turn purple using Universal Indicator solution.

Determining reacting volumes by titration

1 Burette, pipette, conical flask, white tile.

2 The liquid is added from the burette 1 cm^3 at a time until the indicator changes colour.

3 The colour will change.

4 a 24.20 cm^3 and 25.80 cm^3
  b $(24.50 + 24.60)/2 = 24.55\ cm^3$

Energy changes

Exothermic and endothermic reactions

1 a Exothermic
  b i Final temperature = 45°C Exothermic
   ii Temperature change = –5°C Endothermic

2 Thermal decomposition reactions; Some reactions of acids with hydrogen carbonates and carbonates; The dissolving of ammonium compounds in water.

3 Hand warmers, cooking packs and coffee warmers

Investigation into the variables that affect temperature changes in chemical reactions

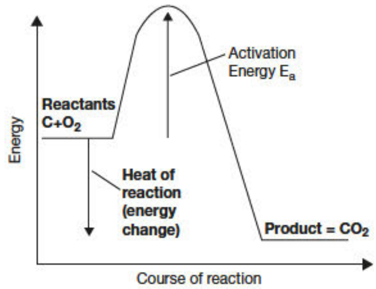
1 Amount of reactant, surface area of a solid reactant, the concentrations of any solutions involved, and the reactivity of any metals involved in the reaction.

2 a The reaction was between the magnesium and the acid, and the reaction was exothermic. As the amount of magnesium was increased there were more reactions taking place, and the temperature increased.
  b At reaction 5 all of the acid had reacted and so the temperature rise was at a maximum. For reaction 6 adding more magnesium would have no effect so the temperature would not increase any more.

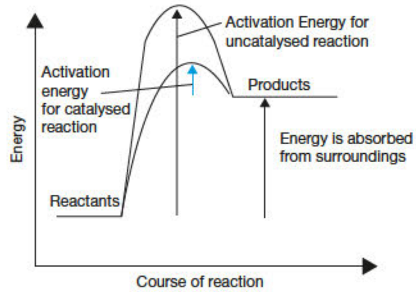
3 Metals with acids; neutralisation reactions – acids and alkalis.

4 Add measured amounts of hydrochloric acid to identical test tubes or calorimeters. Measure the temperature of the acid in each test tube/calorimeter. Add equal amounts of powdered metal to each test tube/calorimeter and measure the maximum temperature obtained in the reaction. The more reactive the metal the greater the temperature change.

Reaction profiles

1


2 a i A catalyst speeds up a chemical reaction and is chemically unchanged at the end of the reaction.
   ii A catalyst allows the chemical reaction to proceed by an alternative route that has a lower activation energy.
  b i and ii



The energy changes of reactions

1 a


  b

4 × 415 kJ	2 × 500 kJ	4 × 465 kJ	2 × 800 kJ
1660 kJ	1000 kJ	1860 kJ	1600 kJ

   i 2660 kJ
   ii 3460 kJ
   iii 800 kJ/mol
  c More energy is given out than taken in, therefore the reaction is exothermic.

Chemical cells and fuel cells

1 2 metals of different reactivities and an electrolyte.

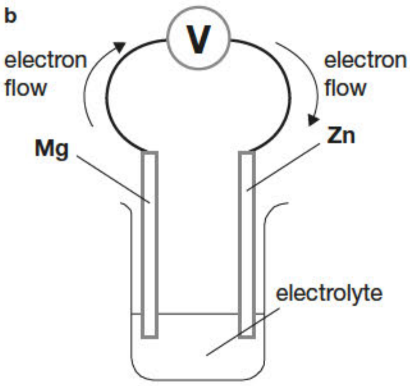
2 Water

3 The one formed from the copper and magnesium electrodes. The difference in reactivity between magnesium and copper is greater than the difference in reactivity between zinc and copper. This means that the magnesium loses its electrons more easily to the copper than the zinc, therefore producing a greater voltage.

4 $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
  $2H_2(g) + 4OH^- \rightarrow 4H_2O(l) + 4e^-$

5 a $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$
  $Zn^{2+}(aq) + 2e^- \rightarrow Zn$

b



Rates of reaction and equilibrium

Ways to follow a chemical reaction

1 a Follow the volume of CO_2 gas given off with time. Follow the reduction in mass with time.

b Follow the volume of H_2 gas given off with time. Time how long it takes for the magnesium to dissolve.

2 a The concentration of acid

b The volume of gas

3 a It relies on the senses (sight) to see when the cross is obscured, so could be inaccurate because of human error. When the reaction is slow it will be unclear when the cross is obscured. The darkness of the cross is variable and will give different results.

b i Place the bulb below the reaction vessel and the light datalogger above it. As the cloudiness increases the light reaching the datalogger will decrease.

ii The second method is better because it does not rely on the senses. It can also be used to measure the rate directly.

Calculating the rate of a reaction

1 Divide the total number of moles, total volume or total mass gained by the time taken for reaction to get to completion.

OR mean rate = $\frac{\textit{amount of product formed in reaction}}{\textit{time taken for reaction to reach completion}}$

2 a Plot graph

b i Draw tangents to graph at 0 s, 10 s and 30 s.

ii At 0 s rate = 7.25 cm^3/s; at 10 s rate = 2.25 cm^3/s

At 30 s rate = 0.68 cm^3/s

iii As the reaction progresses the concentration of the acid decreases and acid particles are less crowded and therefore there are fewer collisions per second and the rate decreases.

c The gradient is zero because all the acid has been used up and the reaction is complete.

d i No. of moles of $CO_2 = \frac{80}{24000}$ $= 3.33 \times 10^{-3}$

ii The number of moles of HCl

$= 2 \times$ no. of moles of CO_2

$= 6.66 \times 10^{-3}$

iii Volume of acid $= \frac{100}{1000}$ dm^3

$= 0.1$ dm^3

Concentration of HCl

$= \frac{n}{V} = 6.66 \times 10^{-3}/0.1$

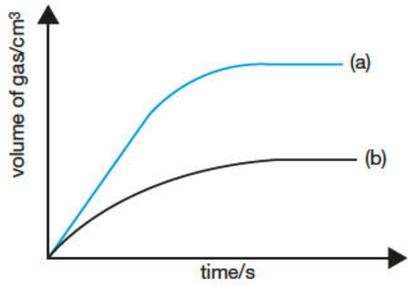
$= 6.66 \times 10^{-2}$ mol/dm^3

The effect of concentration and pressure on reaction rate and the effect of pressure on the rate of gaseous reactions

1 It decreases

2 As the concentration increases the reacting particles get more crowded and they collide more frequently increasing the chance of reaction.

3



Rates of reaction – the effect of surface area

1 Powder

2 As the surface area increases the number of solid particles exposed to reaction increases, therefore the frequency of collisions increases and so does the rate of reaction.

3 a By using lumps (small surface area) and powder (large surface area).

b Follow the volume of gas given off with time OR follow the loss in mass with time.

c Using a bar chart because lumps and powder are not continuous variables.

The effects of changing the temperature and adding a catalyst

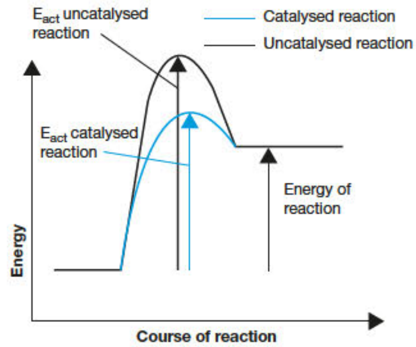
1 This increases the rate

2 As the temperature increases the particles collide more frequently and with greater force, so the frequency of effective collisions increases and so does the rate.

3 a A catalyst speeds up a chemical reaction and is unchanged at the end of the reaction.

b A catalyst allows the reaction to proceed by an alternative route which has a lower activation energy.

4



Investigation into how changing different factors affects the rate of reaction

1 a Volume of water missing values 20, 10, 0

Reaction rates of missing cells 0.0078; 0.016; 0.031; 0.045; 0.063

b Variables kept constant - Temperature; concentration of acid; for the cross to be obscured these must be kept the same.

c The line is a straight line and this shows that the rate of reaction is proportional to the concentration of sodium thiosulfate.

Reversible reactions

1 $\rightleftharpoons$

2 It is a reaction where the reactants can react to form products and the products can react to form the reactants.

3 a $A + B \rightleftharpoons Y + Z$

b The forward reaction is exothermic and the reverse reaction is endothermic.

c Because not enough X and Y are present to form the reverse reaction.

d iii and iv

The effect of changing conditions on equilibrium

1 A chemical system is the reactants and products of a reversible reaction together in a closed container.

2 It means the reaction is reversible.

3 The reverse reaction is the reaction where the products of a reaction react together to form the reactants.

4 If a chemical system is at equilibrium and one or more of the three conditions is changed then the position of equilibrium will shift to remove the effects of the change; we get either more reactants or more products.

5 a If the pressure is increased it favours the reaction that forms fewer gas molecules and this is the forward reaction. This is the formation of ethanol.

b If the temperature is raised the equilibrium will shift so as to lower it. This means the endothermic reaction is favoured, this is the reverse reaction, and therefore less ethanol is formed.

c It has no effect. The catalyst speeds up the forward and reverse reactions equally and has no effect on the position of equilibrium.

Organic chemistry

Carbon compounds, hydrocarbons and alkanes

1 A compound of hydrogen and carbon only

2 A homologous series is a series of compounds that:

- Have the same general formula
- Have similar chemical properties
- Have the same functional group
- Show a gradation in physical properties like melting and boiling point as the molecules in the series get larger
- Each member of the series differs from the next one by $-CH_2$

3 General formula = C_nH_{2n+2}; C_6H_{14}

Crude oil, fractionation and petrochemicals

1 Petroleum gases – fuels and feedstock for making other chemicals

Gasoline /petrol – fuel for cars

Naphtha – feedstock for other chemicals

Paraffin/kerosene – aeroplane fuel

Diesel oil – fuel for large cars and lorries

Lubricating oil – making parts of machinery work more efficiently and smoothly

Fuel oil – fuel for ships

Bitumen – road surfaces

2 Crude oil is a mixture of miscible liquids and gases with similar boiling points. The best way to separate such a mixture is by fractional distillation.

3 The boiling points get higher. As the column is descended the temperature increases and only fractions with higher boiling points will condense at these temperatures.

4 Fraction X has a lower boiling point, is lighter in colour, is less thick or less viscous, is easier to light.

5 The cobalt chloride paper changes from blue to pink. Limewater changes from colourless and clear to milky or cloudy.

6 a $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

b $C_4H_{10}(g) + 6\frac{1}{2}O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$

The structural formulae and reactions of alkenes

1 C_nH_{2n}

2 a Butene

b Alkenes must have a double bond between two carbons. Methene could only have 1 carbon.

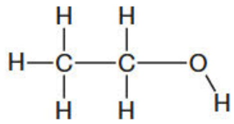
3 a They have a double bond between two carbons OR they have less than the maximum number of hydrogens.

b i C_4H_8

ii $C_4H_8 + 2O_2 \rightarrow C + 4H_2O$

4 Addition reactions

5 a



b $C_2H_4 + H_2O \rightarrow C_2H_5OH$ (or C_2H_6O)

Cracking and alkenes

1 Cracking is the breaking down of large alkane molecules into smaller alkane molecules and alkenes.

2 The large alkanes are passed over a heated catalyst OR the alkanes are mixed with steam and heated to a high temperature.

3 a C_nH_{2n}

b If bromine water is added to an alkene, the bromine water is decolourised.

c Alkenes are used for making polymers.

4 After fractionation the amount of smaller alkanes such as the petrol fraction is not enough to meet the demand. For the fractions with large alkanes the amount from fractionation is greater than that required. Also, crude oil does not contain alkenes. Therefore cracking is used to make economically important and useful compounds from less useful ones.

5 a C_4H_8

b C_3H_8

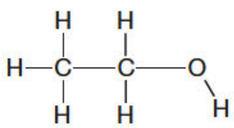
c C_6H_{14}

Alcohols

1 Propanol

2 The - OH or hydroxyl group (not hydroxide)

3 CH_3CH_2OH or



4 a $CH_3CH_2CH_2CH_2OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$

b $CH_3OH + 1\frac{1}{2}O_2 \rightarrow CO_2 + 2H_2O$

5 Refer to page 116

6 a Ethanoic acid

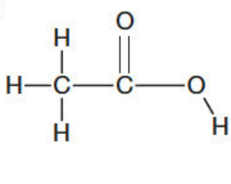
b i The acidified potassium manganate (VII) would be decolourised, or it goes from purple to colourless.

ii The acidified potassium dichromate(VI) goes from orange to green.

Carboxylic acids

1 The –COOH group

2 CH_3COOH

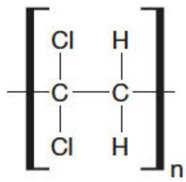


3 The fizzing is caused by the gas carbon dioxide. The reaction is slow because the ethanoic acid is a weak acid and the concentration of hydrogen ions is low.

Addition polymerisation

1 A small alkene molecule that can join with other monomers to form a polymer.

2



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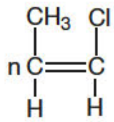


4 Polybutene

Condensation polymerisation

1 a i A reaction between 2 or more small molecules to form a large molecule. It also involves the elimination of a small molecule.

ii Water

b Condensation polymerisation forms polymers through a condensation reaction—where molecules join together—losing small molecules as by-products such as water. Addition polymerisation is the reaction of unsaturated monomers.

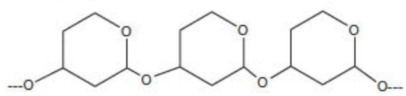
2 $-[OCCOOCH_2CH_2O]-$

3 $HOCH_2OH$ and HOOC-COOH

Amino acids and DNA

1 Water, H_2O

2



3 DNA consists of 2 polymer chains, which are condensation polymers formed from 4 monomers called nucleotides.

4 $-[HNCH_2CO]-$

Chemical analysis

Testing for gases

1 a (Oxygen) Relights a glowing splint.

b (Carbon dioxide) Turns limewater milky/cloudy.

c (Hydrogen) Pops with a lighted splint.

d (Chlorine) Bleaches blue litmus paper or UI paper.

Identifying metal ions using flame tests and flame emission spectroscopy

1 Ca^{2+} gives an orange-red colour/brick – red

K^+ gives a lilac colour

2 More sensitive, the colour of the flame of one metal is not masked by others, can detect the different metals in a mixture.

Identifying metal ions using sodium hydroxide solution

1 a White
b Brown
c Blue

2 They both give white precipitates. The difference is that the precipitate formed by aluminium ions will dissolve when excess sodium hydroxide solution is added.

3 Copper(II) sulfate(aq) + sodium hydroxide(aq) → copper(II) hydroxide(s) + sodium sulfate(aq)

$CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$

4 $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$

5 a Fe^{3+}
b Fe^{2+} has lost an electron

Testing for negative ions (anions) in salts

1 a Nitric acid followed by silver nitrate solution.
b Hydrochloric acid followed by barium chloride solution.
c Hydrochloric acid, if a gas is given off then test the gas with limewater.

2 Bromide and sulfate ions

Identifying ions in an ionic compound

1 A = iodide
B = sulfate and carbonate
C = chloride

2 a White precipitate with sodium hydroxide shows Mg^{2+} ion. This precipitate does not dissolve with excess sodium hydroxide solution. When hydrochloric acid is added followed by barium chloride solution a white precipitate is formed. This shows the SO_4^{2-} present.
b The sodium ion will give a yellow flame in the flame test. If hydrochloric acid is added there will be effervescence and the gas formed will turn limewater cloudy. This shows the carbonate ion is present.
c The iron(II) ion will give green precipitate with sodium hydroxide solution. The chloride will give a white precipitate when nitric acid and silver nitrate solution are added.
d The potassium ion will give a lilac flame in the flame test. The iodide will give a yellow precipitate when nitric acid and silver nitrate solution are added.

Chemistry of the atmosphere

The composition and evolution of the Earth's atmosphere

1 Carbon dioxide, water vapour, methane, nitrogen and ammonia.

2
- Dissolving in water (the oceans)
- Taken up by plankton in the ocean to form calcium carbonate and these were compressed to form limestone
- Sometimes these marine animals were covered with mud and compressed to form oil
- Sometimes plants are covered by mud and compressed to form coal
- Photosynthesis uses carbon dioxide to form glucose and oxygen

3 Carbon dioxide + water → glucose + oxygen

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

Climate change

1 Carbon dioxide and methane

2 The rise in carbon dioxide shows the same pattern as the rise in global temperature.

3 Infrared

4 The burning of fossil fuels.

Reducing the carbon footprint

1 The total amount of carbon dioxide emitted over the lifetime of an activity or product.

2 a Removing carbon dioxide by planting trees and plants which remove carbon dioxide through photosynthesis.
b The carbon dioxide from power plants is pumped into porous rocks, especially those by disused oil wells deep below the sea.

3 Two out of:
- Countries and companies find it more economical to burn fossil fuels
- Disagreement over the cause of global warming
- People are reluctant to change their lifestyles
- Lack of awareness by people of the consequences of using lots of energy

4 Their manufacture requires energy

5 a Cavity wall insulation because a terraced house only has exposed front and back walls.
b Loft insulation saves emission of 990 kg of CO_2.
Mass of $CO_2 = 990 \times 10^3$ g $= 990 \times 10^3/44$ moles of $CO_2 = 2.25 \times 10^4$ mol
c Volume of $CO_2 = 2.25 \times 10^4 \times 24 = 5.4 \times 10^5\ dm^3$

Atmospheric pollutants

1
- Carbon monoxide – toxic
- Particulates – cause respiratory problems and reduce sunlight reaching Earth's surface
- Oxides of nitrogen – dissolve in water to cause acid rain and also harmful to respiratory system
- Sulfur dioxide – dissolves in water to cause acid rain

2 If the room is not ventilated then there is insufficient oxygen present for complete combustion. The coal or wood then undergoes incomplete combustion to form carbon monoxide which is toxic.

3 a i $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
ii $CH_4(g) + 1\frac{1}{2}O_2(g) \rightarrow CO(g) + 2H_2O(l)$

Using resources

Finite and renewable resources, sustainable development

1 a Finite resources will run out.
b These can be replaced at the same rate as they are used up. They are derived from plant sources.
c Sustainable development meets the needs of present development without depleting natural resources.

2
- Have reactions with high atom economy – this means that there is less waste
- Use renewable resources – this means that the process will not rely on resources that are running out
- Have as few steps as possible – the less the number of steps the less waste is produced, the less energy used and lower the amounts of resources use
- Use catalysts – using a catalyst saves energy and speeds up production

3 a The amount of coal remaining = 17.7×10^9 tonnes
The number of years left $= 17.7 \times \frac{10^9}{175} \times 10^6 = 101$ years
Use alternative sources of energy; increased energy saving by domestic and industrial consumers.

Life cycle assessments (LCAs)

1 A life cycle assessment is an analysis of the environmental impact of a product at each stage of its lifetime from its production all the way to its disposal.

2
- The extraction/production of raw materials
- The production process – making the product, including packaging and labelling
- How the product is used and how many times it is used
- The end of the life of the product – how is it disposed of at the end of its lifetime. Is it recycled?

3 a Both forms of power generation burn fossil fuels and therefore emit large amounts of carbon dioxide which is a greenhouse gas.
b Silicon voltaic cells use solar radiation to power them and therefore do not burn fossil fuels. However, energy from fossil fuels is used in their production and disposal which explains the small amounts of greenhouse emissions. Similarly with nuclear power stations which use energy from nuclear fission for power generation. Fossil fuels are also burned in producing the materials used to build the nuclear power station.

4 a Energy is required to extract and produce the materials used for the cell and this energy comes from burning fossil fuels.

b The coal-powered power station burns large amounts of the fossil fuel during its lifetime and this is much larger than the equivalent amounts used when it is built and dismantled.

Alternative methods of copper extraction

1 a They are low in copper.

b i mass $= \frac{0.5}{100} \times 1 \times 10^6$

$= 5 \times 10^3$ tonnes

ii $n = \frac{mass}{relative\ atomic\ mass} = \frac{5000}{63.5} =$ 78.7 mol

2 a Copper is less reactive than carbon and therefore carbon can be used to reduce copper oxide to copper.

b Firstly the copper carbonate is decomposed to copper oxide by heating:

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

Then the oxide is reduced to copper by heating with carbon:

$2CuO(s) + C(s) \rightarrow 2Cu(s) + CO_2(g)$

3 a Bacteria

b The advantages are that it works with low-grade ores and uses less energy than smelting to recover the copper. The disadvantage is that it is slow.

4 The impure copper is made at the anode. Copper from the anode dissolves into the electrolyte and is then deposited as pure copper on the cathode.

Making potable water and waste-water treatment

1 a Water that is safe to drink.

b i Evaporate off the water.

ii Add dilute nitric acid followed by silver nitrate solution. If a white precipitate is formed then chloride ions are present.

c i Place some of the liquid being tested on blue cobalt chloride paper. If water is present the cobalt chloride paper turns pink. Alternatively the liquid under test can be added to anhydrous copper(II) sulfate. If water is present the anhydrous copper(II) sulfate turns from white to blue.

ii The boiling point of pure water is 100°C.

2 Filtration

3 a A process which takes place in the absence of oxygen.

b A process which takes place in the presence of oxygen.

c A process in which larger particles settle in a liquid by gravitation.

4 a The anaerobic digestion produces methane which can be used as a fuel for powering the water treatment process. This means that the water treatment process uses less energy derived from fossil fuels.

b The sludge remaining after anaerobic digestion can be used for fertilisers.

5 Filtration

6 a Both the chloride and bromide ions would react with the silver nitrate solution to form precipitates with very similar colours (white and pale cream). Therefore it would be very difficult to distinguish these precipitates and the answer would not be clear-cut.

b If chlorine gas was passed through one sample of the water, the chlorine would displace the bromide ions from solution. Bromine would be formed as a pale orange/yellow solution.

Ways of reducing the use of resources

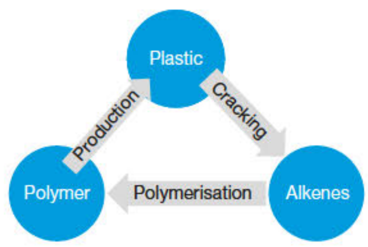
1 Any 3 from:

- Saves energy because do not have to extract raw materials from the Earth
- Saves energy because no energy required for the production process
- Reduces waste from production process
- Conserves raw material in ground for future use – increases lifetime of raw material
- Increases awareness of public of the need to conserve materials
- Reduces greenhouse emissions

2 a
- Extraction of aluminium is expensive
- Bauxite, the ore of aluminium, is running out so recycling conserves the ore and increases its lifetime
- Reduces environmental destruction when mining for ore
- Reduces energy used in aluminium extraction

b Using a magnet. The aluminium is not magnetic.

3 Polymers are made from alkenes. Polymers are used to make plastics which can be cracked to form alkenes.



Rusting

1 Corrosion occurs when a metal reacts with substances in the environment. This leads to weakening of the metal.

2 Air (oxygen) and water

3 $4Fe(s) + 3O_2(g) + nH_2O(l) \rightarrow 2Fe_2O_3.nH_2O(s)$

4 It acts as a barrier so that air and water cannot get to the iron.

5 Magnesium is more reactive than iron and acts as a sacrificial metal which means that it reacts instead of the iron.

Alloys as useful materials

1 An alloy is a mixture of two or more metals.

2 The steel becomes softer, more malleable and easier to shape.

3 a Copper and zinc

b Copper and tin

c Iron, chromium and nickel

4 Number of moles of tin present bronze $= \frac{14.3}{119} = 0.12$ mol

Number of moles of copper $= \frac{55.9}{63.5} =$ 0.88mol

Therefore tin makes up $\frac{0.12}{0.12 + 0.88} \times 100\% = 12\%$

Copper makes up 100 − 12% = 88%

Ceramics, polymers and composites

1 Sand and boron trioxide

2 The particles are randomly arranged

3 a LDPE = Low-density polyethene

HDPE = High-density polyethene

b The chains are closely packed and aligned.

c The intermolecular forces between the chains are stronger and the chains cannot move so easily.

4 a Composites are materials made from two or more materials that have different properties and when combined produce a material with different properties from the constituent materials.

b Composites consist of a supporting matrix. In reinforced concrete this is the cement. They also consist of a strengthening material and in reinforced concrete this is the steel wires and the gravel.

5 The polymer chains are joined by strong covalent bonds, these stop the chains sliding over each other and therefore the plastic does not melt.

6 a It is four times harder than stainless steel.

b It is harder than stainless steel and would withstand being hit by another material.

The Haber process

1 Raising the pressure favours making fewer molecules which means more ammonia is made.

2 If a low temperature is used the reaction would be too slow. A temperature of 450ºC means the reaction proceeds at a reasonable rate and the yield of ammonia is not too low.

3 No effect.

4 They are recycled.

5 1000 dm^3.

Production and uses of NPK fertilisers

1 A fertiliser that contains nitrogen, phosphorus and potassium.

2 It contains a high percentage of nitrogen and it is soluble.

3 Cheaper to pipe the ammonia to the site of fertiliser production than it is to transport it. Also ammonia is very toxic and dangerous to transport.

4 $2NH_3 + H_3PO_4 \rightarrow (NH_4)_2HPO_4$

5 Relative formula mass of $(NH_4)_2HPO_4$

$= (2 \times 14) + (8 \times 1) + 1 + (1 \times 31) + (4 \times 16)$

$= 28 + 8 + 1 + 31 + 64 = 132$

% by mass of phosphorus = 132

$31 \times 100\% = 23.5\%$

Analysis and purification of a water sample

1 a i A pH meter

ii It would not contaminate the water

b Hydrogen chloride (hydrochloric acid)

2
- Before distillation the water contained a dissolved compound
- This substance was a compound of sodium because it gave a yellow flame in the flame test
- It also contained iodide ions as shown by the yellow precipitate with silver nitrate solution
- The dissolved compound was sodium iodide
- The distillation was successful as it gave no flame and no precipitate when the tests were repeated.