12.1 NITROGEN AND SULPHUR

Learning outcomes

Candidates should be able to:

1. explain the lack of reactivity of nitrogen, with reference to triple bond strength and lack of polarity
2. describe and explain:
   (a) the basicity of ammonia, using the Brønsted–Lowry theory
   (b) the structure of the ammonium ion and its formation by an acid–base reaction
   (c) the displacement of ammonia from ammonium salts by an acid–base reaction
3. state and explain the natural and man-made occurrences of oxides of nitrogen and their catalytic removal from the exhaust gases of internal combustion engines
4. understand that atmospheric oxides of nitrogen (NO and NO_2) can react with unburned hydrocarbons to form peroxyacetyl nitrate, PAN, which is a component of photochemical smog
5. describe the role of NO and NO_2 in the formation of acid rain both directly and in their catalytic role in the oxidation of atmospheric sulfur dioxide

Unreactivity of Nitrogen

- Nitrogen makes up 78% by volume of dry air.
- The element is very unreactive. There are two reasons for this.
- Firstly, the nitrogen-to-nitrogen triple bond is very strong (945 kJ mol^{-1}) and so its reactions with other elements are usually endothermic; for example, with oxygen
  $N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta H_1 = +181$ kJ mol^{-1}
- Secondly, the strong nitrogen-to-nitrogen bond means that reactions involving nitrogen have a very high activation energy, and as a result, will be very slow even if they are exothermic; this is the reason why the Haber Process to make ammonia requires such extreme conditions.
- The fact that the nitrogen molecule is non-polar may also contribute to the high activation energies of reactions involving nitrogen.

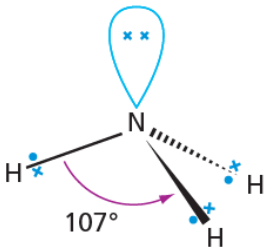
1. Nitrogen, N_2, is generally an unreactive molecule but it does react under certain conditions.
   Give **two** reasons to explain the lack of reactivity of nitrogen. [2]

2. Explain the lack of reactivity of nitrogen gas, $N_2(g)$. [2]
3. $N_2(g)$ is less reactive than CO(g) even though $N_2(g)$ has a lower bond energy than CO(g).
   Suggest why CO(g) is more reactive than $N_2(g)$. [1]

4. Nitrogen and oxygen do not react at normal atmospheric temperatures.
   Explain why. [2]

Ammonia

The ammonia molecule is a trigonal pyramid in shape. There are four pairs of electrons around the nitrogen atom: three bond pairs and one lone pair. The presence of a lone pair makes the H¬N¬H angle slightly less than 109½ ° and the actual value is 107 °.

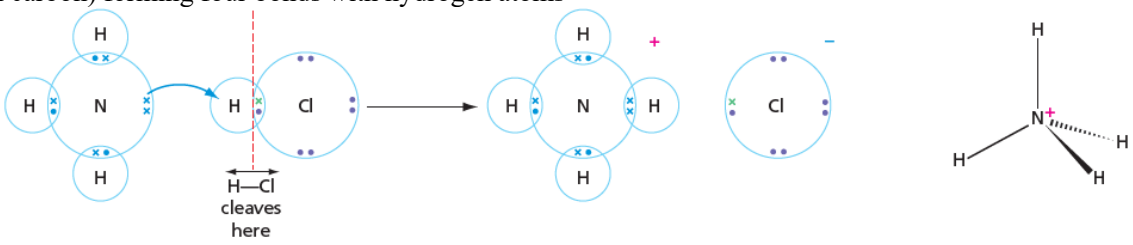


The lone pair easily combines with a proton, making ammonia a weak Brønsted–Lowry base.

$NH_3 + HCl \rightarrow NH_4^+ + Cl^-$

base-1 acid-2 acid-1 base-2

The resulting ammonium ion is exactly tetrahedral; all four N¬H bonds are identical, once formed. It can be thought of as being formed either by the lone pair of electrons from the nitrogen being donated to the proton, or by a N^+ ion (isoelectronic with carbon) forming four bonds with hydrogen atoms



The ammonium ion reacts with strong bases such as NaOH to give ammonia, an alkaline gas that turns moist red litmus paper blue. This is a **test** for ammonium salts.

$NH_4^+(s) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$

5. Nitrogen gas, N_2, is very unreactive.
   (a) Explain why nitrogen gas is so unreactive. [2]

   (b) It is difficult to make ammonia, $NH_3(g)$, directly from its elements but it can be made from NH_4Cl (s). Identify a reagent and the conditions required to make $NH_3(g)$ from $NH_4Cl(s)$. [1]

1. Solid R is added to a solution of ammonium nitrate and the mixture is heated. A gas is given off which turns red litmus to blue.
   What could be R?

   A aluminium chloride **B** magnesium chloride **C** sodium oxide **D** phosphorus oxide

2. Ammonium chloride dissolves readily in water.
   Which statement about the colourless solution formed is correct?
   A Ions in the solution can form hydrogen bonds with water molecules.
   B The solution is slightly basic.
   C The solution would smell of chlorine.
   D When sodium hydroxide is added, a gas is formed which turns damp blue litmus paper red.

3. The results of tests performed on a white crystalline solid, X, are given in the table.

reagent and conditions	Observation
X is gently heated	X sublimes
X is shaken with H_2O	a colourless solution, Y, forms
Y is warmed with NaOH(aq)	a gas is given off
$AgNO_3$(aq) is added to Y	a white precipitate, Z, forms
Z is shaken with NH_3(aq)	a colourless solution forms

What is the identity of X?

A aluminium bromide
B aluminium chloride
C ammonium bromide
D ammonium chloride

4. Ammonium sulfate, $(NH_4)_2SO_4$, and ammonium nitrate, NH_4NO_3, are used as fertilisers.
These salts have different percentages by mass of nitrogen. They have the same effect as each other on the pH of wet neutral soil.
Which row is correct?

	higher percentage of nitrogen by mass	effect on pH of soil
A	ammonium nitrate	decrease
B	ammonium nitrate	increase
C	ammonium sulfate	decrease
D	ammonium sulfate	increase

5. R is a solid. R fizzes when hydrochloric acid is added.
R reacts with hot aqueous sodium hydroxide, giving off a gas which turns red litmus blue.
What is the formula of R?

A NH_4CO_3 **B** $(NH_4)_2CO_3$ **C** $(NH_4)_2HCO_3$ **D** $(NH_4)_2SO_4$

6. Ammonium ions, NH_4^+, are formed when ammonia gas reacts with hydrogen chloride gas.
Which statement about the changes that occur in this reaction is correct?

A The dipole moment of an ammonium ion is greater than the dipole moment of an ammonia molecule.
B The H-N-H bond angle decreases when an ammonium ion is formed.
C The hybridisation of nitrogen does **not** change.
D There is electron transfer from nitrogen to chlorine.

7. NaOH(aq) is added to NH_4Cl (aq). The mixture is warmed.
The gas that is produced turns damp red litmus paper blue.
Which row is correct?

	behaviour of the water present on the litmus paper	behaviour of the ammonium ion in NH_4Cl
A	Brønsted–Lowry acid	Brønsted–Lowry base
B	Brønsted–Lowry acid	Brønsted–Lowry acid
C	Brønsted–Lowry base	Brønsted–Lowry acid
D	Brønsted–Lowry base	Brønsted–Lowry base

8. Which statement about ammonia or the ammonium ion is correct?

A Ammonia gas is produced when an aqueous solution containing the ammonium ion is reacted with a strong acid.
B Silver iodide is soluble in a concentrated aqueous solution of ammonia.
C The ammonium ion has the same number of electrons as a methane molecule.
D The square planar ammonium ion contains a dative covalent bond.

9. NH_4Cl reacts with NaOH in an aqueous solution.
Which statement is correct?

A The reaction gives rise to two different polar product molecules.
B The bond angle in the nitrogen-containing species remains unchanged.
C The ammonium ion acts as a base.
D The oxidation state of nitrogen increases in the reaction.

10. Which statement describes a property of an ammonium ion?

A An aqueous ammonium ion is a weak Brønsted–Lowry base.
B Aqueous ammonium sulfate reacts with dilute hydrochloric acid to make ammonia gas.
C An ammonium ion has a pyramidal shape with an H–N–H bond angle of 107^o.
D The four N–H covalent bonds in an ammonium ion are identical to each other.

11. Ammonia exists as simple covalent molecules, NH_3. Ammonia can react with suitable reagents to form products containing ammonium ions, NH_4^+. Ammonia can also react with suitable reagents to form products containing amide ions, NH_2^-.
Which of these nitrogen-containing species are present in an aqueous solution of ammonia?

A ammonia molecules and amide ions
B ammonia molecules and ammonium ions
C ammonia molecules only
D ammonium ions only

12. Which reaction mixture produces an acidic gas?
A aqueous ammonium nitrate and solid calcium oxide
B calcium and aqueous hydrochloric acid
C potassium chloride and concentrated sulfuric acid
D sodium oxide and water

13. When some solid $Ca_5(PO_4)_3OH$ is added to a beaker of water, an equilibrium is set up.
$Ca_5(PO_4)_3OH(s) \rightleftharpoons 5Ca^{2+}(aq) + 3PO_4^{3-}(aq) + OH^-(aq)$
Which compound, when added to the equilibrium mixture, increases the amount of $Ca_5(PO_4)_3OH(s)$ present?

A NH_3 **B** NH_4Cl **C** CH_3CO_2H **D** $NaCl$

14. Three statements about ammonia molecules and ammonium ions are given.

1 In aqueous solution, ammonia molecules form coordinate bonds with hydroxide ions.
2 Ammonium ions are Brønsted–Lowry acids.
3 The H–N–H bond angle is larger in the ammonium ion than in the ammonia molecule.

Which statements are correct?

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

15. Which statement about ammonia or the ammonium ion is correct?

A Ammonia gas is produced when an aqueous solution containing the ammonium ion is reacted with a strong acid.
B Silver iodide is soluble in a concentrated aqueous solution of ammonia.
C The ammonium ion has the same number of electrons as a methane molecule.
D The square planar ammonium ion contains a dative covalent bond.

Nitrogen oxides in the atmosphere

In the extreme conditions in a thunderstorm, lightning can trigger the reaction between nitrogen and oxygen to form gaseous nitrogen oxides: nitrogen(II) oxide, NO, and nitrogen(IV) oxide, NO_2.
A similar oxidation of nitrogen takes place at the high temperature inside a car engine. In the engine, a mixture of air (which is mainly nitrogen, 78%, and oxygen, 21%) and fuel is compressed and ignited by a spark. Under this high pressure and high temperature, nitrogen can form nitrogen oxides. These oxides of nitrogen are then released into the atmosphere through the car's exhaust fumes.
Nitrogen oxides pollute our atmosphere. They cause acid rain and photochemical smog.

6. State **one** natural and **one** man-made occurrence of oxides of nitrogen.

……

…… [1]

7. Identify one natural process and one man-made process that cause the formation of atmospheric NO and NO_2.[1]

8. Nitrogen oxides can be formed naturally in the Earth's atmosphere from nitrogen and oxygen in the air.
State **one** way that nitrogen oxides are produced naturally. [1]

Acid rain

Nitrogen(II) oxide, formed in lightning strikes, is oxidised to form nitrogen(IV) oxide in air:
$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$
This is followed by further oxidation to nitric acid when nitrogen(IV) oxide dissolves and reacts in water with oxygen:
$NO_2(aq) + H_2O(l) + 1.5\ O_2(g) \rightarrow 2HNO_3(aq)$
The water is often in the form of tiny droplets that make up clouds. The droplets get larger as the temperature drops when clouds rise. When heavy enough the droplets, containing dilute nitric acid, will fall as acid rain.

Dilute sulfuric acid is also found in acid rain. This comes from another pollutant called sulfur dioxide gas (or sulfur(IV) oxide). Nitrogen oxides, as well as causing acid rain directly, can also act as catalysts in the reactions that make dilute sulfuric acid in the atmosphere. NO and NO_2 catalyse the oxidation of sulfur dioxide gas, SO_2, during the formation of acid rain. The gas sulfur trioxide, SO_3, that is produced by this oxidation of SO_2, reacts with rainwater, forming dilute sulfuric acid:
$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

The reactions below show the catalytic activity of the nitrogen oxides:
$SO_2(g) + NO_2(g) \rightarrow SO_3(g) + NO(g)$
Then NO_2 is regenerated as NO reacts with oxygen in the air:
$NO(g) + O_2(g) \rightarrow NO_2(g)$
This NO_2 molecule can then go on to oxidise another sulfur dioxide molecule. At the same time, the reaction also produces an NO molecule to make another NO_2 molecule. This will oxidise another sulfur dioxide molecule, and so on. Therefore, NO_2 effectively catalyses the oxidation of SO_2.

9. NO_2 has a catalytic role in the oxidation of atmospheric sulfur dioxide.
   (i) Write equations to show the catalytic role of NO_2 in this oxidation. [2]

   (ii) State **one** environmental consequence of the oxidation of atmospheric sulfur dioxide. [1]

10. Describe how acid rain is formed in the atmosphere in the presence of oxides of nitrogen and SO_2. Identify the role of the oxides of nitrogen in this process. Include all relevant equations. [3]

11. Write equations which describe the two reactions occurring when NO_2 acts as a catalyst in the formation of sulfur trioxide from sulfur dioxide. [2]

12. The release of nitrogen monoxide into the atmosphere causes atmospheric pollution.
State and explain the effect of nitrogen monoxide gas in contact with moist air. [2]

16. Two procedures are described.
1 Sulfur is burned in an excess of oxygen and then NO is added to the product mixture.
2 Sulfur is burned in an excess of oxygen and then NO_2 is added to the product mixture.
Which procedures will produce some sulfur trioxide, SO_3?

A both 1 and 2 **B** 1 only **C** 2 only **D** neither 1 nor 2

17. Nitrogen forms pollutant oxide Y in a car engine.
Further oxidation of Y to Z occurs in the atmosphere. In this further oxidation, 1mol of Y reacts with 0.5mol of gaseous oxygen molecules.
Which statement is correct?

A Compound Z does not react further in the atmosphere.
B A molecule of Y has 15 electrons.
C The oxidation number of nitrogen increases by one from Y to Z.
D Y is a non-polar molecule.

13. State the environmental consequences of releasing $SO_2(g)$ into the atmosphere. [1]

18. Which emission from an internal combustion engine contributes to the erosion of marble statues?

A carbon monoxide **B** nitrogen **C** nitrogen dioxide **D** unburnt hydrocarbons

19. Sulfur dioxide can be catalytically oxidised by an oxide of nitrogen in the atmosphere.
Which reaction shows how the catalyst is reformed?

A $N_2 + 2O_2 \rightarrow 2NO_2$
B $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$
C $N_2 + O_2 \rightarrow 2NO$
D $NO + \frac{1}{2} O_2 \rightarrow NO_2$

14. N_2 can react with oxygen in an internal combustion engine to form a mixture of NO and NO_2.

reaction 1 $N_2 \xrightarrow{O_2}$ NO and NO_2

reaction 2 $NO_2 \xrightarrow{H_2O}$ products

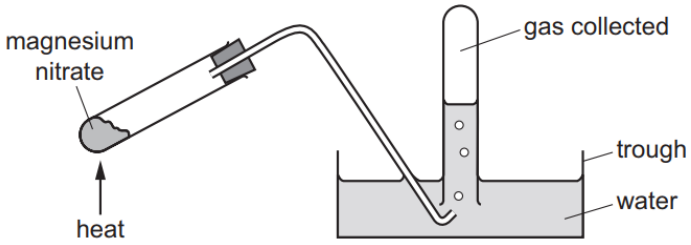
reaction 3 $NO_2 \xrightarrow{\text{unburned hydrocarbons}}$ peroxyacetyl nitrate (PAN)

Fig. 3.1 shows a reaction scheme involving N_2.

(i) Write an equation to show the formation of a mixture of NO and NO_2 in reaction 1. [1]

(ii) State one environmental consequence of reaction 3. [1]

20. A sample of magnesium nitrate is heated in the apparatus shown.



The pH of the solution in the trough is measured.
The gas collected is tested with a glowing splint.
What are the results?

	pH of solution in trough	splint test
A	8	relights
B	2	relights
C	8	extinguished
D	2	extinguished

Photochemical smog

The oxides of nitrogen are also dangerous in the atmosphere because they react to make other pollutants. These other pollutants formed are called *secondary pollutants*. This is because they are not given off directly from human activity: for example, they are not vehicle exhaust gases or gases from power plants. Nitrogen oxides are examples of *primary pollutants* as they are given off directly into the air from the source of pollution.

Other primary pollutants in exhaust fumes are volatile organic compounds (VOCs). These are largely unburnt **hydrocarbons** from fuel, and their oxidised products. The VOCs can react in sunlight with oxides of nitrogen to make peroxyacetyl nitrate (also called **PAN**). Its chemical formula can be written as $CH_3CO_3NO_2$. Sunlight provides the energy needed to start the reactions off in the atmosphere, so we call them **photochemical reactions**.

PAN is one of the harmful pollutants found in photochemical smog. PAN affects the lungs and eyes, and in high concentrations also affects plant-life.

15. SO_2 and SO_3 are found in the atmosphere.
The oxidation of SO_2 to SO_3 in the atmosphere is catalysed by NO_2.
The first step of the catalytic oxidation is shown in equation 1.
equation 1 $SO_2(g) + NO_2(g)$ $SO_3(g) + NO(g)$
(i) Construct an equation to show how NO_2 is regenerated in the catalytic oxidation of SO_2. [1]

(ii) NO_2 can also react with unburned hydrocarbons to form photochemical smog.
State the product of this reaction that contributes to photochemical smog. [1]

21. Carbon monoxide, CO, nitrogen dioxide, NO2, and sulfur dioxide, SO2, are all atmospheric pollutants.
Which reaction occurs in the atmosphere?

A CO is spontaneously oxidised to CO_2.
B NO_2 is reduced to NO by SO_2.
C NO_2 is reduced to NO by CO.
D SO_2 is oxidised to SO_3 by CO_2.

22. Photochemical smog is a type of air pollution produced in urban areas by the effect of sunlight on substances released from vehicle exhausts.
Which mixture of primary pollutants leads to the formation of photochemical smog?

A carbon dioxide and water vapour
B carbon monoxide and unburnt hydrocarbons
C nitrogen oxide and unburnt hydrocarbons
D sulfur dioxide and water vapour

23. Which statement is correct?

A An ammonium ion is basic due to a lone pair of electrons on the nitrogen atom.
B Nitrogen monoxide, NO, reacts with peroxyacetyl nitrate to produce a component of photochemical smog.
C Nitrogen dioxide catalyses the oxidation of atmospheric sulfur dioxide.
D Nitrogen is very unreactive due to the very strong permanent dipole–permanent dipole attractions between the nitrogen atoms.

24. Compound L decomposes on heating. One of the products is gas M.
M reacts with unburned hydrocarbons to form peroxyacetyl nitrate, PAN.
What could be the formula of L?

A $CaNO_3$ **B** $Ca(NO_3)_2$ **C** $MgCO_3$ **D** $Mg(CO_3)_2$

16. State **one** other type of air pollution that is caused by the production of oxides of nitrogen in an internal combustion engine. [1]

Reducing the effects of nitrogen oxides

Nowadays, car exhaust systems are fitted with catalytic converters to help reduce the pollutants from motor vehicles. The reaction of pollutant gases inside the converter takes place on the surface of the hot catalyst, for example platinum. The nitrogen oxides are reduced to form harmless nitrogen gas, which is released from the vehicle's exhaust pipe.

$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$

25. The equation shows are action that occurs between carbon monoxide and nitrogenmonoxide in a catalytic converter.
$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$
Which statement is correct?

A The catalyst used is finely divided iron.
B The reaction prevents greenhouse gas emissions into the atmosphere.
C The reaction reduces the possibility of the formation of photochemical smog.
D The reaction results in increased ozone depletion.

26. A catalytic converter reduces the amount of pollutants in the fumes from a car exhaust.
Which row identifies a pollutant and shows how it is removed by the action of the catalyst?

	pollutant	chemical removal
A	carbon dioxide	reduced to carbon
B	carbon monoxide	oxidised to carbon dioxide
C	oxides of nitrogen	oxidised to nitric acid
D	unburnt hydrocarbons	oxidised to carbon dioxide and hydrogen

27. Which statement about the oxides of nitrogen is correct?

A During lightning storms, atmospheric oxygen and nitrogen combine to form oxides of nitrogen.
B In a catalytic converter, nitrogen monoxide is removed by reaction with carbon dioxide.
C In car engines, the restricted supply of oxygen eliminates the possibility of the formation of oxides of nitrogen.
D In the atmosphere, nitrogen monoxide reacts with sulfur dioxide to produce sulfur trioxide.

28. In a catalytic converter, 5.6 g of carbon monoxide react with an excess of nitrogen monoxide.
What is produced in this reaction?

A 2.4 g of C and 6.0 g of NO_2
B 2.4 g of C and 9.2 g of NO_2
C 8.8 g of CO_2 and 1.4 g of N_2
D 8.8 g of CO_2 and 2.8 g of N_2

29. Nitrogen oxides are removed from the exhaust gases of internal combustion engines by the action of a catalyst in a catalytic converter.
Which row is correct?

	change in oxidation number of nitrogen	type of catalyst
A	Decrease	Heterogeneous
B	Decrease	Homogeneous
C	Increase	Heterogenous
D	Increase	Homogenous

17. Nitrogen oxides, NO_2 and NO, are produced in internal combustion engines. Release of these gases into the atmosphere leads to the formation of photochemical smog.
(i) Outline how nitrogen oxides are involved in the formation of photochemical smog. [2]

(ii) Construct an equation to demonstrate how a catalytic converter reduces the amount of nitrogen oxide gases released into the atmosphere.

[1]

(iii) *CO_2 and SO_2 are acidic gases.*
Construct an equation for the reaction of CO_2 with $Mg(OH)_2$. *[1]*

(iv) *$SO_2(g)$ can be removed from the air by reacting it with NaOH(aq).*
Construct an equation for the reaction of $SO_2(g)$ with NaOH(aq). Include state symbols.

18. When oxides of nitrogen escape into the atmosphere they may be involved in:
• formation of acid rain from sulfur dioxide
• formation of photochemical smog.
(i) Identify the role of NO and NO_2 in the formation of H_2SO_4 from SO_2 in the atmosphere to produce acid rain. Use relevant equations to support your answer. [3]

(ii) Outline how NO and NO_2 may contribute to the formation of photochemical smog. [2]

30. At 550 °C nitrogen dioxide reacts with unburnt hydrocarbon fragments, such as CH_3, in the catalytic converter of a motor vehicle.
$4CH_3 + 7NO_2 \rightarrow 3\ _2\ _{21}N + 4CO_2 + 6H_2O$
Which row gives the energy change for this reaction and a possible reason for it?

	energy change of reaction	reason why the reaction is endothermic or exothermic
A	endothermic	chemical energy is converted to heat energy
B	endothermic	the N≡N bond energy is very high
C	exothermic	CO_2 and H_2O have negative $\Delta H_f^{\ominus}$ values
D	exothermic	double bonds are broken in NO_2

31. The Contact process takes place at a pressure between 100 000 Pa and 200 000 Pa. A catalyst is used.
Which statement is correct?

A V_2O_5 catalyst is added to increase the equilibrium yield of the reaction.
B Changes in pressure have no effect on the position of equilibrium.
C The equilibrium yield of the reaction is very high under the conditions used.
D An iron catalyst is added to increase the rate of reaction.

32. The table describes two possible environmental consequences of adding too much ammonium nitrate fertiliser to the soil.
Which row is correct?

	increased plant growth in rivers	photochemical smog
A	✗	✗
B	✓	✗
C	✗	✓
D	✓	✓

33. Nitrogen dioxide is a gas that contributes to air pollution. It is produced in internal combustion engines.
Which statement is correct?

A Nitrogen dioxide acts as a catalyst in the atmospheric oxidation of sulfur dioxide to sulfur trioxide.
B Nitrogen dioxide reacts to form nitrogen monoxide in the catalytic converter of a car exhaust system.
C PAN forms when nitrogen dioxide reacts with the gases formed by complete combustion of the fuel.
D Under high pressure in an internal combustion engine, nitrogen dioxide forms from impurities in the fuel.

34. What is produced when 60 g of nitrogen monoxide reacts with an excess of carbon monoxide in a catalytic converter?

A 12 g of carbon and 92 g of nitrogen dioxide
B 24 g of carbon and 92 g of nitrogen dioxide
C 88 g of carbon dioxide and 28 g of nitrogen
D 88 g of carbon dioxide and 56 g of nitrogen

35. Catalytic converters are fitted in the exhaust systems of many cars.
Gas X:
- causes acid rain if it is released into the air
- is removed from car exhaust fumes by a catalytic converter.

What is gas X?

A carbon dioxide
B carbon monoxide
C hydrocarbon vapour
D nitrogen dioxide

36. Nitrogen monoxide, NO, is a primary pollutant produced by petrol engines and is found in their exhaust gases.
Which reaction occurs in a catalytic converter and decreases the emission of nitrogen monoxide?

A $NO(g) + CO(g) \rightarrow NO_2(g) + C(s)$
B $NO(g) + CO_2(g) \rightarrow NO_2(g) + CO(g)$
C $2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$
D $2NO(g) + CO_2(g) \rightarrow 2NO_2(g) + C(s)$

37. Oxides of nitrogen are present in the environment due to natural and man-made sources.
Which row is correct?

	natural source of nitrogen oxides	man-made source of nitrogen oxides
A	electrical discharges in the atmosphere	internal combustion engines
B	electrical discharges in the atmosphere	as a by-product of the Haber process
C	decomposition of dead plants in rivers	internal combustion engines
D	decomposition of dead plants in rivers	as a by-product of the Haber process

38. A reaction between two gases takes place on the surface of the catalytic converter of a petrol-engined car.
In this reaction, four reactant molecules produce three product molecules.
What could be the two reactant gases in this reaction?

A nitrogen and carbon dioxide
B nitrogen monoxide and carbon dioxide
C nitrogen monoxide and carbon monoxide
D nitrogen dioxide and carbon monoxide

39. 7.5 g of nitrogen monoxide reacts with 7.0 g of carbon monoxide on the surface of the catalytic converter in the exhaust system of a car.
What is the total volume of the product gases measured at room conditions?

A 3.0 dm^3 **B** 6.0 dm^3 **C** 9.0 dm^3 **D** 12.0 dm^3