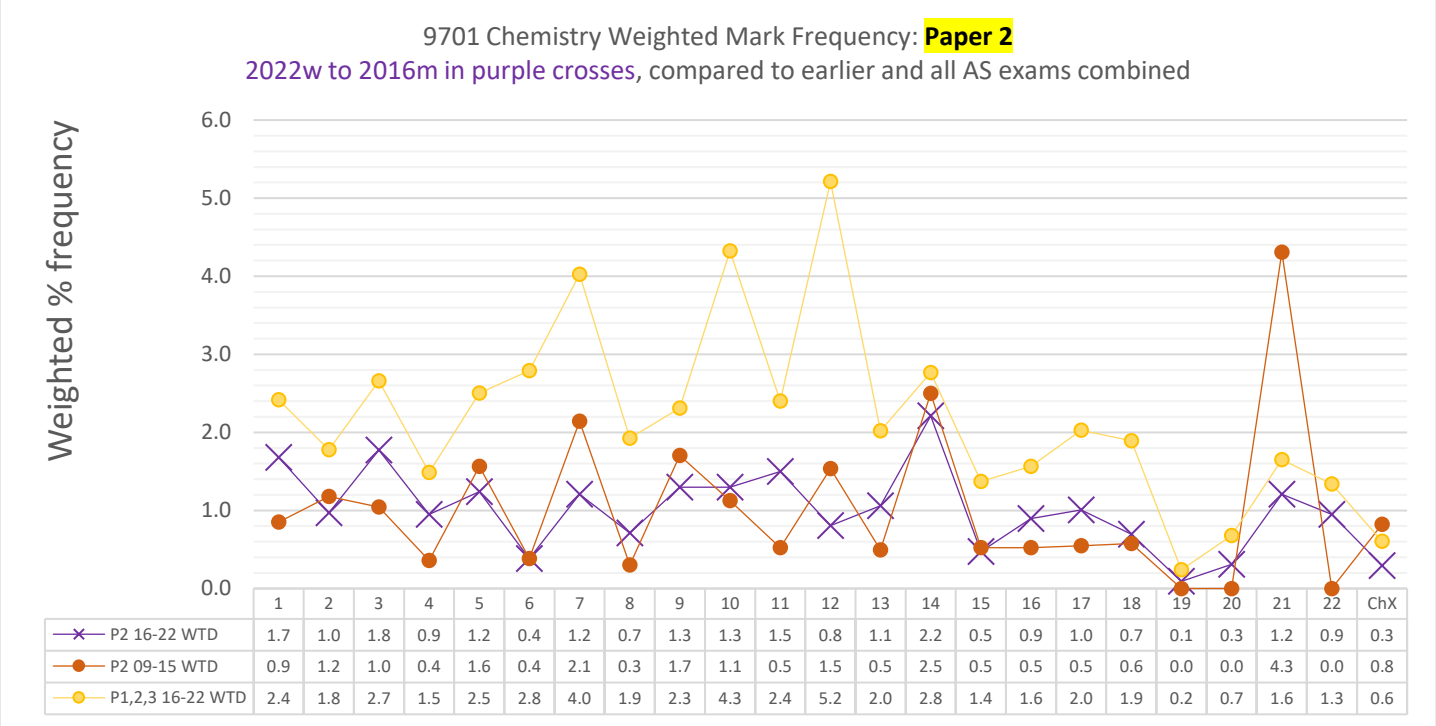
Name: Class: Date:

ALvl Chem 12 EQ P2 22w to 09s Paper 2 Nitrogen and sulfur 100marks

As you start and work through this worksheet you can tick off your progress to show yourself how much you have done, and what you need to do next. The first task is just to read the first question and should take you less than one minutes to complete.

Paper 2 Topic 12 Checklist Tick each task off as you go along	RANK:	P1 Noob	P1 Novice	P1 Bronze	P1 Silver	P1 Gold	P1[1] Winner	P1 Hero	P1 Legend
		1 Q started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topic (marks)	100		4	10	25	40	50	75	100
Time @75s/mark (minutes)	125		5	13	31	50	63	94	125



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	ChX
P2 16-22 WTD	1.7	1.0	1.8	0.9	1.2	0.4	1.2	0.7	1.3	1.3	1.5	0.8	1.1	2.2	0.5	0.9	1.0	0.7	0.1	0.3	1.2	0.9	0.3
P2 09-15 WTD	0.9	1.2	1.0	0.4	1.6	0.4	2.1	0.3	1.7	1.1	0.5	1.5	0.5	2.5	0.5	0.5	0.5	0.6	0.0	0.0	4.3	0.0	0.8
P1,2,3 16-22 WTD	2.4	1.8	2.7	1.5	2.5	2.8	4.0	1.9	2.3	4.3	2.4	5.2	2.0	2.8	1.4	1.6	2.0	1.9	0.2	0.7	1.6	1.3	0.6

What the most thoughtful students will get out of their extensive studying will be a capacity to do meaningful brain-based work even under stressful conditions, which is a part of the self-mastery skillset that will continue to deliver value for the whole of their lives. Outstanding grades will also happen, but the most important goal from skillful action in study is being better at any important task, even if circumstances do not feel ideal.

As you are moving through your studies you can learn more about yourself by trying out new ways to manage yourself, and analysing how effective those new techniques were. In this reflective process not only will you get better at working positively and productively to deliver ambitious and successful outcomes, but you will be working towards one aspect of life's highest pursuit, summarised and inscribed on the Temple of Apollo at Delphi: "know thyself".

1. To complete these questions, as important as your answer, is checking your answer against the mark scheme.
2. For each page or group of 10-20 marks, convert your mark score into a percentage. This will allow you to see (and feel) your progress as you get more experience and understanding with each topic.
3. Multiple choice questions, done carefully where you explain and show yourself your thinking using written notes as you move through each question, can be more useful than just Paper 2 for students aiming for a C or B grade. Paper 2 should be the larger focus for students aiming for A and A* grades, however.
4. If you find you get a higher percentage answering short answer questions than multiple choice questions that often means you are NOT using the marking scheme correctly; your correct answer might not be fully complete for all the marks you are awarding. The marks easiest to miss rely on providing the largest amount of detail.

[1] **DO NOT** work on these higher levels of completion in your AS year unless you have also achieved at least a "**Silver**" (25%) in the same topic in **Paper 1**, which tend also to be easier questions, as well as ""**Silver**" (25%) in the same topic, if it exists, in Paper 3.

12 Nitrogen and sulfur

12.1 Nitrogen and sulfur

Learning outcomes

Candidates should be able to:

1 explain the lack of reactivity of nitrogen, with reference to triple bond strength and lack of polarity

2 describe and explain:

(a) the basicity of ammonia, using the Brønsted–Lowry theory

(b) the structure of the ammonium ion and its formation by an acid–base reaction

(c) the displacement of ammonia from ammonium salts by an acid–base reaction

3 state and explain the natural and man-made occurrences of oxides of nitrogen and their catalytic removal from the exhaust gases of internal combustion engines

4 understand that atmospheric oxides of nitrogen (NO and NO_2) can react with unburned hydrocarbons to form peroxyacetyl nitrate, PAN, which is a component of photochemical smog

5 describe the role of NO and NO_2 in the formation of acid rain both directly and in their catalytic role in the oxidation of atmospheric sulfur dioxide

Q# 250/ ALvl Chemistry/2022/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

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

(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]

Q# 251/ ALvl Chemistry/2022/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2 Some oxides of elements in Period 3 are shown.

$$Na_2O \quad Al_2O_3 \quad P_4O_6 \quad P_4O_{10} \quad SO_2 \quad SO_3$$

(a) Na reacts with O_2 to form Na_2O. Na is the reducing agent in this reaction.

(d) SO_2 and SO_3 are found in the atmosphere.
The oxidation of SO_2 to SO_3 in the atmosphere is catalysed by NO_2.
The first step of the catalytic oxidation is shown in equation 1.

equation 1 $\quad SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$

(i) Construct an equation to show how NO_2 is regenerated in the catalytic oxidation of SO_2.

..... [1]

(ii) NO_2 can also react with unburned hydrocarbons to form photochemical smog.

State the product of this reaction that contributes to photochemical smog.

..... [1]

Q# 252/ ALvl Chemistry/2021/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(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]

Q# 253/ ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 Carbon monoxide gas, CO(g), and nitrogen gas, $N_2(g)$, are both diatomic molecules.

(b) $N_2(g)$ is less reactive than CO(g) even though $N_2(g)$ has a lower bond energy than CO(g).

Suggest why CO(g) is more reactive than $N_2(g)$.

.....

..... [1]

Q# 254/ ALvl Chemistry/2020/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(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]

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.

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

(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]

3 Crude oil is a natural source of hydrocarbons that are used as fuels.

(b) Thiophene, $C_4H_4S(l)$, is an organic compound that is found as a contaminant in crude oil.

(i) Construct the equation for the complete combustion of thiophene, $C_4H_4S(l)$.

Include state symbols in your answer.

..... [2]

Q# 257/ ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1 Nitrogen, N_2, is the most abundant gas in the Earth's atmosphere and is very unreactive.

(a) State why N_2 is very unreactive.

..... [1]

(c) **(i)** State the industrial importance of ammonia.

..... [1]

(ii) One method of producing NH_3 is by heating ammonium chloride, NH_4Cl, with CaO.

$$2NH_4Cl + CaO \rightarrow 2NH_3 + CaCl_2 + H_2O$$

Explain why the reaction of NH_4Cl with CaO produces ammonia.

.....

.....

..... [2]

(d) Three oxides of nitrogen, NO, NO_2 and N_2O, can be formed under different conditions.

(i) Complete the table to give the oxidation numbers of nitrogen in NO and NO_2.

compound	NO	NO_2
oxidation number of N		

[1]

(ii) NO_2 can be formed by different chemical reactions.

Write equations for the formation of NO_2 by:

- the reaction of N_2 with O_2

.....

- the thermal decomposition of magnesium nitrate.

.....

[2]

Q# 258/ ALvl Chemistry/2018/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

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]

(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]

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

(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]

Q# 259/ ALvl Chemistry/2018/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

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-}.

(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.

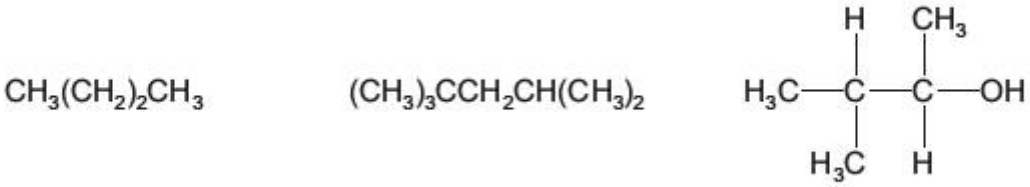
Give your answer to **two** significant figures.

(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]

Q# 260/ ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 4/www.SmashingScience.org

4 The following compounds were all found to be components of a sample of petrol.



G **H** **J**

(c) Fossil fuels are often contaminated with sulfur.

State and explain why supplies of fossil fuels that contain sulfur pose a problem to the environment.

.....

.....

..... [2]

Q# 261/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 Heptane, C_7H_{16}, is an undesirable component of petrol as it burns explosively causing 'knocking' in an engine.

(iii) Incomplete combustion can also lead to emission of unburnt hydrocarbons.

State one environmental consequence of this.

..... [1]

Q# 262/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

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

(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]

Q# 263/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(c) Although nitrogen gas makes up about 79% of the atmosphere it does not easily form compounds.

(i) Explain why nitrogen is so unreactive.

.....

..... [1]

(ii) Explain why the conditions in a car engine lead to the production of oxides of nitrogen.

.....

..... [1]

(iii) Give an equation for a reaction involved in the removal of nitrogen monoxide, NO, from a car's exhaust gases, in the catalytic converter.

..... [1]

One of the main reasons for reducing the amounts of oxides of nitrogen in the atmosphere is their contribution to the formation of acid rain.

(iv) Write an equation for the formation of nitric acid from nitrogen dioxide, NO_2, in the atmosphere.

..... [1]

(v) Write equations showing the catalytic role of nitrogen monoxide, NO, in the oxidation of atmospheric sulfur dioxide, SO_2.

.....

..... [2]

Q# 264/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 The Contact process for the manufacture of sulfuric acid was originally patented in the 19th century and is still in use today.

The key step in the overall process is the reversible conversion of sulfur dioxide to sulfur trioxide in the presence of a vanadium(V) oxide catalyst.

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

(a) One way in which the sulfur dioxide for this reaction is produced is by heating the sulfide ore iron pyrites, FeS_2, in air. Iron(III) oxide is also produced. Write an equation for this reaction.

..... [2]

(b) The sulfur trioxide produced in the Contact process is reacted with 98% sulfuric acid. The resulting compound is **then** reacted with water to produce sulfuric acid.

(i) Explain why the sulfur trioxide is not first mixed directly with water.

.....

..... [1]

(ii) Write equations for the two steps involved in the conversion of sulfur trioxide into sulfuric acid.

.....

..... [2]

(d) The conversion of sulfur dioxide into sulfur trioxide is carried out at a temperature of 400 °C.

(i) With reference to Le Chatelier's Principle and reaction kinetics, state and explain one advantage and one disadvantage of using a higher temperature.

.....

.....

.....

.....

.....

..... [4]

(ii) State the expression for the equilibrium constant, K_p, for the formation of sulfur trioxide from sulfur dioxide.

K_p =

[1]

(iii) 2.00 moles of sulfur dioxide and 2.00 moles of oxygen were put in a flask and left to reach equilibrium.
At equilibrium, the pressure in the flask was 2.00×10^5 Pa and the mixture contained 1.80 moles of sulfur trioxide.

Calculate K_p. Include the units.

K_p = ...

units = ...
[5]

[Total: 19]

Q# 265/ ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5 Propane, C_3H_8, and butane, C_4H_{10}, are components of Liquefied Petroleum Gas (LPG) which is widely used as a fuel for domestic cooking and heating.

(b) When propane or butane is used in cooking, the saucepan may become covered by a solid black deposit.

(i) What is the chemical name for this black solid?

.....

(ii) Write a balanced equation for its formation from butane.

.....
[2]

Q# 266/ ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(c) Ammonia is a weak base which forms salts containing the ammonium ion.

Describe, with the aid of an equation, the formation and structure of the ammonium ion.
You should use displayed formulae in your answer.

[3]

[Total: 13]

2 Ammonium sulfate, $(NH_4)_2SO_4$, is widely used as a fertiliser.

In order to determine its percentage purity, a sample of ammonium sulfate fertiliser was analysed by reacting a known amount with an excess of NaOH(aq) and then titrating the unreacted NaOH with dilute HC*l*.

(a) Ammonium sulfate reacts with NaOH in a 1 : 2 ratio.
Complete and balance the equation for this reaction.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow \text{.....}NH_3 + \text{.....} + \text{.....}$$

[2]

(b) A 5.00 g sample of a fertiliser containing $(NH_4)_2SO_4$ was warmed with 50.0 cm^3 (an excess) of 2.00 mol dm^{-3} NaOH.

When all of the ammonia had been driven off, the solution was cooled.

The remaining NaOH was then titrated with 1.00 mol dm^{-3} HC*l* and 31.2 cm^3 were required for neutralisation.

(i) Write a balanced equation for the reaction between NaOH and HC*l*.

.....

(ii) Calculate the amount, in moles, of HC*l* in 31.2 cm^3 of 1.00 mol dm^{-3} HC*l*.

(iii) Calculate the amount, in moles, of NaOH in 50.0 cm^3 of 2.00 mol dm^{-3} NaOH.

(iv) Use your answers to **(i)**, **(ii)** and **(iii)** to calculate the amount, in moles, of NaOH used up in the reaction with $(NH_4)_2SO_4$.

(v) Use your answer to **(iv)** and the equation in **(a)** to calculate the amount, in moles, of $(NH_4)_2SO_4$ that reacted with NaOH.

(vi) Use your answer to **(v)** to calculate the mass of $(NH_4)_2SO_4$ that reacted with NaOH.

(vii) Hence, calculate the percentage purity of the ammonium sulfate fertiliser.

[7]

[Total: 9]

Q# 268/ ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(d) Sulfur dioxide is present in small, but significant, amounts in the Earth's atmosphere.

(i) State **one** way by which sulfur dioxide enters the atmosphere.

.....

(ii) Give the formula of another sulfur compound which is formed in the atmosphere from sulfur dioxide.

.....

(iii) What are the environmental consequences of the compound you have identified in **(ii)**?

.....

[3]

Q# 269/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 Crude oil contains a mixture of hydrocarbons together with other organic compounds which may contain nitrogen, oxygen or sulfur in their molecules.

At an oil refinery, after the fractional distillation of crude oil, a number of other processes may be used including 'cracking', 'isomerisation', and 'reforming'.

One of the sulfur-containing compounds present in crude oil is ethanethiol, C_2H_5SH, the sulfur-containing equivalent of ethanol. Ethanethiol is toxic and is regarded as one of the smelliest compounds in existence.

When ethanethiol is burned in an excess of air, three oxides of different elements are formed.

(c)

When ethanethiol is burned in an excess of air, three oxides of different elements are formed.

(c) (i) Construct a balanced equation for this reaction.

.....

(ii) **Two** of the oxides formed cause serious environmental damage.

One oxide is CO2 which leads to enhanced greenhouse effect causing global warming.
For the other oxide, identify the type of pollution caused and describe one consequence of this pollution.

.....

.....

..... [4]

(d) A small amount of ethanethiol is added to liquefied gases such as butane that are widely used in portable cooking stoves.

Suggest a reason for this.

.....[1]

Q# 270/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

In many countries, new cars have to comply with regulations which are intended to reduce the pollutants coming from their internal combustion engines.

Two pollutants that may be formed in an internal combustion engine are carbon monoxide, CO, and nitrogen monoxide, NO.

(e) (i) Outline how **each** of these pollutants may be formed in an internal combustion engine.

CO .....

.....

NO .....

.....

(ii) State the main hazard associated with **each** of these pollutants.

CO .....

NO ..... [4]

Pollutants such as CO and NO are removed from the exhaust gases of internal combustion engines by catalytic converters which are placed in the exhaust system of a car.

(f) (i) What metal is most commonly used as the catalyst in a catalytic converter?

.....

(ii) Construct **one** balanced equation for the reaction in which **both** CO **and** NO are removed from the exhaust gases by a catalytic converter.

..... [2]

Q# 271/ ALvl Chemistry/2010/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(d) Hydrogen cyanide, HCN, is a gas which is also isoelectronic with N_2 and with CO. Each molecule contains a strong triple bond with the following bond energies.

bond	bond energy / kJ mol^{-1}
–C≡N in HCN	890
N≡N	994
C≡O	1078

Although each compound contains the same number of electrons and a strong triple bond in its molecule, CO and HCN are both very reactive whereas N_2 is not.

Suggest a reason for this.

.....

..... [1]

Q# 272/ ALvl Chemistry/2009/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 Concern over the ever-increasing use of fossil fuels has led to many suggestions for alternative sources of energy. One of these, suggested by Professor George Olah, winner of a Nobel Prize in chemistry, is to use methanol, CH_3OH, which can be obtained in a number of different ways.

Methanol could be used instead of petrol in a conventional internal combustion engine or used to produce electricity in a fuel cell.

(a) Construct a balanced equation for the **complete** combustion of methanol.

..... [1]

When hydrocarbon fuels are completely burned in an internal combustion engine, several toxic pollutants may be formed.

(b) State **two toxic** pollutants that can be produced after **complete** combustion of a hydrocarbon fuel in an internal combustion engine.

.....

..... [2]

Mark Scheme ALvl Chem 12 EQ P2 22w to 09s Paper 2 Nitrogen and sulfur 100marks

Q# 250/ ALvl Chemistry/2022/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(b)(i)	**M1** react with (unburnt) hydrocarbons **M2** (form) PAN / peroxyac(et)yl nitrate	2
2(b)(ii)	$2NO + 2CO \rightarrow 2CO_2 + N_2$ OR $NO_2 + 2CO \rightarrow \frac{1}{2}N_2 + 2CO_2$	1

2(c)	any Group 1 hydroxide or $Ca(OH)_2$ / $Sr(OH)_2$ / $Ba(OH)_2$	1

Q# 251/ ALvl Chemistry/2022/m/TZ 2/Paper 4/Q# 2/www.SmashingScience.org

2(d)(i)	$NO + \frac{1}{2}O_2 \rightarrow NO_2$	1
2(d)(ii)	peroxyac(et)ylnitrate / PAN	1

Q# 252/ ALvl Chemistry/2021/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(d)(ii)	acid rain	
1(d)(iii)	**M1** $SO_2(g) + 2NaOH(aq) \rightarrow Na_2SO_3(aq) + H_2O(l)$ **AND** correct species and balancing **M2** State symbols	2

Q# 253/ ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(b)	CO / it is a polar molecule / it has a (permanent) dipole (but N_2 is non-polar)	1

Q# 254/ ALvl Chemistry/2020/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(b)(iii)	(homogeneous) catalyst	1

Q# 255/ ALvl Chemistry/2020/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3(c)	**M1** nitrogen has a triple bond **M2 EITHER** high energy is needed to break the bond **OR** at normal temperatures there is not enough energy to break the bond / to overcome the activation energy	2
3(d)	lightning	1
3(e)(i)	**M1** *define homogeneous* (homogeneous catalyst is) in the same phase / state as the reactants **M2 and M3** *Define catalyst* *All 3 points scores 2 marks. Any 2 points scores 1 mark* increase the rate **AND** lowers the activation energy **AND** without being chemically altered at the end of the reaction / are regenerated at the end of the reaction	
3(e)(ii)	**M1** $NO_2 + SO_2 \rightarrow NO + SO_3$ **M2** $NO + \frac{1}{2} O_2 \rightarrow NO_2$	2

Q# 256/ ALvl Chemistry/2019/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3(b)(i)	$C_4H_4S(l) + 6O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l) + SO_2(g)$ • correct species • balancing • state symbols Award one mark for two correct bullet points, award two marks for all three correct.	2

Q# 257/ ALvl Chemistry/2019/m/TZ 2/Paper 4/Q# 1/www.SmashingScience.org

1(a)	strong triple bond / strong N≡N OR high activation energy / E_a OR non-polar	1
1(c)(i)	(it is used to make) fertilisers	1
1(c)(ii)	**M1** CaO displaces NH_3 (from its salt / NH_4^+) **M2** CaO is a stronger base / more basic (than NH_3)	2
1(d)(i)	<table><tr><td>NO</td><td>NO_2</td></tr><tr><td>(+)2 / (+)II</td><td>(+)4 / (+)IV</td></tr></table>	1
1(d)(ii)	**M1** $\frac{1}{2}N_2 + O_2 \rightarrow NO_2$ **M2** $Mg(NO_3)_2 \rightarrow MgO + 2NO_2 + \frac{1}{2}O_2$	2

Q# 258/ ALvl Chemistry/2018/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2(a)(i)	1 mark for each bullet, max 2 • triple bond • non-polar / no dipole • needs a lot of energy to break / strong	2
2(b)(i)	(lightning) provides the (high) activation energy	1
2(b)(ii)	**M1** $NO + \frac{1}{2}O_2 \rightarrow NO_2$ **M2** $2NO_2 + H_2O + \frac{1}{2}O_2 \rightarrow 2HNO_3$	2
2(d)(ii)	**M1** ammonia / NH_3 **M2** displaces NH_3	2

Q# 259/ ALvl Chemistry/2018/w/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

1(c)(i)	**M1** acid rain **M2** • destroys / damages / weathers / erodes / buildings / statues • kills/harms fish / coral / plants / crops / trees / deforestation • leaches salts / ions (aluminium) from soil (into rivers / lakes) • leaches away soil nutrients • breathing difficulties • lowers pH / increases acidity of soil / rivers / oceans / seas	2
1(c)(ii)	balanced equation with $11O_2$ and $8SO_2$ **M1**: O_2 and SO_2 **M2**: 11 and 8	2
1(c)(iii)	**M1** *is for process of calculating number of moles of* Fe_2O_3 33.18 ÷ 159.6 (= 0.2079 mol) **M2** *for correct use of stoichiometry and 120.0 with candidate's* ***M1*** **M2** (0.2079) × 4 / 2 × 120.0 = 49.89 (g)	2
1(c)(iv)	(0.37/(0.37+49.89)) = 0.74	1

Q# 260/ ALvl Chemistry/2016/m/TZ 2/Paper 4/Q# 4/www.SmashingScience.org

(c)	sulfur dioxide would be produced on combustion (which contributes to) acid rain	[1] [1]	[2]

Q# 261/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(iii)	global dimming / PAN / smog / global warming	[1]	[1]

Q# 262/ ALvl Chemistry/2015/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(ii)	(oxides of nitrogen / NO_x / NOs) cause acid rain $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$ OR $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$ OR $SO_2 + NO_2 \rightarrow SO_3 + NO$ AND $SO_3 + H_2O \rightarrow H_2SO_4$	[1] [1]	[2]

Q# 263/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(c) (i)	strong triple bond	[1]	[1]
(ii)	high temperature (needed for reaction between N_2 and O_2)	[1]	[1]
(iii)	$2NO + 2CO \rightarrow N_2 + 2CO_2$ **OR** $2NO + C \rightarrow N_2 + CO_2$	[1]	[1]
(iv)	$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$	[1]	[1]
(v)	$NO + ½O_2 \rightarrow NO_2$ $NO_2 + SO_2 \rightarrow NO + SO_3$ **OR** $NO_2 + SO_2 + H_2O \rightarrow NO + H2SO_4$	[1] [1]	[2]

Q# 264/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 (a)	$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$	1 1	[2]
(b) (i)	Very exothermic / gets very hot OR creates (acid / H_2SO_4) spray / mist / fog / fumes	1	1
(ii)	$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$	1 1	[2]
(d) (i)	Advantage = higher rate Greater KE / energy / speed / collision frequency / proportion of successful collisions / more particles with E>Ea Disadvantage – reduced yield / less product (Forward reaction) **exothermic AND** (hence in accordance with LCP) equilibrium / reaction **shifts left** (to counteract inc T) ora	1 1 1 1	[4]
(ii)	$K_p = \frac{pSO_3^2}{pSO_2^2 \times pO_2}$	1	[1]

(iii)	$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ 2 2 0 (–1.8) (–0.9) 0.2 1.1 1.80 $xSO_3 = 1.8/3.1 = 0.581$ $xSO_2 = 0.2/3.1 = 0.065$ $xO_2 = 1.1/3.1 = 0.355$ $K_p = \frac{0.581^2 \times (2 \times 10^5)^2}{0.065^2 \times (2 \times 10^5)^2 \times 0.355 \times 2 \times 10^5} = 1.13 \times 10^{-3}\ Pa^{-1}$	1 1 1 1+1	[5]

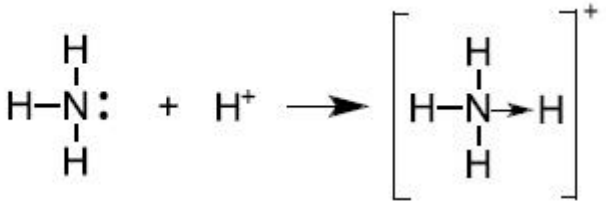
Q# 265/ ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

(b) (i) **carbon** allow graphite (1)

(ii) $2C_4H_{10} + 5O_2 \rightarrow 8C + 10H_2O$
allow balanced equations which include CO and/or CO_2 (1) [2]

Q# 266/ ALvl Chemistry/2012/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

(c)



correct displayed eqn.,
with positive charge clearly shown (1)
lone pair on NH_3 (1)
co-ordinate / dative bond clearly shown (1) [3]

Q# 267/ ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

2 (a) $(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$
correct products (1)
correctly balanced equation (1) [2]

(b) (i) $NaOH + HCl \rightarrow NaCl + H_2O$ (1)

(ii) $n(HCl) = \frac{31.2}{1000} \times 1.00 = 0.0312 = 0.03$ (1)

(iii) $n(NaOH) = \frac{50.0}{1000} \times 2.00 = 0.10$ (1)

(iv) $n(NaOH)$ used up $= 0.10 - 0.0312 = 0.0688 = 0.07$ (1)

(v) $n[(NH_4)_2SO_4] = \frac{0.0688}{2} = 0.0344 = 0.03$ (1)

(vi) mass of $(NH_4)_2SO_4 = 0.0344 \times 132 = 4.5408 = 4.54$ (1)

(vii) percentage purity $= \frac{4.5408 \times 100}{5.00} = 90.816 = 90.8$ (1) [7]

Q# 268/ ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(d) (i) combustion of fossil fuels – e.g. from car engines
from car exhausts **or**
during the extraction of metals from sulfide ores or
volcanic eruptions/burning sulfur from volcanoes or
burning biomass (1)

(ii) H_2SO_4
or
SO_3 allow H_2SO_3 **formula required** (1)

(iii) acid rain
or
its consequences e.g. damage to buildings,
damage to crops, plants, marine life
deforestation
or
SO_3 is toxic (1) [3]

Q# 269/ ALvl Chemistry/2011/s/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(c) (i) $C_2H_5SH + {}^9/_2 O_2 \rightarrow 2CO_2 + SO_2 + 3H_2O$ **or**
$2C_2H_5SH + 9O_2 \rightarrow 4CO_2 + 2SO_2 + 6H_2O$
correct products (1)
correct equation which is balanced (1)

(ii) **for CO_2**
enhanced greenhouse effect (1)
global warming (1)

for SO_2
formation of acid rain (1)
damage to stonework of buildings/
dissolving of aluminium ions into rivers/
damage to watercourses or forests/
aquatic life destroyed/
corrosion of metals (1) [6]

(d) help detect leaks of gas (1) [1]

(e) temperature of 450°C (1)
pressure of 1 – 2 atm (1)
V_2O_5/vanadium(V) oxide/vanadium pentoxide catalyst (1) [3]

[Total: 15]

Q# 270/ ALvl Chemistry/2010/w/TZ 1/Paper 4/Q# 2/www.SmashingScience.org

(e) (i) CO by incomplete combustion of the hydrocarbon fuel (1)

NO by reaction between N_2 and O_2 in the engine (1)

(ii) CO toxic/effect on haemoglobin (1)

NO toxic/formation of acid rain (1) [4]

(f) (i) platinum/Pt – allow palladium/Pd **or** rhodium/Rh (1)

(ii) $2CO + 2NO \rightarrow 2CO_2 + N_2$ (1) [2]

[Total: 14]

Q# 271/ ALvl Chemistry/2010/s/TZ 1/Paper 4/Q# 1/www.SmashingScience.org

(d) CO and HCN both have a dipole **or** N_2 does not have a dipole (1) [1]

Q# 272/ ALvl Chemistry/2009/s/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3 (a) $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$ (1) [1]

(b) SO_2 (1)

NO_x / NO_2 / NO – **not** N_2O (1)
Pb compounds – **not** Pb (1) (any 2)

If more than two answers are given any wrong ones will be penalised. [2]