

UNIT 12

NON-METALS AND THEIR COMPOUNDS

Answers

Lesson 1 – What are non-metals and what are some of their properties?



Summary Activity 1.1: What can you remember about Non-Metals?

- A non-metal is an element which does not contain metallic bonding (or which contains covalent bonding)
- Hydrogen, carbon, oxygen, nitrogen, fluorine, chlorine, bromine, iodine
- Diamond - giant covalent structure (lattice of carbon atoms held together by covalent bonds)
- Chlorine – two atoms held together by a covalent bond to form a molecule; weak Van der Waal's forces between the molecules



Test your knowledge 1.2: Group 0 – understanding the noble gases

- (a) Eg ionisation energies very high so cannot lose electrons, outer shell full so cannot share or accept electrons easily
- (b) Increase on descending the group; more electrons per atom so stronger Van der Waal's forces between atoms
- (c) Increase on descending the group; mass of nucleus increases much faster than volume of atoms
- (d) Helium – hot air balloons/oxygen tanks for diving; neon – lighting; argon – inert atmosphere



Test your knowledge 1.3: Group 7 – understanding the halogens (physical properties)

- (a) Eg ionisation energies very high so cannot lose electrons, outer shell full so cannot share or accept electrons easily
- (b) Increase on descending the group; more electrons per atom so stronger Van der Waal's forces between atoms
- (c) Increase on descending the group; mass of nucleus increases much faster than volume of atoms
- (d) Helium – hot air balloons/oxygen tanks for diving; neon – lighting; argon – inert atmosphere

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Lesson 2 – What are the main chemical properties of halogens and halides (part 1)?



Test your knowledge 2.1: Group 7 – understanding redox properties of halogens and halides

- (a) Decreases down the group from fluorine to iodine; more shells means more shielding, so electrons are less strongly attracted into the outer shell on descending the group and the halogen does not accept an electron as readily
- (b) Increases down the group from fluoride to iodide; more shells means more shielding, so electrons in the outer shell are less strongly held and can be more easily lost
- (c) The orange colour disappears and a yellow/brown colour appears; this is because I_2 is being produced; $Br_2 + 2I^- \rightarrow 2Br^- + I_2$; Br_2 is a stronger oxidising agent than I_2 so Br will displace I from its compounds
- (d) No reaction; Br_2 is a weaker oxidising agent than I_2 so Br will not displace Cl from its compounds



Practical 2.2: Carry out halogen displacement reactions

Chemicals needed per group: access to bottles containing solutions of Cl_2 , Br_2 , I_2 (max conc. Possible), KCl, KBr, KI (1 M) and cyclohexane - each group will require around 5 cm³ - each bottle must have its own dropping pipette

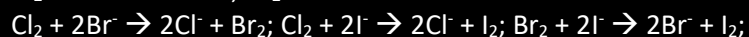
Apparatus needed per group: 6 test tubes and a test tube rack

In water, all solutions can appear yellow/orange/brown after the reaction; the addition of cyclohexane should give a distinct orange colour (for bromine) and a distinct purple colour (for iodine)

	Cl_2		Br_2		I_2	
	water	cyclohexane	water	cyclohexane	water	cyclohexane
Cl^-			yellow/orange	orange	yellow/brown	purple
Br^-	yellow/orange	orange			yellow/brown	purple
I^-	yellow/brown	purple	yellow/brown	purple		

The halogen changes during the following reactions:

Cl_2 with KBr and KI, Br_2 with KI:



Lesson 3 – How else can we compare the reducing properties of halide ions?



Test your knowledge 3.1: Group 7 – comparing the reducing power of halides

- (a) $H_2SO_4(l) + 2KCl(s) \rightarrow K_2SO_4(s) + 2HCl(g)$
- (b) $2H_2SO_4(l) + 2KBr(s) \rightarrow SO_2(g) + Br_2(g) + 2H_2O(l) + K_2SO_4(s)$
- (c) $5H_2SO_4(l) + 8KI(s) \rightarrow H_2S(g) + 4I_2(g) + 4H_2O(l) + 4K_2SO_4(s)$
- (d) Cl^- is the weakest reducing agent; it does not reduce H_2SO_4 ; Br^- is a stronger reducing agent; it reduces S in H_2SO_4 from +6 to +4; I^- is the strongest reducing agent; it reduces S in H_2SO_4 from +6 to -2
- (e) MnO_2 ; it should also oxidise Br^- and I^- because these are stronger reducing agents than Cl^-



Demonstration 3.2: Compare the reactions of concentrated sulphuric acid with the different halide ions

Equipment and chemicals needed: three test tubes, 2 g NaCl, 2 g KBr, 2 g KI, each with a spatula, one test tube rack; 10 cm³ of conc H₂SO₄ with dropping pipette; filter paper soaked in conc NH₃, dichromate paper - you must use gloves and a fume cupboard for this experiment

The vapour with KCl is white; the vapour with KBr is orange; the vapour with KI is purple; NH₃ will give a white smoke with all gases as HBr and HI are also produced and also give a white smoke with ammonia

White – HCl; orange – Br₂; purple – I₂; KCl reaction not redox; in KBr reaction S in H₂SO₄ is reduced and Br⁻ is oxidised; in KI reaction S in H₂SO₄ is reduced and I⁻ is oxidised

Can't do this experiment? Watch this video instead: [www.youtube.com/watch?v= I5O5dYEdO4](http://www.youtube.com/watch?v=I5O5dYEdO4)

Lesson 4 – What else do I need to know about halogens and halides?



Summary Activity 4.1: What can you remember about tests for halide ions?

- Add HNO₃ and then AgNO₃; Cl⁻ will give a white precipitate, Br⁻ will give a cream precipitate and I⁻ will give a yellow precipitate



Test your knowledge 4.2: Group 7 – describing other reactions of halogens and halides

- Mg + Cl₂ → MgCl₂; Mg + Br₂ → MgBr₂
- Chlorine is more reactive than bromine as it attracts electrons more strongly
- Cl₂(g) + H₂O(l) ⇌ HCl(aq) + HClO(aq); HClO is an oxidising agent and can kill bacteria but is not harmful to humans in small concentrations
- Cl₂(g) + 2NaOH(aq) → NaCl(aq) + NaClO(aq) + H₂O(l); NaClO is a strong oxidising agent and is used in domestic bleach
- It changes from 0 to +1 and -1
Use blue litmus paper; chlorine turns it red and then bleaches it
- Add HNO₃ and then AgNO₃; Cl⁻ will give a white precipitate, Br⁻ will give a cream precipitate and I⁻ will give a yellow precipitate
- Chlorine used to sterilise water; iodine used to sterilise wounds; sodium chlorate (I) used in bleach, silver bromide used in photography

Lesson 5 – Why is water special?



Summary Activity 5.1: The special properties of water

- simple molecular; water forms molecules (H₂O) which are held together by hydrogen bonding
- Heat a sample of water in a flask connected to a distillation apparatus with a thermometer in the head; record the maximum temperature reached; the intermolecular forces in water are stronger than between other molecules of a similar size, due to hydrogen bonding
- Most ionic compounds dissolve in water, especially those containing NH₄⁺, K⁺, Na⁺ or NO₃⁻; simple molecules dissolve in water only if they are polar or can form hydrogen bonds; most giant covalent substances do not dissolve in water



Demonstration 5.2: Demonstrate the polarity of water

Apparatus needed: an inflated balloon and some water

The water stream should bend towards the balloon

This is because water is polar and polar molecules are attracted to charged particles

Ethanol and ethanoic acid should give the same effect

Most oils and paraffin should give no effect



Practical 5.3: Investigate the solubility of different substances in water

Chemicals needed: salt, sugar, chalk, wax, sand (1 g per group), each container needs its own spatula; paraffin and ethanol (2 cm³ per group) each bottle needs its own dropping pipette, bottles of distilled water

Apparatus needed per group: seven test tubes and one test tube rack; one 10 cm³ measuring cylinder

Salt, sugar and ethanol will dissolve; wax, sand, chalk and paraffin will not

- Salt and chalk are ionic; ionic compounds sometimes dissolve in water, but only if the attraction between the ions and water is stronger than the attraction between the ions; in NaCl it is but in CaCO₃ it is not
- wax, sugar, ethanol and paraffin are simple molecular; simple molecular substances will dissolve in water if they can form hydrogen bonds with water; sugar and ethanol (which have -OH groups) can, wax and paraffin (which are non polar) cannot
- sand is giant covalent and giant covalent structures are usually insoluble in water



Test your knowledge 5.4: Understanding the Importance of Water

- (a) High boiling point, high surface tension and lower density in solid state than liquid state; these anomalous properties are due to strong hydrogen bonding in water
- (b) Sodium chloride (and most ionic compounds), sucrose, ethanol (and most molecules with hydrogen bonding) all dissolve in water; chalk (and some other ionic compounds), sand (and most giant covalent substances), wax and paraffin (and most non-polar molecules) do not
- (c) Add NaOH or AgNO₃ - a precipitate may form if dissolved substances are present; test pH - if not 7 then dissolved substances are present; test conductivity - if conducts then dissolved substances are present; evaporate off water – if residue left then dissolved substances are present
- (d) Add a few drops to anhydrous copper sulphate; if the copper sulphate turns blue then water is present
- (e) Add positively charged ions to water, which causes some particles and dissolved substances to coagulate; separate off larger particles which settle at bottom; filter remaining water; add disinfectant

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Lesson 6 – What do I need to know about hydrogen, oxygen and their compounds?



Summary Activity 5.1: What do you know about hydrogen, oxygen and their compounds?

- both simple molecular; both form diatomic molecules with very weak Van der Waal's forces holding the molecules together
- Eg $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$; Mg, Al, Zn, Fe, Sn and Pb react steadily with acids; hydrogen gas is produced in this reaction
- H^+ ions turn blue litmus red; also it will give bubbles if added to CaCO_3 or another carbonate
- OH^- ions turn red litmus paper blue; they also give a pungent-smelling gas when warmed with ammonium chloride
- CaO : $\text{CaO} + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}$; Na_2O : $\text{Na}_2\text{O} + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O}$
- SO_2 : $\text{SO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_3 + \text{H}_2\text{O}$; Cl_2O : $\text{Cl}_2\text{O} + 2\text{NaOH} \rightarrow 2\text{NaClO} + \text{H}_2\text{O}$
- ZnO : $\text{ZnO} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2\text{O}$; $\text{ZnO} + 2\text{NaOH} \rightarrow \text{Na}_2\text{ZnO}_2 + \text{H}_2\text{O}$



Activity 6.2: What is the best way to put out a fire?



Test your knowledge 6.3: Understanding the reactions of hydrogen, oxygen and their compounds

- Insert a lit splint into the test tube – the hydrogen burns with a squeaky pop
- H-O-O-H
- $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$; used in the laboratory preparation of oxygen
- The air is cooled to a very low temperature to ensure that N_2 , O_2 and Ar all condense; liquid air run into base of fractionating column; temperature allowed to rise slowly; N_2 and Ar boil first, leaving oxygen at base of column
- $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$; this is how all living things generate energy to function
- Water
- A fire extinguisher containing carbon dioxide or foam
- Covalent oxides (ie oxides of non-metals) are acidic; ionic oxides (ie oxides of metals) are basic
- Acidic: CO_2 , SO_3 , ClOH , $\text{HPO}(\text{OH})_2$, SiO_2 ; basic: MgO , NaOH , FeO ; amphoteric: Al_2O_3
- $\text{CaO} + \text{SO}_2 \rightarrow \text{CaSO}_3$; $2\text{NaOH} + \text{SiO}_2 \rightarrow \text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}$; $\text{CO}_2 + \text{MgO} \rightarrow \text{MgCO}_3$

Lesson 7 – What do I need to know about sulphur and its compounds?



Summary Activity 7.1: What can you remember about sulphur dioxide?

- SO_2 ; it is acidic – $\text{SO}_2 + 2\text{OH}^- \rightarrow \text{SO}_3^{2-} + \text{H}_2\text{O}$
- It will turn blue litmus paper red and will turn acidified dichromate paper from orange to green
- H_2SO_4 ; (i) $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$, acid-base or neutralisation; (ii) $\text{H}_2\text{SO}_4 + 2\text{NH}_3 \rightarrow (\text{NH}_4)_2\text{SO}_4$, acid-base or neutralisation; (iii) $\text{H}_2\text{SO}_4 + 2\text{NaCl} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{HCl}$, acid-base or acid-salt; (iv) $2\text{H}_2\text{SO}_4 + 2\text{NaBr} \rightarrow \text{Na}_2\text{SO}_4 + \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O}$, redox; (v) $2\text{H}_2\text{SO}_4 + 2\text{NaBr} \rightarrow \text{Na}_2\text{SO}_4 + \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O}$, redox; $5\text{H}_2\text{SO}_4(\text{l}) + 8\text{NaI}(\text{s}) \rightarrow \text{H}_2\text{S}(\text{g}) + 4\text{I}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l}) + 4\text{K}_2\text{SO}_4(\text{s})$, redox
- Na_2S , S^{2-}
- Add dilute HCl and then BaCl_2 (aq), white precipitate seen


Test your knowledge 7.2 – understanding sulphur and its compounds

- (a) The S can be oxidised from +4 to +6; SO₂ is added to wine and sulphate (IV) ions are added to food to prevent oxidation
- (b) Low temperature gives higher yield of SO₃ but slows down reaction so compromise temperature of 450 oC used; high pressure gives higher yield of SO₃ and fast reaction but is expensive so 200 kPa used; V₂O₅ catalyst speeds up reaction
- (c) It is an acid and reacts with water in the air to form acid rain: SO₃ + H₂O → H₂SO₄
- (d) (i) it reacts ammonia to make ammonium sulphate which is a fertiliser and it can be used in the laboratory preparation of HCl and HNO₃; (ii) it is used in the laboratory preparation of SO₂; (iii) it is used to dry the SO₂ produced in the laboratory preparation of SO₂
- (e) Zn + S → ZnS (S reduced from 0 to -2)
- (f) ZnS + 2HCl → ZnCl₂ + H₂S (not a redox reaction)
- (g) 2ZnS + 3O₂ → 2ZnO + 2SO₂ (S oxidised from -2 to +4) this is the first stage in the extraction of Zn from its ore
- (h) See above
- (i) It smells of rotten eggs

Lesson 8 – What do I need to know about carbon and its inorganic compounds?

Summary Activity 8.1: What can you remember about carbon, carbon dioxide and carbonate ions?

- Diamond has a giant covalent structure; each C atom attached to four other C atoms in a tetrahedral shape; graphite has a giant covalent structure; each C atom attached to three other C atoms in a trigonal planar shape; this results in hexagonal layers; the layers are held together by Van der Waal's forces; each C has one extra electron in its outer shell which is delocalised; graphite conducts electricity due to its delocalised electrons but diamond does not; graphite is soft as the layers can slide over each other but diamond is hard because all atoms are fixed in place
- CO₂ + H₂O H₂CO₃ H⁺ + HCO₃⁻; CO₂ + 2NaOH → Na₂CO₃ + H₂O (CO₂ is acidic)
- Turns limewater milky and then colourless again
- Bubbles on addition of HCl; CO₂ given off; precipitate formed on addition of BaCl₂ but precipitate dissolves in HCl


Test your knowledge 8.2 – understanding carbon and its compounds

- (a) Peat is plant and animal matter partially decayed in acidic, anaerobic conditions (<60% C); lignite is a sedimentary rock formed when peat is compressed (60 – 70% C); continued pressure converts lignite into coal (70 – 87% C) and continued high temperature and pressure converts coal into a metamorphic rock called anthracite (>87% C)
- (b) Coke is produced by the destructive distillation of coal; coal gas, coal tar and coal oil are also produced
- (c) Mixture of CO and H₂, produced by heating coke at 700 oC in a limited supply of oxygen
- (d) CO₂ + 2OH⁻ → CO₃²⁻ + H₂O; CO₃²⁻ + 2H⁺ → CO₂ + H₂O; 2HCO₃⁻ → CO₃²⁻ + CO₂ + H₂O or HCO₃⁻ + H⁺ → CO₂ + H₂O and HCO₃⁻ + OH⁻ → CO₃²⁻
- (e) Add dilute HCl to CaCO₃; collect CO₂ by downward delivery
- (f) It is not flammable and more dense than air
- (g) Na₂CO₃ – water softener and used to make glass; CaCO₃ – used in steel manufacture and to neutralise acidic soil; NaHCO₃ – baking powder

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Lesson 9 – What do I need to know about nitrogen and ammonia?



Summary Activity 9.1: What can you remember about nitrogen and ammonia?

- It is simple molecular, forming diatomic molecules (N_2) in which two N atoms are joined by triple covalent bonds; the molecules are held together by weak Van der Waal's forces
- It is simple molecular, consisting of (NH_3) molecules in which the N atom is attached to three H atoms by covalent bonds; the molecules are held together by hydrogen bonds
- $NH_3 + HCl \rightarrow NH_4Cl$
- It turns red litmus blue and forms a white smoke in the presence of concentrated HCl
- If warmed with NaOH, it gives off NH_3 which has a pungent smell



Test your knowledge 9.1 – Understanding Nitrogen and Ammonia

- The air is cooled to a very low temperature to ensure that N_2 , O_2 and Ar all condense; liquid air run into base of fractionating column; temperature allowed to rise slowly; Ar boils first, then N_2 , so N_2 collected at top of column
- NH_4Cl reacts with $NaNO_2$; redox reaction; N_2 not very soluble in water so can be collected over water
- $Ca(OH)_2$ reacts with NH_4Cl ; acid-base reaction; NH_3 very soluble in water so not collected over water; less dense than air so collected by upward delivery
- Low temperature gives higher yield of ammonia but slows down reaction so compromise temperature of $450\text{ }^\circ\text{C}$ used; high pressure gives higher yield of ammonia and fast reaction so 25 MPa used; Fe catalyst speeds up reaction
- To make fertilisers

Lesson 10 – What do I need to know about nitric acid and nitrates?



Summary Activity 10.1: What can you remember about nitric acid and nitrates?

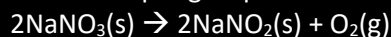
- HNO_3 , NO_3^-
- Nitric acid is a strong acid, so nitrate ions are neutral
- $HNO_3 + NH_3 \rightarrow NH_4NO_3$
- Add aluminium powder, NaOH and heat; a pungent gas (NH_3) is given off which turns damp red litmus paper blue



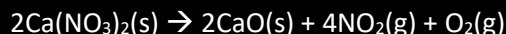
Practical 10.2: Decompose different nitrate salts

Chemicals needed per group: calcium nitrate and sodium nitrate (around 2 g per group), each container with its own spatula

Apparatus needed per group: 2 test tubes, 1 tongs, 1 Bunsen burner, 1 splint



The N is reduced from +5 to +3 and the O is oxidised from -2 to 0



The N is reduced from +5 to +4 and the O is oxidised from -2 to 0

The glowing splint re-lights, confirming the presence of oxygen

The brown gas is NO_2


Test your knowledge 10.3 – Nitric acid and nitrates

- (a) By adding concentrated sulphuric acid to potassium nitrate: $\text{H}_2\text{SO}_4(\text{l}) + \text{KNO}_3(\text{s}) \rightarrow \text{HNO}_3(\text{g}) + \text{K}_2\text{SO}_4(\text{s})$; acid-base or acid-salt reaction
- (b) To make fertilisers (mainly ammonium nitrate)
- (c) $2\text{NaNO}_3(\text{s}) \rightarrow 2\text{NaNO}_2(\text{s}) + \text{O}_2(\text{g})$; $2\text{Cu}(\text{NO}_3)_2(\text{s}) \rightarrow 2\text{CuO}(\text{s}) + 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g})$

Lesson 11 – How can we prepare and collect gases in the laboratory? (Part 1)

Summary Activity 11.1: Which reactions can be used to prepare different gases in the laboratory?

- H_2 : $\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$ (redox or metal-acid); O_2 : $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ (redox or disproportionation); N_2 : $\text{NH}_4\text{Cl} + \text{NaNO}_2 \rightarrow \text{N}_2 + 2\text{H}_2\text{O} + \text{NaCl}$ (redox); Cl_2 : $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$ (redox); HCl : $\text{H}_2\text{SO}_4 + 2\text{KCl} \rightarrow \text{K}_2\text{SO}_4 + 2\text{HCl}$ (acid-salt); SO_2 : either $\text{Na}_2\text{SO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{SO}_2 + \text{H}_2\text{O}$ (acid-base) or $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$ (redox); CO_2 : $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$ (acid-base); NH_3 : $\text{Ca}(\text{OH})_2 + 2\text{NH}_4\text{Cl} \rightarrow \text{CaCl}_2 + 2\text{NH}_3 + 2\text{H}_2\text{O}$ (acid-base)
- H_2 burns with a squeaky pop; O_2 relights a glowing splint; there is no specific test for N_2 ; Cl_2 turns blue litmus red and then white; HCl will give white fumes in contact with a strip of filter paper soaked in NH_3 ; SO_2 will turn dichromate paper from orange to green; CO_2 will turn limewater milky and then colourless again; NH_3 will give white fumes in contact with a strip of filter paper soaked in HCl


Demonstration 11.2: Prepare H_2 gas in the laboratory

Equipment and chemicals needed as described above (a flask, a dropping funnel, a delivery tube, a bung to fit the flask with holes both for a delivery tube and a dropping funnel, a trough of water, a gas jar with lid, clamp, stand, boss, 2 moldm⁻³ HCl, zinc granules)

Bubbles can be clearly seen when the HCl is added, and bubbles should be seen entering the gas jar; the water level in the gas jar should drop

- $\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$
- Zn is oxidised (from 0 to +2) and the H^+ in the acid is reduced from +1 to 0
- it is insoluble in water because it is non-polar
- hydrogen gas is less dense than air so it rises, if you remove the lid from underneath the jar, most of the gas will remain in the jar; if you remove the lid from the top of the jar, the gas will all escape
- It burns with a squeaky pop
- The hydrogen is reacting with oxygen: $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$


Demonstration 11.3: Prepare O₂ gas in the laboratory

Equipment and chemicals needed as described above (wear gloves for this experiment) (a flask, a dropping funnel, a delivery tube, a bung to fit the flask with holes both for a delivery tube and a dropping funnel, a trough of water, a gas jar with lid, clamp, stand, boss, 2 moldm⁻³ H₂O₂, MnO₂ powder)

Bubbles can be clearly seen when the H₂O₂ is added, and bubbles should be seen entering the gas jar; the water level in the gas jar should drop

- $2\text{H}_2\text{O}_2(\text{l}) \rightarrow 2\text{H}_2\text{O} + \text{O}_2(\text{g})$
- In this reaction the O is both oxidised (from -1 to 0, in O₂) and reduced (from -1 to -2, in H₂O)
- it is insoluble in water because it is non-polar
- It relights a glowing splint
- The wood in the splint is reacting with the oxygen in a combustion reaction


Demonstration 11.4: Prepare N₂ gas in the laboratory

Equipment and chemicals needed as described above (a flask, a dropping funnel, a delivery tube, a bung to fit the flask with a delivery tube, Bunsen, tripod, gauze, a trough of water, a gas jar with lid, clamp, stand, boss, 14 g NaNO₂, 11 g of NH₄Cl)

Bubbles should be visible shortly after heating starts; bubbles should be seen entering the gas jar; the water level in the gas jar should drop

- $\text{NH}_4\text{Cl} + \text{NaNO}_2 \rightarrow \text{N}_2 + 2\text{H}_2\text{O} + \text{NaCl}$
- N in NH₄⁺ is oxidised from -3 to 0 and N in NO₂⁻ is reduced from +3 to 0
- it is insoluble in water because it is non-polar


Demonstration 11.5: Prepare Cl₂ gas in the laboratory

Equipment and chemicals needed: a round-bottomed flask, two conical flasks, a dropping funnel, three bungs to fit the flasks, each with two holes, three delivery tubes, a gas jar, Bunsen burner, tripod, gauze, MnO₂, conc HCl, conc H₂SO₄, damp blue litmus paper) **you must use gloves for this experiment**

Bubbles can be clearly seen when the conc HCl is added; heating may not be necessary; bubbles should be seen passing through the water and the sulphuric acid; the gas may appear as a pale green colour in the gas jar

- $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$
- The Mn is reduced from +4 to +2; the Cl⁻ is oxidised to Cl₂ (-1 to 0)
- Water removes the HCl and concentrated H₂SO₄ removes the water
- Chlorine gas is denser than air
- $\text{Cl}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HCl}(\text{aq}) + \text{HClO}(\text{aq})$; HCl contains H⁺ and turns litmus red; HClO is a bleaching agent and turns it white


Test your knowledge 11.6: Describing the collection of different gases (Part 1)

- (a) (i) H_2 : $\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$ (redox or metal-acid); (ii) O_2 : $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ (redox or disproportionation); (iii) N_2 : $\text{NH}_4\text{Cl} + \text{NaNO}_2 \rightarrow \text{N}_2 + 2\text{H}_2\text{O} + \text{NaCl}$ (redox); (iv) Cl_2 : $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$ (redox)
- (b) H_2 , O_2 and N_2 have limited solubility in water so are collected over water; Cl_2 reacts with water and is denser than air so is collected by downward delivery
- (c) H_2 burns with a squeaky pop; O_2 relights a glowing splint; Cl_2 turns blue litmus red and then white

Lesson 12 – How can we prepare and collect gases in the laboratory? (Part 2)

Demonstration 12.1: Prepare HCl gas in the laboratory

Equipment and chemicals needed: round-bottomed flask, dropping funnel, bung for flask with 2 holes, delivery tube, gas jar, spatula, dropping pipette, gas jar, clamp, stand and boss; solid KCl, conc H_2SO_4 , filter paper soaked in conc NH_3 (you must use gloves for this experiment and use a fume cupboard if you have one)

- HCl collected by downward delivery as it is denser than air
- HCl not collected over water as it is very soluble in water
- $\text{H}_2\text{SO}_4(\text{l}) + 2\text{KCl}(\text{s}) \rightarrow \text{K}_2\text{SO}_4(\text{s}) + 2\text{HCl}(\text{g})$
- $\text{HCl}(\text{g}) \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$ (H^+ turns the blue litmus red)
- $\text{NH}_3(\text{g}) + \text{HCl}(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{s})$ (NH_4Cl is the white smoke)


Demonstration 12.2: Prepare SO_2 gas in the laboratory (Part 1)

Equipment and chemicals needed: (round-bottomed flask, dropping funnel, conical flasks, two delivery tubes, two bungs to fit the flasks, each with two holes, a gas jar, clamp, stand, boss, Bunsen, tripod, gauze, 5 g Na_2SO_3 , 50 cm^3 1 mol dm^{-3} HCl, blue litmus paper, dichromate paper); **you must use gloves for this experiment**
 Bubbles can be clearly seen when the dilute HCl is added; heating should increase the rate of production of bubbles and bubbles should be seen passing through the sulphuric acid

- $\text{Na}_2\text{SO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
- Acid-base reaction
- concentrated H_2SO_4 removes the water
- SO_2 is denser than air
- SO cannot be collected over water as it is soluble in water
- $\text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{SO}_3(\text{aq}) \rightleftharpoons 2\text{H}^+(\text{aq}) + \text{SO}_3^{2-}(\text{aq})$; H^+ and turns litmus red
- SO_2 is a reducing agent; it gets oxidised to SO_4^{2-} ions and reduces dichromate ions to Cr^{3+}


Demonstration 12.3: Prepare SO_2 gas in the laboratory (Part 2)

Equipment and chemicals (round-bottomed flask, dropping funnel, delivery tube, bung to fit the flask with two holes, gas jar, Bunsen burner with tripod and gauze, clamp, stand, boss, conc H_2SO_4 (50 cm^3), Cu turnings (5 g), blue litmus paper, dichromate paper) **you must use gloves for this experiment**
 Bubbles should be seen when the mixture is heated

- $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$
- S reduced from +6 to +4; Cu oxidised from 0 to +2


Demonstration 12.4: Prepare CO₂ gas in the laboratory

Equipment and chemicals needed: (round-bottomed flask, dropping funnel, delivery tube, bung to fit the flask with two holes, gas jar, test tube, clamp with stand and boss, marble chips (5 g), 2 moldm⁻³ HCl (50 cm³), limewater, 10 cm³, splint)

Bubbles can be clearly seen when the dilute HCl is added

- $\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
- Acid-base reaction
- CO₂ is denser than air
- CO₂ turns limewater milky and then colourless again; the milky appearance is due to the insoluble calcium carbonate; $\text{CO}_2(\text{g}) + \text{Ca}(\text{OH})_2(\text{aq}) \rightarrow \text{CaCO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$; $\text{CaCO}(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{Ca}(\text{HCO}_3)_2(\text{aq})$
- Carbon dioxide extinguishes a lit splint as it is not flammable


Demonstration 12.5: Prepare NH₃ gas in the laboratory

Equipment and chemicals needed: round-bottomed flask with a bung attached to a delivery tube, CaO tower, gas jar, Bunsen burner, NH₄Cl (2 g), Ca(OH)₂ (2 g), red litmus paper

Bubbles should be visible after gently heating the mixture for a short time

- $\text{Ca}(\text{OH})_2(\text{s}) + 2\text{NH}_4\text{Cl}(\text{s}) \rightarrow \text{CaCl}_2(\text{s}) + 2\text{NH}_3(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
- A neutralisation or acid-base reaction is taking place
- Ammonia is very soluble in water so cannot be collected over water
- To remove any water from the gaseous mixture
- It is less dense than air
- It turns red litmus paper blue; NH₃ is a base and reacts with water on the paper to form OH⁻ ions


Test your knowledge 12.6: Describing the collection of different gases (Part 2)

- (a) (i) HCl: $\text{H}_2\text{SO}_4 + 2\text{KCl} \rightarrow \text{K}_2\text{SO}_4 + 2\text{HCl}$ (acid-salt); (ii) SO₂: either $\text{Na}_2\text{SO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{SO}_2 + \text{H}_2\text{O}$ (acid-base) or $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$ (redox); (iii) CO₂: $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$ (acid-base); (iv) NH₃: $\text{Ca}(\text{OH})_2 + 2\text{NH}_4\text{Cl} \rightarrow \text{CaCl}_2 + 2\text{NH}_3 + 2\text{H}_2\text{O}$ (acid-base)
- (b) HCl, SO₂, CO₂ and NH₃ are highly soluble in water so cannot be collected over water; HCl, SO₂ and CO₂ are denser than air so collected by downward delivery; NH₃ is less dense than air so collected by upward delivery
- (c) HCl will give white fumes in contact with a strip of filter paper soaked in NH₃; SO₂ will turn dichromate paper from orange to green; CO₂ will turn limewater milky and then colourless again; NH₃ will give white fumes in contact with a strip of filter paper soaked in HCl

UNIT 12 – NON-METALS AND THEIR COMPOUNDS

Lesson 13 – What do I need to know about rocks?



Test your knowledge 13.1 – understanding rocks

- (a) Mineral – substance of fixed composition found in the earth's crust; rock – mixture of minerals
- (b) Igneous – formed by cooling lava or magma; sedimentary – formed by small rock deposits being compressed; metamorphic – formed by subjecting sedimentary rocks to high temperature and pressure
- (c) Breaking down of rocks into smaller particles
- (d) Hydrolysis - breaking down a rock by reacting it with water, acid or alkali; hydration - absorption of water by a rock; carbonation – dissolving a rock in carbonic acid; oxidation – reaction of a rock with oxygen

Lesson 14 – What have I learned about non-metals and their compounds?



14.1 END-OF-UNIT QUIZ

UNIT 12 – NON-METALS AND THEIR COMPOUNDS

1. Ar = simple atomic, Van der Waal's forces between atoms; Cl₂, H₂, O₂, N₂ = simple molecular, diatomic molecules with single covalent bonds (Cl-Cl and H-H) or double covalent bonds (O=O) or triple covalent bonds (N≡N between atoms; S₈ crown shaped molecule with eight S atoms held together in a ring by single covalent bonds, Van der Waal's forces between all molecules)
2. O₂: decomposition of H₂O₂ in presence of MnO₂; Cl₂: oxidation of concentrated HCl by MnO₂; N₂: oxidation of NH₄Cl by NaNO₂; redox reactions; Cl₂ collected by downward delivery as denser than air and reacts with water; N₂ and O₂ collected over water as they are not very soluble in water
3. HCl: H₂SO₄ with KCl (acid-base or acid-salt); NH₃: NH₄Cl with Ca(OH)₂ (acid-base); CO₂: CaCO₃ with HCl (acid-base); HCl and NH₃ highly soluble in water so not collected over water; HCl denser than air so collected by downward delivery; NH₃ less dense than air so collected by upward delivery; CO₂ denser than air so collected by downward delivery (or over water)
4. H₂: burns with a squeaky pop; O₂: relights a glowing splint; Cl₂: turns blue litmus paper red and then white; N₂: negative test for all other gases
5. (a) $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$
(b) $\text{Cl}_2 + 2\text{NaBr} \rightarrow 2\text{NaCl} + \text{Br}_2$
6. Fractional distillation; air is cooled until it completely liquefies and inserted into the base of a fractionating column; N₂ has a lower boiling point and is collected at the top of the fractionating column
7. $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$; 450 °C (compromise temperature: high temperature gives faster reaction but lower yield); 25 MPa (high pressure gives fast reaction and good yield); Fe catalyst to increase rate of reaction
8. (a) $2\text{Ca}(\text{NO}_3)_2 \rightarrow 2\text{CaO} + 4\text{NO}_2 + \text{O}_2$
(b) $2\text{NaNO}_3 + 2\text{NaNO}_2 + \text{O}_2$
(c) $2\text{CuS} + 3\text{O}_2 \rightarrow 2\text{CuO} + 2\text{SO}_2$
9. Peat compressed into lignite and then into coal; over millions of years it is further compressed at high temperatures into anthracite
10. Igneous – formed from cooling lava or magma; sedimentary – formed by compression and sedimentation of small rock deposits; metamorphic – formed by further compression of sedimentary rock at high temperature
11. Breaking down of rocks into smaller pieces (hydration, hydrolysis, carbonation and oxidation)