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

1 Planning

An acid can be represented by the general formula, H_xA, where x represents the basicity of the acid.

A bottle of a dilute aqueous solution of an acid, either monobasic or dibasic, was found. However, the label on the bottle had been damaged. Only the concentration of the acid, 1.00 mol dm^{-3} was readable.

A student was given a 1.00 mol dm^{-3} sodium hydroxide solution. She was asked to determine the basicity of the acid in the bottle by mixing different volumes of the acid and sodium hydroxide.

(a) (i) Write an equation to represent the enthalpy change of neutralization between sodium hydroxide and H_xA.

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(ii) A student determined the basicity of the acid by performing the following experiments:

Experiment 1: 30 cm^3 of H_xA(aq) was added to 60 cm^3 of NaOH(aq)
Experiment 2: 60 cm^3 of H_xA(aq) was added to 30 cm^3 of NaOH(aq)

The changes in temperature of the mixture were measured for Experiment 1 and Experiment 2 as ΔT_1 and ΔT_2 respectively.

Suggest and explain the basicity of H_xA if $\Delta T_1 = 2 \times \Delta T_2$.

[3]

(b) For this part, you may assume that the acid is a monobasic acid, HA.

A student decided to determine whether the acid, HA, is a strong or weak acid by performing a series of experiments involving mixing of hydrochloric acid with sodium hydroxide and HA with sodium hydroxide.

Explain how, from the suggested experiment, the student might be able to determine whether HA is a strong or weak acid.

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FA 1 is a solution of sodium hydroxide of unknown concentration.
FA 2 is 1.0 mol dm^{-3} of hydrochloric acid.

Since neutralization reaction is exothermic, a series of experiments can be performed by mixing different volumes of **FA 1** and **FA 2** to determine the concentration of sodium hydroxide.

(c) (i) Write a procedure to determine the temperature changes for the series of reactions between **FA 1** and **FA 2**.

Your answers should include choice of apparatus to measure the volume and temperature of the solutions. Give suitable headings for the columns numbered **1** to **5** as part of the plan of the experiment.

Volume of **FA 1** /cm^3	Volume of **FA 2** /cm^3	**1**	**2**	**3**	**4**	**5**
30.00	40.00					
33.00	37.00					
36.00	34.00					
40.00	30.00					
44.00	26.00					
48.00	22.00					
50.00	20.00					

Headings for

1: ……………………………………………………………………………

2: ……………………………………………………………………………

3: ……………………………………………………………………………

4: ……………………………………………………………………………

5: ……………………………………………………………………………

Procedure

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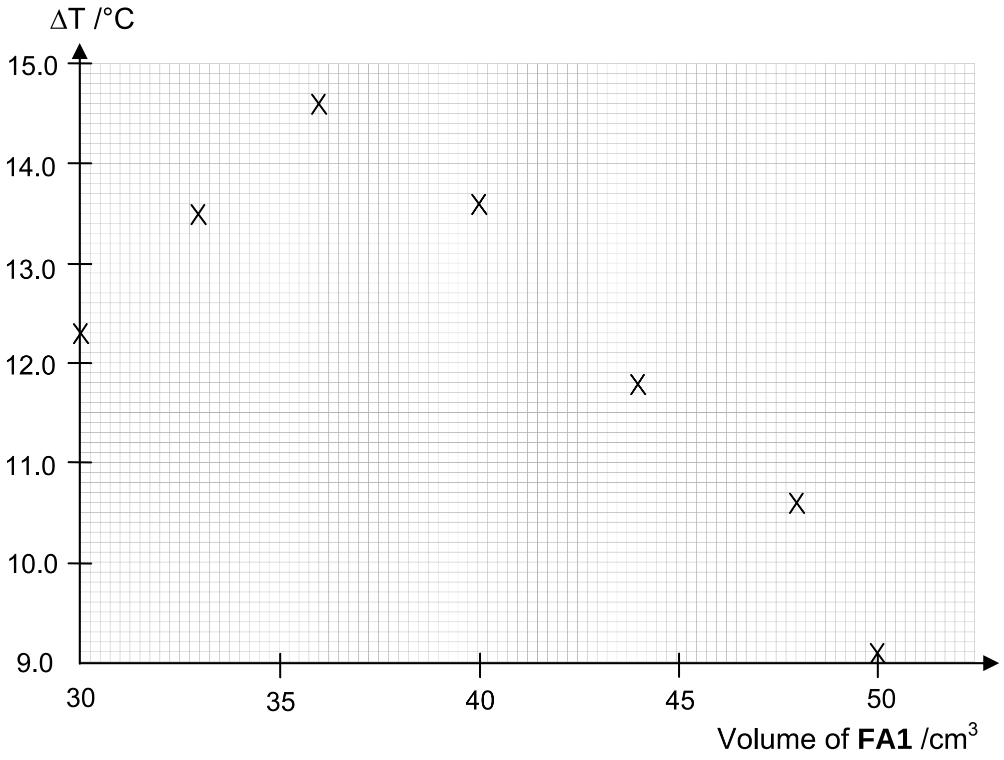
(ii) The following points were plotted on a grid after an experiment. Draw a suitable graph through the plotted points.



(iii) By using the graph in **(ii)**, calculate the concentration of sodium hydroxide in the experiment.

[7]

[Total: 12]

2 Oxoanions of Group VII elements have the general formula **X**O_m^-, where m = 1, 2, 3 or 4. These oxoanions are strong oxidizing agents.

(a) Explain why fluorine does not form oxoanions.

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....[2]

(b) 1.25 x 10^{-3} mol of a bromate salt containing the BrO_m^- anion was added to excess potassium iodide. The resulting mixture was washed with chloroform to dissolve the iodine, and the aqueous and organic layers were separated. Silver nitrate solution was added to the aqueous layer, and a mixture of two precipitates was obtained.

(i) Identify the two precipitates formed.

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(ii) The iodine collected in the organic layer was titrated against 0.500 mol dm^{-3} sodium thiosulfate. 14.90 cm^3 of titrant was required to discharge the blue-black colour of the starch indictor. Calculate the value of $\boldsymbol{m}$.

(iii) The two precipitates can be separated by addition of concentrated aqueous ammonia, followed by filtration. Describe what you expect to observe and explain the chemical principles behind this method.

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[7]

(c) 0.500 g of a Group II iodate(V) salt, $M(IO_3)_2$, was heated and decomposed to give a white solid, a purple gas, and a colourless gas that rekindles a glowing splint.

(i) Identify the 3 decomposition products.

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(ii) Write a balanced equation for the decomposition reaction, including state symbols.

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(iii) Given that 0.0532 g of the white solid was collected, calculate the relative atomic mass of the metal, and hence deduce its identity.

[4]

(d) Predict how the thermal decomposition of barium iodate(V) differs from that of $M(IO_3)_2$. Explain your reasoning.

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....[3]

[Total: 16]

3 The two most abundant atmospheric gases react to a small extent at 298 K in the presence of a catalyst to achieve dynamic equilibrium as shown:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad K_p = 0.30$$

(a) Explain the term *dynamic equilibrium*.

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....[1]

(b) Atmospheric oxygen and nitrogen, each at a partial pressure of 0.780 atm, are put into a 1 dm^3 evacuated flask at 298 K with a catalyst and equilibrium is established after 30 minutes. Calculate the equilibrium partial pressure for each of the three components at 298 K.

[3]

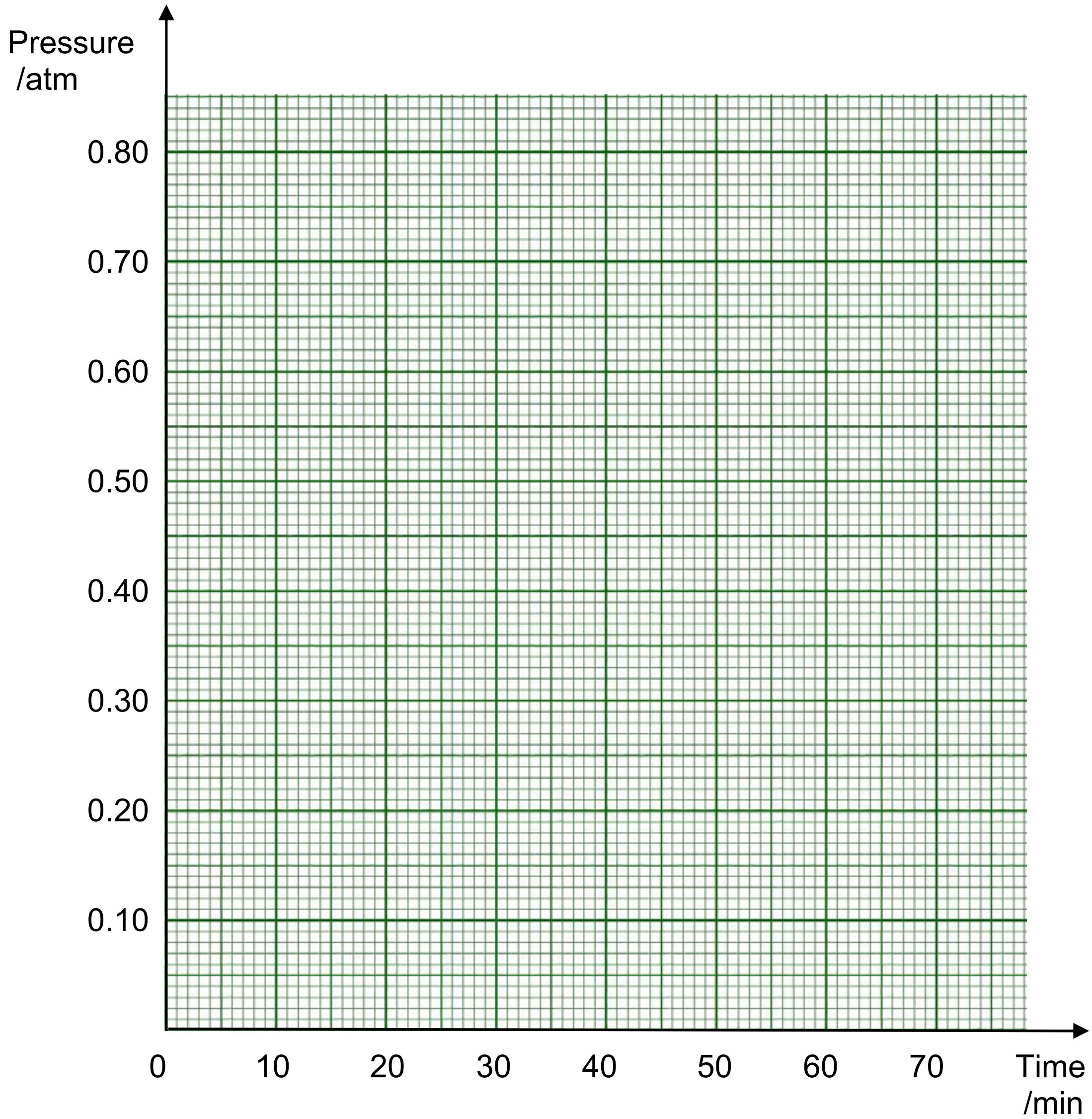
(c) What is the total pressure in the container at equilibrium?

[1]

(d) Find K_c for this reaction at 298 K.

[1]

(e) On the grid below, sketch pressure versus time curves for N_2 and NO under the conditions as described in **(b)** at 298 K from 0 to 40 minutes. Label the curves and indicate significant values on the axes.



[2]

(f) The temperature of the system was raised to 350 K at 40 min.

Given that the reaction is endothermic and equilibrium is re-established at 60 min, sketch on the same axes above, the pressure versus time curves for N_2 and NO from 40 min to 70 min.

[2]

(g) NO is readily oxidised to reddish-brown NO_2. Both NO and NO_2 chemically combine to form N_2O_3.

Draw dot-and-cross diagrams to show the bonding in NO_2 and N_2O_3.

NO_2	N_2O_3

[2]

(h) Explain in terms of structure and bonding, why N_2O_4 has a higher boiling point than NO_2.

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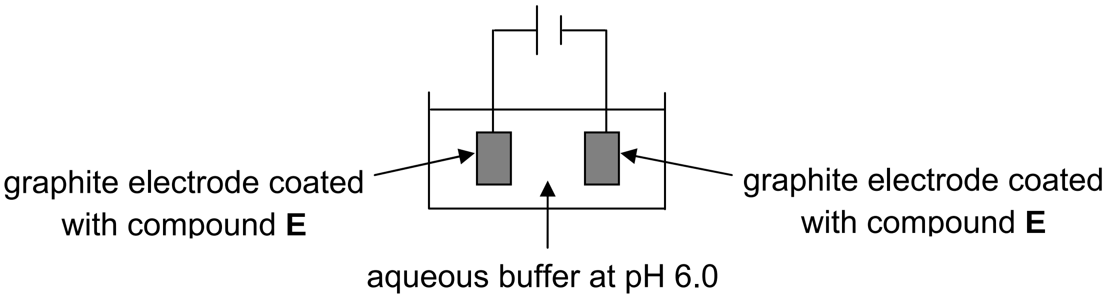
....[2]

[Total: 14]

4 The electrolysis of organic compounds has been well studied since the 1970s. For instance, Kolbe studied the electrolysis of a series of aromatic organic compounds. Compound **E** with the molecular formula, C_6H_7NO is a **1,4-disubstituted aromatic compound** studied using the experimental set-up as shown.



(a) (i) Compound **E** dissolves in both aqueous hydrochloric acid and aqueous sodium hydroxide. However, it does not dissolve in aqueous sodium carbonate. Deduce the structure of compound **E**.

(ii) Compound **E** is oxidised to compound **F**, C_6H_5NO at the anode.

A series of chemical tests was performed on compound **F.** When 2,4-dinitrophenylhydrazine was added, an orange precipitate was observed. No silver mirror was obtained when warmed with aqueous $Ag(NH_3)_2^+$ solution. One mole of compound **F** reacts with excess hydrogen gas in the presence of platinum catalyst to yield compound **G** with molecular formula $C_6H_{13}NO$.

Deduce the structures of compounds **F** and **G**.

[5]

(b) (i) Compound **F** is reduced at the cathode back to compound **E**. Write the half-equation for this reduction using the given molecular formulae.

Cathode: ....

(ii) Using relevant $E^{\ominus}$ data from the *Data Booklet*, explain whether the standard reduction potential of the half equation in **(b)(i)** has a positive or negative value.

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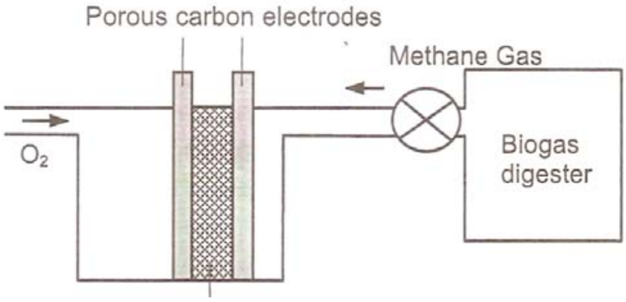
(iii) A current of 2.0 A is supplied to the experimental set-up. Using the half-equation in **(b)(i)**, calculate, in mg/min, the average rate of mass gain at the cathode, given that the molecular mass of compound **E** is 109.0.

[4]

(c) Tonnes of organic waste are dumped into rivers annually in the rural areas of China. Environmental scientists have warned of the danger of dead seas forming in a few decades due to eutrophication (depletion of oxygen in water bodies).

To encourage the reduction of disposal of organic waste into the rivers, the Chinese government built biogas tanks in the rural areas where the inhabitants can obtain electricity from the **combustion of methane gas** generated from the organic waste.

One such biogas tank is shown below:



(i) With reference to methane, define *standard enthalpy change of combustion*.

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(ii) It was found that 10 kg of organic waste on the average generate 0.35 kg of methane gas in a biogas tank. Using relevant data from the *Data Booklet*, estimate the average amount of energy released from 50.5 kg of organic waste deposited into the biogas tank.

(iii) Write the half-equations for the reactions occurring at the anode and cathode of the biogas tank.

Anode: ……………………………………………………………………………

Cathode: …………………………………………………………………………

[6]

[Total: 15]

5 (a) A study by a Dutch research firm tested the efficacy of using pig's blood to filter the harmful chemicals normally ingested by humans when smoking. It was found that pig haemoglobin, when used in cigarette filters, rendered them more effective at trapping harmful chemicals which are thus prevented from entering a smoker's lungs.

The basic structure of this new choice filter is similar to that of any carbon based cigarette filter, but contains haemoglobin absorbed in the activated carbon. These two substances in combination work as a highly efficient scavenger of the harmful gas compounds present in cigarette smoke.

(i) Describe the *quaternary* structure of haemoglobin.

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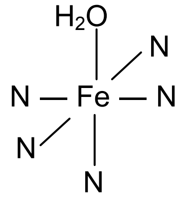
(ii) The iron atom in the haemoglobin molecule contains six 3d electrons and it is surrounded by six ligand atoms as shown below. Five of these are nitrogen atoms from the protein, and one is an oxygen atom from a water molecule.



Predict how haemoglobin is able to function as an efficient scavenger of the harmful carbon monoxide gas present in cigarette smoke.

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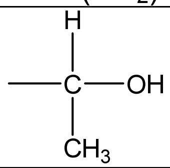
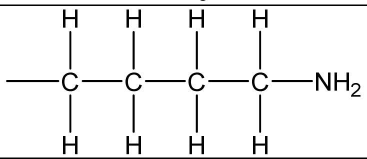
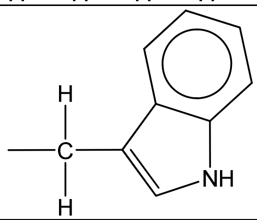
[4]

Optimum amino acid balance is important to maximize growth and efficiency in pigs. Diets are routinely formulated to meet the threonine:lysine and tryptophan:lysine ratio requirement in pig feed.

Information of the three amino acids in the pig feed is listed below.

Amino Acid	Formula of side chain (R' in $R'CH(NH_2)CO_2H$)	Isoelectric Point
Threonine (thr)		5.60
Lysine (lys)		9.60
Tryptophan (trp)		5.89

(b) Draw the structural formula of the dipeptide, lys-trp.

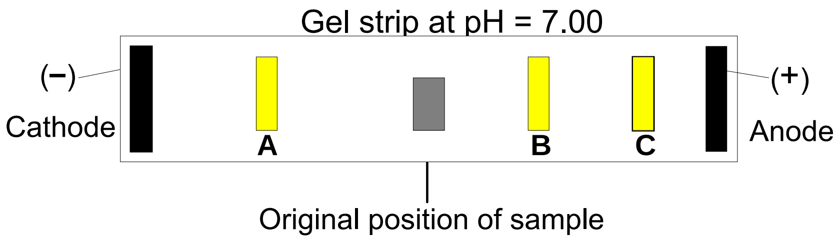
[1]

(c) Draw the structure of threonine at pH = 5.60.

[1]

(d) The technique known as electrophoresis can be used to separate the amino acids. This technique involves placing a solution of different amino acids at the centre of an agarose gel placed in an aqueous solution of a known pH. An electric potential is then applied through electrodes which are connected to the two ends of the gel strip.

An electrophoresis experiment is run on a solution containing the 3 amino acids mentioned above at pH 7.00 and the relative positions of the amino acids are obtained as shown in the diagram.



Draw the structural formulae of the species found at positions **A**, **B** and **C** at the end of the experiment.

Position	Structure at pH = 7.00
A	
B	
C	

[3]

(e) Predict and explain the relative basicity of tryptophan and lysine.

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(f) Draw the structural formula of the organic products when

(i) PCl_5 is added to threonine (thr);

(ii) chloromethane is added to threonine (thr);

(iii) propanoyl chloride is added to tryptophan (trp).

[3]

[Total: 15]