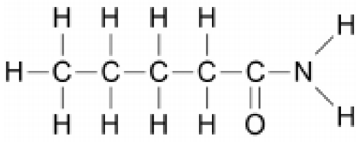
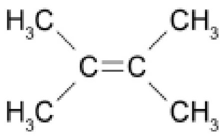
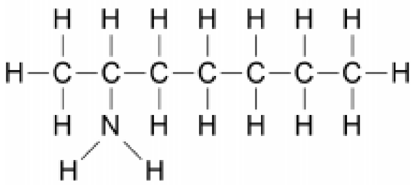
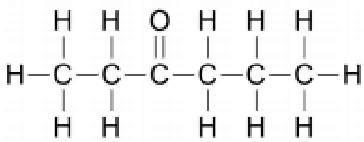
Practice Revision Exam 2021

Short answers

1.

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	Marks
	**Answer** pentanamide	1
	**Answer** 2,3-dimethylbut-2-ene Accept 2,3-dimethyl-2-butene dimethylbut-2-ene dimethyl-2-butene	1
Answer 	heptan-2-amine	1
Answer 	hexan-3-one	1
	Total	**4**

Note:

- Structural formula must have all hydrogen atoms for the mark to be allocated.
- Condensed structures are also accepted.
- All structures require numbers except those which would have a 1.

2.

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

Description	Marks
Test Tube I	
• salmon pink (brown/orange/copper colour) solid in	1
• a colourless liquid/solution	1
Test Tube II	
• black solid in a	1
• blue (green) liquid/solution	1
Total	**4**

(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)

Description	Marks
Correct reactants and products	1
Balanced	1
Correct state symbols	1
Total	**3**
Example of a three mark response: $CuO(s) + 2\,H^{+}(aq) \rightarrow Cu^{2+}(aq) + H_2O(\ell)$	

(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)

Description	Marks
Test tube II contains a black solid while test tube III contains a green solid	2
Test tube II contains no sign of a gas while test tube III contains colourless bubbles (no colours described)	1
Total	**2**
Note: Colour of solid - reference to both test tubes must be made as they each contain a different colour.	

3.

(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)

Description	Marks
One mark for correct products and reactants	1
One mark for correct balancing	1
Total	**2**
Example of a two mark response: $2\ SO_2(g) + O_2(g) + 2\ H_2O(\ell) \rightleftharpoons 2\ H_2SO_4(\ell)$	

(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)

Description		Marks
High Temperature		
Advantage	increase rate	1
Disadvantages	two of: decrease yield, high energy cost **or** high safety hazards, (more) expensive	1–2
High Pressure		
Advantages	increase rate increase yield	1 1
Disadvantage	high cost (of construction and maintaining pressure) **or** high safety hazards	1
	Total	**6**

Note:
- The answers may be expressed in different ways but must clearly indicate these understandings.
- No explanation required.

3b.

(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)

Description	Marks
Step 1: React the resultant solution with excess (1) silver nitrate (silver ion) solution (1)	1-2
Step 2: Filter off the precipitate and wash	1
Step 3: Dry the precipitate	1
Step 4: Weigh precipitate	1
One mark for the equation	
Example of a one mark response: $Ag^+(aq) + C\ell^-(aq) \rightarrow AgC\ell(s)$	1
Total	**6**
Note: • Accept alternative answers such as redox titrations, precipitations or answers that show the appropriate chemistry.	

(b) Use this information to calculate the empirical formula of Salvarsan. Show **all** workings. (9 marks)

Description	Marks
Identifying the mass in 100 g (%) for C, H, Cℓ and N **or** converting % to mass in 5.22 g for C, H, Cℓ and N	1
Converting mass of arsenic in 5.22 g sample to 34.1%	1
Determining the % of oxygen	1
Conversion of % by mass to moles	1–4
Determining simplest ratio by dividing all by the factor of 0.455 or 0.456	1
Writing the empirical formula $C_6H_7AsC\ell NO$	1
Total	**9**

Example of a nine mark response:

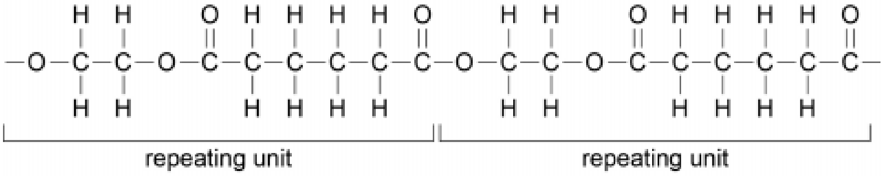
	C	H	As	Cℓ	N	O
% (mass in 100g)	32.83	3.21	1.78x100/5.22 = 34.1	16.18	6.38	100 – (32.83 + 3.21 + 34.1 + 32.4 + 6.38) = 7.3
n	32.83/12.01 = 2.73	3.21/1.008 = 3.18	34.1/74.92 = 0.455	16.18/35.45 = 0.456	6.38/14.01 = 0.455	7.3/16.0 = 0.456
ratio (/0.455)	6	7	1	1	1	1

Empirical formula: $C_6H_7AsC\ell NO$

4.

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

(2 marks)

Description	Marks
 (one minor error is 1 mark only)	1–2
Total	**2**
Note: • If only one repeating unit is shown allocate a maximum of one mark only. • Minor errors include missing hydrogens or terminating the ends of the polymer. • Incorrect or missing ester links is a major error, allocate 0 marks.	

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

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

Description	Marks
ester/polyester	1
Total	**1**

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

Description	Marks
condensation (polymerisation/reaction)/esterification)	1
Total	**1**

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

Description	Marks
addition (polymerisation/reaction)	1
Total	**1**

5.

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

Description	Marks
$K = \frac{[H_2]^4}{[H_2S]^2\ [CH_4]}$ (one minor error is 1 mark only)	1–2
Total	**2**
Note: • Minor errors include one superscript missing or K= missing. • Accept partial pressures.	

(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)

Description	Marks
Reduced concentration/pressure of CH_4 means a decrease in the frequency of collisions between CH_4 and H_2S molecules.	1
This decreases the rate of the forward reaction.	1
The rate of the reverse reaction is not affected initially.	1
The rate of the reverse reaction, therefore, is greater than the rate of the forward reaction.	1
The equilibrium position, therefore, shifts to the left/equilibrium favours the reverse reaction.	1
Total	**5**

(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)

Description	Marks
Value of K decreases	1
The graph shows that as the temperature increases the number of moles (yield) of H_2 present at equilibrium decreases.	1
Recognises any two of: • $[H_2S]$ and $[CH_4]$ increase • $[H_2]$ decreases • the reverse reaction has been favoured.	1–2
Total	**4**
Note: • A justification based on Le Châtelier's Principle is acceptable. For example: As temperature increases, an endothermic reaction is favoured. This is the reverse reaction in this case.	

6.

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

Description	Marks
Independent variable = identity of the (cleaning) solvent	1
Dependent variable = the amount/extent to which the black spray paint is dissolved/removed	1
Total	**2**

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

Description	Marks
Identification of one variable that needs to be controlled.	1
Identification of another (different) variable that needs to be controlled.	1
Total	**2**
Answers could include: • the brand of black spray paint • the concrete/wall the paint is sprayed on • thickness of paint • drying temperature • size of the painted areas • drying time • volume of cleaning solvent used • method used to apply the cleaning solvent.	

(c) What could the students do to ensure that their investigation was: (2 marks)

(i) valid?

Description	Marks
To make their investigation valid they will need to (either) • design/perform an investigation that compares the effectiveness of different cleaning solvents on the removal of black spray paint from concrete. • ensure the control variables are controlled.	1
Total	**1**

(ii) reliable?

Description	Marks
To make their investigation reliable they will need to repeat their investigation several times (if they obtain consistent/reproducible results then their investigation is reliable).	1
Total	**1**

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

Description	Marks
Identification of one safety risk	1
States how to minimise that risk	1
Identification of another (different) safety risk	1
States how to minimise that risk	1
Total	**4**
Answers could include: • chemicals contacting the eyes, wear safety glasses • inhalation of fumes, wear suitable mask • chemicals contacting skin on hands, wear safety gloves • spilling chemicals on feet, wear enclosed shoes • spilling chemicals on exposed skin, wear enclosed shoes/gloves and/or lab coat.	
Note: • The risk must be a plausible risk for the investigation detailed in the question. • For full marks the minimising strategy must match the risk. • If only minimising risk box is filled in, 0 marks.	

(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 determine the predominant type of intermolecular force occurring between the pigment molecules in the black paint used by the students. Explain your reasoning. (3 marks)

Description	Marks
The paint's pigment molecules must have dispersion forces as their predominant intermolecular force because the best solvents have dispersion forces as their predominant intermolecular force.	1
• This is because for substances to be soluble in each other they must be able to disrupt the existing intermolecular forces and form new intermolecular forces with each other. • This can only be done if the intermolecular forces are of similar strength (hence they all need dispersion forces as their predominant intermolecular force).	1–2
Total	**3**

Extended Answers

1.

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

Description	Marks
primary	1
Total	**1**

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

Description	Marks
Accept anything reasonable, e.g. There are five α-amino acids that are common to both types of Cytochrome C. They both contain lysine.	1
The third amino acid is different. The only difference is that in the position where human Cytochrome C has serine, grey whale Cytochrome C has alanine (the third amino acid in their respective sequences).	1
Total	**2**

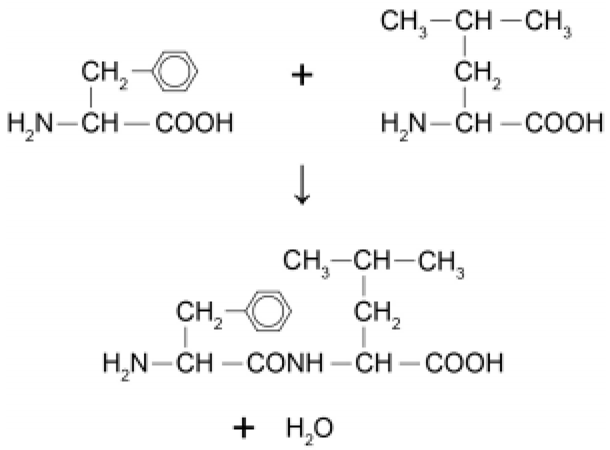
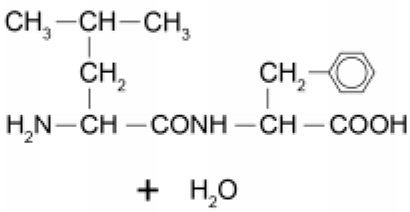
(c) Complete the following table by identifying the predominant side chain interaction for each α-amino acid pair. (3 marks)

Description	Marks
Ala and Val = dispersion forces	1
Gln and His = hydrogen bonding	1
Cys and Cys = disulfide bridge (disulfide bond/covalent bond and dipole-dipole also acceptable)	1
Total	**3**

(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)

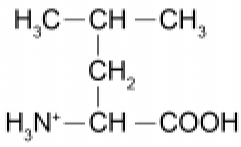
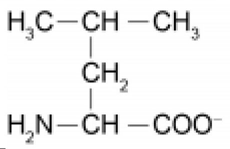
Description	Marks
secondary	1
Total	**1**

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

Description	Marks
 **Or** 	1–2
Total	**2**

Note:
- One minor error maximum one mark e.g. no water, single transcription error.
- Out of two possible organic products, only one is required.
- Zwitterion form is also accepted.

(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)

Description		Marks
Structural formula of leucine	**pH**	
	acidic	1
	alkaline	1
	Total	**2**

2.

(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)

Description	Marks
Option One	
(i) magnesium	1
(ii) copper or graphite	1
(iii) (1.0 mol L^{-1}) magnesium sulfate (solution)	1
(iv) (1.0 mol L^{-1}) copper(II) sulfate (solution)	1
or	
Option Two	
(i) Copper or graphite	1
(ii) magnesium	1
(iii) (1.0 mol L^{-1}) copper(II) sulfate (solution)	1
(iv) (1.0 mol L^{-1}) magnesium sulfate (solution)	1
Total	**4**
Note: • Accept formulae instead of names.	

(b) Add arrows to the diagram in part (a) to show the direction of movement of electrons through the external circuit.
(1 mark)

Description	Marks
arrow on/near the wire pointing from Mg to Cu/C	1
Total	**1**

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

Description	Marks
Anode half-equation $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$	1–2
Cathode half-equation $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	1–2
Total	**4**
Note: • Anode and cathode reactions in wrong boxes – maximum of 3 marks. • Negative charge missing from electrons – maximum of 3 marks. • State symbols are not required.	

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

Description	Marks
+2.70	1
V or Volts	1
Total	**2**
Note: • Must have correct value, with or without the '+' sign. • Working out is not necessary (e.g. +2.36 + 0.34).	

(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)

Description	Marks
Any one of the following: A salt bridge • maintains charge neutrality • completes the circuit • allows transfer of ions between two half-cells • prevents polarisation.	1
Total	**1**

(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)

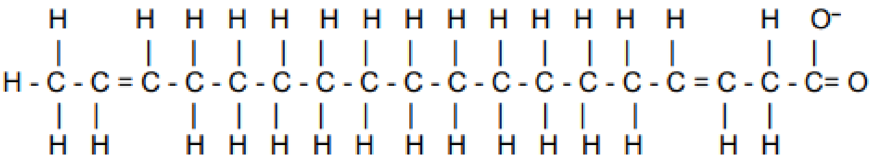
Description	Marks
Negative ions travel through the salt bridge and move (migrate) into the anode half-cell	1
Due to an increase in positive ions/charge (as a result of the oxidation of magnesium producing positive ions that enter the electrolyte)	1
Positive ions travel through the salt bridge and move (migrate) into the cathode half-cell	1
Due to a removal of positive ions/charge (as a result of the reduction of copper ions from the electrolyte)	1
Total	**4**

3.

(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)

Description	Marks
Structural diagram includes:	
• COO^-	1
• all bonds including both double bonds.	1
Total	**2**

Example of a two mark response:



Note:

- One triple bond instead of two double bonds is acceptable.

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

Description	Marks
Equation has:	
• a hydroxide with the fat	1
• correct products	1
• correct balancing.	1
Total	**3**

Example of a three mark response:

$$\begin{array}{l} C_{17}H_{31}COOCH_2 \\ \quad\quad\quad\quad\quad | \\ C_{17}H_{31}COOCH \\ \quad\quad\quad\quad\quad | \\ C_{17}H_{31}COOCH_2 \end{array} + 3\ OH^-(aq) \rightleftharpoons 3\ C_{17}H_{31}COO^- + \begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{array}$$

Note:

- No mark penalty for using molecular versions with KOH or NaOH.

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

Description	Marks
Predicts high temperature	1
Explains high temperature and higher rate due to:	
• a greater proportion of particles having sufficient energy to react when they collide	1
• a higher frequency of collision as the average kinetic energy of the particles is higher.	1
• higher yield as the forward rate will increase more than the reverse rate when temperature is increased.	1
Predicts high concentration of (sodium/potassium) hydroxide solution	1
Explains high concentration of sodium hydroxide solution and higher rate due to:	
• (more particles present in same volume, therefore) greater frequency of collisions and so greater number of successful collisions	1
• higher yield as forward reaction will be faster than reverse reaction until equilibrium re-established.	1
States agitation or removal	
Agitation will increase the surface area, increasing the contact/collisions between reacting particles and hence rate (will have no impact on yield) **or** Removal of product (soap/glycerol) as produced to minimise/inhibit reverse reaction	1
Total	**8**

Note:
- In order to achieve full marks, students must refer to the collision theory and reference both rate and yield for temperature and concentration of sodium hydroxide.
- Pressure changes do not affect this reaction.
- Oil/grease does not have a concentration and should not be referred to.
- Catalysts are not used in saponification. No penalty if a catalyst is referenced. Candidates do not need to state that catalysts have no effect on yield.

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)

$$Fe_2O_3 + 3\,CO \rightarrow 2\,Fe + 3\,CO_2$$

Description	Marks
Correct answer as above. Equation must be balanced.	1
Question incorrectly answered or not attempted.	0
Total	**1**

(b) Identify the oxidant and reductant in the above process. (1 mark)

Oxidant: **Fe_2O_3**
Reductant: **CO**

Description	Marks
Both oxidant and reductant correctly identified.	1
Question incorrectly answered or not attempted.	0
Total	**1**

(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)

$$n(Fe_2O_3) = \frac{0.965 \times 1000 \text{ kg tonne}^{-1} \times 1000 \text{ g kg}^{-1}}{M(Fe_2O_3)}$$

$$= \frac{9.65 \times 10^5 \text{ g}}{159.7 \text{ gmol}^{-1}}$$

$$= 6.04258 \times 10^3 \text{ mol} Fe_2O_3$$

$$PV = nRT \therefore n(CO) = \frac{1.12 \text{ atm} \times 101.3 \text{ kPa atm}^{-1} \times 2.70 \times 10^6 \text{ L}}{(8.315 \text{ JK}^{-1})(1986+273)}$$

$$= 1.6308 \times 10^4 \text{ mol CO}$$

$n(CO)$ needed = $3 \times n(Fe_2O_3)$ = $3 \times 6.042 \times 10^3$mol = 1.8126×10^4mol CO needed

mol CO available (1.6308×10^4) < mol CO needed (1.8126×10^4),
therefore CO is limiting reactant.

Description	Marks
1 mark each for n(CO) and n(Fe_2O_3) calculated	1-2
Comparison of stoichiometric ratio to actual ratio.	1
CO is limiting reactant with any valid method for determining limiting reactant supporting this conclusion.	1
Question incorrectly answered or not attempted.	0
Total	**4**

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

$$n(Fe)\ produced=\frac{2}{3}n(CO)=\frac{2}{3}(1.6308\times10^4)=1.0872\times10^4\ mol$$

$n(Fe_2O_3)$ in excess$=6.06\times10^2\times M(Fe_2O_3)=6.06\times10^2\times159.7$
$=9.6778\times10^4$ g$=9.68\times10^4$ g Fe_2O_3 in excess

$n(Fe)$ produced $=1.0872\times10^4$ mol$\times55.85$ gmol^{-1}
$=6.07201\times10^5$ mol
$=6.07\times10^5$ g

Description	Marks
6.07×10^5 g Fe produced (accept answers between 6.01×10^5 g and 6.13×10^5 g).	2
No. moles Fe calculated but mass not calculated or mass incorrectly calculated.	1
Question incorrectly answered or not attempted.	0
Total	**2**

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

$$n(Fe_2O_3)\ consumed=\frac{1}{3}n(CO)\ consumed=\frac{1}{3}\ 1.6308\times10^4$$

$=5.436\times10^3$ mol Fe_2O_3 consumed

$n(Fe_2O_3)$ in excess$=(6.042\times10^3-5.436\times10^3)$ mol$=6.06\times10^2$ mol

Description	Marks
9.68×10^4 g Fe_2O_3 in excess (accept answers between 9.58×10^4 g and 9.78×10^4 g).	3
$n(Fe_2O_3)$ in excess and mass not calculated or incorrectly calculated.	2
$n(Fe_2O_3)$ consumed.	1
Question incorrectly answered or not attempted.	0
Total	**3**

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

Description	Marks
$\%yield=\frac{0.556}{0.607}\times100=91.6\%$ 91.6 % (accept answers between 90.6 % and 92.6 %).	1
Question incorrectly answered or not attempted.	0
Total	**1**

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)

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

Description	**Marks**
$M(H_2C_2O_4{\cdot}2H_2O)$ = 126.068 g mol^{-1}	1
$n(H_2C_2O_4) = \dfrac{2.42}{126.068} = 1.9196 \times 10^{-2}$ mol	1
$c(H_2C_2O_4) = \dfrac{1.9196 \times 10^{-2}}{0.250} = 7.68 \times 10^{-2}$ mol L^{-1}	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

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

Description	Marks
$n(H_2C_2O_4) = 7.68 \times 10^{-2} \times 0.02 = 1.536 \times 10^{-3}$ mol	1
$n(MnO_4^-) = \frac{2}{5} \times n(H_2C_2O_4) = 6.144 \times 10^{-4}$ mol	1
$V_{av}(MnO_4^-) = 8.033$ mL	1
*$n(MnO_4^-)$ in 100 mL = $\frac{6.144 \times 10^{-4}}{8.033 \times 10^{-3}} \times 0.100 = 7.648 \times 10^{-3}$ mol	1–2
Thus n(Mn) in sample = 7.648×10^{-3} mol	1
$m(Mn) = 7.648 \times 10^{-3} \times 54.94 = 0.4202$ g	1
$\%Mn = \frac{0.4202}{5.31} \times 100 = 7.91\%$	1
Question incorrectly answered	0
Question not attempted	-
Total	**8**

*Calculation of the concentration of the MnO_4^- solution and then calculation of $n(MnO_4^-)$ in 100 mL is also acceptable.

(c) Suggest the most suitable indicator for this titration and describe the colour change that would be observed during the titration. (2 marks)

Indicator	No indicator needs to be added; MnO_4^- acts as indicator
Description of colour change	Solution will turn from colourless to pale pink

Description	Marks
Recognition that no indicator needs to be added	1
Solution will turn from colourless to pale pink (i.e., that is the end point)	1
Question incorrectly answered	0
Question not attempted	-
Total	**2**

N.B.: "Self indicating" is acceptable

3.

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

Description	Marks
P = 148 × 101.3 = 1.49924 × 10^4 kPa (conversion of atm to kPa; alternatively students may use R = 0.08206 in the next step and be awarded 1 mark for remembering it)	1
Calculation of total number of moles: $n_{total} = \frac{PV}{RT} = \frac{1.49924 \times 10^4 \times 5000}{8.315 \times 473} = 1.906 \times 10^4$ mol	1
$n(NH_3) = 0.62 \times 1.906 \times 10^4 = 1.182 \times 10^4$ mol	1–3
$n(CO_2)$ = 0.38 × 1.906 × 10^4 = 7.243 × 10^3 mol	
From balanced eq'n: 2 mol NH_3 reacts with 1 mol CO_2 Thus 1.182 × 10^4 mol NH_3 needs 5.909 × 10^3 mol CO_2 Hence NH_3 is the limiting reagent. **Any acceptable method for finding LR may be used as long as it is supported with correct working.**	
Question incorrectly answered	0
Question not attempted	–
Total	**5**

N.B.: the 62% may be "applied" in any logical way

Students may choose to get the moles of NH_3 and CO_2 by finding the volume occupied by each of these gases and using the Ideal gas law twice. Gay-Lussac's law may also be used. Any valid method should be accepted. Use of a correct method for LR calculation based on incorrectly calculated moles of reagents should be rewarded.

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

Description	Marks
$n(NH_2CONH_2)$ = ½ × $n(NH_3)$ = 0.5 × 1.182 × 10^4 = 5.909 × 10^3 mol	1
$M(NH_2CONH_2)$ = 60.062 g mol^{-1}	1
$m(NH_2CONH_2)$ = 60.062 × 5.909 × 10^3 = 3.55 × 10^5 g	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

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

Description	Marks
$n(CO_2)$ used = ½ × $n(NH_3)$ = 0.5 × 1.182 × 10^4 = 5.909 × 10^3 mol	1
$n(CO_2)$ remaining = 7.243 × 10^3 - 5.909 × 10^3 = 1.334 × 10^3 mol	1
$m(CO_2)$ remaining = 44.01 × 1.334 × 10^3 = 5.87 × 10^4 g	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

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

Description	Marks
$P = \frac{nRT}{V} = \frac{1.334 \times 10^3 \times 8.315 \times 298}{5000} = 6.61 \times 10^2 \text{kPa}$ (or 6.53 atm) 1 mark for correct rearrangement of eq'n; 1 mark for final answer	1–2
Question incorrectly answered	0
Question not attempted	–
Total	**2**

Award marks for follow through for correct working when moles of CO_2 from (c) is incorrect.

(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)

Description	Marks
$m(NH_2CONH_2)$ = 3.76 ×10^5 × 0.83 = 3.1208 × 10^5 g	1
$\text{Yield} = \frac{3.1208 \times 10^5}{3.55 \times 10^5} \times 100 = 87.9\%$	1
Question incorrectly answered	0
Question not attempted	–
Total	**2**

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

(i) What mass of nitrogen is contained in 5 tonne of fertiliser that is 45.0% by weight urea? (1 tonne = 1×10^6 g) (2 marks)

Description	Marks
$m(NH_2CONH_2)$ in fertiliser batch = $0.45 \times 5 \times 10^6 = 2.25 \times 10^6$ g	1
m(N) in fertiliser = $\frac{28.02}{60.062} \times 2.25 \times 10^6 = 1.05 \times 10^6$ g	1
Question incorrectly answered	0
Question not attempted	–
Total	**2**

(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)

Description	Marks
n(N) in fertiliser = $\frac{1.05 \times 10^6}{14.01} = 7.492 \times 10^4$ mol	1
$n((NH_4)_2SO_4) = 0.5 \times 7.492 \times 10^4 = 3.746 \times 10^4$ mol	1
$m((NH_4)_2SO_4) = 132.144 \times 3.746 \times 10^4 = 4.95 \times 10^6$ g	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

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.

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

(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)

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

Description	Marks
Conversion of mass to moles For 100% = $m(Fe_9Ni_9S_8)/M(Fe_2Ni_9S_8)$ = 2.2×10^6 g/1287.42	1
Accurate figure; accounts for correct molar mass and calculation = 1.7089×10^3 mol	1
Recognition of 1:8 mol ratio $n(SO_2) = 8 \times n(Fe_9Ni_9S_8)$ $= 8 \times 1.7089 \times 10^3$ $= 1.3671 \times 10^4$	1
Recognition of efficiency conversion At 72% efficiency $n(SO_2) = 0.72 \times 1.3671 \times 10^4 = 9.84284 \times 10^3$ mol	1
Correct use of ideal gas equation $V(SO_2) = nRT/P = \frac{9.843 \times 10^3 \times 8.314 \times 573.15}{165.0}$	1
Correct answer (also accounts for use of temperature conversion) = 284262 L = 2.84262×10^5 L	1
Correct to **two** significant figures = 2.8×10^5 L	1
Total	**7**

(b) State **two** justifications for the use of catalysts in this process. (2 marks)

Description	Marks
One mark for each justification. Maximum two marks.	1–2

Answers may include, but are not limited to the following:
• increases rate of formation of (the desired) product
• better yield of at lower temperature, so catalysts make the rate viable
• reusable making them cost effective
• lowers operating temperature and pressure
  ◦ so saving fuel which is a major cost
  ◦ making it safer
  ◦ reducing thermal pollution.	

Total	**2**

5.

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

Description	Marks
$n(Na_2CO_3)$ =m/M = 5.74×10^{-6} mol	1
$c(Na_2CO_3)$ = n/2 = 2.868×10^{-6} mol L^{-1}	1
$n(Na_2CO_3)$ = c x 0.0164 (mL to L conversion) = 4.7038×10^{-8} mol	1
n(HCl) = 2 x $n(Na_2CO_3)$ = 9.4077×10^{-8} mol	1
c(HCl) = n/0.025 (mL to L conversion) = 3.76×10^{-6} mol L^{-1}	1
Total	**5**

(b) Outline **two** reasons why sodium hydroxide, NaOH(s) is **not** a suitable primary standard for this titration. (2 marks)

Description	Marks
One mark for each reason. Two marks maximum.	1–2
Answers may include, but are not limited to the following: • difficult to obtain in a very pure form • readily absorbs moisture, H_2O from air (deliquescent) **or** hydroscopic • readily absorbs carbon dioxide, CO_2 from air • mass varies over time • has a relatively low molar mass.	
Total	**2**

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

Description	Marks
n(HCl) = cV = 8.02×10^{-8} mol	1
n(HCl) = n(NaOH)	1
c(NaOH) = $8.02 \times 10^{-8}/0.025$ (mL to L conversion) = 3.21×10^{-6} mol L^{-1}	1
Total	**3**

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

Description	Marks
Burette – NaOH solution	1
Conical flask – distilled or deionised water (H_2O)	1
Pipette – diluted rainwater	1

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

Description	Marks
19.66	1
Total	**1**
Note: Units (mL) stated in table heading and first titre is not used in average	

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

Description	Marks
n(NaOH) = conc. and titre volume from part c and e $= 3.21 \times 10^{-6} \times 1.966 \times 10^{-2}$ $= 6.31 \times 10^{-8}$ mol	1
$n(H^+) = n(NaOH)$ $c(H^+)_{25mL} = 6.31 \times 10^{-8}/0.025$ $= 2.52 \times 10^{-6}$ mol L^{-1}	1
$n(H^+)_{250mL} = 2.52 \times 10^{-6} \times 0.250$ $= 6.30 \times 10^{-7}$ mol	1
$c(H^+)_{100mL} = 6.30 \times 10^{-7}/0.100$ $= 6.30 \times 10^{-6}$ mol L^{-1}	1
$pH = -\log(6.30 \times 10^{-6}) = 5.20$	1
The rain water sample would not be classified as acid rain (No marks awarded unless accompanied by supporting working.)	1
Total	**6**

(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)

Description	Marks
pH = 4.0 $c(H^+)_{total} = 1 \times 10^{-4}$ mol L^{-1}	
pH = 5.6 $c(H^+)_{CO2} = 2.51 \times 10^{-6}$ mol L^{-1}	1
$c(H^+)_{SO2} = c(H^+)_{total} - c(H^+)_{CO2}$ $= 100.0 \times 10^{-6} - 2.51 \times 10^{-6}$ $= 9.75 \times 10^{-5}$ mol L^{-1}	1
$n(H^+)_{SO2} = 9.75 \times 10^{-5} \times 0.100$ $= 9.75 \times 10^{-6}$ mol	1
$n(H_2SO_3) = n(H^+)/2$ $= 9.75 \times 10^{-6}/2$ $= 4.88 \times 10^{-6}$ mol	1
1:1 ratio between SO_2 and H_2SO_3	1
$V(SO_2) = nRT/P$ $= 4.88 \times 10^{-6} \times 8.314 \times 289.15/97.2$ $= 1.21 \times 10^{-4}$ L	1
Total	**6**