

Solutions

Section One: Multiple-choice**50 Marks**
[2 marks each]

Question No	Answer
1	d
2	b
3	d
4	c
5	b
6	b
7	a
8	d
9	c
10	a
11	b
12	c
13	a
14	b
15	b
16	a
17	b
18	a
19	b
20	c
21	c
22	c
23	b
24	a
25	c

Section Two: Short answer**35% (70 Marks)****Question 26****(5 marks)**

A buffer solution is needed for preserving “Tango” fruit juice. A chemist at the fruit juice company prepared a benzoic acid/sodium benzoate buffer with concentrations of 0.105 mol L^{-1} $\text{C}_6\text{H}_5\text{COOH}$ and 0.125 mol L^{-1} $\text{C}_6\text{H}_5\text{COONa}$.

- (a) What is a “buffer solution”, and what is its purpose?

(2 mark)**[1 mark each part]**

A solution of a weak acid and its weak conjugate base; or a solution of a weak base and its weak conjugate acid. A buffer will keep the solution pH relatively constant (resists changes in pH) if a small amount of acid or base is added to it.

- (b) Explain, using Le Chatelier's principle, how this solution acts as a buffer solution. (use equations in your answer). (3 marks)

When a small amount of acid is added: $\text{C}_6\text{H}_5\text{COO}^- + \text{H}^+ \rightarrow \text{C}_6\text{H}_5\text{COOH}$.

The added H^+ ions react with the benzoate ion and so are removed.

When a small amount of base is added: $\text{C}_6\text{H}_5\text{COOH} + \text{OH}^- \rightarrow \text{C}_6\text{H}_5\text{COO}^- + \text{H}_2\text{O}$.

The added OH^- ions react with benzoic acid molecules and so are removed.

[2 marks for the explanation and 1 marks for equations]

Question 27

(2 marks)

Toluene (methyl benzene), C_7H_8 (g) is an important solvent and precursor to many other organic compounds such as trinitrotoluene (TNT). It can be produced according to the following equilibrium:



When 3.00 mol of C_7H_{14} (g) was introduced into a 1.00 L container, 1.20 mol of H_2 (g) was produced at equilibrium.

What were the equilibrium concentrations, in mol L^{-1} , of C_7H_8 and C_7H_{14} ?

At equilibrium, $n(\text{H}_2) = 1.20$ mol, therefore $n(\text{C}_7\text{H}_8)$ formed = $n(\text{C}_7\text{H}_{14})_{\text{reacted}} = 1/3 \times 1.20 = 0.40$ mol. Therefore, $n(\text{C}_7\text{H}_{14})_{\text{left}} = 3.00 - 0.40 = 2.60$ mol

[1 mark each]

Question 28

(4 marks)

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

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

If no change is observed, you should state this.

- (a) Potassium sulfide solution is added to lead (II) nitrate solution. (2 marks)

Observation: **Two colourless solutions combine to produce a black precipitate in a colourless solution.** [1 or 2 marks]

- (b) Sodium metal is added to pentanol.

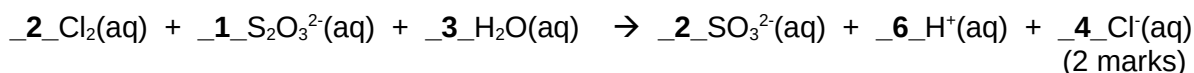
Observation: **A grey/lustrous solid and a colourless solution combine vigorously to produce a colourless solution and a colourless, odourless gas is evolved. The solid dissolves.** [1 or 2 marks]

Question 29

(2 marks)
(3 marks)

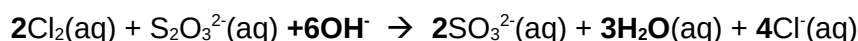
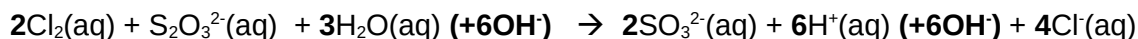
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- (a) Consider the reaction half equations and then balance the following redox equation:



[1 mark for half equations; 1 mark for balanced redox whole]

- (b) Re-write the redox equation, for alkaline (basic) conditions. (1 mark)



Question 30

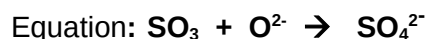
(4 marks)

Write the equation for the reaction that occurs in each of the following procedures. If no reaction occurs, write 'no reaction'. For full marks, chemical equations should refer only to those species consumed in the reaction and the new species produced. These species may be ions [for example $\text{Ag}^+(\text{aq})$], molecules [for example $\text{NH}_3(\text{g})$, $\text{NH}_3(\text{aq})$, $\text{CH}_3\text{COOH}(\text{l})$] or solids [for example $\text{BaSO}_4(\text{s})$, $\text{Cu}(\text{s})$, $\text{Na}_2\text{CO}_3(\text{s})$].

- (a) Potassium phosphate solution is added to copper (II) sulfate solution. (2 marks)



- (b) Sulfur trioxide gas is bubbled through a sodium oxide solution. (2 marks)

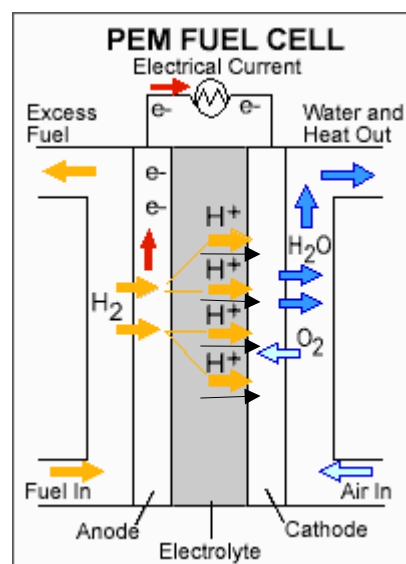


Question 31

(7 marks)

Commercial buses, and cars, can operate using a proton exchange membrane fuel cell (PEM) to provide the required energy. They use a solid polymer sandwiched between two sheets of carbon fibre paper as an electrolyte, and porous carbon electrodes containing a platinum catalyst. They need only hydrogen, oxygen from the air, and water to operate. They are typically fuelled with pure hydrogen supplied from storage tanks or onboard reformers. The cell operates at a temperature of around 80°C.

A Picture of the Hydrogen Fuel Cell Transit Bus



- (a) What is **one** advantage of a solid polymer membrane electrolyte over the liquid chemical electrolyte, KOH (used in other fuel cells)? (1 mark)

Lighter [less weight]; not a corrosive substance; other possibilities

See next page

- (b) State **one** environmental advantage, and **one** sustainability advantage; of this PEM fuel cell over the use of conventional fuels such as diesel? (2 marks)

No toxic wastes (CO) or greenhouse gas emissions (CO₂, NO_x, etc). Less pollution.
[1 mark]

O₂ and H₂ are renewable gases. Diesel (from fossil fuels) is not a renewable resource.
[1 mark]

- (c) What are **two** disadvantages of the O₂/H₂ fuel cell, as energy sources, over conventional fuels such as diesel? (2 marks)

H₂ readily explodes and therefore needs to be carefully stored and managed.

The fuel cells need more regular "re-charging". They cannot cover the same distance without refuelling.

Cost of cell (Pt catalyst is expensive) [1 mark, for each of two examples]

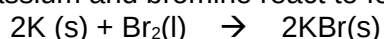
- (d) Some fuel cells use methanol as a source of hydrogen (as H⁺), which combines with oxygen to produce carbon dioxide and water. Write half equations and then a balanced redox equation for this process. (2 marks)



Question 32

(8 marks)

On heating, a mixture of potassium and bromine react to form potassium bromide, according to the equation:



- (a) The melting points of potassium, bromine and potassium iodide are 63.3 °C, -7.2 °C and 734 °C respectively. For each of the substances state the type of **inter-particle** bonding present and the nature of the attractive forces holding each substance together. (6 marks)

Substance	Type of bonding	Nature (strength) of bonding
Potassium	Metallic	strong
Bromine	Dispersion forces	weak
Potassium bromide	Ionic	strong

- (b) Briefly explain why the melting point of bromine is much lower than that of sodium bromide. (2 marks)

**The dispersion forces between bromine molecules require less to break [1 mark]
than the stronger ionic bonds between sodium cations and bromide anions.**
[1 mark]

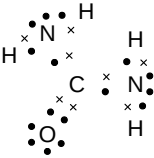
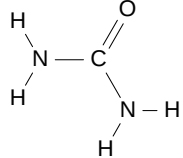
Question 33

(15 marks)

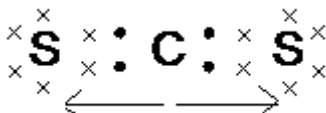
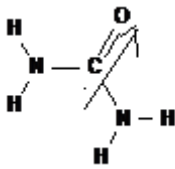
- (a) For each species listed in the table below, draw the structure, representing all valence shell electron pairs either as : or as — **and** state or draw the shape of the molecule or ion. (9 marks)

(for example, water $\text{H}:\ddot{\text{O}}:\text{H}$ or $\text{H}-\ddot{\text{O}}-\text{H}$ or $\text{H}-\ddot{\text{O}}^--\text{H}$ bent)

[2 marks diagram; 1 mark shape]

Compound	Electron-dot structure (showing all valence shell electrons)	Shape (sketch or name)
Carbon disulfide CS_2	$\begin{array}{c} \times \\ \times \end{array} \text{S} \begin{array}{c} \times \\ \times \end{array} \begin{array}{c} \times \\ \times \end{array} \text{C} \begin{array}{c} \times \\ \times \end{array} \begin{array}{c} \times \\ \times \end{array} \text{S} \begin{array}{c} \times \\ \times \end{array}$	<i>linear</i>
Strontium nitrate $\text{Sr}(\text{NO}_3)_2$	$\text{Sr}^{2+} \dots\dots 2 \left[\begin{array}{c} \text{O} \\ \times \\ \times \\ \times \end{array} \text{N} \begin{array}{c} \times \\ \times \\ \times \end{array} \text{O} \right]$	<i>3-D network lattice (or provide a lattice diagram)</i>
Diaminomethanone NH_2CONH_2 ("urea")		<i>Trigonal planar (about the central carbon atom)</i> 

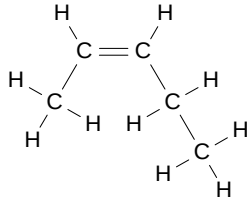
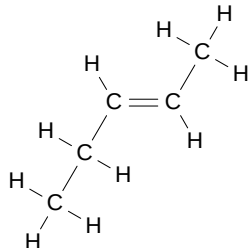
- (b) Compare, and explain, the molecular polarity of carbon disulfide and urea. (6 marks)
[1 + 2(explan.) marks each]

Compound	Polar or non-polar	Explanation
CS ₂	Non-polar	<p>Sulfur is more electronegative than carbon and so a partial negative charge exists over it and a partial positive pole over each carbon atom. The molecule has two bond dipoles but these cancel each other out i.e. the molecule has a symmetrical distribution of charge <u>or</u> no net dipole moment <u>or</u> the average position of positive charge is the same as the average position of negative charge.</p> 
H ₂ NCONH ₂	Polar	<p>Oxygen is the most electronegative atom in the molecule. The molecule has many bond dipoles. Summatively, the average net negative charge lies over the oxygen atom and the net positive charge close to the carbon atom <u>or</u> the molecule has an asymmetrical distribution of charge <u>or</u> a net dipole moment.</p> 

Question 34

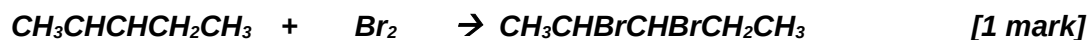
(5 marks)

- (a) **Draw and label** the geometric isomeric forms of 2-pentene (pent-2-ene). (3 marks)
[1 mark each diagram; 1 mark for both correct form names]

 <p>Form: <i>cis</i></p>	 <p>Form: <i>trans</i></p>
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- (b) What chemical test could be used to distinguish between pent-2-ene and pentane? (chemical equation required) (2 marks)

Add bromine water ($\text{Br}_2(\text{aq})$) separately to a sample of each in test tubes. The yellow bromine solution will decolour with the pent-2-ene only. [1 mark]

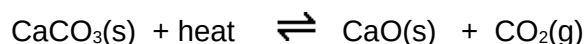


Question 35

(10 marks)

Industrially, calcium carbonate can be thermally decomposed (roasted) to form calcium oxide ('quicklime'). This product is used to change pH, in calcium silicate brick manufacture, in aluminium and gold production, and in the building industry (plaster).

The chemical reaction for its production is:



- (a) What is the K_{eq} expression for the reaction? (1 mark)

$K = [\text{CO}_2]$ [1 mark]

- (b) In practice, conditions can be changed to alter the rate of reaction and the yield of product. Indicate any effects of imposed change on the system in the table below. (9 marks)
[1 mark each]

Imposed change	Initial forward reaction rate (increase, decrease, or no effect)	Initial reverse reaction rate (increase, decrease, or no effect)	Effect on new equilibrium position (to right \rightarrow , to left \leftarrow , or no effect)
Increase the partial pressure of the carbon dioxide	No effect	Increase	To the <u>left</u>
The temperature is decreased	Decrease	Decrease	To the <u>left</u>
Increase surface area of the CaCO_3	Increase	No effect	No effect

Question 36

(3 marks)

See next page

Older second hand cars can have bubbling of paint on the panels during to iron corrosion ("rusting") under the sealed paint (i.e. an anodic region). This is often noticed close to the wheel hubs or the base of doors or windows. The paint under normal circumstances provides a physical barrier to corrosion.

- (a) What is the likely cause of the corrosion? (2 marks)

There is an exposed metal region surface (cathodic region) [1 mark] which is drawing electrons away from the anodic region (area of metal oxidation) [1 mark]

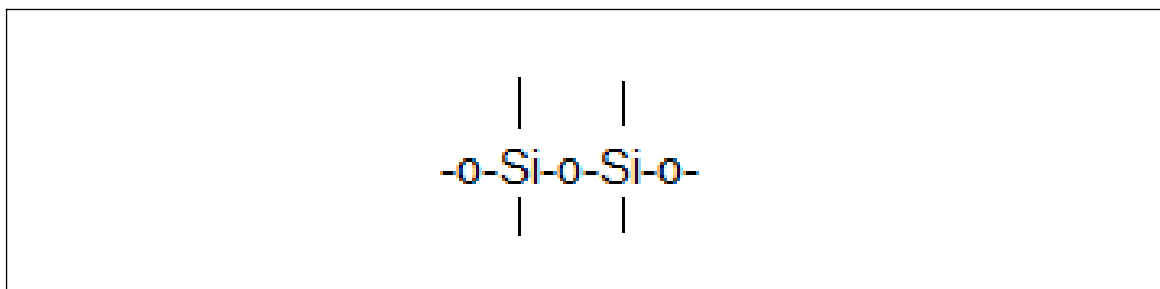
i.e. $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ (cathode) c.f. $Fe \rightarrow Fe^{2+} + 2e^-$ (anode)

- (b) Suggest a practical chemical solution to the problem. (1 mark)

Seal the inner damaged surface (cathodic region) with paint or silicone. The damaged body paint would also need to be removed and replaced.

Question 37 (4 marks)

- (a) Illustrate the backbone structure of a **silicone**. (1 mark)



- (b) Silicones don't exhibit hydrogen bonding yet are able to form rigid structures. What is this due to? (1 mark)

Cross-linking of silicone chains. This occurs when using monomers with three functional groups i.e. trichlorosilanes ($RSiCl_3$).

- (c) Explain **one** useful property of a silicone. (2 marks)
[1 mark for the property and 1 mark for relating property to use]

A number of possible answers e.g. excellent electrical conductors (localised valence electrons); good lubricants (weak dispersion forces between polymer strands); very stable to heat (strong covalent bonding between atoms of oxygen and silicon); water repellent (hydrophobic...no hydrogen or dipole-dipole bonding with water molecules).

Section Three: Extended answer

40% (80 Marks)

This section contains **five (5)** questions. You must 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.

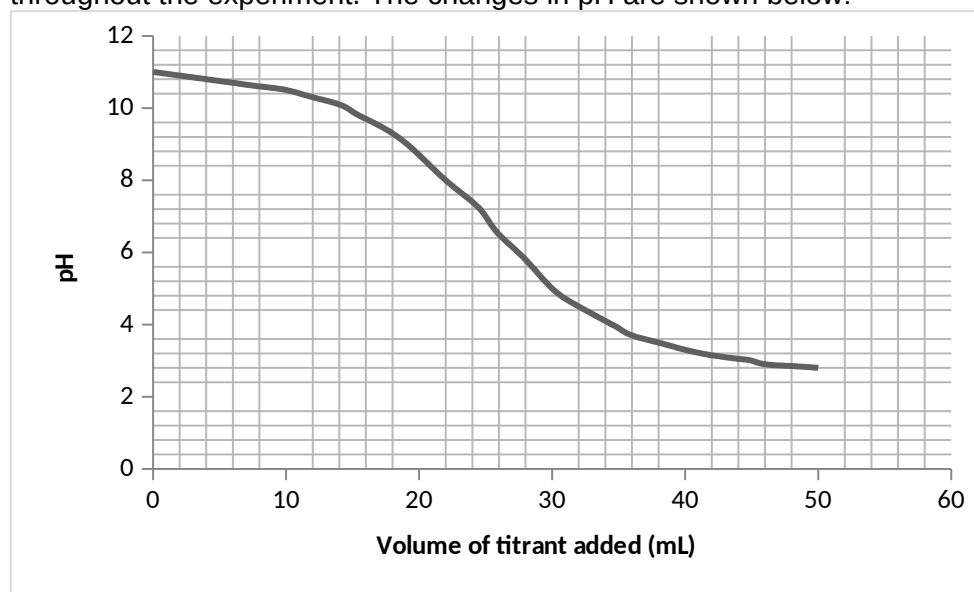
- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s)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

Suggested working time for this section is 70 minutes.

Question 38**(14 marks)**

A student carried out two acid-base practical investigations, at 25°C:

A titration was performed where 20.0 mL of an unknown solution was pipetted into a conical flask and titrated with another unknown solution from a burette. The pH was monitored with a pH meter, recorded with a data logger and the results displayed on a computer screen throughout the experiment. The changes in pH are shown below:



- (a) What is meant by the term “equivalence point”? (1 mark)

Is when the acid and base are in stoichiometric proportions (amounts).

- (b) What was the pH of the mixture at the equivalence point? (1 mark)

7.0

- (c) (i) A pH meter had to be used in this investigation. Explain, why there was no suitable acid-base indicator that could be used for this titration? (1 mark)

The endpoint would not be sharp and therefore difficult to detect accurately. There is no “vertical” part of the curve only a point of inflection.

- (ii) What does this tell us about the acid and base added together? (1 mark)

A weak acid and a weak base.

- (iii) Give an example of the acid and base that could have been used to give these results? (1 mark)

Acid _____ ***Ethanoic acid*** _____ Base _____ ***Ammonia*** _____ ***[many answers]***

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- (iv) Which species was in the conical flask? (1 mark)

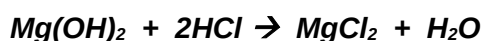
The base. The pH is above 7 initially then decreases as titrant is added.

- (e) What was the concentration of $\text{OH}^-(\text{aq})$ (mol L^{-1}) in the mixture after 15.0 mL of titrant had been added? (2 marks)

The pH of the solution at this point is 10.0 [1 mark] therefore the concentration of H^+ ions is $10^{-10} \text{ mol L}^{-1}$ at 25°C . So the $[\text{OH}^-] = 10^{-4} \text{ mol L}^{-1} = 0.000100 \text{ mol L}^{-1}$ [1 mark]

A commercial brand of antacid, "Easiflux", was tested to see how much acid it could neutralize. A 5.00 mL sample of the mixture was used where the active ingredient was stated to be magnesium hydroxide, $\text{Mg}(\text{OH})_2$. The mixture was reacted with 12.90 mL of 72.9 g L^{-1} hydrochloric acid, HCl (stomach acid).

- (f) Write a balanced formula equation for this reaction. (1 mark)



- (g) How many moles of HCl reacted? (2 marks)

$$m(\text{HCl}) = 0.01290 \text{ L} \times 72.9 \text{ g L}^{-1} = 0.94041 \text{ g} \quad [1 \text{ mark}]$$

$$n(\text{HCl}) = 0.94041 / (35.45 + 1.008) = 0.0258 \text{ mol} \quad [1 \text{ mark}]$$

- (h) What mass (g) of magnesium hydroxide would react with this amount of HCl? (2 marks)

$$n(\text{Mg}(\text{OH})_2) = \frac{1}{2} \times n(\text{HCl}) = 0.0129 \text{ mol} \quad [1 \text{ mark}]$$

$$m(\text{Mg}(\text{OH})_2) = 0.0129 \times (24.31 + 2 \times 16.00 + 2 \times 1.008) = 0.752 \text{ g} \quad [1 \text{ mark}]$$

- (i) The suggested dose for bad indigestion is 800 mg of $\text{Mg}(\text{OH})_2(\text{s})$ in a 5.00 mL dose. How does the sample tested compare with this? (1 mark)

This is very close to the suggested dose i.e. 752 mg compared to 800 mg (suggested). [1 mark]

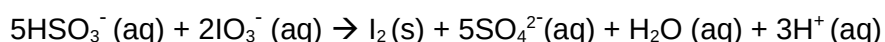
Question 39

(17 marks)

There are many ways of observing and measuring the rates of chemical reactions. A student investigated one reaction involving colour change; an "iodine clock" reaction.

At standard room temperature, a reaction occurs when potassium iodate solution is mixed with sodium hydrogen sulfate solution that contains a small amount of starch. In a laboratory, 12.00 mL of a $0.0160 \text{ M NaHSO}_3(\text{aq})$ solution containing starch were placed in each of six test tubes. Different volumes of $0.0240 \text{ M KIO}_3(\text{aq})$ and enough distilled water to maintain a constant volume were added to each test tube and the time taken for the dark-blue colour to appear was measured. Several trials of each concentration were conducted. The results data were recorded in the table over the page.

- (a) The chemical reaction was:



See next page

What is the "dark-blue" colour due to? (1 mark)

The iodine that is produced reacts with the starch (a dark- blue complex forms).

(b) Is this a redox reaction? Justify your answer. (2 marks)

**This is a redox reaction. The oxidation number changes between reactant and products are: S (+5 to +6) and I (+5 to 0) i.e. HSO_3^- oxidized and IO_3^- is reduced.
[1 mark for answer; 1 mark for justification]**

(b) Describe a procedure for diluting the stock $0.0240 \text{ mol L}^{-1} \text{ KClO}_3$ solution to give a $0.00800 \text{ mol L}^{-1}$ reaction mixture test solution. (2 marks)

[1 mark equipment and 1 mark steps]

Using pipettes or measuring cylinders or a burette, combine 8.00 mL of $0.0240 \text{ mol L}^{-1} \text{ KClO}_3$ solution with 4.00 mL of distilled water. This provides a $0.0160 \text{ mol L}^{-1} \text{ KClO}_3$ solution. When combined with the other reactant i.e. 12.0 mL of $0.0160 \text{ M NaHSO}_3(\text{aq})/\text{starch}$ solution, the desired test solution concentration is made.

(c) What is the independent variable for the investigation? (1 mark)

The concentration of the iodate (mol L^{-1}) solution (reaction mixture).

(d) What variables need to be controlled? (1 mark)

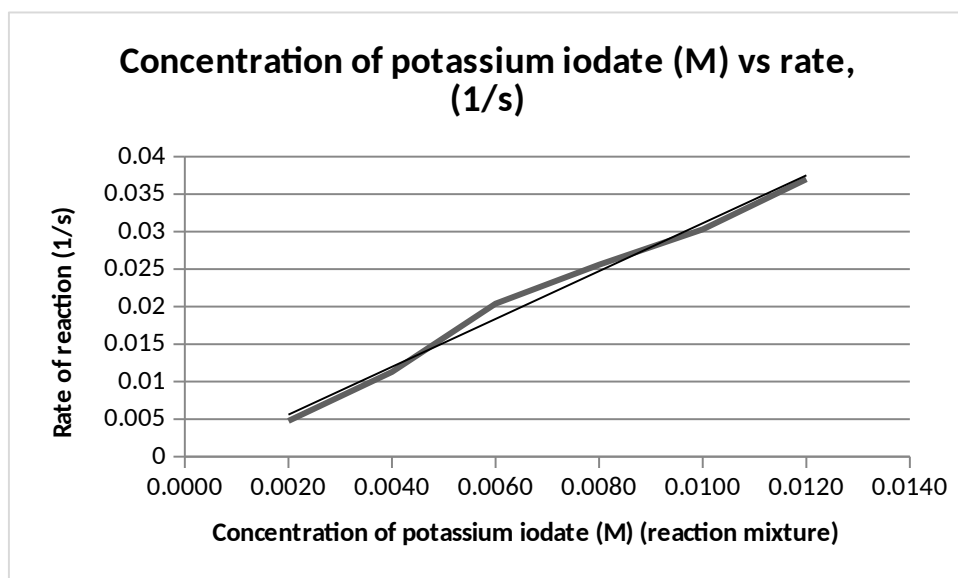
[at least two examples=1 mark]

Temperature, mixing, concentration of solutions, same apparatus (systematic error), etc.

(e) Complete the table below, and graph the data of reaction rate ($1/t$) versus concentration of potassium iodate (mol L^{-1}). (5 marks)

[1 mark each for: data in table, axes labelled, scale, line of best fit, correct labels]

Concentration of IO_3^- (mol L^{-1}) in reaction mixture.	Reaction time (s).	Reaction rate, $1/t$ (s^{-1}).
0.00200	210	0.00476
0.00400	88	0.0114
0.00600	49	0.0204
0.00800	39	0.0256
0.0100	33	0.0303
0.0120	27	0.0370



- (f) What conclusion can be drawn from the graph about the relationship between the rate of the reaction and the concentration of the potassium iodate? (1 mark)

As the concentration of iodate solution increases so too does the reaction rate (extension: first order with respect to iodate concentration).

- (e) Use your graph to predict the time taken for a 0.00500 mol L⁻¹ potassium iodate solution, at standard room temperature, to react. (1 mark)

From the graph, rate (1/t) = 0.0150 therefore t = approx. 67 s.

- (f) The procedure described above was repeated at a number of different temperatures between 10 °C and 70 °C and the reaction times were measured as before. Would you expect the reaction times to increase, decrease, or stay the same, as the temperature was increased? Use Collision Theory to justify your answer.

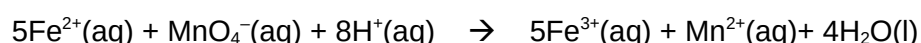
(3 marks)

As temperature increases (average kinetic energy of particles increases) the particles would move faster and collide more frequently [1 mark], with more collisions of the required energy (E_a) [1 mark], and so reaction rate should increase [1 mark].

Question 40

(15 marks)

Iron is one of the most abundant metals on Earth, is essential to most forms of life and to normal human physiology. Sometimes people take iron supplements. The iron content of a particular brand of iron tablets was determined by titration with a freshly standardised solution of potassium permanganate, KMnO₄. The equation for the titration reaction is:



- (a) Why are iron tablets sometimes medically prescribed? (1 mark)

To prevent or reduce anaemia; blood loss etc.

- (b) What is the **oxidation number** of manganese in the permanganate ion? (1 mark)
+7
- (c) (i) Why must potassium permanganate solutions be standardised? (2 mark)

It is unstable for long periods of time and readily reacts (is reduced) with contaminants in storage bottles [1 mark]. Accordingly, a solution of it is often impure (variable composition) [1 mark].

- (ii) What reagent is used for this purpose? (1 mark)

A standardised solution of oxalic acid.

250 mL of Fe^{2+} solution was prepared from ten (10) iron tablets, each of mass 0.328 g.

- (e) Explain why additional dilute sulfuric acid must be added to the titration flask before each titration is carried out. (1 mark)

If the permanganate ions are added to a non-acidified 'environment' then black/brown manganese dioxide forms which clouds the solution mixture i.e. partial reduction of permanganate ions occur and the endpoint is difficult to detect.

- (f) How was the end-point detected? (1 mark)

The solution changes from colourless to pale pink.

A standardised 0.0100 M potassium permanganate was used to react with 25.0 mL portions of the iron solution prepared from the 10 tablets.

- (g) A number of titrations were performed and the following titre values obtained.

Titre (mL)	21.00	18.79	18.76	17.45	18.70
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What is the average titre used? (1 mark)

Average (concordant) titre = $(18.79 + 18.76 + 18.70) / 3 = 18.75 \text{ mL}$

- (g) What is the **concentration** (mol L^{-1}) of the Fe^{2+} solution? (3 marks)

$n(\text{MnO}_4^-) = 0.0100 \times 0.01875 = 0.0001875 \text{ mol}$ [1 mark]

therefore $n(\text{Fe}^{2+})_{\text{in } 25 \text{ mL (flask)}} = 5 \times n(\text{MnO}_4^-) = 5 \times 0.0001875 = 0.0009375 \text{ mol}$ [1 mark]

therefore $[\text{Fe}^{2+}]_{\text{in } 25 \text{ mL (flask)}} = 0.0009375 / 0.0250 = 0.0375 \text{ mol L}^{-1}$ [1 mark]

- (h) What is the **total mass** (mg) of iron in one tablet? (3 marks)

$n(\text{Fe})_{\text{in } 250 \text{ mL volumetric flask}} = 10 \times 0.0009375 \text{ mol} = 0.009375 \text{ mol}$ [1 mark]

therefore $n(\text{Fe})_{\text{per tablet}} = 0.009375 / 10 = 0.0009375 \text{ mol}$ [1 mark]

therefore $m(\text{Fe})_{\text{per tablet}} = 0.0009375 \times 55.85 = 0.0523 \text{ g} = 52.3 \text{ mg}$ [1 mark]

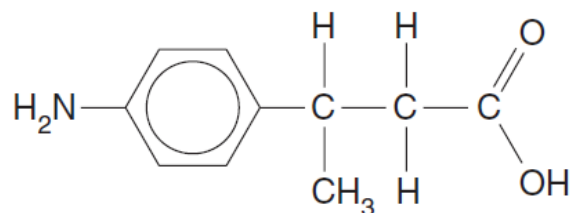
- (i) What is the **percentage, by mass**, of iron in each tablet? (1 mark)

% Fe (each tablet) = $0.0523 / 0.328 \times 100\% = 15.9\%$

Question 41

(22 marks)

Many drugs are produced by chemically combining several molecules. A newly developed amino acid, in combination with another substance, has the potential to be a new anti-inflammatory drug. The structure of the amino acid ($M_r = 179.214$) is:



- (a) (i) Explain, why it is considered to be an amino acid? (2 marks)

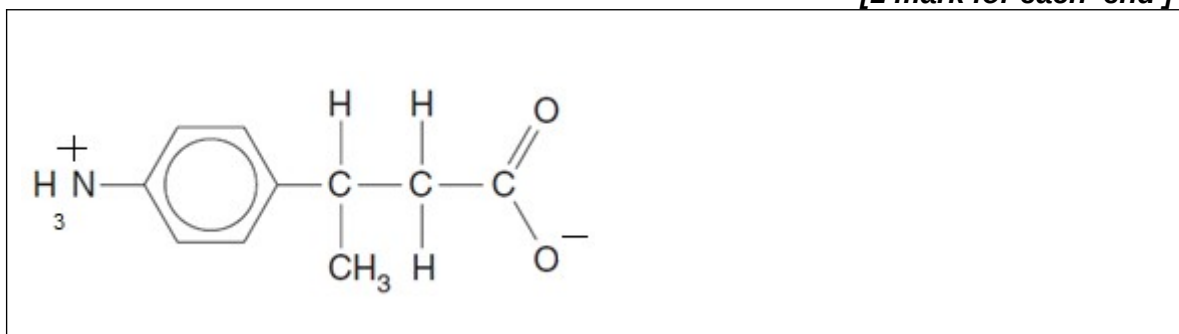
The structure has the amino and carboxylic acid [1 mark] functional groups [1 mark].

- (ii) State the general formula of an α -amino acid. Explain whether or not the above amino acid fits this category. (2 marks)

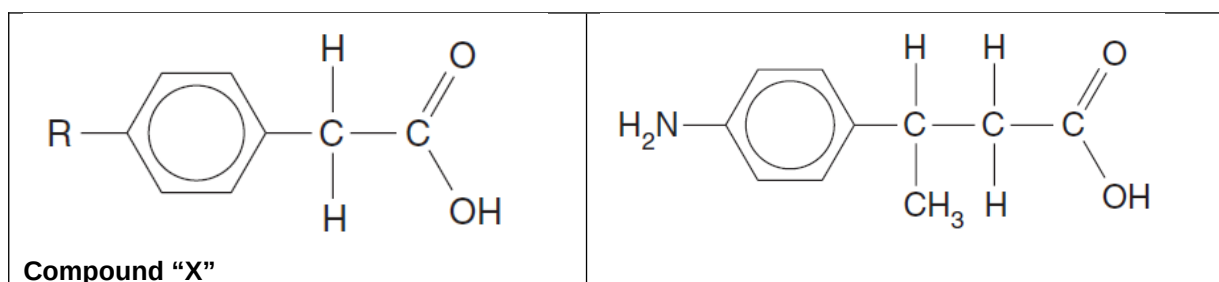
An α -amino acid has a single carbon atom placed between the amino and carboxylic acid functional groups [1 mark]. The above amino acid does not fit this group. [1 mark]

The amino acid above exists as a zwitterion in aqueous solution.

- (b) Draw the structure of this **zwitterion**. (2 marks)
[1 mark for each 'end']

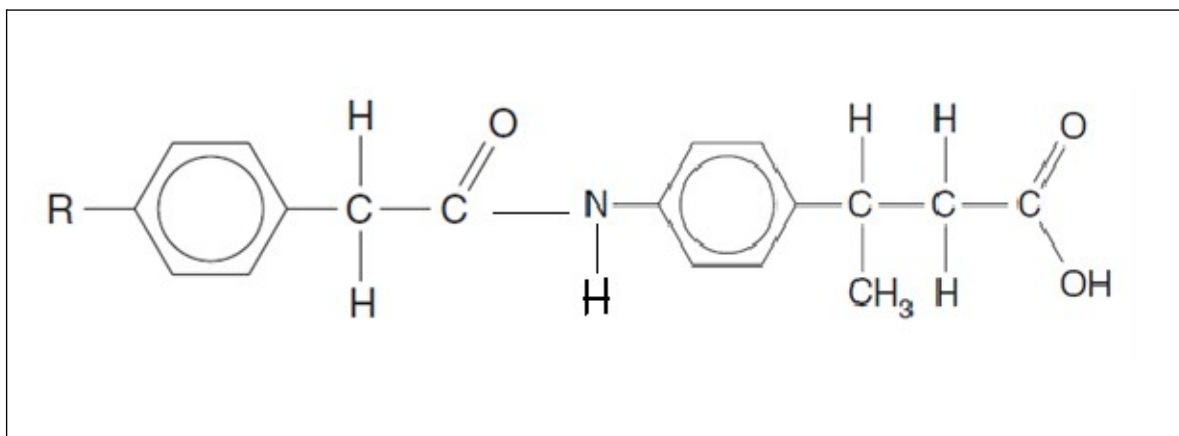


The anti-inflammatory drug is made by combining the amino acid, with the molecule shown below, called compound **X**. R represents a small side chain.



- (c) (i) Combine both structures to show the structure of the **drug**. (1 mark)

See next page



(ii) What type of chemical linkage forms? (1 mark)
Amide (or peptide) linkage.

(iii) What type of reaction occurs, and what small molecule is released? (2 marks)

Condensation polymerisation [1 mark]; H_2O [1 mark]

(d) Spectroscopy analysis showed compound **X** contained the elements C, H, O, and chlorine(Cl).

Experimentally, the identity of R was found by combusting 0.425 g of the compound **X** in excess air. It was found that 0.912 g of carbon dioxide and 0.187 g of water was produced.

Further testing of a further 0.396 g sample of compound **X** produced 27.9 mL of chlorine gas (Cl_2), under conditions of 40 °C and 100 kPa.

(i) Determine the percentage composition, by mass, of each element in compound **X** (7 marks)

$$n(CO_2) = 0.912 / 44.01 = 0.2072 \text{ mol} = n(C) \quad [1 \text{ mark}]$$

$$m(C) = 0.2072 \times 12.01 = 0.2489 \text{ g}$$

$$\% C = 0.2489 / 0.425 \times 100\% = 58.56\% \quad [1 \text{ mark}]$$

$$\text{and } n(H_2O) = 0.187 / 18.016 = 0.01034 \text{ mol} \quad [1 \text{ mark}]$$

$$n(H) = 2 \times 0.01034 = 0.02076 \text{ mol}$$

$$m(H) = 0.02076 \times 1.008 = 0.02092 \text{ g}$$

$$\% H = 0.02092 / 0.425 \times 100\% = 0.0859 = 4.92\% \quad [1 \text{ mark}]$$

$$n(Cl_2) = PV / RT = 100 \times 0.0279 / (8.315 \times 313) = 0.001072 \text{ mol} \quad [1 \text{ mark}]$$

$$n(Cl) = 2 \times 0.001072 = 0.002144 \text{ mol}$$

$$m(Cl) = 0.002144 \times 35.45 = 0.07601 \text{ g}$$

$$\% Cl = 0.07601 / 0.396 \times 100\% = 19.19\% \quad [1 \text{ mark}]$$

$$\text{Therefore } \% O = 100 - (58.56 + 4.92 + 19.19) = 17.33\% \quad [1 \text{ mark}]$$

(ii) Determine the **empirical formula** of compound **X**. (2 marks)

	C	H	O	Cl	
<i>n</i>	58.56/12.01	4.92/1.008	17.33/16.00	9.19/35.45	[1 mark]
<i>n</i>	4.88	4.884	1.083	0.541	
<i>n</i>	9	9	2	1	

therefore $EF = C_9H_9O_2Cl$

[1 mark]

(iii) What is the **molar mass** of compound X?

(1 mark)

$$M(EF) = 9 \times 12.01 + 9 \times 1.008 + 2 \times 16.00 + 35.45 = 184.61$$

Given that the side chain R is small the EF must be the MF.

Therefore the $M(\text{drug}) = 184.61$

[1 mark]

(iv) What is the **identity** of the side branch, R?

(2 marks)

R must contain chlorine.

$$\text{Therefore } M(R) = 184.61 - [(8 \times C) + (7 \times H) + (2 \times O)]$$

$$= 184.61 - 135.136$$

$$= 49.48$$

[1 mark]

$$\text{Therefore, } 49.48 - M(Cl) = 14.03 \text{ and } M(CH_2) = 14.026$$

R is the side chain $-CH_2Cl$

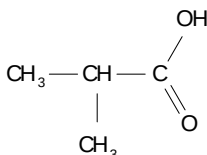
[1 mark]

Question 42

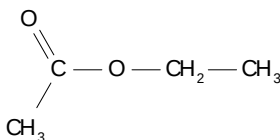
(12 marks)

Butanoic acid, $CH_3CH_2CH_2COOH$, is a ubiquitous, oily, colourless substance with a diverse range of origins and uses. It occurs naturally but can be manufactured through the fermentation of sugar and starch, and then the addition of putrefying cheese, with calcium carbonate added to neutralize the acid.

- (a) Draw and name two structural isomers of $C_4H_8O_2$ (other than butanoic acid) (4 marks)
[1 mark structure; 1 mark correct name]. Others possible e.g. 1-hydroxy butan-2-one



Name: **2-methylpropanoic acid**



Name: **ethyl ethanoate**

Butanoic acid is a rancid smelling substance that gives parmesan cheese its characteristic odour. It has been used as a nausea inducing repellent by anti-whaling protesters against whalers. Butanoic acid can undergo **esterification** with ethanol, CH_3CH_2OH , to form a much more pleasant smelling pineapple flavoured ester.

- (b) What is the common catalyst used for this reaction?

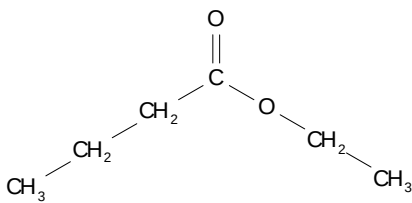
(1 mark)

Sulfuric acid (H_2SO_4)

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(c) Draw, and name the ester formed.

(2 marks)



Name: ***ethyl butanoate***

The perspiration stains in clothes are partly due to the presence of butanoic acid. Soap powders form alkaline solutions, often containing sodium carbonate, which are used to neutralise this acidity.

Fats and oils can be removed from clothing by the action of soaps and detergents. Soaps are typically sodium or potassium salts of long chain fatty acids e.g. $\text{CH}_3(\text{CH}_2)_{16}\text{COONa}$, whereas detergents are alkylbenzenesulfonate substances e.g. $\text{CH}_3(\text{CH}_2)_{11}\text{C}_6\text{H}_4\text{SO}_3\text{Na}$.

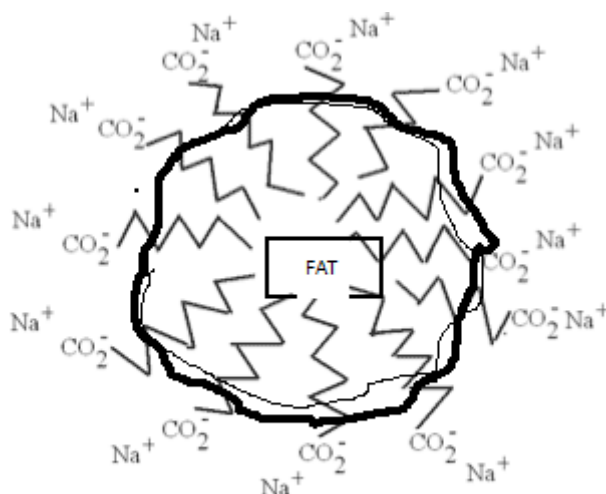
(d) Discuss, with illustrations, the action of soaps **or** detergents. Use the terms:

- dispersion forces
- surfactant (or emulsifying agent)
- polar and non-polar
- hydrophobic and hydrophilic
- micelle

(5 marks)

[1 mark each dot point]

Soap molecular ions have a long hydrophobic tail (non-polar) which bond by dispersion forces with the molecules of fats and oils. They also have a hydrophilic 'head' (polar) which has a negative charge and bonds with water molecules in the solution process. Soaps act as surfactants i.e. they change the surface properties of non-polar fat and oil molecules by giving them a charge (-). This increases spreading and wetting properties by reducing surface tension.



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End of questions