PART 1: MULTIPLE CHOICE ANSWER SHEET

YOUR NAME: ......Solutions......

INSTRUCTIONS: Using a pen mark your selections on this sheet by using a X. If you need to make a correction make sure you intent is clear.

You may choose to carefully remove this answer sheet

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

PART 2 Short Answer (70 marks)

This part contains **nine (9)** questions. Answer **all** questions. Write your answers in the space provided.

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

Suggested working time: 60 minutes.

Question 1 **[12 marks]**

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

- colours
- odours
- precipitates (state the colour)
- gases evolved (state the colour or describe as colourless).

If no change is observed, you should write "no visible change".

(a) Copper(II) nitrate solution is added to excess sodium carbonate solution.

Equation **(2 marks)**

$Cu^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CuCO_3(s)$

Observation **(1 mark)**

Blue solution reacts to form a blue/green precipitate

(b) A colourless organic liquid methylpropan-2-ol is added to a dilute acidified solution of potassium dichromate.

Equation **(2 marks)**

no visible change

Observation **(1 mark)**

Solution stays orange.

(c) Sodium metal is added to pure acetic acid (ethanoic acid).

Equation **(2 marks)**

$2Na + 2CH_3COOH \rightarrow 2Na^+ + 2CH_3COO^- + H_{2(g)}$

Observation **(1 mark)**

Colourless gas evolved, silver metal dissolves to form a colourless sol^n.

(d) An acidified potassium dichromate solution is reacted with oxalic acid ($H_2C_2O_4$) to produce chromium (III) ions, carbon dioxide and water.

Equation **(2 marks)**

$3H_2C_2O_4 + Cr_2O_7^{2-} + 8H^+ \rightarrow 6CO_2 + 2Cr^{3+} + 7H_2O.$

Observation **(1 mark)**

Colourless gas evolved as solution changes colour from orange to green.

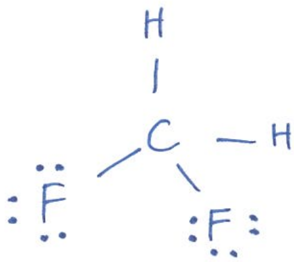
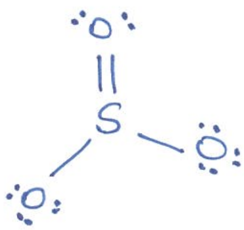
$3H_2C_2O_4 \rightarrow 6CO_2 + \cancel{6H^+} + \cancel{6e^-}$

$Cr_2O_7^{2-} + \cancel{14}\,8H^+ + \cancel{6e^-} \rightarrow 2Cr^{3+} + 7H_2O.$

Question 2 **(9 marks)**

For each species listed in the table below, draw the Lewis structure, representing all valence shell electron pairs either as : or as — **and** state or sketch the shape of the species **and** state the polarity of the molecule.

(for example, water H:Ö:H or H—Ö—H or H—Ō—H bent, polar)

Species	Structure (showing all valence electrons)	Name of shape	Polarity of molecule (polar or non-polar)
Hydrogen cyanide HCN	H — C ≡ N:	linear	polar
Difluoromethane CH_2F_2		tetrahedral	polar
Sulfur trioxide SO_3		triangular planar	non-polar

3x [2]

6x [½]

Question 3 **(5 marks)**

Trichloroethanoic acid ($CC\ell_3COOH$) is a weak acid that is sometimes used in the removal of warts and tattoos. It allows new skin cells to appear by removing the first few layers of skin. The sodium salt of the acid (sodium trichloroethanoate) is also used as a weedkiller.

(a) Write an equation to show the reaction that takes place when trichloroacetic acid is dissolved in water. (1 mark)

$CCl_3COOH + H_2O \rightleftharpoons H_3O^+ + CCl_3COO^-$

(b) State and explain –using your equation above, what would happen to the pH (increase, decrease, or no change) of a 1 mol L^{-1} trichloroethanoic acid solution if it were mixed with a solution of sodium trichloroethanoate. (4 marks)

[1]

Effect on pH (circle one) Increases Decreases No change

Reason

Adding CCl_3COO^- will move E'm position to the LHS. ∴ $[H_3O^+]$ ↓ and pH ↑

[1] [1] [1]

Question 4 **(5 marks)**

Give the name (or formula) of the species that match each of the following descriptions.

i. The conjugate base of carbonic acid. HCO_3^- (1 mark)

ii. A tertiary alcohol with 4 carbon atoms. methylpropan-2-ol (1 mark)

iii. A diatomic element with a triple bond. N_2 (1 mark)

iv. A covalent network compound. SiC or SiO_2 (1 mark)

v. A polar oxide of carbon. CO (1 mark)

Question 5 **(10 marks)**

Wines often contain a small amount of sulfur dioxide that is added as a preservative. The amount of sulfur dioxide added needs to be carefully calculated; too little and the wine goes bad; too much and the wine tastes of sulphur dioxide. Edward and Anthony are investigating this problem.

The sulfur dioxide content of a wine can be found by titrating the wine with aqueous iodine solution. In this reaction the sulfur dioxide, $SO_2(aq)$, is converted to sulfate ions and the iodine, $I_2(aq)$, to iodide ions.

(a) Using the information above determine the two half-equations and overall equation for the reaction taking place in acidic conditions. (4 marks)

$2H_2O + SO_2 \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ [2]

$I_2 + 2e \rightarrow 2I^-(aq)$ [1]

$I_2 + 2H_2O + SO_2 \rightarrow SO_4^{2-} + 2I^- + 4H^+$ [1]

(b) State, with a reason, whether sulfur dioxide is oxidised or reduced in this reaction (1 marks)

SO_2 is oxidised

lost electrons

O.N increases from $4 \rightarrow 6$

(b) The sulfur dioxide content of a wine can be found by titration. Anthony finds that the sulfur dioxide in 50.0 mL of white wine reacted with exactly 16.4 mL of 0.0100 mol L^{-1} aqueous iodine.

(i) Suggest a suitable indicator to use in this titration (1 mark)

Starch

(ii) Calculate the concentration of sulfur dioxide in the wine in grams per litre

$n(I_2) = 0.0164 \times 0.01$

$= 1.64 \times 10^{-4}$ mol [1]

$\therefore n(SO_2) = 1.64 \times 10^{-4}$ mol

$\therefore [SO_2] = \frac{n}{V}$ — 0.05

$= 3.28 \times 10^{-3}$ mol L^{-1} [1]

$= 0.210$ g L^{-1} [1]

(3 marks)

(a) The generally accepted maximum concentration of sulfur dioxide in wine is 0.25 g L^{-1}.

A concentration of less than 0.01 g L^{-1} is insufficient to preserve the wine.
Comment on the effectiveness of the sulfur dioxide in the wine analysed in (b). (1 mark)

On the high side but under the accepted maximum, ∴ OK.

Question 6 **[5 marks]**

Arrange the following compounds (all of similar molecular weight) in order of decreasing boiling point. In the table write "1" for the compound with the highest boiling point, down to "5" for the compound with the lowest boiling point.

all have 5 Carbons.

Compound	Boiling points in order (1=highest, 5=lowest)
$CH_3CH_2CH_2CH_2CH_3$ — dispersion	4
$CH_3CH_2CH_2CH_2COOH$ — H-bonding	1
$CH_3CH_2CH_2(CH_3)_2$ — dispersion (branch.)	5 [1] for each
$CH_3CH_2CH_2CH_2CH_2OH$ — H-bond.	2 correct position
$CH_3CH_2CH_2CH_2CHO$ — polar.	3

Question 7 **(4 marks)**

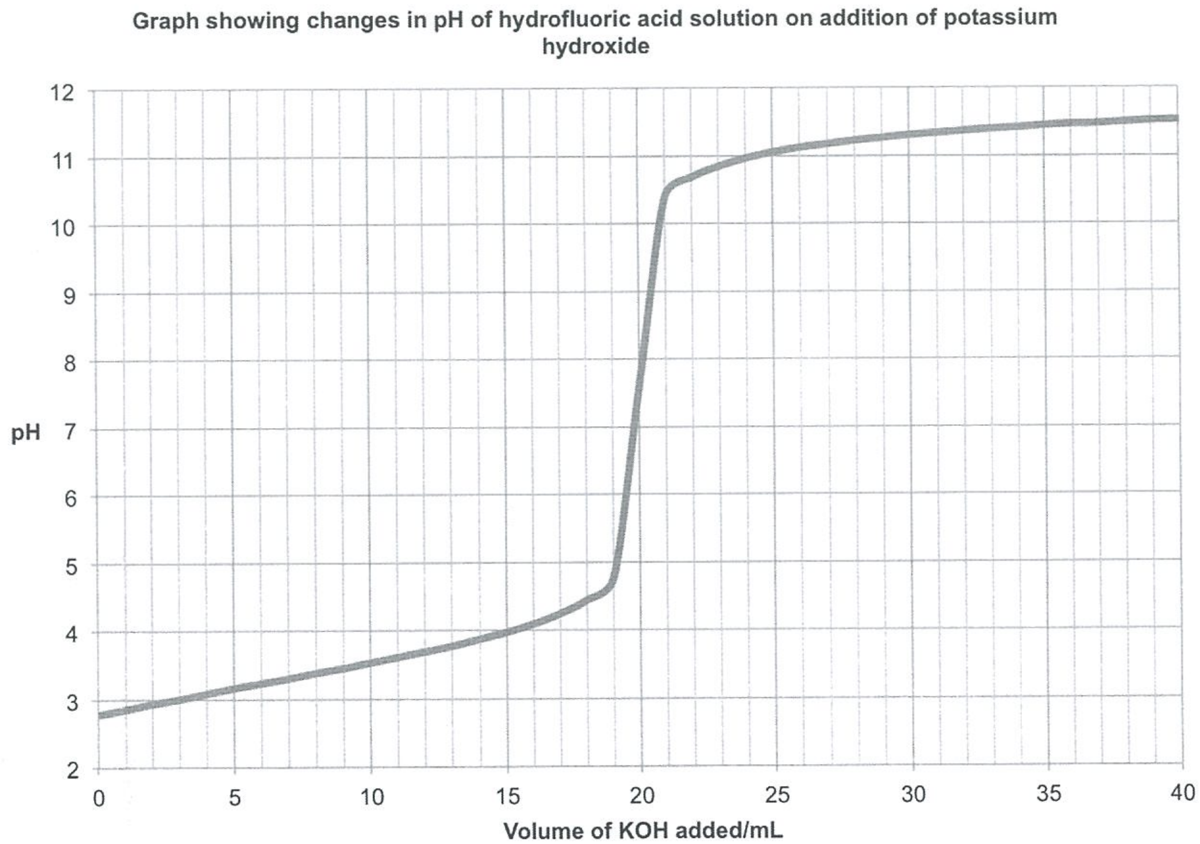
Give the IUPAC name of the following compounds.

Formula	Name
$CH_3(CH_2)_5CH(OH)CH_3$	C–C–C–C–C–C–C–C (OH on second C) octan-2-ol or 2-octanol
$CH_3CH_2COOCH_2CH_3$	ethyl propanoate
$CH_3CH_2COCH_2CH_3$	C–C–C(=O)–C–C propan-3-one
$CH_3CH_2CH_2CHO$	butanal

4 x [1]

Question 8 **(8 marks)**

0.0100 mol L^{-1} potassium hydroxide was placed in a burette, and titrated against 20.0 mL aliquots of 0.0100 mol L^{-1} hydrofluoric acid. The pH of the solution was measured using a pH probe after the addition of each 1.00 mL of potassium hydroxide until 40.0 mL had been added. The results of the experiment are shown in the graph below:



The measured pH at the start of the experiment was 2.77.

(a) Using the given concentration of HF and the initial pH, determine the percentage of HF molecules which have been ionised (2 marks)

$HF \rightleftharpoons H^+ + F^-$

0.0100 mol L^{-1} $[H^+] = 10^{-2.77} = 1.70 \times 10^{-3}$ mol L^{-1} [1]

% ionised $= \frac{1.70 \times 10^{-3}}{0.0100} \times 100 = 17\%$ [1]

(b) Explain why the pH at the equivalence point was not 7. (3 marks)

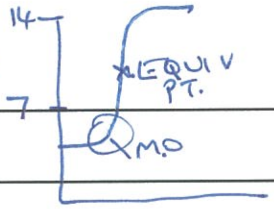
[1]
HF is a weak acid and KOH is a strong base.
[1]
At the equivalence pt the F^- ion produces some OH^- ions which result in an alkaline equiv pt : $F^- + H_2O \rightleftharpoons HF + OH^-$
[1]
pH > 7.

In a similar experiment to determine the concentration of ethanoic acid in a vinegar solution, a 5.00 mL sample of vinegar was diluted to 250 mL by adding water in a volumetric flask. 20.00 mL aliquots of this solution were then titrated against the same solution of potassium hydroxide but this time using an indicator instead of the pH probe.

(c) From a choice of phenolphthalein or methyl orange which indicator would you use and would be the effect on the calculated value of the acid concentration if you use the 'wrong' indicator (3 marks)

+ OH^-

Δ CH_3COOH



Use phenolphthalein [1]

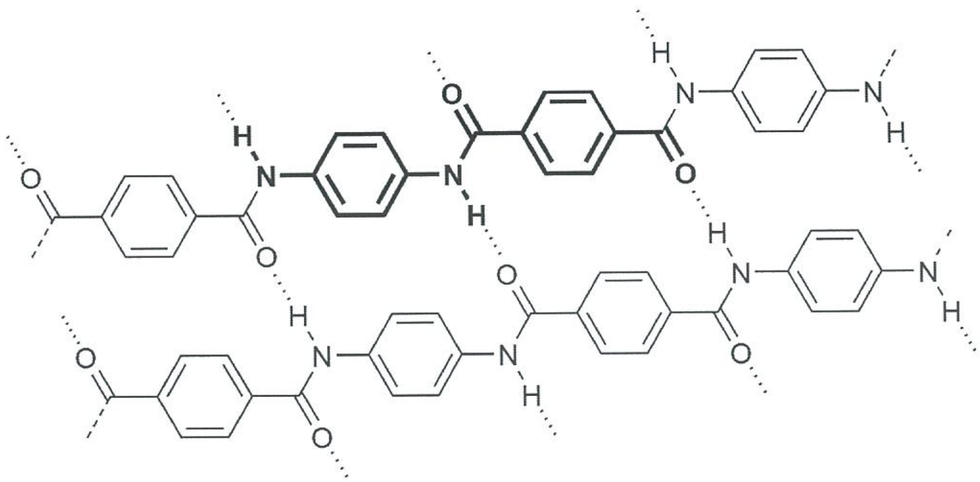
With methyl orange: end pt comes before the equiv pt ∴ $n(OH^-)$ ↓ [2]

∴ $n(CH_3COOH)$ ↓ ∴ $[CH_3COOH]$ ↓

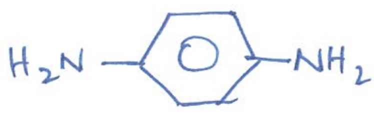
hence calculated result is LESS than true value. [1]

Question 9 **(12 marks)**

Kevlar is a synthetic fibre used in windsurfing sails and bulletproof vests. Like Nylon and Rayon, it is a condensation polymer, but its breaking strength is around ten times that of Nylon. The structure of Kevlar is shown below, with its repeating unit in bold.

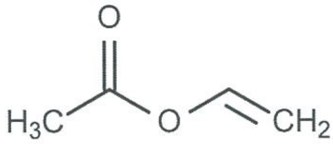


(a) Draw the structure of the two monomers that could be used to make Kevlar. (2 marks)

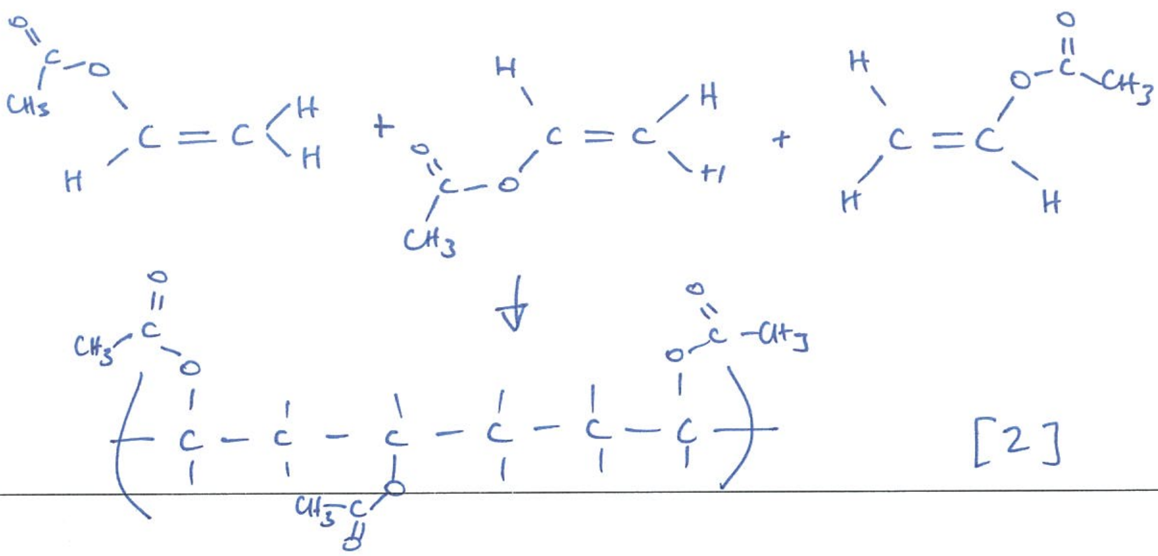
Monomer 1	Monomer 2
	 2 x [1]

SEE NEXT PAGE

Polyvinylacetate is a different polymer built up using the monomer vinyl acetate, whose formula is $CH_3COOCHCH_2$, and whose skeletal formula is shown below.



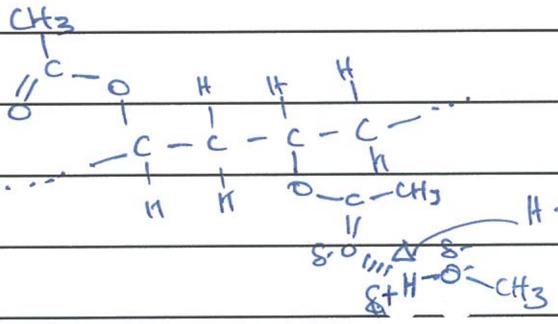
(b) In the space below, draw the structure of a length of polyvinyl acetate that would form from three vinyl acetate molecules. (2 marks)



[2]

Polyvinyl acetate can be dissolved in methanol to form polyvinyl alcohol (PVA).

(c) Use your knowledge of intermolecular forces to explain why ~~poly~~poly vinyl acetate is soluble in methanol. You may use a diagram to aid your explanation. (~~3~~2 marks)



H-bonds form between PVA and CH_3OH

[2]

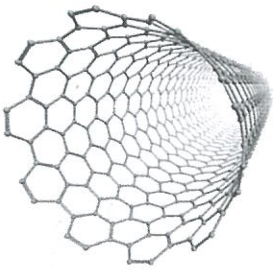
(d) The monomer unit, vinyl acetate, being an ester can also be hydrolysed in alkaline conditions to form two products. Write the equation for this reaction.

(2 marks)

$CH_3COOCHCH_2 \xrightarrow{OH^-} CH_3COO^- + CH_2CHOH$ [2]

Salt of acid alcohol.

Early in 2012, chemists working at Hanyang University in Korea were able to synthesise the toughest polymer yarn known at the time by mixing PVA with carbon nanotubes (CNTs) during the spinning of the yarns. One type of fibre, which was manufactured using PVA (polyvinyl alcohol) and single-walled carbon nanotubes (SWCNTs), had a toughness of 870 J/g, making it far stronger than spider silk (165 J/g) and more than ten times as strong as Kevlar (78 J/g).



Carbon nanotubes are an allotrope of carbon whose structure is shown in the picture, and is similar to that of graphite. They were discovered in 1991 as a spin-off from research into Buckminsterfullerenes, and have since found uses in a huge variety of applications, from medicine to electronics and molecular manufacturing.

(e) With reference to the structure and bonding present, explain whether or not you would expect carbon nanotubes to be able to conduct electricity. (3 marks)

Structure is similar to graphite. Each carbon has three covalent bonds using 3 v/e [1] and there is one remaining which is delocalised [1]. The delocalised electrons carry charge and so it would conduct electricity [1]

End of Part 2

PART 3: Extended answer **40% (80 Marks)**

This part contains **six (6)** questions. You must answer **all** questions. Write your answers in the spaces provided.
Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time for this section is 65 minutes.

Question 1 10. **[~~11~~ marks]**

The Haber process for the manufacture of ammonia is operated by passing a mixture of nitrogen and hydrogen over finely divided iron at a pressure of 300 atm and a temperature of 450 °C. The reaction is exothermic.

(a) (i) Write a balanced chemical equation for the reversible reaction between nitrogen and hydrogen. (2 marks)

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(ii) What is the purpose of the iron? (~~2~~ 1 marks)

It is a catalyst

(b) Referring to Le Chatelier's principle explain why using high pressures are used. (3 marks)

High pressures increase the rate of rxn. [1]
In this rxn with 4 gas molecules on the LHS and two on the RHS high pressures will favour the side with less gas molecules which is the products [2]

(c) Even higher pressure would be more advantageous, however, in practice they are not used. Why is that? (1 mark)

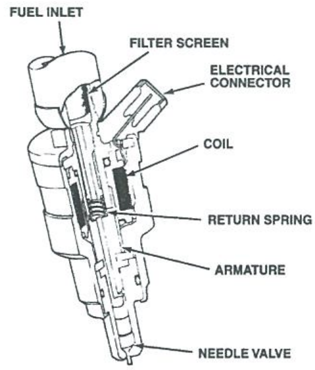
Very very high pressures have a much greater cost involved + economically it isn't worth it. [1]

(d) A temperature much higher than 450˚C could also be considered. Explain one advantage and one disadvantage of using a higher temperature. (3 marks)

An advantage is a higher rate of rxn. [1]
A disadvantage is that the endothermic back rxn will be favoured so the yield of ammonia will be less. [1]

Question 2 **(19 marks)**

The diagram shows a fuel injector of the type used in many combustion engines. The engine management system causes the needle valve to open and then close, ensuring that a precise amount of fuel enters the cylinder. The fuel enters the cylinder as a fine mist, and mixes with air. The cylinder then compresses the fuel-air mixture to around one tenth of its original volume



Modern combustion engines running on unleaded petrol use fuel composed mainly of octane and isomers of octane such as 2,2,4-trimethylpentane.. The research octane number (RON) gives an indication as to the composition of the mixture

(a) Write a balanced equation for the complete combustion of octane, C_8H_{18} (2 marks)

$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ [2]

(b) Using collision theory, explain the effect on the rate of the combustion reaction of the following reaction conditions.

i. Injecting the fuel as a fine mist. (2 marks)

Increase in surface area of fuel ∴ more collisions and hence more successful collisions per unit time and a faster rxn rate [2]

ii. Compressing the air-fuel mixture prior to ignition. (2 marks)

Compression will ↓ volume and increase concentration of reactants ∴ more collisions, hence more successful collisions per unit time + a faster rxn rate [2]

(c) ~~(e)~~ At a normal engine operating temperature of 1000°C, an injector injects 1.00 g of fuel for every 60.0 litres of air entering the cylinder at atmospheric pressure. Assuming all the components of the fuel have the molecular formula C_8H_{18}, and that air is exactly 20% oxygen by volume, find the limiting reagent.

If $P = 100\,kPa$
$n(O_2) = 0.1134$

(5 marks)

$V(O_2) = 12.0\,L$ @ 1000°C

$n(O_2) = \frac{PV}{RT}$ (P = 101.3, V = 12.0, R = 8.31, T = 1273)

$= 0.115$ mol [2]

$n(C_8H_{18}) = \frac{1.00}{114}$

$= 0.00877$ mol [1]

Eqn ratio $= \frac{n(O_2)}{n(fuel)} = \frac{25}{2} = 12.5$

Actual " $= \frac{0.115}{0.00877} = 13.1$ [1]

A/R > E/R $\therefore$ O_2 is in excess

and Octane is the L/R. [1]

(d) ~~(f)~~ Calculate the mass of any unused reactant from the above reaction mixture. (~~2~~ 3 marks)

$n(\text{octane}) = 0.00877$

from eqn $n(O_2)$ reacting $= 12.5 \times 0.00877$

$= 0.109$ mol [1]

$\therefore n(O_2)$ IN XS $= 0.115 - 0.109 = 0.006$ mol [1]

hence $m(O_2) = 0.192\,g$ [accept between $0.17 \rightarrow 0.19\,g$] [1]

Since regulations governing emissions from motor vehicles have become stricter, fuel injection technology is found on most newly manufactured vehicles, owing to the fact that it significantly reduces the occurrence of incomplete combustion.

(e) ~~(g)~~ With reference to the products of the reaction, explain why it is important to prevent this reaction occurring.

(2 marks)

Incomplete combustion produces $CO_{(g)}$ [1] and $C_{(s)}$ [1]

$C_{(s)}$ = SOOT (smoke)

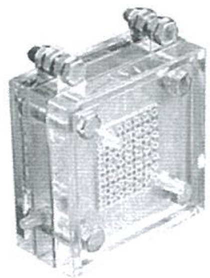
$CO_{(g)}$ poisonous [1]

SOOT causes asthma, lung disease, etc [1]

* only need two points

As concern over the effect of burning fossil fuels mounts, alternatives are being sought to the internal combustion engine.

The photograph shows a proton exchange membrane (PEM) fuel cell, capable of offering outputs of up to 250 kW. Whilst not as efficient as some other designs of fuel cell, this type of cell offers the advantage that it runs at low temperatures and consists of a solid, flexible electrolyte that will not leak. As a result, this type of fuel cell is particularly well suited to use in automotive applications. The cell uses hydrogen as its fuel, which is combined with oxygen to produce water.



(f) State the cell voltage that can be obtained from a single fuel cell such as this. (1 mark)

$0.40 - (-0.83) = 1.23\text{V}$ or $1.23 - 0 = 1.23\text{V}$

(g) State TWO environmental advantages of the use of fuel cells to power motor vehicles, compared to combustion engines. (2 marks)

- no CO_2 (green house gas) or nitrogen oxide pollutants [1]
- renewable — no depleting fossil fuel supplies [1]

Question 3 **(18 marks)**

Kaleb conducted a series of experiments to investigate the physical and chemical properties of basic solutions. In the first experiment, he made a solution by dissolving 10.0 g of barium hydroxide in 250 mL of water.

(a) Calculate the pH of this solution. (5 marks)

$n(Ba(OH)_2) = \frac{10.0}{171.3}$

$= 0.0584$ mol [1]

$\therefore n(OH^-) = 2 \times 0.0584$

$= 0.1168$ mol [1]

hence $[OH^-] = \frac{n}{V \to 0.250} = 0.467 \text{ mol L}^{-1}$ [1]

Since $[H^+][OH^-] = 10^{-14}$

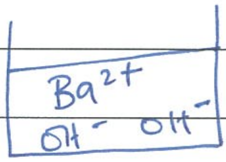
then $[H^+] = \frac{10^{-14}}{0.467} = 2.14 \times 10^{-14}$ [1]

$\therefore pH = -\log(\checkmark) = 13.7$ [1]

(b) During the first experiment excess sulfuric acid was slowly added to the barium hydroxide solution and the electrical conductivity of the solution was measured. Kaleb observed the measurements were high at the start of the experiment, gradually fell to almost zero and then increased again.
Explain these observations. (4 marks)

$Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$

Initially lots of ions, $Ba(OH)_2$ completely dissociates → high conductivity [1]



Adding H^+ and SO_4^{2-} (sulfuric acid)

$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4(s)$

$H^+ + OH^- \rightarrow H_2O$

Ba^{2+} and OH^- ions have been removed, at the equivalence point the conductivity is ~ 0 (H_2O has a v. low conductivity) [2]

Addition of more acid, now means H^+ and SO_4^{2-} are in XS and so conductivity increases. [1]

Wanting to carry out experiments on basic solutions found outside of the laboratory, Kaleb decided to investigate milk of magnesia. Reading the information on the label, he realised that this was a saturated solution of magnesium hydroxide in water. The mixture gets its name from the fact that undissolved solid is suspended in the liquid, giving it a milky appearance.

In the mixture, the following reaction takes place:

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

(c) Write an expression for the equilibrium constant, K, for the above reaction. (1 mark)

$K = [Mg^{2+}][OH^-]^2$

(d) Explain whether you would you expect the value of K to be greater than one (> 1) or less than one (< 1). (2 marks)

Since $Mg(OH)_2$ isn't very soluble, $K < 1$, E'm on LHS
[1] [1]

Kaleb then wished to investigate whether the mass of solid present in the mixture could be affected by various changes. The mixture was divided equally amongst ~~four~~ three beakers, and Kaleb carefully filtered the mixtures after each experiment to find the mass of undissolved magnesium hydroxide. One beaker was left unchanged to act as a control.

(e) For each of the changes described below, predict and explain what effect the change would have on the mass of solid present once the system had returned to equilibrium.

i. Distilled water was added to the mixture. $Mg(OH)_{2(s)} \rightleftharpoons Mg^{2+} + 2OH^-$ (3 marks)

Effect on mass of solid (circle one) INCREASE DECREASE NO CHANGE [1]

Explanation

Adding H_2O, decreases the $[Mg^{2+}]$ and $[OH^-]$ [1]
So E'm moves to the RHS hence less $Mg(OH)_2$ present. [1]

ii. A few drops of vinegar were added to the mixture. (3 marks)

Effect on mass of solid (circle one) INCREASE DECREASE [1] NO CHANGE

Explanation

Adding vinegar will decrease $[OH^-]$ as vinegar is acidic. ∴ E'm moves to the RHS [1]
hence less $Mg(OH)_2$ present. [1]

Question 4 **(11 marks)**

In order to find the formula of hydrated copper(II) sulfate, $CuSO_4.nH_2O$, 5.02 g of the hydrated sulfate was dissolved in water, and the solution made up to 100 mL. To this solution was added excess potassium iodide, forming iodine according to the following equation:

$+S_2O_3^{2-}$

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Δ I_2

10.0 mL portions of the resulting solution containing iodine were titrated using 0.100 mol L^{-1} sodium thiosulfate solution ($Na_2S_2O_3$), 20.02 mL being required for complete reaction. In this titration, thiosulfate ions reduce iodine to iodide, and are themselves converted to tetrathionate ions ($S_4O_6^{2-}$).

(a) Write ionic half-equations for this iodine/thiosulfate reaction to show the reduction and oxidation processes taking place.

(2 marks)

Reduction	$I_2 + 2e^- \rightarrow 2I^-$ [1]
Oxidation	$2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e^-$ [1]

(b) Write an overall ionic equation to show the reaction between thiosulfate ions and iodine.

(1 mark)

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$ [1]

(c) Calculate the number of moles of copper ions in the original 5.02 g sample of hydrated copper(II) sulfate.

(4 marks)

$n(S_2O_3^{2-}) = 0.02002 \times 0.100$

$= 2.002 \times 10^{-3}$ mol [1]

from eqn, $n(I_2)$ in 10 mL $= \frac{1}{2} \times 2.002 \times 10^{-3}$

$= 1.001 \times 10^{-3}$ mol [1]

$\therefore$ $n(I_2)$ in 100 mL $= 1.001 \times 10^{-2}$ mol [1]

hence from 1st eqn $n(Cu^{2+}) = 2 \times n(I_2)$

$= 2.00\cancel{2} \times 10^{-2}$ mol [1]

SEE NEXT PAGE

(d) Find the value of *n* in the formula of this hydrated sulfate and write its correct formula.

(4 marks)

5.02 g of $CuSO_4 \cdot nH_2O$ equates to 0.0200 mol [1]

let molar mass($CuSO_4 \cdot nH_2O$) = x

$\therefore \frac{5.02}{x} = 0.0200$

$\therefore x = 250$ [2]

64 32 64

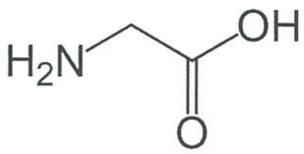
$\underbrace{CuSO_4}_{160} \cdot nH_2O \Rightarrow (H_2O)_n = 90$

$\therefore n = 5$ [1]

Question 5 **(16 marks)**

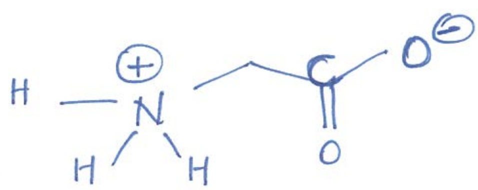
Amino acids are the building blocks of proteins in biological systems, as well as playing important roles as intermediates in metabolism. There are 20 naturally occurring amino acids found in proteins. Ten of these are produced within the human body. The other ten, known as *essential* amino acids, must be obtained from food. Failure to obtain sufficient quantities of these can lead to degradation of the body's proteins. Since the body cannot store amino acids, it is therefore important that these *essential* amino acids are in food every day.

The simplest amino acid found in proteins is known as glycine. The skeletal formula of glycine is shown below.



In neutral solutions, glycine is found in a *zwitterion* form. Solutions of this ion can act as buffers.

(a) Draw the structure of the zwitterion ion for glycine in the space below. (1 mark)

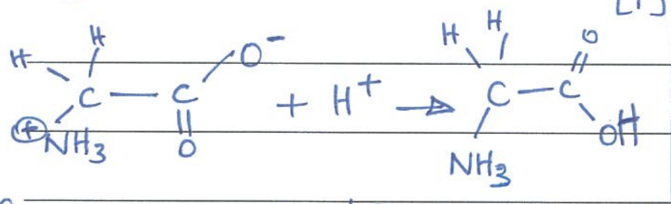


(b) Briefly explain what buffer solutions can do and then use equations to explain how glycine in its *zwitterion* form is able to act as a buffer.

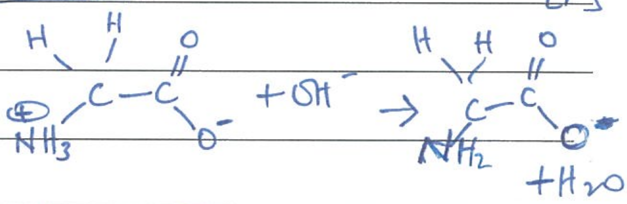
(4 marks)

Buffer solution are able to resist changes in pH if small volumes of acid or base are added [1]

Adding acid [1]



Adding base [1]



Glycine is able to react with either H^+ or OH^- and maintain the pH. [1]

Lysine is one of the ten *essential* amino acids. Elemental analysis shows that it is composed of the elements nitrogen, hydrogen, carbon, and oxygen. In an experiment to find its empirical formula, 2.175 g of lysine was combusted, producing 3.93 g of carbon dioxide and 1.87 g of water vapour. In a separate experiment, 1.986 g of lysine was reacted to turn all the nitrogen present into ammonia. It was found that 0.462 g of ammonia was formed.

(c) Determine the empirical formula of lysine. (7 marks)

$CNHO \xrightarrow{O_2} CO_2 + H_2O$

2.175g 3.93g 1.87g

$n(CO_2) = \frac{3.93}{44.01}$

$= 0.0893$ mol

$\therefore n(C) = 0.0893$ mol

$\therefore m(C) = 1.072$ g

$= 49.3\%$ [1]

$n(H_2O) = \frac{1.87}{18.016}$

$= 0.1038$

$\therefore n(H) = 0.2076$ mol

$\therefore m(H) = 0.209$ g

$= 9.62\%$ [1]

$n(NH_3) = \frac{0.462}{17}$

$= 0.0272$ mol

$\therefore n(N) =$ "

$\therefore m(N) = 0.380$ g

$= 19.2\%$. [1]

% O = 100 − 49.3 − 9.62 − 19.2
= 21.9%. [1]

	C	H	N	O	
% in 100g	49.3	9.62	19.2	21.9	
M	12.01	1.008	14.01	16.00	
n	4.10	9.54	1.37	1.37	
Ratio	3 :	7	1 :	1	[2]

E/F C_3H_7NO [1]

Another sample of lysine, weighing ~~1.68 g~~ 2.58g, was heated in the absence of air. It was found that the vapour occupied a volume of 549 mL at 100°C and 100 kPa.

(d) Find the molecular formula of lysine (4 marks)

$n = \frac{PV}{RT}$ 100 0.549 8.31 373

$= 0.0177$ mol [2]

$n = \frac{m}{M}$ 0.0177 2.58

$\Leftrightarrow$ $M = 146$ [1]

let molecular formula $= (C_3H_7NO)_x$

$\therefore$ $73x = 146$

$x = 2$

Hence Molecular Formula $= C_6H_{14}N_2O_2$ [1]

Question 6 **[6 marks]**

The amount of iron, as Fe^{2+}, present in a multivitamin tablet may be determined by titrating against potassium permanganate, $KMnO_4$. In one determination, two tablets were dissolved in 20.00 mL of distilled water in a conical flask. This required 15.85 mL of 0.002500 mol L^{-1} $KMnO_4$ to reach the equivalence point.

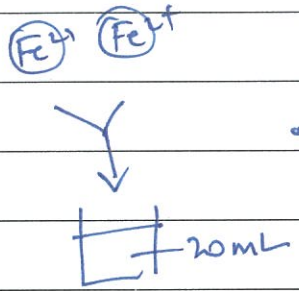
(a) Write the balanced equation for this reaction. (2 marks)

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

$8H^+ + MnO_4^- + 5e^- \rightarrow Mn^{2+} + 4H_2O.$

$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$ [2]

(b) Calculate the mass of iron, as Fe^{2+}, in one multivitamin tablet? (4 marks)



$n(MnO_4^-) = 0.01585 \times 0.00250$

$= 3.96 \times 10^{-5}$ mol [1]

$\therefore n(Fe^{2+})_{\text{two tablets}} = 5 \times (\text{"})$

$= 1.98 \times 10^{-4}$ mol [1]

$\therefore m(Fe^{2+}) = 1.98 \times 10^{-4} \times 55.9$

$= 0.0111$ g [1]

$\therefore m(Fe^{2+})_{\text{in 1 tablet}} = \frac{1}{2} \times 0.0111$ g

$= 5.54 \times 10^{-3}$ g

$= 5.54$ mg. [1]

END OF PART 3