Beatty Secondary School
Science Department (Chemistry Unit)
Chemistry 6092

Name: _____ ( ) Date: _____

Class: 4E1

TOPIC: AIR – ATMOSPHERE & ENVIRONMENT (WORKSHEET 1)

Learning Objectives:

(a) Describe the volume composition of gases present in dry air as being approximately 78% nitrogen, 21% oxygen and the remainder being noble gases (with argon as the main constituent) and carbon dioxide.

(b) Name some common atmospheric pollutants, e.g. carbon monoxide; methane; nitrogen oxides (NO and NO_2); ozone; sulfur dioxide; unburned hydrocarbons.

(c) State the sources of these pollutants as:
(i) carbon monoxide from incomplete combustion of carbon-containing substances
(ii) nitrogen oxides from lightning activity and internal combustion engines
(iii) sulfur dioxide from volcanoes and combustion of fossil fuels

(d) Describe the reactions used in possible solutions to the problems arising from some of the pollutants named
(i) the redox reactions in catalytic converters to remove combustion pollutants,
(ii) the use of calcium carbonate to reduce the effect of 'acid rain' and in flue gas desulfurisation.

(e) Discuss some of the effects of these pollutants on health and on the environment:
(i) the poisonous nature of carbon monoxide
(ii) the role of nitrogen dioxide and sulfur dioxide in the formation of 'acid rain' and its effects on respiration and buildings.

Multiple-Choice Questions

1 Which of the following noble gases has the highest percentage composition in the air?

A argon **B** helium
C neon **D** xenon (**A**)

2 Which of the following is obtained industrially from the fractional distillation of air?

A methane **B** hydrogen
C oxygen **D** sulfur dioxide (**C**)

3 Which of the following gases is **not** present in clean air?

A oxygen **B** nitrogen
C carbon dioxide **D** hydrogen (**D**)

4 Which of the following is **not** a source of sulfur dioxide? containing Sulfur

A combustion of coal **B** combustion of crude oil
C lightning activity **D** volcanic eruption (**C**)

5 Which of the following gases does **not** affect the pH of water?

A carbon dioxide **B** carbon monoxide
C nitrogen dioxide **D** sulfur dioxide (**B**)

6 Which of these chemicals can be used to test for the presence of sulfur dioxide in polluted air?

A aqueous acidified potassium manganate(VII)
B anhydrous copper(II) sulfate
C aqueous hydrogen peroxide
D limewater (**A**)

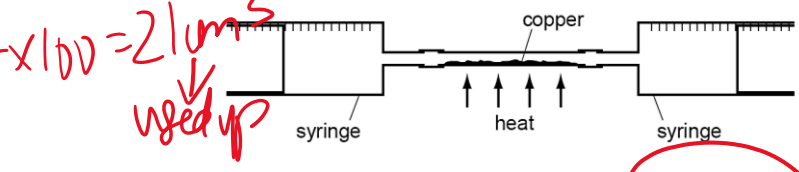
7 Which of the following about nitrogen dioxide is true?

A It is a greenhouse gas.
B It is produced when plant and animal matter decay.
C It is released during complete combustion of petrol.
D It causes acid rain. (**D**)

8 Which of the following is **not** a harmful effect of carbon monoxide?

A It causes headaches.
B It causes breathing difficulties.
C It causes cancer.
D It causes death. (**C**)

9 In the apparatus shown, 100 cm^3 of air are passed backwards and forwards between the two syringes until reaction is complete.



On cooling to room temperature, what volume of gas remained?

A 20 cm^3 **B** 28 cm^3
C 32 cm^3 **D** 80 cm^3 (**D**)

10 It was found that cars which were parked near a coal-fired power station often corroded more quickly. Which gas, when present in above average levels in the air, is a possible cause?

A carbon dioxide **B** ozone
C sulfur dioxide **D** water vapour (**C**)

11 Which atmospheric pollutants, emitted by internal combustion engines, are reacted together to convert them to less harmful products?

A carbon monoxide and nitrogen dioxide
B carbon monoxide and unburnt hydrocarbons
C nitrogen dioxide and sulfur dioxide
D sulfur dioxide and unburnt hydrocarbons (**A**)

12 Fossil fuels are used to power some internal combustion engines. Which pollutants are produced by an internal combustion engine burning fossil fuels?

1 carbon monoxide
2 nitrogen oxides
3 sulfur dioxide

A 1, 2 and 3 **B** 1 and 2 only
C 1 and 3 only **D** 2 and 3 only (**A**)

13 Which statements about the pollutant carbon monoxide are correct?

1 It is a colourless, odourless gas.
2 It is formed by incomplete combustion of natural gas.
3 It reacts with haemoglobin in the blood.

A 1 and 2 only **B** 1 and 3 only
C 2 and 3 only **D** 1, 2 and 3 (**D**)

14 Which gas is **not** produced when hydrocarbons are burnt in the internal combustion engine?

A carbon dioxide **B** carbon monoxide
C hydrogen **D** nitrogen oxides (**C**)

15 Which of the following substance is used in the removal of sulfur dioxide gas during flue gas desulfurisation?

A calcium nitrate **B** calcium sulfate
C calcium chloride **D** calcium carbonate (**D**)

16 The table gives the relative concentrations of polluting gases in the air in four different industrialised cities. In which city are limestone buildings most threatened by pollution?

	sulfur dioxide	nitrogen dioxide	ozone
A	17	46	23
B	32	33	30
C	38	40	11
D	45	14	21

(**C**)

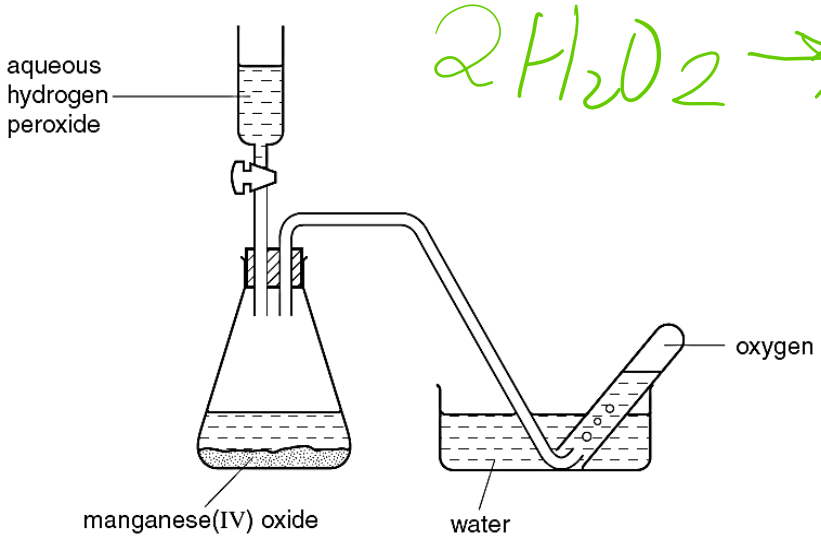
17 A sample of air was shaken with an alkaline solution of a compound called pyrogallol. The gases remaining **did not** support combustion. Which one of the following pairs of gases was removed from the air by the alkaline pyrogallol?

A carbon dioxide and nitrogen **B** oxygen and carbon dioxide
C oxygen and nitrogen **D** nitrogen and water vapour (**B**)

18 Why are catalytic converters fitted to car exhausts?

A to decrease the amount of carbon dioxide emitted
B to decrease the amount of nitrogen oxides emitted
C to improve the energy conversion
D to reduce global warming (**B**)

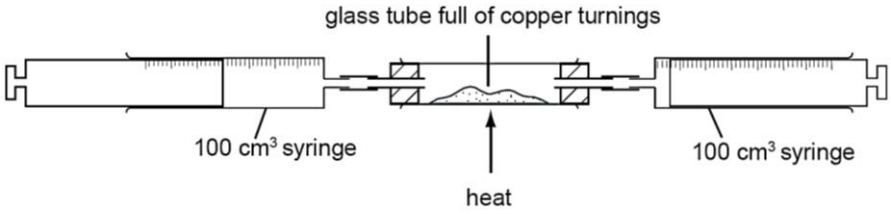
19 Using manganese(IV) oxide as a catalyst, aqueous hydrogen peroxide decomposes to form oxygen. The diagram below shows how oxygen could be produced from the reaction and then collected.



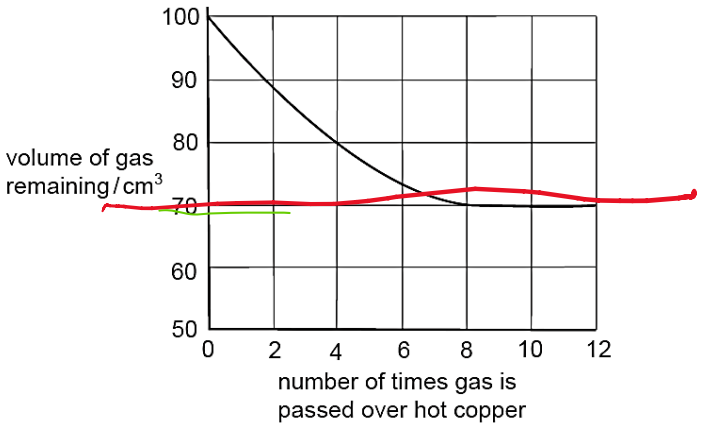
The first few test-tubes of collected gas should be rejected because the oxygen would be contaminated by

A air **B** hydrogen
C hydrogen peroxide **D** manganese(IV) oxide (**A**)

20 A 100 cm^3 sample of bottled gas used for diving was placed in a gas syringe in the apparatus shown.



The gas was passed backward and forward over heated copper turnings. The results obtained were used to plot the graph.

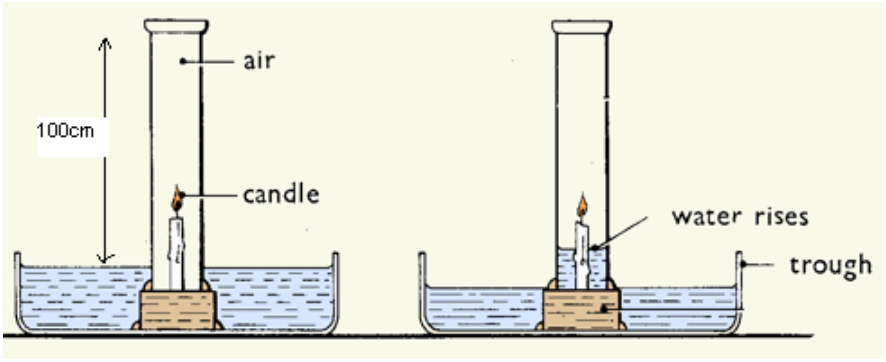


What is the percentage of oxygen in the bottled gas?

A 20% **B** 30%
C 70% **D** 80% (**B**)

Structured Questions

21 A student wanted to find the percentage of oxygen in air. A wax candle was floated on water. The student lit the candle and lowered a gas jar over it, as seen in the following diagram.



The candle flame slowly went out and the water level rose in the jar. The student noted the final water level in the jar.

(a) Explain why the candle flame go out.

All the oxygen has been used up and combustion cannot occur without oxygen

(b) Approximately how far up the gas jar did the water rise?

21 cm

(c) Name **two** gases that are left in the gas jar after the candle goes out.

carbon dioxide / argon / nitrogen

22 The table shows the composition of the atmosphere of the planet Mars.

gas	percentage composition
carbon dioxide	95.3%
nitrogen	1.7%
argon	1.6%
oxygen	0.2%
other gases	1.2%

How does the atmosphere on Mars differ from the atmosphere on Earth?

The most abundant gas on Mars is carbon dioxide while that on Earth is nitrogen.

The atmosphere on Mars is made up of 95.3% carbon dioxide, 1.7% nitrogen, 1.6% argon and 0.2% oxygen while that on Earth is respectively, 0.03%, 78%, 1% and 21%.

23 'Lean burn' engines are a type of car engine. This table shows some information about lean burn engines compared to normal car engines.

type of engine	amount of air mixed with petrol	operating temperature	concentration of CO in exhaust gases	concentration of nitrogen oxides in exhaust gases
normal	less air	higher	higher	higher
lean burn	more air	lower	lower	lower

(a) (i) How is carbon monoxide formed in a car engine?

Carbon monoxide is formed from the incomplete combustion of carbon-containing fuels due to the limited supply of oxygen in the car engine.

(ii) Suggest why lean burn engines produce smaller amounts of carbon monoxide.

More air is available in a lean burn engine. Thus, there is lower probability of incomplete combustion to produce carbon monoxide.

(b) (i) Explain how nitrogen oxides are formed in car engines.

Nitrogen oxides are formed when nitrogen and oxygen in the air react under high temperature in the car engine.

(ii) Suggest why lean burn engines produce smaller amounts of nitrogen oxides.

The operating temperature of a lean burn engine is lower. Thus, smaller amounts of nitrogen oxides are formed.

24 Explain why

(a) the incomplete combustion of carbon-containing fuels can be dangerous to people,

Incomplete combustion of carbon-containing fuels releases carbon monoxide which binds with haemoglobin to prevent transport of oxygen to the body, leading to possible death.

(b) the combustion of fossil fuels can eventually damage buildings.

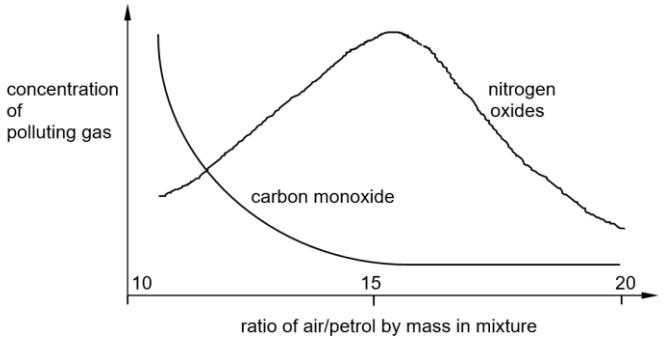
Combustion of fossil fuels containing sulfur compounds may release sulfur dioxide, which reacts with oxygen and rainwater to form acid rain. The acid rain then corrodes limestone / metal buildings.

25 Petrol vapour is mixed with air before being burnt in the engine of a motorcar.

(a) Name the **two** main products of the combustion of petrol in an excess of air.

carbon dioxide and water / water vapour

(b) The amount of air mixed with petrol vapour in an engine can be varied. Two pollutants in the exhaust gases from a motorcar are carbon monoxide and nitrogen oxides. The graph shows how the amounts of these pollutants in the exhaust gases depends on the composition of the air/petrol mixture.



(i) Describe how the concentration of carbon monoxide varies as the air/petrol ratio is increased in the engine.

Concentration of CO decreases as the air/petrol ratio increases.

(ii) Suggest why the concentration of carbon monoxide changes as described in **(b)(i)**.

As the ratio of air/petrol increases, there is more oxygen available for combustion to occur. As such, carbon monoxide would be oxidised to carbon dioxide, leading to a decrease in carbon monoxide concentration.

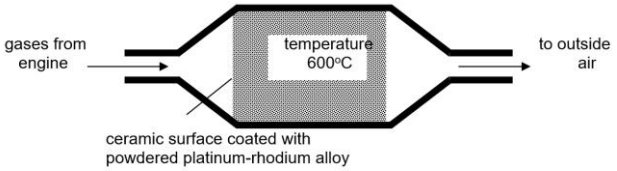
$CO \rightarrow CO_2$

(iii) Motorcars produce the maximum amount of energy when the air/petrol ratio is about 15. Suggest why the maximum amount of nitrogen oxides is produced under this condition.

→ high temperatures

At the ratio of about 15, that is the lowest concentration of carbon monoxide, meaning that highest probability of combustion. Since combustion is an exothermic reaction, it releases the largest amount of heat energy, resulting in high temperatures. This causes more nitrogen and oxygen in the air to react to form nitrogen oxides.

(c) Pollution from motorcars is reduced by catalytic converters. The converter contains an alloy made of platinum and rhodium which acts as a catalyst to destroy the pollutants.



(i) What part or section of the Periodic Table contains platinum and rhodium?

Transition metals / elements

(ii) Suggest why an alloy is used as the catalyst to speed up the reaction.

An alloy is much stronger and harder than pure metals, making it more durable / alloys are more resistant to corrosion.

26 When coal burns, nitrogen monoxide may be formed. One way to reduce the level of nitrogen monoxide in the flue gases of coal-fired power stations is to inject natural gas (methane) into the boiler just above the flame. This reaction converts nitrogen monoxide to nitrogen, carbon dioxide and water.

(a) Write a balanced chemical equation for the reaction between methane (CH_4) and nitrogen monoxide (NO).

$CH_4 + 4NO \rightarrow 2N_2 + CO_2 + 2H_2O$

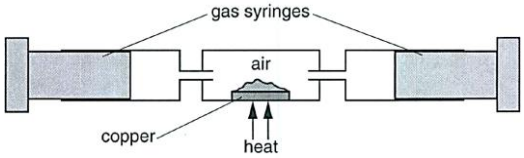
(b) (i) Write a balanced chemical equation to show how nitrogen monoxide may oxidise carbon monoxide to form carbon dioxide and nitrogen.

$2CO + 2NO \rightarrow 2CO_2 + N_2$

(ii) With reference to oxidation states, explain why the reaction in **(b)(i)** is considered to be a redox reaction.

N in NO is reduced to N_2 and C in CO is oxidised to CO_2 at the same time / simultaneously.
Oxidation state of nitrogen decreases from +2 in NO to 0 in N_2.
Oxidation state of carbon increases from +2 in CO to +4 in CO_2

27 An experiment (Experiment 1) was set up to heat copper in air.



At the start of the experiment 1, the apparatus contained a total of 200 cm^3 of air. During the heating, copper reacted with oxygen in the air to form black copper(II) oxide. The copper was heated until the volume of gas, measured at room temperature and pressure, remained constant.

(a) (i) Explain why it was important to continue heating until the volume remained constant.

This is to ensure that all the oxygen in the air has reacted with copper.

(ii) The table shows some data about the mass change during the experiment.

mass of copper at the start	mass of solid left at the end
1.00 g	1.07 g

Use the data in the table to show that the solid left at the end of the experiment contains unreacted copper.

$2Cu + O_2 \rightarrow 2CuO$

No. of mol of Cu = $\frac{1}{64}$ = 0.01563 mol [1]
Mole ratio of Cu : CuO = 1 : 1
No. of mol CuO produced = 0.01563 mol [1]

Mass of CuO produced = 0.01563 x (64 + 16) = 1.25 g
Since the mass of solid left behind is <u>less than 1.25 g (1.07g)</u>, this means that not all of the copper has reacted. [1]
Some copper must have been left behind at the end of the experiment.
Or

No. of mol of CuO = $\frac{1.07}{64 + 16}$ = 0.01338 mol [1]
Mole ratio of Cu : CuO = 1 : 1
No. of mol of Cu that reacted = 0.01338 mol [1]
Mass of Cu that reacted = 0.01338 × 64 = 0.856 g
Since the mass of copper that reacted is <u>less than 1.00 g</u>, this means that not all of the copper has reacted. Some copper must have been left behind at the end of the experiment. [1]

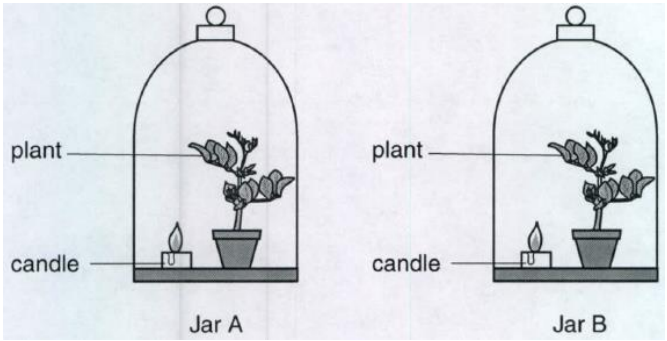
(b) (i) Name the gas that is left in the gas syringes in the largest amount at the end.

<u>nitrogen</u>

(ii) Estimate the total volume of gas left in the gas syringes at the end of the experiment. Explain your reasoning.

<u>The air contains 21% of oxygen. During the reaction, oxygen is used up. (Copper is the reactant in excess.)</u>
<u>Total volume of gas left = 0.79 x 200 = 158 cm^3</u>

(c) A burning candle and a plant were placed in two jars of air. Both jars were left in sunlight.



A 200 cm^3 sample of air from Jar A was tested immediately after the candle burned out using the same procedure as in Experiment 1.

A 200 cm^3 sample of air from Jar B was tested a few days after the candle burned out using the same procedure as in Experiment 1.

Describe and explain how the results of the test would differ for each jar.

***When the gas from Jar A was tested, there would be no change in the volume after the experiment was carried out. The total volume of the gas would still read 200 cm^3. or**
***When the gas from Jar A was tested, there would be no change in the mass of the solid the end of the experiment.**

This is because the candle used up the oxygen in Jar A during combustion. There was no more oxygen available to react with the copper.

When the gas from Jar B was tested, the total volume of gas that remained in the gas syringes at the end of the experiment would be 158 cm^3. *or
***When the gas from Jar B was tested, the mass of the solid at the end of the experiment would read 1.07 g.**

This is because even after the candle used up the oxygen in Jar B, the plant in the jar can still undergo photosynthesis to replenish the oxygen in the jar. Thus, there is still oxygen available for the reaction with copper.

Hence, the mass of solid formed would be higher in the experiment that obtained the gas from Jar B than the gas obtained from Jar A.

28 Car engines are adjusted to work at a particular air:fuel ratio. The amount of air that is mixed with the fuel affects the temperature of the engine, the amount of pollutant gases that form and how efficiently the catalytic converter works.

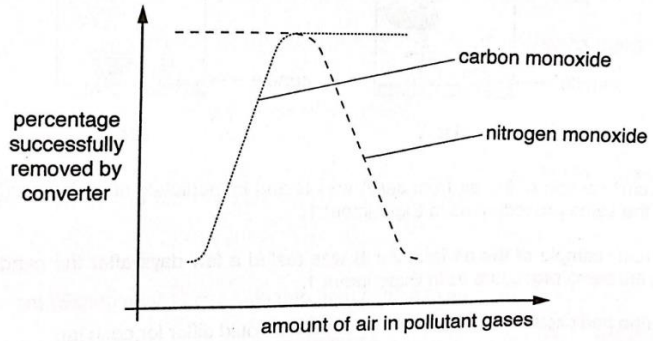
Two major pollutant gases are carbon monoxide and nitrogen monoxide.

(a) The catalytic converter removes pollutant gases. The converter removes carbon monoxide and nitrogen monoxide by oxidation and reduction.

Write an overall equation to show how carbon monoxide and nitrogen monoxide react together in the converter.

$2CO + 2NO \rightarrow 2CO_2 + N_2$

(b) The amount of air in the pollutant gases that enter the catalytic converter affects the reactions in the converter. The graph shows the percentage of carbon monoxide and nitrogen monoxide that the catalytic converter successfully **removes**.



(i) Describe and explain how increased amounts of air affect the removal of carbon monoxide and nitrogen monoxide.

As the amount of air is increased, the percentage of CO removed from the converter increases, while the percentage of NO removed decreases.
An increased in the amount of air provided a larger amount of atmospheric oxygen to oxidise the CO to CO_2. However, this reduces the amount of NO that is required to oxidise CO.

(ii) In the converter, apart from reacting with each other, carbon monoxide and nitrogen monoxide react with other substances as well. How does the graph show that this statement is true?

While the percentage of carbon monoxide removed increases, the percentage of nitrogen monoxide removed remains constantly high. This suggests that there must be other substances reacting with nitrogen monoxide to remove it.