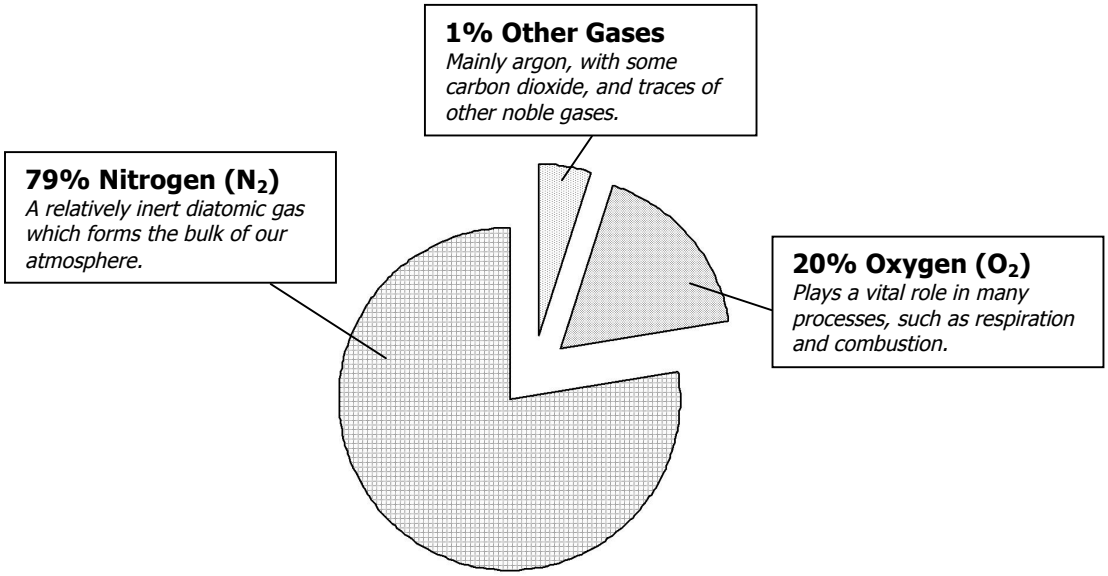
Topic 13: **Answers**
Air & The Atmosphere

SYLLABUS RELEVANCE & TEXTBOOK CHAPTERS		
O-LEVEL PURE (5072)	✓	Chapter 20
O-LEVEL SCIENCE (5116)	✓	Chapter 17
N-LEVEL SCIENCE (5155)	✓	Chapter 13

Lesson Package & Accompanying Slides Designed by Alex Lee (2008)
Last Modified by Alex Lee (2011)

1. Composition of Dry Air

Air is a mixture of gases that is present in our atmosphere. The composition of dry air can be represented in the pie-chart below.



The term 'dry' air above refers to air without ....water vapour.... The composition of water vapour in air can vary between 0.5% to 5.0%, and is often referred to as 'humidity'. Two geographical factors that affect the humidity of a location are ....temperature.... and ....proximity to water bodies....

Air is a ....mixture.... and hence can be separated by physical means. We generally obtain three gases, ...nitrogen....., ...oxygen..... and ....argon....., through ....fractional distillation of liquid air....

The most abundant noble gas in our atmosphere is ....argon....., consisting close to 1% of the total air. This makes the concentration of argon ....higher..... than the concentration of carbon dioxide. The relatively high abundance of argon makes it economically very ....cheap....., and is hence used in many industrial applications such as ....maintaining an inert atmosphere in filament lamps....

2. **Common Gases, Sources and Uses**

Gas	Industrial Source	Uses
Nitrogen	Fractional distillation of liquid air.	Used in the manufacture of ammonia, in method known as *Haber Process*.
Oxygen	Fractional distillation of liquid air.	Essential for life-sustaining processes such as respiration and combustion.
Argon	Fractional distillation of liquid air.	Used to provide an inert environment, e.g. inside light bulbs.
Carbon Dioxide	Usually available as a waste gas in many industrial processes.	Essential for photosynthesis. Produces carbonic acid when dissolved in water.
Water Vapour	Evaporation of liquid water.	Essential to sustain life in both plants and animals.
Hydrogen	Cracking of crude oil, or electrolysis of water.	Rocket fuel, and for hydrogen-powered cars. Also used as a reducing agent.
Chlorine	Electrolysis of concentrated brine (sodium chloride).	Used as a bleach and a disinfectant, e.g. in swimming pools.
Sulfur Dioxide	Combustion of sulfur-containing compounds.	Used as a reducing agent, and also as a preservative in food.
Ammonia	Produced using the *Haber Process*, using nitrogen and hydrogen gases.	Used in the production of nitric acid, and in the production of fertilizers.

(a) Which of the above gases are **not** present in unpolluted air?

hydrogen, chlorine, sulfur dioxide, ammonia

(b) Which of the above gases can be obtained by fractional distillation of liquid air?

nitrogen, oxygen, argon

(c) (i) Which of the above gases are good reducing agents?

hydrogen, sulfur dioxide, ammonia

(ii) Which of the above gases are good oxidising agents?

oxygen, chlorine

(d) Which of the above gases are acidic?

carbon dioxide, chlorine, sulfur dioxide

(e) Which of the above gases are colourless and odourless?

nitrogen, oxygen, argon, carbon dioxide, water vapour, hydrogen

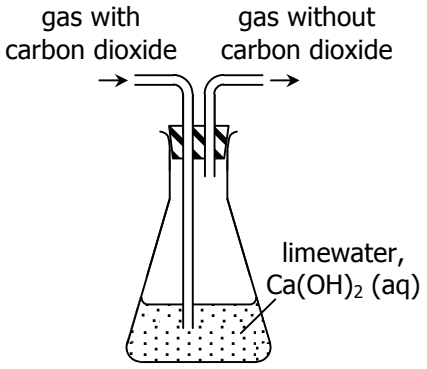
3. **Removal of Gases**

The diagrams below illustrate various methods to **remove a particular gas from a mixture of gases** in a laboratory setting.

Removal of Acidic Gases

Examples: carbon dioxide, chlorine

Method: bubble through an alkali

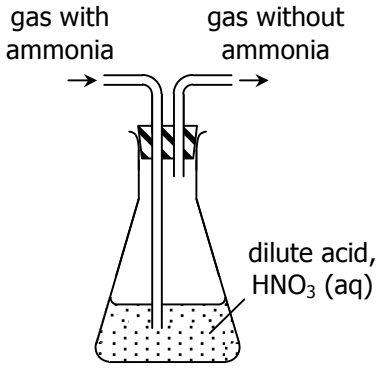


Note that by bubbling through a solution, water vapour may be produced in the process.

Removal of Alkaline Gases

Examples: ammonia

Method: bubble through an acid

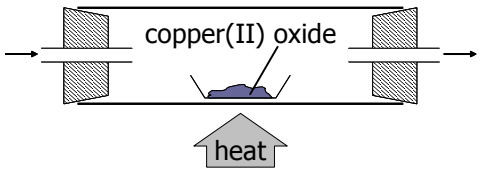


Note that by bubbling through a solution, water vapour may be produced in the process.

Removal of Gaseous Reducing Agents

Examples: hydrogen, carbon monoxide
sulfur dioxide, ammonia

Method: pass the gas sample over heated copper(II) oxide



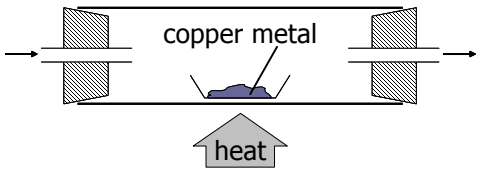
$CuO + H_2 \longrightarrow Cu + H_2O$
$CuO + CO \longrightarrow Cu + CO_2$
$CuO + SO_2 \longrightarrow Cu + SO_3$
$3\ CuO + 2\ NH_3 \longrightarrow 3\ Cu + N_2 + 3\ H_2O$

*The **black** solid (copper(II) oxide) turns into a **brownish-pink** solid (copper metal).*

Removal of Gaseous Oxidising Agents

Examples: oxygen, chlorine, fluorine

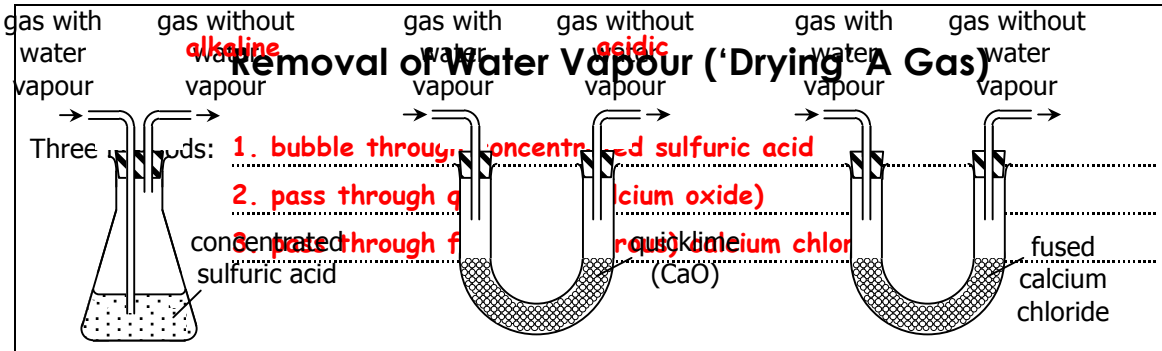
Method: pass the gas sample over heated copper (or any metal)



$2\ Cu + O_2 \longrightarrow 2\ CuO$
*The **brownish-pink** solid (copper metal) turns into a **black** solid (copper(II) oxide).*

$Cu + Cl_2 \longrightarrow CuCl_2$
*The **brownish-pink** solid (copper metal) turns into a **green** solid (copper(II) chloride).*

Removal of Water Vapour ('Drying' A Gas)



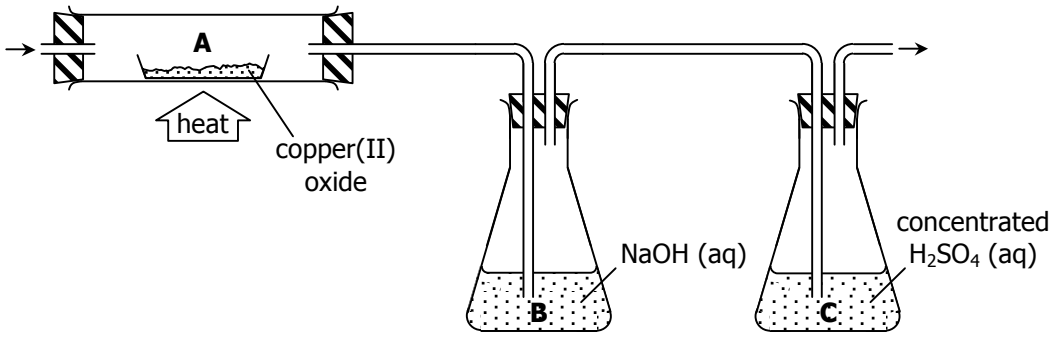
May remove ..... gases at the same time.

May remove ..... gases at the same time.

Note that, in a series of chemical reactions, drying the gas should be done at the very last step as water vapour may be produced in the other steps.

4. **Review Questions**

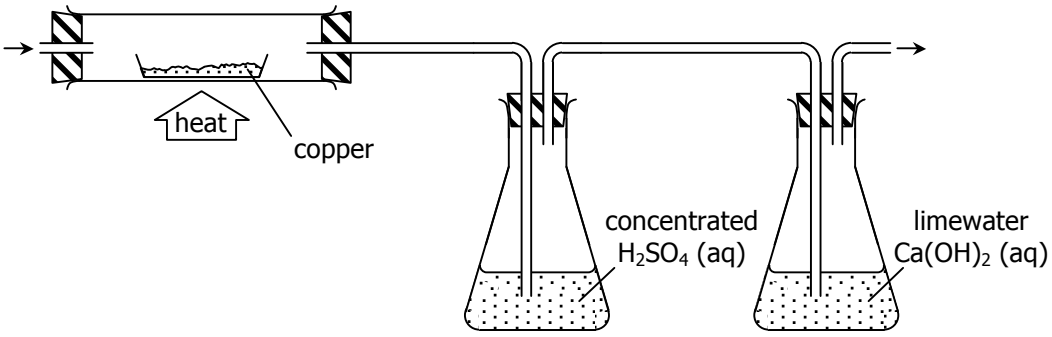
(a) A mixture of gases was passed through the apparatus as shown.



In the table below, name the possible gases that could have reacted / been removed in apparatus **A**, **B** and **C** respectively.

Apparatus	Possible Gases Removed
A	hydrogen, carbon monoxide, sulfur dioxide, ammonia
B	carbon dioxide, sulfur dioxide, chlorine
C	water vapour, ammonia (if not already removed in A)

(b) A sample of clean air was passed through the apparatus as shown.



(i) In the above apparatus, the copper metal is observed to change in colour. Describe this colour change and explain why this occurs.

The brownish-pink copper metal turns black. This is because oxygen, from the air, reacts with copper to form copper(II) oxide, which is a black solid.

(ii) State the purpose of the conical flask containing concentrated sulfuric acid in the above experiment. What mistake has been made in the position of this conical flask, and why?

The concentrated sulfuric acid is to remove water vapour / dry the air. It should have been placed after the conical flask containing limewater, not before so that it can also remove the water vapour produced by the limewater.

(iii) Name the main gases which emerge from the above set-up.

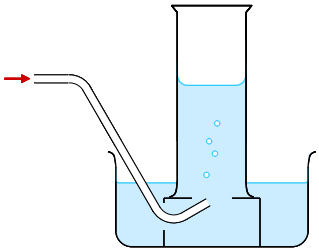
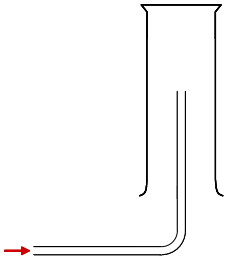
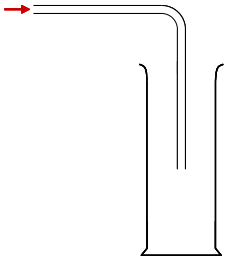
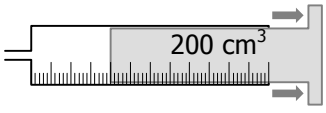
Nitrogen, argon and water vapour

(c) Indicate if the following statements are **true** or **false**.

Hydrogen is the most abundant gas in our atmosphere.	false
Argon has a higher abundance in our atmosphere than carbon dioxide.	true
Air is a mixture of gaseous elements.	false
Air is separated by liquification, followed by fractional distillation.	true
Carbon dioxide is industrially obtained from fractional distillation of liquid air.	false
Hydrogen may be removed from a gaseous mixture by heating with copper.	false
Carbon monoxide, chlorine and hydrogen are examples of reducing agents.	false
Carbon dioxide may be removed from air by bubbling through limewater.	true
Carbon dioxide may be removed from air by bubbling through NaOH (aq).	true
A neutral gas may be dried by bubbling through dilute sulfuric acid.	false

5. **Collection of Gases**

The diagrams below illustrate various methods to **collect a gas sample** from a chemical reaction in a laboratory setting.

Method	Diagram	Remarks	Examples
Displacement of Water		Accurate method as it prevents escape of the gas by diffusion. **However, it may only be used for insoluble gases**.	carbon dioxide hydrogen oxygen
Upwards Delivery		Used for soluble gases which are **less dense than air**, i.e. M_r < 28.	ammonia
Downwards Delivery		Used for soluble gases which are **more dense than air**, i.e. M_r > 28.	chlorine sulfur dioxide
Gas Syringe		Key advantage of this method is that the **volume of gas collected can also be measured**.	May be used to collect all gases.

Suggest which method – displacement of water, upwards delivery, or downwards delivery, would be most suitable to collect

(a) an insoluble gas which is less dense than air — displacement of water

(b) a soluble gas which has an M_r of 64. — downwards delivery

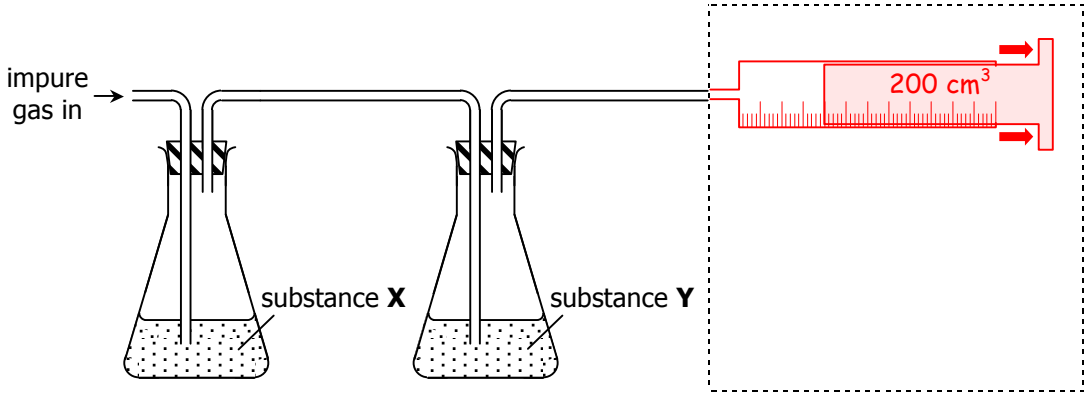
(c) oxygen, which is insoluble in water and neutral in pH — displacement of water

(d) fluorine, which is soluble in water — downwards delivery

(e) methane, which is insoluble in water — displacement of water

6. **Review Questions**

(a) A sample of oxygen is contaminated with some chlorine. The following apparatus is used to obtain a pure, dry sample of oxygen.



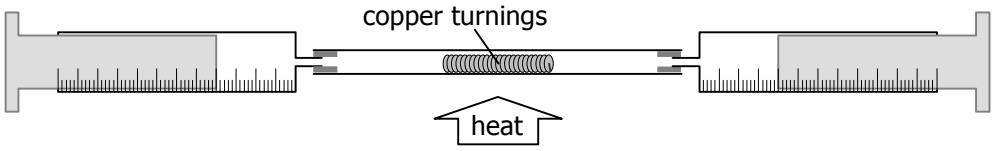
(i) Suggest possible identities for substances **X** and **Y**.

X: water or aqueous sodium hydroxide (or any other alkali)

Y: concentrated sulfuric acid

(ii) In the dotted box above, complete the diagram to show how a pure, dry sample of oxygen can be most accurately collected.

(b) Using a gas syringe, a 200 cm^3 sample of air was passed over a narrow glass tube containing copper turnings as shown in the diagram below. This was repeated until there was no further reduction in volume of air.



(i) Construct a chemical equation, with state symbols, for the reaction that occurs.

$2\ Cu\ (s) + O_2\ (g) \longrightarrow 2\ CuO\ (s)$

(ii) State the volume of gas remaining at the end of the reaction, and identify the main component of this gas mixture.

160 cm^3, mainly nitrogen gas

(c) Briefly explain why

(i) ammonia gas may not be dried by bubbling through concentrated sulfuric acid,

Ammonia is alkaline and hence will react with the sulfuric acid.

(ii) chlorine gas may not be collected by displacement of water.

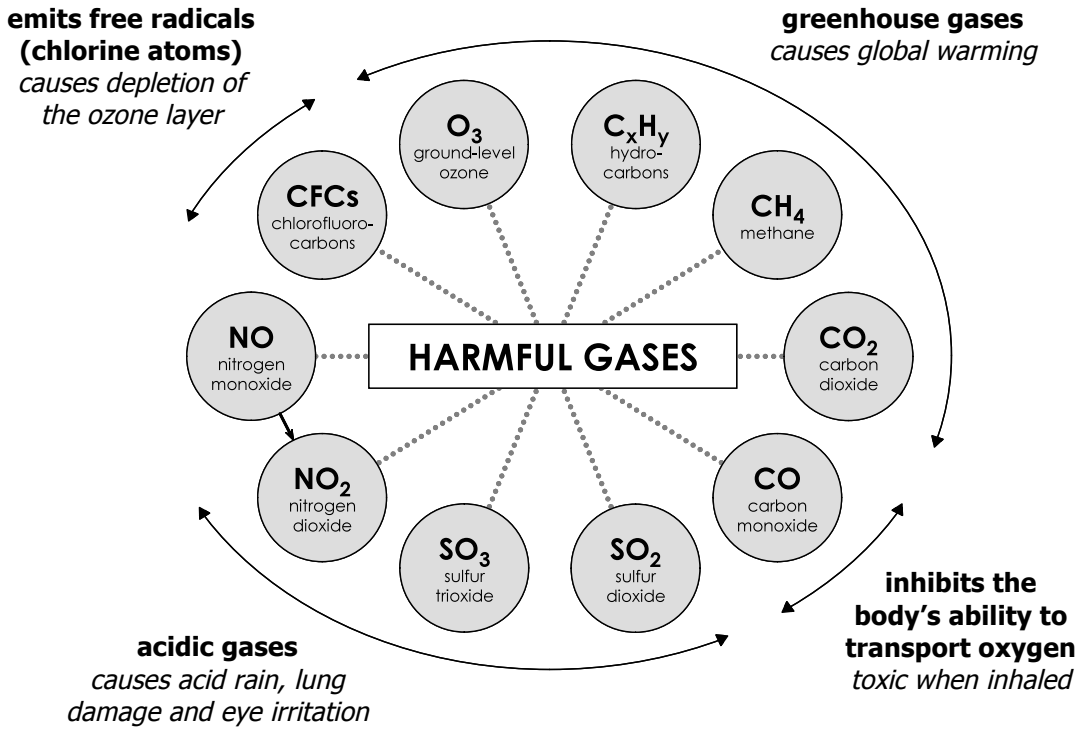
Chlorine gas is soluble in water and hence will dissolve into the water.

7. **Harmful Gases & Air Pollution**

Human activity has resulted in other gases being introduced to our atmosphere, many of which are considered to be air pollutants.

An **air pollutant** is a substance (usually gas) which is introduced to the air by human activity, and has a harmful effect on the environment, including our health.

The diagram below highlights the main gases which inflict harm upon our environment.



(a) To what extent would you consider carbon dioxide to be an air pollutant?

Only to a small extent. Carbon dioxide should not be considered as an air pollutant as it is naturally present in our atmosphere. However, in recent years, it is increasingly being considered as an air pollutant due to its increasing levels in air.

(b) The pH of rain is found to be 6.5. Is this considered to be acid rain? Why or why not?

No. Normal rain is slightly acidic due to the presence of carbon dioxide in our air. Carbon dioxide is only slightly soluble in water, and only forms a weak acid. In contrast, acid rain refers to rain which has a much lower pH, i.e. 4 and below.

8. **Sources & Harmful Effects of Air Pollutants**

Air Pollutant: Carbon Monoxide

Carbon monoxide is formed from the incomplete combustion of carbon-based fuels, such as coal and hydrocarbons. This occurs in vehicles (combustion of petrol or diesel, which are hydrocarbons) and also in coal-powered factories (combustion of coal).

Carbon monoxide is harmful because it binds strongly with haemoglobin in our blood, inhibiting our body from transporting oxygen. Over time, this will cause breathing difficulties, fatigue, headaches and even death.

We can reduce the emissions of carbon monoxide by

① **using cleaner fuels** which have a lower occurrence of incomplete combustion, such as hydrogen, compressed natural gas (CNG) or ethanol,

② **ensure sufficient ventilation** so as to achieve a optimal air-fuel ratio to prevent or reduce incomplete combustion of fuels,

③ **installing a** catalytic converter in vehicle exhausts to oxidize any carbon monoxide formed into carbon dioxide.

Air Pollutant: Sulfur Dioxide

Sulfur dioxide is formed from the combustion of fossil fuels, which contain traces of sulfur impurities, such as coal and hydrocarbons. This occurs in industrial areas where factories combust large amounts of coal. (This does not, however, occur in vehicles as vehicle fuels (e.g. petrol) have been treated to remove sulfur before commercial sale.)

Sulfur dioxide can also be formed naturally at volcanoes, as the high heat allows the sulfur in the volcanic rock to combust and form sulfur dioxide.

Sulfur dioxide is harmful as it reacts readily with air and moisture to form sulfuric acid:

$$2\ SO_2 + O_2 + 2\ H_2O \longrightarrow 2\ H_2SO_4$$

It can react with moisture in the atmosphere to form acid rain, hence damaging buildings, stonework, vegetation and marine life. Sulfur dioxide can also react with moisture in our eyes and lungs, causing eye irritation and lung damage respectively.

We can reduce the emissions of sulfur dioxide by

① **using** desulfurised **fuels**, i.e. fossil fuels which have had the sulfur impurities removed.

② **performing** flue gas desulfurisation, a process by which sulfur dioxide from factory exhausts ('flue gases') are allowed to react with limestone.

Air Pollutant: Nitrogen Monoxide & Nitrogen Dioxide

Nitrogen monoxide and nitrogen dioxide are formed from the combustion of nitrogen, from air, with oxygen, also from air.

$$N_2 + O_2 \longrightarrow 2\,NO$$

$$N_2 + 2\,O_2 \longrightarrow 2\,NO_2$$

Under normal conditions, nitrogen from air does not combust as it is very ....inert.... . However, this can occur due to extremely high temperatures caused naturally by ....lightning...., and in an ....internal combustion engine.... found in motor vehicles.

Nitrogen dioxide is harmful as it reacts readily with air and moisture to form nitric acid:

$$4\,NO_2 + O_2 + 2\,H_2O \longrightarrow 4\,HNO_3$$

Like sulfur dioxide, nitrogen dioxide can react with moisture in the atmosphere to form ....acid rain...., hence ....damaging buildings, stonework, vegetation and marine life.... Nitrogen dioxide also causes ....eye irritation and lung damage....

Nitrogen monoxide itself is a ....neutral.... gas, and hence does not directly react with moisture to form acids. However, it readily oxidises in air to form ....nitrogen dioxide...., and hence should be considered as an air pollutant.

We can reduce the emissions of nitrogen oxides by **installing a** ....catalytic converter.... in the vehicle exhausts to reduce any nitrogen oxides formed into nitrogen gas.

Complete the summary table below.

Gas	Source(s)	Harmful Effect(s)
Carbon Monoxide	Incomplete combustion of carbon-based fuels	Binds with haemoglobin in our blood, inhibiting our body from transporting oxygen. Causes headaches, fatigue and death.
Sulfur Dioxide	Combustion of the sulfur impurities found in fossil fuels and in volcanic rock.	Reacts with air and moisture in the air to form acid rain, damaging buildings, stonework, vegetation and marine life. Also causes eye irritation and lung damage.
Nitrogen Monoxide Nitrogen Dioxide	Combustion of nitrogen, from air, due to high temperatures in an internal combustion engine and due to lightning.	

Self-Designed Summary

Supplementary Questions

1. Use the gases in the box below to answer the questions that follow.

ammonia	**chlorine**	**nitrogen**	**ozone**
argon	**helium**	**nitrogen dioxide**	**sulfur dioxide**
carbon dioxide	**hydrogen**	**nitrogen monoxide**	**sulfur trioxide**
carbon monoxide	**methane**	**oxygen**	**water vapour**

State all of the above gases which
(a) are acidic,
(b) are basic,
(c) are coloured (and specify their colour),
(d) are present in clean air,
(e) can be collected by displacement of water,
(f) can be collected by upward delivery,
(g) can be collected by downward delivery,
(h) can be removed by passing through fused calcium chloride,
(i) can be removed by passing through concentrated sulfuric acid,
(j) can be removed by passing through sodium hydroxide,
(k) causes acid rain,
(l) causes global warming,
(m) are formed from the combustion of fossil fuels,
(n) are formed from volcanoes,
(o) are formed in internal combustion engines and by lightning,
(p) are natural sources of fuel,
(q) are considered inert,
(r) are used to fill light bulbs,
(s) are used to fill weather balloons,
(t) binds strongly with haemoglobin in our blood,

2. Which two gases make up more than 90% of air?
A nitrogen and argon
B nitrogen and carbon dioxide
C oxygen and nitrogen
D oxygen and carbon dioxide

3. Air was passed over hot copper powder. The remaining gas was collected over a solution of sodium hydroxide. The gas collected consists mainly of
A hydrogen **B** carbon dioxide **C** argon **D** nitrogen

4. Air contains about 20% oxygen by volume. When a volume of river water was boiled, the air expelled from the water was found to contain 30% oxygen. What is the best reason for this difference in oxygen content?
A Nitrogen reacts with water.
B Carbon dioxide is more soluble in water than is oxygen.
C Oxygen is more soluble in water than is nitrogen.
D The noble gases are insoluble in water.

5. A sample of air is bubbled through aqueous potassium hydroxide first, and then concentrated sulphuric acid. Which gases are remaining?
A noble gases only
B nitrogen only
C nitrogen and water vapour
D oxygen, nitrogen and noble gases

6. Dry air without carbon dioxide can be obtained by passing a sample of air first through
A quicklime and then through calcium hydroxide solution
B fused calcium chloride and then through calcium hydroxide solution
C calcium hydroxide solution and then through aqueous ammonia
D calcium hydroxide solution and then through concentrated sulfuric acid

7. Which of the following statements about nitrogen monoxide are true?
   A It can be removed through a catalytic converter.
   B It has a pH of less than 7.0.
   C It is a brown, pungent smelling gas.
   D It is formed by combustion of fossil fuels.

8. Which of the following statements about sulfur dioxide are true?
   A It can act as a good reducing agent.
   B It has a yellow colour and a pungent odour.
   C It is formed when sodium sulfate crystals are heated strongly.
   D It is insoluble in water.

9. Which of the following correctly matches the environmental problem with the effects?

	Environmental Problem	***Effect***
A	depletion of ozone layer	widespread famine and drought
B	build-up of greenhouse gases	skin cancer and genetic mutations
C	release of carbon monoxide	acid rain, damage to crops
D	release of sulfur dioxide	lung damage, irritation to eyes

Supplementary Questions (Answers)

Question 1

(a) carbon dioxide, chlorine, nitrogen dioxide, sulfur dioxide, sulfur trioxide
(b) ammonia
(c) chlorine (greenish-yellow), nitrogen dioxide (brown)
(d) argon, carbon dioxide, nitrogen, oxygen, water vapour
(e) argon, carbon dioxide, carbon monoxide, helium, hydrogen, methane, nitrogen, oxygen
(f) ammonia, helium, hydrogen, methane
(g) carbon dioxide, chlorine, nitrogen dioxide, ozone, sulfur dioxide, sulfur trioxide
(h) water vapour
(i) ammonia, water vapour
(j) carbon dioxide, chlorine, nitrogen dioxide, sulfur dioxide, sulfur trioxide
(k) nitrogen dioxide, nitrogen monoxide, sulfur dioxide, sulfur trioxide
(l) carbon dioxide, methane, ozone
(m) carbon dioxide, carbon monoxide, sulfur dioxide, water vapour
(n) sulfur dioxide
(o) nitrogen dioxide, nitrogen monoxide
(p) hydrogen, methane
(q) argon, helium, nitrogen
(r) argon
(s) helium, hydrogen
(t) carbon monoxide

Multiple-Choice Questions

2 C 3 D 4 C 5 D 6 D 7 A 8 A 9 D

Lecture Slides

Air & The Atmosphere

Anglo-Chinese School (Barker Road)

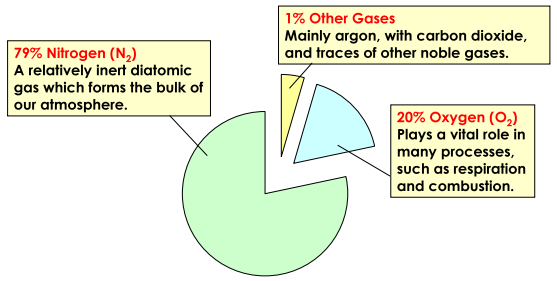
CHEMISTRY
Prepared by Alex Lee

Chapter Overview

In This Chapter, We Will Learn …

1. Composition of Air
2. Removal of Gases
3. Collection of Gases
4. Air Pollution

Composition of Dry Air



Composition of Dry Air

- The term 'dry air' refers to air **without water vapour**.
  - **79% nitrogen**
  - **20% oxygen**
  - **1% argon and other gases**

Carbon dioxide only forms 0.03% of air!

- The water vapour in air (known as 'humidity') can vary between 0.5% to 5.0%, depending on climate.
- Two factors affecting the humidity of a location are **temperature** and **proximity to water bodies**.

Composition of Dry Air

- Air is a **mixture** and hence can be **separated by physical means**.
- We generally obtain three gases – nitrogen, oxygen and argon, through **fractional distillation of liquid air**.
- Uses for these three gases:
  nitrogen – as a coolant (as liquid nitrogen)
  oxygen – to support combustion and respiration
  argon – to provide an inert atmosphere

Composition of Dry Air

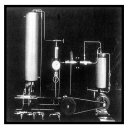
- The most abundant noble gas in air is argon.
- The concentration of argon is even **higher** than carbon dioxide, making it economically very **cheap**.
- Hence it is the preferred choice of noble gas in applications which require an inert atmosphere.
- One example of an industrial use for argon is in **maintaining an inert atmosphere in filament lamps**.

Common Gases

NITROGEN

- **Source:**
  Fractional distillation of liquid air.

- **Uses:**
  Manufacture of ammonia through the Haber process; liquid nitrogen used as a good cooling agent.



Common Gases

OXYGEN

- **Source**:
  Fractional distillation of liquid air.

- **Uses**:
  Making steel; welding; oxygen tanks in aeroplanes, for divers and in hospitals.

Common Gases

ARGON

- **Source**:
  Fractional distillation of liquid air.

- **Uses**:
  Providing an inert environment in a filament lamp, to prevent the tungsten from burning out.

Common Gases

CARBON DIOXIDE

- **Source**:
  Combustion of carbon-containing compounds, e.g. fossil fuels.

- **Uses**:
  Essential ingredient for photosynthesis; also used in carbonated drinks.

Common Gases

WATER VAPOUR

- **Source**:
  Evaporation of liquid water.

- **Uses**:
  Important component of the water cycle – without evaporation of water, many life-sustaining processes such as rain will not occur.

Common Gases

HYDROGEN (not present in air)

- **Source**:
  Cracking of crude oil (petroleum); electrolysis of water.

- **Uses**:
  Manufacture of ammonia in the Haber Process; used as fuel.

Common Gases

CHLORINE (not present in air)

- **Source**:
  Electrolysis of concentrated sodium chloride (brine) from seawater.
- **Uses**:
  Strong oxidizing and bleaching agent; used as disinfectant in swimming pools.

Common Gases

SULFUR DIOXIDE (not present in air)

- **Source**:
  Volcanoes; combustion of sulfur-containing fossil fuels.

- **Uses**:
  Good reducing agent; used in the manufacture of sulfuric acid

Common Gases

AMMONIA (not present in air)

- **Source**:
  Produced in the Haber Process, using nitrogen and hydrogen.

- **Uses**:
  Used to produce nitrates and nitric acid, fertilizers, explosives and cleansing agents.

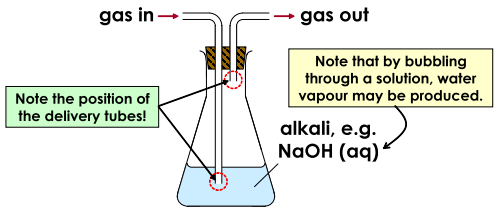
Removal of Gases

- Sometimes, we want to purify a sample of gas (or air) by removing selected gases.
- We shall look at several laboratory methods to do so.

Removal of Gases

REMOVAL OF ACIDIC GASES

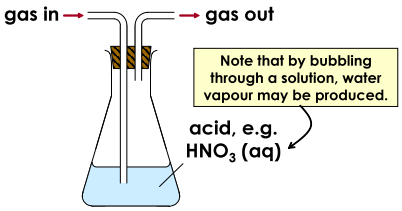
- Examples: carbon dioxide, chlorine
- Method: bubble through an alkali, e.g. NaOH (aq)



Removal of Gases

REMOVAL OF ALKALINE GASES

- Examples: ammonia
- Method: bubble through an acid, e.g. HCl (aq)



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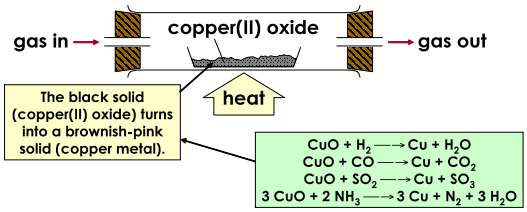
Removal of Gases

REMOVAL OF GASEOUS REDUCING AGENTS

- Examples: hydrogen, carbon monoxide, ammonia
- Method: pass the gas over heated copper(II) oxide



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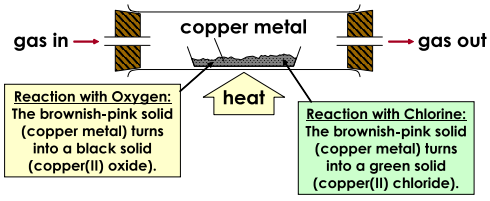
Removal of Gases

REMOVAL OF GASEOUS OXIDISING AGENTS

- Examples: oxygen, chlorine, fluorine
- Method: pass the gas over heated copper metal



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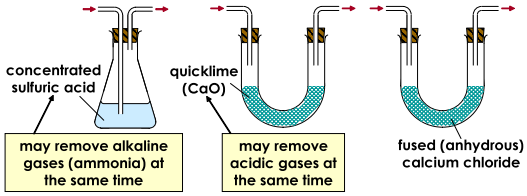
Removal of Gases

REMOVAL OF WATER VAPOUR (several methods)

- bubble through concentrated sulfuric acid
- pass through quicklime (calcium oxide)
- pass through fused calcium chloride



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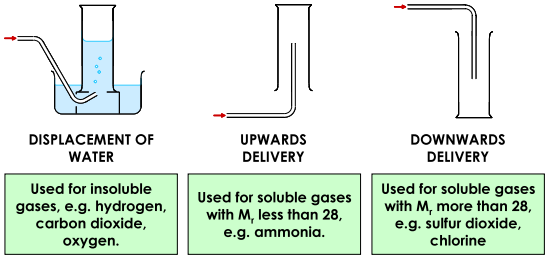
Collection of Gases

- After purifying a gas sample, we also want to be able to collect the gas. We can do so in three ways:



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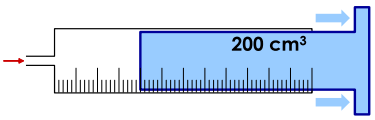
Collection of Gases

- An even better way of collecting a gas is through the use of a **gas syringe –** works for all gases, and even allows you to measure the volume of gas collected!



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Harmful Gases & Air Pollution

- An **air pollutant** is a substance which is introduced to the air by human activity, and has a harmful effect on the environment, including our health.
- Air pollutants are **generally gaseous**, but may also include **particulate matter** (e.g. soot).

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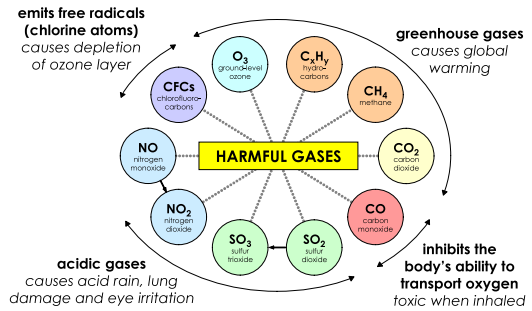
Harmful Gases & Air Pollution



Harmful Gases & Air Pollution

To what extent would one consider carbon dioxide to be an air pollutant?

Only to a small extent. Carbon dioxide should not be considered to be an air pollutant as it is naturally present in our atmosphere.

However, in recent years, it is being considered as an air pollutant due to its increasing levels in air.

Harmful Gases & Air Pollution

The pH of rain is found to be 6.5. Is this considered to be acid rain? Why or why not?

No. Normal rain is slightly acidic due to the presence of carbon dioxide in our air. Carbon dioxide is only slightly soluble in water, and only forms a weak acid.

In contrast, acid rain refers to rain which has a much lower pH, i.e. 4 and below.

Air Pollutants

- We shall now examine three air pollutants in particular:
  - carbon monoxide (CO)
  - sulfur dioxide (SO_2)
  - nitrogen oxides (NO and NO_2)

Air Pollutants

Case Study: Carbon Monoxide

Air Pollutants: Carbon Monoxide

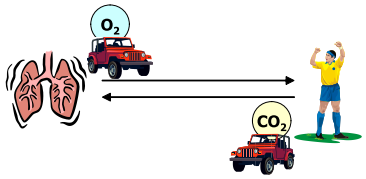
- **Source of Carbon Monoxide**:
  Carbon monoxide is formed from the **incomplete combustion of carbon-based fuels**, such as coal and hydrocarbons.

  In cities, this is mainly caused by vehicles (combustion of petrol or diesel), while in industrial areas, this is mainly caused by coal-powered factories.

Images: http://www.carbonoffsetsolutions.co.uk/Car_Exhaust.jpg (Car Exhaust)
http://www.ecofriend.org/entry/codexis-creates-genetically-modified-enzyme-to-capture-co2-from-flue-gases/ (Factories)

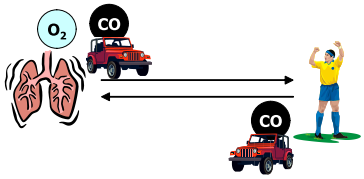
Air Pollutants: Carbon Monoxide

- **Harmful Effect of Carbon Monoxide (part 1 of 3):**
  Haemoglobin in our red blood cells helps to transport oxygen from the lungs to the rest of the body, and carbon dioxide from the rest of the body to the lungs.



Air Pollutants: Carbon Monoxide

- **Harmful Effect of Carbon Monoxide (part 2 of 3):**
  Carbon monoxide is harmful because it **binds strongly with the haemoglobin in our blood**, inhibiting our body from **transporting oxygen**.



Air Pollutants: Carbon Monoxide

- **Harmful Effect of Carbon Monoxide (part 3 of 3):**
  Over time, breathing in carbon monoxide will cause **breathing difficulties, fatigue, headaches and death**.

Air Pollutants: Carbon Monoxide

- **Reducing Carbon Monoxide Emissions:**
  - **using cleaner fuels** which have a lower occurrence of incomplete combustion, such as hydrogen fuel, compressed natural gas (CNG) or ethanol
  - **ensure sufficient ventilation** to achieve an optimal air-fuel ratio to reduce incomplete combustion
  - **installing a catalytic converter** in vehicle exhausts to oxidize carbon monoxide into carbon dioxide

Air Pollutants

Case Study: Sulfur Dioxide

Air Pollutants: Sulfur Dioxide

- **Source of Sulfur Dioxide:**
  Sulfur dioxide is formed from **combustion of fossil fuels containing sulfur impurities**, such as coal and hydrocarbons.

This **occurs in industrial areas** where factories combust large amounts of coal.
However, not present in vehicle exhausts.

Sulfur dioxide can be formed naturally at **volcanoes**, as the high heat allows sulfur in volcanic rock to combust.

Images: http://www.solarnavigator.net/geography/geography_images/Volcano_St_Helens.jpg (Volcano)
http://www.ecofriend.org/entry/codexis-creates-genetically-modified-enzyme-to-capture-co2-from-flue-gases/ (Factories)

Air Pollutants: Sulfur Dioxide

- **Harmful Effects of Sulfur Dioxide (part 1 of 2):**
  Sulfur dioxide is harmful as it reacts readily with air and moisture to form sulfuric acid:

$$2\,SO_2 + O_2 + 2\,H_2O \longrightarrow 2\,H_2SO_4$$

It can react with moisture in the atmosphere to form **acid rain**, hence **damaging buildings, stonework, vegetation and marine life**.

Refers to rain which is abnormally acidic, i.e. pH of 4 and below. Normal rain has a pH of about 6.

Images: http://dsc.discovery.com/earth/gallery/wide-angle/acidtrees-324x205.jpg

Air Pollutants: Sulfur Dioxide

- **Harmful Effects of Sulfur Dioxide (part 2 of 2):**
  Sulfur dioxide can also react with moisture in our eyes and lungs, causing **eye irritation** and **lung damage** respectively.

Air Pollutants: Sulfur Dioxide

- **Reducing Sulfur Dioxide Emissions:**
  - **using 'desulfurised' fuels** , i.e. fossil fuels which have had the sulfur impurities removed.
  - **performing flue gas desulfurisation**, a process by which sulfur dioxide from factory exhausts ('flue gases') are allowed to react with **limestone**.

Air Pollutants

Case Study: Nitrogen Oxides

includes both nitrogen monoxide (NO) and nitrogen dioxide (NO_2)

Air Pollutants: Nitrogen Oxides

- **Source of Nitrogen Oxides (part 1 of 2):**
  Nitrogen monoxide and nitrogen dioxide are both formed from the combustion of nitrogen gas, from air, with oxygen gas, also from air.

$$N_2 + O_2 \longrightarrow 2\,NO$$
$$N_2 + 2\,O_2 \longrightarrow 2\,NO_2$$

Under normal conditions, nitrogen does not combust as it is very **inert**. Hence this can only occur under extremely high temperature or pressure.

Air Pollutants: Nitrogen Oxides

- **Source of Nitrogen Oxides (part 2 of 2):**
  Nitrogen oxides can be produced naturally by **lightning**, and also in an **internal combustion engine**, found in motor vehicles.

Refers to an engine in which the combustion of fuel occurs within the engine itself – in a compartment known as a 'combustion chamber'. All motor vehicles today have internal combustion engines.

Images: http://www.uwec.edu/jolhm/EH3/Group2/background.html (Lightning)
http://www.unlimitedchoice.org/blog/humour/top-things-to-do-in-a-traffic-jam/ (Motor Vehicles)

Air Pollutants: Nitrogen Oxides

- **Harmful Effects of Nitrogen Oxides (part 1 of 2):**

Nitrogen dioxide is harmful as it is an acidic gas. It reacts readily with air and moisture to form nitric acid.

$$4\ NO_2 + O_2 + 2\ H_2O \longrightarrow 4\ HNO_3$$

Like sulfur dioxide, nitrogen dioxide can react with moisture in the atmosphere to form **acid rain**, hence **damaging buildings, stonework, vegetation and marine life**.

Images: http://dsc.discovery.com/earth/gallery/widea gle/acidtrees-324x205.jpg

Air Pollutants: Nitrogen Oxides

- **Harmful Effects of Nitrogen Oxides (part 1 of 2):**

Nitrogen monoxide itself is a **neutral gas**, and hence does not directly react with moisture to form acids.

However, it readily oxidises in air to form **nitrogen dioxide**, and hence is considered as an air pollutant.

$$2\ NO + O_2 \longrightarrow 2\ NO_2$$

Air Pollutants: Nitrogen Oxides

- **Reducing Nitrogen Oxide Emissions:**
  - **installing a catalytic converter** in vehicle exhausts to reduce the nitrogen oxides into nitrogen gas.

Images: http://davisconverters.com/

Air Pollutants: A Summary

Gas	Source(s)	Harmful Effect(s)
Carbon Monoxide	Incomplete combustion of carbon-based fuels	Binds with haemoglobin in our blood, inhibiting our body from transporting oxygen. Causes headaches, fatigue and death.
Sulfur Dioxide	Combustion of the sulfur impurities found in fossil fuels and in volcanic rock.	Reacts with air and moisture in the air to form acid rain, damaging buildings, stonework, vegetation and marine life. Also causes eye irritation and lung damage.
Nitrogen Oxides	Combustion of nitrogen, from air, due to high temperatures in an internal combustion engine and due to lightning.	