CAMBRIDGE INTERNATIONAL AS & A LEVEL CHEMISTRY · 9701

CHEMISTRY



EXAM QUESTION PACK

12 NITROGEN AND SULFUR

SCORE	PERCENTAGE
/	%

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Chapter 12

Nitrogen and sulfur

12.1 Nitrogen and sulfur

691. 9701_m21_qp_12 Q: 18

NO, NO_2, CO and unburnt hydrocarbons are present in the exhaust gases of internal combustion engines. When catalytic converters are used to remove these compounds from the exhaust gases, redox reactions occur.

What happens to each compound in the catalytic converter?

	NO	NO_2	CO	unburnt hydrocarbons
A	oxidised	oxidised	reduced	oxidised
B	oxidised	oxidised	oxidised	oxidised
C	reduced	reduced	oxidised	oxidised
D	reduced	reduced	reduced	reduced

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692. 9701_s21_qp_11 Q: 13

The gaseous products of heating a mixture of $Ca(OH)_2$ and NH_4Cl are passed through solid CaO. A single gaseous product, W, is collected.

A sample of W reacts with Cl_2(g) to produce two gases, X and Y.

X is an element. Y is acidic.

Y reacts with W to produce Z.

What are X and Z?

	X	Z
A	N_2	$CaCl_2$
B	N_2	NH_4Cl
C	O_2	$CaCl_2$
D	O_2	NH_4Cl

---

693. 9701_s21_qp_11 Q: 18

Acid rain is a dilute solution of sulfuric acid.

Which pollutant also contributes to the formation of acid rain?

A carbon monoxide

B carbon dioxide

C nitrogen dioxide

D hydrocarbons

---

694. 9701_s21_qp_12 Q: 18

What is an environmental consequence of the uncontrolled use of nitrate fertilisers?

A acid rain

B low oxygen levels in streams

C ozone depletion

D the greenhouse effect

---

695. 9701_s21_qp_13 Q: 14

Which problem can result if too much NH_4NO_3 is applied to crops by farmers?

A Not all the NH_4NO_3 is used by plants and the excess makes the soil alkaline.

B Rain washes some of the NH_4NO_3 into rivers where it forms a precipitate.

C Some of the NH_4NO_3 dissolves in groundwater which may eventually be used for drinking.

D Ammonia is produced; this lowers the pH of the soil.

---

696. 9701_w21_qp_11 Q: 19

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	✓	✓

---

697. 9701_w21_qp_12 Q: 11

NO and NO_2 are both present in the lower atmosphere as pollutants.

The reaction sequence shows the production of ozone from oxygen in the lower atmosphere.

This sequence repeats many times.

$$NO_2(g) \rightarrow NO(g) + O(g)$$

$$NO(g) + \tfrac{1}{2}O_2(g) \rightarrow NO_2(g)$$

$$O_2(g) + O(g) \rightarrow O_3(g)$$

Which statement about this reaction sequence is correct?

A NO is acting as a catalyst, but NO_2 is not acting as a catalyst.

B NO_2 is acting as a catalyst, but NO is not acting as a catalyst.

C Neither NO nor NO_2 are acting as catalysts.

D Both NO and NO_2 are acting as catalysts.

---

698. 9701_w21_qp_12 Q: 18

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

---

699. 9701_w21_qp_12 Q: 19

Magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride.

Which statement explains this observation?

A The ionic radius of the NH_4^+ ion is similar to that of Mg^{2+} but not that of Na^+.

B NH_4Cl dissociates less fully than $NaCl$.

C The Na^+ and Mg^{2+} ions have the same number of electrons.

D The NH_4^+ ion can donate a proton.

---

700. 9701_w21_qp_13 Q: 2

2.0 g of ammonium nitrate, NH_4NO_3, decomposes to give 0.90 g of water and a single gas.

What is the identity of the gas?

A NO **B** NO_2 **C** N_2O **D** N_2

---

701. 9701_m20_qp_12 Q: 15

Solid ammonium nitrate is put into a test-tube and solution X is added to it. The resulting mixture is warmed and the gas given off is tested with damp red litmus paper. The litmus paper changes colour from red to blue.

What could be the identity of X and its role in the reaction?

	identity of X	role of X
A	NaOH(aq)	proton donor
B	NaOH(aq)	proton acceptor
C	HCl(aq)	proton donor
D	HCl(aq)	proton acceptor

---

702. 9701_m20_qp_12 Q: 19

Which statement about nitrogen or its compounds is correct?

A In the Haber process the temperature is kept high to give a good equilibrium yield of ammonia.

B Nitrogen gas is unreactive because of the strong nitrogen–nitrogen double bond.

C Nitrogen monoxide will react with carbon monoxide under suitable conditions.

D The formula of ammonium sulfate is NH_4SO_4.

---

703. 9701_s20_qp_12 Q: 15

Ammonium carbonate is a crystalline solid. On gentle warming a reaction occurs, forming ammonia as one product.

How are the carbonate ions behaving during this reaction?

A Brønsted-Lowry acid

B Brønsted-Lowry base

C oxidising agent

D reducing agent

---

704. 9701_s20_qp_13 Q: 5

Nitrogen reacts with oxygen to form nitrogen monoxide, NO, and nitrogen dioxide, NO_2. Nitrogen dioxide reacts with water and with hydroxide ions.

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

$$2NO_2(g) + H_2O(l) \rightarrow HNO_2(aq) + H^+(aq) + NO_3^-(aq)$$

$$2NO_2(g) + 2OH^-(aq) \rightarrow NO_2^-(aq) + NO_3^-(aq) + H_2O(l)$$

What can be deduced using **only** the information from these equations?

A HNO_2 is a strong acid.

B HNO_3 is a weak acid.

C NO_2 is a neutral gas.

D NO is a reducing agent.

---

705. 9701_s20_qp_13 Q: 12

Compound T is a white crystalline solid.

When a sample of compound T is mixed with aqueous sodium hydroxide and heated, a gas is produced which turns damp red litmus paper blue.

Further testing of a solution of compound T with aqueous barium chloride produces a dense white precipitate which does not dissolve when dilute hydrochloric acid is added to the mixture.

What is the identity of compound T?

A ammonium carbonate

B ammonium sulfate

C sodium carbonate

D sodium sulfate

---

706. 9701_s20_qp_13 Q: 16

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	heterogeneous
D	increase	homogeneous

---

707. 9701_w20_qp_11 Q: 17

Ammonia can undergo an acid–base reaction with hydrogen chloride to form ammonium chloride.

Which statement is correct?

A The ammonium ion is basic.

B The hydrogen atom from HCl donates a lone pair of electrons to the nitrogen atom.

C The H–N–H bond angle in ammonia is the same as the H–N–H bond angle in the ammonium ion.

D The H–N–H bond angle in the ammonium ion is the same as the H–C–H bond angle in methane.

---

708. 9701_w20_qp_12 Q: 15

Water and ammonia take part in a reaction that produces the ammonium ion.

Which statement about this reaction is correct?

A The ammonia molecule and the ammonium ion do not have dipole moments.

B The bond angle changes from 109.5° in the ammonia molecule to 107° in the ammonium ion.

C The reaction is a redox reaction.

D The water is acting as an acid.

---

709. 9701_m19_qp_12 Q: 19

Ammonia, NH_3, and hydrazine, NH_2NH_2, are two compounds of nitrogen, N_2.

Which statement is correct?

A The N–N bond in NH_2NH_2 is polar.

B NH_3 and NH_2NH_2 have lone pairs of electrons but N_2 does not.

C The oxidation number of each nitrogen in NH_2NH_2 is +2.

D The reaction of nitrogen with hydrogen has a high activation energy.

---

710. 9701_s19_qp_11 Q: 19

Which statement is correct?

A Ammonia reacts with alkalis to form the ammonium ion.

B Ammonium chloride contains ionic, covalent and co-ordinate bonds.

C The ammonium ion reacts with acids to produce ammonia.

D The bond angle in the ammonium ion is approximately 107°.

---

711. 9701_s19_qp_12 Q: 18

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

---

712. 9701_s19_qp_12 Q: 19

Which reaction gives a product that is an atmospheric pollutant causing acid rain?

A $3Mg(s) + SO_2(g) \rightarrow MgS(s) + 2MgO(s)$

B $(NH_4)_2SO_4(s) + Ca(OH)_2(s) \rightarrow 2NH_3(g) + CaSO_4(s) + 2H_2O(l)$

C $2MnO_4^-(aq) + 5SO_2(g) + 2H_2O(l) \rightarrow 2Mn^{2+}(aq) + 4H^+(aq) + 5SO_4^{2-}(aq)$

D $2FeSO_4(s) \rightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$

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713. 9701_s19_qp_13 Q: 18

Which statement about the ammonium ion is correct?

A It can act as a Brønsted-Lowry base.

B It can react with OH^- to give ammonia.

C It is pyramidal with bond angles of 107°.

D The nitrogen atom is sp^2 hybridised.

---

714. 9701_s19_qp_13 Q: 19

In a catalytic converter 5.6 g of carbon monoxide reacts 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

---

715. 9701_w19_qp_11 Q: 18

Which type of reaction occurs when solid ammonium sulfate is heated with an excess of sodium hydroxide solution?

A acid-base

B precipitation

C redox

D thermal decomposition

---

716. 9701_w19_qp_11 Q: 19

Catalytic converters are fitted in the exhaust systems of many cars.

Which gas:

- causes acid rain if it is released into the air
- is removed from car exhaust fumes by a catalytic converter?

A carbon dioxide

B carbon monoxide

C hydrocarbon vapour

D nitrogen dioxide

---

717. 9701_w19_qp_12 Q: 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

---

718. 9701_w19_qp_12 Q: 19

Ammonia, carbon dioxide and water react together to form ammonium carbonate.

Which statement about this reaction is correct?

A It is a redox reaction.

B It is an acid-base reaction.

C The H–N–H bond angle decreases as a consequence of this reaction.

D The three substances react in a 1 : 1 : 1 ratio in this reaction.

---

719. 9701_s18_qp_11 Q: 17

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

---

720. 9701_s18_qp_12 Q: 19

Sulfur dioxide can be catalytically oxidised by an oxide of nitrogen in the atmosphere.

Which reaction shows the regeneration of the catalyst?

A $N_2 + 2O_2 \rightleftharpoons 2NO_2$

B $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

C $N_2 + O_2 \rightarrow 2NO$

D $NO + \frac{1}{2}O_2 \rightarrow NO_2$

---

721. 9701_s18_qp_13 Q: 19

The gaseous products of heating a mixture of $Ca(OH)_2$ and NH_4Cl are passed through solid CaO. This absorbs water vapour and a gas, **W**, is collected.

A sample of **W** is oxidised by Cl_2(g) to produce two gases, **X** and **Y**.

X is an element. **Y** is acidic.

Y reacts with **W** to produce **Z**.

What are **X** and **Z**?

	X	Z
A	N_2	$CaCl_2$
B	N_2	NH_4Cl
C	O_2	$CaCl_2$
D	O_2	NH_4Cl

---

722. 9701_w18_qp_11 Q: 19

Transition elements and their compounds are widely used as catalysts.

What is the identity and what is the oxidation number of the element present in the catalyst used in the Contact process?

	element	oxidation number
A	iron	0
B	iron	+3
C	vanadium	0
D	vanadium	+5

---

723. 9701_w18_qp_12 Q: 18

The product of the Contact process is Z.

Which reaction or process leads to the formation of a gas that can neutralise an aqueous solution of Z?

A atmospheric lightning

B combustion of fuel in an internal combustion engine

C the Haber process

D thermal decomposition of Group 2 nitrates

---

724. 9701_m17_qp_12 Q: 19

Methylamine, CH_3NH_2, has very similar chemical properties to ammonia, NH_3.

Methylamine reacts with hydrogen chloride to form a white crystalline salt, methylammonium chloride.

$$CH_3NH_2 + HCl \rightarrow CH_3NH_3^+Cl^-$$

A sample of methylammonium chloride is heated with aqueous sodium hydroxide.

What are the products?

A ammonia, sodium chloride and water

B ammonia, sodium hydrogencarbonate and sodium chloride

C methylamine, hydrogen chloride and water

D methylamine, sodium chloride and water

---

725. 9701_s17_qp_11 Q: 16

Which statement about nitrogen or its compounds is correct?

A In the Haber process the temperature is kept high to give a good equilibrium yield of ammonia.

B Nitrogen gas is unreactive because of the strong nitrogen-nitrogen double bond.

C Nitrogen monoxide will react with carbon monoxide under suitable conditions.

D The formula of ammonium sulfate is NH_4SO_4.

---

726. 9701_s17_qp_12 Q: 18

The ammonium ion is formed by the following reaction.

$$NH_3 + H^+ \rightarrow NH_4^+$$

Which statement about the species involved in this reaction is correct?

A The ammonia molecule contains a dative covalent bond.

B The ammonium ion is a Brønsted-Lowry base as it has accepted a proton.

C The H–N–H bond angle changes from 107° in ammonia to 90° in the ammonium ion.

D The number of electrons surrounding each nitrogen atom does not change.

---

727. 9701_s17_qp_13 Q: 18

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 only

B ammonia molecules and ammonium ions only

C ammonia molecules only

D ammonium ions only

---

728. 9701_s17_qp_13 Q: 19

What would be produced when 60 g of nitrogen monoxide react 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

---

729. 9701_w17_qp_11 Q: 16

Which fertiliser contains the greatest percentage of nitrogen by mass?

A ammonium nitrate, NH_4NO_3

B ammonium sulfate, $(NH_4)_2SO_4$

C diammonium hydrogen phosphate, $(NH_4)_2HPO_4$

D urea, $CO(NH_2)_2$

---

730. 9701_w17_qp_12 Q: 18

The reaction of nitrogen and oxygen to produce oxides of nitrogen happens at high temperatures in car engines or lightning strikes during thunderstorms.

What is the main reason for these reactions requiring such high temperatures?

A the lack of reactivity of nitrogen, due to the half-filled 2p subshell in the nitrogen atom

B the lack of reactivity of nitrogen, due to the strength of the bond in N_2

C the lack of reactivity of oxygen, due to electron-electron repulsion in one of its 2p orbitals

D the lack of reactivity of oxygen, due to the strength of the bond in O_2

---

731. 9701_m16_qp_12 Q: 17

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 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

---

732. 9701_s16_qp_11 Q: 18

Which statement about the ammonia molecule and/or the ammonium ion is correct?

A Ammonia molecules are basic because they can donate H^+ ions.

B Ammonium ions are basic because they can accept H^+ ions.

C If ammonium ions are heated with NaOH(aq), ammonia molecules are formed.

D The bond angle in NH_4^+ is 2.5° less than the bond angle in NH_3.

---

733. 9701_s16_qp_11 Q: 19

Which reaction **does not** contribute to the problem of acid rain?

A the combustion of fossil fuels

B the oxidation of sulfur dioxide to sulfur trioxide catalysed by nitrogen dioxide

C the reaction between nitrogen monoxide and carbon monoxide in a catalytic converter

D the reaction of sulfur trioxide with water

---

734. 9701_s16_qp_12 Q: 15

Ammonia gas, NH_3, and hydrogen sulfide gas, H_2S, react together to form the salt ammonium sulfide, $(NH_4)_2S$. Ammonium sulfide dissolves in water to produce an orange alkaline solution.

$$(NH_4)_2S(aq) \rightleftharpoons NH_3(aq) + NH_4SH(aq)$$

The addition of NaOH(aq) to this solution produces a gas, **X**.
The addition of HCl(aq) to a separate portion of this solution produces a gas, **Y**.

What are the identities of **X** and **Y**?

	X	Y
A	H_2S	H_2S
B	H_2S	NH_3
C	NH_3	H_2S
D	NH_3	NH_3

---

735. 9701_s16_qp_13 Q: 19

Which statement does **not** describe an effect of acid rain on the environment?

A Acid rain causes erosion of stone buildings.

B Acid rain causes ozone depletion.

C Acid rain increases the corrosion of some metals.

D Acid rain increases the leaching away of essential nutrients and minerals from soils.

---

736. 9701_w16_qp_11 Q: 17

Compound **T** is a white crystalline solid.

When a sample of **T** was mixed with aqueous sodium hydroxide and heated, a pungent smelling gas was produced which turned damp red litmus paper blue. This same gas produced dense white smoke with hydrogen chloride gas.

Further testing of a solution of **T** with barium chloride solution produced a dense white precipitate which did not dissolve when dilute hydrochloric acid was added to the mixture.

What is the identity of compound **T**?

A ammonium carbonate

B ammonium sulfate

C sodium carbonate

D sodium sulfate

---

737. 9701_w16_qp_12 Q: 19

Water and ammonia take part in a reaction that produces the ammonium ion.

Which statement about this reaction is correct?

A Neither the ammonia molecule nor the ammonium ion has a dipole moment.

B The bond angle changes from 109.5° in the ammonia molecule to 107° in the ammonium ion.

C The reaction is a redox reaction.

D The water is acting as an acid.

---

738. 9701_s15_qp_11 Q: 18

Mohr's salt is a pale green crystalline solid which is soluble in water. It contains two cations, one of which is Fe^{2+}, and one anion which is SO_4^{2-}.

The identity of the second cation was determined by heating Mohr's salt with aqueous sodium hydroxide. A colourless gas was evolved which readily dissolved in water giving an alkaline solution.

A green precipitate was also formed.

What are the identities of the gas and the precipitate?

	gas	precipitate
A	NH_3	$Fe(OH)_2$
B	NH_3	Na_2SO_4
C	SO_2	$Fe(OH)_2$
D	SO_2	Na_2SO_4

---

739. 9701_s15_qp_12 Q: 17

Which statement about the ammonium ion, NH_4^+, is correct?

A All bond angles are 107°.

B Ammonium ions are formed when ammonia behaves as an acid.

C Ammonium ions are unreactive when heated with NaOH(aq).

D The bonds are all the same length.

---

740. 9701_s15_qp_12 Q: 18

Carbon monoxide, CO, nitrogen dioxide, NO_2, and sulfur dioxide, SO_2, are all atmospheric pollutants.

Which reaction concerning these compounds occurs in the atmosphere?

A CO is spontaneously oxidised to CO_2

B NO_2 is reduced to NO by CO

C NO_2 is reduced to NO by SO_2

D SO_2 is oxidised to SO_3 by CO_2

Chapter 12

Nitrogen and sulfur

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12.1 Nitrogen

73. 9701_s20_qp_21 Q: 3

Nitric acid, HNO_3, can be made by reacting nitrogen dioxide with water.

The enthalpy change for the reaction can be measured indirectly using a Hess' cycle.

$$3NO_2(g) + H_2O(l) \xrightarrow{\Delta H_r} 2HNO_3(l) + NO(g)$$

(a) Explain what is meant by the term *enthalpy change of formation*.

.....

.....

..... [2]

(b) Complete the Hess' cycle using the values given in the table and hence calculate the enthalpy change, ΔH_r, for this reaction.

Show your working.

substance	ΔH_f / kJ mol^{-1}
$NO_2(g)$	34.0
$H_2O(l)$	–286
$HNO_3(l)$	–173
$NO(g)$	91.1

$$3NO_2(g) + H_2O(l) \xrightarrow{\Delta H_r} 2HNO_3(l) + NO(g)$$

ΔH_r = ... kJ mol^{-1}
[3]

(c) Nitrogen and oxygen do not react at normal atmospheric temperatures.

Explain why.

.....

.....

.....

..... [2]

Nitrogen oxides can be formed naturally in the Earth's atmosphere from nitrogen and oxygen in the air.

(d) State **one** way that nitrogen oxides are produced naturally.

..... [1]

(e) Nitrogen dioxide, NO_2, acts as a homogeneous catalyst in the oxidation of atmospheric sulfur dioxide.

(i) Explain why NO_2 is described as a homogeneous catalyst.

.....

.....

.....

..... [3]

(ii) 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]

[Total: 13]

74. 9701_s20_qp_21 Q: 4

Calcium nitrate, $Ca(NO_3)_2$, reacts with ammonia, carbon dioxide and water to form a mixture of ammonium nitrate and calcium carbonate.

$$Ca(NO_3)_2 + 2NH_3 + CO_2 + H_2O \rightarrow 2NH_4NO_3 + CaCO_3$$

(a) Explain why ammonia is described as a Brønsted-Lowry base in this reaction.

..... [1]

The product mixture can then be added to soil.

(b) State **two** reasons why this mixture of products is added to some soils.

1 .....

2 .....
[2]

(c) Complete the table to name the shape and give the bond angle of each species.

	name of shape	bond angle / °
CO_2		
NH_3		
H_2O		

[3]

[Total: 6]

75. 9701_s20_qp_22 Q: 2

Nitric acid can be made in a 3-stage process.

Stage 1 Ammonia is oxidised by oxygen from the air, to form nitrogen monoxide and water. This reaction is carried out at 10–13 atmospheres pressure and 900 °C in the presence of a platinum catalyst.

Stage 2 Nitrogen monoxide reacts with more oxygen to form nitrogen dioxide.

$$2NO + O_2 \rightleftharpoons 2NO_2 \qquad \Delta H = -114\,kJ\,mol^{-1}$$

Stage 3 Nitrogen dioxide reacts with water to make nitric acid and nitrogen monoxide.

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

(a) Write an equation to show the reaction occurring in stage 1.

..... [1]

(b) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in a molecule of ammonia.

[1]

(c) (i) In the boxes, give the oxidation numbers of nitrogen in the nitrogen-containing species for the reaction in stage 3.

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

[2]

(ii) Explain why the reaction in stage 3 is described as a disproportionation reaction. Include reference to transfer of electrons in your answer.

.....

.....

..... [2]

(d) 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]

(e) The nitric acid made in stage 3 can then be reacted with ammonia to form ammonium nitrate.

Stage 3 $3NO_2 + H_2O \rightarrow 2HNO_3 + NO$

$NH_3 + HNO_3 \rightarrow NH_4NO_3$

Calculate the volume of nitrogen dioxide, measured at room temperature and pressure, required to make 40 tonnes of ammonium nitrate.
[1 tonne = 1000 kg]

Show your working.

volume of nitrogen dioxide = ... [3]

(f) State **one** use of ammonium nitrate.

..... [1]

[Total: 12]

76. 9701_w18_qp_21 Q: 2

(a) Nitrogen, N_2, is an inert gas that makes up 78% of the Earth's atmosphere.

(i) Explain why nitrogen is inert.

.....

.....

..... [2]

(ii) Draw a 'dot-and-cross' diagram of a nitrogen molecule. Show outer electrons only.

[1]

(b) Nitrogen, N_2, and oxygen, O_2, react together in the air during lightning strikes to form nitrogen monoxide, NO.

(i) Explain why the reaction of N_2 and O_2 occurs during lightning strikes.

.....

..... [1]

(ii) Write two equations to suggest how the NO formed reacts further to create nitric acid, HNO_3.

1 .....

2 .....
[2]

(c) Nitrate fertilisers are used to provide nitrogen for plant growth. Uncontrolled use of these can cause a reduction in animal and plant life in natural water supplies.

Explain how uncontrolled use of nitrate fertilisers can cause this problem.

.....

.....

.....

..... [3]

(d) Some soils have compounds such as ammonium nitrate, calcium carbonate and calcium hydroxide added to them.

(i) Suggest why calcium hydroxide is added to some soils.

..... [1]

(ii) When calcium hydroxide reacts with compounds containing the ammonium ion, NH_4^+, a gas is produced.

State the identity of this gas and explain why the reaction occurs.

gas .....

explanation .....

.....

.....

[2]

(iii) Another fertiliser, calcium ammonium nitrate, is formed when solid calcium carbonate is added to a mixture of aqueous ammonium nitrate and dilute nitric acid.

Suggest what would be **observed** in this reaction.

.....

.....

..... [2]

(iv) Calcium nitrate decomposes at a higher temperature than calcium ammonium nitrate.

Write an equation for the thermal decomposition of calcium nitrate.

..... [1]

[Total: 15]

77. 9701_s17_qp_22 Q: 2

Nitrogen gas, N_2, is very unreactive.

(a) Explain why nitrogen gas is so unreactive.

.....

.....

..... [2]

(b) Despite the low reactivity of N_2, oxides of nitrogen occur in the atmosphere through both natural and man-made processes.

(i) Explain why oxides of nitrogen can be produced by internal combustion engines.

.....

.....

..... [2]

(ii) State and explain, using a suitable equation, how oxides of nitrogen produced by internal combustion engines can be prevented from reaching the atmosphere.

.....

..... [2]

(iii) State the role of nitrogen dioxide, NO_2, in the formation of acid rain by oxides of sulfur. Write suitable equations to explain this role.

role .....

equation 1 .....

equation 2 .....
[3]

(iv) Suggest an equation to show how NO_2 can contribute **directly** to acid rain.

..... [1]

(c) Explain how the uncontrolled use of nitrate fertilisers on land can lead to a severe reduction in water quality in rivers.

.....

.....

.....

..... [3]

[Total: 13]

78. 9701_s16_qp_23 Q: 2

Ammonium nitrate is an important fertiliser made by the acid-base reaction between ammonia and nitric acid.

(a) Write an equation for the production of ammonium nitrate from ammonia and nitric acid.

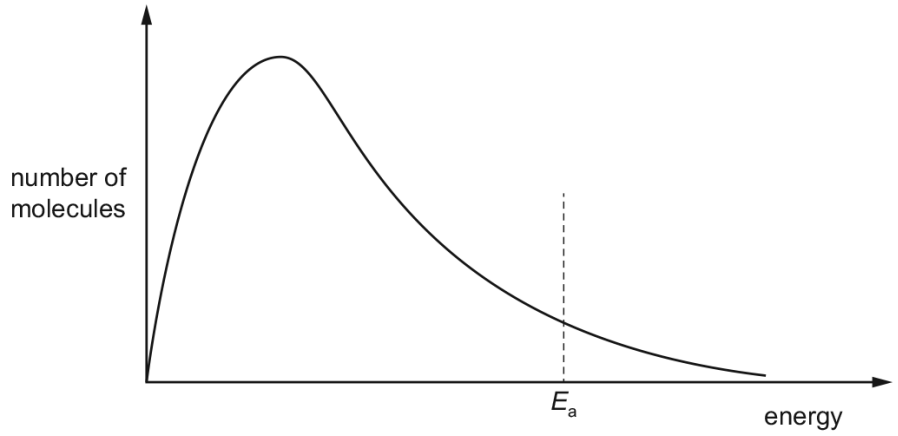
..... [1]

The ammonia for this reaction is produced by the Haber process and the nitric acid is produced by oxidation of ammonia.

(b) The Haber process involves a reaction between nitrogen and hydrogen at a temperature of 450 °C and a pressure of 20 000 kPa. At a higher reaction temperature, the rate of production of ammonia would be greater.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3 \qquad \Delta H = -92\,kJ\,mol^{-1}$$

The Boltzmann distribution curve shows the distribution of energies in a mixture of nitrogen and hydrogen at 450 °C.



(i) Sketch a second line onto the axes above to show the distribution of energies in the same mixture of gases at a higher temperature. [2]

(ii) With reference to the two curves, explain why the rate of production of ammonia would be greater at a higher temperature.

.....

.....

..... [2]

(iii) Add a suitable label to the horizontal axis above and use it to explain why a catalyst is used in the Haber process.

.....

.....

..... [2]

(iv) Explain why a higher temperature is **not** used despite the fact that it would increase the rate of production of ammonia.

.....

.....

..... [2]

(c) The first stage in the production of nitric acid involves the reaction of ammonia with oxygen to form nitrogen monoxide, NO, and water.

Suggest an equation for this reaction and use oxidation numbers to show that it is a redox reaction.

.....

.....

.....

..... [3]

(d) **(i)** Draw a dot-and-cross diagram of the ammonium ion. Show the outer electrons only.
Use the following code for your electrons.
- • electrons from nitrogen
- × electrons from hydrogen

[2]

(ii) State the shape of an ammonium ion and give the H–N–H bond angle.

shape .....

bond angle .....
[2]

(e) State and explain the problems that arise from the overuse of ammonium nitrate fertiliser when the excess is washed into rivers.

.....

.....

.....

..... [3]

[Total: 19]

79. 9701_w15_qp_21 Q: 2

(a) (i) Explain the meaning of the term *enthalpy change of formation*.

.....

.....

..... [2]

(ii) Give the equation for the reaction for which the enthalpy change corresponds to the standard enthalpy change of formation of liquid sulfur trioxide, SO_3. Include state symbols.

..... [1]

(b) Ammonia is manufactured by the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Use bond energies from the *Data Booklet* to calculate the enthalpy change of reaction for the Haber process. Include a sign in your answer.

enthalpy change ..... $kJ\,mol^{-1}$ [3]

(ii) State the essential operating conditions for the Haber process.

.....

.....

..... [3]

(iii) Explain the choices of temperature and pressure for the Haber process.

.....

.....

.....

.....

..... [4]

(c) One of the major uses of ammonia is in the manufacture of fertilisers such as diammonium hydrogen phosphate, $(NH_4)_2HPO_4$.

(i) Write an equation for the formation of diammonium hydrogen phosphate by the reaction between ammonia and phosphoric acid, H_3PO_4.

..... [1]

(ii) Explain this reaction in terms of the Brønsted-Lowry theory.

.....

.....

.....

..... [2]

(d) The use of nitrate fertilisers can give rise to environmental consequences in terms of effects on both rivers and the atmosphere.

(i) Explain how the uncontrolled use of nitrate fertilisers can result in a severe reduction in water quality in rivers.

.....

.....

.....

..... [3]

(ii) Oxides of nitrogen are produced by the action of bacteria on nitrate fertilisers.

Explain the problems associated with the release of oxides of nitrogen into the atmosphere. Include an equation in your answer.

.....

.....

..... [2]

[Total: 21]

12.2 Sulfur: formation of atmospheric sulfur dioxide, role in acid rain

80. 9701_w21_qp_21 Q: 1

Sulfides are compounds that contain sulfur but not oxygen.

(a) Carbon disulfide, CS_2, is a volatile liquid at room temperature and pressure.

(i) State the meaning of *volatile*.

..... [1]

(ii) Draw a 'dot-and-cross' diagram of the CS_2 molecule.

[2]

(iii) Suggest the bond angle in a molecule of CS_2.

..... [1]

(iv) CS_2 is a liquid under room conditions, while CO_2 is a gas.

Explain what causes the difference in the physical properties between CS_2 and CO_2.

.....

.....

..... [2]

(b) The enthalpy change of combustion of $CS_2(l)$ is represented by the following equation.

$$CS_2(l) + 3O_2(g) \xrightarrow{\Delta H_c} CO_2(g) + 2SO_2(g)$$

(i) Define *enthalpy change of combustion*.

.....

.....

..... [2]

(ii) The table shows the enthalpy changes of formation of $CS_2(l)$, $CO_2(g)$ and $SO_2(g)$.

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
$CS_2(l)$	+89.7
$CO_2(g)$	–394
$SO_2(g)$	–297

Use the data in the table to calculate the enthalpy change of combustion, ΔH_c, of $CS_2(l)$, in kJ mol^{-1}.

Show your working.

ΔH_c of $CS_2(l)$ = ... kJ mol^{-1}
[2]

(c) Hydrogen sulfide gas, $H_2S(g)$, is slightly soluble in water. It acts as a weak acid in aqueous solution.

(i) State the meaning of *weak acid*.

.....

..... [1]

(ii) Give the formula of the conjugate base of H_2S.

..... [1]

(iii) $H_2S(aq)$ reacts slowly with oxygen dissolved in water. The reaction is represented by the following equation.

$$H_2S(aq) + \tfrac{1}{2}O_2(aq) \rightarrow H_2O(l) + S(s)$$

Explain, with reference to oxidation numbers, why this reaction is a redox reaction.

.....

.....

.....

..... [2]

(d) The compound As_2S_3 is a common mineral.

When As_2S_3 is heated strongly in air, it forms a mixture of products, as shown.

$$2As_2S_3(s) + 9O_2(g) \rightarrow As_4O_6(s) + 6SO_2(g)$$

(i) A sample containing 0.198 g As_2S_3 is placed in 0.100 dm^3 of pure oxygen, an excess, in a reaction chamber connected to a gas syringe at room temperature.

The reactants are heated until no further change is observed. The products are then allowed to cool to room temperature.

Calculate the volume, in dm^3, of gas present at the end of the experiment.

The molar volume of gas is 24.0 $dm^3\,mol^{-1}$ under these conditions. Assume that the pressure is constant throughout the experiment.

Show your working.

volume of gas remaining = ... dm^3
[4]

(ii) State the environmental consequences of releasing $SO_2(g)$ into the atmosphere.

..... [1]

(iii) $SO_2(g)$ 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.

..... [2]

[Total: 21]

81. 9701_w20_qp_21 Q: 2

Phosphorus, sulfur and chlorine can all react with oxygen to form oxides.

(a) Phosphorus reacts with an excess of oxygen to form phosphorus(V) oxide.

(i) Write an equation to show the reaction of phosphorus with excess oxygen.

..... [1]

(ii) Describe the reaction of phosphorus(V) oxide with water.

.....

.....

..... [2]

(iii) State the structure and bonding of solid phosphorus(V) oxide.

..... [1]

(b) The two most common oxides of sulfur are SO_2 and SO_3.

When SO_2 dissolves in water, a small proportion of it reacts with water to form a weak Brønsted-Lowry acid.

(i) Explain the meaning of the term *weak Brønsted-Lowry acid*.

.....

..... [2]

(ii) Write the equation for the reaction of SO_2 with water.

..... [1]

(iii) SO_2 reacts with NO_2 in the atmosphere to form SO_3 and NO.

NO is then oxidised in air to form NO_2.

$$SO_2 + NO_2 \rightarrow SO_3 + NO$$

$$2NO + O_2 \rightarrow 2NO_2$$

State the role of NO_2 in this two-stage process.

..... [1]

(c) Emissions of SO_2 from coal-fired power stations can be reduced by mixing the coal with powdered limestone.

Limestone is heated to form CaO in reaction 1. This then reacts with SO_2 and O_2 to form $CaSO_4$ in reaction 2.

reaction 1: $CaCO_3(s) \rightarrow CaO(s) + CO_2(s)$

reaction 2: $CaO(s) + SO_2(g) + \frac{1}{2}O_2(g) \rightarrow CaSO_4(s)$

(i) State the type of reaction occurring in reaction 1.

..... [1]

(ii) Use the data to calculate the enthalpy change of reaction 2.

compound	ΔH_f / kJ mol^{-1}
CaO(s)	–635
$SO_2(g)$	–297
$CaSO_4(s)$	–1434

enthalpy change of reaction 2 = ... kJ mol^{-1} [2]

(d) Chlorine forms several oxides, including Cl_2O, ClO_2 and Cl_2O_6.

(i) Draw a 'dot-and-cross' diagram of Cl_2O. Show outer-shell electrons only.

[1]

(ii) ClO_2 can be prepared by reacting $NaClO_2$ with Cl_2.

Write the oxidation state of chlorine in each species in the boxes provided.

$$2NaClO_2 + Cl_2 \rightarrow 2ClO_2 + 2NaCl$$

oxidation state of chlorine: [+3] [ ] [ ] [ ]

[1]

(iii) $Cl_2O_6(g)$ is produced by the reaction of $ClO_2(g)$ with $O_3(g)$.

$$2ClO_2(g) + 2O_3(g) \rightleftharpoons Cl_2O_6(g) + 2O_2(g) \qquad \Delta H = -216\,kJ\,mol^{-1}$$

The reaction takes place at 500 K and 100 kPa.

State and explain the effect on the yield of $Cl_2O_6(g)$ when the experiment is carried out:

- at 1000 K and 100 kPa

.....

.....

.....

.....

- at 500 K and 500 kPa.

.....

.....

.....

.....

[4]

(e) Element **E** is a Period 5 element.

E reacts with oxygen to form an insoluble white oxide that has a melting point of 1910 °C. The oxide of **E** conducts electricity only when liquid.

E also reacts readily with Cl_2(g) to form a white solid that reacts exothermically with water. The resulting solution reacts with aqueous silver nitrate to form a white precipitate that dissolves in dilute ammonia.

(i) Suggest the type of bonding shown by the **oxide** of **E**. Explain your answer.

.....

.....

..... [2]

(ii) Suggest the type of bonding shown by the **chloride** of **E**. Explain your answer.

.....

.....

..... [2]

[Total: 21]

---

82. 9701_s19_qp_23 Q: 4

Release of sulfur dioxide, SO_2, into the atmosphere causes acid rain.

(a) Explain why high levels of SO_2 may be found in the atmosphere near power stations that burn fossil fuels.

.....

.....

..... [2]

(b) The SO_2 released can be converted in the atmosphere into sulfuric acid, H_2SO_4, by reaction with nitrogen dioxide gas, NO_2, and water, H_2O.

$$SO_2 + NO_2 \rightarrow NO + SO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

During one year, 1590 tonnes of SO_2 was released into the atmosphere by a fossil-fuel burning power station.

(i) Use the equations to calculate how many tonnes of H_2SO_4 were formed in the atmosphere. Assume that all of the SO_2 released was converted into H_2SO_4.

mass of H_2SO_4 = ... tonnes [2]

(ii) Describe how NO_2 is also produced by these power stations.

.....

..... [2]

(iii) State one natural cause of NO_2 being formed in the atmosphere.

..... [1]

(iv) Explain why NO_2 can be described as a catalyst in the oxidation of atmospheric SO_2.

.....

.....

..... [2]

[Total: 9]

83. 9701_w19_qp_22 Q: 1

In the Periodic Table, the p block contains elements whose outer electrons are found in the p subshell.

(a) Elements in the p block show a general increase in first ionisation energy as the atomic number increases.

(i) Draw the shape of a p orbital.

[1]

(ii) Write an equation to show the first ionisation energy of silicon.

..... [1]

(iii) Explain why there is a general increase in first ionisation energies of the elements across Period 3.

.....

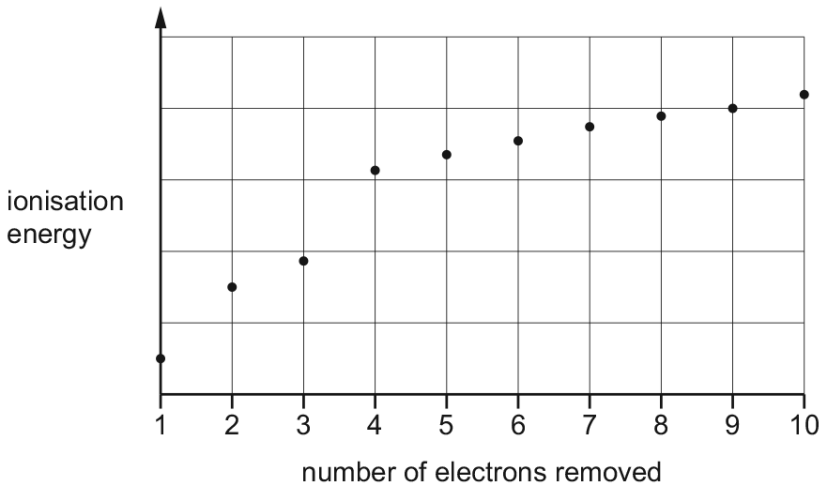
.....

.....

..... [2]

(iv) Element **A** is in the p block.

The graph shows the successive ionisation energies for the removal of the first ten electrons of **A**.



State and explain the group of the Periodic Table that element **A** belongs to.

group number .....

explanation .....

.....

.....

[2]

(b) Silicon is found in many compounds in the Earth's crust. Silicon has only three naturally occurring isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

(i) The table shows data for ^{28}Si, ^{29}Si and ^{30}Si.

	^{28}Si	^{29}Si	^{30}Si
relative isotopic mass	28.0	29.0	30.0

A sample of silicon contains 92.2% ^{28}Si. The total percentage abundance of ^{29}Si and ^{30}Si in the sample is 7.8%.

The relative atomic mass, A_r, of silicon in the sample is 28.09.

Calculate the percentage abundance of ^{30}Si.

Give your answer to **one** decimal place.

percentage abundance of ^{30}Si = ... %
[3]

(ii) Silicon reacts with nitrogen gas to form Si_3N_4.

Si_3N_4 is a solid with a melting point of 1900 °C. It is insoluble in water and does not conduct electricity when molten.

Suggest the type of bonding in **and** structure of Si_3N_4. Explain your answer.

.....

.....

.....

.....

..... [3]

(c) Sulfur-containing compounds, such as C_2H_5SH, are found in fossil fuels, and produce SO_2 when they are burned.

(i) Write the equation to show the complete combustion of C_2H_5SH.

..... [1]

(ii) State why the presence of SO_2 in the atmosphere has environmental consequences. Describe **one** of the consequences on the environment.

.....

.....

..... [2]

(d) SO_2 can react with ozone, O_3, to form SO_3 in two different reactions.

(i) In one reaction, SO_2 reacts with O_3 until a dynamic equilibrium is established.

$$SO_2(g) + O_3(g) \rightleftharpoons SO_3(g) + O_2(g)$$

State and explain the effect of an increase in pressure on the composition of the equilibrium mixture.

.....

.....

..... [2]

(ii) In the other reaction, a different equilibrium is established at 300 K as shown.

$$3SO_2(g) + O_3(g) \rightleftharpoons 3SO_3(g) \qquad \Delta H = +462.3\,kJ\,mol^{-1}$$

Suggest a temperature needed to increase the yield of SO_3 at equilibrium.

Explain your answer.

.....

.....

..... [2]

[Total: 19]

84. 9701_w18_qp_21 Q: 1

Iron pyrite, FeS_2, has a yellow colour that makes it look like gold metal. The compound contains the ions Fe^{2+} and S_2^{2-}.

(a) (i) Give the full electronic configuration of Fe^{2+}.

$1s^2$ ..... [1]

(ii) Calculate the oxidation number of sulfur in the S_2^{2-} ion.
Assume that each sulfur atom in the ion has the same oxidation number.

oxidation number of sulfur in the S_2^{2-} ion = ... [1]

(b) Describe the metallic bonding in gold.

.....

.....

..... [2]

(c) Iron pyrite is often called *fool's gold* because of its appearance. Impure samples of iron pyrite often contain a small amount of gold.

The gold can be obtained from impure iron pyrite. The impure iron pyrite is roasted in oxygen, to produce iron(III) oxide and sulfur dioxide. Gold does not react with oxygen.

(i) The sulfur dioxide produced during roasting would cause environmental consequences if released into the atmosphere.

State and explain **one** of these environmental consequences.

.....

.....

..... [2]

(ii) Complete the equation to show the roasting of iron pyrite in oxygen.

$4FeS_2$ + ... $\rightarrow$ $2Fe_2O_3$ + ...

[2]

(iii) A sample of impure iron pyrite was roasted in oxygen. The composition of the mixture of solid products is shown.

solid product	mass / g
Fe_2O_3	33.18
Au	0.37

Calculate the mass of FeS_2 present in the sample of impure iron pyrite.
Assume that all the FeS_2 was converted to Fe_2O_3 during the roasting process.

(M_r: FeS_2, 120.0; Fe_2O_3, 159.6)

mass of FeS_2 = ... g [2]

(iv) Use your answer to **(iii)** to calculate the percentage by mass of gold in this sample of impure iron pyrite. Assume that gold is the only impurity in this sample of impure iron pyrite.

Give your answer to **two** significant figures.

(If you were unable to calculate an answer to **(iii)**, use 55.00 g as the mass of FeS_2 in this calculation. This is **not** the correct answer.)

percentage by mass of gold = ... % [1]

[Total: 11]

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85. 9701_w18_qp_22 Q: 2

The table gives some data for elements in the third period and some of their compounds.

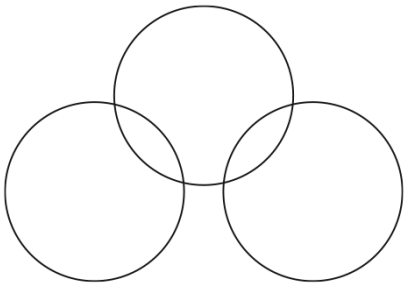
element	Na	Mg	Al	Si	P	S
type of bonding	metallic				covalent	covalent
formula of oxide					P_4O_{10}	SO_2
formula of chloride	NaCl	$MgCl_2$				SCl_2

(a) Complete the table to show the bonding in the elements, and the formulae of their oxides and chlorides. [3]

(b) SCl_2 is formed in the following reaction.

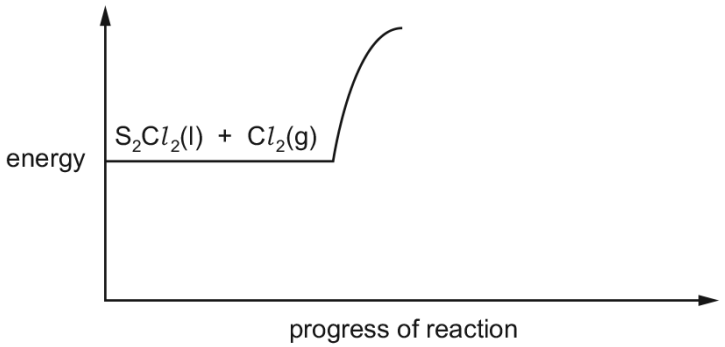
$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l) \qquad \Delta H = -40.6\,kJ\,mol^{-1}$$

(i) Complete the 'dot-and-cross' diagram to show the bonding in a molecule of SCl_2. Show outer electrons only.



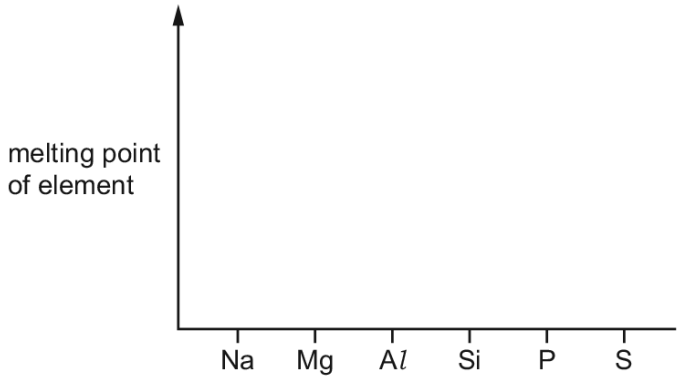
[1]

(ii) Complete and fully label the reaction pathway diagram for the reaction between S_2Cl_2 and Cl_2. Include labels for activation energy, E_a, and enthalpy change of the forward reaction, ΔH.



[2]

(c) (i) On the axes, sketch the trend in melting point of the elements Na to S.



[1]

(ii) Give three statements to explain your sketch.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(d) Write an equation for the reaction of P_4O_{10} with water.

..... [1]

(e) SO_2 can be released into the atmosphere when fossil fuels containing sulfur are burnt.

State and explain one environmental consequence of the release of SO_2 into the atmosphere.

.....

.....

.....

..... [2]

(f) The elements in the third period show a general increase in their first ionisation energies from left to right.

Identify **two** pairs of successive elements in the third period that do **not** agree with this statement.
For each pair, explain why the change in ionisation energy does **not** agree with this statement.

Use of the Data Booklet may help you to answer this question.

pair 1 .....

explanation .....

.....

.....

.....

.....

pair 2 .....

explanation .....

.....

.....

.....

.....

[4]

[Total: 17]

86. 9701_S15_qp_22 Q: 2

Sulfuric acid is an important chemical with a variety of uses.

It is manufactured by the Contact process, the first stage of which involves the conversion of sulfur or a sulfide ore, such as galena, PbS, into sulfur dioxide, SO_2.

(a) (i) Write an equation for the reaction between galena and oxygen to form sulfur dioxide and lead(II) oxide.

..... [2]

(ii) Identify the oxidation number changes that take place during this reaction.

.....

..... [2]

(b) The second stage of the Contact process involves the production of sulfur trioxide, SO_3, from sulfur dioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197\,kJ\,mol^{-1}$$

(i) State the temperature usually chosen for this conversion and explain this in terms of reaction rates and Le Chatelier's principle.

temperature .....

explanation .....

.....

.....

..... [3]

(ii) State and explain the pressure conditions that would give the best rate and best yield of sulfur trioxide. Explain why these conditions are **not** actually used.

.....

.....

.....

.....

..... [3]

(c) In the third stage of the process the sulfur trioxide is dissolved in 98% sulfuric acid followed by carefully controlled addition of water.

(i) Explain why the sulfur trioxide is not dissolved directly in water to produce sulfuric acid.

.....

..... [1]

(ii) Write equations for the reaction of sulfur trioxide with sulfuric acid and for the subsequent reaction with water.

.....

..... [2]

(d) Explain why sulfur dioxide is used as an additive in some foods and wines.

.....

.....

..... [2]

(e) The sulfur dioxide content of wine is most commonly measured by the Ripper Method which involves titration with iodine in the presence of starch as an indicator.

$$SO_2(aq) + I_2(aq) + 2H_2O(l) \rightarrow 2I^-(aq) + SO_4^{2-}(aq) + 4H^+(aq)$$

A 50.0 cm^3 sample of wine required 12.35 cm^3 of 0.010 mol dm^{-3} $I_2(aq)$ for complete reaction with the SO_2.

(i) How many moles of SO_2 are present in 50.0 cm^3 of wine?

moles of SO_2 in 50.0 cm^3 = ... [1]

(ii) How many moles of SO_2 are present in 1 dm^3 of wine?

moles of SO_2 in 1 dm^3 = ... [1]

(iii) How many milligrams, mg, of SO_2 are present in 1 dm^3 of wine? Give your answer to **three** significant figures. (1 g = 1000 mg)

mass of SO_2 in 1 dm^3 = ... mg [1]

[Total: 18]

87. 9701_w15_qp_22 Q: 3

The elements in Period 3, Na, Mg, Al, P and S, all react with oxygen when heated in air.

(a) (i) Give the formula of the oxide formed when each element is heated in air. One has been completed for you.

Na = ... Mg = ... Al = Al_2O_3

P = ... S = ...

[2]

(ii) Describe what you would **see** when sodium and sulfur are each heated separately in air and give an equation for each reaction.

Na .....

equation .....

S .....

equation .....

[4]

(b) The oxides show variations in their behaviour when added to water, acids and alkalis.

(i) Place the symbols of the elements in **(a)(i)** in the appropriate row of the table to indicate this behaviour.

acidic	
amphoteric	
basic	

[2]

(ii) State the bonding present in acidic and basic oxides.

acidic .....

basic .....

[2]

(iii) Write equations for the reaction of aluminium oxide with each of hydrochloric acid, HCl, and sodium hydroxide, NaOH.

with HCl .....

with NaOH .....

[2]

(c) Explain how the presence of an impurity in carbonaceous fuels can give rise to acid rain.

name of impurity .....

.....

..... [2]

[Total: 14]

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1.
Sulphur dioxide is an important food preservative.

What property makes sulphur dioxide useful in this role?

A It is a gas.

B It is a reducing agent.

C It reacts with oxygen to form sulphur trioxide.

D It reacts with water to form an acidic solution.

[2002 M/J (18)]

2.
The propellant used in the solid rocket booster of a space shuttle is a mixture of aluminium and compound **X**. Compound **X** contains chlorine in an oxidation state of +7.

Which of the following could be compound **X**?

A NH_4Cl **B** NH_4ClO_3 **C** NH_4ClO_4 **D** N_2H_5Cl

[2002 M/J (15)]

3.
When ammonia is converted into nitric acid on a commercial scale, the following reactions can occur.

In which reaction does the greatest change in oxidation number of the nitrogen occur?

reaction	
A	$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$
B	$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$
C	$2NO + O_2 \rightarrow 2NO_2$
D	$4NH_3 + 6NO \rightarrow 5N_2 + 6H_2O$

[2003 M/J (8)]

4.
Which reagent, when mixed and heated with ammonium sulphate, liberates ammonia?

A aqueous bromine

B dilute hydrochloric acid

C limewater

D acidified potassium dichromate(VI)

[2003 M/J (18)]

5.
Which pollutant is formed in the internal combustion engine and, if not removed by the catalytic converter, may become involved in the formation of acid rain?

A C **B** C_8H_{18} **C** CO **D** NO

[2003 M/J (19)]

6.
Which statements are reasons why sulphur dioxide is used as a food preservative?

1 It is a reducing agent and therefore an anti-oxidant.

2 It prevents alcohols forming sour-tasting acids.

3 It does not smell and therefore can be used in more than trace quantities.

[2003 M/J (35)]

7.
In a solution of ammonia in water, what combination of ionic and molecular forms of ammonia are present?

A ions only

B ions and simple molecules only

C simple molecules and hydrogen-bonded molecules only

D simple molecules, hydrogen–bonded molecules and ions

[2003 O/N (18)]

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8.
Nitrogen is frequently used as an inert atmosphere because it is an unreactive gas.

Which is the best explanation of this unreactivity?

A Its molecule contains a triple bond.

B The bond energy of the molecule is high (994 kJ mol^{-1}).

C The bond in its molecule is very short (0.110 nm).

D The three p orbitals of nitrogen are half-filled.

[2003 O/N (19)]

9.
Which processes involve the conversion of sulphur dioxide into sulphur trioxide?

1 the combustion of sulphur contaminated carbonaceous fuels

2 the Contact process for manufacturing sulphuric acid

3 the catalytic oxidation of sulphur dioxide by oxides of nitrogen

[2003 O/N (36)]

10.
Which of these equations represents the reaction of sulphur dioxide with an excess of aqueous sodium hydroxide?

A $SO_2 + NaOH \rightarrow NaHSO_3$

B $SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$

C $SO_2 + 2NaOH \rightarrow Na_2SO_4 + H_2O$

D $SO_2 + 2NaOH \rightarrow Na_2SO_4 + H_2$

[2004 M/J (13)]

11.
Nitrogen dioxide and sulphur dioxide have some properties in common.

Which property is shown by **one** of these compounds, but **not** by the other?

A forms 'acid-rain'

B is a reducing agent

C is insoluble in water

D is used as a food-preservative

[2004 M/J (19)]

12.
When coal is burnt, gaseous oxides of carbon and sulphur are formed which pollute the atmosphere. One method of preventing such pollution involves adding calcium carbonate to the burning coal. The temperature of the process causes the decomposition of the calcium carbonate into calcium oxide.

Which reactions will be important in helping to reduce atmospheric pollution?

1 Calcium oxide reacts with sulphur dioxide to form calcium sulphite.

2 Calcium oxide reacts with sulphur dioxide and more air to form calcium sulphate.

3 Calcium oxide reacts with carbon monoxide to form calcium carbonate.

[2004 M/J (35)]

13.
Which reaction of ammonia does **not** involve the non-bonding pair of electrons on the nitrogen atom?

A $NH_3(g) + CH_3I(g) \rightarrow CH_3NH_3^+I^-(s)$

B $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$

C $2NH_3(l) + 2Na(s) \rightarrow 2NaNH_2(s) + H_2(g)$

D $2NH_3(aq) + Ag^+(aq) \rightarrow [Ag(NH_3)_2]^+(aq)$

[2004 O/N (18)]

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14.
Ammonia is produced commercially by the Haber process in which nitrogen and hydrogen react as shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \; ; \; \Delta H = -92\,kJ\,mol^{-1}$$

Which statements are true of the commercial process?

1 A temperature of 1000 °C is used.

2 A pressure of 100 - 200 atm is used.

3 The yield of ammonia is less than 20%.

[2004 O/N (32)]

15.
Concentrated sulphuric acid is added to separate solid samples of sodium chloride, sodium bromide or sodium iodide.

With which sample(s) does sulphuric acid act as an oxidising agent?

A sodium chloride only

B sodium chloride and sodium bromide

C sodium bromide and sodium iodide

D sodium iodide only

[2005 M/J (15)]

16.
In an historically famous experiment Wöhler heated "inorganic" ammonium cyanate in the absence of air. The only product of the reaction was "organic" urea, $CO(NH_2)_2$. No other products were formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

A CNO **B** CNO^2 **C** CO **D** NO

[2005 M/J (18)]

17.
How does ammonia behave when its aqueous solution is used to dissolve silver chloride, AgCl?

A as a base

B as a ligand with the Ag^+ ion

C as a ligand with the Cl^- ion

D as a reducing agent

[2005 O/N (17)]

18.
Lime, CaO, is used to reduce the acidity of soil, and ammonium sulphate is a nitrogenous fertiliser.

Why can they **not** be used in a mixed form?

A The dry mixture is explosive.

B $CaSO_4$, formed on mixing, causes hard water.

C When dampened, ammonia is given off.

D Sulphuric acid will form.

[2005 O/N (18)]

19.
Which equations represent stages in the Contact process for manufacturing sulphuric acid?

1 $S + O_2 \rightarrow SO_2$

2 $H_2O + SO_2 \rightarrow H_2SO_3$

3 $H_2SO_3 + \frac{1}{2}O_2 \rightarrow H_2SO_4$

[2005 O/N (37)]

20.
The emissions from a power station contain about 14 tonnes of SO_2 per hour from the oxidation of FeS_2 contained in the coal.

What is the most practical way of preventing the SO_2 from being released into the atmosphere?

A Cool the gases and the SO_2 will liquefy and can be removed.

B Dissolve the ionic FeS_2 in hexane.

C Pass the emissions through a bed of calcium oxide.

D Pass the gases through concentrated sulphuric acid to dissolve the SO_2.

[2006 M/J (18)]

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21.
Ammonia and chlorine react in the gas phase.

$$8NH_3 + 3Cl_2 \rightarrow N_2 + 6NH_4Cl$$

Which statements are correct?

1 Ammonia behaves as a reducing agent.

2 Ammonia behaves as a base.

3 The oxidation number of the hydrogen changes.

[2006 M/J (36)]

22.
Sulphur dioxide is an important food preservative.

Which property makes sulphur dioxide useful in this role?

A It is a gas.

B It is a reducing agent.

C It reacts with oxygen to form sulphur trioxide.

D It reacts with water to form an acidic solution.

[2006 O/N (18)]

23.
In the Contact process for the production of sulphuric acid, sulphur dioxide is mixed with air and passed over a vanadium(V) oxide catalyst at about 450 °C and a pressure slightly above atmospheric pressure.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3 \; ; \; \Delta H \text{ negative}$$

What affects the choice of conditions for this reaction?

A A lower temperature would not raise the concentration of SO_3 at equilibrium.

B At a lower temperature of 300°C the V_2O_5 catalyst would not be effective.

C At 450 °C nitrogen and oxygen from the air combine to form nitrogen oxides which are needed as additional catalysts.

D The heat generated by the reaction raises the temperature of the catalyst bed to 600 °C at which temperature the reaction begins to take place.

[2006 O/N (19)]

24.
Which fertilisers, when washed out of soil by rain, cause excessive growth of river plants and algae with the result that fish in the river die?

1 K_2SO_4

2 NH_4NO_3

3 $NaNO_3$

[2006 O/N (36)]

25.
A solid nitrate fertiliser reacts with an alkali to produce a gas which turns damp pH paper blue.

What is the empirical formula of this fertiliser?

A NO_3 **B** NHO_3 **C** NH_2O **D** $N_2H_4O_3$

[2007 M/J (18)]

26.
Nitrogen and oxygen react in a hot car engine to form nitrogen monoxide which is a serious pollutant in our cities and in the countryside. However, nitrogen and oxygen do not react at room temperature.

Which statements help to explain why nitrogen and oxygen do not react at room temperature?

1 The reaction is endothermic.

2 A high activation energy is required.

3 Nitrogen has a high bond energy.

[2007 M/J (37)]

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27.

There are three stages in the Contact process for the production of sulphuric acid.

1 $S + O_2 \rightarrow SO_2$

2 $SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$

3 $SO_3 + H_2O \rightarrow H_2SO_4$

Which statement about this process is correct?

A In the first stage a large excess of air under high pressure is used to improve the yield.

B Two of the three stages are equilibria.

C All three stages are exothermic.

D In the final stage SO_3 is absorbed by water droplets.

[2007 O/N (17)]

28.

Which reagent, when mixed and heated with ammonium sulphate, liberates ammonia?

A aqueous bromine

B dilute hydrochloric acid

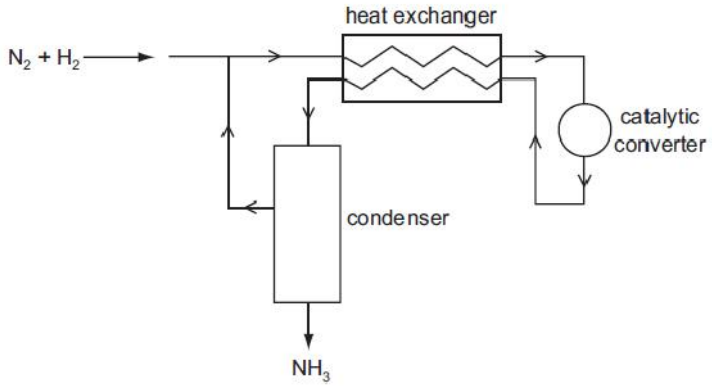
C limewater

D acidified potassium dichromate(VI)

[2008 M/J (17)]

29.

The diagram represents the Haber process for the manufacture of ammonia from nitrogen and hydrogen.



What is the purpose of the heat exchanger?

A to cool the incoming gas mixture to avoid overheating the catalyst

B to cool the reaction products and separate the NH_3 from unused N_2 and H_2

C to warm the incoming gas mixture and shift the equilibrium to give more NH_3

D to warm the incoming gas mixture and speed up the reaction

[2008 M/J (18)]

30.

Total elimination of the pollutant sulphur dioxide, SO_2, is difficult, both for economic and technical reasons. Its emission can be reduced in furnace chimneys using desulphurisation plants, where the gases are scrubbed (washed) with calcium hydroxide to remove the SO_2.

What is the main product formed initially?

A CaO **B** $Ca(OH)_2$ **C** $CaSO_3$ **D** $CaSO_4$

[2008 M/J (19)]

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31.

Catalysts are used in many reversible reactions in the chemical industry. Vanadium(V) oxide is used in this way in the Contact process for the formation of SO_3.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

What effect does vanadium(V) oxide have on this equilibrium?

1 It speeds up the forward reaction.

2 It increases the value of K_p.

3 It increases the value of E_a for the reverse reaction.

[2008 M/J (32)]

32.

Which salt is produced by adding aqueous ammonia to aqueous sulphur dioxide until just alkaline?

A NH_4SO_3 **B** NH_4SO_4 **C** $(NH_4)_2SO_3$ **D** $(NH_4)_2SO_4$

[2008 O/N (14)]

33.

When gaseous chemicals are transported by road or by rail they are classified as follows.

flammable non-flammable poisonous

Which gas is poisonous?

A butane

B carbon dioxide

C hydrogen

D sulphur dioxide

[2008 O/N (18)]

34.

Mohr's salt is a pale green crystalline solid which is soluble in water. It is a 'double sulfate' which contains two cations, one of which is Fe^{2+}.

The identity of the second cation was determined by heating solid Mohr's salt with solid sodium hydroxide and a colourless gas was evolved. The gas readily dissolved in water giving an alkaline solution. A grey-green solid residue was also formed which was insoluble in water.

What are the identities of the gas and the solid residue?

	gas	residue
A	H_2	$FeSO_4$
B	NH_3	Na_2SO_4
C	NH_3	$Fe(OH)_2$
D	SO_2	$Fe(OH)_2$

[2009 M/J (18)]

35.

When sulfur trioxide is manufactured from sulfur dioxide and oxygen, using the Contact process, which condition affects the value of the equilibrium constant, K_c?

A adjusting the temperature

B adjusting the pressure

C using a catalyst

D removing SO_3 from the equilibrium mixture

[2009 O/N-11 (17)]

36.

Most modern cars are fitted with three-way catalytic converters in the exhaust system.

Which three gases are removed by such a catalytic converter?

A carbon monoxide, hydrocarbons, nitrogen oxides

B carbon monoxide, carbon dioxide, nitrogen oxides

C carbon monoxide, nitrogen oxides, sulfur dioxide

D hydrocarbons, nitrogen oxides, sulfur dioxide

[2009 O/N-11 (18)]

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37.
A farmer added lime to damp soil, followed by the nitrogenous fertiliser ammonium sulfate. A chemical reaction occurred in the soil.

Which substances were formed in this reaction?

1 sulfuric acid

2 calcium sulfate

3 ammonia

[2009 O/N-11 (35)]

38.
The Haber process for the manufacture of ammonia is represented by the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

Which statement is correct about this reaction when the temperature is increased?

A Both forward and backward rates increase.

B The backward rate only increases.

C The forward rate only increases.

D There is no effect on the backward or forward rate.

[2010 M/J-11 (7)]

39.
How does concentrated sulfuric acid behave when it reacts with sodium chloride?

A as an acid only

B as an acid and oxidising agent

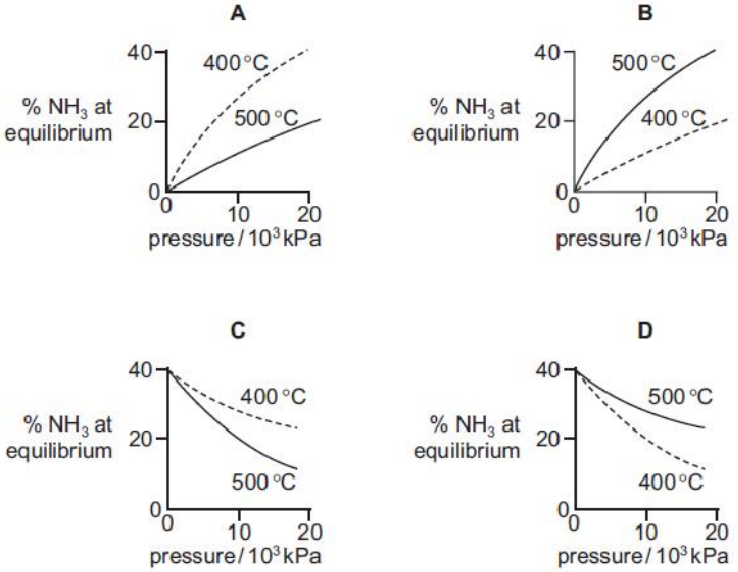
C as an oxidising agent only

D as a reducing agent only

[2010 M/J-11 (13)]

40.
The percentage of ammonia obtainable, if equilibrium were established during the Haber process, is plotted against the operating pressure for two temperatures, 400 °C and 500 °C.

Which diagram correctly represents the two graphs?



[2010 M/J-11 (15)]

41.
In a car engine, non-metallic element X forms a pollutant oxide Y.

Further oxidation of Y to Z occurs in the atmosphere. In this further oxidation, 1 mol of Y reacts with ½ mol of gaseous oxygen.

What can X be?

1 carbon

2 nitrogen

3 sulfur

[2010 M/J-11 (35)]

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42.
Sulfur dioxide and sulfites are used in food preservation.

Why are they used for this purpose?

1 They are reducing agents so retard the oxidation of food.

2 They inhibit the growth of aerobic bacteria.

3 They react with $NO_2(g)$ converting it to $NO(g)$.

[2010 M/J-11 (36)]

43.
Ammonium sulfate in nitrogenous fertilisers in the soil can be slowly oxidised by air producing sulfuric acid, nitric acid and water.

How many moles of oxygen gas are needed to oxidise completely one mole of ammonium sulfate?

A 1 **B** 2 **C** 3 **D** 4

[2010 O/N-11 (15)]

44.
Sulfur dioxide is used to bleach wood pulp in the production of paper. It is also used as an additive in the production of jam and marmalade, often in the form of sulfite compounds. When it is present in quantities greater than 10 mg / kg it is required to be listed as an ingredient of the jam.

Why is sulfur dioxide added to jam?

A It is a bleaching agent and removes the undesirable colours from the fruit used in the jam.

B It is a preservative that destroys unwanted bacteria and enzymes.

C It is a reducing agent and removes the acids that give the jam a sharp taste.

D It is an acidic gas and maintains the pH of the jam at a suitable value to give it a sharp taste.

[2010 O/N-11 (18)]

45.
When ammonia, NH_3, is produced in a school or college laboratory, it is usually dried before being collected.

Which drying agents may be used to dry ammonia?

1 calcium oxide, CaO

2 phosphorus(V) oxide, P_4O_{10}

3 concentrated sulfuric acid, H_2SO_4

[2010 O/N-12 (31)]

46.
In which ways are the main reactions in the Haber and Contact processes similar?

1 A higher yield is favoured by higher pressures.

2 The reaction is a redox process.

3 The forward reaction is exothermic.

[2010 O/N-12 (35)]

47.
A car burning lead-free fuel has a catalytic converter fitted to its exhaust. On analysis its exhaust gases are shown to contain small quantities of nitrogen oxides.

Which modifications would result in lower exhaust concentrations of nitrogen oxides?

1 an increase in the surface area of the catalyst in the converter

2 an increase in the rate of flow of the exhaust gases through the converter

3 a much higher temperature of combustion in the engine

[2010 O/N-12 (36)]

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48.
Ammonium nitrate, NH_4NO_3, is manufactured in large quantities for use in fertiliser.

Which statement about ammonium nitrate fertiliser is **not** correct?

A It can cause environmental problems.

B It consists of 35% nitrogen by mass.

C It is insoluble in water.

D Nitric acid is used in its manufacture.

[2011 M/J-11 (17)]

49.
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 $2NO(g) + CO_2(g) \rightarrow 2NO_2(g) + C(s)$

[2011 M/J-11 (18)]

50.
Which descriptions of the ammonium ion are correct?

1 It contains ten electrons.

2 It has a bond angle of 109.5°.

3 It has only three bonding pairs of electrons.

[2011 M/J-11 (37)]

51.
Ammonia is manufactured on a large scale by the Haber process.

In a particular plant, conditions of 400 °C and 250 atm in the presence of an iron catalyst are used.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92\ kJ\ mol^{-1}$$

What could contribute most to increasing the equilibrium yield of ammonia?

A adding more catalyst

B increasing the pressure to 400 atm

C increasing the temperature to 1000 °C

D using air rather than nitrogen

[2011 M/J-12 (5)]

52.
Concentrated sulfuric acid can behave **both** as a strong acid **and** as an oxidising agent.

With which compound does concentrated sulfuric acid react in this way?

A ethanol

B magnesium carbonate

C propanenitrile

D sodium bromide

[2011 M/J-12 (17)]

53.
In the Contact process, what is the nature of the gaseous product and what is the identity of the catalyst?

	nature of gaseous product	catalyst
A	acidic	Fe
B	acidic	V_2O_5
C	basic	Fe
D	basic	V_2O_5

[2011 M/J-12 (18)]

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54.
In a car engine pollutant oxide **Y**, which contains non-metallic element **X**, is formed.

Further oxidation of **Y** to **Z** occurs in the atmosphere. In this further oxidation, 1 mol of **Y** reacts with 0.5 mol of gaseous oxygen.

X could be either nitrogen or sulfur.

Which statements about **X**, **Y** and **Z** can be correct?

1 The oxidation number of **X** increases by two from **Y** to **Z**.

2 **Y** may have an unpaired electron in its molecule.

3 **Y** is a polar molecule.

[2011 M/J-12 (36)]

55.
In the last century the Haber process was sometimes run at pressures of 1000 atm and higher. Now it is commonly run at pressures below 100 atm.

What is the reason for this change?

A An iron catalyst is used.

B Maintaining the higher pressures is more expensive.

C The equilibrium yield of ammonia is increased at lower pressures.

D The rate of the reaction is increased at lower pressures.

[2011 M/J-13 (5)]

56.
Total removal of the pollutant sulfur dioxide, SO_2, is difficult, both for economic and technical reasons. The quantities emitted from furnace chimneys can be lowered by using desulfurisation plants. The gases are scrubbed (washed) with calcium hydroxide to remove the SO_2.

What is the main product formed **initially**?

A $Ca(HSO_4)_2$ **B** CaS **C** $CaSO_3$ **D** $CaSO_4$

[2011 O/N-11 (18)]

57.
A farmer spreads lime on land which has already been treated with an ammonium nitrate fertiliser.

Which reactions will occur in the treated soil?

1 $Ca(OH)_2 + 2NH_4^+(aq) \rightarrow Ca^{2+}(aq) + 2NH_3 + 2H_2O$

2 $Ca(OH)_2 + 2H^+(aq) \rightarrow Ca^{2+}(aq) + 2H_2O$

3 $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

[2011 O/N-11 (34)]

58.
In a car engine, non-metallic element X forms a pollutant oxide Y.

Further oxidation of Y to Z occurs spontaneously in the atmosphere. In this further oxidation, 1 mol of Y reacts with 0.5 mol of gaseous oxygen.

Which statements about X, Y and Z are correct?

1 X forms a basic hydride.

2 Y is a diatomic molecule.

3 Z is a polar molecule.

[2011 O/N-11 (36)]

59.
In the Haber process for the manufacture of ammonia, why is the heterogeneous catalyst iron in a finely divided state?

A to increase its surface area

B to produce the maximum reduction in the activation energy

C to reduce its loss during the reaction

D to reduce its surface area

[2011 O/N-12 (1)]

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60.
Methyl mercaptan, CH_3SH, has a foul smell and is often used to impart a smell to natural gas.

What will be formed when CH_3SH is burned in an excess of air?

A CO H_2O SO_2

B CO_2 H_2O H_2S

C CO_2 H_2O SO_2

D CO_2 H_2O SO_3

[2011 O/N-12 (13)]

61.
Nitrogenous fertilisers are used extensively in modern farming. If rainwater washes excess fertiliser into a nearby lake, a process called eutrophication may occur.

Three of the stages of eutrophication are described below.

P Water plants growing on the lake bed die due to lack of sunlight.

Q An excessive growth of algae occurs.

R Excessive bacterial activity causes a reduction in oxygen levels.

In which order do these three stages occur?

A $P \rightarrow Q \rightarrow R$

B $P \rightarrow R \rightarrow Q$

C $Q \rightarrow P \rightarrow R$

D $Q \rightarrow R \rightarrow P$

[2011 O/N-12 (14)]

62.
In a car engine, non-metallic element ***X*** forms a pollutant oxide ***Y***.

Further oxidation of ***Y*** to ***Z*** occurs spontaneously in the atmosphere. In this further oxidation, 1 mol of ***Y*** reacts with 0.5 mol of gaseous oxygen.

Which statements about ***X***, ***Y*** and ***Z*** are correct?

1 The oxidation number of ***X*** increases by 2 from ***Y*** to ***Z***.

2 The molecule of ***Y*** has no unpaired electrons.

3 The molecule of ***Z*** contains three oxygen atoms.

[2011 O/N-12 (36)]

63.
Ammonia is manufactured by the Haber Process, in an exothermic reaction.

Assuming that the amount of catalyst remains constant, which change will **not** bring about an increase in the rate of the forward reaction?

A decreasing the size of the catalyst pieces

B increasing the pressure

C increasing the temperature

D removing the ammonia as it is formed

[2012 M/J-11 (12)]

64.
Ammonia and chlorine react in the gas phase.

$$8NH_3 + 3Cl_2 \rightarrow N_2 + 6NH_4Cl$$

Which statements are correct?

1 Ammonia behaves as a reducing agent.

2 Ammonia behaves as a base.

3 The oxidation number of the hydrogen changes

[2012 M/J-11 (34)]

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65.

In the manufacture of sulfuric acid the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ usually takes place at 400 °C and 1 atm pressure. In one industrial plant, it is decided to change the pressure to 20 atm.

What will be the consequences of this change?

1 increased running costs

2 an increased percentage of sulfur trioxide in the equilibrium mixture

3 the rate of the backward reaction increases

[2012 M/J-11 (36)]

66.

In which substance does nitrogen exhibit the highest oxidation state?

A NO **B** N_2O **C** N_2O_4 **D** $NaNO_2$

[2012 M/J-12 (11)]

67.

Which gas is present in the exhaust fumes of a car engine in a much greater amount than any other gas?

A carbon dioxide

B carbon monoxide

C nitrogen

D water vapour

[2012 M/J-12 (13)]

68.

Use of the Data Booklet is relevant to this question.

Sodium and sulfur react together to form sodium sulfide, Na_2S.

How do the atomic radius and ionic radius of sodium compare with those of sulfur?

	atomic radius	ionic radius
A	sodium > sulfur	sodium > sulfur
B	sodium > sulfur	sodium < sulfur
C	sodium < sulfur	sodium > sulfur
D	sodium < sulfur	sodium < sulfur

[2012 M/J-12 (18)]

69.

Which substance does **not** produce a poisonous gas, when burnt in a limited amount of air?

A hydrogen

B methane

C propene

D sulfur

[2012 M/J-12 (19)]

70.

Which statements are true about the Haber process for the manufacture of ammonia?

1 At higher temperatures, the yield goes down but the rate of production of ammonia is faster.

2 At higher pressures, the yield goes down but the rate of production of ammonia is faster.

3 In the presence of a catalyst, the yield goes down but the rate of production of ammonia is faster.

[2012 M/J-12 (36)]

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71.

In a car engine, non-metallic element *X* forms a pollutant oxide *Y*. *Y* can be further oxidised to *Z*. Two students made the following statements.

Student P The molecule of *Y* contains lone pairs of electrons.

Student Q The oxidation number of *X* increases by 1 from *Y* to *Z*.

X could be carbon or nitrogen or sulfur.

Which student could be correct if *X* were any of these elements?

A P only

B Q only

C both P and Q

D neither P nor Q

[2012 O/N-11 (16)]

72.

How may nitrogen exist in compounds?

1 bonded by a triple covalent bond

2 as part of a cation

3 having lost 3 electrons to form an anion

[2012 O/N-11 (31)]

73.

Which equations represent stages in the Contact process for manufacturing sulfuric acid?

1 $SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$

2 $SO_2 + H_2O \rightarrow H_2SO_3$

3 $H_2SO_3 + \frac{1}{2}O_2 \rightarrow H_2SO_4$

[2012 O/N-11 (35)]

74.

Mohr's salt is a pale green crystalline solid which is soluble in water. It contains two cations, one of which is Fe^{2+} and one anion which is SO_4^{2-}.

The identity of the second cation was determined by heating solid Mohr's salt with solid sodium hydroxide and a colourless gas was evolved. The gas readily dissolved in water giving an alkaline solution.

A grey-green solid residue was also formed which was insoluble in water.

What are the identities of the gas and the solid residue?

	gas	residue
A	NH_3	$Fe(OH)_2$
B	NH_3	Na_2SO_4
C	SO_2	$Fe(OH)_2$
D	SO_2	Na_2SO_4

[2012 O/N-13 (13)]

75.

In the Haber process, the reaction between the two gaseous reactants requires the use of a catalyst that contains a transition element.

What is the metal and in what mole ratio do the gases react?

	metal	mole ratio
A	Fe	1:2
B	Fe	1:3
C	V	1:2
D	V	1:3

[2012 O/N-13 (17)]

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76.
Deposits of ammonium sulfate have been discovered in areas of high atmospheric pollution.

They are believed to arise from the following reaction.

$$SO_3 + H_2O + 2NH_3 \rightarrow (NH_4)_2SO_4$$

What does **not** occur in this reaction?

A acid/base neutralisation

B dative bond formation

C ionic bond formation

D oxidation/reduction

[2012 O/N-13 (19)]

77.
How may nitrogen exist in compounds?

1 bonded by a triple covalent bond

2 as part of a cation

3 in an oxidation state of +5

[2012 O/N-13 (31)]

78.
Sulfur trioxide is manufactured from sulfur dioxide and oxygen, using the Contact process.

Which condition affects the value of the equilibrium constant, K_c?

A adjusting the temperature

B increasing the pressure

C removing SO_3 from the equilibrium mixture

D using a catalyst

[2013 M/J-11 (18)]

79.
Which reagent, when mixed and heated with ammonium sulfate, liberates ammonia?

A aqueous bromine

B dilute hydrochloric acid

C limewater

D potassium dichromate(VI) in acidic solution

[2013 M/J-11 (19)]

80.
Which statement about ammonia is completely correct?

A Ammonia acts as a nucleophile by accepting a pair of electrons when it reacts with bromoethane.

B Ammonia can form a co-ordinate bond with a hydrogen ion to form an ammonium ion.

C Ammonia is a base and accepts hydroxide ions.

D The shape of the ammonia molecule is pyramidal with bond angles of 109.5°.

[2013 M/J-12 (17)]

81.
Sulfur dioxide is an atmospheric pollutant that causes acid rain. One of the reactions in this process is the oxidation of sulfur dioxide to sulfur trioxide.

This oxidation takes place by a two stage reaction involving oxygen and nitrogen monoxide, NO.

$$NO + \tfrac{1}{2}O_2 \rightarrow NO_2$$

$$NO_2 + SO_2 \rightarrow SO_3 + NO$$

Which statements are correct?

1 Nitrogen monoxide is acting as a catalyst for the oxidation.

2 Nitrogen atoms are oxidised in the second stage.

3 Oxygen atoms are first reduced and are then oxidised.

[2013 M/J-12 (36)]

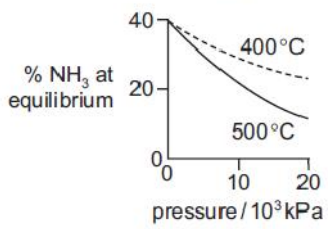
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82.

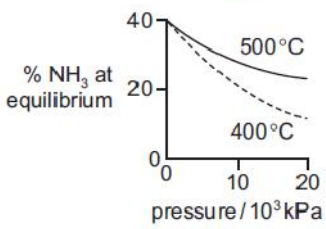
Graphs can be drawn to show the percentage of ammonia at equilibrium when nitrogen and hydrogen are mixed at different temperatures and pressures.

Which diagram correctly represents these two graphs?

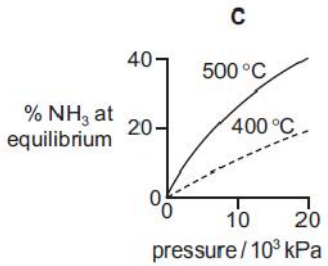
A



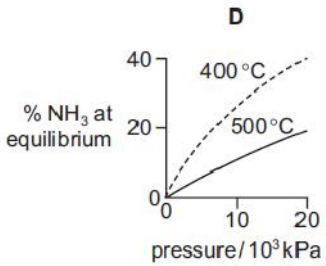
B



C



D



[2013 M/J-13 (17)]

83.

In a famous experiment, Wöhler heated 'inorganic' ammonium cyanate in the absence of air. The only product of the reaction was 'organic' urea, $CO(NH_2)_2$. No other products were formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

A CNO^- **B** CNO^{2-} **C** CO^- **D** NO^-

[2013 M/J-13 (18)]

84.

Transition elements and their compounds are important as catalysts.

In which process is a transition element compound used, rather than the element itself?

A catalytic converters

B Contact process

C Haber process

D hydrogenation of oils

[2013 M/J-13 (19)]

85.

Element **J** is a solid. It occurs as a contaminant of fossil fuels.

Its oxide **K** is formed in car engines.

In the atmosphere, **K** can be further oxidised to **L**.

Which statements about **J**, **K** and **L** are correct?

1 Atoms of **J** have paired p electrons.

2 The atmospheric oxidation of **K** to **L** is a catalysed reaction.

3 With water, **L** forms a strong acid.

[2013 M/J-13 (36)]

86.

Transition metals and their compounds are used as catalysts.

Which row is correct?

	transition metal present in the catalyst used in the Contact process	transition metal present in the catalyst used in the Haber process
A	iron	iron
B	iron	vanadium
C	vanadium	iron
D	vanadium	vanadium

[2013 O/N-11 (18)]

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87.

Sulfur dioxide and sulfites are used in food preservation.

Why are they used for this purpose?

1 They are reducing agents which slow down the oxidation of food.

2 They inhibit the growth of aerobic bacteria.

3 They react with $NO_2(g)$ converting it to NO(g).

[2013 O/N-11 (36)]

88.

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, ammonium ions and amide ions

B ammonia molecules and ammonium ions only

C ammonia molecules only

D ammonium ions only

[2013 O/N-13 (15)]

89.

Carbon, nitrogen and sulfur are non-metals.

Which statement about their oxides, XO_2, is correct? (Where X represents carbon, nitrogen or sulfur.)

A All of the XO_2 molecules are linear.

B In XO_2, each element has its highest oxidation number.

C All XO_2 molecules dissolve in water to form dibasic acids.

D All XO_2 molecules are formed as a result of burning petrol in a car engine.

[2013 O/N-13 (16)]

90.

The Contact process is used in the manufacture of sulfuric acid. The equation for the main reaction is shown below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

Which statement about this reaction is **incorrect**?

A Increased pressure gives a higher yield of SO_3.

B Increased temperature gives a higher yield of SO_3.

C In the forward reaction the oxidation state of sulfur changes from +4 to +6.

D Vanadium(V) oxide is used as a catalyst.

[2014 M/J-11 (7)]

91.

Use of the Data Booklet is relevant to this question.

A chemist took 2.00 dm^3 of nitrogen gas, measured under room conditions, and reacted it with a large volume of hydrogen gas, in order to produce ammonia. Only 15.0% of the nitrogen gas reacted to produce ammonia.

What mass of ammonia was formed?

A 0.213 g **B** 0.425 g **C** 1.42 g **D** 2.83 g

[2014 M/J-11 (18)]

92.

Pollutant oxide **Y**, which contains non-metallic element **X**, is formed in a car engine.

Further oxidation of **Y** to **Z** occurs in the atmosphere. In this further oxidation, **1** mol of **Y** reacts with 0.5 mol of gaseous oxygen molecules.

X could be either nitrogen or sulfur.

Which statements about **X**, **Y** and **Z** can be correct?

1 The oxidation number of **X** increases by two from **Y** to **Z**.

2 **Y** has an unpaired electron in its molecule.

3 **Y** is a polar molecule.

[2014 M/J-11 (35)]

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93.
Ammonium sulfate in the soil is slowly oxidised by air, producing sulfuric acid, nitric acid and water as the only products.

How many moles of oxygen gas are needed for the complete oxidation of one mole of ammonium sulfate?

A 1 **B** 2 **C** 3 **D** 4

[2014 M/J-12 (14)]

94.
A car has a catalytic converter fitted to its exhaust. On analysis its exhaust gases are shown to contain small quantities of nitrogen oxides.

Which modifications would result in lower exhaust concentrations of nitrogen oxides?

1 an increase in the surface area of the catalyst in the converter

2 an increase in the rate of flow of the exhaust gases through the converter

3 a much higher temperature of combustion in the engine

[2014 M/J-12 (36)]

95.
Which statements explain why sulfur dioxide is used as a food preservative?

1 It is a reducing agent and therefore an anti-oxidant.

2 It prevents alcohols in foods forming sour-tasting acids.

3 It does not smell and therefore can be used in large quantities.

[2014 M/J-13 (35)]

96.
Total removal of the pollutant sulfur dioxide, SO_2, is difficult. The quantities emitted from furnace chimneys can be lowered by using desulfurisation plants. The gases are reacted with calcium hydroxide to remove the SO_2.

What is the main product formed **initially**?

A $Ca(HSO_4)_2$ **B** CaS **C** $CaSO_3$ **D** $CaSO_4$

[2014 O/N-11 (18)]

97.
Element **X** is a solid. It is found in some fuels.

Its oxide **Y** is formed in car engines. **Y** is acidic.

Further oxidation of **Y** to **Z** can occur in the atmosphere.

Which statements about **Y** and **Z** are correct?

1 Molecule **Y** has lone pairs of electrons.

2 The atmospheric oxidation of **Y** to **Z** is a catalysed reaction.

3 **Y** is a colourless gas.

[2014 O/N-13 (36)]

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Nitrogen and sulfur – 2021 AS

1. Nov/2021/Paper_12/No.34

When the liquid N_2F_4 is heated, it decomposes into a **single** product, X.

Which statements are correct?

1 N–F bonds are broken during this decomposition.

2 The enthalpy change when N_2F_4 decomposes into X is approximately $+160\,kJ\,mol^{-1}$.

3 Molecules of X are non-linear.

2. Nov/2021/Paper_13/No.19

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	✓	✓

3. Nov/2021/Paper_13/No.34

Which molecules contain at least one unpaired electron?

1 NO

2 NO_2

3 NH_3

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4. Nov/2021/Paper_21/No.1

Sulfides are compounds that contain sulfur but not oxygen.

(a) Carbon disulfide, CS_2, is a volatile liquid at room temperature and pressure.

(i) State the meaning of *volatile*.

..... [1]

(ii) Draw a 'dot-and-cross' diagram of the CS_2 molecule.

[2]

(iii) Suggest the bond angle in a molecule of CS_2.

..... [1]

(iv) CS_2 is a liquid under room conditions, while CO_2 is a gas.

Explain what causes the difference in the physical properties between CS_2 and CO_2.

.....

.....

..... [2]

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(b) The enthalpy change of combustion of $CS_2(l)$ is represented by the following equation.

$$CS_2(l) + 3O_2(g) \xrightarrow{\Delta H_c} CO_2(g) + 2SO_2(g)$$

(i) Define *enthalpy change of combustion*.

.....

.....

..... [2]

(ii) The table shows the enthalpy changes of formation of $CS_2(l)$, $CO_2(g)$ and $SO_2(g)$.

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
$CS_2(l)$	+89.7
$CO_2(g)$	–394
$SO_2(g)$	–297

Use the data in the table to calculate the enthalpy change of combustion, ΔH_c, of $CS_2(l)$, in kJ mol^{-1}.

Show your working.

ΔH_c of $CS_2(l)$ = ... kJ mol^{-1}
[2]

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(c) Hydrogen sulfide gas, $H_2S(g)$, is slightly soluble in water. It acts as a weak acid in aqueous solution.

(i) State the meaning of *weak acid*.

.....

..... [1]

(ii) Give the formula of the conjugate base of H_2S.

..... [1]

(iii) $H_2S(aq)$ reacts slowly with oxygen dissolved in water. The reaction is represented by the following equation.

$$H_2S(aq) + \tfrac{1}{2}O_2(aq) \rightarrow H_2O(l) + S(s)$$

Explain, with reference to oxidation numbers, why this reaction is a redox reaction.

.....

.....

.....

..... [2]

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(d) The compound As_2S_3 is a common mineral.

When As_2S_3 is heated strongly in air, it forms a mixture of products, as shown.

$$2As_2S_3(s) + 9O_2(g) \rightarrow As_4O_6(s) + 6SO_2(g)$$

(i) A sample containing 0.198 g As_2S_3 is placed in 0.100 dm^3 of pure oxygen, an excess, in a reaction chamber connected to a gas syringe at room temperature.

The reactants are heated until no further change is observed. The products are then allowed to cool to room temperature.

Calculate the volume, in dm^3, of gas present at the end of the experiment.

The molar volume of gas is 24.0 $dm^3 mol^{-1}$ under these conditions. Assume that the pressure is constant throughout the experiment.

Show your working.

volume of gas remaining = ... dm^3
[4]

(ii) State the environmental consequences of releasing $SO_2(g)$ into the atmosphere.

..... [1]

(iii) $SO_2(g)$ 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.

..... [2]

[Total: 21]

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5. Nov/2021/Paper_23/No.1

Sulfides are compounds that contain sulfur but not oxygen.

(a) Carbon disulfide, CS_2, is a volatile liquid at room temperature and pressure.

(i) State the meaning of *volatile*.

..... [1]

(ii) Draw a 'dot-and-cross' diagram of the CS_2 molecule.

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Show your working.

ΔH_c of $CS_2(l)$ = ... kJ mol^{-1}
[2]

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The molar volume of gas is 24.0 $dm^3 mol^{-1}$ under these conditions. Assume that the pressure is constant throughout the experiment.

Show your working.

volume of gas remaining = ... dm^3
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Construct an equation for the reaction of $SO_2(g)$ with NaOH(aq). Include state symbols.

..... [2]

[Total: 21]

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6. March/2021/Paper_12/No.18

NO, NO_2, CO and unburnt hydrocarbons are present in the exhaust gases of internal combustion engines. When catalytic converters are used to remove these compounds from the exhaust gases, redox reactions occur.

What happens to each compound in the catalytic converter?

	NO	NO_2	CO	unburnt hydrocarbons
A	oxidised	oxidised	reduced	oxidised
B	oxidised	oxidised	oxidised	oxidised
C	reduced	reduced	oxidised	oxidised
D	reduced	reduced	reduced	reduced

7. March/2021/Paper_12/No.36

Nitrogen dioxide gas is produced when petrol is burned in car engines.

Which acids are made in the atmosphere as a result of this release of nitrogen dioxide into the air?

1 H_2SO_3

2 H_2SO_4

3 HNO_3

8. June/2021/Paper_11/No.18

Acid rain is a dilute solution of sulfuric acid.

Which pollutant also contributes to the formation of acid rain?

A carbon monoxide

B carbon dioxide

C nitrogen dioxide

D hydrocarbons

9. June/2021/Paper_12/No.18

What is an environmental consequence of the uncontrolled use of nitrate fertilisers?

A acid rain

B low oxygen levels in streams

C ozone depletion

D the greenhouse effect

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10. June/2021/Paper_12/No.19

Ammonia gas, NH_3, and hydrogen sulfide gas, H_2S, react together to form the salt ammonium sulfide, $(NH_4)_2S$. Ammonium sulfide dissolves in water to produce an orange alkaline solution.

$$(NH_4)_2S(aq) \rightleftharpoons NH_3(aq) + NH_4SH(aq)$$

The addition of NaOH(aq) to this solution produces a gas, X.
The addition of $HCl(aq)$ to a separate portion of this solution produces a gas, Y.

X and Y could represent different gases or identical gases.

What are the identities of X and Y?

	X	Y
A	H_2S	H_2S
B	H_2S	NH_3
C	NH_3	H_2S
D	NH_3	NH_3

11. June/2021/Paper_13/No.13

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. June/2021/Paper_13/No.14

Which problem can result if too much NH_4NO_3 is applied to crops by farmers?

A Not all the NH_4NO_3 is used by plants and the excess makes the soil alkaline.

B Rain washes some of the NH_4NO_3 into rivers where it forms a precipitate.

C Some of the NH_4NO_3 dissolves in groundwater which may eventually be used for drinking.

D Ammonia is produced; this lowers the pH of the soil.

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Nitrogen and sulfur compounds – 2022 June AS Chemistry 9701

1. June/2022/Paper_11/No.24

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

2. June/2022/Paper_11/No.25

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

3. June/2022/Paper_11/No.29

Carbon monoxide, CO, nitrogen dioxide, NO_2, and sulfur dioxide, SO_2, 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.

4. June/2022/Paper_12/No.24

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

5. June/2022/Paper_13/No.25

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

6. June/2022/Paper_13/No.24

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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

7. June/2022/Paper_21/No.2(a_ c)

Nitrogen molecules, $N_2(g)$, contain two atoms attracted to each other by a triple covalent bond.

(a) Describe how the triple covalent bond forms in a $N_2(g)$ molecule. Refer to orbital overlap and hybridisation in your answer.

.....

.....

.....

..... [3]

(b) 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]

(c) $N_2(g)$ is very unreactive. 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]

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