Section I
Total Marks (75)

Part A
Total marks (15)
Attempt Questions 1-15
Allow about 30 minutes for this part

INSTRUCTIONS
Use the multiple choice answer sheet below.
Select the alternative A, B, C or D that best answers the question. Fill in the response square completely.

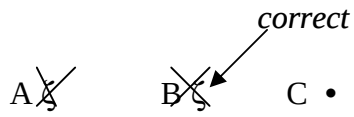
Sample 2+4= (A) 2 (B) 6 (C) 8 (D)9

A • B ζ C • D •

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ζ B ~~ζ~~ C • D •

If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows:



1.Which set of aqueous solutions contain $[H_3O^+]$ less than 10^{-7} mol L^{-1} ?

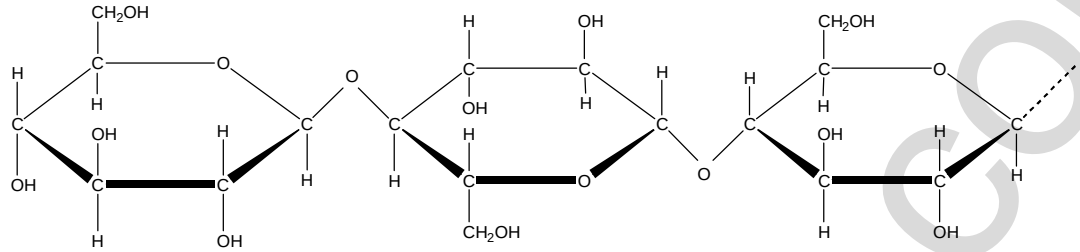
(A) CH_3COOH, HCl, H_2SO_4
(B) NaCl, NH_3, H_2CO_3
(C) $C_6H_{12}O_6$, C_2H_5OH, CH_3COOH
(D) Na_2CO_3, $Ca(OH)_2$, $NaHCO_3$

Outcome: H8

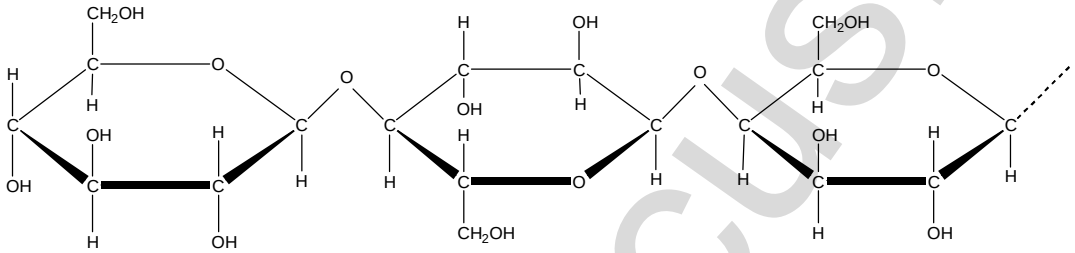
Answer: D

2. Which of the following is a segment of the structure of cellulose?

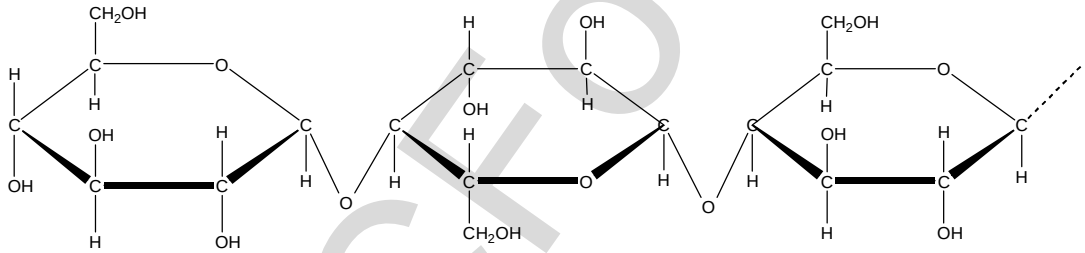
(A)



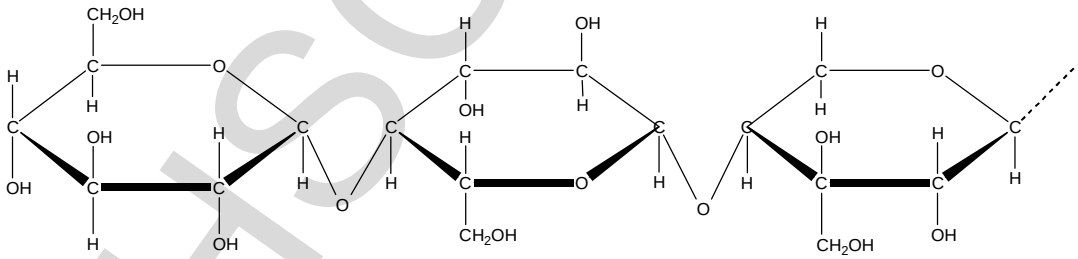
(B)



(C)



(D)



Outcome: H9

Answer: A

3. Which of the following galvanic cells would produce the greatest voltage?

(A) $3Mg_{(s)} + 2Al^{3+}$ **à** $2Al_{(s)} + 3Mg^{2+}$
(B) $Sn_{(s)} + Pb^{2+}$ **à** $Sn^{2+} + Pb_{(s)}$
(C) $Zn_{(s)} + Cu^{2+}$ **à** $Zn^{2+} + Cu_{(s)}$
(D) $2Ag^{+} + Cu_{(s)}$ **à** $2Ag_{(s)} + Cu^{2+}$

<u>Outcome</u>: H8
<u>Answer</u>: C

4. These half-reactions show manganese gaining electron(s) and becoming reduced. In which of the half-reactions is manganese being reduced to the greatest extent?

(A) $MnO_4^- + a\,e^-$ **à** MnO_4^{2-}
(B) $Mn^{2+} + b\,e^-$ **à** $Mn_{(s)}$
(C) $MnO_{2\,(s)} + 4H^+ + c\,e^-$ **à** $Mn^{2+} + 2H_2O$
(D) $MnO_4^- + 4H^+ + d\,e^-$ **à** $MnO_{2\,(s)} + 2H_2O$

<u>Outcomes</u>: H8, H10

<u>Answer</u>: D

5.Which reaction shows a transuranic element being produced?

(A) $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{138}_{56}Ba + {}^{95}_{36}Kr + 3\,{}^{1}_{0}n$
(B) $^{252}_{98}Cf + {}^{10}_{5}B \longrightarrow {}^{258}_{103}Lr + 4\,{}^{1}_{0}n$
(C) $^{238}_{92}U + {}^{1}_{0}n \longrightarrow {}^{239}_{92}U$
(D) $^{9}_{4}Be + {}^{4}_{2}He \longrightarrow {}^{12}_{6}C + {}^{1}_{0}n$

<u>Outcomes</u>: H8, H10

<u>Answer</u>: B

6. Repairs are done on a cracking unit at an oil refinery. An analytical chemist is asked to test the product output from the cracking unit to ensure proper operation.

Which of the following would be a valid test?

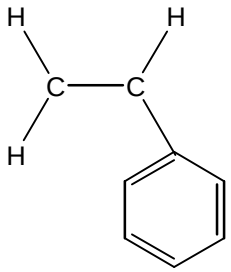
(A) test with a homologous catalyst
(B) test with limewater
(C) test with bromine water
(D) test with methyl orange

<u>Outcome</u>: H8

<u>Answer</u>: C

7. Which of these is the structure of styrene?

(A)



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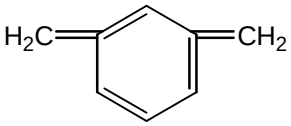

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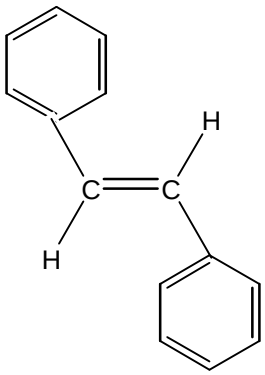
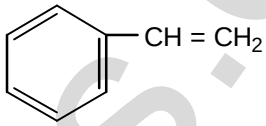


(D)



Outcome: **H9**

Answer: **D**

8. Which lower atmosphere pollutant and its source is incorrectly listed?

	Pollutant	Source
(A)	ozone	photochemical smog
(B)	sulfur dioxide	metal extraction
(C)	carbon monoxide	motor cars
(D)	oxides of nitrogen	combustion (impurities in the fuel)

Outcome: **H4**

Answer: **D**

9. Which technique or instrumentation would be most useful in qualitatively identifying very low concentrations of heavy metal ions in solution.

(A) Atomic Absorption Spectrometry
(B) pH meter
(C) flame test
(D) precipitation with suitable reagents

Outcome: **H13**

Answer: **no correct answer**

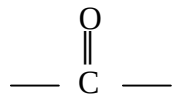
10. Which is the correct IUPAC name for citric acid?

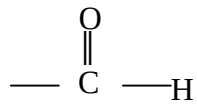
(A) 2-hydroxypropane-1,2,3-tricarboxylic acid
(B) 2-hydroxypropane-triethanoic acid
(C) 1,1,1-tricarboxylic acid
(D) ethanoic acid

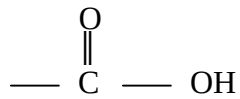
Outcome: H9

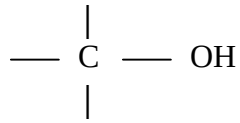
Answer: A

11. The 'sour' taste of fruits is often caused by the presence of alkanoic acids. The functional group responsible for the properties of alkanoic acids is

(A) 

(B) 

(C) 

(D) 

Outcome: H9

Answer: C

12. High concentrations of SO_2 have been blamed for the increased mortality rates occurring in times of 'smog'.
Which process would NOT release SO_2 into the atmosphere?

(A)the action of water on superphosphate fertilizers
(B) the combustion of crude oil
(C) the oxidation of sulfide ores in a smelter
(D) large eruption volcano emissions

Outcome: H4, H16

Answer: A

13. Sulfuric acid can react with pyrosulfuric acid according to the equation:

$$H_2SO_4(l) + H_2S_2O_7\ (l) \rightleftharpoons H_3SO_4^+(l) + HS_2O_7^-(l)$$

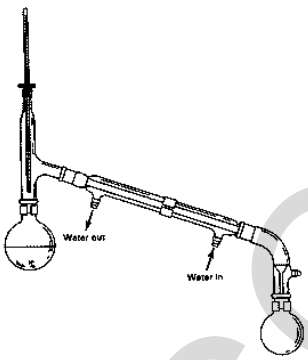
Which species are acting as acids in this reaction?

(A)H_2SO_4, $H_3SO_4^+$
(B)$H_2S_2O_7$, $HS_2O_7^-$
(C)H_2SO_4 , $HS_2O_7^-$
(D)$H_2S_2O_7$, $H_3SO_4^+$

Outcome: H8

Answer: D

14. Which type of glassware is used in titration to deliver solution *X* to a known volume of solution *Y*?

(A) 

(C) 

(B) 

(D) 

Outcome: H12

Answer: D

15. Which statement corresponds best with Davy's ideas about acids and bases?

(A)An acid is a substance that provides H^+ ions in aqueous solution.

(B)All acids contain the element hydrogen.

(C)The presence of oxygen in compounds formed from non-metals, causes acidity.

(D)An acid is a proton donor.

Outcome: H1

Answer: B

Student Number ……

Section A **Mark -----/15**

Multiple Choice Answer Sheet

1.	A •	B •	C •	D ζ
2.	A ζ	B •	C •	D •
3.	A •	B •	C ζ	D •
4.	A •	B •	C •	D ζ
5.	A •	B ζ	C •	D •
6.	A •	B •	C ζ	D •
7.	A •	B •	C •	D ζ
8.	A •	B •	C •	D ζ
9.	A •	B •	C •	D •
10.	A ζ	B •	C •	D •
11.	A •	B •	C ζ	D •
12.	A ζ	B •	C •	D •
13	A •	B •	C •	D ζ
14.	A •	B •	C •	D ζ
15.	A •	B ζ	C •	D •

Section I (continued)

Part B - 60 marks
Attempt Questions 16 -28
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided
Show all relevant working in questions involving calculations

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Question 16 (3 marks) **MARKS**

During the last twelve months, much media coverage has been devoted to the controversial use of ethanol as an additive to petrol.

(a) Explain why ethanol is added to petrol. **1**

Outcome: H4

Answer: Ethanol is added to petrol to reduce the consumption of oil which is a non-renewable resource. OR Ethanol is added to petrol to reduce greenhouse gas emissions. OR Ethanol is added as an octane booster.

(b) Evaluate the success or otherwise of the use of ethanol–petrol fuel blends based on recent Australian experience **2**

Outcome: H3

Answer: The use the ethanol–petrol blends has been of mixed success. (1 mark)
Blends with of ≤ 10% ethanol appear compatible with modern motors, however blends sold with up to 20% ethanol have caused damage to fuel lines and the engine. Car makers have threatened to void new car warranties if owners use high ethanol fuel.
Based on recent field trials, the Federal government will legislate to cap ethanol content at 10%. (1 mark)

Question 17 (4 marks) **MARKS**

Biopolymers have a long history of use (e.g. cellulose and rubber), but much chemical research is proceeding on a new generation of biopolymers with exciting potential applications.

Complete the table providing information about a recently developed biopolymer you have studied. **4**

Name of biopolymer	
Specific enzyme or organism used to synthesize the biopolymer	
Possible use of biopolymer	
Property of the biopolymer which relates to it use	

Outcome: H5

Answer: Each cell = 1 mark. Several answers are possible including…

Name of biopolymer	**Polylactic acid (Must be name not abbreviation)**
Specific enzyme or organism used to synthesize the biopolymer	**fermenting bacteria**
Possible use of biopolymer	**food packaging**
Property of the biopolymer which relates to it use	**transparent, strong, moisture & grease resistant, heat sealable**

Question 18 (4 marks)

(a) The following nuclear reaction is incomplete.

Re-write the entire equation providing the missing numbers and/or symbols. **1**

$$^{231}_{91}? \longrightarrow {}^{?}_{?}? + {}^{?}_{?}He + {}^{?}_{?}\gamma$$

Outcomes: H8, H10

Answer: $$^{231}_{91}Pa \longrightarrow {}^{227}_{89}Ac + {}^{4}_{2}He + {}^{0}_{0}\gamma$$

(b) Identify an instrument (other than a Geiger counter) which could be used to detect radiation. **1**

Outcome: H4

Answer: One of the following: cloud chamber, bubble chamber, scintillation counter, dosimeter.
N.B. Photography film is unacceptable as it is not an instrument.

(c) Cobalt–60 is widely used for the irradiation of cancerous tumours because it is a potent gamma–emitter.

Identify a problem (for patient and radiotherapist) with its use and explain how the problem is overcome **2**

……

……

Outcome: H4

Answer: Gamma radiation poses a serious biohazard to all healthy tissue in the patient and/or radiotherapist. (1 mark)

The problem is solved by providing adequate lead shielding and directing a narrow beam of gamma rays specifically to the tumour. (1 mark)

Question 19 (3 marks)

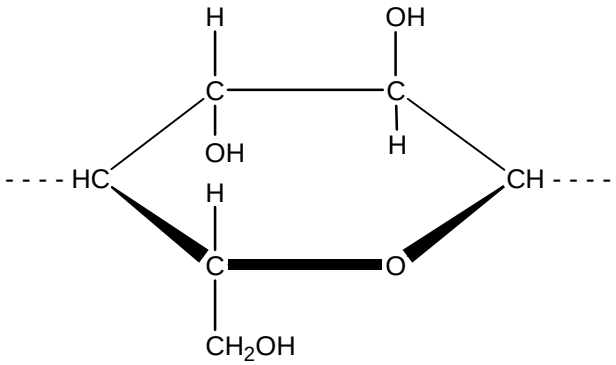
(a) Discuss the need for alternative, non-oil based sources of petrochemicals in the future. **2**

Outcomes: H3, H4

Answer: Oil is a limited, non-renewable resource. (1 mark)

Since petrochemicals (e.g. plastics, lubricating oil, grease, motor fuels) are essential for industry and technology, alternatives must be found. (1 mark)

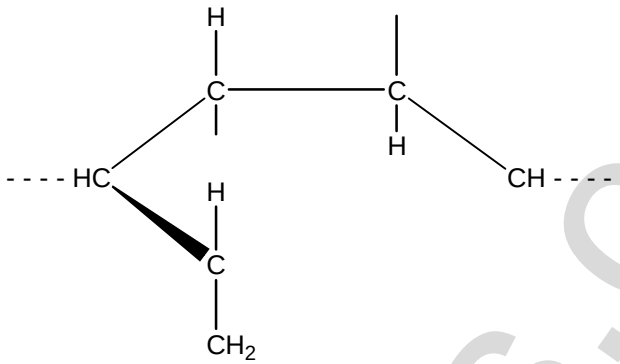
(b) The structure shown is a fragment of a cellulose molecule….



Draw a complete, unbroken border around the part of the structure, which could be used in the future to make oil-like substitutes **1**

Draw a complete, unbroken border around the part of the structure which could be used in the future to make oil-like substitutes. **(1 mark)**

Outcome: **H9**



Answer: **Border should enclose only the hydrocarbon content of the molecule.**

Question 20 (4 marks)

(a) Explain the chemistry of the dry cell or lead-acid cell in terms of oxidation and reduction. Support your answer with equation data. **2**

Outcome: **H8**

Answer: **DRY CELL…**

Oxidation: $Zn_{(s)} \rightarrow Zn^{2+} + 2e^-$ **(1 mark)**

Reduction: $NH_4^+{}_{(aq)} + MnO_{2\,(s)} + H_2O_{(l)} + e^- \rightarrow Mn(OH)_{3\,(s)} + NH_{3\,(g)}$ **(1 mark)**

OR

LEAD–ACID….

Oxidation: $Pb^{2+} + SO_4^{2-} \rightarrow PbSO_{4\,(s)} + 2e^-$ **(1 mark)**

Reduction: $PbO_{2\,(s)} + SO_4^{2-} + 4H^+ + 2e^- \rightarrow PbSO_{4(s)} + 2H_2O_{(l)}$ **(1 mark)**

***Student could also give the complete reaction equation and then clearly state species undergoing oxidation and reduction.**

(b) Describe the flow of electrons in an operating galvanic cell in terms of anode and cathode. **2**

Outcome: H8

Answer: The electrons flow from the anode to the cathode (1 mark) … through the external circuit. (1 mark)

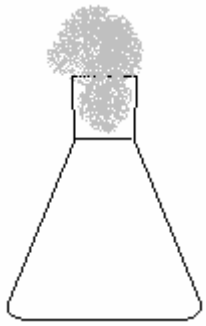
Question 21 (8 marks)

An alcoholic fermentation is performed to quantitatively determine the mass loss during the course of the reaction**.** An aqueous glucose mixture is fermented in a vessel resting on the pan of an electronic balance, which is connected to a data logger, set to record the mass at one hour intervals.

(a) Draw a labelled diagram of a fermentation vessel suitable for the purpose of this investigation. **1**

Outcome: H11

Answer: A labelled diagram showing a flask with a cotton wool plug which allows the release of CO_2 while preventing the entry of fresh air and *aceti* bacteria.



(b) Describe storage conditions for the vessel, which would favour the 12-hour fermentation **1**

Outcome: H11

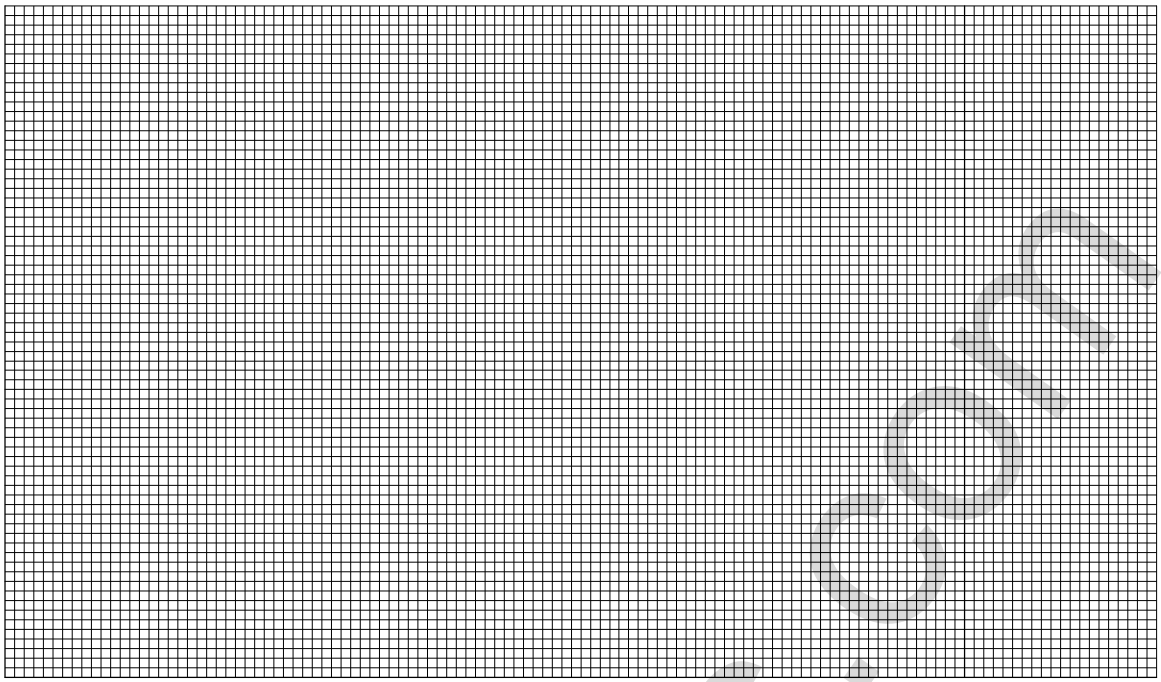
Answer: A warm ambient temperature (25 – 35°C).

(c) The table shows the downloaded file from the data logger.

Elapsed Time (h)	Mass of vessel (g)	Elapsed Time (h)	Mass of vessel (g)
0	173.25	7	170.40
1	173.10	8	170.35
2	172.50	9	170.30
3	171.15	10	170.25
4	170.75	11	170.25
5	170.60	12	170.25
6	170.50		

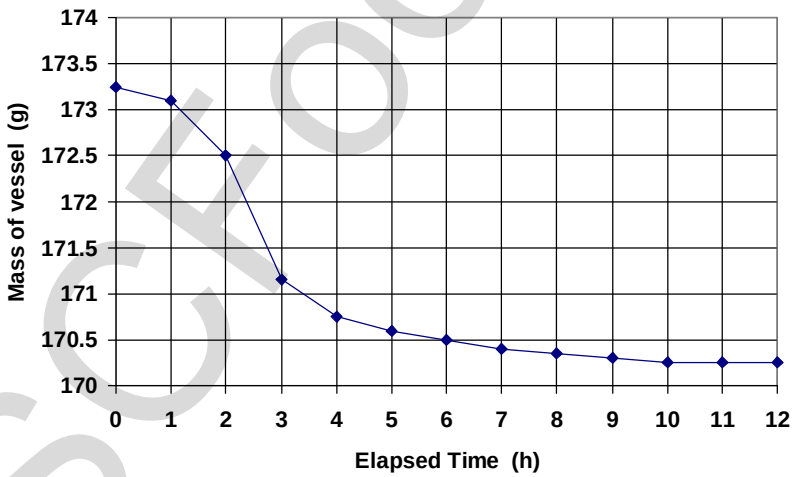
Plot the table data on the graph grid. **2**

Question 21 (continuation)



Outcome: **H13**

Answer: **Reasonable y-axis scale; labelled axes with units. (1 mark)**
Accurate plotting of 13 data points. (1 mark)



(d) During which one-hour interval was the fermentation most active ? **1**

Outcome: **H14**

Answer: **Between 2 – 3 hours.**

(e) Suggest a plausible cause for the plateau on the graph **1**

Outcome: H14

Answer: All the glucose has been consumed by the yeast.

OR

The build up of ethanol has killed the active yeast.

(f) Write the formulae equation for the fermentation process. **1**

Outcome: H9

Answer: $C_6H_{12}O_{6\,(aq)} \xrightarrow{\text{yeast (zymase)}} 2C_2H_5OH_{\,(aq)} + 2CO_{2\,(g)}$

Must include yeast (zymase).

(g) Calculate the volume of carbon dioxide gas which escaped (at STP) after 6 hours of fermentation. **1**

Outcome: H10

Answer: After 6 hours, mass of CO_2 was lost = 173.25 g – 170.50 g = 2.75 g

\ 2.75 g ÷ 44.01 g/mol • 22.71 L/mol = 1.42 L

MARKS

Question 22 (4 marks)

CFCs and halons have been identified as the main causes of the upper atmosphere ozone layer depletion.

(a) Identify one origin of CFCs and one of halons in the atmosphere. **1**

Criterion	Mark(s)
Origin of both CFCs and halons	1

Outcome:H3, H13, H16

Answer:

CFCs were widely used as refrigerants and propellants in aerosol cans while halons were mainly used in fire extinguishers used in cars and boats. Through time, because of their inherent insolubility in water and unreactivity CFCs and halons found their way into the stratosphere.

(b) The graph shows the mean October ozone concentrations over the south pole. Describe the changes observed and explain how this information was obtained. **3**

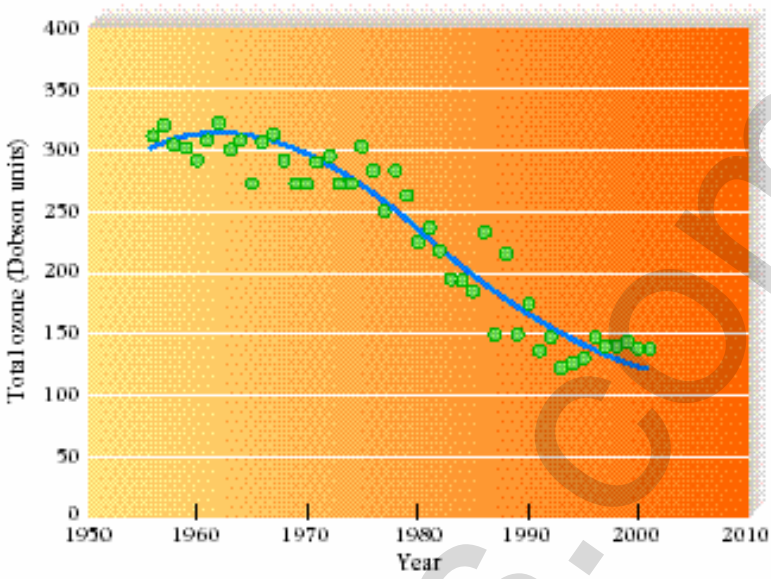


Figure 15.3 Mean October ozone concentration over the South Pole. The continuous curve is one representation of the trend of the individual annual points shown by circles. (Data from J. Shanklin, British Antarctic Survey, Cambridge, England)

Diagram taken from Chemistry in your Life, by C. Baird and W. Gloffke, Freeman, 2003

Criteria	Mark(s)
Description of changes	1
How information was obtained	1
Explanation of how information was obtained	1

Outcomes: H4,H16
Answer:

The diagram shows the annual spring ozone concentration over the south pole which shows a steady decline in the ozone concentration starting in the mid-1960s. This is followed by a greater rate of decline between 1970 and 1990. The rate seemed to have slowed down starting mid 1990s.
The information was most probably gathered from ground -based instruments, from instruments in a satellite and from instruments in balloons. In the ground-based instruments UV spectrophotometers are pointing vertically upwards through the atmosphere. The intensity of the light received from the sun at a wavelength at which ozone absorbs and then at wavelengths at either side of this at which ozone does not absorb is measured. .Spectrophotometers on board satellites have been able to scan through the atmosphere measuring the ozone concentration as a function of altitude and geographical position.

Question 23 (4 marks)

Ammonium sulfate has been used as fertilizer. Analysis of fertilizer is often done gravimetrically

(a) Write the main formulae equation for the gravimetric determination of sulfate in fertilizer **1**

Criteria	Mark(s)
balanced equation formulae equation	1

Outcome: H13

Answer:

$BaCl_2 + (NH_4)_2SO_4$ **à** $BaSO_4(s) + 2\ NH_4Cl$

(b) Based on the data given below, calculate the **percentage sulfate** in a fertilizer sample. **2**

mass of fertilizer: = 0.5010 g
mass of sintered glass crucible = 20.2052 g
mass of sintered glass crucible + dried precipitate = 20.7351 g

Outcome: H13, H10

Criteria	Mark(s)
Correct moles of $BaSO_4$	1
Correct percentage sulfate	1

Answer:

mass of $BaSO_4(s)$ = mass of crucible + precipitate - mass of empty crucible
= 20.7351 - 20.2052 = 0.5299 g

moles $BaSO_4$ = mass $BaSO_4$/ molar mass $BaSO_4$ = (0.5299/ 233.39) = 2.270×10^{-3} mole
mole SO_4^{2-} = moles $BaSO_4$ = 2.270×10^{-3} mole **1**
mass SO_4^{2-} = moles SO_4^{2-} x molar mass SO_4^{2-} = 2.270×10^{-3} mole x 96.06 g/mole
= 0.2181 g

% SO_4^{2-} = mass SO_4^{2-} / mass sample = (0.2181 g/ 0.501 g) x 100 % = 43.5 % **1**

(c) Identify one source of error in this determination. Explain how this error will affect the percentage sulfate determined? **2**

Outcome: H14

Answer:

A source of error in this determination is the incomplete precipitation of the sulfate ion as $BaSO_{4=}$ in the fertilizer. This mistake will result in a negative error, a lower reported percentage sulfate compared with the true value

Another source of error is the incomplete washing of the barium sulfate precipitate. This results in a higher measured mass of barium sulfate and hence a higher percentage of sulfate in the fertilizer. compared with the true value.
Inefficient/ineffective filtration method/medium

Question 24 (5 marks)

Describe and assess the effectiveness of methods used to purify and sanitize mass water supplies. **3**

Outcome: H16,H3,H14

Criteria	Mark(s)
Description of the methods	1
Other methods stated	1
Assessment of the methods	1

Answer:
Water treatment consists of removing very small particulate by flocculation.. The water is then sand filtered to remove bigger particulate. Finally, it is treated with chlorine to kill microorganisms. .Alternative methods of filtration such as membrane filtration and ozone sterilization may be both more efficient in removing particulate including microorganisms such as Giardia and Cryptosporidium. However, these latter techniques are expensive to implement.

Question 25 (4 marks)

Outline the role of a chemist employed in a named industry or enterprise. Identify the branch of chemistry undertaken by the chemist and describe a chemical principle that the chemist uses. **4**

Outcomes: H3
Answer:

Criteria	Mark(s)
Named Industry	1
Branch of Chemistry	1
Chemical Principle used	1
Brief outline of Chemists role	1

Plastics industry as a plant chemist. This is a branch of Organic chemistry. Catalytic cracking is used to change the long chain alkanes to shorter chain alkanes which can be used in polymerisation. The chemist role is to monitor product quality, waste management and collaborate with engineers to optimise operating conditions at the cracking furnace.

Question 26 (3 marks)

Ammonia can be synthesized from its component gases nitrogen and hydrogen as shown by the equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Using Le Chateliers principle, explain why the yield of product in this process is reduced at higher temperatures. Identify the synthesis reaction as endothermic or exothermic in your answer. **3**

Outcomes: H8
Answer:

The synthesis reaction, i.e., the foraward reaction, is exothermic (DH = -92kJ/mol). By Le Chateliers principle, if the temperature is increased, equilibrium will shift to <u>oppose the change</u>, i.e., (absorb the energy). The reaction that uses heat is the endothermic reaction, thus, at higher temperatures, equilibrium will <u>shift to the left</u> , the endothermic reaction and the [NH_3] will decrease

Question 27(6 marks)

Describe the procedure you used to prepare an ester in the school laboratory. Include a diagram and any relevant equations in your answer in your answer **6**

Outcomes: H11,H12
Answer:

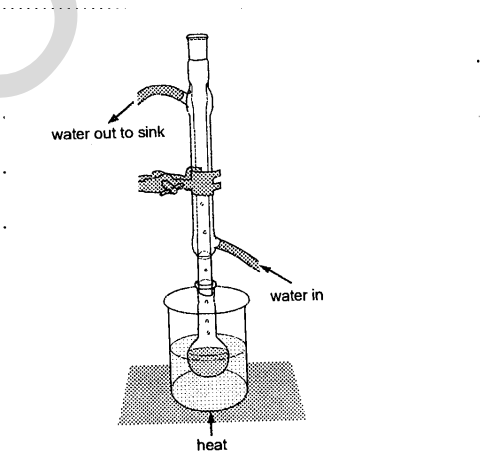
Criteria	Mark
equation	**2**
method	**2**
diagram	**2**

Sample answer:

$$C_2H_5OH + CH_3COOH \xrightarrow[H_2SO_4]{\text{conc}} H_3C-\overset{\overset{O}{\|}}{C}-O-C_2H_5 + H_2O$$

Method

1. **Mix together 12 mL of ethanol and 40 mL of ethanoic acid in a distilling flask.**
2. **Cautiously add 1 mL of concentrated H_2SO_4**
3. **Attach a reflux condenser and reflux the mixture on a Bunsen flame for 20 minutes.**
4. **Pour the mixture into a separatory funnel containing 20 mL of water.**
5. **Allow to cool. Note the characteristic odur of the ester.**
6. **Remove the water layer.**
7. **Add 10 mL of a saturated solution of sodium carbonate . This process separates the ethyl ethanoated from any unreacted ethanol and ethanoic acid, and removes unreacted ethanoic acid.**



Using reflux to react and retain chemicals in a flask.

MARKS

Question 28 (4 marks)

Solutions of acids of the same concentrations were measured and given in the table below:

Acid	Concentration (mol L^{-1})	pH
citric	0.1	2.1
ethanoic	0.1	2.9
hydrochloric	0.1	1.0

Outcomes: H2, H8
Answer:

(a) List the acids in order of strength starting from the weakest. **1**

ethanoic acid, citric acid, hydrochloric acid

(b) What is the hydrogen ion concentration of the citric acid solution?

$[H^+] = 10^{-2.1} = 7.9 \times 10^{-3}$ mol L^{-1}

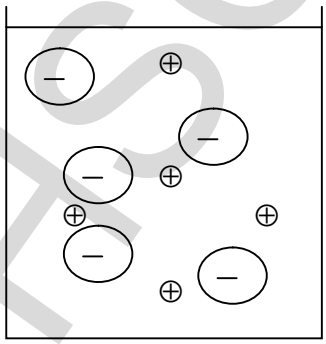
……

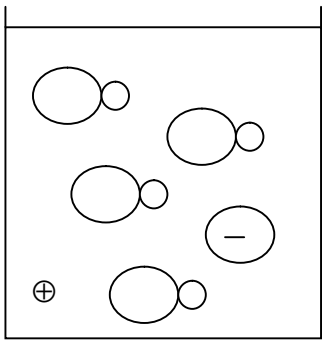
(c) Model the molecular nature and ionization of strong and weak acids in the beakers below using the following symbols.


acid molecule


acid anion

⊕ hydrogen ion


strong acid


weak acid

Question 29 (3 marks)

Aluminium carbide (Al_4C_3) reacts with excess water to produce methane (CH_4) and aluminium hydroxide.

(a) Write the balanced formulae equation for the reaction. **1**

Outcomes: H10
Answer:

$$Al_4C_3 + 12\ H_2O \rightarrow 3\ CH_4 + 4\ Al(OH)_3$$

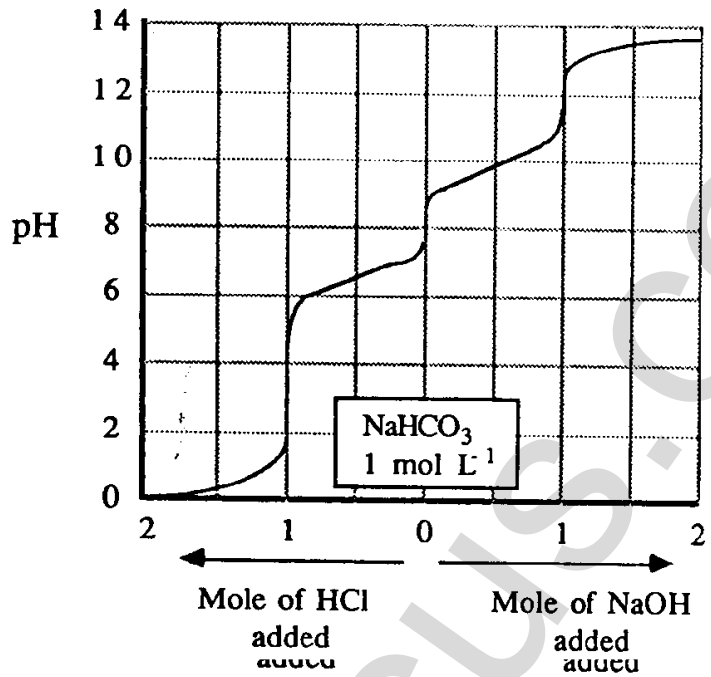
(b) What mass of aluminium carbide is required to produce 24.71 L of methane at 25^0C and 100 kPa? **2**

Outcomes: H10
Answer:

mol CH_4 = 1 (24.79 L)
\ mol Al_4C_3 required = 1/3 mol
or mass Al_4C_3 = mol x fw = 1/3 x ((26.98 x 4) + (3x12))
= 47.97 g

Question 30 (4 marks)

A 1.0 molL^{-1}solution of sodium hydrogen carbonate was titrated in separate experiments with hydrochloric acid and sodium hydroxide. The results are shown in the graph below. The starting point in both titrations was the 0 position indicated on the x-axis.



Outcomes: H8
Answer:

(a) What is an amphiprotic species? Write balanced ionic equations showing how the hydrogen carbonate ion may react as an amphiprotic species.

An amphiprotic species can act as both a proton donor and a proton acceptor. **1**

$HCO_3^- + H^+ \rightarrow H_2CO_3 \rightarrow CO_2 + H_2O$
$HCO_3^- + OH^- \rightarrow CO_3^{2-} + H_2O$ **2**
$HCO_3^- + H_2O \rightleftharpoons H_3O^+ + CO_3^{2-}$

$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$ **(Smith: p 143)**

(b) What is the pH of a 1.0 molL^{-1} solution of sodium hydrogen carbonate?

8 **1**

Section II

25 marks

Attempt Question 31
Allow about 45 minutes for this section.

Answer the question in a writing booklet provided
Show all relevant working in questions involving calculations

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Question 31 **MARKS**

(a) Write anode and cathode reactions during the electrolysis of copper (II) chloride solution and sodium sulfate solution using copper metal electrodes and the minimum possible voltage. **4**

Criterion	Mark(s)
One mark for each equation	1x4

Reaction at the anode and cathode during electrolysis of two solutions

Electrode	Copper(II)chloride	Sodium sulfate
Anode	$Cu\ (s) \rightarrow Cu^{2+} + 2e^-$	$Cu\ (s) \rightarrow Cu^{2+} + 2e^-$
Cathode	$Cu^{2+} + 2e^- \rightarrow Cu\ (s)$	$2e^- + 2\ H_2O \rightarrow H_2(g) + 2OH^-$

(b) Cathodic protection is one way of protecting iron and iron-based materials from corrosion.

Identify two applications/ techniques for corrosion prevention utilising cathodic protection. Use relevant ionic equations to support your answer. **4**

Criteria	Mark(s)
Two applications	2
Two ionic equations	2

Outcomes:H2,H3,H4,H5

(a)Galvanising the iron uses cathodic protection to protect the surface from corrosion.after the zinc layer has been scratched. The coating zinc becomes the sacrificial anode
$Zn(s) \rightarrow Zn^{2+} + 2e^-$ anode
$4e^- + 2\ H_2O + O_2 \rightarrow 4OH^-$ cathode
$2Zn(s) + 2\ H_2O + O_2 \rightarrow 2Zn^{2+} + 4OH^-$

(b) voltage is applied to an inert (i.e. non- sacrificial) anode and the metal to be protected is given a negative potential. The voltage forces electrons on to the metal to be protected and hence prevents its oxidation.

$4e^- + O_2 + 2\ H_2O \rightarrow + 4\ OH^-$ cathode (negative electrode, the metal to be protected)
$2\ H_2O \rightarrow O_2(g) + 4H^+ + 4e^-$ anode (inert electrode)

(c) Discuss one technique other than cathodic protection which is used to protect a ship's metal hull. from corrosion. **2**

Criteria	Mark(s)
More detailed discussion of other methods for protection against rust	2

Outcome:H5
Answer: Any of the following:

- **Surface alloys: Formation of a stainless steel -like alloy on the surface of a ship by bombarding the surface with ions of chromium and nickel. The metal ions are formed in a high temperature plasma**

- **Use of new paints such as RUSTMASTER PRO, a new polymer-based paints which when cured on the surface forms a layer which is impervious to oxygen and water. Additives in the paint react with surface atoms in the steel to form a non-conductive layer**

.

(d) Discuss the nature of the corrosion that can occur if a lead gutter were nailed to a house using tin nails

Criteria	Mark(s)
Prediction of which metal will corrode	1
Justification for the prediction	1

A galvanic cell can be formed at the point of contact of the two metals. The metal that is most easily reduced (more positive reduction potential) will serve as the cathode whereas the other metal serves as the anode: By comparing standard reduction potentials of Sn and Pb we see that Sn will be the anode. The lead gutter will not corrode but the Sn nails would corrode leaving the gutter on the ground.

	Reduction Potential
$Sn^{2+} + 2e^- \rightarrow Sn(s)$	$E^0 = -0.14$ v
$Pb^{2+} + 2e^- \rightarrow Pb(s)$	$E^0 = -0.13$ v

(e) (,i.) Use the information given in the following diagram to predict the effect of low temperatures at great depths on the rate of corrosion of a metal. Justify your prediction. **4**

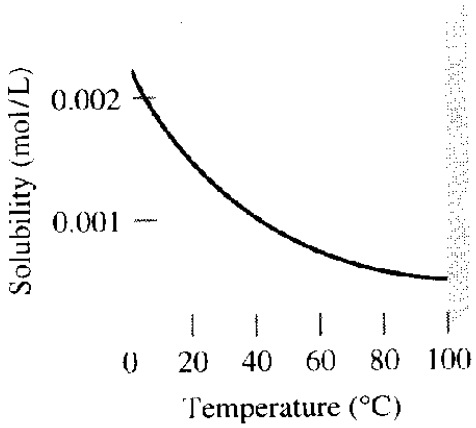

Diagram 1: Graph of solubility of O_2 gas as a function of temperature.

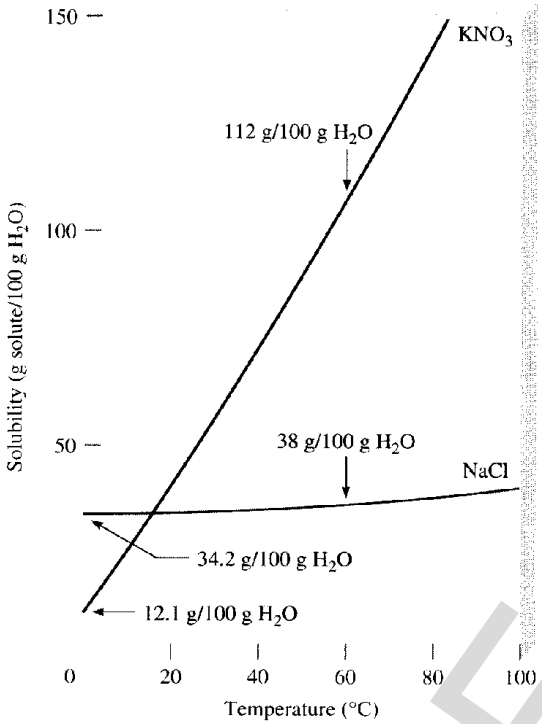

Diagram 2: Graph of the solubility of solids against temperature.

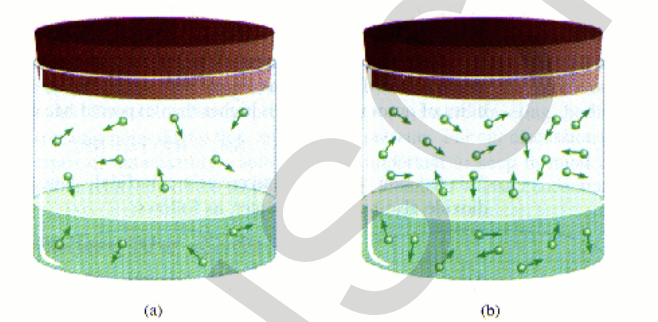

Diagram taken from Chemistry, by Chang, 1996.

Diagram 3: Effect of pressure on the solubility of a gas.

Outcomes:H14,H13,H12,H11,H8,H2

Criteria	Mark(s)
Conclusions drawn on the basis of diagrams	2
justification of prediction	2

Answer:

At great depths, the temperature of water is very low. At this temperature, the solubility of

oxygen as detailed in Diagram 1 is higher. A higher oxygen concentration results in a higher rate of corrosion. On the other hand, a lower temperature should result in s lower rate of corrosion due to the absence of the necessary activation energy required for the reaction,. The opposing factors results in a rate of corrosion which is not easily predictable. Salt concentration (NaCl) is not much affected as shown by Diagram 2 by change in temperature and hence the change in depth, will not affect the rate of corrosion by way of change in the electrolyte concentration.

(e)(ii.) Other than the information given in these diagrams, identify factors or processes that control the concentration of oxygen and carbon dioxide in the ocean waters. **2**

Criteria	Mark(s)
Factors controlling the concentration of gases	2

Other factors that control the concentration of gases, particularly, oxygen and carbon dioxide are the consumption of oxygen and production of CO_2 by marine plants and animals and the consumption of CO_2 and the production of oxygen by plants.

(f) What is the best way to store partly used steel wool in the kitchen? The options available are :

- keeping it immersed in plain tap water
- keeping it immersed in soapy water (a basic solution)
- keeping it immersed in a carbonated drink

Plan an investigation to find out the option which is least conducive to rusting **7**
Your plan must include the following:

- your hypothesis and a justification for this
- a brief outline of the procedure or the strategy of the determination.
- an identification of the dependent, independent and controlled variables in the in the experiment.
- a suggestion for improving the reliability of the experiment

You should organize your answers in such a way as to explicitly address the above 4 points

Outcomes:H11, H12, H13, H14,H15

Criteria	Mark(s)
Hypothesis	1
Valid procedure	2
Identification of variables	3
Proposal to increase reliability	1

Answer:

HYPOTHESIS: The best option is immersing the steel wool in soap solution as a basic solution inhibits corrosion more than neutral or acidic (carbonated) solution. This can be shown by considering that the reduction of oxygen is more likely in acidic than in neutral or basic solution

$\frac{1}{2} O_2 + 2H_2O + 2e^- \rightarrow 2 OH^-$ +0.40 v
$\frac{1}{2} O_2 + 2 H^+ + 2e^- \rightarrow H_2O$ +1.23 v

PROCEDURE:

(A) **Soak identical masses of steel wool , ideally from the same packet of steel wool into identical beakers containing identical volumes of water, soap solution and carbonated drink. Before dropping the steel wool, test each of the solutions with $K_3Fe(CN)_6$ reagent . A blue precipitate indicates the presence of Fe^{2+} ions.**

(B) **Set-up control beakers, beakers containing only the solutions to be tested but which do not contain steel wool**

(C) **Cover each of the solutions tightly and store under identical temperature conditions**

(D) **After a set period of time, say, 24 hours, test each of the solutions for the presence of Fe^{2+}**

VARIABLES

Dependent: presence of Fe^{2+} ions i.e. development of rust

Independent variable: nature of solution in contact with steel : water, soap solution, and carbonated drink

Controlled variable: temperature, volume of test solution , size of steel wool, immersion of the steel wool

RELIABILITY: The reliability of the experiment can be improved by repeating the experiment several times and setting up identical beakers with same conditions for the dependent variables. If the results are reproducible, they are more reliable.