SECTION 2 Short Answer **13 questions** **(80 marks 40%)**

Answer ALL questions in Section 2 in the spaces provided below.

Question 26.

Write equations for the reaction that occurs in each of the following procedures. If no reaction occurs, write 'no reaction'.

In each case describe what you would observe, including any
* colour change
* odour
* precipitate (give the colour)
* Gas evolutions (state the colour or describe as colourless)

If a reaction occurs but the change is not observable, you should state this.

(a) Oxygen gas is bubbled through an acidified solution of iron (II) sulfate.

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

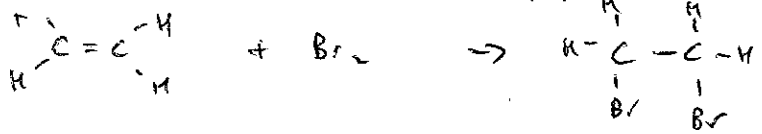
$Fe^{2+} \rightarrow Fe^{3+} + e^-$

Equation $O_{2(g)} + 4H^+_{(aq)} + 4Fe^{2+}_{(aq)} \rightarrow 4Fe^{3+}_{(aq)} + 2H_2O$ 2

Observation pale green solution changed from pale green to brown colour 2

(4 marks)

(b) Ethene gas is bubbled through bromine water (aqueous solution of bromine).



Equation $C_2H_{4(g)} + Br_{2(aq)} \rightarrow C_2H_4Br_{2(aq)}$ 2

Observation Orange liquid turns colourless 2

when colourless gas is bubbled through it.

(4 marks)

1 mark error

Question 27.

A non-acidic organic compound has a molecular formula of $C_4H_8O_2$ and has a **single functional group**.

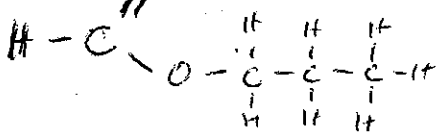
(i) What is the ~~name~~ of the functional group in this compound? (1 mark)

unnecessary

Ester. 1

No acids
No 2+ f^n groups

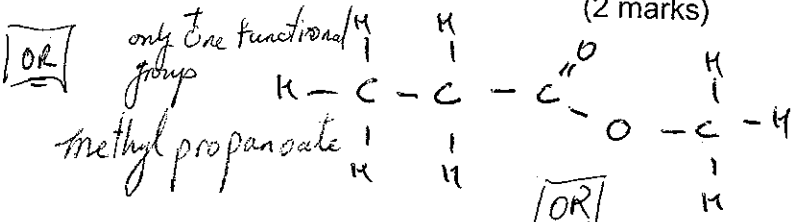
(ii) Draw the structural formulae of two different isomers that fit this molecular formula. NB 2 conditions. = non-acidic (2 marks)



propyl methanoate

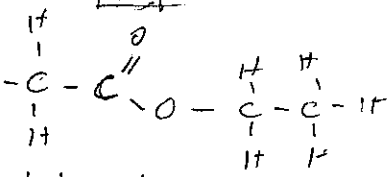
OR

only one functional group



methyl propanoate

OR



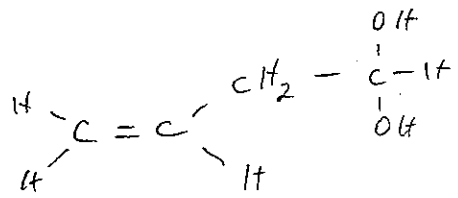
ethyl ethanoate

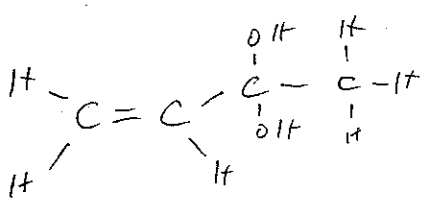
(iii) Select one of your isomers in part (ii) above. Write a balanced equation to show how this isomer could be produced in the laboratory. Include in your answer:

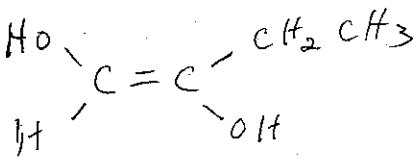
- structural formulae and names of all organic compounds involved;
- the name of a suitable catalyst. (3 marks)

eg. $CH_3CH_2COOH + CH_3OH \xrightarrow{H_2SO_4} + H_2O$ 1

propionic acid methanol methyl propanoate water 2







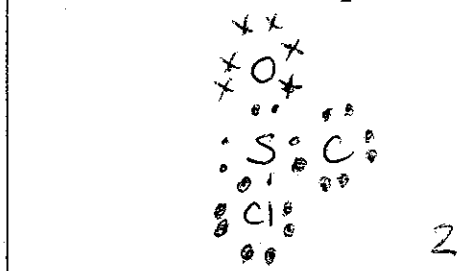
1 mark structural
1 mark name
1 mark catalyst

Question 28.

Draw electron-dot diagrams showing the arrangement of all valence electrons in the following chemical species.

Describe the shape of each (eg: linear/bent/etc)

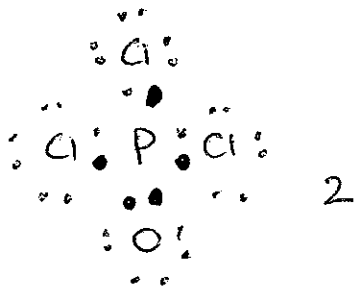
$OSCl_2$



2

Shape pyrimidal. triangular pyramid 1

$OPCl_3$



2

Shape tetrahedral 1

(6 marks)

Question 29.

Methane reacts with fluorine to form four different fluorinated compounds.

Write the names and formulas of **all** the fluorinated methanes that are **polar**.

$CH_4 + F_2 \rightarrow CH_3F + HF$

$CH_3F + F_2 \rightarrow CH_2F_2 + HF$

$CH_2F_2 + F_2 \rightarrow CHF_3 + HF$

fluoromethane
difluoromethane
trifluoromethane

2 mks Names
2 mks structure

take off 1 mark for each error

(4 marks)

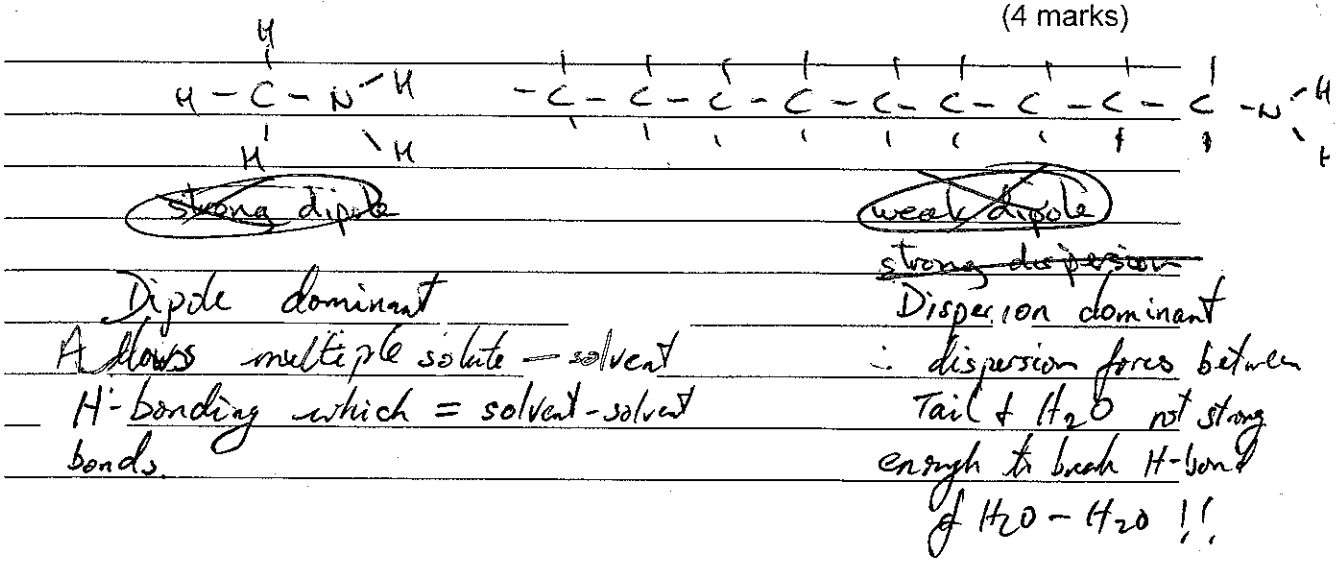
Question 30.

The following table shows the solubilities of two amines in water.

Amine	Methyl amine CH_3NH_2	Dodecyl amine $CH_3(CH_2)_{11}NH_2$
Solubility (g/100 mL)	108	0.05

Explain why their solubilities are so different.
Include a labelled diagram.

(4 marks)



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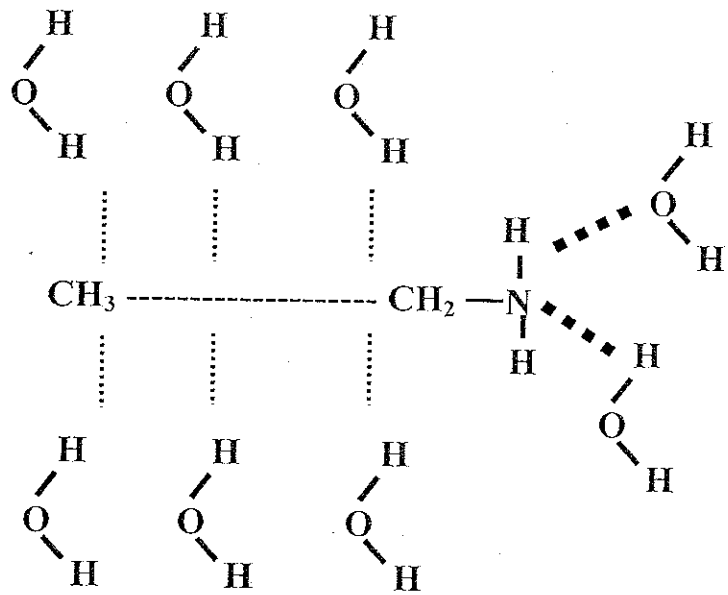
Solubility (g/100 mL)	108	0.05

Explain why their solubilities are so different. Include a labelled diagram.

2 well-explained reasons 3 marks
diagram = 1 marks

- **New solute-solvent bonds should be at least as strong as original solute-solute and solvent-solvent bonds**
- **Both can hydrogen-bond, BUT dodecyl isomer has a long non-polar chain that can only interact with H_2O by dispersion force attraction,**
- **The new forces of attraction would be much weaker than the bonds broken between water molecules**



▪▪▪▪▪▪▪▪▪▪

Strong H-bonds replacing strong H-bonding between H_2O molecules and NH_2 groups

.....

Only weak dispersion forces replacing strong H-bonding between H_2O molecules

(6 marks)

Q 31

Three unlabelled beakers each contain the same volume of 1 mol L^{-1} solution. The three solutions are:

- sodium hydrogensulfate ($NaHSO_4$)
- sulfuric acid (H_2SO_4), and
- phosphoric acid (H_3PO_4).

The student is asked to identify the solutions. He is also given a bottle of sodium hydroxide (NaOH) solution, a choice of indicators and is allowed to use any other item of laboratory glassware. The student was successful.
How did the student correctly identify the acids?
Include equations to support your answer.

Add measured amount/volumes of NaOH solution to each 1
(burette / graduated cylinder)

using 3 diff indicators. 1

if fixed Vol. of NaOH added (less than eq. Vol) → least acidic

Protic ity

$NaHSO_4$ is monoprotic acid – will need 1 volume ½ 1

$HSO_4^- + OH^- \rightarrow SO_4^{2-} + H_2O$

H_2SO_4 is diprotic acid – will need 2 volumes ½ 1

$H_2SO_4 + 2\ OH^- \rightarrow SO_4^{2-} + H_2O$

H_3PO_4 is triprotic acid – will need 3 volumes ½ 1

$H_3PO_4 + 3\ OH^- \rightarrow PO_4^{3-} + 3\ H_2O$

Most acidic, alternative

1 → mentioning volumes

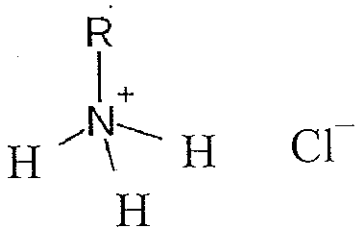
1 Equations

(7 marks)

SEE NEXT PAGE

Q.32

Quaternary ammonium salts can be represented by the following structural formula.



If the alkyl group (**R**) is long then the salt acts like a soap or detergent. If it is short the salt has no cleaning properties.

Explain these two differences in properties.

Include a labelled diagram.

2 well-explained reasons = 3 or 4 marks
diagram = 2 or 3 marks

- **Grease is non-polar**
- **Cleaning agent needs a long non-polar tail to stick deep into the layer of grease so that when the water is agitated and pulls at the polar head sticking out of the grease layer the tail will remain bonded in the grease**
- **A short tail will not provide sufficient dispersion interaction**
- ***Causing the grease to break up into micelles/globules that can be rinsed away (not required)***

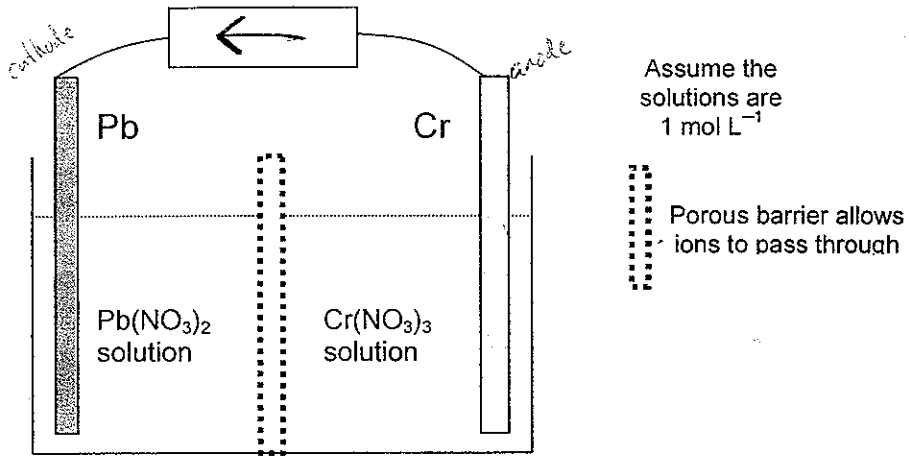
The exposed negative charges keep micelles from rejoining

(6 marks)

Italicised parts not required

Question 33.

An electrochemical cell contains the two half cells separated by a porous membrane, which allows ions to migrate through. Each half cell has a metal rod placed in a solution of its nitrate.



(a) Write the two half reactions that occur, their standard reduction potentials and state whether each is oxidation, or reduction,

reduction: $Pb^{2+} + 2e^- \rightarrow Pb$ ① $E^\circ = -0.13V$ ①

oxidation: $Cr \rightarrow Cr^{3+} + 3e^-$ ① $E^\circ = +0.74V$ ①

(4 marks)

(b) Write the equation for the net redox equation.

$3\,Pb^{2+}_{(aq)} + 2Cr_{(s)} \rightarrow 3Pb_{(s)} + 2Cr^{3+}_{(aq)}$ ② (2 mark)

(c) What is the emf (electromotive force, or voltage) of the cell?

$E^\circ_{cell} = E^\circ_{ox} + E^\circ_{red} = +0.74 + (-0.13) = 0.61V$ ① (1 mark)

(d) Draw an arrow in the top box to show the direction of current (electron flow) in the wire connecting the two electrodes. (1 mark)

(e) What change (or changes) will be observed in the cell?

① • More grey metal forms on Pb electrode (shiny crystals)

① • Cr electrode gets thinner (disappears)

① • Cr solution becomes more green

(3 marks)

Question 34.

A student is asked to identify four organic liquids, contained in four separate flasks.

- Octene
- Hexan-3-ol (3-hexanol)
- Hexan-3-one (3-hexanone)
- Butanoic acid

The student has access to any chemicals and glassware required.
Describe the tests that should be carried out, and the observations, that enable the liquids to be identified.
Include equations to justify the choice of tests. (8 marks)

Mix with bromine water → orange colour disappears (turns colourless)
Identify octene
$C_8H_{16} + Br_2 \rightarrow C_8H_{16}Br_2$

no reaction ↓

Mix with sodium carbonate solution → bubbling
Identify Butanoic acid
$2C_3H_7COOH + Na_2CO_3 \rightarrow 2C_3H_7COONa + H_2O + CO_2$

no reaction ↓

Mix with acidified potassium permanganate (or potassium dichromate) solution → colour change
purple → colourless (for permanganate)
orange → green (for dichromate)

no reaction ↓

Identify Hexan-3-one (ketones will not oxidise)

Identify Hexan-3-ol

$5C_6H_{14}O + 2MnO_4^- + 6H^+ \rightarrow 5C_6H_{12}O + 8H_2O + 2Mn^{2+}$

or

$3C_6H_{14}O + Cr_2O_7^{2-} + 8H^+ \rightarrow 2Cr^{3+} + 7H_2O + 3C_6H_{12}O$

- Note octene can also be oxidised

SEE NEXT PAGE

Question 35.

The following table gives information about two substances. Use the information to determine whether each substance is acting as an oxidising agent (oxidant), or reducing agent (reductant) and provide a brief explanation to justify your answer.

Substance	Information	Oxidant or reductant?
Concentrated sulfuric acid H_2SO_4 (+1)(+6)(-2) H_2SO_4	Reacts with copper to produce sulfur dioxide. (+4)(-2) SO_2	Oxidant (1) Why? S changes from (+6) to (+4) is reduced ∴ an oxidant (1)
Hydrogen peroxide H_2O_2	Reacts with chlorine to produce chloride ion. (0) (-1) $Cl_2 \rightarrow 2Cl^-$	Reductant (1) Why? Cl changes from (0) to (-1) and is reduced (ie oxidant) this indicates H_2O_2 was oxidised (1)

(4 marks)

Question 36.

A student pours some silver nitrate solution into a bronze (copper-tin alloy) container.
Is this wise?
Explain why, or why not. Include an equation. (3 marks)

- No not wise
- Both Cu and Sn are more reactive than silver so will react with the Ag^+ ion (1)
- The container will dissolve (how much depends on the moles of Ag and contaminate the solution (1)

$2Ag^+_{(aq)} + Cu_{(s)} \rightarrow 2Ag_{(s)} + Cu^{2+}_{(aq)}$

$2Ag^+_{(aq)} + Sn_{(s)} \rightarrow 2Ag_{(s)} + Sn^{2+}_{(aq)}$ (1)

Question 37.

Vinegar is about 4% by mass acetic acid and is safe to consume in foods. The same strength sulfuric acid is not safe to consume. Explain why. Include equations.

(4 marks)

Sulfuric acid is a strong acid and completely ionises in solution (1)

$H_2SO_{4(aq)} \rightarrow H^+_{(aq)} + HSO_4^-{}_{(aq)}$ (1)

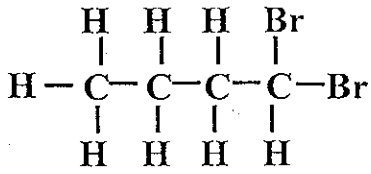
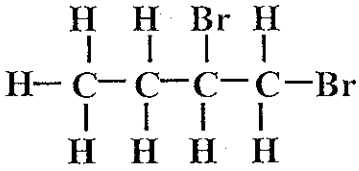
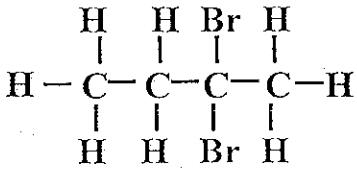
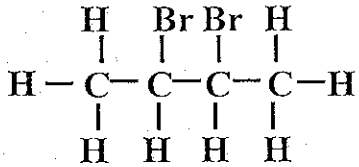
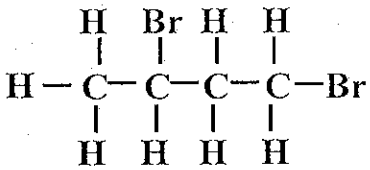
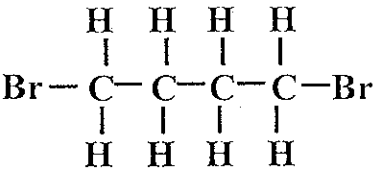
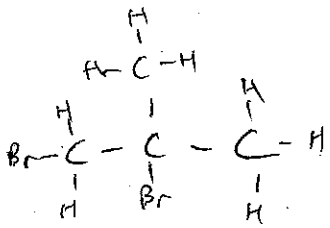
$HSO_{4(aq)}^- \rightleftharpoons H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

Acetic acid is a weak acid and ionise to only a small extent (about 1%) (1)

$CH_3COOH \rightleftharpoons H^+_{(aq)} + CH_3COO^-{}_{(aq)}$ (1)

Sulfuric acid has a much higher H^+ concentration

13. Name, and draw structural diagrams for, the following organic compounds.

Compound	Structural diagram	Name
An isomer of dibromobutane 2 + 1 $C_4H_8Br_2$		1,1 – dibromobutane
		1,2 - dibromobutane
		2,2 - dibromobutane
		2,3 - dibromobutane
		1,3 - dibromobutane
		1,4 - dibromobutane
		1,2-dibromo-2-methyl propane

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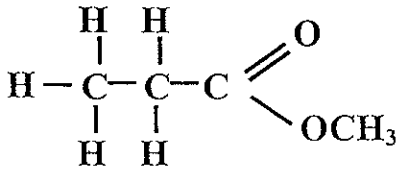
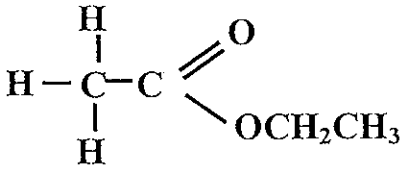
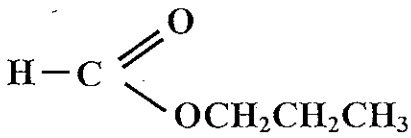
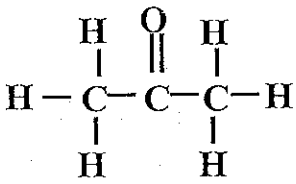
An ester containing 4 carbon atoms 2 + 1	  	**methyl propanoate** **ethyl ethanoate** **propyl methanoate**
The ketone with the least number of carbon atoms 2 + 1		**propanone** **acetone**

(9 marks)

SECTION 3 Extended Answers **6 Questions** **(70 marks 35%)**

Answer ALL questions in Section 3 in the spaces provided.

Question 39.

Treatment of waste by-products in chemical industry **16 marks**

In a chemical industries complex one production plant produces a waste caustic soda (NaOH) solution, which it stores in a large pond. Another production plant produces waste carbon dioxide. The chemical engineers decide to combine both wastes to produce the environmentally friendly by-product, sodium carbonate, by bubbling the carbon dioxide through the caustic soda solution.

$$2\,NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

The caustic soda pond contains 500 kL and has a hydroxide (OH^-) concentration of 1.00×10^{-2} mol L^{-1} (at 20° C).

(a) What is the pH of the solution? (3 marks)

$[OH^-] = 1.00 \times 10^{-2}\ mol\,L^{-1}$

$K_w = 1.00 \times 10^{-14} = [H^+][OH^-] = [H^+](1.00 \times 10^{-2})$ 1

$[H^+] = 1.00 \times 10^{-12}\ mol\,L^{-1}$ 1

$pH = -\log_{10}[H^+] = -\log_{10}[1.00 \times 10^{-12}]$

$= 12$ 1

(b) What is the mass of sodium hydroxide in the caustic soda pond? (2 marks)

$V(NaOH) = 500 \times 10^3\ L$ $c(NaOH) = 1.00 \times 10^{-2}\ mol\,L^{-1}$

$n(NaOH) = cV = 500 \times 10^3 \times 1.00 \times 10^{-2} = 5000\ mol$ 1

$M(NaOH) = 22.99 + 16.00 + 1.008$

$= 39.998\ g\,mol^{-1}$

$m(NaOH) = 5000 \times 39.998$

$= 199999\ g$

$= 199.99\ kg$

$= 200\ kg$ 1

(c) What mass of carbon dioxide is needed to completely react with sodium hydroxide? ***[If you did not answer Part (b) above, use a mass of 100 kg sodium hydroxide.]***

(4 marks)

$n(CO_2) = \frac{1}{2} n(NaOH)$ 1

$= \frac{1}{2} \times 5000 = 2500$ mol 1

$M(CO_2) = 12.01 + 2 \times 16.00 = 44.01$ g mol^{-1} 1

$m(CO_2) = n \times M = 2500 \times 44.01 = 110025$ g

$= 110$ kg 1

If $m(NaOH) = 100$kg $m(CO_2) = 55$kg

(d) The carbon dioxide is first cooled to 10°C (283K) and is pumped at a pressure of 200 kPa, delivering 150 L per minute.
How long does it take to complete the reaction? (5 marks)

$T = 283$K

$P = 200$kPa

$R = 8.315$

$V = ?$

$n = 2500$ mol

$PV = nRT$ 1

$V = \frac{nRT}{P}$

$= \frac{2500 \times 8.315 \times 283}{200}$ 1

$= 29400$ L 1

150 L/min 1

$\therefore$ time $= \frac{29400}{150} = 196$ min 1

If using 100kg NaOH

$t = 98$

(e) The pond solution is still found to be basic with a pH of about 9. Assuming all the carbon dioxide has reacted suggest a reason why is it still alkaline.

Na_2CO_3 is a basic salt (made from weak acid + strong base) 2

Na_2CO_3 hydrolyses to produce OH^- ion

$CO_3^{2-}_{(aq)} + H_2O_{(l)} \rightleftharpoons HCO_3^-_{(aq)} + OH^-_{(aq)}$ (2 marks)

Question 40. **15 marks**

Electrochemistry

The metal tin, Sn, is often used to surface coat steel cans to protect them from corrosion.

(a) In terms of the mechanisms of corrosion, explain how this protective coating works. (2 marks)

$Fe \rightarrow Fe^{2+} + 2e^-$ $E^\circ =$ } 1

$O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$ } 1

Sn prevents O_2 and H_2O reacting Fe } 1

SnO coating prevents further corrosion

$Sn \rightarrow Sn^{2+} + 2e^-$ $E^\circ =$

(b) Once the coating is scratched and the steel is exposed, corrosion actually occurs more rapidly than if the tin were not there. In terms of corrosion mechanisms, explain why this occurs. (2 marks)

Dissimilar metals in contact Sn + Fe - sets up electrochemical cell

Sn is less reactive than Fe, Sn is a cathode, Fe is anode. ~~large surface area~~

Sn acts as a cathode.

(c) A second alternative for the protection of steel from corrosion is to galvanise with zinc. Give a chemical reason, with equation, why Zn galvanising is **not** used to protect steel food cans from corrosion. (2 marks)

$Zn \rightleftharpoons Zn^{2+} + 2e^-$ reacts to produce els to reverse $Fe \rightleftharpoons Fe^{2+} + 2e^-$ reaction.

Zn^{2+} is not healthy.

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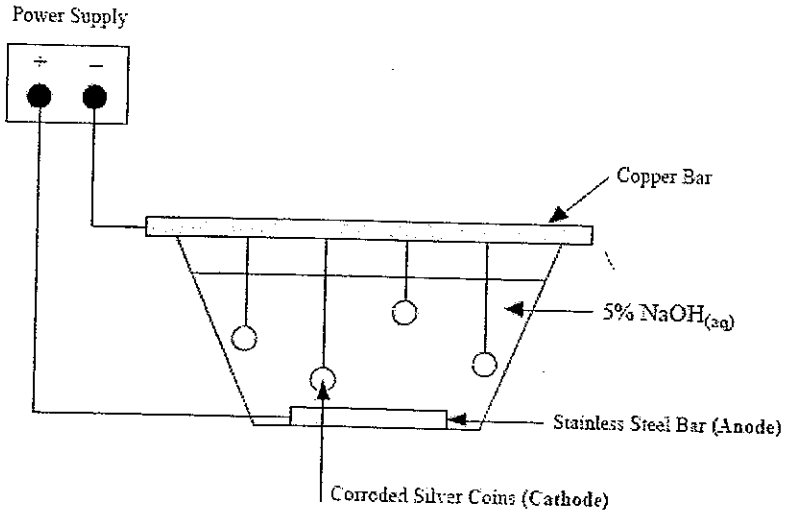
People searching for silver coins and jewellery at the bottom of the sea usually find them coated with the corrosion product silver sulfide, $Ag_2S_{(s)}$, a black solid. To restore the silver coins 'cathodic reduction' is used. A possible cell for this process is shown in the diagram below.

Recovery of Corroded Silver Coins



At the cathode: $Ag_2S_{(s)} + 2e^- \rightarrow 2Ag(s) + S^{2-}_{(aq)}$ ×2 ← need

At the anode: $4OH^-_{(aq)} \rightarrow O_{2(g)} + 2H_2O_{(l)} + 4e^-$

(d) Write a net ionic equation for this reaction. (2 marks)

$2Ag_2S_{(s)} + 4OH^-_{(aq)} \rightarrow 4Ag_{(s)} + 2S^{2-}_{(aq)} + O_{2(g)} + 2H_2O_{(l)}$ 2

(e) At the cathode a few bubbles of gas may also be seen. Suggest what this gas might be and account for its presence in terms of the appropriate half equation. (2 marks)

Cathode – Reduction occurs – gain of electrons 1

only gas that is produced by reduction is H_2

ie $2H^+_{(aq)} + 2e \rightarrow H_{2(g)}$ 1

SO_2 ? NO

$S^{2-} + 2H_2O \rightarrow SO_2 + 4H^+ + 6e$ ox

not at cathode

H_2S gas?

$S^{2-} + 2H^+ \rightarrow H_2S$ ✗ ~~KO~~ Yes

at cathode (where S^{2-} present)

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These recovered silver coins will re-tarnish ($Ag_2S_{(s)}$ reforms) when exposed to air.

(f) A thin electroplated coating of the metal rhodium onto the surface will protect the silver from tarnish. Give a reason why a thin coating of rhodium protects the coins from retarnishing. (2 marks)

rhodium is a noble metal ✓ prevents sulfide (S^{2-}), water and oxygen reaching silver ✓

(g) The question above refers to "cathodic reduction". There is a **completely different** process called "cathodic protection". Give an example of where is it used and how it works. (3 marks)

Cathodic protection is where a metal structure is protected by a power supply -ve terminal connected ✓ to structure whilst +ve terminal comected to scrap iron ✓

note $X \rightleftharpoons X^{2+}$ r2e'

↑ having excess electrons promotes reverse reaction

Question 41.

Production of phosphorus from fluoroapatite **6 marks**

The mineral fluoroapatite [$Ca_{10}(PO_4)_6F_2$] is mixed with sand [SiO_2] and powdered carbon in a high temperature furnace. The phosphorus is produced as a gas [P_2], along with carbon monoxide. The reaction actually produces calcium oxide [CaO], which has a very high melting point. This would make the mixture difficult to control. So, as the calcium oxide is produced it reacts with the sand to form a low melting point slag, calcium silicate [$CaSiO_3$]. This liquid slag is easily separated from the furnace. The reaction occurring is:

$$Ca_{10}(PO_4)_6F_2\,(s) + 9\,SiO_2\,(s) + 15\,C\,(s) \rightarrow 3\,P_2\,(g) + 15\,CO\,(g) + 9\,CaSiO_3\,(l) + CaF_2\,(s)$$

In a laboratory trial a 155 g sample of fluoroapatite (molar mass = 1008.62) is heated with excess sand and 25.0 g of carbon.

What mass of phosphorus would be produced? (6 marks)

$Ca_{10}(PO_4)_6F_2\,(s)$ + 15 C → $3P_2\,(g)$ + ...

155 g 25.0 g

Find LR:

$SR = \frac{n(Fap)}{n(C)} = \frac{1}{15} = 0.066$

$AR = \frac{n(Fap)}{n(C)} = \frac{0.154}{2.08} = 0.074$

Carbon is LR

Find (or allow) relationship 1

$n(Fap) = \frac{155}{1008.62} = 0.154$ mol 1

$n(C) = \frac{25.0}{12.01} = 2.08$ mol 1

$n(P_2) = \frac{3}{15}\,n(C) = 0.2\,n(C)$

$= 0.2 \times 2.08 = 0.416$ mol 1

$m(P_2) = 0.416 \times (2 \times 30.97)$

$= 25.77$ g

$= 25.8$ g 1

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Question 42.

Analysing an organic compound **12 marks**

A certain organic compound is known to contain only carbon, hydrogen and oxygen.

The compound was analysed as follows.

- A 2.149 g sample was burned and the carbon dioxide produced was bubbled through a barium hydroxide solution, producing 11.27 g of barium carbonate ($BaCO_3$).

$$CO_2 + Ba(OH)_2 \rightarrow BaCO_3 + H_2O$$

- The mass of water produced by burning of the sample was 0.7721 g
- The compound was found to have a molecular weight of 150.1

(a) What is the empirical formula of the compound? (9 marks)

$C_x H_y O_z + O_2 \rightarrow CO_2 + H_2O$

$CO_2 + Ba(OH)_2 \rightarrow BaCO_3$

$n(CO_2) = n(BaCO_3)$

$n(C) = n(CO_2) = \frac{11.27}{197.31}$

$= 0.05712$ mol 1

$M(BaCO_3) = 137.3 + 12.01 + 3 \times 16.00$

$= 197.31$ g mol^{-1} 1

$m(C) = 0.05712 \times 12.01$

$= 0.68599$ g. 1

$m(H_2O) = 0.7721$ g

$n(H_2O) = \frac{0.7721}{2 \times 1.008 + 16.00} = 0.04286$ mol 1

$n(H) = 2 \times n(H_2O) = 0.08571$ mol 1

$m(H) = 0.08571 \times 1.008$

$= 0.08639$ g. 1

$m(O) = m(\text{sample}) - m(C) - m(H) = 2.149 - 0.68599 - 0.08639$

$= 1.3766$ g. 1

$n(O) = \frac{1.3766}{16.00} = 0.0860$ mol 1

C	H	O	
0.05712	0.08639	0.0860	
1.0	1.5	1.5	1

EF = $C_2H_3O_3$ 1

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(9 marks)

(b) What is the molecular formula of the compound? (2 marks)

$E(C_2H_3O_2) = 12.01 \times 2 + 3 \times 1.008 + 2 \times 16.00$

$= 75.044 \text{ g mol}^{-1}$ 1

$M(\quad) = 150.1 \text{ g mol}^{-1}$

$\therefore MF = 2 \cdot EF$

$= C_4H_6O_6$ 1

(c) The compound is also known to be a carboxylic acid; that is, containing one COOH group.

Write the molecular formula in the form of $C_XH_YO_Z$ COOH (giving values for X, Y and Z). (1 mark)

C_3HO_4COOH $X = 3$

$Y = 5$

$Z = 4$ 1

Question 43. **10 marks**

Determining concentration of cerium (II) sulfate solution by titration

Cerium is a metal with atomic number 58 that has, in addition its many industrial uses, also many medical uses for its cerium (III) ion.
Cerium (II) ion can be converted to cerium (III) ion by hydrogen peroxide according to the following equation.

$$H_2O_2 + 2\,H^+ + 2\,Ce^{2+} \rightarrow 2\,H_2O + 2\,Ce^{3+}$$

Balanced equ

A solution of cerium (II) sulfate was analysed by the following steps:

I. 50.00 mL of the solution was diluted to 500.0 mL in a volumetric flask
II. 20.00 mL of this diluted solution was pipetted into a conical flask
III. About 20 mL of dilute sulfuric acid was added to the flask
IV. Standardised hydrogen peroxide solution of concentration 0.05145 mol L^{-1} was delivered from a burette
V. The following titres of the hydrogen peroxide were required for the complete reaction:

Titre	Rough	1	2	3	4	5
Volume (mL)	35	35.40	34.55	35.50	35.45	35.45

(a) Why was 20 mL of sulphuric acid added in step III? Why wasn't some other acid added, say HCl? (2 marks)

H_2SO_4 was added to provide H^+ 1 in $H_2O_2 + 2H^+ + 2Ce^{2+} \rightarrow 2H_2O + 2$

if HCl was use Cl^- may be a reactant 1

(b) Referring to the results in step V, explain why the titre value used in subsequent calculations is 35.45 mL. (2 marks)

Do not use Rough and reading 2 1 If Readings 1, 3, 4, 5 are averaged: average = 35.45 mL 1

(c) What was the concentration in moles per litre (mol L^{-1}) of the **original** undiluted cerium sulfate solution? (5 marks)

$V(Ce^{2+}) = 20.00\ mL = 0.02000\ L$
$c(H_2O_2) = 0.05145\ mol\ L^{-1}$ } 1
$V(H_2O_2) = 35.45\ mL = 0.03545\ L$

$n(H_2O_2) = \frac{1}{2} n(Ce^{2+}) = c \times V = 0.05145 \times 0.03545$
$= 1.8239 \times 10^{-3}\ mol$ 1

diluted sample $n(Ce^{2+}) = 2 \times 1.8239 \times 10^{-3}\ mol$
$= 3.6478 \times 10^{-3}\ mol$ 1
$c(Ce^{2+}) = \frac{n}{V} = \frac{3.6478 \times 10^{-3}}{0.02000} = 0.1823\ mol\ L^{-1}$ (dilute) 1

undiluted sample $c(Ce^{2+}\ dil) \cdot V(Ce^{2+}\ dil) = c(Ce^{2+}\ conc) \cdot V(Ce^{2+}\ conc)$
$0.1823 \times 500.0 \times 10^{-3} = c(Ce^{2+}\ conc) \times 50.00 \times 10^{-3}$
$c(Ce^{2+}\ conc) = 1.823\ mol\ L^{-1}$ 1

(d) Calculate the value of the **original** undiluted cerium sulphate solution in grams per litre (g L^{-1})? (1 mark)

$M(CeSO_4) = 140.1 + 32.06 + 4 \times 16.00 = 236.16$
$m(CeSO_4) = n \times M = 1.823 \times 236.16 = 430.5\ g.$ 1

$c(CeSO_4) = 430.5\ g/L$

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Question 44. **11 marks**

The vanadium battery is being developed as an alternative to the lead/acid rechargeable battery for use in electric vehicles. As a vanadium battery discharges the unbalanced, overall reaction is:

$$VO_2^+{}_{(aq)} + V^{2+}{}_{(aq)} \rightarrow VO^{2+}{}_{(aq)} + V^{3+}{}_{(aq)}$$

(a) What is meant by the term 'rechargeable battery'? (1 mark)

Reverse reaction is viable

(b) What kind of cell (primary or secondary) is a rechargeable battery? (1 mark)

Secondary

(c) What is the oxidation state of the vanadium in each of the species shown in this equation? (4 marks)

VO_2^+ +5 V^{2+} +2

VO^{2+} +4 V^{3+} +3

(d) Using the half equation technique, balance the overall equation shown. **Show all half equations.** (3 marks)

$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$ RED

$V^{2+} \rightarrow V^{3+} + e^-$ OX

$VO_2 + 2H^+ + V^{2+} \rightarrow VO^{2+} + V^{3+} + H_2O$ discharg

(e) While the cell is **recharging** identify the anode half equation. (2 marks)

ANODE = OXIDATION

$VO^{2+} + H_2O \rightarrow VO_2^+ + 2H^+ + e^-$

End of Examination

This page is available for extra working space. Be sure to clearly label the question number.

(d) ALTERNATIVE

$VO_2^+ + 4H^+ + 2e \rightarrow V^{3+} + 2H_2O$ RED

$V^{2+} + H_2O \rightarrow VO^{2+} + 2H^+ + 2e$ OX

$VO_2^+ + V^{2+} + 2H^+ \rightarrow V^{3+} + VO^{2+} + H_2O$ discharge

(e) Recharging reaction:

$V^{3+} + 2H_2O \rightarrow VO_2^+ + 4H^+ + 2e$