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CHEMISTRY

STAGE 3

2015

Name: _____

Teacher: _____

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes
Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:

- This Question/Answer Booklet
- Multiple-choice Answer Sheet
- Chemistry Data Sheet

To be provided by the candidate:

- Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, eraser, correction tape/fluid, ruler, highlighters
- Special items: non-programmable calculators approved for use in the WACE examinations

IMPORTANT NOTE TO CANDIDATES

- No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	/50	/25
Section Two: Short answer	10	10	60	/70	/35
Section Three: Extended answer	5	5	70	/80	/40
					/100

Instructions to candidates

1. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each questions shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer Booklet.

2. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to three significant figures and include appropriate units where applicable.

3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

4. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

5. The Chemistry Data Sheet is **not** handed in with your Question/Answer Booklet.

SEE NEXT PAGE

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Section One: Multiple-choice **25% (50 marks)**

This section has 25 questions. Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

---

1. The subatomic particle arrangement of five different species is shown below. Which of the following are **correct**?

	Species	Protons	Neutrons	Electron configuration
(i)	^{9}Be	9	9	2,7
(ii)	^{39}K	19	20	2,8,8,1
(iii)	$^{31}P^{3-}$	15	16	2,8,5
(iv)	^{12}C	6	6	2,6
(v)	$^{25}Mg^{2+}$	12	13	2,8

(a) (i), (ii) and (iv) only
(b) (ii), (iv) and (v) only
(c) (ii) and (v) only
(d) (ii), (iii), and (v) only

2. The first five ionisation energies of four different elements are shown below. Which of these is **most likely** to be a non-metal element? (All values are stated in kJ mol^{-1}.)

(a)	801	2427	3660	25026	32827
(b)	738	1451	7733	10543	13630
(c)	419	3052	4420	5877	7975
(d)	1402	2856	4578	7475	9445

3. Consider the solubility information given in the table below for the substances butan-1-ol and hexan-1-ol.

	Solubility in water at 20 ˚C (grams per 100 mL)
butan-1-ol	7.7
hexan-1-ol	0.59

Which of the following gives the **best** explanation for the difference in water solubility?

(a) Only butan-1-ol forms hydrogen bonds with water.
(b) Hexan-1-ol is non-polar.
(c) Butan-1-ol has a smaller non-polar region.
(d) The molecular weight (M) of hexan-1-ol is higher.

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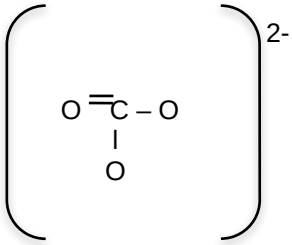
4. A standard solution of potassium permanganate was being used in volumetric analysis to determine the concentration of a solution of oxalic acid. The potassium permanganate was placed in the burette and delivered into the conical flask, which contained a mixture of oxalic and sulfuric acids. What colour change should be observed in the conical flask as the titration achieves equivalence?

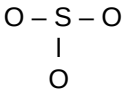
(a) Purple to pale pink.
(b) Purple to colourless.
(c) Colourless to purple.
(d) Colourless to pale pink.

5. Which of the following structural diagrams is **correct** for the species named?

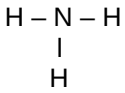
(a) carbonate



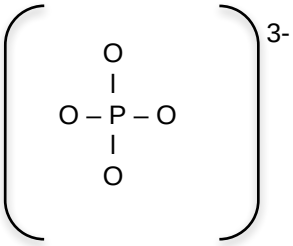
(b) sulfur trioxide



(c) ammonium



(d) phosphate



6. Four test tubes each contain a different clear colourless solution. These solutions are known to be silver nitrate, lead(II) nitrate, ammonium nitrate and calcium nitrate. If a few drops of aqueous sodium sulfide (Na_2S) is added to each, what colour precipitate would form in each test tube?

	$AgNO_3$	**$Pb(NO_3)_2$**	**NH_4NO_3**	**$Ca(NO_3)_2$**
(a)	pale yellow	white	none	white
(b)	black	grey	none	white
(c)	black	white	white	none
(d)	pale yellow	grey	white	none

SEE NEXT PAGE

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Questions 7 and 8 refer to the experiment described below.

Two beakers contained equal volumes of 0.75 mol L^{-1} hydrogen peroxide. To one beaker, 5.0 g of manganese(IV) oxide **powder** was added. To the second beaker, 5.0 g of manganese(IV) oxide **chips** were added. The reaction that took place in both beakers is shown in the equation below.

$$2\ H_2O_2(aq) \xrightarrow{MnO_2} 2\ H_2O(l) + O_2(g)$$

In both beakers the reaction was allowed to go to completion. The liquid in the beakers was tested at the conclusion of the experiment and only water remained in each.

7. Which of the following statements is **not** correct regarding this experiment?

   (a) The reaction with the MnO_2 powder would have finished first.
   (b) The reaction with the MnO_2 chips would have produced the same total volume of oxygen gas.
   (c) The MnO_2 powder lowered the activation energy of the reaction more than the MnO_2 chips.
   (d) The smaller surface area of the MnO_2 chips allowed fewer molecular collisions per unit time.

8. The oxygen gas from each experiment was collected and bubbled through two 100 mL samples of water. One water sample was at room temperature (25 ˚C) and one had been stored in the fridge (4 ˚C). Which of the following describes the expected result?

   (a) The room temperature water contained more dissolved oxygen.
   (b) The fridge water contained more dissolved oxygen.
   (c) Both samples of water have the same concentration of dissolved oxygen.
   (d) Neither sample contained dissolved oxygen.

9. Consider the following equation, which shows the auto-ionisation of water.

$$H_2O(l) + H_2O(l) + \text{heat} \rightleftarrows H_3O^+(aq) + OH^-(aq)$$

   If the temperature of this system is decreased, which of the following statements are **true**?

   (i) The pH of the water rises
   (ii) The water becomes less acidic
   (iii) The value of K_w becomes greater
   (iv) $[H_3O^+]$ decreases
   (v) $[H_3O^+] = [OH^-]$

   (a) (i), (iv) and (v) only
   (b) (i), (ii) and (iv) only
   (c) (ii) and (iii) only
   (d) (i) and (v) only

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Questions 10 and 11 refer to the information below.

Potassium dichromate ($K_2Cr_2O_7$) is a common oxidising agent (oxidant). In solid form it appears as orange-red crystals, and is very harmful to human health when ingested.

10. When potassium dichromate is said to 'act as an oxidising agent' this means that:

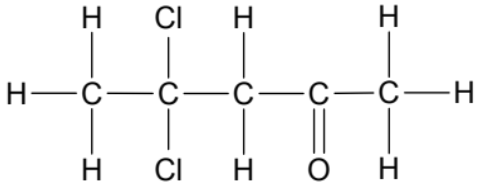
(a) it will react with oxygen.
(b) it will be oxidised.
(c) its oxidation state will increase.
(d) it will gain electrons.

11. Which of the following substances would **not** react with a solution of acidified potassium dichromate under standard conditions?

(a) NaBr(aq)
(b) Ag(s)
(c) LiCl(aq)
(d) Na(s)

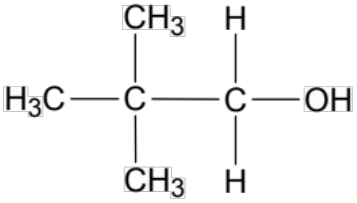
12. Examine the organic substances shown below. Which of the following has been **correctly** named using IUPAC nomenclature?

(a)



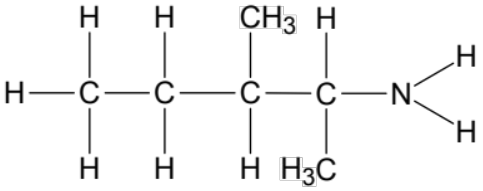
2,2-dichloropentan-4-one

(b)



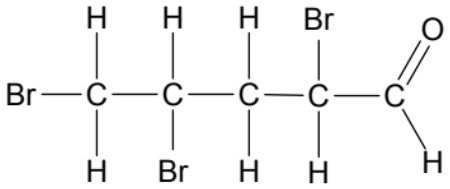
dimethylpropan-1-ol

(c)



1,2-dimethylbutan-1-amine

(d)



2,4,5-tribromopentan-1-al

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13. The physical properties of a substance were examined and recorded in a laboratory book as stated below.

> *"The substance is a hard, white solid. It does not dissolve in water. The solid does not conduct electricity. The substance cannot be shaped by applying pressure. When heated to 1600 ℃ it melted. In molten state, it still did not conduct electricity."*

Which type of bonding is this substance **most likely** to exhibit?

(a) metallic
(b) ionic
(c) covalent molecular
(d) covalent network

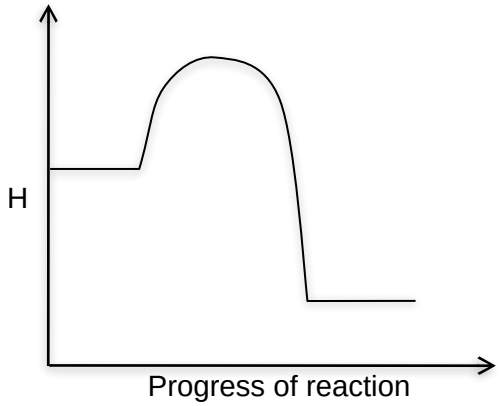
14. In which of the following aqueous solutions would ion-dipole forces exist?

(i) $PbSO_4(aq)$
(ii) NaCl(aq)
(iii) HCl(aq)

(a) (ii) only
(b) (i) and (ii) only
(c) (ii) and (iii) only
(d) (i), (ii) and (iii)

15. A chemistry student began to sketch the potential energy diagram for a reaction (shown below).

The activation energy (Ea) for the forward reaction was 457 kJ. However the addition of a catalyst lowered this value to 320 kJ. The activation energy for the uncatalysed reverse reaction was 903 kJ.



What are the values of ΔH(rev) (i.e. the enthalpy change for the reverse reaction) and Ea(rev, cat) (i.e. the activation energy for the catalysed reverse reaction).

	ΔH(rev) (kJ mol^{-1})	**Ea(rev, cat)** (kJ)
(a)	-446	583
(b)	+446	766
(c)	-446	766
(d)	+446	583

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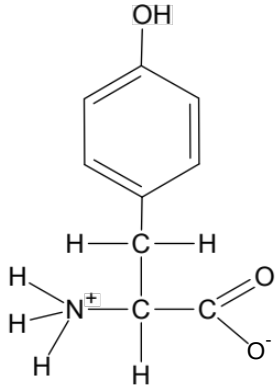
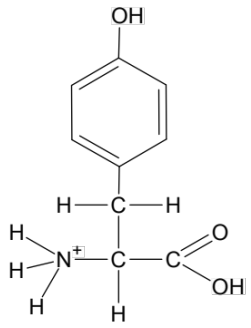
Questions 16 and 17 refer to the information below.

The molecule below is tyrosine. It was first discovered in cheese, but is now known to be present in many protein foods. Tyrosine is shown below in its common 'zwitterion form' which means that it is a neutral molecule with both a positive and negative charge.

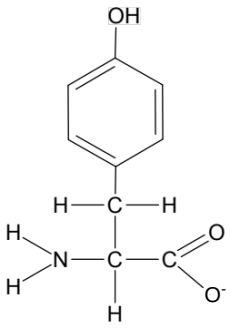


16. What is the conjugate base of tyrosine?

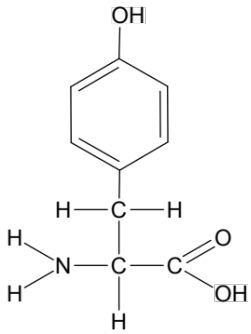
(a)



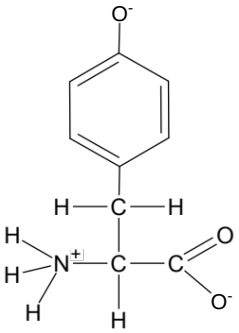
(b)



(c)



(d)



17. Which of the following statements regarding tyrosine are **correct**?

(i) Tyrosine is an amino acid
(ii) Tyrosine is an α-amino acid
(iii) The molecular formula of tyrosine is $C_9H_7NO_3$

(a) (i) and (ii) only
(b) (i) and (iii) only
(c) (ii) and (iii) only
(d) (i), (ii) and (iii)

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18. Which of the following statements is **not** correct regarding the substance octane?

(a) It can undergo substitution to form chlorooctane.
(b) It can undergo combustion to produce carbon dioxide and water vapour.
(c) It can react with bromine to form dibromooctane and hydrogen gas.
(d) Is has the empirical formula C_4H_9.

Questions 19 and 20 refer to the equilibrium system below.

Some methanol and ethanoic acid were mixed together in a beaker. A few drops of sulfuric acid were added and the mixture was gently warmed. The reaction was allowed to proceed until the equilibrium system below was established.

$$CH_3OH(l) + CH_3COOH(l) \rightleftarrows CH_3COOCH_3(l) + H_2O(l)$$

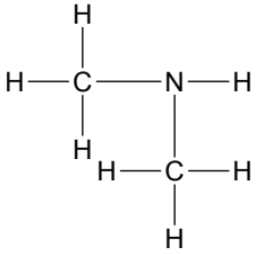
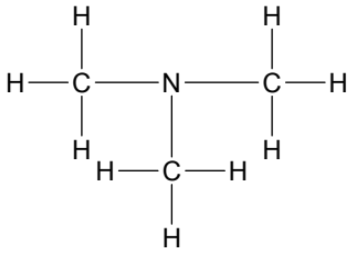
19. Which of the following would **not** be true for the equilibrium system?

(a) Gently warming the mixture will allow it to reach equilibrium faster.
(b) At equilibrium the pH would remain constant.
(c) At equilibrium $[CH_3COOCH_3] = [H_2O]$.
(d) The H_2SO_4 will be consumed as equilibrium is attained.

20. Once the system is in equilibrium, which of the following changes will decrease the rate of the forward reaction?

(a) Decreasing the pressure of the system.
(b) Adding a few drops of CH_3COOH to the system.
(c) Decreasing the temperature of the system.
(d) Adding a few drops of CH_3COOCH_3 to the system.

21. Examine the information in the table below.

Dimethylamine	Trimethylamine
	
Boiling point 8 ˚C	Boiling point -3 ˚C

Which is the **best** explanation for the difference in boiling point of these two substances?

(a) Dimethylamine forms hydrogen bonding while trimethylamine does not.
(b) Trimethylamine is more polar than dimethylamine.
(c) Dimethylamine has stronger dispersion forces than trimethylamine.
(d) Trimethylamine has stronger dispersion forces than dimethylamine.

SEE NEXT PAGE

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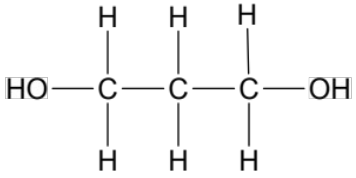
22. The equilibrium constant expression for a reaction is as follows;

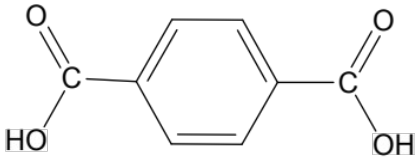
$$K = \frac{[HF]^6\,[(NH_4)_3C_6H_5O_7]}{[NH_4HF_2]^3\,[C_6H_8O_7]}$$

Assuming no other species are present in the reaction, which of the following reactions is occurring?

(a) $(NH_4)_3C_6H_5O_7 + 6\ HF \rightleftarrows 3\ NH_4HF_2 + C_6H_8O_7$
(b) $3\ NH_4HF_2 + C_6H_8O_7 \rightleftarrows (NH_4)_3C_6H_5O_7 + 6\ HF$
(c) $6\ (NH_4)_3C_6H_5O_7 + HF \rightleftarrows NH_4HF_2 + 3\ C_6H_8O_7$
(d) $NH_4HF_2 + 3\ C_6H_8O_7 \rightleftarrows 6\ (NH_4)_3C_6H_5O_7 + HF$

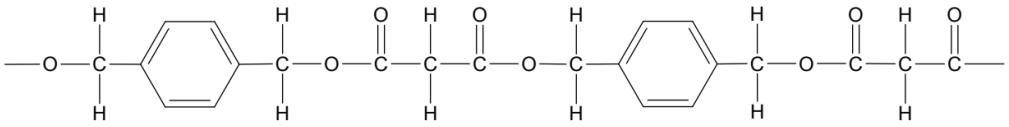
23. The polymer PTT (polytrimethylene terephthalate) was patented in 1941 and is used in the manufacture of carpet fibres. It is produced from the polymerisation of the monomers propane-1,3,-diol and terephthalic acid.



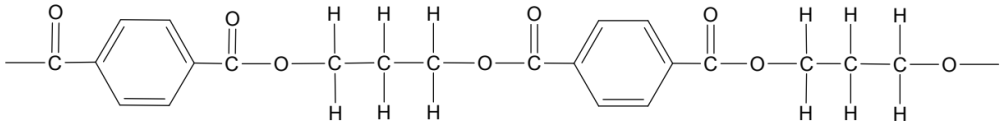


Which of these structural diagrams represents PTT?

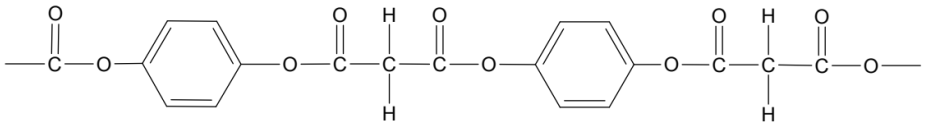
(a)



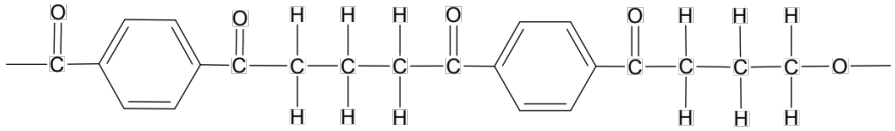
(b)



(c)



(d)



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Questions 24 and 25 refer to the following experiment.

A group of students were investigating the hydrogen half-cell and its role as part of an electrochemical cell. A hydrogen half-cell was set up by placing 1 mol L^{-1} hydrochloric acid into a beaker with an inert platinum electrode. This half-cell was then linked, in turn, to four different metal/metal ion half-cells. The voltage produced by each cell was measured and recorded. All half-cells were set up and measured under standard conditions.

24. Which of the following half-cells, when linked with the hydrogen half-cell described above, would **not** have produced a voltage?

(a) Ag/Ag^{+}
(b) Ni/Ni^{2+}
(c) Fe/Fe^{2+}
(d) Al/Al^{3+}

25. A manganese/manganese(II) sulfate half-cell was linked to the hydrogen half-cell and the measured voltage matched that predicted by the table of standard reduction potentials. Which of the following conditions could have been used, to produce a measured voltage equal to the predicted voltage?

(a) The manganese metal contained 2.0% carbon impurities.
(b) The room temperature was 20 °C.
(c) The concentration of HCl(aq) was 1.5 mol L^{-1}.
(d) The concentration of $MnSO_4$(aq) was 1.5 mol L^{-1}.

End of Section One

SEE NEXT PAGE

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Section Two: Short answer **35% (70 marks)**

This section has 10 questions. Answer all questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to three significant figures and include appropriate units where applicable.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 26 **(9 marks)**

The heterogeneous equilibrium system below exists between liquid phosphorus tribromide, gaseous bromine, and solid phosphorus pentabromide.

$$\underset{\textit{colourless}}{PBr_3(l)} + \underset{\textit{red}}{Br_2(g)} \rightleftarrows \underset{\textit{yellow}}{PBr_5(s)}$$

(a) Draw the Lewis / electron dot diagram for phosphorus tribromide, representing all valence shell electron pairs either as : or –. (1 mark)

(b) Write the equilibrium constant expression for this reaction. (1 mark)

SEE NEXT PAGE

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(c) As the temperature of the system is increased from room temperature to 100 ˚C, it is observed that the yellow solid all but disappears and only a thick red vapour is visible. What information does this provide regarding:

(i) the enthalpy change (ΔH) of this reaction? Explain your answer. (3 marks)

(ii) the value of K for this reaction at 100 ˚C? Explain your answer. (2 marks)

(d) As the temperature of the system is increased to 100 ˚C, explain the effect this would have on the rate of **both** the forward and reverse reactions. (2 marks)

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Question 27 **(6 marks)**

The following table provides information about the conductivity of two different compounds in their pure forms as a solid and liquid, and also if they were **mixed** with water.

	(s)	(l)	(aq)
HCl	✗	✗	✓
$CaCO_3$	✗	✓	✗

Explain the conductivity of each substance in its solid form, liquid form and when mixed with water. Use chemical equations to support your answer where appropriate.

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Question 28 **(6 marks)**

The two organic molecules below are alkene isomers.

$CH_3C(CH_3)=CHCH_2CH_2CH_3$ $CH_3CH=CHCH(CH_3)CH_2CH_3$

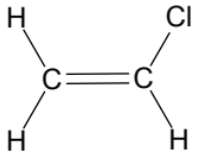
Only one of these molecules exhibits geometric (*cis-trans*) isomerism.

(a) Circle this molecule and explain your choice. (2 marks)

(b) Draw structural formulas for both geometric isomers and name each using the IUPAC system. (2 marks)

Name:	Name:

The alkene below is involved in many different chemical reactions.



(c) Draw the structural diagram for the organic product formed when this alkene is: (2 marks)

(i) mixed with bromine water, $Br_2(aq)$	
(ii) polymerised to form PVC (show 3 repeating units)	

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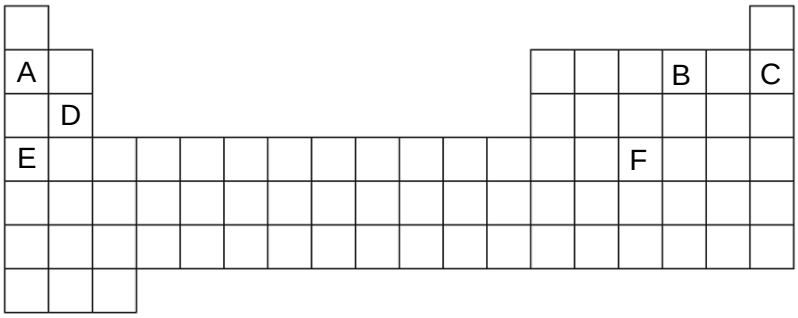
Question 29 **(8 marks)**

Consider elements A-E on the periodic table below.



(a) Which element has: (3 marks)

(i) the highest electronegativity? _____

(ii) the largest atomic radius? _____

(iii) the highest ionisation energy? _____

(b) Write the electron configuration for element D. (1 mark)

_____

(c) Which two elements are most likely to have the same bonding capacity? (1 mark)

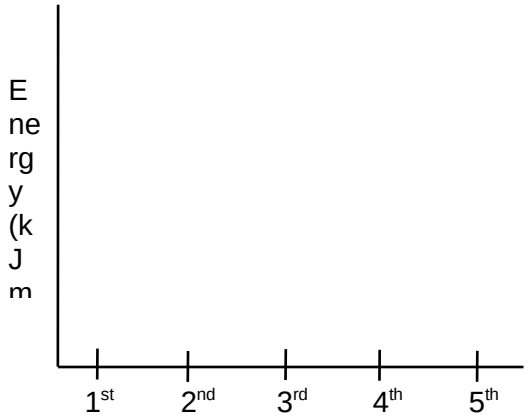
_____

(d) What is the likely formula of the substance produced when A and B form chemical bonds? What type of bonding is likely to occur? (2 marks)

_____

_____

(e) Sketch a rough graph showing the first 5 ionisation energies for element D. (1 mark)



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Question 30 **(7 marks)**

Five organic compounds and their corresponding boiling points are shown below.

	CH_4	CH_3Br	CH_2Br_2	$CHBr_3$	CBr_4
Boiling point (˚C)	-161	3.5	96	147	190

(a) Explain why all these molecules are tetrahedral in shape. (2 marks)

(b) Place ticks (✓) in the table to indicate the types of intermolecular forces present in each of these 5 substances. (3 marks)

	Dispersion	Dipole-dipole	Hydrogen bonds
CH_4			
CH_3Br			
CH_2Br_2			
$CHBr_3$			
CBr_4			

(c) Explain why CBr_4 has the highest boiling point. (2 marks)

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Question 31 **(5 marks)**

Examine the following closed system that has reached equilibrium.

$$2\ FeS_2(s) + 7\ O_2(g) + 2\ H_2O(l) \rightleftarrows 2\ Fe^{2+}(aq) + 4\ SO_4^{2-}(aq) + 4\ H^+(aq)$$

What effect would each of these changes have on the final concentration of H^+, once equilibrium was re-established? State 'increase', 'decrease' or 'no change'.

	Effect on $[H^+]$ (increase, decrease, no change)
Several drops of HCl(aq) are added	
Several drops of $Ba(NO_3)_2$(aq) are added	
A small amount of solid FeS_2 is added	
The pressure on the system is decreased	
Several drops of $FeCl_2$(aq) are added	

Question 32 **(6 marks)**

Tellurium (Te) is a rare, silver metalloid that can be used in solar panels and as a semiconducting material. It can be produced by reacting the mineral tellurite (TeO_2) with hypophosphoric acid (H_3PO_2). This produces tellurium metal and phosphorous acid (H_3PO_3).

Write the oxidation and reduction half-equations and the overall redox equation for this reaction, assuming acidic conditions.

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

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Question 33 **(8 marks)**

Consider the following covalent molecules.

PH_3	HF	CO_2	F_2
CH_2O	SO_2	NF_3	HCN

(a) Complete the table below by selecting a molecule from the list above that matches the description. Each molecule may **only be used once**. (5 marks)

Description	Molecule
A molecule that is linear and polar	
A molecule that contains only non polar bonds	
A molecule that is trigonal (triangular) planar	
A molecule that would exhibit hydrogen bonding	
A non-polar molecule with polar bonds	

Oxygen (O_2) is only found on Earth in the gaseous state because its boiling point is -183 ˚C (90 K). When gaseous oxygen condenses, pale blue liquid oxygen is formed. During this phase change, the dispersion forces between the oxygen molecules become stronger.

(b) Explain why dispersion forces occur. (3 marks)

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Question 34 **(9 marks)**

The molecular equation below shows the chemical reaction that takes place when barium hydroxide solution is mixed with aqueous ammonium nitrate.

___ $Ba(OH)_2(aq)$ + ___ $NH_4NO_3(aq)$ → ___ $Ba(NO_3)_2(aq)$ + ___ $NH_3(aq)$ + ___ $H_2O(l)$

(a) Complete the reaction above by adding coefficients to balance the equation, and write the ionic equation below, showing only those species that are reacting. (2 marks)

(b) Name or give the formula for one substance present in the equation above that is basic. Write a chemical equation to support your answer. (2 marks)

(c) Name or give the formula for one substance present in the equation above that is acidic. Write a chemical equation to support your answer. (2 marks)

(d) Which 2 substances present in the equation above could be combined to form a buffer? Explain how you could design this buffer so that it has the capacity to maintain a near constant pH when acid or base is added. (3 marks)

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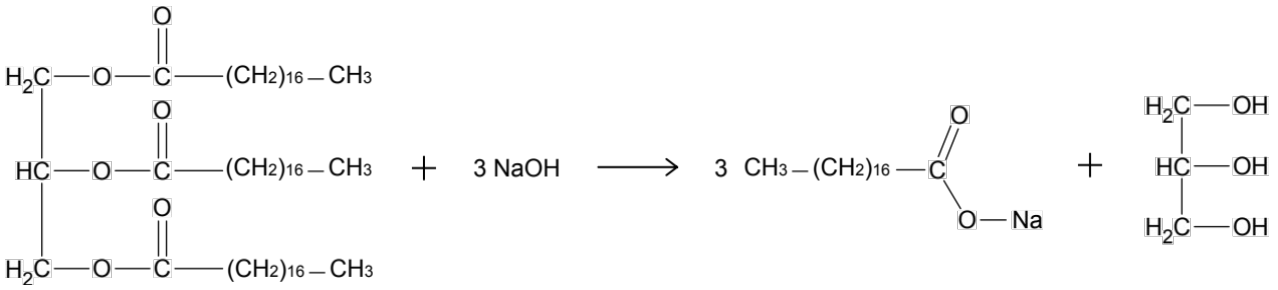
Question 35 **(6 marks)**

The saponification equation below shows the reaction used to produce soap from the fat ‘stearin’.



stearin *soap* *glycerol*

(a) Name the type of functional group present in the following substances. (2 marks)

	Functional group present
Stearin	
Glycerol	

(b) Describe the mechanism by which soaps clean, including the disadvantage of using soaps in hard water. (4 marks)

End of Section Two

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Section Three: Extended answer **40% (80 marks)**

This section contains five (5) questions. You must answer all questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to three significant figures.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

Question 36 **(15 marks)**

A chemist had five bottles sitting on his laboratory bench, each containing a clear colourless liquid. The bottles contained the organic substances:

- 3-methylbutanoic acid
- ethyl propanoate
- pentanoic acid
- 3-methylbutan-2-ol
- 3-methylbutanone

Unfortunately his laboratory assistant had not finished labelling the bottles before he left on vacation, so the chemist set out to determine the identity of each.

(a) What chemical test could the chemist use to quickly distinguish which substance was 3-methylbutan-2-ol? Include a chemical equation in your answer and give expected observations. (4 marks)

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The chemist then took one of the remaining unknown substances and analysed it by combustion to determine its formula. A 0.368 g sample of the substance was burnt in air and produced 0.790 g of carbon dioxide and 0.325 g of water vapour.

(b) Determine the empirical formula of the substance and state which of the unknown organic substances it may be. (9 marks)

A small amount of solid sodium carbonate (Na_2CO_3) was added to a separate sample of the same unknown substance analysed in (b). However, no reaction was observed.

(c) Identify the unknown substance and state **one** characteristic physical property this substance would likely have. (2 marks)

_____

_____

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Question 37 **(23 marks)**

'Drano' is a drain-cleaning product that was invented in 1923 by Harry Drackett. The active ingredient in Drano products is sodium hydroxide, which is used because of its ability to break down the grease, fat and hair that is often the cause of a blocked drain. According to the manufacturer, Drano crystals contain between 30-40% sodium hydroxide by mass. The water-soluble ingredients in the original Drano crystals are:

- sodium hydroxide, NaOH(s)
- sodium nitrate, $NaNO_3(s)$
- sodium chloride, NaCl(s)

Small pieces of solid aluminium are also added to this mixture before packaging to produce the final Drano product. A group of chemistry students decided to investigate some of the properties of Drano and were provided with a sample of the water-soluble components (listed above). They dissolved a spoonful of the crystals in some water and attempted to measure the resulting pH.

(a) Explain why the sodium chloride and sodium nitrate salts will not have any effect on the pH of the solution when the Drano crystals are dissolved in water. (2 marks)

_____

_____

_____

The students dissolved 100 g of crystals in a beaker containing 1.00 L of water. Assuming the manufacturer is correct, and sodium hydroxide comprises between 30.0-40.0% by mass of the Drano crystals;

(b) Calculate the possible pH range of the solution formed when the crystals dissolve. (You may assume the final volume is still 1.00 L and the pH of the solution is entirely determined by the initial amount of sodium hydroxide.) (6 marks)

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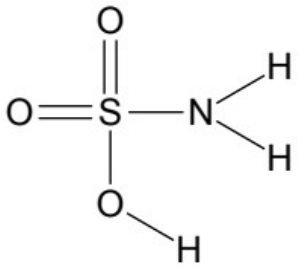
Another group of chemistry students set out to investigate a different batch of Drano crystals (water-soluble components only) and decided to analyse them by titration, in order to determine the percent mass of NaOH present in the crystals.

They decided to titrate a solution of the crystals against a standard solution of sulfamic acid (H_3NSO_3). Sulfamic acid is a weak, monoprotic acid, which appears as white crystals in solid form. Amongst its other properties, sulfamic acid is non-hygroscopic, allowing it to be used as a primary standard in volumetric analysis.

Sulfamic acid



(c) Describe the difference between a **primary standard** and a **standard solution**. (4 marks)

(d) Name an appropriate indicator for use in this titration. Explain your choice and use a chemical equation to support your answer. (3 marks)

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To perform the titration, 2.107 g of the water-soluble Drano crystals were dissolved in water and transferred to a volumetric flask where the volume was made up to 500.0 mL with distilled water. From this solution, 20.00 mL aliquots were taken and titrated against the standard sulfamic acid solution. An average titre of 24.25 mL was required for complete reaction. The reaction that took place during the titration is shown in the molecular equation below.

$$H_3NSO_3(aq) + NaOH(aq) \rightarrow NaH_2NSO_3(aq) + H_2O(l)$$

If it was determined that this batch of Drano crystals contained exactly 40.0% by mass sodium hydroxide;

(e) Calculate the concentration of the standard sulfamic acid solution that was used in this titration. (6 marks)

(f) Another group that was performing the same titration found that their titration volumes for sulfamic acid were consistently **lower** than expected. State an error that would account for these results. Explain your answer. (2 marks)

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Question 38 **(15 marks)**

The Daniell cell was invented in 1836 and was one of the earliest batteries to be designed. Essentially, the Daniell cell can be thought of as two half-cells consisting of a copper electrode submerged in copper(II) sulfate solution (Cu/Cu^{2+}) and a zinc electrode submerged in zinc sulfate solution (Zn/Zn^{2+}). In the original design, a porous clay pot was used to separate the half-cells and act as what we now call the salt bridge. The EMF produced by the Daniell cell is 1.1 V under standard conditions.

A chemistry class was studying the basic design of the Daniell cell and decided to investigate the effect of changing the metals used for each electrode/electrolyte. They decided to construct a cell using tin metal, chromium metal, tin(II) sulfate solution and chromium(III) sulfate solution. They set up their apparatus as shown in the diagram below.

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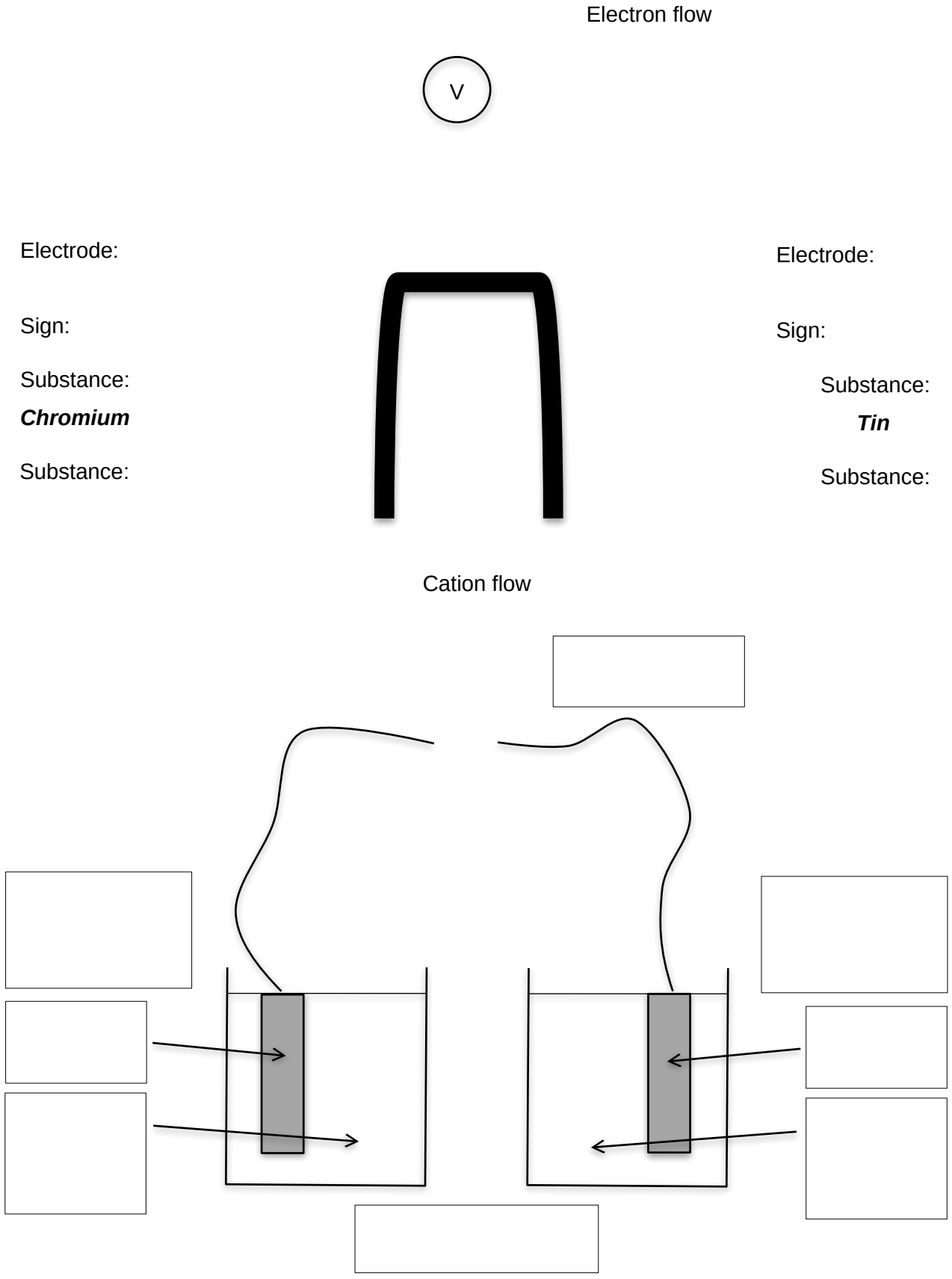

(a) Label all remaining components of the cell in the diagram above, including: (6 marks)

(i) cathode and anode
(ii) sign of each electrode
(iii) substance used for each half-cell electrolyte

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(iv) direction of electron and cation flow

(b) Note two observations that would be made as this electrochemical cell operates. (2 marks)

_____

_____

_____

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The overall equation for the operation of this electrochemical cell is;

$$3\ Sn^{2+}(aq) + 2\ Cr(s) \rightarrow 3\ Sn(s) + 2\ Cr^{3+}(aq)$$

Just like the Daniell cell, the cell designed by the students is a primary cell, which means it cannot be recharged. Therefore, over time the reactants will run out, as the chemicals stored within the electrochemical cell are used to produce electricity.

If the chromium electrode has a mass of 36.2 g and there was 475 mL of 2.10 mol L^{-1} tin(II) sulfate solution present;

(c) Determine the limiting reagent. (5 marks)

(d) If the chromium half-cell was replaced with a Cu/Cu^{2+} half-cell, would the students be able to produce a higher or lower EMF? Explain. (2 marks)

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Question 39 **(15 marks)**

The thermal reduction process, or Pidgeon Process, is one of the methods used to produce magnesium (Mg) metal. This process was developed in the early 1940s by Dr Lloyd Montgomery Pidgeon and currently dominates world magnesium production over electrolytic methods.

The Pidgeon Process makes use of the ore 'dolomite', which contains magnesium / calcium carbonate, $MgCO_3.CaCO_3$. This ore is heated at around 1100-1200 ˚C to remove the carbon from the compound as shown in Step 1.

Step 1: $MgCO_3.CaCO_3(s) \rightarrow MgO.CaO(s) + 2\ CO_2(g)$

The resulting magnesium / calcium oxide is heated with silicon and the thermal reduction process occurs as in Step 2. This reaction is highly endothermic and produces magnesium vapour, as well as a dicalcium silicate slag.

Step 2: $2\ MgO.CaO(s) + Si(s) \rightleftarrows 2\ Mg(g) + Ca_2SiO_4(l)$

A very high temperature of 1200-1250 ˚C is used for this thermal reduction step and the pressure is kept close to a vacuum, at only 65 Pa. The magnesium vapour is removed as it forms and crystallises into solid magnesium with a purity of between 99.6-99.9%.

(a) Discuss the conditions used in Step 2 of the magnesium extraction process, in terms of **both** reaction rate and yield. (6 marks)

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A manufacturing plant carrying out the Pidgeon process can generally produce 12.0 kg of pure magnesium vapour for every 8 hours of operation.

(b) What volume would this mass of magnesium vapour occupy at 1250 ˚C and 65.0 Pa? (Note: 1000 Pa = 1 kPa) (4 marks)

If 12.0 kg of pure magnesium is extracted from 128 kg of dolomite ore for every 8 hours of operation and the dolomite ore consists of 75.6% magnesium/calcium carbonate, ($MgCO_3.CaCO_3$);

(c) Calculate the efficiency of extraction of the magnesium from the dolomite ore. (5 marks)

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Question 40 **(12 marks)**

Hydrazine (N_2H_4) is a colourless, oily, flammable liquid. It is a toxic substance with an odour similar to ammonia (NH_3). Exposure to hydrazine can cause irritation of the eyes, nose and throat, as well as dizziness, headaches and nausea. High levels of exposure can damage the liver, kidneys and central nervous system. Hydrazine is corrosive and can cause burns if skin contact occurs.

Hydrazine has a boiling point of 114 $^{\circ}$C, which is quite high for a substance with a molar mass of 32.05 g mol^{-1}. In contrast, ethane (C_2H_6) has a comparable molar mass of 30.07 g mol^{-1} but a boiling point of -89 $^{\circ}$C. Hydrazine is miscible with (soluble in) water.

Hydrazine is quite an unstable compound unless it is dissolved in water and handled as an aqueous solution. When mixed with water it acts as a Bronsted-Lowry base and ionises in a similar way to ammonia. The value of K for this ionisation is 1.3×10^{-6}.

One method for synthesising hydrazine is by the 'peroxide process' where ammonia and hydrogen peroxide (H_2O_2) react to form hydrazine and water. There are several other ways to manufacture hydrazine, however they all generally rely on the oxidation of a nitrogen-containing compound.

Hydrazine is used in the manufacture of polymers, not directly as a monomer, but in the production of polymer catalysts and foaming agents. It is also used in the manufacture of pesticides, pharmaceuticals and to prepare the chemicals used in vehicle air bags. The volatile nature and highly exothermic combustion of hydrazine also make it a useful component in the fuel used to power rockets and other spacecraft.

(a) Discuss two physical properties of hydrazine, namely its boiling point and water solubility, in terms of the bonding present in the compound. Your answer should include a Lewis / electron dot diagram for hydrazine representing all valence shell electron pairs as : or –.
(4 marks)

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(b) Discuss the acid-base properties of hydrazine in aqueous solution. Your answer should include a chemical equation representing the ionisation of hydrazine, as well as an indication of what information the value of K provides. (4 marks)

(c) Hydrazine is synthesised by a redox reaction. Write a chemical equation representing the 'peroxide process' and use this equation to elaborate on redox processes. Your answer should include a definition of a redox reaction, as well as identifying which species have been oxidised or reduced in this reaction by way of oxidation numbers. (4 marks)

End of questions

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Spare answer page

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