SECTION B

Answer **all** *the questions in the spaces provided.*

5. *(a)* Polluting gases such as sulfur dioxide, SO_2, produced from power stations, can cause the acidification of lakes far from the source of the pollution. At a lake-water pH of 6·0, water snails start to die and when the pH reaches 5·5, fish also begin to die.

State how you would explain to the general public how the pH scale is used to describe levels of acidity. [2]

.....

.....

.....

(b) An equation for the reaction of sulfur dioxide with water is shown below.

$$SO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HSO_3^-(aq)$$

(i) Use the equation to explain why sulfur dioxide is described as an acidic oxide. [1]

.....

.....

(ii) A solution of sulfur dioxide in water reaches a position of *dynamic equilibrium*. Explain what is meant by the term ***dynamic equilibrium***. [1]

.....

.....

(iii) Use Le Chatelier's principle to explain how the concentration of hydrogen ions, $H^+(aq)$, would change if more sulfur dioxide were dissolved in a solution that had reached dynamic equilibrium. [2]

.....

.....

.....

SECTION B

Answer **all** *the questions in the spaces provided.*

5. *(a)* Polluting gases such as sulfur dioxide, SO_2, produced from power stations, can cause the acidification of lakes far from the source of the pollution. At a lake-water pH of 6·0, water snails start to die and when the pH reaches 5·5, fish also begin to die.

State how you would explain to the general public how the pH scale is used to describe levels of acidity. [2]

.....

.....

.....

(b) An equation for the reaction of sulfur dioxide with water is shown below.

$$SO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HSO_3^-(aq)$$

(i) Use the equation to explain why sulfur dioxide is described as an acidic oxide. [1]

.....

.....

(ii) A solution of sulfur dioxide in water reaches a position of *dynamic equilibrium*. Explain what is meant by the term ***dynamic equilibrium***. [1]

.....

.....

(iii) Use Le Chatelier's principle to explain how the concentration of hydrogen ions, $H^+(aq)$, would change if more sulfur dioxide were dissolved in a solution that had reached dynamic equilibrium. [2]

.....

.....

.....

9. Sodium hydroxide and chlorine are important industrial chemicals.
Two methods for making them from sodium chloride solution (brine) are the mercury cell and the diaphragm cell.

Process	*Operation*	*Quality of product*
Diaphragm cell	Needs diaphragm replacing regularly. High electrical current needed.	Contains unreacted sodium chloride. Concentration varies and is relatively low.
Mercury cell	No diaphragm used. High electrical current.	Pure sodium hydroxide solution produced at high concentration.

(a) (i) Use the table to suggest **one** important consideration when choosing which process to use. [1]

.....

(ii) If a new process is to be developed as an **alternative** to the two processes outlined above, suggest **two** environmental or technical factors that should be considered when developing this new process. [2]

1. .....

.....

2. .....

.....

(b) Some students obtained a sample of the sodium hydroxide solution from the diaphragm cell process.

(i) This solution was too concentrated for a normal titration and they needed to dilute it **exactly** ten times using water.
Describe, stating the apparatus used and any essential details, how this dilution was done.
You should assume that you need 250 cm^3 of the diluted solution. [4]
QWC [2]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(ii) 20·0 cm^3 of the diluted sodium hydroxide solution reacted with 0·00500 mole of hydrochloric acid.

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

I. State the number of moles of sodium hydroxide present in the 20·0 cm^3 sample. [1]

.....

II. Calculate the concentration of the **diluted** sodium hydroxide solution. [2]

.....

.....

..... mol dm^{-3}

III. State the concentration of the **original** sodium hydroxide solution. [1]

.....

.....

..... mol dm^{-3}

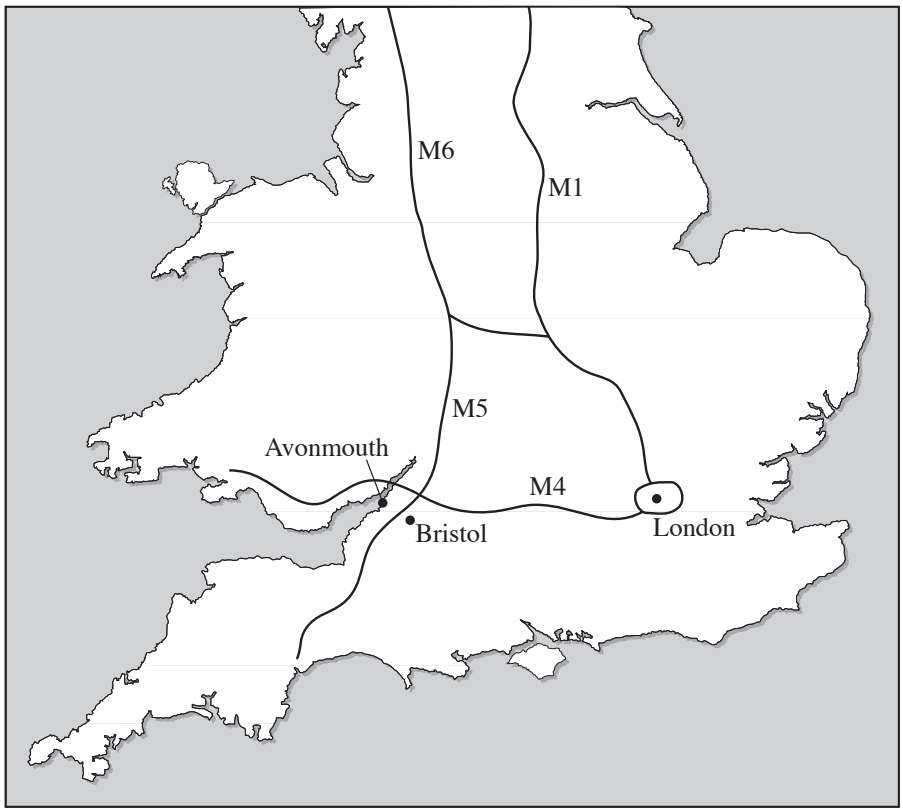
IV. State how you would identify the end-point of this titration. [1]

.....

Total [14]

Section B Total [70]

(iv) In Britain, an ammonia factory is sited at Avonmouth on the banks of the River Severn near Bristol.



Give **two** reasons why this site was chosen. [2]

.....

.....

(b) (i) Write an equation for the acid-base reaction of ammonia with sulfuric acid. [1]

.....

(ii) Explain why ammonia behaves as a base in this reaction. [1]

.....

.....

(iii) Farmers use ammonium sulfate as a fertiliser.

Calculate the percentage by mass of nitrogen in ammonium sulfate, $(NH_4)_2SO_4$. [2]

.....

.....

.....

Total [15]

(b) In some countries, ethanol is replacing petrol (octane) as a car fuel.

(i) When ethanol, C_2H_5OH, is burnt in air, the only products are carbon dioxide and water.

Balance the following equation for this reaction. [1]

C_2H_5OH + ... O_2 ⟶ ..... CO_2 + ... H_2O

(ii) Use the standard enthalpy change of formation values given in the table to calculate the standard enthalpy change, $\Delta H^{\ominus}$, for the combustion of ethanol. [2]

Compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$C_2H_5OH(l)$	–278
$CO_2(g)$	–394
$H_2O(l)$	–286
$O_2(g)$	0

.....

.....

.....

.....

(iii) The standard enthalpy change of combustion for octane $\Delta H_c^{\ominus}(C_8H_{18})$ is –5512 kJ mol^{-1}.

Using this value and your answer to *(b)*(ii), show that octane gives more energy per gram of fuel burned than ethanol. [2]

.....

.....

.....

.....

(iv) Suggest a reason why ethanol is being used rather than petrol. [1]

.....

.....

Total [11]

9. Elinor is given a mixture containing sodium carbonate and she carries out a two-part experiment to determine the percentage of sodium carbonate in the mixture.

In part 1, she accurately weighs 2.05 g of the mixture, transfers all of it to an appropriate container, adds 100 cm^3 of distilled water to ensure that it all dissolves and accurately makes up the solution to 250 cm^3 with distilled water.

In part 2, she pipettes 25.0 cm^3 of the solution into a container, adds 3 drops of an appropriate indicator and titrates this solution with hydrochloric acid of concentration 0.100 mol dm^{-3}. She repeats this procedure three times and obtains the following results.

Titration	1	2	3	4
Final reading (cm^3)	23.50	24.10	24.10	23.40
Initial reading (cm^3)	0.40	0.15	0.90	0.25
Titre (cm^3)				

(a) Name a suitable container to make up the solution that could be used in part 1. [1]

.....

(b) Complete the table to show the values of the titres. [1]

(c) Identify clearly any anomalous results and calculate a mean value. [1]

.....

.....

(d) The equation for the reaction between sodium carbonate and hydrochloric acid is given below.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

(i) Use your answer to part *(c)* to calculate the number of moles of HCl used in the titration. [1]

.....

.....

(ii) Deduce the number of moles of Na_2CO_3 in 25.0 cm^3 of the solution. [1]

.....

(iii) Calculate the total number of moles of Na_2CO_3 in the original 250 cm^3 solution. [1]

.....

.....

(iv) Calculate the mass of Na_2CO_3 in the original solution. [1]

.....

.....

(v) Calculate the percentage of Na_2CO_3 in the mixture. [1]

.....

.....

(e) Elinor's percentage for sodium carbonate was slightly lower than the actual value. When asked why, she stated 'I did not add the acid drop by drop at the end and so overshot the end-point'.

State **two** other common sources of error in such experiments and explain why Elinor's statement cannot be correct.
(Assume that all the equipment is clean and all chemicals are pure.) [4]

QWC [2]

.....

.....

.....

.....

.....

.....

.....

.....

Total [14]

Section B Total [70]

Examiner only

5. Sketch a diagram to show the shape of a p-orbital. [1]

6. *(a)* Explain the term *dynamic equilibrium* for a chemical system. [1]

.....

.....

(b) Explain how you would tell, from the properties of the system, that equilibrium has been reached. [1]

.....

.....

Section A Total [10]

Examiner only

8. Because of the link to global warming, much effort is being devoted to investigating how emissions of carbon dioxide, CO_2, into the atmosphere by power stations burning fossil fuels can be reduced or eliminated.

(a) One area of investigation is the removal of CO_2 by sodium carbonate. Three possible reactions are:

$Na_2CO_3(s) + CO_2(g) + H_2O(g) \rightleftharpoons 2NaHCO_3(s)$ **Reaction 1**

$3Na_2CO_3(s) + CO_2(g) + 5H_2O(g) \rightleftharpoons 2Na_2CO_3.NaHCO_3.2H_2O(s)$ **Reaction 2**

$5Na_2CO_3(s) + 3CO_2(g) + 3H_2O(g) \rightleftharpoons 2Na_2CO_3.3NaHCO_3(s)$ (Wegscheider's Salt) **Reaction 3**

(i) Giving a reason, determine from the equations which of the three reactions uses sodium carbonate, $Na_2CO_3(s)$, most effectively to absorb $CO_2(g)$. [2]

QWC [1]

.....

.....

.....

(ii) State Le Chatelier's Principle. [1]

.....

.....

.....

(iii) Giving your reasons, use Le Chatelier's Principle to determine whether $CO_2(g)$ removal will be more efficient at high gas pressure or low gas pressure. [2]

.....

.....

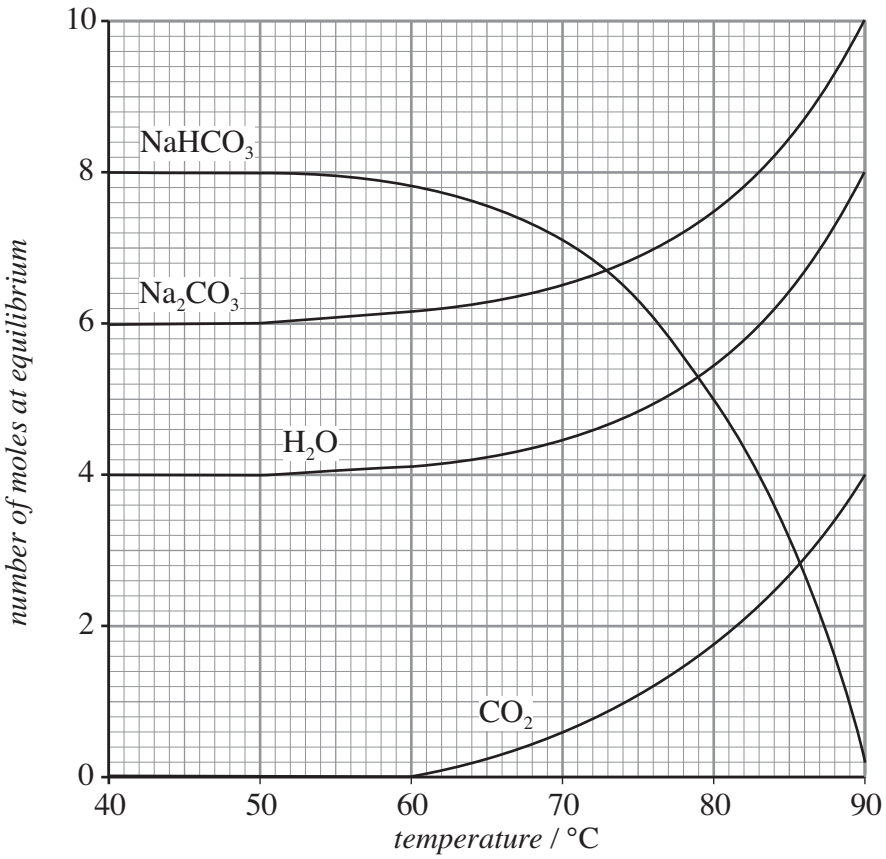
.....

Examiner only

(b) For one industrial system using **Reaction 1**

$$Na_2CO_3(s) + CO_2(g) + H_2O(g) \rightleftharpoons 2NaHCO_3(s)$$

the amount of each species present at equilibrium was measured over a range of temperatures. The graph below shows the results.



(i) Giving your reasoning, determine from the graph whether the forward reaction in **Reaction 1** is exothermic or endothermic. [2]

.....

.....

.....

(ii) After the removal of $CO_2(g)$, the solid $NaHCO_3$ residue is taken away and recycled to regenerate sodium carbonate, $Na_2CO_3(s)$.

I By using the graph, or otherwise, determine how sodium carbonate, $Na_2CO_3(s)$, can be regenerated from the $NaHCO_3$ residue. [1]

.....

II State **one** problem associated with the regeneration of sodium carbonate, $Na_2CO_3(s)$, by the method you have given. [1]

.....

.....

Examiner only

(c) Another area of investigation is the use of a new type of plastic membrane, structured by means of nanotechnology, to catch carbon dioxide gas whilst allowing other waste gases to pass freely through.

If 1000 dm^3 of waste gas at 25 °C yielded 275 g of carbon dioxide, separated by a plastic membrane, calculate:

(i) the number of moles of carbon dioxide in the 275 g separated by the membrane; [2]

.....

.....

(ii) the volume of carbon dioxide separated at 25 °C; [1]

.....

.....

[One mole of gas has a volume of 24.0 dm^3 at 25 °C and 1 atm pressure]

(iii) the percentage by volume of carbon dioxide in the waste gas. [1]

.....

.....

(d) Carbon dioxide, CO_2 is an *acid gas*.

(i) Define the term *acid*. [1]

.....

(ii) By considering its interaction with water, explain how carbon dioxide can behave as an acid. [1]

.....

.....

(iii) Though the pH of pure water is 7, explain why naturally-occurring water in contact with air has a pH of less than 7. [1]

.....

.....

Total [17]

Examiner only

10. Ammonia, NH_3, and hydrochloric acid, HCl, undergo an acid-base reaction in aqueous solution.

$$NH_3(aq) + HCl(aq) \longrightarrow NH_4^+(aq) + Cl^-(aq)$$

(a) Explain why this is an acid-base reaction, clearly identifying **both** the acidic and basic reactants. [2]

.....

.....

.....

.....

(b) A 25 cm^3 sample taken from a stock aqueous solution of ammonia was mixed with 25 cm^3 of a solution containing excess hydrochloric acid. The temperature of the mixture rose by 0.7 °C.

(i) Given that the enthalpy change for the reaction, ΔH, is $-53.4\ kJ\ mol^{-1}$, use the equation below to calculate n, the number of moles of ammonia, NH_3, which has reacted.

$$\Delta H = \frac{-vc\Delta T}{n}$$

where v is the **total** volume of solution (cm^3)
c is the specific heat capacity ($4.2\ J\ cm^{-3}\ °C^{-1}$)
ΔT is the temperature change (°C)
n is the number of moles of ammonia reacted [3]

.....

.....

.....

(ii) Calculate the concentration (mol dm^{-3}) of the original ammonia stock solution. [1]

.....

.....

Examiner only

(c) The concentration of the same stock aqueous solution of ammonia used in part *(b)* was also determined by an acid-base titration. Three separate 25.00 cm^3 samples of the ammonia solution were titrated against hydrochloric acid of concentration 0.1000 mol dm^{-3} from a burette, using an appropriate indicator.

The three titre volumes were 31.25 cm^3, 31.25 cm^3 and 31.20 cm^3 respectively.

(i) Calculate the mean titre volume and use this to find the concentration (mol dm^{-3}) of the ammonia solution. [2]

.....

.....

.....

(ii) Compare the concentration values for the stock ammonia solution obtained by the two experimental methods, *(b)*(ii) and *(c)*(i). State which experiment will give the more precise value, giving **two** reasons for your choice. [3]

.....

.....

.....

.....

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

7. Ammonia, NH_3, is produced from nitrogen and hydrogen.

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

(a) Typically, this process is carried out at a temperature of 450 °C, at a pressure of 250 atmospheres and in the presence of an iron catalyst. The yield is around 15%.

(i) If this reaction were carried out using a reduced pressure of 50 atmospheres, the process would be safer because of the lower pressure used.

State **one** disadvantage of using this lower pressure. [1]

.....

(ii) In the actual process some of the ammonia is removed as the reaction proceeds.

State and explain what effect this removal has on the position of equilibrium. [2]

.....

.....

.....

(iii) How would the equilibrium yield be affected if the reaction were run without using the catalyst? [1]

.....

(b) Some of the ammonia is reacted with sulfuric acid to produce the fertiliser ammonium sulfate.

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

(i) State the molar masses of

ammonia ..... g ammonium sulfate ..... g [1]

(ii) Calculate the maximum mass of ammonium sulfate, in tonnes, that can be made from 17.03 tonnes of ammonia. [3]

.....

.....

.....

.....

Examiner only

SECTION B

Answer **all** *questions in the spaces provided.*

7. Ammonia, NH_3, is produced from nitrogen and hydrogen.

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

(a) Typically, this process is carried out at a temperature of 450 °C, at a pressure of 250 atmospheres and in the presence of an iron catalyst. The yield is around 15%.

(i) If this reaction were carried out using a reduced pressure of 50 atmospheres, the process would be safer because of the lower pressure used.

State **one** disadvantage of using this lower pressure. [1]

.....

(ii) In the actual process some of the ammonia is removed as the reaction proceeds.

State and explain what effect this removal has on the position of equilibrium. [2]

.....

.....

.....

(iii) How would the equilibrium yield be affected if the reaction were run without using the catalyst? [1]

.....

(b) Some of the ammonia is reacted with sulfuric acid to produce the fertiliser ammonium sulfate.

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

(i) State the molar masses of

ammonia ..... g ammonium sulfate ..... g [1]

(ii) Calculate the maximum mass of ammonium sulfate, in tonnes, that can be made from 17.03 tonnes of ammonia. [3]

.....

.....

.....

.....

Examiner only

(c) In sea water there are equilibria between carbon dioxide, hydrogencarbonate (HCO_3^-) ions and carbonate (CO_3^{2-}) ions.

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

$$H^+(aq) + CO_3^{2-}(aq) \rightleftharpoons HCO_3^-(aq)$$

(i) Use Le Chatelier's Principle to predict the effect on the first equilibrium and the change in pH when more carbon dioxide is dissolved. [2]

.....

.....

.....

(ii) State what would be the effect on the concentration of carbonate (CO_3^{2-}) ions of increasing the concentration of hydrogen (H^+) ions in the second equilibrium. [1]

.....

(d) The solubility of carbon dioxide, M_r 44, in water at 25 °C and atmospheric pressure is 0.145 g / 100 g H_2O.

Calculate its concentration in mol dm^{-3}. [2]

.....

.....

.....

Total [15]

Examiner only

11. Potash is a common name for potassium carbonate. Originally, potash was obtained by adding water to the ash produced from the burning of wood, filtering and evaporating the filtrate.

(a) Meirion was asked to find the percentage of potash that could be obtained from some wood ash. He added water to a known mass of wood ash, stirred the mixture and then filtered the product. The filtrate was then made up to a volume of 250 cm^3.

(i) State why the mixture was stirred. [1]

.....

.....

(ii) Describe, giving full practical details, how the volume was made up to **exactly** 250 cm^3. [4]

.....

.....

.....

.....

.....

.....

(iii) The filtrate was an alkaline solution of potassium carbonate. This was titrated against a standard hydrochloric acid solution to find the concentration of the potassium carbonate.

$$K_2CO_3 + 2HCl \longrightarrow 2KCl + CO_2 + H_2O$$

Methyl orange was used as an indicator; this turns from yellow in the potassium carbonate solution to pink when the potassium carbonate is neutralised by the hydrochloric acid. The following results were obtained using 25.00 cm^3 samples of the potassium carbonate solution.

Burette finish / cm^3	24.80	26.20	26.55
Burette start / cm^3	0.00	1.60	2.00

I Calculate the mean volume of hydrochloric acid added, using all three sets of results. [1]

.....

.....

Examiner only

II Describe the practical steps used to obtain a titration value. You should start by measuring 25.00 cm^3 of the potassium carbonate solution from the 250 cm^3 stock solution, with the acid already in the burette. [5]

QWC [1]

.....

.....

.....

.....

.....

.....

.....

(b) In another experiment Penny obtained white crystals of potassium carbonate, K_2CO_3, from the wood ash.

(i) Show that the percentage by mass of potassium in K_2CO_3 is 56.6. [2]

.....

.....

(ii) Some of Penny's crystals were analysed for potassium by flame emission spectroscopy. The results showed that the percentage of potassium present was 44.9%.
Penny suggested that the crystals of potassium carbonate might be a hydrate, $K_2CO_3.2H_2O$.

Explain why the percentage of potassium in the hydrate is lower than the value stated in (i). [1]

.....

.....

(c) Potassium compounds are usually obtained from mineral deposits of potassium chloride rather than from wood ash.

Suggest **one** environmental disadvantage of using wood ash to obtain potassium compounds. [1]

.....

.....

Total [16]

Section B Total [70]

Examiner only

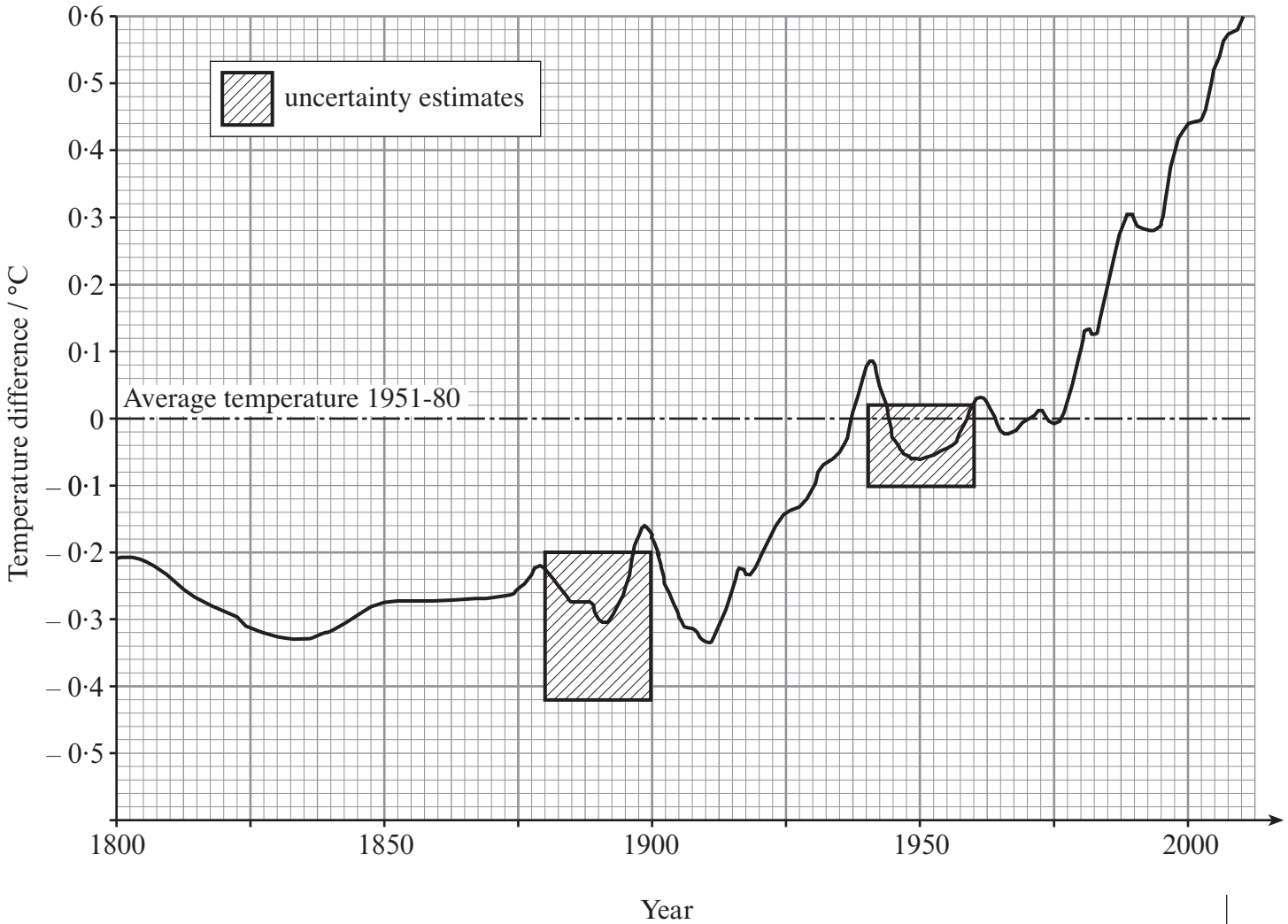
8. *(a)* During the last 200 years, the average temperature of the Earth has risen. One hypothesis put forward by many scientists is that this is due to increased concentrations of carbon dioxide and other greenhouse gases in the atmosphere.

The table below shows the concentration of carbon dioxide in the atmosphere at 50 year intervals since 1800.

	Year				
	1800	1850	1900	1950	2000
Concentration of carbon dioxide in the atmosphere / % by volume	0.0282	0.0288	0.0297	0.0310	0.0368

The following graph based on data from NASA research, shows the annual global temperature relative to the average temperature between 1951 and 1980.

Global Temperature



Examiner only

(i) Explain how these two sets of data led many scientists to this hypothesis. [2]
QWC [1]

.....

.....

.....

.....

.....

(ii) Suggest why the data does not convince all scientists that this hypothesis is true.[1]

.....

.....

(iii) Suggest **two** reasons why the uncertainty is greater in the period 1880-1900 than the period 1940-1960. [2]

.....

.....

.....

.....

(iv) Give **two** reasons for the changing amounts of carbon dioxide in the atmosphere after 1900. [2]

.....

.....

.....

Examiner only

(b) In fizzy drinks, carbon dioxide is dissolved in water under pressure and when the pressure is released the 'fizz' appears.

In a bottle of fizzy drink, the following chemical equilibrium exists:

$$CO_2(g) \rightleftharpoons CO_2(aq)$$

(i) Chemical equilibria are often described as dynamic equilibria.
Explain the term *dynamic equilibrium.* [1]

.....

.....

(ii) When the top is removed from a bottle of fizzy drink it goes 'flat' because much of the dissolved carbon dioxide comes out of solution.
Explain why this happens in terms of chemical equilibria. [2]
QWC [1]

.....

.....

.....

.....

Total [12]

Examiner only

(b) Recently hydrogen has been receiving interest as a 'source of energy'.
It can be prepared by the steam reforming of methane.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = 206\,kJ\,mol^{-1}$$

(i) State Le Chatelier's Principle. [1]

.....

.....

.....

(ii) Giving your reasons, state how the equilibrium yield of hydrogen is affected, if at all, by

I increasing the temperature at constant pressure, [2]

.....

.....

.....

II increasing the pressure at constant temperature. [2]

.....

.....

.....

(iii) Calculate the atom economy of hydrogen production in the above reaction. [2]

.....

.....

.....

Examiner only

(c) Describe how industry is adapting to the challenges of *Green Chemistry*. Your answer should include reference to the

- overall aim of Green Chemistry,
- materials used or produced,
- energy used. [3]

QWC [1]

.....

.....

.....

.....

.....

.....

.....

Total [12]

Examiner only

9. This question is about equilibria in seawater and the effect of carbon dioxide from burning fuels on the acidity of seawater. It involves the use of Le Chatelier's principle.

(a) State *Le Chatelier's principle*. [1]

.....

.....

(b) Describe in simple terms what is meant by pH. [1]

.....

.....

(c) About half of the carbon dioxide formed by burning fossil fuels dissolves in the oceans. The equilibrium may be written simply as:

$$CO_2 + H_2O \rightleftharpoons H^+ + HCO_3^-$$

(i) State, giving a reason in both cases, the effect that increasing carbon dioxide concentrations have on

I the ocean's acidity, [1]

.....

.....

II the pH of seawater. [1]

.....

.....

(ii) Another important equilibrium in the ocean is that between hydrogencarbonate and carbonate ions.

$$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$$

State, giving a reason, the effect of increasing acidity on the amount of carbonate present. [1]

.....

.....

(iii) Many animals in the ocean make shells of calcium carbonate using the equilibrium:

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightleftharpoons CaCO_3(s)$$

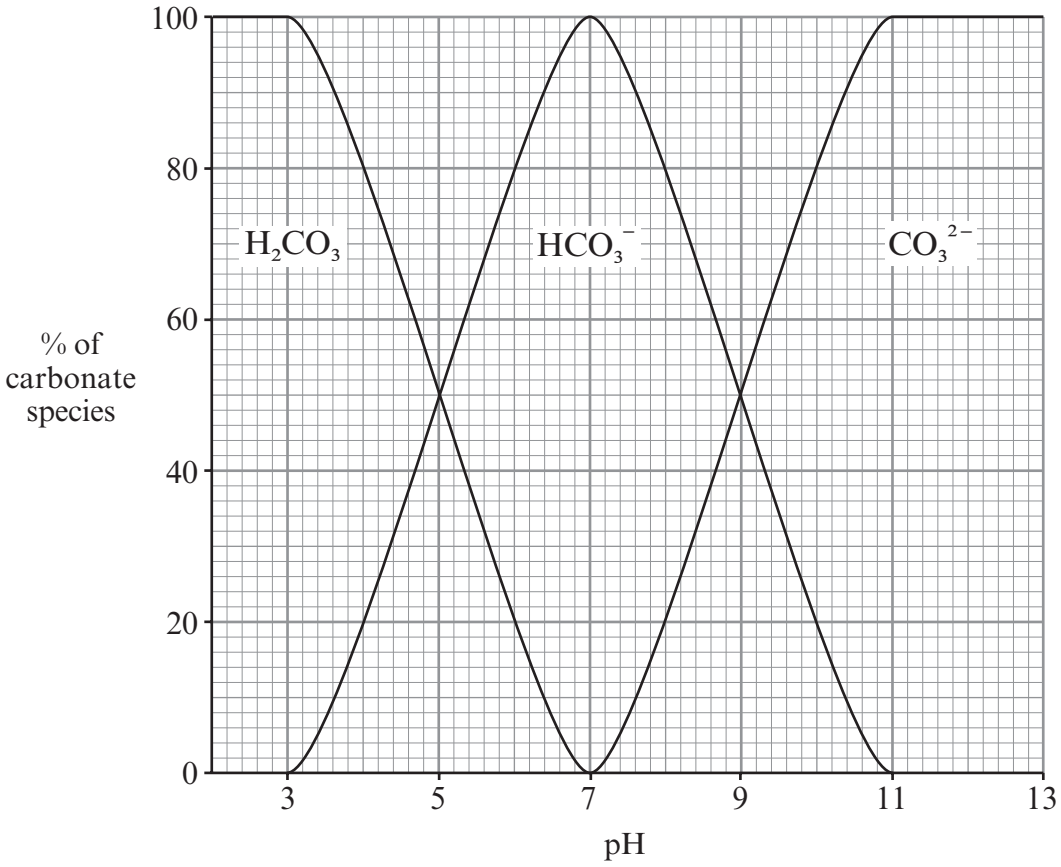
Using your answer to parts (i) and (ii), state and explain the effect of increasing acidity on their ability to make shells. [1]

.....

.....

Examiner only

(d) The plot below shows how the proportions of the three carbonate species in the ocean change with pH.



Using the graph, find the pH of the ocean if it contains 90% hydrogencarbonate ions and 10% carbonate ions. [1]

.....

(e) A study of a model ocean included measuring a hydrogencarbonate concentration by titrating with acid.
25.00 cm^3 of hydrogencarbonate solution was neutralised by 19.60 cm^3 of hydrochloric acid of concentration 0.095 mol dm^{-3}, the equation being:

$$HCO_3^- + H^+ \longrightarrow H_2CO_3$$

Calculate the concentration of hydrogencarbonate ions in the solution. [2]

.....

.....

.....

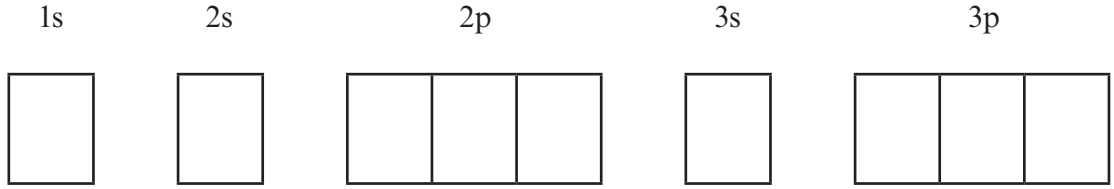
Total [9]

Examiner only

SECTION A

Answer **all** *questions in the spaces provided.*

1. By inserting arrows to represent electrons, complete the boxes below to show the electronic configuration of a sulfur atom. [1]



2. State the number of protons present in an aluminium ion, Al^{3+}. [1]

A 10
B 13
C 14
D 16

.....

3. Weak *acids* establish a *dynamic equilibrium* when dissolved in water.
Give brief explanations of what is meant by the following terms. [2]

Acid .....

.....

Dynamic equilibrium .....

.....

.....

Examiner only

(c) One method of producing the hydrogen gas required for the Fischer-Tropsch process is to use the reversible reaction below.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -42\,kJ\,mol^{-1}$$

(i) State and explain the effect, if any, of increasing pressure on the yield of hydrogen gas produced at equilibrium. [2]

.....

.....

.....

(ii) State and explain the effect, if any, of increasing temperature on the yield of hydrogen gas produced at equilibrium. [2]

.....

.....

(iii) This reaction uses a catalyst based on iron oxide. State the effect of using a catalyst on the position of equilibrium. [1]

.....

Total [19]

Examiner only

9. Ethanol is an important industrial chemical and can be made by the direct hydration of ethene using a phosphoric acid catalyst.

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \quad \Delta H = -46\,kJ\,mol^{-1}$$

(a) State, giving your reasons, the general conditions of temperature and pressure required to give a high equilibrium yield of ethanol in this process. [4]

QWC [1]

.....

.....

.....

.....

.....

.....

(b) Using the standard enthalpy change for the reaction above and the standard enthalpy changes of formation ($\Delta H_f^{\ominus}$) given in the table below, calculate the standard enthalpy change of formation of gaseous ethanol. [3]

Compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$CH_2{=}CH_2(g)$	52.3
$H_2O(g)$	–242

.....

.....

.....

.....

Examiner only

10. Berian was asked to find the identity of a Group 1 metal hydroxide by titration.

He was told to use the following method.

- Fill a burette with hydrochloric acid solution.
- Accurately weigh about 1.14 g of the metal hydroxide.
- Dissolve all the metal hydroxide in water, transfer the solution to a volumetric flask then add more water to make exactly 250 cm^3 of solution.
- Accurately transfer 25.0 cm^3 of this solution into a conical flask.
- Add 2-3 drops of a suitable indicator to this solution.
- Carry out a rough titration of this solution with the hydrochloric acid.
- Accurately repeat the titration several times and calculate a mean titre.

Berian's results are shown below:

Mass of metal hydroxide = 1.14 g

Concentration of acid solution = 0.730 g HCl in 100 cm^3 of water

Mean titre = 23.80 cm^3

(a) Give a reason why Berian does not simply add 1.14 g of metal hydroxide to 250 cm^3 of water. [1]

.....

.....

(b) Name a suitable piece of apparatus for transferring 25.0 cm^3 of the metal hydroxide solution to a conical flask. [1]

.....

(c) State why he adds an indicator to this solution. [1]

.....

(d) Suggest why Berian was told to carry out a rough titration first. [1]

.....

.....

Examiner only

(e) Explain why he carried out several titrations and calculated a mean value. [1]

.....

.....

(f) The equation for the reaction between the metal hydroxide and hydrochloric acid is given below. M represents the symbol of the Group 1 metal.

$$MOH + HCl \longrightarrow MCl + H_2O$$

(i) Calculate the concentration, in mol dm^{-3}, of the HCl in the burette. [2]

.....

.....

(ii) Calculate the number of moles of HCl used in the titration. [1]

.....

.....

(iii) Deduce the number of moles of MOH in 25.0 cm^3 of the solution. [1]

.....

(iv) Calculate the total number of moles of MOH in the original solution. [1]

.....

.....

(v) Calculate the relative molecular mass of MOH. [1]

.....

.....

(vi) Deduce the Group 1 metal in the hydroxide. [1]

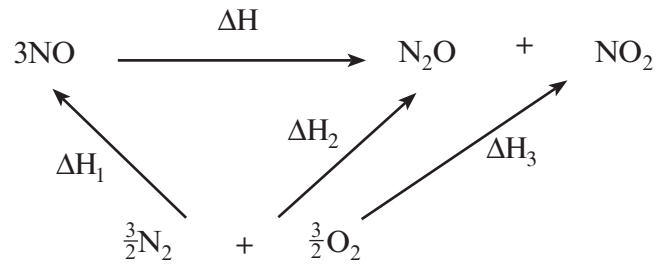
.....

Total [12]

Section B Total [70]

Examiner only

4. The energy cycle for a decomposition of nitrogen(II) oxide is shown below.



(a) Complete the equation to show ΔH in terms of ΔH_1, ΔH_2 and ΔH_3. [1]

ΔH = ...

(b) Write the chemical equation for the standard molar enthalpy change of formation of gaseous nitrogen(II) oxide, NO. [1]

.....

5. Carbon oxide sulfide, COS, is obtained by heating together carbon monoxide and gaseous sulfur.

$$2CO(g) + S_2(g) \rightleftharpoons 2COS(g)$$

State and explain any change that occurs when more carbon monoxide is added to the equilibrium mixture. [2]

.....

.....

.....

.....

.....

.....

1091 010003

Examiner only

(d) When sodium carbonate is added to water, some of the carbonate ions react with the water to give an alkaline solution.

$$CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^{-}(aq) + OH^{-}(aq)$$

(i) Explain why this reaction is considered to be an acid-base reaction. [2]

.....

.....

.....

.....

(ii) The pH of a sodium carbonate solution is 11.4.
How would you explain the meaning of the pH scale to a member of the public? [3]

.....

.....

.....

.....

.....

.....

Total [15]

Examiner only

(d) Scientists have commented that 'an increase in the amount of carbon dioxide dissolved in sea water will cause problems for animals whose shells are composed of calcium carbonate'.

$$CO_2(aq) + H_2O(l) + CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + 2HCO_3^-(aq)$$

Use the equation above to help you discuss the problem that is caused for these animals by this increase in carbon dioxide concentration. [3]

QWC [1]

.....

.....

.....

.....

.....

.....

.....

.....

Total [15]

Examiner only

11. *(a)* An aqueous solution of methanoic acid can be used to dissolve 'lime scale' in kettles. The concentration of a methanoic acid solution used for this purpose can be found by a titration using sodium hydroxide solution. For this purpose a 25.0 cm^3 sample of aqueous methanoic acid was diluted to 250 cm^3.

(i) State the name of the piece of apparatus used to

I measure out 25.0 cm^3 of aqueous methanoic acid, [1]

.....

II contain exactly 250 cm^3 of the diluted solution. [1]

.....

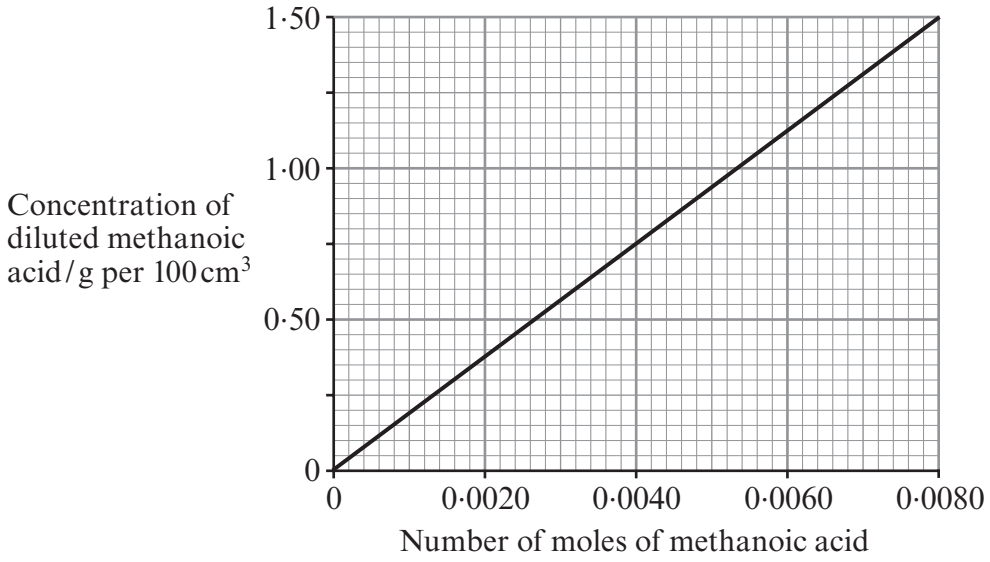
(ii) A 25.0 cm^3 sample of the diluted methanoic acid was titrated with sodium hydroxide solution of concentration 0.200 mol dm^{-3}. A volume of 32.00 cm^3 was needed to react with all the methanoic acid present.

Calculate the number of moles of sodium hydroxide used. [1]

Moles of sodium hydroxide = ... mol

Examiner only

(iii) Methanoic acid and sodium hydroxide react together in a 1:1 molar ratio. Use the graph below and your result from (ii) to find the concentration of methanoic acid present in the diluted solution in g per 100 cm^3 of solution. [1]



Concentration = ... g per 100 cm^3

(iv) State the concentration of the original methanoic acid in g per 100 cm^3 solution. [1]

Original concentration = ... g per 100 cm^3

Examiner only

(c) The relative molecular mass of methanoic acid is 46.02.

State why this quantity does not have units. [1]

.....

.....

(d) Methanoic acid reacts with propan-1-ol to give 1-propyl methanoate.

$$HCOOH + CH_3CH_2CH_2OH \rightleftharpoons \underset{\text{1-propyl methanoate}}{HCOOCH_2CH_2CH_3} + H_2O$$

(i) This reaction eventually reaches dynamic equilibrium.
State what is meant by *dynamic equilibrium*. [1]

.....

.....

.....

(ii) Give the empirical formula of 1-propyl methanoate. [1]

Empirical formula .....

Total [12]

Section B Total [70]

END OF PAPER

Examiner only

5. Name an element that has a half-filled set of *p*-orbitals. [1]

.....

6. Vinegar is a dilute solution of a weak acid.

(a) State what is meant by an *acid*. [1]

.....

.....

(b) Suggest a pH value for vinegar. [1]

.....

Section A Total [10]

Examiner only

10. Hydrated sodium carbonate, $Na_2CO_3.xH_2O$, is a crystalline solid that can be used to prepare a standard solution for titration.

(a) The relative molecular mass of this hydrated sodium carbonate is 286.2. Calculate the value of x in this formula. [1]

x = ...

(b) Emily wants to prepare 250 cm^3 of a solution of sodium carbonate of concentration 0.200 mol dm^{-3} using this hydrated sodium carbonate.

(i) Calculate the mass of hydrated sodium carbonate needed to prepare this solution. [2]

Mass of hydrated sodium carbonate = ... g

(ii) Emily proposes to make the solution by the following method.

- Weigh the required mass of hydrated sodium carbonate.
- Place the hydrated sodium carbonate in a beaker and add 250 cm^3 of distilled water.
- Stir the mixture until all the sodium carbonate dissolves.
- Transfer the solution to the volumetric flask and shake.

Her teacher said that the method was not correct. Suggest **two** changes that Emily should make to her method. [2]

1. .....

.....

.....

2. .....

.....

.....

Examiner only

(c) Emily then prepared 250 cm^3 of sodium carbonate solution of concentration 0.200 mol dm^{-3} using a correct method. She took 25.0 cm^3 samples of the sodium carbonate solution and titrated these using a solution of sulfuric acid, H_2SO_4, of unknown concentration. The acid was placed in the burette.

Describe how Emily should perform one titration to find the volume of sulfuric acid needed for complete reaction. [4]

QWC [1]

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

Total [10]

Examiner only

12. *(a)* The combustion of fossil fuels containing sulfur impurities is known to cause acid rain. This acid rain can cause the erosion of marble statues as the calcium carbonate in them reacts with the acid in the rain.

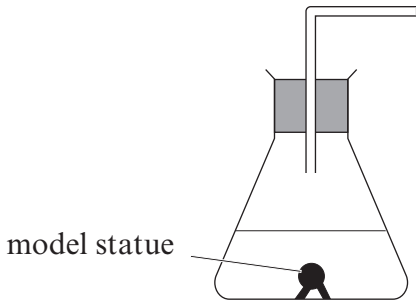
Give **one** other problem caused by acid rain. [1]

.....

.....

(b) A chemist is developing coatings for marble that will slow down the rate of their erosion by acid rain. To compare different coatings he uses small model statues, all of which are the same size and shape as each other. He proposes to measure the rate of reaction by adding acid and measuring the volume of gas given off at set time intervals.

(i) Complete the diagram to show the apparatus that could be used to perform this experiment. [1]



(ii) Explain why it is important that the model statues are the same size and shape as each other. [1]

.....

.....

(iii) State **two** other factors he will need to keep constant if he is to collect valid data. [2]

.....

.....

Examiner only

(c) One gas that causes acid rain is sulfur dioxide. This gas is used to produce sulfur trioxide in the Contact Process. The reaction occurring is shown in the following equation.

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

(i) State and explain the effect of increasing pressure on the equilibrium yield of sulfur trioxide. [2]

.....

.....

.....

.....

(ii) When the temperature is increased the rate at which equilibrium is reached is increased and the yield of sulfur trioxide is decreased.

I State whether this reaction is endothermic, exothermic or neither, giving a reason for your answer. [2]

.....

.....

.....

.....

Examiner only

10. *(a)* Sodium carbonate can be manufactured in a two-stage process as shown by the following equations.

$$NaCl + NH_3 + CO_2 + H_2O \longrightarrow NaHCO_3 + NH_4Cl$$

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$

Calculate the maximum mass of sodium carbonate which could be obtained from 900 g of sodium chloride. [3]

Maximum mass of sodium carbonate = ... g

(b) Sodium carbonate can form a hydrate, $Na_2CO_3.xH_2O$.

When 4.64 g of this hydrate was heated, 2.12 g of anhydrous Na_2CO_3 remained.

(i) State the mass of water in 4.64 g of the hydrate. [1]

.....

(ii) Calculate the number of moles of sodium carbonate and the number of moles of water in 4.64 g of the original hydrate. Use these values to calculate the value of x in $Na_2CO_3.xH_2O$. [2]

x = ...

QUESTION 10 CONTINUES ON PAGE 16

Examiner only

(c) Hannah is given an impure sample of anhydrous sodium carbonate and she carries out an experiment to determine the percentage of sodium carbonate in the sample.
She finds that she needs 18.0 cm^3 of hydrochloric acid of concentration 0.50 mol dm^{-3} to react completely with 0.55 g of the impure sample. The impurity does not react with hydrochloric acid. The equation for the reaction is given below.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

(i) Calculate the number of moles of HCl used in the titration. [1]

Number of moles of HCl = ... mol

(ii) Deduce the number of moles of Na_2CO_3 that reacted with the HCl. [1]

.....

(iii) Calculate the mass of Na_2CO_3 in the sample. [1]

Mass of Na_2CO_3 *in sample* = ... g

(iv) Calculate the percentage by mass of Na_2CO_3 in the sample. [1]

Percentage by mass = ... %

Total [10]

Section B Total [70]

END OF PAPER

Examiner only

10. The decomposition of dinitrogen(IV) oxide into nitrogen(IV) oxide is a reversible reaction that establishes a dynamic equilibrium.

$$\underset{\text{pale yellow}}{N_2O_4(g)} \rightleftharpoons \underset{\text{dark brown}}{2NO_2(g)} \qquad \Delta H = +57 \text{ kJ mol}^{-1}$$

(a) State the meaning of the term *dynamic equilibrium*. [1]

.....

.....

(b) The conditions applied to an equilibrium mixture of dinitrogen(IV) oxide and nitrogen(IV) oxide were changed. For each of the following, state what was **seen** and explain any change that occurred. [5]

Temperature increased

.....

.....

.....

Pressure increased

.....

.....

.....

A catalyst was added

.....

.....

Examiner only

(c) Hydrazine, N_2H_4, is an unstable liquid that decomposes according to the following equation.

$$N_2H_4(l) \longrightarrow N_2(g) + 2H_2(g)$$

(i) Calculate the volume of gas that could be obtained from 14 kg of hydrazine. Assume that the volume of 1 mol of gas is 24.0 dm^3. [3]

Volume of gas = ... dm^3

(ii) One use of hydrazine is as a fuel in rockets. Apart from any energy changes, state **one** feature of this reaction that suggests it would be useful in rocket propulsion. [1]

.....

.....

(d) Nitrogen (IV) oxide reacts with water.

$$H_2O + 2NO_2 \longrightarrow HNO_2 + HNO_3$$

Both nitric(III) acid, HNO_2, and nitric(V) acid, HNO_3, are described as being acids.

(i) Define an *acid*. [1]

.....

(ii) Complete the equation to show nitric(III) acid behaving as an acid. [1]

$$HNO_2 + H_2O \longrightarrow$$

(iii) When concentrated nitric(V) acid is mixed with concentrated sulfuric acid the reaction shown below occurs.

$$HNO_3 + H_2SO_4 \longrightarrow H_2NO_3^+ + HSO_4^-$$

Explain this reaction in terms of acid-base behaviour. [2]

.....

.....

Total [14]