Chemistry 3AB

Semester Two Examination, 2011

Question/Answer Booklet

NAME: Solutions

TEACHER: _____

Marker use only

Part	Marks achieved	Marks available
1 Multiple choice	/50	50 (25%)
2 Short answer	/70	70 (35%)
3 Extended answers	/80	80 (40%)
TOTAL		200 (100%)

%

Time allowed for this paper
Reading time before commencing work: Ten minutes
Working time for paper: Three hours

Materials required/recommended for this paper

To be provided by the supervisor
This Question/Answer Booklet
Separate Multiple Choice Answer Sheet
Separate Chemistry Data Sheet

To be provided by the candidate
Standard Items: Pens, pencils, eraser or correction fluid and ruler
Special Items: A 2B, B or HB pencil for the separate Multiple Choice Answer Sheet and calculators satisfying the conditions set by the Curriculum Council for this subject.

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

Part	Number of questions available	Number of questions to be attempted	Suggested working time (minutes)	Marks available
1 Multiple choice	25	ALL	50	50 (25%)
2 Short answer	11	ALL	60	70 (35%)
3 Extended answers	7	ALL	70	80 (40%)
			Total marks	200 (100%)

Instructions to candidates

Answer the questions according to the following instructions:

Part 1: Answer **all** questions, using a 2B, B or HB pencil on the separate Multiple Choice Answer Sheet. **Do not** use a ballpoint or ink pen.

If you consider that two or more of the alternative responses are correct, choose the one you think is best. If you think you know an answer, mark it even if you are not certain you are correct. Marks will **not** be deducted for incorrect answers.

Feel free to write or do working on the question paper; many students who score high marks on the Multiple Choice Section do this.

Parts 2 and 3 Write your answers in the spaces provided in this Question/Answer Booklet. A blue or black ball point or ink pen should be used.

Questions containing specific instructions to show working should be answered with a complete, logical, clear sequence of reasoning showing how the final answer was arrived at. Correct answers which do not show working will **not** be awarded full marks.

The examiners recommend that you spend your reading time mainly reading the Instructions to Candidates and Parts 2 and 3.

At the end of the examination make sure that your name is on your Question/Answer Booklet and on your separate Multiple Choice Answer Sheet.

Chemical Equations
For full marks, chemical equations should refer only to those specific species consumed in the reaction and the new species produced. These species may be **ions** [for example $Ag^{+}_{(aq)}$], **molecules** [for example $NH_{3(g)}$, $CH_3COOH_{(l)}$, $CH_3COOH_{(aq)}$] or **solids** [for example $BaSO_{4(s)}$, $Cu_{(s)}$, $Na_2CO_{3(s)}$].

SEE NEXT PAGE

NAME: Solutions

TEACHER: _____

Mark:	
*	/50

DIRECTIONS:

1. Use$ A '2B'. 'B' or 'HB' pencil. Do not use a ballpoint or ink pen.
2. Mark the boxes in the following way [A] [B] [C] [D].
3. Please ensure your name is recorded on the sheet.
4. Give only one answer for each question. If you change your mind erase your mark completely and then mark your new answer. More than one answer will invalidate the answer.
5. Your answer sheet will be collected separately by the supervisor at the end of the examination.

* two marks for each correct multi-choice

1 [A] [B] [C] [D]	**11** [A] [B] [C] [D]	**21** [A] [B] [C] [D]
2 [A] [B] [C] [D]	**12** [A] [B] [C] [D]	**22** [A] [B] [C] [D]
3 [A] [B] [C] [D]	**13** [A] [B] [C] [D]	**23** [A] [B] [C] [D]
4 [A] [B] [C] [D]	**14** [A] [B] [C] [D]	**24** [A] [B] [C] [D]
5 [A] [B] [C] [D]	**15** [A] [B] [C] [D]	**25** [A] [B] [C] [D]
6 [A] [B] [C] [D]	**16** [A] [B] [C] [D]	
7 [A] [B] [C] [D]	**17** [A] [B] [C] [D]	
8 [A] [B] [C] [D]	**18** [A] [B] [C] [D]	
9 [A] [B] [C] [D]	**19** [A] [B] [C] [D]	
10 [A] [B] [C] [D]	**20** [A] [B] [C] [D]	

PART 1 (50 marks = 25% of paper)

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. Marks will not be deducted for incorrect answers. Each question in this part is worth 2 marks.

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1. Which of the following elements has the highest second ionisation energy?

   (a) Calcium (2,8,8,2)
   (b) Magnesium (2,8,2)
   (c) Potassium (2,8,8,1)] 2nd e⁻ from full shell.
   (d) Sodium (2,8,1)] closer to nucleus.

2. An element, E, is able to react to form both ionic and covalent compounds. How many valence electrons would its atoms most likely possess?

   (a) 1] can not share to fill shell
   (b) 2]
   (c) 7
   (d) 8 – none to share

3. In which of the following pairs of atomic species is the first species larger than the second species?

(a)	sodium ion (lose e⁻ smaller)	sodium atom
(b)	oxide ion	sulfide ion – more shells larger
(c)	calcium atom	magnesium ion
(d)	potassium ion (more shells, lose e⁻ smaller)	potassium atom

4. Three of the following species have the same number of protons. Which has the different number of protons?

(a)	carbonium ion	CH_3^+	9
(b)	neon ion	Ne^+	10
(c)	fluoride ion	F^-	9
(d)	amide ion	NH_2^-	9

Covalent network

5. Which of the following statements about graphite and silicon dioxide is true?

(a) Both have atoms bonded together by sharing electrons. ✓
(b) Both have delocalised electrons. ✗
(c) Graphite has a very high melting point while silicon dioxide has a very low melting point. ✗
(d) Silicon dioxide is ionic while graphite is metallic. ✗

6. What is the shape of a water molecule?

(a) Linear
(b) Bent (V–shape)
(c) Pyramidal
(d) Tetrahedral

7. Which type of bonding is not present in solid hydrogen chloride?

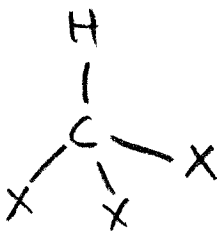
technically a difference between bond and intermolecular force

Bond — (a) covalent

Intermolecular forces — (b) dipole – dipole; (c) dispersion force; (d) hydrogen bonding

8. The boiling points of a family of trihalomethanes (CHX_3) are listed below.

trifluoromethane	CHF_3	–84 °C
trichloromethane	$CHCl_3$	62 °C
tribromomethane	$CHBr_3$	150 °C
triiodomethane	CHI_3	330 °C



The increase in boiling points moving down the list is due to an increase in the strength of:

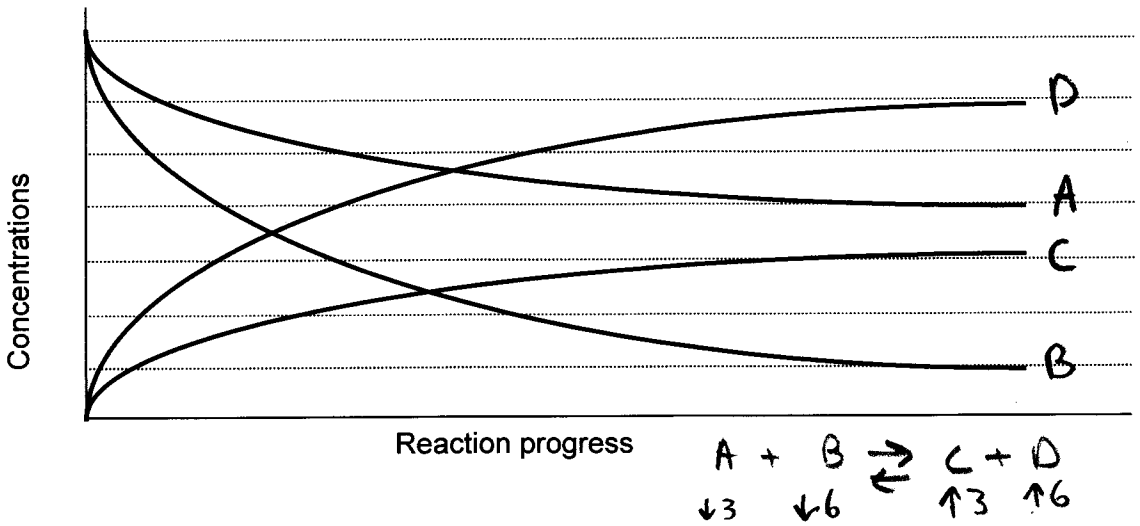
(a) covalent bonding.
(b) dispersion forces.
(c) dipole-dipole bonding.
(d) hydrogen bonding.

remove 'attraction'

9. Which of the following saturated solutions has the highest concentration of ions?

(a)	barium hydroxide	$Ba(OH)_2$ soluble
(b)	calcium phosphate	$Ca_3(PO_4)_2$ insoluble
(c)	silver sulfate	Ag_2SO_4 slightly soluble
(d)	zinc carbonate	$ZnCO_3$ insoluble

10. Two gases are mixed in a **sealed flask**. They react to produce two new gases. The reaction is reversible and after some time equilibrium is reached. The following graph shows the concentrations of the four gases as equilibrium is established.



A + B ⇌ C + D
↓3 ↓6 ↑3 ↑6

Which of the following equations represents the reaction?

1 : 2 1 : 2 ← mol ratio's

(a) $Cl_2O_{7\,(g)} + 2\,CO_{(g)} \rightleftharpoons Cl_2O_{5\,(g)} + 2\,CO_{2\,(g)}$

(b) $N_2O_{5\,(g)} + SO_{2\,(g)} \rightleftharpoons N_2O_{4\,(g)} + SO_{3\,(g)}$

(c) $N_2O_{(g)} + 2\,ClO_{2\,(g)} \rightleftharpoons N_2O_{5\,(g)} + Cl_{2\,(g)}$

(d) $2\,PH_{3\,(g)} + 3\,COF_{2\,(g)} \rightleftharpoons 2\,PF_{3\,(g)} + 3\,CH_2O_{(g)}$

11. Molybdenum (III) chloride, $MoCl_3$, is a yellow solid. When dissolved in water the molybdenum ions reacts reversibly with chloride ions to form hexachloromolybdenum (III) ions, which are blue.

$$Mo^{3+}(aq) + 6\,Cl^-(aq) \rightleftharpoons [MoCl_6]^{3-}(aq) + 33\text{ kJ}$$

(yellow) *(blue)*

As a result of the equilibrium the solution appears green. Which of the following procedures will cause the green solution to turn blue? shift to right

✓ I. Bubbling hydrogen chloride gas through the solution ↑Cl^- conc

✗ II. Adding a solution of silver nitrate ↓Cl^-

✗ III. Heating the solution shift left

✗ IV. Adding a suitable catalyst to increase the forward reaction rate

(a) I only

(b) I and IV only

(c) II and III only

(d) II, III and IV only

12. Arsenine (AsH_3) can be produced by the hydrogen reduction of tetraarsenic hexoxide. The reaction is exothermic and reversible.

$$3\,As_4O_6(s) + 36\,H_2(g) \rightleftharpoons 12\,AsH_3(g) + 18\,H_2O(g) + 125\text{ kJ}$$

Which of the following conditions will maximise the rate of forward reaction?

✓ I. Continuously adding hydrogen at high pressure

✗ II. Maintaining a high temperature

✓ III. Continuously cooling the mixture

✓ IV. Continuously removing the arsenine

(a) I and II

(b) II and III

(c) I and III

(d) I, III and IV

13. Which of the following ions does not have a conjugate base?

(a) CH_3COO^- ✗
(b) HCO_3^- → CO_3^{2-} +
(c) NH_4^+ → NH_3 +
(d) H_3O^+ → H_2O +

14. Water can act as an acid or as a base. In which of the following reactions is water acting as an acid? proton donor

✗ I.	H_2O	+	NH_4^+	→	H_3O^+	+	NH_3
✓ II.	H_2O	+	HPO_4^{2-}	→	OH^-	+	$H_2PO_4^-$
✓ III.	H_2O	+	SO_4^{2-}	→	OH^-	+	HSO_4^-
✗ IV.	H_2O	+	HCl	→	H_3O^+	+	Cl^-

(a) I only
(b) I and IV only
(c) II and III only
(d) IV only

15. Three of the following solutions have a pH of very close to 7. One has a pH of close to 4. Which is the pH 4 solution?

(a)	ammonium acetate	$NH_4CH_3COO \approx 7$
(b)	ammonium chloride	$NH_4Cl < 7$
(c)	ammonium phosphate	$(NH_4)_3PO_4 \approx 7$
(d)	sodium bromide	$NaBr \approx 7$

16. In which of the following species does platinum have the lowest oxidation number?

(a) H_2PtCl_6 (+4)
(b) $NaPtCl_4$ (+3)
(c) Pt_2O_3 (+3)
(d) $PtCr_2O_7$ (+2)

SEE NEXT PAGE

solution of metal ion is reduced

17. Which of the following metals can be produced by bubbling hydrogen gas through a solution of its chloride?

(a) Copper
(b) Iron
(c) Sodium
(d) Zinc

$H_2 \rightarrow 2H^+ + 2e^-$ (ox)

Must have -ve red potential to be spontaneous

18. A group of students is designing an electrochemical cell consisting of two half cells joined by a salt bridge. Each of the half cells consists of a metal rod placed in a 1 mol L^{-1} solution of its nitrate. Which of the following pairs of half cells will produce the highest voltage (emf)?

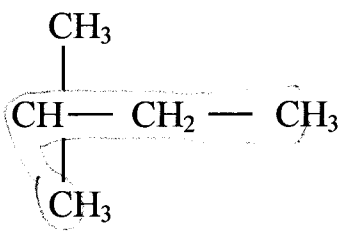
(a) Aluminium in aluminium nitrate solution and iron in iron (II) nitrate solution 1·22V
(b) Copper in copper (II) nitrate solution and zinc in zinc nitrate solution 1·10 V
(c) Lead in lead (II) nitrate solution and manganese in manganese (II) nitrate solution 1·03V
(d) Silver in silver nitrate solution and tin in tin (II) nitrate solution 1·10 V

19. Which of the following will oxidise **quickly** in moist air if its surface is scratched, but further oxidation is prevented by the oxide layer that has formed on the surface?

(a) A sheet of aluminium
(b) A sheet of galvanised iron (completely coated with a thin layer of zinc)
(c) A sheet of copper
(d) A 'tin' can (iron coated completely with a thin layer of tin)

20. The following structural diagram represents a saturated hydrocarbon. What is the correct (IUPAC) name for the hydrocarbon?

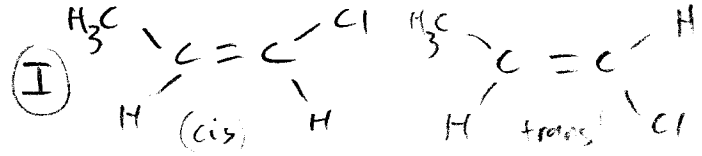
(a) Dimethyl propane
(b) Ethyl propane
(c) Methyl butane
(d) Pentane



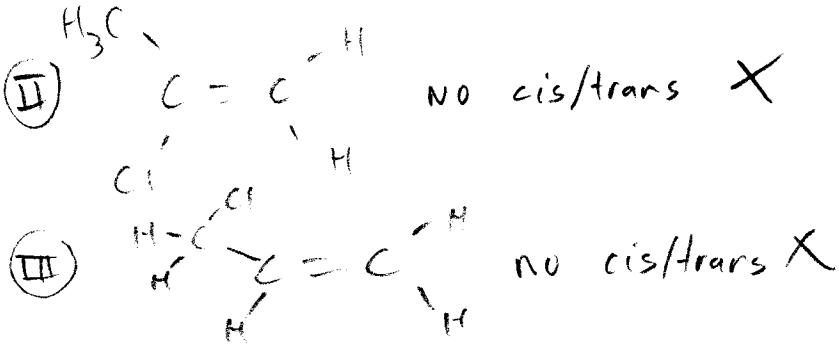
2-methylbutane

21. Which of the following chlorinated propenes has two geometric (cis-trans) forms?

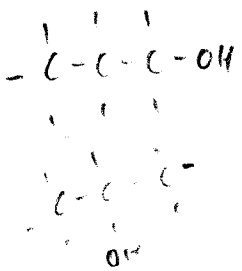
I. 1 – chloropropene
II. 2 – chloropropene
III. 3 – chloropropene



(a) I only
(b) I and III only
(c) II and III only
(d) III only



22. Which of the following substances is **least likely** to react with an acidified solution of sodium permanganate? — oxidising agent



(a) 1 – propanol 1° → Aldehyde → carboxylic acid
(b) 2 – propanol 2° → ketone
(c) Propanal Aldehyde → carboxylic acid
(d) Propanone ketone → N.R

23. One mole of an organic compound, containing only carbon, hydrogen and oxygen, required five moles of oxygen for complete combustion. Four moles of carbon dioxide and four moles of water were produced. What was the formula of the compound?

(a) C_2H_4O
(b) $C_4H_4O_2$
(c) C_4H_8O
(d) $C_4H_8O_2$

$1\ C_xH_yO_2 + 5O_2 \rightarrow 4CO_2 + 4H_2O$

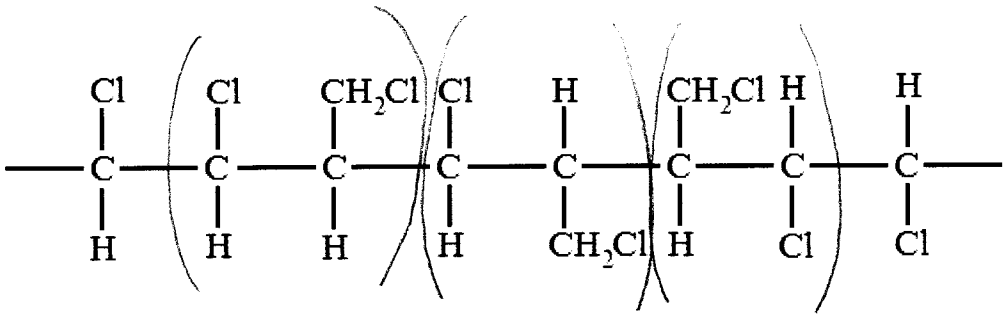
$\downarrow$

$C_4H_8O_2$

$O = [(4 \times 2) + 4] - 10$

$= 2$

24. The following diagram represents part of a polymer chain in a plastic.



This polymer could be produced from

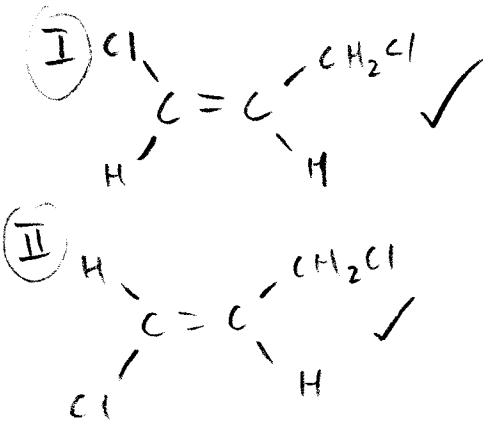
should read 1,3-dichloropropane

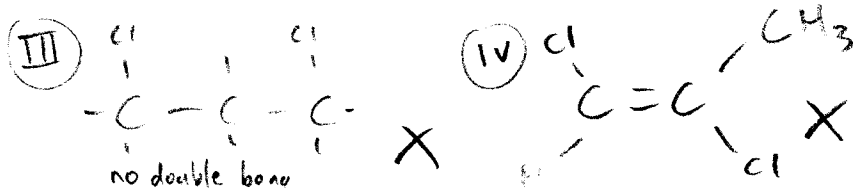
I. cis – 1,3 – dichloropropene

II. trans – 1,3 – dichloropropene

III. dichloropropane

IV. 1,2 - dichloropropene





(a) I or II only

(b) II or IV only

(c) II or IV only

(d) I, II or IV only

25. Which of the following substances will not act as a surfactant (soap / detergent)?

(a) Ammonium stearate Yes (stearate ion = $C_{17}H_{35}COO^-$)

(b) Magnesium stearate insoluble (stearate ion = $C_{17}H_{35}COO^-$)

(c) Hexadecylammonium sulfate (hexadecylammonium ion = $C_{16}H_{33}NH_3^+$) Yes

(d) Sodium hexadecylsulfonate (hexadecylsulfonate ion = $C_{16}H_{33}SO_3^-$) Yes

END OF PART 1

PART 2 (70 marks = 35% of paper)

This section contains 12 questions. Answer **ALL** questions in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your answers 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 a spare page to continue an answer, indicate in the original answer space where the answer is continued, i.e. state the page number. Write 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 **(4 marks)**

Write equations for the reactions that occur in each of the following procedures.
If no reaction occurs, write 'no reaction'. For full marks, chemical equations should refer only to those species consumed in the reaction and the new species produced. These species may be **ions** [for example, Ag^+], **molecules** [for example NH_3] or **solids** [example $CaCO_3$].

E^0 calcs just for reference

(a) Chlorine gas is bubbled through an acidified solution of hydrogen peroxide. (2 marks)

Equation $Cl_2 + 2e^- \longrightarrow 2Cl^-$ (+1.36V)

$H_2O_2 \longrightarrow O_2 + 2H^+ + 2e^-$ (−0.68V)

$Cl_{2(g)} + H_2O_{2(\ell)} \longrightarrow 2Cl^-_{(aq)} + O_{2(g)} + 2H^+_{(aq)}$ ($E^0 = 0.68$V)

(b) Copper wire is added to concentrated nitric acid (2 marks)

Equation $NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$ [×2] (+0.80V)

$Cu \longrightarrow Cu^{2+} + 2e^-$ [×1] (−0.34V)

$Cu_{(s)} + 2NO_{3(aq)}^- + 4H^+_{(aq)} \longrightarrow 2NO_{2(g)} + Cu^{2+}_{(aq)}$ + $2H_2O$

($E^0 = 0.46$V)

Question 27 **(4 marks)**

Write observations for any reactions that occur in the following procedures. In each case describe in full what you would observe, including any

- colours
- precipitates
- gases produced

If no change is observed, you should state this.

(a) Hydrogen peroxide is added to an acidified solution of iron (II) sulfate. (2 marks)

working $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$

$Fe^{2+} \rightarrow Fe^{3+} + e^-$ $E^\circ = 1.01\ V$ spontaneous

Observation

A clear and colourless solution is added to a clear pale green solution forming a clear brown/yellow solution.

(b) Copper wire is placed in a solution of nickel chloride (2 marks)

working no ppt's $Cu \rightarrow Cu^{2+} + 2e^-$

$Ni^{2+} + 2e^- \rightarrow Ni$ $E^\circ = -0.59\ V$ not spontaneous

Observation

A salmon pink metal is placed into a clear, green solution, no reaction is observed.

Question 28 **(4 marks)**

Anions such as hydrogencarbonate (HCO_3^-) and hydrogenphosphate (HPO_4^{2-}) are able to act as bases in aqueous solutions. However, in water hydrogensulfate ion (HSO_4^-) does not act as a base.

Explain these facts. Include equations in your answer.

(4 marks)

hydrogen carbonate and hydrogen phosphate ions come from weak acids and so some of the ions will accept protons from water to form the unionised acid forms:

$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$

$HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_2PO_4^-(aq) + OH^-(aq)$

this shows how these ions are bases in solution.

The hydrogen sulfate ion comes from the strong acid H_2SO_4. The HSO_4^- ion does not accept a proton to become unionised H_2SO_4 and can only act as an acid:

$HSO_4^-(aq) + H_2O(l) \rightleftharpoons SO_4^{2-} + H_3O^+(aq)$

alternatives:

HCO_3^- is the conjugate base of a weak acid so is basic in solution. (H_2CO_3)

HPO_4^{2-} is also a conjugate base of a weak acid ($H_2PO_4^-$) (and a conjugate acid of a weak base PO_4^{3-}) but by strength HPO_4^{2-} acts as a base.

HSO_4^- is a conjugate base of a strong acid H_2SO_4 and the conjugate acid of a weak base SO_4^{2-}

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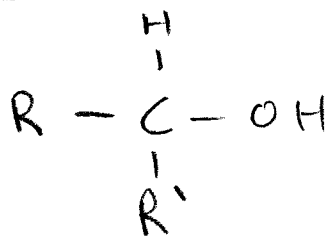
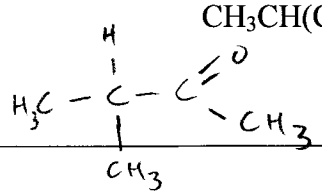
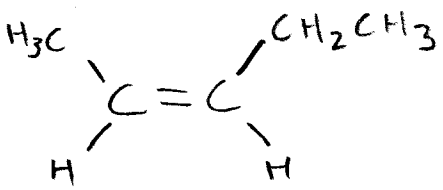
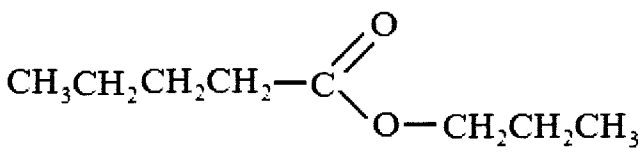
Question 29 **(4 marks)**

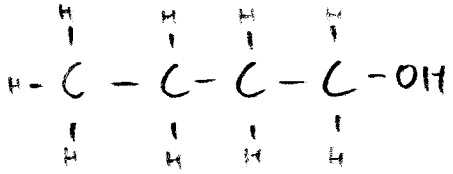
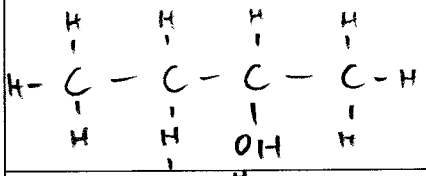
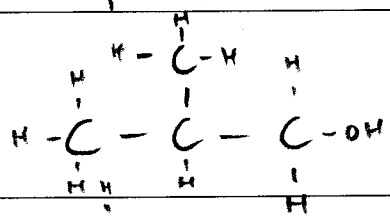
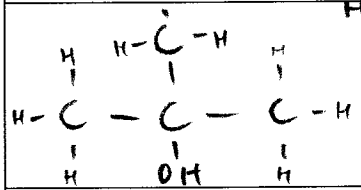
Write the IUPAC name, or draw a structural formula, for the following organic compounds.

A secondary alcohol	 any R or R' (1 mark)
3-methyl-2-butanone (1 mark)	$CH_3CH(CH_3)COCH_3$ 
cis – 2 – pentene	 (1 mark)
propylpentanoate (1 mark)	

Question 30 **(8 marks)**

In the table, draw the structural diagram of **all** isomeric alcohols of molecular formula $C_4H_{10}O$. Name each alcohol, and identify each as primary (1°), secondary (2°) or tertiary (3°). You may not need all the rows in the table.

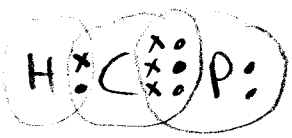
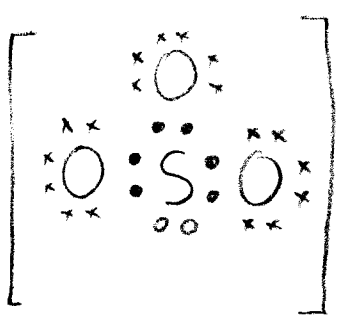
(8 marks)

Structure	Name	1°, 2°, or 3°
	1-butanol	1°
	2-butanol	2°
	2-methyl-1-propanol	1°
	2-methyl-2-propanol	3°
no others		

Question 31 **(5 marks)**

For each species in the following table, draw the structural diagram, representing all valence shell electron pairs as dots (:) or as dashes (—), and indicate the shape (name or sketch) of the species.

(for example, water H:Ö:H or H—Ö—H or H—Ō—H, Bent or V-shaped)

Species	**Structural diagram** (showing all valence shell electron pairs)	**Shape** (name or sketch)
Methylidyne phosphane HCP	 H–C≡P: (1 mark)	linear (1 mark)
Sulfite ion SO_3^{2-}	 2- (2 mark)	trigonal pyramidal (1 mark)

Question 32 **(6 marks)**

Dodecane can be catalytically cracked to produce lower molecular weight hydrocarbons.

$$C_{12}H_{26}\,(g) + 725\ kJ \rightleftharpoons C_8H_{18}\,(g) + C_4H_8\,(g)$$

In a laboratory experiment a reaction vessel, whose volume can be changed, contains an equilibrium mixture of all three gases, and 40% of the mixture is dodecane.

Complete the table by predicting and explaining the effect on the position of equilibrium of the following imposed changes. (simply stating Le Chateliers principle does not constitute an explanation)

Imposed change	**Affect on equilibrium position To right, to left or no change**	**Explanation**
(a) The volume is decreased keeping the temperature constant.	to the left (1 mark)	↓ volume will ↑ pressure The imposed change move the equilibrium to decrease the number of gaseous molecules, this releases the pressure (1 mark)
(b) The temperature is increased keeping the volume constant.	to the right (1 mark)	The imposed change ↑ the temp. The endothermic reaction would be favoured shifting the equilibrium and absorbing the added heat. (1 mark)
(c) Some C_4H_8 (g) is removed from the vessel.	to the right (1 mark)	↓ the conc. of C_4H_8 will favour the reaction that produces it to reestablish equilibrium. (1 mark)

Question 33 **(9 marks)**

Phosphoric acid (H_3PO_4) is a polyprotic acid.

(a) List all the **anions** present (in order of decreasing concentration) in a solution of phosphoric acid (excluding hydroxide). Write equations to show how you determined this.

(3 marks)

$H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$

$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$

$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$

each successive ionisation produces less ions

∴ in decreasing concentration. (anions only)

$H_2PO_4^- > HPO_4^{2-} > PO_4^{3-}$

Of these ions, which is the most basic?

(1 marks)

PO_4^{3-}

(c) Phosphoric acid is a weak acid. However, it becomes stronger when heated. Explain why.

(3 marks)

- The ionisation of H_3PO_4 is reversible and endothermic.

$H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$ $\Delta H = +ve$

- Heating shifts equilibrium to the right, increasing the H_3O^+ concentration
- Strength of an acid is related to the extent of ionisation (proportion)

SEE NEXT PAGE

(c) Dispite having several hydrogen atoms, propanoic acid (CH_3CH_2COOH) is not a polyprotic acid? Explain why

(2 marks)

- only the H in the carboxylic acid group can be ionised ($R-C(=O)-OH$ ← ionisable)
- The other hydrogens are bonded to carbon very tightly and can not be ionised

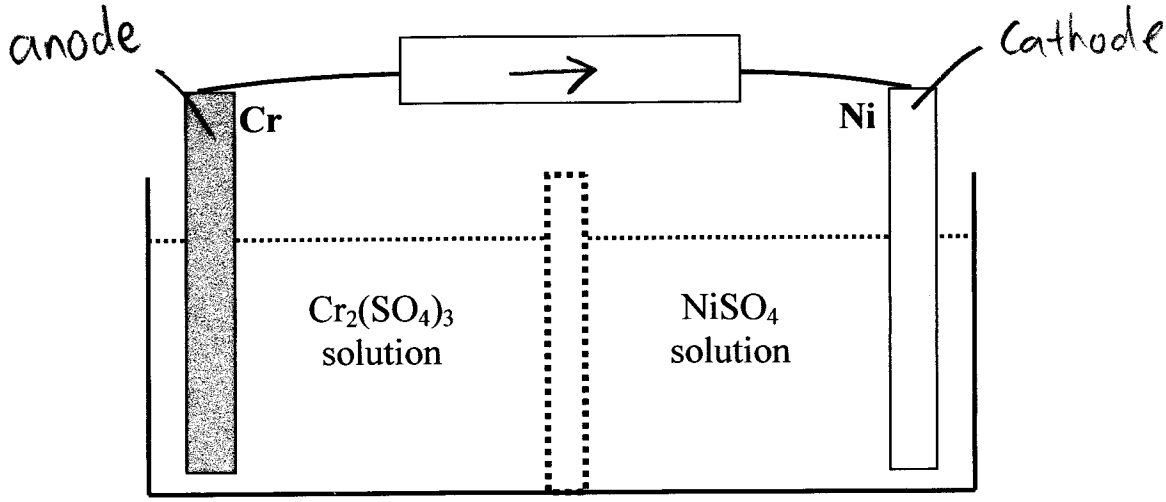
* alternative preferred ?

the H in the carboxylic acid group has a very polar bond compared to the other H's bonded to carbon. This is due to the highly electronegative oxygen. The hydrogen gains a positive dipole making it attractive to water molecules and able to be ionised.

The other hydrogens bonded to carbon (low electronegativity) are not charged enough to attract water molecules and be ionised.

Question 34 **(11 marks)**

The following diagram represents an electrochemical cell based on chromium and nickel. A porous barrier separates the two half cells but allows ions to migrate between them.



(a) Write the half cell equations and the overall balanced reaction that occurs. (3 marks)

$Ni^{2+} + 2e^- \longrightarrow Ni$ [x 3]

$Cr \longrightarrow Cr^{3+} + 3e^-$ [x 2]

$3Ni^{2+} + 2Cr \longrightarrow 3Ni + 2Cr^{3+}$

(b) On the diagram, label the electrode that is the anode and the cathode. (1 mark)

ox red

(c) Draw an arrow in the box provided to show the direction of the **electron flow** in the wire. (1 mark)

(d) What emf (voltage) will be generated? (Assume 1 mol L^{-1} concentrations.) (1 mark)

$E^\circ_{cell} = E^\circ_{ox} + E^\circ_{red}$

$= +0.74 + (-0.25)$

$= 0.49\,V$

(e) Which metal cation will migrate through the porous barrier?

(1 mark)

Cr^{3+}

(f) List TWO changes that will be observed.

(2 marks)

- Metallic silver coating on nickel electrode (↑ in mass / becomes thicker)
- Chromium electrode is consumed and gets thinner (↓ in mass / becomes thinner)
- Some changes to the 'darkness' of green solutions. (but both Ni^{2+} and Cr^{3+} are green)

(g) What will be observed if the porous barrier is removed and the solutions become mixed?

(2 marks)

- No external current (if load present)
- Metallic silver coating forms on chromium metal. (Ni plates onto Cr). Pitting on chromium electrode
- Solution becomes dark green

[now a direct reaction between Ni^{2+} and Cr]

Question 35 **(8 marks)**

The inside surface of copper frying pans used for cooking foods such as eggs can develop a black coating due to the formation of copper (II) sulfide. These blackened pans can be restored by adding an electrolytic solution such as sodium chloride and placing aluminium foil in the pan. The aluminium foil is held down so that it makes good contact with the copper surface. This method does not remove any of the copper from the pan. The two half reactions that occur are:

$CuS(s) + 2e^- \rightarrow Cu + S^{2-}$ [x 3]

$Al(s) \rightarrow Al^{3+} + 3e^-$ [x 2]

The by-product of this process is aluminium sulfide.

(a) Write an equation for the net redox reaction. (2 marks)

$3CuS + 2Al \rightarrow 3Cu + 3S^{2-} + 2Al^{3+}$

(b) Why must the aluminium foil be touching the copper surface? (2 marks)

To allow a transfer of electrons.

(d) A frying pan has a 0.0525 g coating of copper sulfide. What mass of aluminium sulfide will be formed as the copper is restored? (4 marks)

$m(CuS) = 0.0525g$ $n(CuS) = \frac{m}{M} = \frac{0.0525}{95.61} = 5.49 \times 10^{-4}$ mol

$M(CuS) = 95.61 g mol^{-1}$

$n(Al^{3+}) = \frac{2}{3} . n(CuS) = \frac{2}{3} \times 5.49 \times 10^{-4}$

$= 3.66 \times 10^{-4}$ mol

$n(Al_2S_3) = \frac{1}{2} . n(Al^{3+})$

$= \frac{1}{2} \times 3.66 \times 10^{-4} = 1.83 \times 10^{-4}$ mol

$M(Al_2S_3) = 150.14 g mol^{-1}$

$m(Al_2S_3) = n.M = 1.83 \times 10^{-4} \times 150.14$

$= 0.0275g$

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Question 36 **(7 marks)**

Explain each of the following facts about reactions between acids and metals. Include equations.

(a) Zinc reacts with hydrochloric acid, but copper does not.

(4 marks)

$Zn \rightarrow Zn^{2+} + 2e^-$ $E^\circ_{ox} = +0.76V$

$Cu \rightarrow Cu^{2+} + 2e^-$ $E^\circ_{ox} = -0.34V$

$2H^+ + 2e^- \rightarrow H_2$ $E^\circ_{red} = 0.00V$

for : $Cu + 2H^+ \rightarrow Cu^{2+} + H_2$ $E^\circ_{cell} = -0.34V$

not spontaneous

$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$ $E^\circ_{cell} = +0.76V$

spontaneous

only Zinc will react with hydrochloric acid

(b) Copper reacts with nitric acid and a gas is produced. The gas is not hydrogen.

(3 marks)

H^+ and NO_3^-

$NO_{3\,(aq)}^- + 2H_{(aq)}^+ + e^- \rightarrow NO_{2\,(g)} + H_2O_{(l)}$ $E^\circ_{red} = 0.80V$

(gas)

$Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2e^-$ $E^\circ_{ox} = -0.34V$

$2NO_{3\,(aq)}^- + 4H_{(aq)}^+ + Cu_{(s)} \rightarrow 2NO_{2(g)} + 2H_2O_{(l)} + Cu^{2+}_{(aq)}$

$E^\circ_{cell} = +0.46V$

spontaneous

Copper metal and nitric acid form nitrogen dioxide gas

END OF PART 2

PART 3 (80 marks = 40% of paper)

This section contains 6 questions. You must answer **ALL** questions. Write your answers in the spaces provided.

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 (3) significant figures, and provide units where applicable. Information which may be necessary for solving the problems is located on the separate Chemistry Data Sheet.

Spare pages are included at the end of this booklet. They can be used for planning your answers 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 a spare page to continue an answer, indicate in the original answer space where the answer is continued, i.e. state the page number. Write the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes

Question 37 **(10 marks)**

A swimming pool holds 250 cubic metres of water. The owner tests the water and finds its hydroxide ion concentration, $[OH^-]$, is 5.55×10^{-5} mol L^{-1}.
Note: Assume temperature of 25 °C and that (1 cubic metre = 1000 L)

(a) What is the pH of the pool water?

(4 marks)

$K_w = [H^+][OH^-]$

$\therefore [H^+] = \frac{K_w}{[OH^-]} = \frac{1.00 \times 10^{-14}}{5.55 \times 10^{-5}} = 1.80 \times 10^{-10}$ mol L^{-1}

$pH = -\log [H^+] = -\log (1.80 \times 10^{-10})$

$= 9.74$

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(b) Thinking the pH is too low, the owner adds to the water 3.00 kg of caustic soda (NaOH). The water pump ensures that the caustic soda dissolves and becomes evenly mixed in the pool.

What is the new pH of the water?

(6 marks)

M(NaOH) = 39.998 g mol^{-1}

$n(OH^-)_{initial} = c.V = 5.55 \times 10^{-5} \times 250\,000 = 13.875$ mol

$n(OH^-)_{added} = n(NaOH) = \frac{m}{M} = \frac{3000}{39.998} = 75.004$ mol

$n(OH^-)_{total} = n(OH^-)_{initial} + n(OH^-)_{added} = 13.875 + 75.004$

$= 88.879$ mol

$c(OH^-) = \frac{n}{V} = \frac{88.879}{250\,000} = 3.55 \times 10^{-4}$ mol

$[H^+] = \frac{k_w}{[OH^-]} = \frac{1.00 \times 10^{-14}}{3.55 \times 10^{-4}} = 2.812 \times 10^{-11}$ mol

$pH = -\log [H^+] = -\log (2.812 \times 10^{-11})$

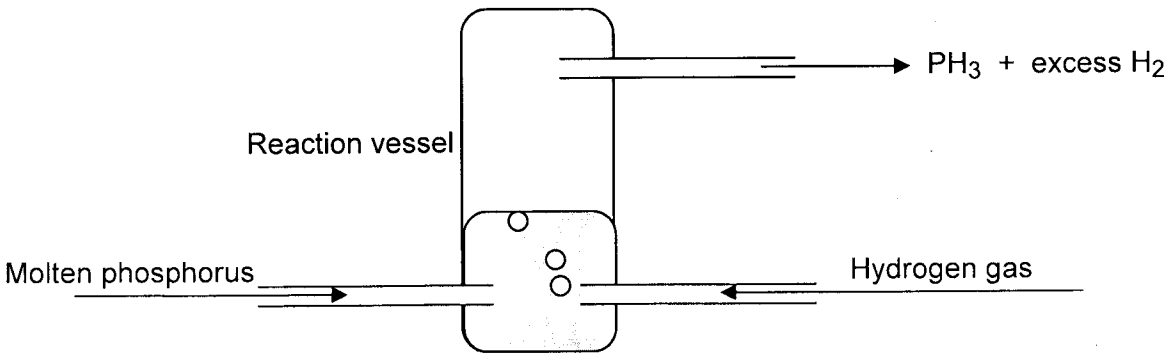
$= 10.55$

Question 38 **(15 marks)**

Phosphine (PH_3) is a gas that could be produced by bubbling hydrogen gas through molten phosphorus.

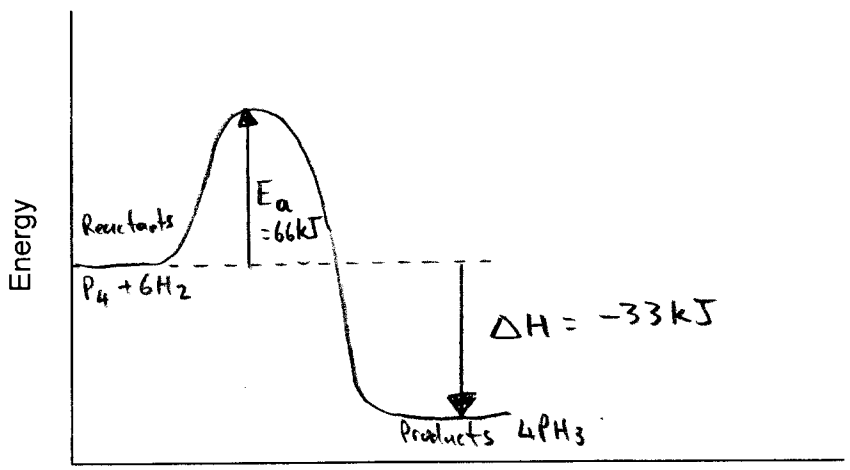
The reaction is reversible P_4 (l) + 6 H_2 (g) $\rightleftharpoons$ 4 PH_3 (g) + 33 kJ

Activation energy = 66 kJ



(a) Draw a labelled energy profile graph to represent the process.
Indicate clearly the reactants, products, activation energy and enthalpy change.

(4 marks)



(b) Would a high temperature, or a low temperature, be used in the process? Consider the reaction rate and the product yield in your answer.

(3 marks)

- A high temperature will provide a fast reaction rate but being endothermic will favour reactants (poor yield)
- A low temperature will have a slow reaction rate but favour the formation of the products (high yield)
- A temperature compromise would be required to optomise yield and reaction rate

(c) Would a high pressure, or a low pressure, be used in the process? Consider the reaction rate and the product yield in your answer.

(3 marks)

- A high pressure would give a fast reaction rate (due to the increased frequency of collisions) and would favour the products (high yield) as there are fewer product gaseous molecules, allowing a compensation in pressure.
- A low pressure would have a slow reaction rate and not be as effective in shifting equilibrium.
- High pressure would be preferred

(d) If the process is only 70.0% efficient what mass of phosphorus would be needed to produce 4500 kL of phosphine (stored at 3.55 atmospheres pressure in cylinders at 30.0 °C)?

(5 marks)

$P = 3.55 atm = 3.55 atm \times 101.3 \frac{kPa}{atm} = 360 kPa$

$T = 30°C = 303.1 K$

$R = 8.315 JK^{-1}mol^{-1}$

$V = 4500 L$

$M(P_4) = 123.88 gmol^{-1}$

$PV = nRT$

$\therefore n = \frac{PV}{RT} = \frac{360 \times 4500}{8.315 \times 303.1}$

$= 6.42 \times 10^5 mol$

$n(P_4) = \frac{1}{4} . n(PH_3) = \frac{1}{4} \times 6.42 \times 10^5$

$= 1.60 \times 10^5 mol$

as >0% eff will require more reagent

$n(P_4)_{required} = \frac{100}{70} \times 1.60 \times 10^5$

$= 2.29 \times 10^5 mol$

$m(P_4) = n.M = 2.29 \times 10^5 \times 123.88$

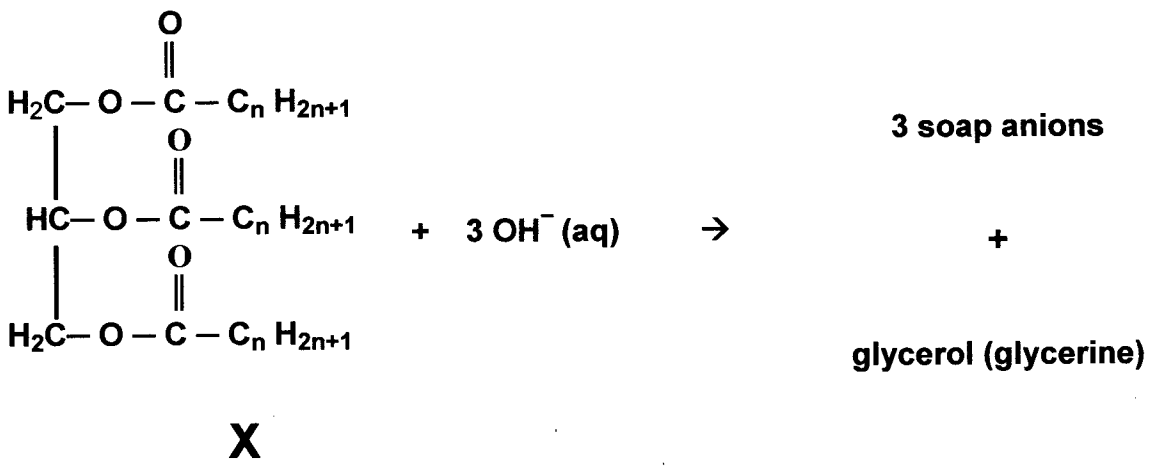
$= 2.84 \times 10^7 g$

$= 28.4$ tonnes

SEE NEXT PAGE

Question 39 **(11 marks)**

Soap can be produced by the alkaline hydrolysis of animal fat. The structure of the fat can be represented by the formula, **X**, below. The number n is large, usually about 16. The equation represents the hydrolysis reaction. Soap is simply the sodium salt of the anion.



X

(a) What is another name for this process of producing soap?

(1 mark)

Saponification (could accept hydrolysis)

(b) What is the general name for compounds represented by the letter **X**?

(1 mark)

Triglyceride (accept fatty acid triesters of glycerol)

(c) Write a formula for soap, substituting numbers for the letter n.

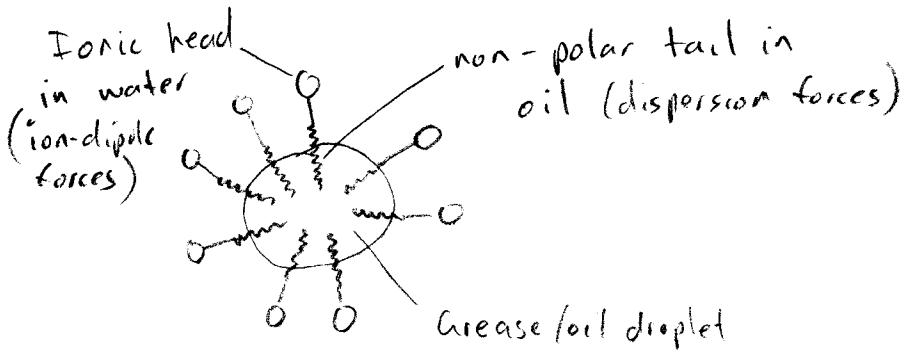
(1 mark)

for n = 16

$C_{16}H_{33}COO^-Na^+$

(d) Why does the hydrocarbon chain (C_nH_{2n+1}) have to be long? Include a diagram.

(4 mark)



- The hydrocarbon chain is needed so that it is non-polar and can penetrate the grease/oil.
- The long chain attaches to the grease/oil by dispersion forces.
- The ionic head is strongly attracted to the water with ion-dipole forces.
- If the hydrocarbon chain was too short the dispersion forces would not be strong enough to keep it in the grease/oil and the water would pull them out.

(e) When n = 16 in the formula C_nH_{2n+1} the molecular molar mass of the fat is 848.54g/mol. What mass of sodium hydroxide is needed to convert 1 tonne of fat into soap? [1 tonne = 1000 kg]

(4 mark)

$n(fat) = \frac{m}{M} = \frac{1000000}{848.54} = 1178\,mol$

$n(NaOH) = n(OH^-) = \frac{3}{1} \cdot n(fat) = \frac{3}{1} \times 1178$

$= 3535\,mol$

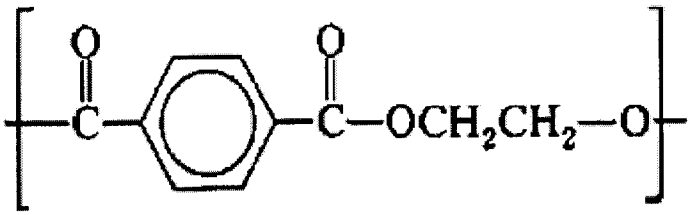
$m(NaOH) = n\,M = 3535 \times 39.998$

$= 141412\,g$

$= 141\,kg$

Question 40 **(7 marks)**

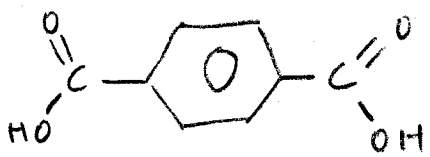
The structural formula for the repeating unit of the polyester Dacron is shown below:



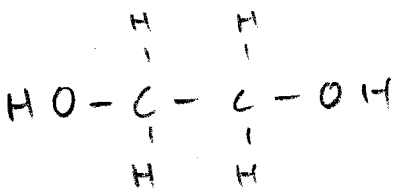
Dacron (also known as terylene or PET) is produced by condensation polymerisation. It is a thermoplastic and a good barrier material (moderately resistant).

(a) Draw the monomers used in the production of this polymer

dicarboxylic acid



diol



(2 marks)

(b) Why is this reaction called condensation polymerisation?

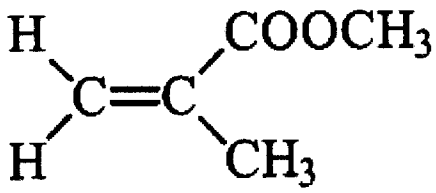
as it produces water on the formation of the polymer

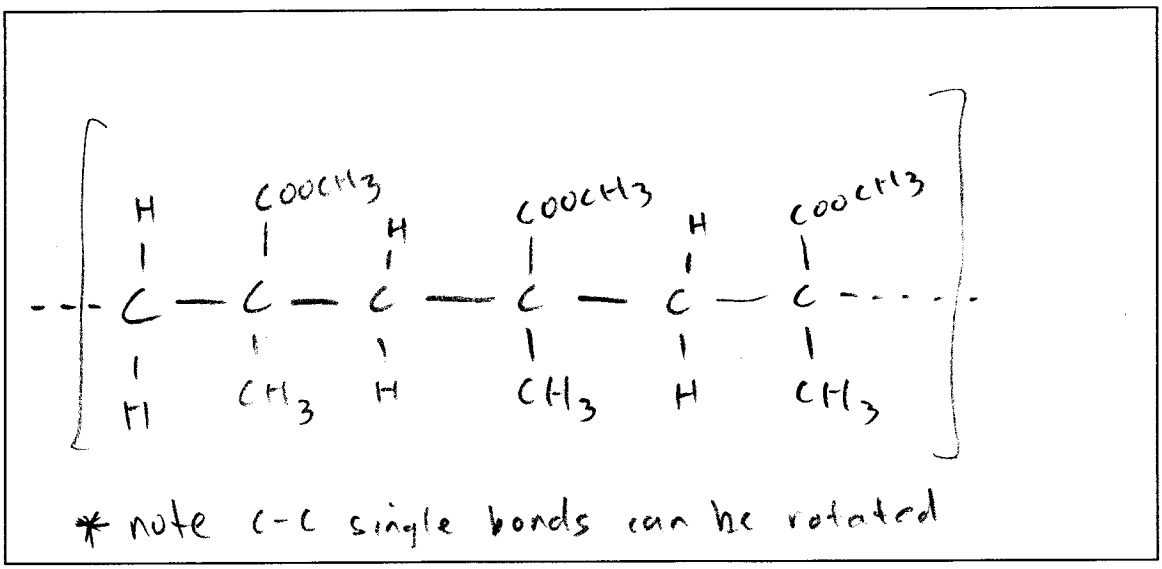
(1 mark)

(c) Why is this polymer called a "polyester"?

The monomers are joined together with a ester linkage, making the polymer a polyester. (1 mark)

(c) Given the monomer below, draw a portion of the polymer that would be produced from it (your polymer should contain a minimum of three monomer units).





and monomer can alternate orientation (2 marks)

(d) What type of polymer has been produced here?

(1 marks)

addition polymer

Question 41 **(14 marks)**

An organic compound containing only **carbon, hydrogen, oxygen and nitrogen** is analysed by the following steps:

- 1.473 g is burned in oxygen, converting the carbon to 2.515 g of carbon dioxide and the hydrogen to 1.158 g of water.
- Another 1.473 g is treated so that the nitrogen is oxidized to 0.6573 g of nitrogen dioxide (NO_2).
- When vaporized 1.473 g of the compound occupies 116 mL at 204 kPa pressure and 127 °C.

(a) What is the empirical formula of the compound?

(10 marks)

(b) What is its molecular formula?

(4 marks)

a) $C_xH_yO_zN_q + O_2 \longrightarrow CO_2 + H_2O + ?(N)$

$m = 1.473\,g$ $\quad m = 2.515\,g$ $\quad m = 1.158\,g$

$n(H)_{\text{in sample}} = 2 \times n(H_2O) = 2 \times \frac{m}{M} = 2 \times \frac{1.158}{18.016} = 0.129\ mol$

$n(C)_{\text{in sample}} = n(CO_2) = \frac{m}{M} = \frac{2.515}{44.01} = 0.0571\ mol$

$C_xH_yO_zN_q \xrightarrow{ox} NO_2$

$m = 1.473\,g$ $\quad 0.6573\,g$

$n(N)_{\text{in sample}} = n(NO_2) = \frac{m}{M} = \frac{0.6573}{46.01} = 0.0143\ mol$

For the same mass sample (1.473 g)

$m(O)_{\text{in sample}} = m(\text{sample}) - [m(C) + m(H) + m(N)]$

$= 1.473 - [(0.0571 \times 12.01) + (0.129 \times 1.008) + (0.0143 \times 14.01)]$

$= 0.457\,g$

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$\therefore$ $n(O)_{\text{in sample}} = \frac{m}{M} = \frac{0.457}{16.00} = 0.0286\ mol$

	C	H	O	N
moles in sample	0.0571 mol	0.129 mol	0.0286 mol	0.0143 mol
Simplest ratio	$\frac{0.0571}{0.0143}$	$\frac{0.129}{0.0143}$	$\frac{0.0286}{0.0143}$	$\frac{0.0143}{0.0143}$
	4.000	8.998	1.999	1.000

Empirical formula = $C_4H_9O_2N$

b) $V = 116\ mL = 0.116\ L$

$P = 204\ kPa$

$T = 127^\circ C = 400.1\ K$

$R = 8.315\ J\ K^{-1}\ mol^{-1}$

$PV = nRT$

$n = \frac{PV}{RT} = \frac{204 \times 0.116}{8.315 \times 400.1}$

$= 7.11 \times 10^{-3}\ mol$

for 1.473g sample

$M = \frac{m}{n} = \frac{1.473}{7.11 \times 10^{-3}} = 207.08\ g\ mol^{-1}$

empirical formula mass = $103.122\ g\ mol^{-1}$

$\frac{\text{molecular formula}}{\text{empirical formula}} = \frac{\text{molecular formula mass}}{\text{empirical formula mass}}$

molecular formula = $C_4H_9O_2N \times \frac{207.08}{103.122}$

$\simeq 2$

$= C_8H_{18}O_4N_2$

SEE NEXT PAGE

Question 42 **(13 marks)**

A student wanting to produce ethyl oxalate prepares a mixture of 50.0 g of oxalic acid (HOOCCOOH) and 50.0 g of alcohol (CH_3CH_2OH) in a boiling flask. She adds a few drops of concentrated sulfuric acid and boils the mixture for about an hour.

The equation for the reaction is

$$HOOCCOOH + 2\,CH_3CH_2OH \rightarrow CH_3CH_2OOCCOOCH_2CH_3 + 2\,H_2O$$

(a) What is the function of the sulfuric acid?

(1 marks)

The sulfuric acid acts as a catalyst

(b) Determine the limiting reactant.

(4 marks)

$M(\text{oxalic acid}) = 90.036\,g\,mol^{-1}$ $\quad n(\text{oxalic acid}) = \frac{m}{M} = \frac{50.0}{90.036} = 0.555\,mol$

$M(\text{ethanol}) = 46.068\,g\,mol^{-1}$

$n(\text{ethanol}) = \frac{m}{M} = \frac{50.0}{46.068} = 1.09\,mol$

$\text{Stoic ratio} = \frac{n(\text{oxalic acid})}{n(\text{ethanol})} = \frac{1}{2} = 0.500$

$\text{Actual ratio} = \frac{n(\text{oxalic acid})}{n(\text{ethanol})} = \frac{0.555}{1.09} = 0.512$

As A.R. > S.R ethanol is limiting

oxalic acid is in excess

* for ratio other ways:

$S.R = \frac{n(\text{ethanol})}{n(\text{oxalic acid})} = \frac{2}{1} = 2.00$ As A.R < S.R

ethanol is limiting reagent

oxalic acid is in excess

$A.R. = \text{" "} = \frac{1.09}{0.555} = 1.96$

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(c) What is the expected mass of ethyl oxalate that would be produced?

(4 marks)

$n(ester) = \frac{1}{2} \cdot n(ethanol) = \frac{1}{2} \times 1.09 = 0.543\ mol$

$m(ester) = nM = 0.543 \times 146.14$

$= 79.31g$

$M(ester) = [6 \times M(C)] + [10 \times M(H)] + [4 \times M(O)]$

$= 6 \times 2.011 - (10 \times 1.008) + 4 \times 16.00$

$= 146.14\ g\,mol^{-1}$

(d) After the mixture has cooled she adds 100 mL of water. Soon she observes that there are two layer of liquid in the flask

(i) Suggest a reason for adding water.

(2 marks)

To separate the ester which is insoluble in water and remove the soluble sulfuric acid, ethanol and excess oxalic acid.

(ii) Why were there two liquid layers?

(2 marks)

The product (ester) is slightly polar and has weak dipole-dipole intermolecular forces. They are not as strong as the hydrogen bonding between water molecules and so can not move them apart to become hydrated. This makes the two immiscible and form two layers.

Question 43 **(10 marks)**

A jar containing a pale pink powder is labelled *commercial grade manganese (II) sulfate* $MnSO_4$. A chemist needs to know its percentage by mass purity. He decides to analyse it by utilizing the reaction between hydrogen peroxide and manganese ion. The manganese ions are converted into a black precipitate of manganese (III) oxide. The black oxide quickly settles to the bottom of the conical flask. The equation for the reaction is

$$H_2O_2 + 2\,Mn^{2+} + H_2O \rightarrow Mn_2O_3 + 4\,H^+$$

The end point is taken to be when the final drop of hydrogen peroxide no longer produced a black precipitate.

The chemist dissolved 2.000 g sample of the impure manganese (II) sulfate in water in a 100 mL volumetric flask. He then pipetted 25.00 mL of this solution and diluted it to 250 mL in another volumetric flask.

Next, he titrated 20.00 mL aliquots of the diluted manganese (II) sulfate solution against 0.002211 mol L^{-1} hydrogen peroxide solution. The average titre required was 46.55 mL.

(a) How many moles of hydrogen peroxide were consumed in an average titration?
(2 marks)

$n(H_2O_2) = c.V = 0.002211 \times \frac{46.55}{1000}$

$= 1.03 \times 10^{-4}$ mol

(b) How many moles of manganese (II) ions were oxidised in an average titration?
(2 marks)

$n(Mn^{2+}) = \frac{2}{1} . n(H_2O_2) = \frac{2}{1} \times 1.03 \times 10^{-4}$

$= 2.06 \times 10^{-4}$ mol

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(c) How many moles of manganese (II) sulfate were present in the impure sample? (3 marks)

for aliquot:

$c(Mn^{2+}) = \frac{n}{V} = \frac{2.06 \times 10^{-4}}{20.00 \times 10^{-3}} = 1.03 \times 10^{-2}\ mol\,L^{-1}$

from dilution: $c_1V_1 = c_2V_2$

$\therefore c_2 = \frac{c_1V_1}{V_2} = \frac{1.03 \times 10^{-2} \times 250 \times 10^{-3}}{25 \times 10^{-3}}$

$= 1.03 \times 10^{-1}\ mol\,L^{-1}$

for initial dissolved sample:

$n(MnSO_4) = n(Mn^{2+}) = c.V = 1.03 \times 10^{-1} \times \frac{100}{1000} = 1.03 \times 10^{-2}\ mol$

(d) What was the percentage purity of the commercial manganese (II) sulfate? (3 marks)

$M(MnSO_4) = 151.00\ g\,mol^{-1}$ $m(MnSO_4) = n\,M = 1.03 \times 10^{-2} \times 151.00$

$= 1.55g$

$\%\ purity = \frac{m(pure\ MnSO_4)}{m(impure\ sample)} \times 100$

$= \frac{1.55}{2.00} \times 100$

$= 77.7\%$

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