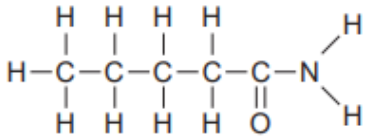
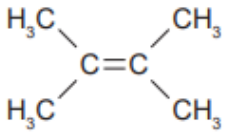
Practice Revision Exam 2021

Short answers

1. [4]

Complete this table by giving the IUPAC name or full structural formula of the indicated organic compounds. All hydrogen atoms must be shown.

Full structural formula	IUPAC name
	
	
	heptan-2-amine
	hexan-3-one

2.

Dilute hydrochloric acid, HCℓ(aq), is added to three labelled test tubes.

(I) Excess copper metal, Cu(s), is added to the first test tube.
(II) Excess copper(II) oxide, CuO(s), is added to the second test tube.
(III) Excess copper(II) carbonate, $CuCO_3$(s), is added to the third test tube.

(a) Describe the contents of the first and second test tubes once **any** reactions are complete. (4 marks)

Test Tube	Description
(I)	
(II)	

(b) Write the balanced equation, with appropriate state symbols, for the reaction that takes place between the copper(II) oxide and the hydrochloric acid. (3 marks)

(c) If the labels of test tubes (II) and (III) became smudged, describe **all** the observations that could be used to distinguish between these test tubes once **any** reactions are complete. (2 marks)

_____

_____

_____

_____

3.

Sulfuric acid is a very useful chemical that is produced industrially by a multi-stepped process. These steps are summarised by the following equations.

Equation 1	$S(\ell)$	+	$O_2(g)$	→	$SO_2(g)$		
Equation 2	$2\ SO_2(g)$	+	$O_2(g)$	⇌	$2\ SO_3(g)$	+	198 kJ
Equation 3	$H_2SO_4(\ell)$	+	$SO_3(g)$	→	$H_2S_2O_7(\ell)$		
Equation 4	$H_2O(\ell)$	+	$H_2S_2O_7(\ell)$	→	$2\ H_2SO_4(\ell)$		

When dihydrogen sulfate, $H_2SO_4(\ell)$, is mixed with water, it produces sulfuric acid, $H_2SO_4(aq)$.

(a) Combine these equations to produce an overall equation for the production of dihydrogen sulfate, $H_2SO_4(\ell)$, from sulfur dioxide, $SO_2(g)$. (2 marks)

(b) Complete the following table by listing the advantages and disadvantages of using high temperatures and high pressures for the reaction represented by Equation 2 above. Consider yield, rate, cost and safety. (6 marks)

	Advantage/s	**Disadvantage/s**
High temperature		
High pressure		

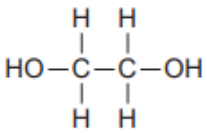
Salvarsan is an organic compound that contains the elements: carbon (C), hydrogen (H), arsenic (As), chlorine (Cℓ), nitrogen (N) and oxygen (O). It was one of the first drugs used in chemotherapy and for treating sleeping sickness.

The empirical formula of this compound can be determined in a series of analyses. One process involves the reaction of a known mass of Salvarsan with excess strong acid to convert all the chlorine into aqueous chloride ions.

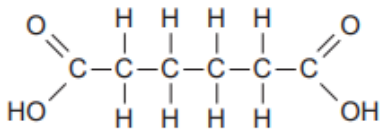
(a) Describe the laboratory process involved in determining the mass of chlorine in this sample of Salvarsan once it has been treated with the acid. You should reference any chemicals used and include a balanced equation in your answer. (6 marks)

4.

Poly(ethylene adipate) is an inexpensive, biodegradable polymer. It is formed when ethylene glycol and adipic acid react. The structural formulae of these two monomers are shown below.



ethylene glycol



adipic acid

(a) Draw the structural formula of poly(ethylene adipate). Show two repeating units. (2 marks)

(b) Classify poly(ethylene adipate) according to the:

(i) functional group or groups present in its structure. (1 mark)

(ii) type of reaction resulting in its formation. (1 mark)

(c) Identify a different type of reaction that results in the formation of a polymer. (1 mark)

5.

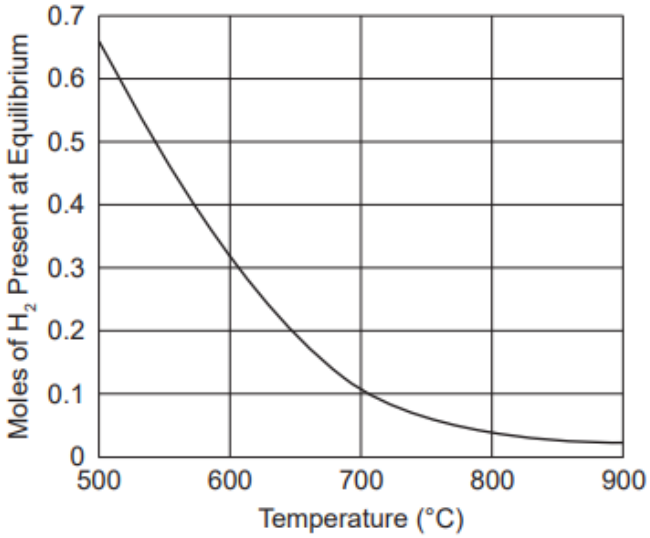
Some hydrogen sulfide and methane were sealed inside a reaction vessel and the following equilibrium was established:

$$2\ H_2S(g) + CH_4(g) \rightleftharpoons CS_2(\ell) + 4\ H_2(g)$$

(a) Write the equilibrium constant expression (K) for this reaction system. (2 marks)

(b) Some methane was removed from the reaction vessel. What effect did this have on the position of the equilibrium? Use collision theory to justify your answer. (5 marks)

The temperature inside the reaction vessel was increased. The heating process was stopped every so often and, once equilibrium had been established at the attained temperature, the amount of hydrogen present in the system was measured. The results are shown on the following graph.



(c) Using the graph and your answer to part (a), predict the effect of an increase in temperature on the numerical value of K. Justify your prediction. (4 marks)

6.

Some students were asked to identify the 'best' cleaning solvent for the removal of graffiti from concrete. They were given black spray paint and five different cleaning solvents.

The students sprayed five different 10 cm by 10 cm areas of a concrete wall with the black paint and allowed the paint to dry for 24 hours. They then used 100 mL of cleaning solvent to try to remove the black paint, with a different cleaning solvent being used for each square. The students subsequently ranked the cleaning solvents from 1 to 5 based on their ability to dissolve the black paint with 1 being the best and 5 being the worst.

The results of the students' investigation, plus some information about the composition of each cleaning solvent, are shown in the table below.

Solvent	Investigation ranking	Composition of cleaning solvent
distilled water	5	water
turpentine	2	straight-chain hydrocarbons containing ten carbon atoms and one double bond
acetone	3	propanone
white spirit	1	straight-chain hydrocarbons C7 to C12
methylated spirits	4	5% methanol, 95% ethanol

(a) Identify the independent and dependent variables in the students' investigation. (2 marks)

Independent variable	
Dependent variable	

(b) State **two** variables that the students needed to control in their investigation. (2 marks)

One: _____

_____

Two: _____

_____

(c) What could the students do to ensure that their investigation was:

(i) valid? (1 mark)

(ii) reliable? (1 mark)

(d) Identify **two** safety risks associated with the students' investigation and state how each risk could be minimised. (4 marks)

Safety risk	How to minimise the risk

(e) Paints contain, among other things, a pigment (which is the paint colour) and a solvent (which dissolves the pigment). When paint dries, the solvent evaporates, leaving the pigment behind.

Use this information, the students' results and your knowledge of chemistry to identify the predominant type of intermolecular force occurring between the pigment molecules in the black paint used by the students. Explain your reasoning. (3 marks)

Extended Answers

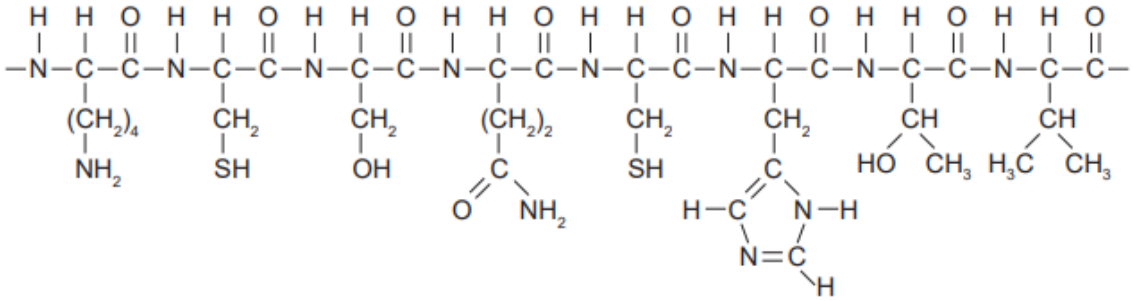
1.

Cytochrome C is a protein found in the cells of many organisms. A biochemist analysed the Cytochrome C from a human and a grey whale to establish their respective α-amino acid sequences.

(a) What protein structure level does the α-amino acid sequence represent? (1 mark)

_____

The structural formula of a small segment of human Cytochrome C, as written by the biochemist in her notebook, is shown below.



The biochemist wrote the sequence of α-amino acids in the corresponding grey whale Cytochrome C segment in an abbreviated form:

– Lys – Cys – Ala – Gln – Cys – His – Thr – Val –

(b) Identify **one** similarity and **one** difference between the given α-amino acid sequences of human and grey whale Cytochrome C. (2 marks)

Similarity: _____

_____

_____

Difference: _____

_____

_____

The biochemist examined the overall three-dimensional folded shape of grey whale Cytochrome C. The biochemist did this by identifying the predominant types of interactions occurring between the side chains of α-amino acids located near each other in grey whale Cytochrome C. Three of the α-amino acid pairs considered by the biochemist are shown in the following table.

(c) Complete the following table by identifying the predominant side chain interaction for each α-amino acid pair. (3 marks)

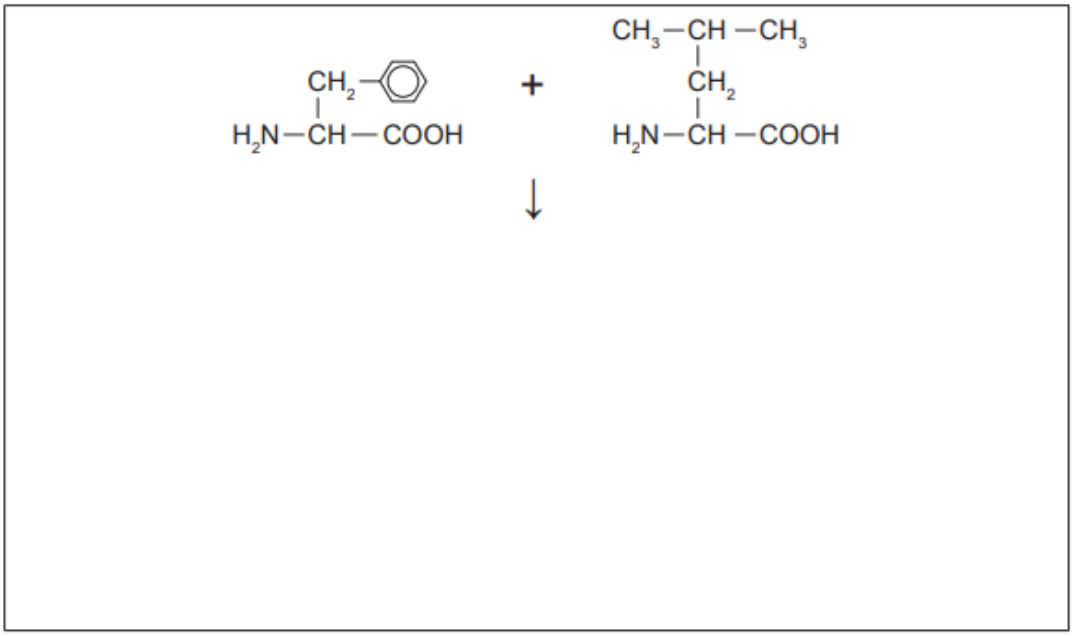
α-Amino acid pairs	**Predominant side chain interaction**
Ala and Val	
Gln and His	
Cys and Cys	

(d) The biochemist found that both human and grey whale Cytochrome C contain several alpha helices but no beta-pleated sheets. What protein structure level do alpha helices and beta-pleated sheets represent? (1 mark)

_____

Further analysis of human Cytochrome C showed that there was a segment where two other α-amino acids (phenylalanine and leucine) were adjacent to each other. The biochemist obtained pure samples of each of these amino acids and set up an experiment to facilitate their reaction with each other.

(e) Write a balanced equation, using condensed structural formulae, for a reaction that occurs between phenylalanine and leucine. (2 marks)



(f) The biochemist decided to examine how the structure of leucine changes with solution pH. Complete the following table by drawing the structural formula of leucine at the indicated pH. (2 marks)

Structural formula of leucine	pH
	acidic
	alkaline

2.

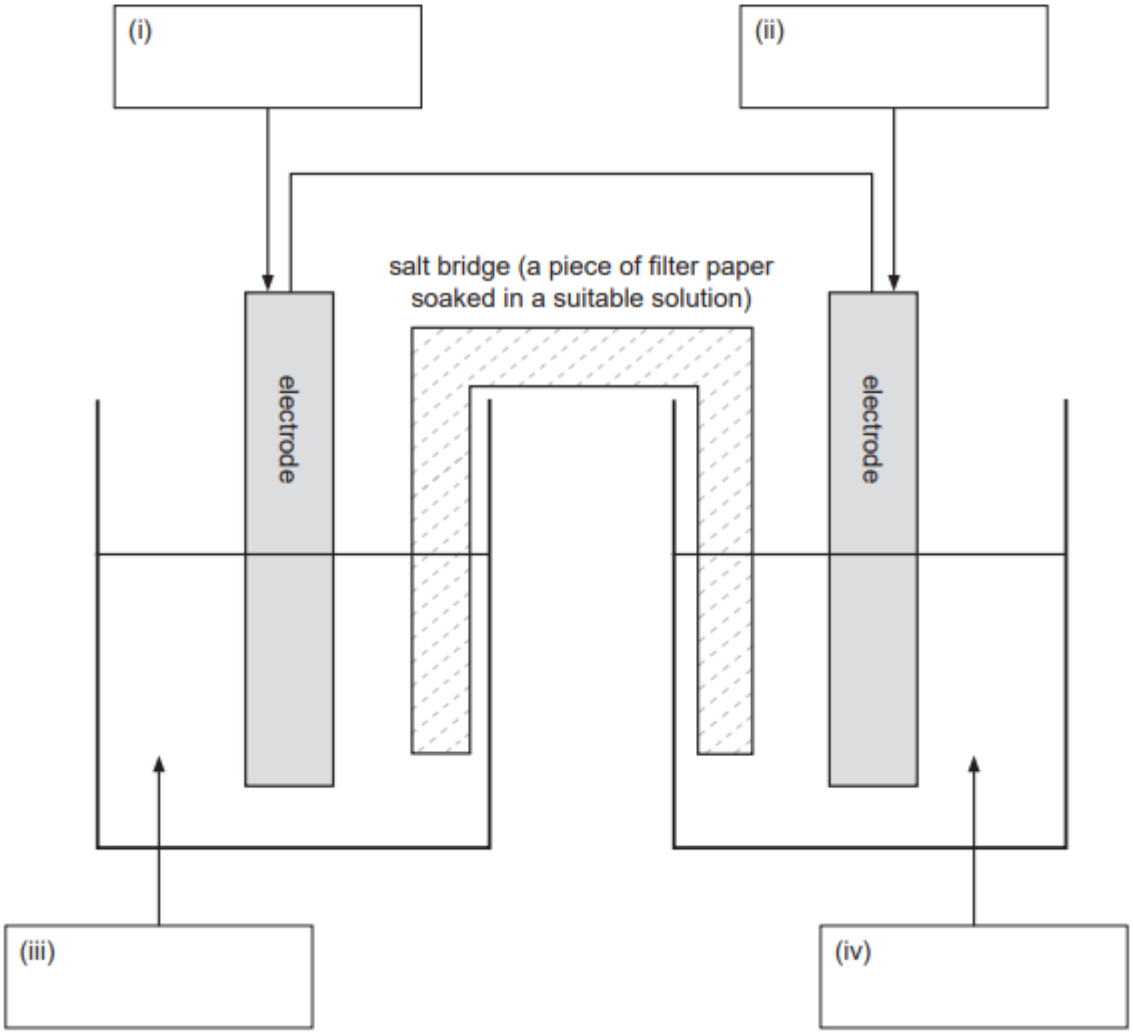
A student was asked to build a functioning galvanic cell, having been provided with all of the required hardware plus the following substances:

- a piece of magnesium measuring 1 mm by 2 cm by 6 cm
- a piece of copper measuring 1 mm by 2 cm by 6 cm
- a 6 cm long graphite (carbon) rod with a diameter of 1 cm
- 1.0 mol L^{-1} sodium carbonate solution
- 1.0 mol L^{-1} magnesium sulfate solution
- 1.0 mol L^{-1} copper(II) sulfate solution.

There was no requirement for the student to use all of these substances.

(a) A partially-labelled diagram of the galvanic cell built by the student is shown below. What substances should the student have used in the parts labelled (i) to (iv) to build a functioning galvanic cell? Write the names of these substances in the boxes provided.

(4 marks)



(c) Write the half-equations for the reactions occurring at the anode and the cathode in the student's galvanic cell. (4 marks)

Anode half-equation	
Cathode half-equation	

(d) Calculate the electrical potential difference of the student's galvanic cell. Assume standard conditions. Include appropriate units in your answer. (2 marks)

(e) Galvanic cells, such as the one shown in the diagram, need a salt bridge.

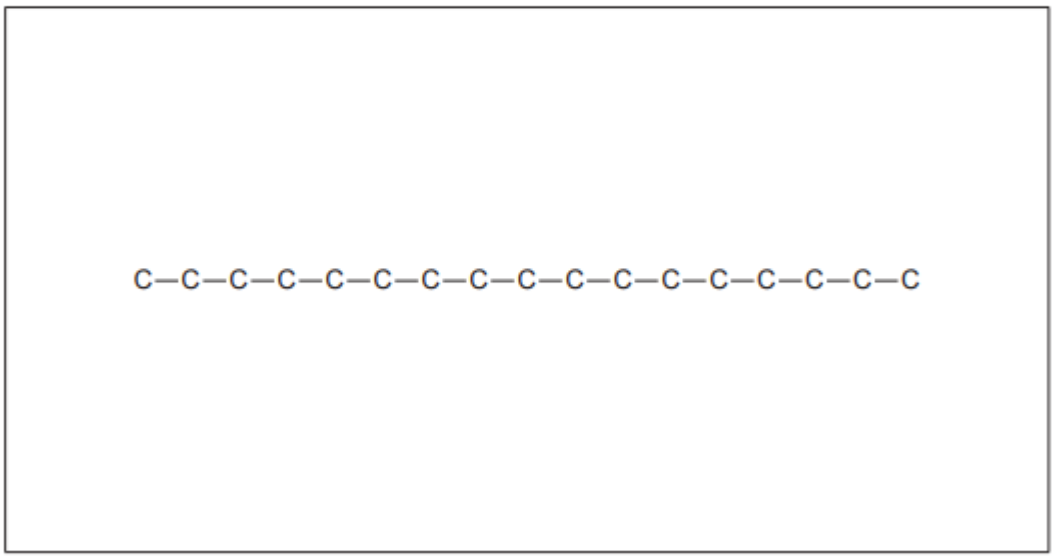
(i) State why galvanic cells need a salt bridge. (1 mark)

(ii) Describe, with reference to ion movement, how the salt bridge in a galvanic cell works. Also state why ion movement occurs as you have described. (4 marks)

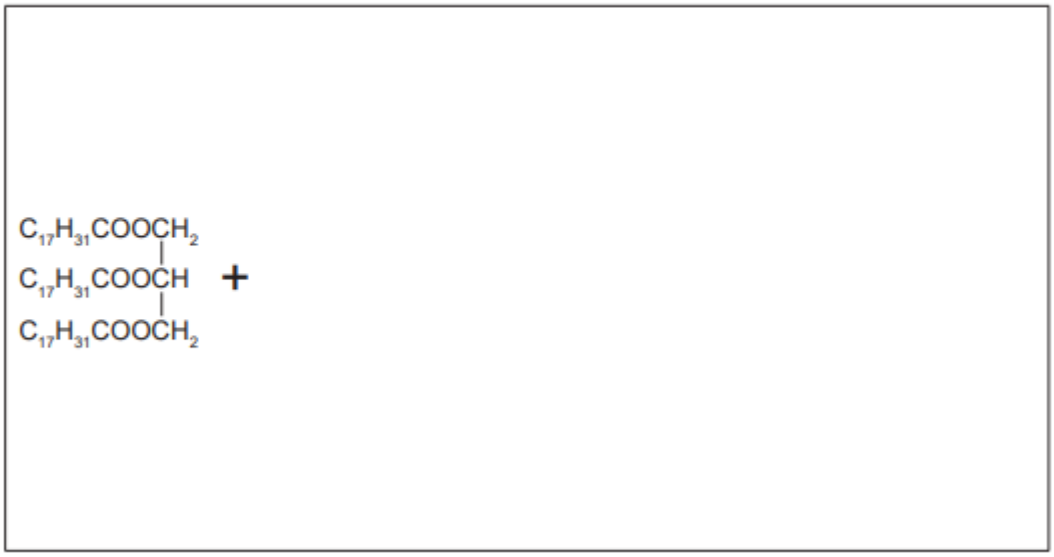
3.

Alkenes can also form soaps.

(c) Draw a structural diagram for the soap ion, $C_{17}H_{31}CO_2^-$ using the incomplete structure below. Show **all** atoms and bonds. (2 marks)



(d) Write an equation showing the formation of this soap from the fat (triglyceride) shown below. (3 marks)



The formation of soap is both an endothermic and equilibrium reaction.

(e) Predict and explain the conditions that would result in the highest yield of soap in the shortest amount of time. (8 marks)

Calculation questions

1.

A blast furnace is a large furnace operated at very high temperatures to convert iron(III) oxide (in iron ore) to iron using carbon monoxide, which is itself converted to carbon dioxide during the process.

(a) Write the equation for the reaction of iron(III) oxide with carbon monoxide. (1 mark)

_____

(c) 1.00 tonne of iron ore containing 96.5% iron(III) oxide is fed into the blast furnace with 2.70×10^6 L of carbon monoxide at 1.12 atm pressure and 1986°C.
Note: 1 tonne = 1×10^6 g

(i) Determine the limiting reactant for this reaction. (4 marks)

(ii) What mass of iron is theoretically produced in this reaction? (2 marks)

(iii) Calculate the mass of the reactant in excess. (3 marks)

(d) If 5.56×10^{-1} tonne of iron is actually produced, what is the overall percentage yield of the process? (1 mark)

2.

The percentage of manganese in steel needs to be monitored carefully. To determine this, a 5.31 g sample of steel was dissolved in concentrated acid and the manganese oxidised to permanganate ion, MnO_4^-. The volume of this solution was made up to 100.0 mL in a volumetric flask.

The concentration of permanganate ion was determined by titration against a standard solution of oxalic acid. The oxalic acid solution was prepared by dissolving 2.42 g of oxalic acid dihydrate ($H_2C_2O_4 . 2H_2O$) in a small volume of water, which was then made up to a final volume of 250.0 mL in a volumetric flask.

A 20.00 mL aliquot of the standard oxalic acid solution was transferred into a conical flask and acidified with some sulfuric acid. The permanganate solution was then titrated against this 20.00 mL aliquot of oxalic acid solution. This was repeated three times. The results are shown in the table below.

The balanced equation for the reaction between oxalic acid and permanganate ion is as below.

$$6\ H^+ + 2\ MnO_4^- + 5\ H_2C_2O_4 \rightarrow 2\ Mn^{2+} + 10\ CO_2 + 8\ H_2O$$

	1	2	3	4
Final reading (mL)	9.54	17.59	25.57	33.64
Initial reading (mL)	0.97	9.54	17.59	25.57
Titre volume (mL)				

(a) Calculate the concentration of the standard oxalic acid solution. (3 marks)

(b) Determine the percentage of manganese in the original sample of steel. (8 marks)

3.

The sandy soils of Western Australia are deficient in several elements essential to the growth of plant life. One of these elements is nitrogen, and there are a number of nitrogen-containing fertilisers available on the market. Urea, $CO(NH_2)_2$, is a commonly-used fertiliser that contains nitrogen. Urea is produced as crystals by the reaction of ammonia with carbon dioxide. Water is also produced in the reaction. The equation for this reaction is shown below.

$$2\,NH_3 + CO_2 \rightarrow CO(NH_2)_2 + H_2O$$

A reaction vessel designed for the synthesis of urea is operated at 200°C and 148 atmospheres. It has a total volume capacity of 5000 L, and ammonia and carbon dioxide are fed into it in batches so that ammonia occupies 62.0% of the volume and carbon dioxide occupies the remainder.

(a) Determine the limiting reagent for the reaction under the above operating conditions. Show **all** your workings. (5 marks)

(b) What mass of urea is theoretically produced in this reaction? (3 marks)

(c) Calculate the mass of the excess reactant remaining after reaction. (3 marks)

(d) Calculate the pressure of the remaining gas in the reactor after it is allowed to cool to room temperature (25°C).
(The volume occupied by the urea crystals and water formed can be ignored.) (2 marks)

(e) 376 kg of impure crystals are formed in the above reaction and found, on analysis, to contain 83.0% urea. Calculate the percentage yield of the above process. (2 marks)

(f) Urea is added to fertiliser preparations at about 45.0% by mass. Ammonium sulfate is an alternative source of nitrogen often used in fertilisers.

(i) What mass of nitrogen is contained in 5.00 tonne of fertiliser that is 45.0% by mass urea? (1 tonne = 1×10^6 g) (2 marks)

(ii) What mass of ammonium sulfate, $(NH_4)_2SO_4$, is needed to prepare 5.00 tonne of fertiliser with the same mass of nitrogen as your answer in (i) above? (3 marks)

4.

Pentlandite, $Fe_9Ni_9S_8$, is a common nickel sulfide ore that can be used to obtain the materials required to produce sulfuric acid. This metal sulfide ore is combusted in air to form sulfur dioxide according to the following equation.

$$Fe_9Ni_9S_8 + 17\ O_2 \rightarrow 9\ NiO + 9\ FeO + 8\ SO_2$$

(a) What is the volume of sulfur dioxide produced if 2.2 tonne of pentlandite is combusted in air? The process has a yield of 72.0%, and takes place at 300.0 °C and 165.0 kPa. Express your answer to the appropriate number of significant figures.

Molar mass of $Fe_9Ni_9S_8$ = 1287.42 g mol^{-1}. (7 marks)

5.

Acid rain is a significant issue in many industrialised areas of the world; particularly around power stations using fossil fuels. Legislation has been developed in Australia to minimise the formation of sulfur dioxide, $SO_2(g)$, such as from the use of low-sulfur fuels in automobiles, which can cause acid rain. Normal rain has a pH of about 5.6; it is slightly acidic because carbon dioxide, $CO_2(g)$ dissolves into it, forming weak carbonic acid. Rain with a pH less than 4.4 is usually classified as acid rain.

Testing was carried out on a rainwater sample taken near a coal-fired power station by titration, using sodium hydroxide solution, NaOH(aq). Standardisation of the sodium hydroxide solution was carried out before it was used in the titration. An anhydrous sodium carbonate, $Na_2CO_3(s)$, primary standard was used to standardise a hydrochloric acid solution, HCℓ(aq) and subsequently used to standardise the NaOH(aq) solution.

Sodium carbonate, $Na_2CO_3(s)$ was heated at 110 °C in a drying oven for 1 hour before 6.08×10^{-4} g was dissolved in distilled water to make 2.00 L of the primary standard. Three 25.0 mL aliquots of HCℓ(aq) were titrated and an average titre of 16.4 mL was required for neutralisation.

(a) Demonstrate, by means of calculation, that the concentration of HCℓ(aq) solution is 3.76×10^{-6} mol L^{-1}. (5 marks)

An average titre of 21.3 mL of the standardised (3.76×10^{-6} mol L^{-1}) HCℓ(aq) solution was required to neutralise 25.0 mL aliquots of NaOH(aq) solution.

(c) Calculate the concentration of the NaOH(aq) solution. (3 marks)

The standardised NaOH(aq) solution was then used for the titration of a rainwater sample. A 100.0 mL sample of rain water was collected near a coal-fired power station and diluted to 250.0 mL with distilled water in a volumetric flask. 25.0 mL aliquots of the diluted rainwater were used in the titration.

(d) Complete the table below to state with what the following pieces of glassware should be rinsed for this titration. (3 marks)

Glassware	Final rinse
Burette	
Conical flask	
Pipette	

The titre values obtained for the rainwater sample are shown in the table below:

Titre volume of NaOH (mL)				Average titre volume (mL)
Trial 1	Trial 2	Trial 3	Trial 4	
21.81	19.64	19.67	19.66	

(e) Calculate the average titre volume and record it in the table above. (1 mark)

(f) Calculate the pH of the undiluted rainwater sample. Determine if it would be classified as acid rain or not. (6 marks)

(g) If carbon dioxide, $CO_2(g)$ alone accounts for rain with a pH of 5.60, then calculate the volume of sulfur dioxide, $SO_2(g)$ at 16.0 °C and 97.2 kPa, that would also need to be dissolved to produce 0.100 L of an acid rain sample with a pH of 4.0. Use the equation below.

$$SO_2(g) + H_2O(\ell) \rightleftharpoons H_2SO_3(aq)$$

For this calculation, assume the complete ionisation of $H_2SO_3(aq)$. (6 marks)

End of Questions