ES – Exam Questions

Use these questions to help you revise the ES unit – please note these questions are from the old course but they are still relevant content to cover.

Explain the benefits and disadvantages of using chlorine to treat drinking water. Include references to the transport and storage of chlorine.

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.... **[5]**

The phenylethene monomer is made by passing ethylbenzene vapour over a heated catalyst at a low pressure. **Equation 2.1** represents the reaction that occurs.

$$C_6H_5CH_2CH_3(g) \rightleftharpoons C_6H_5CHCH_2(g) + H_2(g) \quad \Delta H = +117\,kJ\,mol^{-1}$$ **equation 2.1**

Describe and explain the effect of the following changes on the **yield** of phenylethene produced in the equilibrium represented by **equation 2.1**.

Carrying out the reaction at a higher temperature.

In your answer, you should use technical terms, spelled correctly.

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.... **[2]**

Carrying out the reaction at a higher pressure.

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..... [2]

Some people are advised to reduce the amount of sodium chloride in their diet, as sodium salts can contribute to high blood pressure. One method for making this dietary change is to use a 'low salt' alternative, which contains a mixture of sodium and potassium chlorides.

A certain brand of 'low salt' contains one third potassium chloride, KC*l*, and two thirds sodium chloride, NaC*l*, by mass. Calculate the mole ratio of sodium to potassium in the mixture.

mole ratio Na : K = 1 : ..... [2]

A student tests the 'low salt' for the presence of chloride ions. A sample of 'low salt' is dissolved in water and silver nitrate solution is added. A precipitate forms confirming the presence of chloride ions.

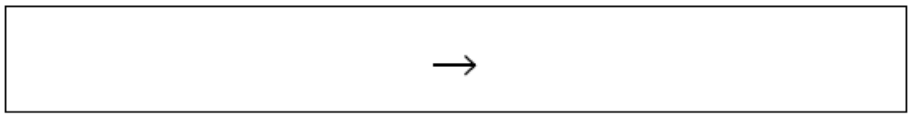
(i) Give the colour of the precipitate that the student would see.

..... [1]

(ii) Give the chemical name of the precipitate.

..... [1]

(iii) Write an ionic equation for the reaction that takes place to form the precipitate.



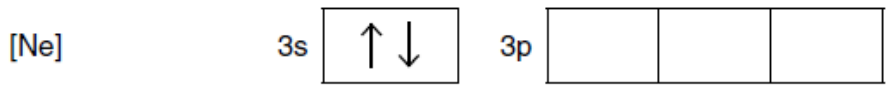
[1]

Potassium chloride can be made by burning potassium in chlorine.

Give the appearance and physical state of chlorine at room temperature.

..... [1]

Complete the diagram below, showing the arrangement of electrons in atomic orbitals for a chlorine atom.



[1]

Two methods for making potassium chloride are shown below.

method 1: $2K(g) + Cl_2(g) \rightarrow 2KCl(s)$

method 2: $KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

State which method has the greater atom economy and explain your answer.

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..... **[1]**

Explain why the reaction with the greater atom economy is not the more economical method to use for making potassium chloride.

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..... **[1]**

Give the oxidation state of sulfur in hydrogen sulfide and in sulfuric acid.

H_2S .....

H_2SO_4 ..... **[2]**

Name the substance that has been reduced during the reaction of hydrogen sulfide with oxygen gas to form sulfuric acid. Explain your answer.

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..... **[2]**

When carbon dioxide dissolves in water, the following reactions occur.

$$CO_2(g) \rightleftharpoons CO_2(aq) \qquad \textbf{equation 1.1}$$

$$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \qquad \textbf{equation 1.2}$$

$$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq) \qquad \textbf{equation 1.3}$$

Give the systematic name of the HCO_3^- ion.

..... **[1]**

The reaction in **equation 1.3** can reach a state of dynamic equilibrium.

Explain what is meant by the term *dynamic equilibrium*.

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..... **[2]**

The concentration of hydrogen ions in a sample of sea water is increased.

Using **equation 1.3**, describe and explain what would happen, if anything, to the concentration of carbonate ions.

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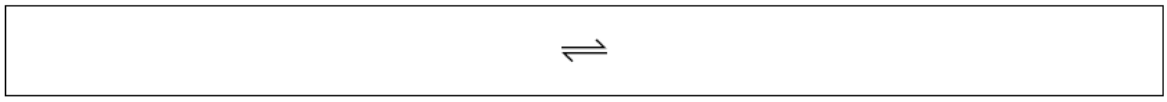
..... **[2]**

Give the overall equation for the reaction of gaseous carbon dioxide with water that produces CO_3^{2-} ions.



[1]

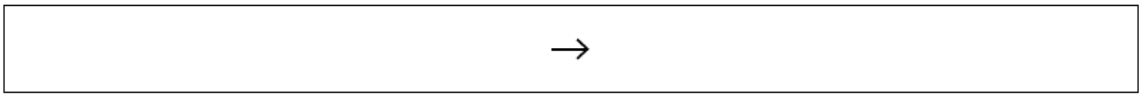
Mineral water often contains dissolved carbon dioxide. The water also contains a range of dissolved ionic compounds.

A student analyses a sample of mineral water to check the amount of dissolved sulfate ions, SO_4^{2-}, it contains.

(i) The student adds barium chloride solution to the water to precipitate out the sulfate ions as barium sulfate. The student collects, dries and weighs the precipitate.

Write the **ionic** equation for the precipitation of barium sulfate.

Include state symbols.



[2]

(ii) From the results, the student calculates that the mineral water contains sulfate ions at a concentration of 7.4×10^{-5} mol dm^{-3}. The student looks at the label on the bottle and finds that the concentration is quoted in g dm^{-3}.

Calculate the concentration of sulfate ions in the water in g dm^{-3}.

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

concentration of sulfate ions = ... g dm^{-3} **[3]**

(iii) Suggest why the presence of CO_3^{2-} ions in the mineral water might lead to the student obtaining a higher value for the sulfate ion concentration than is given on the label on the bottle.

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..... **[1]**

The concentration of sulfur dioxide in a sample of white wine can be found by titrating the wine with a solution of iodine.

The equation for the reaction between sulfur dioxide and iodine is shown below.

$SO_2(aq) + I_2(aq) + 2H_2O(l) \rightarrow SO_4^{2-}(aq) + 2I^-(aq) + 4H^+(aq)$ **equation 3.1**

(i) Give the oxidation states of the iodine and sulfur before and after the reaction.

Oxidation state of sulfur in:

SO_2 ..... SO_4^{2-} .....

Oxidation state of iodine in:

I_2 ..... I^- ..... **[3]**

(ii) Give the reducing agent in the reaction shown in **equation 3.1**.

Explain your answer in terms of oxidation states.

reducing agent: .....

explanation: .....

..... **[2]**

(iii) Give the colour and physical state of the iodine that would be used to make the iodine solution.

..... **[1]**

A sample of white wine is analysed for its sulfur dioxide content by titrating it with an aqueous solution of iodine.

$SO_2(aq) + I_2(aq) + 2H_2O(l) \rightarrow SO_4^{2-}(aq) + 2I^-(aq) + 4H^+(aq)$ **equation 3.1**

(i) Name a suitable piece of equipment for adding the aqueous iodine solution to the wine.

..... **[1]**

(ii) $15.80\,cm^3$ of $0.0100\,mol\,dm^{-3}$ aqueous I_2 solution is needed to react with $50.00\,cm^3$ of the wine.

Calculate the number of moles of iodine, I_2, used in the titration.

moles I_2 = ... mol **[1]**

(iii) Use your answer to **(ii)** and **equation 3.1** to write down the number of moles of sulfur dioxide in the 50.00 cm^3 of wine.

moles sulfur dioxide = ... mol **[1]**

(iv) What is the concentration of sulfur dioxide in the wine in mol dm^{-3}?

concentration = ... mol dm^{-3} **[1]**

(v) In Britain, the maximum amount of sulfur dioxide that can be added to white wine is 3.28×10^{-3} mol dm^{-3}. Above this limit, the taste of the wine is affected.

A concentration of less than 1.56×10^{-4} mol dm^{-3} is insufficient to preserve the wine.

Use this information to comment on your answer to **(iv)**.

.....

..... **[1]**

The concentration of sulfur dioxide in wine can also be found by converting the sulfur dioxide to sulfuric acid. The sulfuric acid is then titrated with sodium hydroxide solution.

How would you know when the end-point of the titration of sulfuric acid with sodium hydroxide has been reached?

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..... **[1]**

Chlorine can be manufactured from sodium chloride solution using electrolysis. The process also produces hydrogen and sodium hydroxide, which themselves have uses.

If an accident occurred during chlorine manufacture, people dealing with the incident would wear breathing apparatus. Explain why this would be necessary.

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..... **[2]**

Equation 1.1 represents the overall reaction that occurs in the electrolysis cell.

$$2NaCl(aq) + 2H_2O(l) \rightarrow H_2(g) + Cl_2(g) + 2NaOH(aq) \qquad \textbf{equation 1.1}$$

Calculate the volume of chlorine gas that would be produced from 100 kg of dissolved sodium chloride.

Assume that 1 mol of gas occupies 24 dm^3 under the conditions of the experiment.

volume = ... dm^3 **[3]**

Explain, using ideas of atom economy, why this electrolysis is a particularly useful industrial process.

.....

..... **[1]**

The table below gives information about three types of electrolysis cell that are used for chlorine production. In some cases, the NaOH(aq) must be slowly evaporated, by heating with steam, to produce the concentration required for further use.

Table 1.1

	mercury cell	**diaphragm cell**	**membrane cell**
amount of electricity used	most → least		
mass of steam used [tonnes steam/tonne NaOH (aq)]	none	3	1
purity of products	extremely pure	Cl_2 contains O_2 and must be purified before use	Cl_2 contains some O_2 and may need purifying before use
environmental concerns unique to this method	mercury loss causes environmental damage	none	none

Suggest **one** advantage and **one** disadvantage of the diaphragm cell over the mercury cell.

advantage of diaphragm cell: .....

.....

disadvantage of diaphragm cell: .....

..... **[2]**

Suggest why a company might build a new chlorine manufacturing plant near to an existing plant.

.....

..... **[1]**

All of the methods shown in **Table 1.1** involve the conversion of chloride ions to chlorine molecules. Write a half-equation for this reaction.

→

[2]

Write the electronic configuration, in terms of s and p sub-shells, for a chlorine atom.

..... **[1]**

Chlorine can be used to produce bromine. The chlorine is passed through a solution, obtained from seawater, which contains bromide ions.

$$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$$ **equation 1.2**

Give the oxidation states of chlorine in Cl_2 and Cl^-.

Cl_2 ..... Cl^- ..... **[2]**

Give the name of the process in which Cl_2 is converted to Cl^- giving an explanation for your choice.

.....

..... **[2]**

Chlorine can be used to produce bromine. The chlorine is passed through a solution, obtained from seawater, which contains bromide ions.

$$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$$ **equation 1.2**

Explain why the reaction represented by **equation 1.2** happens, by reference to the oxidising ability of chlorine and bromine.

..... **[1]**

Give a use for the bromine that is produced in **equation 1.2**.

..... **[1]**

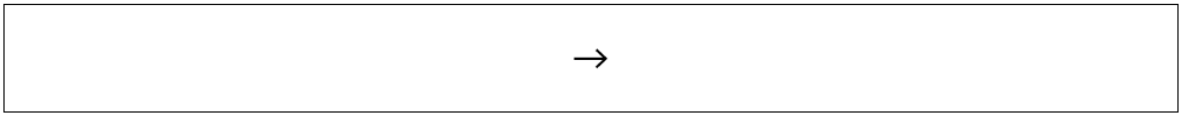
Chlorine is present in seawater as chloride ions.

Seawater can be tested, to show it contains chloride ions, by mixing it with a solution containing silver ions.

Give the colour of the silver chloride precipitate that would form.

..... **[1]**

Write the ionic equation that describes the precipitation of silver chloride, showing state symbols.



[2]

The seawater also contains sulfate ions. These react with the silver ions, forming silver sulfate. Give the formula of silver sulfate.

..... **[1]**

Seawater is slightly alkaline. This is due to the presence of HCO_3^- ions in the water.

$$HCO_3^-(aq) + H^+(aq) \rightleftharpoons CO_2(aq) + H_2O(l)$$ **equation 2.1**

Use **equation 2.1** and le Chatelier's principle to explain what would happen to the concentration of HCO_3^- ions in the seawater if more carbon dioxide were to dissolve in the water.

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..... **[2]**

The reaction represented by **equation 2.1** can reach a position of dynamic equilibrium.

Explain what is meant by the term *dynamic equilibrium*.

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..... **[2]**

Iodine can be extracted from some types of seaweed which have taken up iodine compounds from the seawater. Iodine is present in seawater, as both iodide, I^-, and iodate, IO_3^-, ions.

Give the oxidation state of iodine in I^- and IO_3^-.

I^- ..... IO_3^- ..... **[2]**

Iodate ions can be converted to iodide ions by reacting them with a solution of sulfur dioxide. The reaction that occurs is represented by **equation 1.1**.

$$IO_3^- + 3SO_2 + 3H_2O \rightarrow 6H^+ + 3SO_4^{2-} + I^- \qquad \textbf{equation 1.1}$$

Which element has been oxidised in the reaction represented by **equation 1.1**?

..... **[1]**

A solution contains IO_3^- ions at a concentration of 0.15 mol dm^{-3}.

Calculate the concentration of IO_3^- ions in the solution in g dm^{-3}.

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

M_r: IO_3^-, 174.9

concentration = ... g dm^{-3} **[2]**

Equation 1.2 is the incomplete half-equation for the conversion of iodate ions to iodide ions. Complete and balance **equation 1.2**.

$$IO_3^- + \text{.....}\ H^+ + \text{.....} \rightarrow I^- + 3H_2O \qquad \textbf{equation 1.2 [2]}$$

When silver nitrate solution is added to a solution containing iodide ions, a reaction occurs.

What would be **seen** when this reaction occurs?

.....

..... **[2]**

Write the ionic equation for the reaction, including state symbols.

→

[2]

Write the electron configuration for the highest energy sub-shell for iodine.
(For example, for lead it would be $6p^2$).

..... **[1]**

Chlorine atoms are more readily reduced than iodine atoms.

State what is meant by *reduction* in terms of electrons.

..... **[1]**

Using your answers to **(i)**, **(ii)** and **(iii)**, suggest why chlorine atoms are more readily reduced than iodine atoms.

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..... **[2]**

'Nitrous oxide' gas, N_2O, is formed in the soil by denitrifying bacteria.

Give the systematic name for nitrous oxide.

..... **[1]**

One model of the bonding in nitrous oxide includes a dative covalent bond between the oxygen atom and the central nitrogen atom. Complete the '*dot-and-cross*' diagram for a molecule of nitrous oxide based on this model.

Suggest a shape for the molecule.

N N O

shape ..... **[3]**

Nitrate ions, NO_3^-, in soil undergo denitrification to nitrous oxide.

Give the oxidation state of nitrogen in:

nitrate, NO_3^- ..... nitrous oxide .....**[2]**

Balance the half-equation below by writing numbers on the dotted lines.

.....H^+ + $2NO_3^-$ + ...e^- ⟶ N_2O + ...H_2O **[2]**

Give **two** reasons why this process can be referred to as **reduction**.

1 .....

2 ..... **[2]**

When an electric spark is passed through a sample of another oxide of nitrogen it decomposes completely to nitrogen and oxygen. When the oxygen is removed from the mixture, the volume decreases by 67%.

Calculate the formula of the oxide of nitrogen, showing your working.

formula = ... **[2]**

A novel way of removing carbon dioxide from the atmosphere has been reported. This method involves converting carbon dioxide to carbon monoxide, using the reaction shown in **equation 3.1**. The carbon monoxide can be used as a fuel or converted into hydrocarbons.

$2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g) \quad \Delta H = +566\,kJ\,mol^{-1}$ **equation 3.1**

A reaction temperature of 2000 K is quoted, and this is obtained by focussing sunlight on to the reaction chamber.

(i) Describe and explain, in terms of equilibrium, the effect on the yield of carbon monoxide of increasing temperature and increasing pressure.

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..... **[4]**

Write the equation for K_c for the reaction in **equation 3.1**.

K_c =

[1]

Use the data below to calculate the value for K_c at 2000 K. Give the units of K_c.

Give your answer to an **appropriate** number of significant figures.

substance	equilibrium concentration at 2000 K / mol dm^{-3}
CO_2	1×10^{-2}
CO	2×10^{-8}
O_2	1×10^{-8}

K_c = ... units .....**[3]**

Give the oxidation state of arsenic in $Cu(AsO_2)_2$, assuming that copper has the +2 oxidation state.

..... [1]

Suggest the systematic name for $Cu(AsO_2)_2$.

..... [1]

(i) Complete the electron configuration for the Cu^{2+} ion.

$1s^2 2s^2 2p^6$ [1]

Ammonium nitrate is an inorganic fertiliser that is manufactured from NH_3 and HNO_3.

(i) Give the oxidation states of nitrogen in:

NH_3 ..... HNO_3 ..... [2]

(ii) Write an ionic half-equation for the conversion of NH_3 to HNO_3 in the presence of H_2O, given that the number of electrons involved is the same as the oxidation state change.

[2]

(iii) Write an equation for the reaction of NH_3 with HNO_3 to form ammonium nitrate. Give the atom economy of this reaction.

Equation:

atom economy = ... % [2]

Carbonic anhydrase is a catalyst for the reaction shown below.

$$CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+ \quad \textbf{equation 4.1}$$

Give the systematic name of the ion HCO_3^-.

..... [1]

Describe and explain the effect that carbonic anhydrase will have on the position of the equilibrium shown in **equation 4.1**.

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..... [2]

Esters can be made by heating acids and alcohols under reflux with a catalyst.

$$ROH + RCOOH \rightleftharpoons RCOOR + H_2O$$

In one experiment, 1.10 mol of an organic acid and 1.10 mol of an alcohol are heated under reflux. When equilibrium is reached, 0.40 mol of acid remain.

(i) Suggest how the initial and equilibrium amounts of acid could be measured.

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..... **[2]**

(ii) Use the equation for the reaction to calculate the amount, in moles, of ester that forms.

amount of ester = ... mol **[1]**

(iii) Calculate a value for the equilibrium constant at the temperature of the reaction.

K_c = ... **[3]**

Sulfur hexafluoride is a colourless, non-toxic gas. It reacts with lithium to give off a large amount of heat energy that is used to power torpedoes.
Sulfur hexafluoride can be made by oxidising sulfur tetrafluoride with oxygen.
Sulfur tetrafluoride can be made by heating sulfur with copper(II) fluoride as shown in **equation 2.1** below.

$$3S + 2CuF_2 \rightarrow SF_4 + 2CuS \qquad \textbf{equation 2.1}$$

(i) In **equation 2.1**, what is oxidised and what is reduced?

..... is oxidised from oxidation state ..... to .....

..... is reduced from oxidation state ..... to ..... **[4]**

(ii) Suggest an equation for the reaction of sulfur tetrafluoride with oxygen to form sulfur hexafluoride.

[1]

(i) Write the electron configuration for a sulfur atom, in terms of s and p electrons.

[1]

(ii) Draw a '*dot-and-cross*' diagram for sulfur **hexa**fluoride, SF_6.

[2]

(iii) Draw a three-dimensional diagram to show the shape of **SF_6**. Show **one** bond angle on the diagram and indicate its value.

[3]

The reaction of sulfur **hexa**fluoride with lithium is:

$$8Li + SF_6 \rightarrow Li_2S + 6LiF \qquad \Delta H = -3000\,kJ\,mol^{-1} \qquad \textbf{equation 2.2}$$

(i) Calculate the mass of lithium needed to react with 297 kg of sulfur hexafluoride. Give your answer to an **appropriate** number of significant figures.

mass = ... kg **[3]**

(ii) Give the systematic name for Li_2S.

..... **[1]**

(i) Give the formula of potassium chlorate(VII).

..... **[1]**

Methanol is added to ethanol to make the ethanol unfit to drink.

Methanol can be made by the following reaction.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\,kJ\,mol^{-1} \qquad \textbf{equation 1.1}$$

A pressure of between 50 and 100 atmospheres is used for this reaction.

Raising the pressure increases both the **rate** of the reaction and the **yield** of methanol.

Give the reasons for this.

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..... **[4]**

Give **one** reason why the use of high pressures is expensive.

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..... **[1]**

Describe and explain how the **yield** of methanol at equilibrium would change with increasing temperature.

In your answer you should make it clear how the points you make link together.

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..... **[3]**

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $\Delta H = -91\,kJ\,mol^{-1}$ **equation 1.1**

Write the expression for the equilibrium constant, K_c, for the reaction in **equation 1.1**.

$K_c =$

[1]

The composition of an equilibrium mixture of the gases shown in **equation 1.1** was determined at 500 K.

gas	concentration / mol dm^{-3}
CO(g)	0.10
H_2(g)	0.10
CH_3OH(g)	1.03

Calculate the value of K_c at 500 K and give its units.

K_c = ... units ..... **[2]**

Diborane can be made industrially by reacting boron trifluoride with sodium hydride.

$$2BF_3 + 6NaH \longrightarrow B_2H_6 + 6NaF$$

Some data for the compounds in this equation are given below.

substance	M_r	melting point / K
BF_3	67.8	129
NaH	24.0	1073
B_2H_6	27.6	108
NaF	42.0	1266

Calculate the atom economy for the production of diborane by the reaction shown.

Comment on the implications of this value for an industrial process.

atom economy = ... %

comment .....

..... **[2]**

Use the data to suggest the type of bonding in NaH and draw a '*dot-and-cross*' diagram for NaH.

Show outer electrons only.

type of bonding .....

'*dot-and-cross*' diagram:

[3]

Diborane reacts vigorously and exothermically with oxygen difluoride, OF_2. This mixture has been investigated as a rocket propellant.

The possible products of the reaction are boron(III) oxide and hydrogen fluoride.

(i) Write an equation for the above reaction.

[2]

(ii) Use your equation in **(i)** to calculate the maximum mass of OF_2 that could react with 25 g of diborane in this reaction.

Give your answer to an **appropriate** number of significant figures.

mass = ... g **[3]**

The pigment *smalt* was used by painters in the sixteenth century. It is a glass pigment made by melting cobalt(II) arsenate(V) with sand (silicon dioxide) and potassium carbonate.

The arsenate(V) ion can be written as $(AsO_4)^{n-}$.

Work out the value of *n* and give the formula of cobalt(II) arsenate(V).

n = ... formula = ... **[2]**

Complete the electron configuration for the cobalt(II) ion.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

[1]

The overall equation for the formation of $NO_2(g)$ is given below.

$$N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +66\,kJ\,mol^{-1} \qquad \textbf{equation 1.3}$$

(i) At room temperature and pressure:

- Show that the concentration of oxygen in air is $8.3 \times 10^{-3}\,mol\,dm^{-3}$.
- Calculate the concentration of nitrogen in air.

Assume that air consists of nitrogen and oxygen in the mole ratio 4.0 : 1.0 and that one mole of gas occupies $24\,dm^3$ at room temperature and pressure.

$[N_2]$ = ... $mol\,dm^{-3}$ **[2]**

(ii) Write the expression for the equilibrium constant, K_c, for the reaction shown in **equation 1.3**.

K_c =

[1]

(iii) Use the concentrations of N_2 and O_2 from **(i)** to work out the equilibrium concentration of NO_2 in air at room temperature and pressure.

$K_c = 4 \times 10^{-19}\,dm^3\,mol^{-1}$ at room temperature for **equation 1.3**.

Give your answer to an **appropriate** number of significant figures.

$[NO_2]$ = ... $mol\,dm^{-3}$ **[3]**

(iv) How would the value of the **equilibrium constant** for the equilibrium shown in **equation 1.3** change, if at all, if the temperature were raised to 1500 K?

Give reasons for your answer.

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..... **[3]**

(v) The pressure was increased to 100 atmospheres, keeping the temperature at room temperature.

What effect would this have on the **equilibrium position** for **equation 1.3**?

Give a reason for your answer.

.....

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..... **[2]**