Cambridge AS & A Level

CHEMISTRY

Paper 2

Topical Past Paper Questions

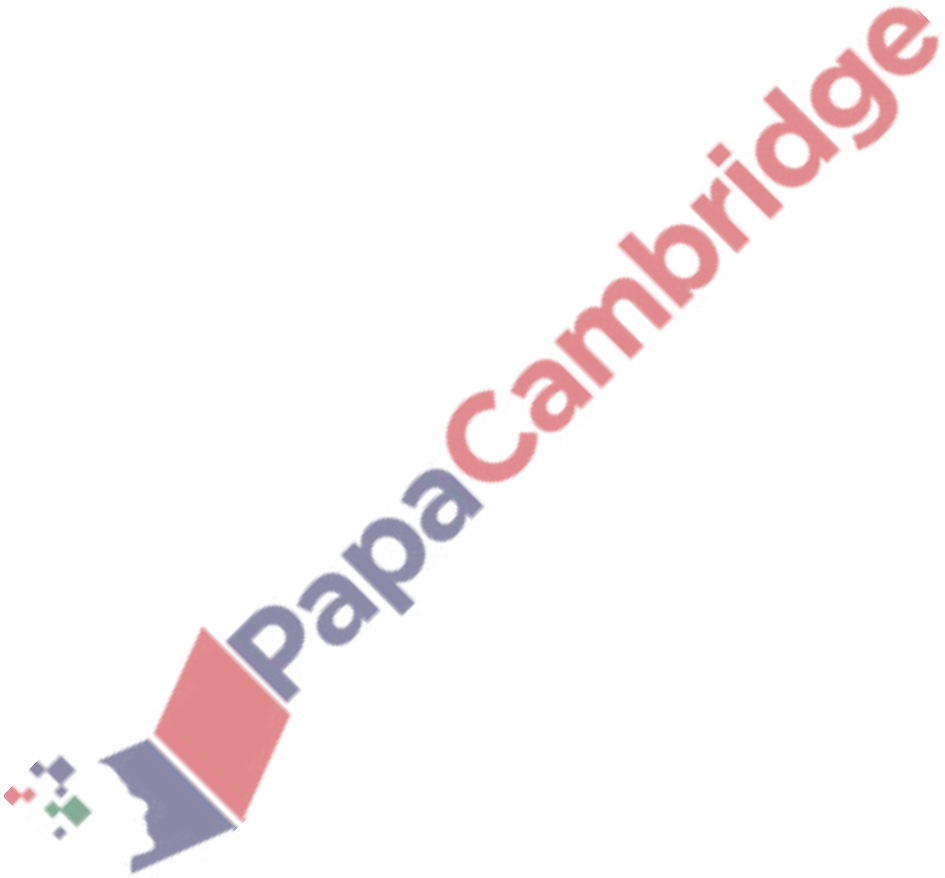
+ Answer Scheme

2015 - 2021

PapaCambridge

Chapter 12

Nitrogen and sulfur



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.

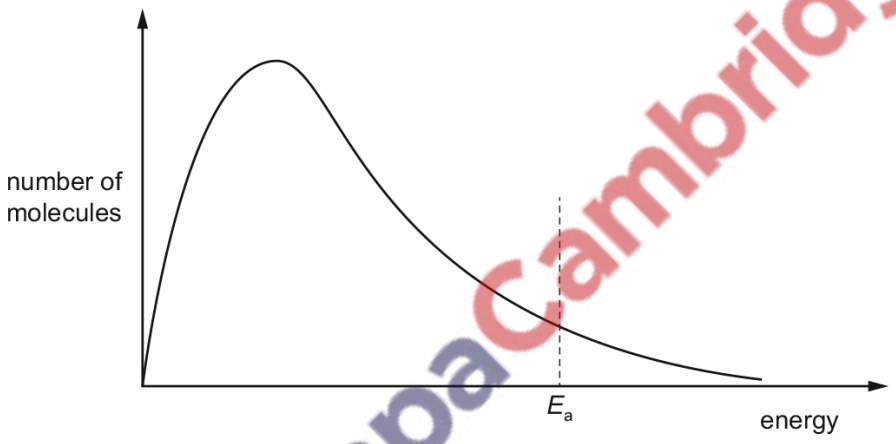
..... [1]

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.

.....

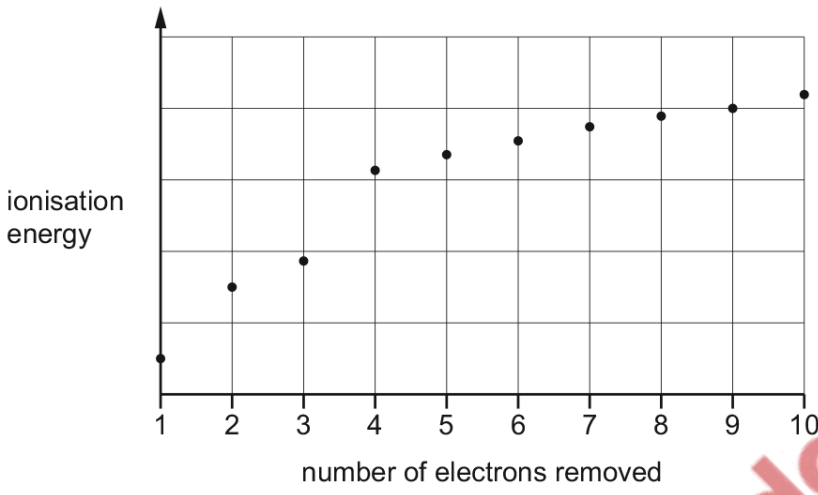
.....

.....

..... [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.

$4FeS_2$ + ... → $2Fe_2O_3$ + ...

[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]

85. 9701_w18_qp_22 Q: 2

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

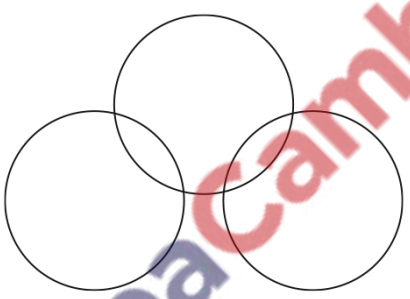
element	Na	Mg	Al	Si	P	S
type of bonding	metallic				covalent	covalent
formula of oxide					P_4O_{10}	SO_2
formula of chloride	NaCl	$MgCl_2$				SCl_2

(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.

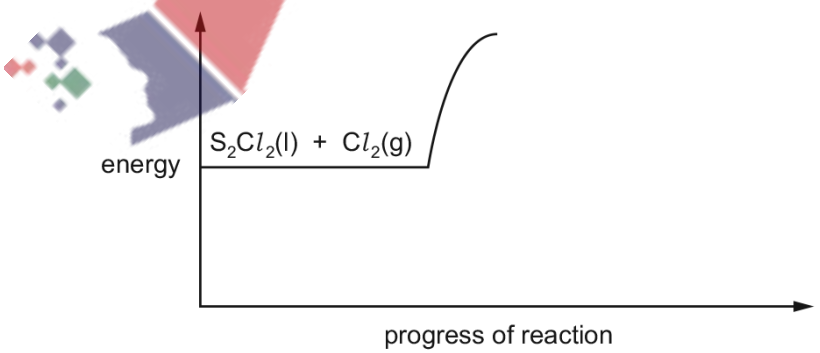
$$S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l) \qquad \Delta H = -40.6\,kJ\,mol^{-1}$$

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



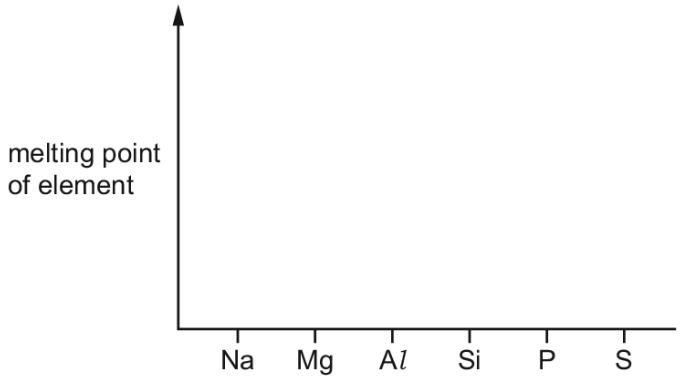
[1]

(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]