Government of **Western Australia**
Curriculum Council

WACE
Western Australian Certificate of Education

CHEMISTRY

Stage 3

Sample WACE Examination 2010

Marking Key

Marking keys are an explicit statement about what the examiner expects of candidates when they respond to a question. They are essential to fair assessment because their proper construction underpins reliability and validity.

When examiners design an examination, they develop provisional marking keys that can be reviewed at markers' meetings and modified as necessary in the light of student responses.

This marking key has been developed by examiners in conjunction with the sample examination paper and, as is the case with any external examination developed by the Curriculum Council, is a provisional document that can be modified if necessary in the light of student responses.

2009/30338

Section One: Multiple-choice **50 Marks**

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

Section Two: Short answer **70 marks**

Question 26 **(2 marks)**

Write the equilibrium constant expression for each of the following.

Equation	$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$
Equilibrium constant expression	$K = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$ or $K = \frac{p(SO_3)^2}{p(SO_2)^2\,p(O_2)}$

(1 mark)

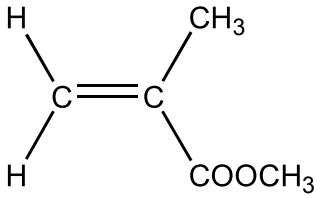
Equation	$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$
Equilibrium constant expression	$K = [CO_2]$ **or** $K = pCO_2$

(1 mark)

Mark	Description
1	Correct answer
0	Question incorrectly answered or not attempted

Question 27 **(4 marks)**

Poly(methyl methacrylate) is a polymer used in the manufacture of plexiglass and paints.
The structure of methyl methacrylate, the monomer used in its preparation, is shown below.

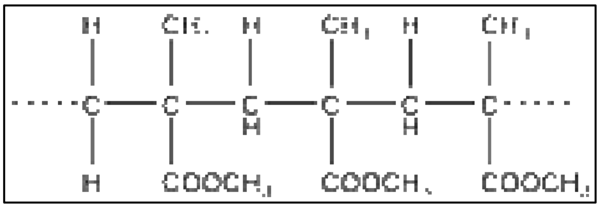


(a) Is geometric isomerism possible in methyl methacrylate? Explain your answer. (2 marks)

No. Groups about the double bond are the same (i.e. two hydrogen atoms on C_1). Geometric isomerism is only possible there where are different atoms or groups of atoms on the sp^2 hybridised carbons.

Mark	Description
2	The correct answer and explanation
1	The correct answer only (*i.e.* 'No') (explanation not given)
0	Incorrect answer and explanation **or** correct answer but incorrect explanation or question not attempted

(b) Draw a structure for poly(methyl methacrylate). Show three repeating units in your structure. . Show all atoms. (2 marks)



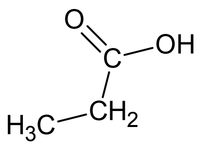
Full marks if they show all atoms in the same way as in the methyl methacrylate.
.

Mark	Description
2	The correct structure (note that groups such as CH_3, CH are acceptable)
1	A nearly correct structure
0	Incorrect structure or question not attempted

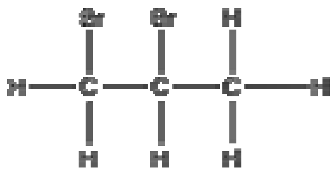
Question 28 **(6 marks)**

Draw structural formulae and give the IUPAC name for the organic products formed in each of the following reactions. **Show all atoms in the structural formulae.**

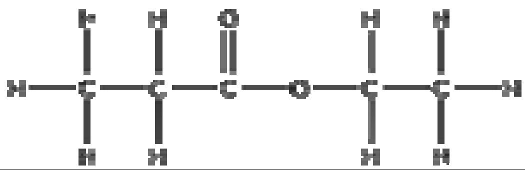
(a) When propan-1-ol is fully oxidised by acidified $K_2Cr_2O_7$ (2 marks)

Structure	Name
	propanoic acid

(b) When propene reacts with bromine solution (2 marks)

Structure	Name
	1,2 - dibromopropane

(c) When propanoic acid reacts with ethanol in the presence of H^+ (2 marks)

Structure	Name
	ethyl propanoate

Mark	Description
2	The correct structure and name
1	The correct structure or the correct name
0	Question incorrectly answered or not attempted

Question 29 **(9 marks)**

(a) Some compounds can behave as buffers, that is, they have a buffering capacity.

(i) Explain qualitatively the concept of buffering capacity, and give one factor upon which buffering capacity depends. (2 marks)

A buffer keeps the pH of a solution the same when small amounts of acid or base are added to it. The extent to which the buffer is able to resist a change In pH or 'absorb' the additional acid or base is referred to as the buffer capacity of the buffer. Buffer capacity depends on the (a) relative concentrations of the weak acid and the conjugate base and (b) the concentration of the weak acid and its conjugate base.

Mark	Description
2	Brief explanation of buffer capacity and **either** (a) **or** (b) as factors upon which buffer capacity depends.
1	**Either** a correct explanation of buffer capacity **or** a correct factor upon which buffer capacity depends.
0	Question incorrectly answered or not attempted

(ii) Explain using Le Chatelier's principle how buffers respond to the addition of H^+ and OH^- ions. (2 marks)

NB: Ideally, an example would be used to answer this question.

E.g. $NH_3\ (g) + H_2O\ (\ell) \rightleftharpoons NH^{4+}\ (aq) + OH^-\ (aq)$

When acid is added to the NH_3/NH_4^+ buffer system, it reacts with the OH^- in the system. This removes OH^- from the ammonium equilibrium system, and causes the equilibrium position to move to the right to counteract this change. The pH of the system therefore does not change a great deal even though acid has been added.

Mark	Description
2	Two important points: (i) added H^+ or OH^- ions react with species in the buffer system and (ii) equilibrium system adjusts to counteract this change, therefore pH changes very little.
1	Incomplete explanation
0	Question incorrectly answered or not attempted

(b) How would the buffering capacity of a 0.01M NH_3 / 0.01 M NH_4NO_3 solution differ, if at all, from a 0.01 M NH_3 / 0.01 M $NH_4C\ell$ solution? That is, would the buffering capacity of the 0.01M NH_3 / 0.01 M NH_4NO_3 solution be greater than, less than or the same as the NH_3 / $NH_4C\ell$ solution? Explain. (2 marks)

Circle the correct answer: Greater than Less than Same as

Same as. The anions $C\ell^-$ and NO_3^- are not involved in the buffering process.

Mark	Description
2	Correct answer circled, complete explanation.
1	Correct answer circled, incomplete or no explanation.
0	Question incorrectly answered or not attempted

See next page

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 $Ag^+(aq)$], **molecules** [for example $NH_3(g)$, $NH_3(aq)$, $CH_3COOH(\ell)$] or **solids** [for example $BaSO_4(s)$, $Cu(s)$, $Na_2CO_3(s)$].

(a) Magnesium oxide solid is mixed with hydrochloric acid solution. (2 marks)

Equation: $\mathbf{MgO(s) + 2\,H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(\ell)}$

Mark	Description
2	Correct equation
1	$MgO(s) + 2\,HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2O(\ell)$ [or similar] **OR** correct equation not balanced
0	Question incorrectly answered or not attempted

(b) Barium nitrate solution is mixed with sulfuric acid solution. (2 marks)

Equation: $\mathbf{Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)}$

Mark	Description
2	Correct equation
1	$Ba(NO_3)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2\,HNO_3(aq)$ [or similar] **OR** correct equation not balanced
0	Question incorrectly answered or not attempted

Question 31 **(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) A slight excess of iron (II) sulfate solution is mixed with acidified potassium permanganate solution. (2 marks)

Observation: A pale green solution is mixed with a purple solution to produce a pale green- brown (or yellow/pale yellow) solution.

(b) Excess copper (II) nitrate solution is mixed with sodium hydroxide solution. (2 marks)

Observation: A blue solution is mixed with a colourless solution to give a pale blue gelatinous precipitate. Colour of the supernatant becomes paler.

2 marks for each answer for a total of 4 marks

See next page

Mark	Description
2	An accurate observation (not an inference)
1	Products of the reaction are named
0	Question incorrectly answered or not attempted

Question 32 **(6 marks)**

The uptake of carbon dioxide from the atmosphere by the oceans is leading to gradual acidification of the oceans (*i.e.* the oceans are becoming less alkaline). When carbon dioxide dissolves, it reacts with water to form carbonic acid, which in turn forms hydrogencarbonate and then carbonate ions.

(a) Write equilibrium equations that show the formation of these products in water. (3 marks)

(i) $\mathbf{CO_2(g) + H_2O(\ell) \rightleftharpoons H_2CO_3(aq)}$

(ii) $\mathbf{H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)}$

(iii) $\mathbf{HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq)}$

1 mark for each correct equation

Mark	Description
3	Three correct equations. *NB:* equivalent equilibria involving water for (ii) and (iii) also acceptable. $H_2CO_3(aq) \rightleftharpoons 2\ H^+(aq) + CO_3^{2-}(aq)$ acceptable (but not desirable) in answer to (iii)
2	Two correct equations
1	One correct equation
0	Question incorrectly answered or not attempted.

The pH of the ocean varies rather widely from place to place, but is currently, on average, The pH of the ocean varies rather widely from place to place, but is currently, on average, about 8.2.

(b) Calculate the average $[H^+]$ of the oceans. (1 mark)

$pH = -\log [H^+] \qquad \therefore [H^+] = 10^{-8.2} = 6.31 \times 10^{-9}\ mol\ L^{-1}$

Mark	Description
2	Correct answer
1	$10^{-8.2}$ shown but incorrect final answer given **or** units omitted
0	Question incorrectly answered or not attempted

One of the most significant consequences of ocean acidification is the effect on shellfish and other marine life that produce and rely on calcium carbonate as a major component of the exoskeleton or other supporting structure. If the water is sufficiently acidic, the carbonate structures may not form completely. Ocean acidification is thought to lead to a reduction in the availability of carbonate ions. Further reaction of the dissolved carbon dioxide occurs as shown below.

$$CO_2\,(g) + CO_3^{2-}\,(aq) + H_2O\,(\ell) \rightleftharpoons 2\ HCO_3^-\,(aq)$$

(c) What can you conclude about the magnitude of the equilibrium constant for the above reaction, and the relative proportions of products and reactants in the system? (2 marks)

K > 1 and there is a greater proportion of products than reactants.

Mark	Description
2	K > 1 **and** greater proportion of products than reactants
1	K > 1 **or** greater proportion of products than reactants
0	Question incorrectly answered or not attempted

Question 33 **(10 marks)**

(a) A substance is said to be amphoteric if it can behave as either an acid or a base. Water is an amphoteric substance. (2 marks)

(i) Write a reaction equation showing water behaving as an acid.

Any valid reaction

(ii) Write a reaction equation showing water behaving as a base.

Any valid reaction

Mark	Description
2	Two valid reactions (one for each process)
1	One valid reaction **or** two slightly incorrect reactions (*e.g.* not balanced)
0	Question incorrectly answered or not attempted

Water ionises according to the equation

$$H_2O\ (\ell) \rightleftharpoons H^+\ (aq)\ +\ OH^-\ (aq)$$

K_w, the self-ionisation constant for water, has the form $K_w = [H^+][OH^-]$.

At 25 °C, $[H^+] = [OH^-] = 1.0 \times 10^{-7}$ mol L^{-1}, and $K_w = 1.0 \times 10^{-14}$ mol^2 L^{-2}. At 50°C, the K_w value changes to approximately 5.5×10^{-14} mol^2 L^{-2}.

(b) Use the information above, and Le Châtelier's principle, to predict whether the self-ionisation of water is an endothermic or exothermic process. Explain. (3 marks)

At 50 °C, the value for K_w increases, suggesting $[H^+] = [H_3O^+] = [OH^-]$ increase. This indicates that the reaction shifts to the right, suggesting that the reaction must be endothermic, as the system has moved to consume heat.

Mark	Description
3	Answer as above. Important points are (i) **$[H^+] = [H_3O^+] = [OH^-]$ increase**, suggesting (ii) **reaction has shifted to the right**, therefore (iii) **endothermic**
2	Correct conclusion but not all important points noted
1	Correct answer only (*i.e.* endothermic)
0	Question incorrectly answered or not attempted

See next page

(c) Calculate $[OH^-]$ in a neutral solution at 50 °C. (2 marks)

$K_w = 5.5 \times 10^{-14} = [H_3O^+][OH^-]$

Neutral solution $\therefore$ $[H_3O^+] = [OH^-] = \sqrt{5.5 \times 10}$ $= 2.34 \times 10^{-7}$ mol L^{-1}

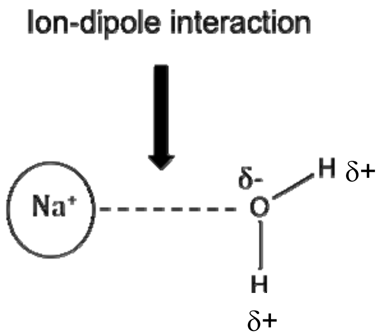
Mark	Description
2	Correct answer (2.34×10^{-7} mol L^{-1})
1	Incorrect answer, but some logic somewhere
0	Question incorrectly answered or not attempted

(d) What is the predominant intermolecular force in ice? (1 mark)

Hydrogen bonding

Mark	Description
1	Hydrogen bonding
0	Question incorrectly answered or not attempted

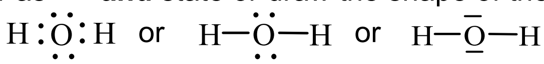
(e) Water readily dissolves ionic substances such as sodium chloride. Draw and label a diagram that illustrates the intermolecular force between water molecules and sodium ions in solution. (2 marks)

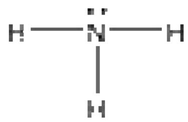
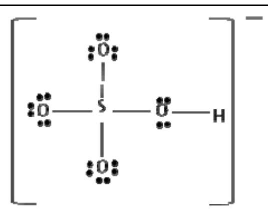


Mark	Description
1	Any diagram correctly illustrating the ion dipole interaction
0	Question incorrectly answered or not attempted

Question 34 **(6 marks)**

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

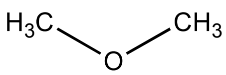
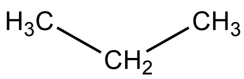
(for example, water  bent

Molecule	Structural formula (showing all valence shell electrons)	Shape (sketch or name)
ammonia NH_3		pyramidal or trigonal pyramidal
Hydrogensulfate HSO_4^-		tetrahedral
ethyne C_2H_2		linear

1 mark for each correct structure/answer for 6 marks in total

Question 35 **(8 marks)**

Complete the following table.

Molecule	Major type of intermolecular attraction (choose from dispersion forces, dipole-dipole or hydrogen bonding)	Boiling point ranking (1 = highest, 4 = lowest)
	Dipole-dipole	2
	Dispersion	3
CH_3CH_3	Dispersion	4
CH_3CH_2OH	Hydrogen bonding	1

1 mark for each correct answer for a total of 8 marks

See next page

Question 36 **(11 marks)**

Corrosion is the process of metal oxidation and, while in many cases it is a destructive and costly process, in the case of some metals, the corrosive process can be beneficial in that it provides a protective coating on the metal. This is the case for aluminium; the aluminium is oxidised when exposed to the oxygen and water vapour in the atmosphere to form a thin layer of its hydroxide.

(a) Write the oxidation and reduction half equations and the overall equation for the oxidation of aluminium. (3 marks)

(i) Oxidation: $A\ell(s) \rightarrow A\ell^{3+} + 3\ e^-$

(ii) Reduction: $O_2(g) + 2\ H_2O(\ell) + 4\ e^- \rightarrow 4\ OH^-$

(iii) Overall: $4\ A\ell(s) + 3\ O_2(g) + 6\ H_2O(\ell) \rightarrow 4\ A\ell(OH)_3(s)$

1 mark for each correct equation for 3 marks in total

(For overall, also accept $4\ A\ell(s) + 3\ O_2(g) + 6\ H_2O(\ell) \rightarrow 4\ A\ell^{3+}(aq) + 12\ OH^-(aq)$)

The aluminium hydroxide initially formed in this process dehydrates to give a continuous layer of insoluble aluminium oxide.

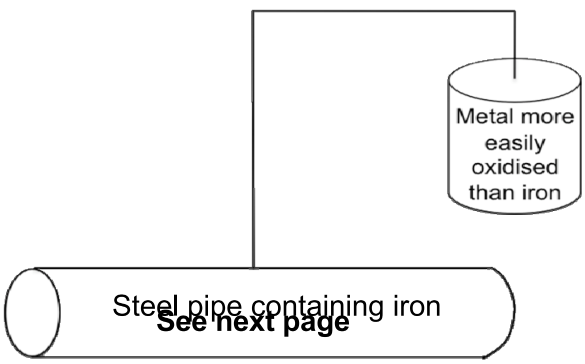
(b) Consider the above information and explain how the corrosive process forms a protective layer. Use a reaction equation or equations to aid your explanation. (2 marks)

$2\ A\ell(OH)_3\ (s) \rightarrow A\ell_2O_3(s) + 3\ H_2O$

The aluminium oxide formed in the dehydration process creates an impervious layer on the surface of aluminium, preventing oxygen and water from contacting the aluminium, thus preventing oxidation/corrosion.

Mark	Description
2	Correct equation **and** explanation
1	Correct equation **or** correct explanation
0	Question incorrectly answered or not attempted

Corrosion can be prevented by cathodic protection, a method often used to protect iron in steel in pipelines that are buried. A metal that is more readily oxidised than iron is connected by a wire to the pipe that must be protected from corrosion, as indicated in the diagram below. This metal then acts as an anode in a redox reaction. Aluminium is a metal that may theoretically be used for cathodic protection of iron.



(c) By referring to the Standard Reduction Potential table, suggest two other metals that may be connected to a steel pipe as cathodic protectants. (2 marks)

Mark	Description
2	Any two of Zn, Mg (most sensible answers), Cr or Mn. Na and Ca **not** acceptable
1	One metal only given
0	Question incorrectly answered or not attempted

(d) Explain why, in practice, aluminium may not be very effective as a cathodic protectant. (1 mark)

The protective aluminium oxide layer formed means it is not easily oxidised, and the electrons required for the reduction half equation don't flow (i.e. it cannot act as an anode).

Mark	Description
1	Correct explanation
0	Question incorrectly answered or not attempted

(e) If copper was connected to the steel pipe, the surface of the copper would be cathodic and the iron in the steel anodic. The cathodic reaction on the surface of the copper and the anodic reaction of the iron are shown below.

Cathodic reaction: $O_2(g) + 2\,H_2O(\ell) + 4\,e^- \rightarrow 4\,OH^-(aq)$

Anodic reaction: $Fe(s) \rightarrow Fe^{2+}(aq) + 2\,e^-$

If 500.0 kg of iron corroded in the steel pipe, what mass of H_2O reacts at the surface of the copper? (3 marks)

n(Fe) = $\frac{500 x 10\ g}{55.847\ g mol^{-1}} = 8953.0392\ mol$

$n(e^-)$ released at anode = 17906.06478 mol

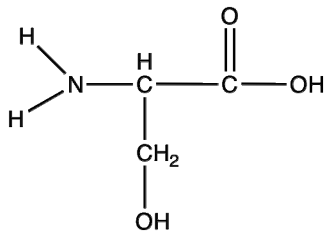
$n(H_2O)$ consumed = = 8953.032392 mol

∴ mass H_2O reacted = 8953.032392 mol × 18.01534 g mol^{-1} = 1.61×10^2 kg H_2O (3 s.f.)

Mark	Description
3	Correct answer (1.61×10^2 kg H_2O)
2	Calculates $n(H_2O)$ reacted
1	Calculates n(Fe)
0	Question incorrectly answered or not attempted

Question 37 **(3 marks)**

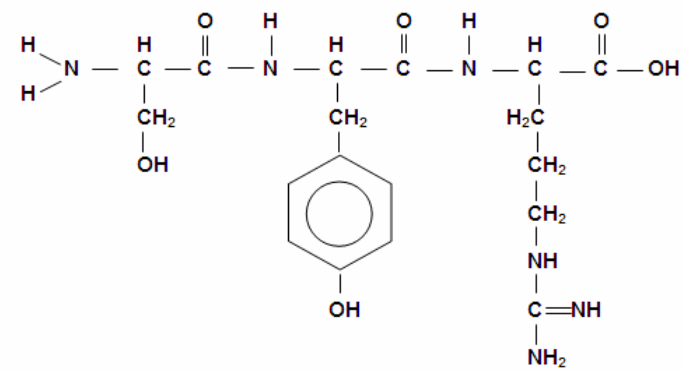
(a) To what class of compound does the structure below belong? (1 mark)



Amino acids

Mark	Description
1	Correct answer (amino acids)
0	Question incorrectly answered or not attempted

(b) The compound below is composed of the compound illustrated in (a) and two other compounds belonging to the same class. Would you expect the compound below to be miscible with water? Explain your answer. (2 marks)



Yes. The OH groups in the side chains will undergo hydrogen bonding with water.

Mark	Description
2	Correct answer (yes). Explanation must include mention of hydrogen bonding with water.
1	Correct answer and no explanation or incorrect explanation
0	Question incorrectly answered or not attempted

End of Section Two

Section Three: Extended answer **80 Marks**

N.B. One mark per question should be deducted throughout this section for incorrect use of significant figures.

Question 38 **(9 marks)**

Fungi and mildews can cause great damage to grape vines. One spray used to combat these diseases is called Bordeaux mixture. A home gardener who wishes to treat his grapes with Bordeaux mixture prepares a mixture using the instructions given below.

1. Add 25.0 g of calcium hydroxide powder to 25.0 g of copper(II) sulfate pentahydrate powder.
2. Mix these powders with a small amount of water to make a paste.
3. Add the paste to 5.00 L of water and mix well.
4. Use the mixture immediately after preparation.

(a) Write a balanced molecular or ionic equation for any reaction that occurs **after the powders are mixed with water.** (2 marks)

$Cu^{2+}(aq) + 2\ OH^{-}(aq) \rightarrow Cu(OH)_2(s)$

or

$CuSO_4(aq) + Ca(OH)_2(aq) \rightarrow Cu(OH)_2(s) + CaSO_4(s)$

Mark	Description
2	Correct equation
1	Correct equation not balanced
0	Question incorrectly answered or not attempted

(b) Determine the limiting reagent for the above reaction. (4 marks)

$$n[Ca(OH)_2] = \frac{25.0g}{74.096gmol^{-1}} = 0.337400 = 3.37 x 10^{-1} mol$$

$$n(CuSO_4 \bullet 5H_2O) = \frac{25.0g}{249.69gmol^{-1}} = 0.10012 = 1.00 x 10^{-1} mol$$

$Ca(OH)_2 : CuSO_4 \bullet 5H_2O = 1:1 \therefore CuSO_4$ is limiting reagent

Mark	Description
4	Correct answer with all correct working (*i.e.* **any valid** method)
3	Number of moles of $Ca(OH)_2$ **AND** $CuSO_4 \bullet 5H_2O$, ratio noted, but incorrect reagent identified as limiting
2	Number of moles of $Ca(OH)_2$ **AND** $CuSO_4 \bullet 5H_2O$
1	Number of moles of $Ca(OH)_2$ **OR** $CuSO_4 \bullet 5H_2O$ calculated
0	Question not attempted or answered incorrectly

(c) Calculate the mass of reagent in excess. (2 marks)

Reagent in excess = $Ca(OH)_2$

n[($Ca(OH)_2$] remaining = (3.374×10^{-1}) – (1.0012×10^{-1}) = 0.23728 mol

$\therefore$ mass ($Ca(OH)_2$ remaining) = 0.23728×74.096 = 17.58 g = 1.76×10^{1} g

Mark	Description
2	1.76×10^{1} g (or an answer between 1.74×10^{1} g and 1.78×10^{1} g)
1	Correct calculation of number of moles, but error in calculating mass
0	Question incorrectly answered or not attempted

(d) What colour (if any) will the solution have? (1 mark)

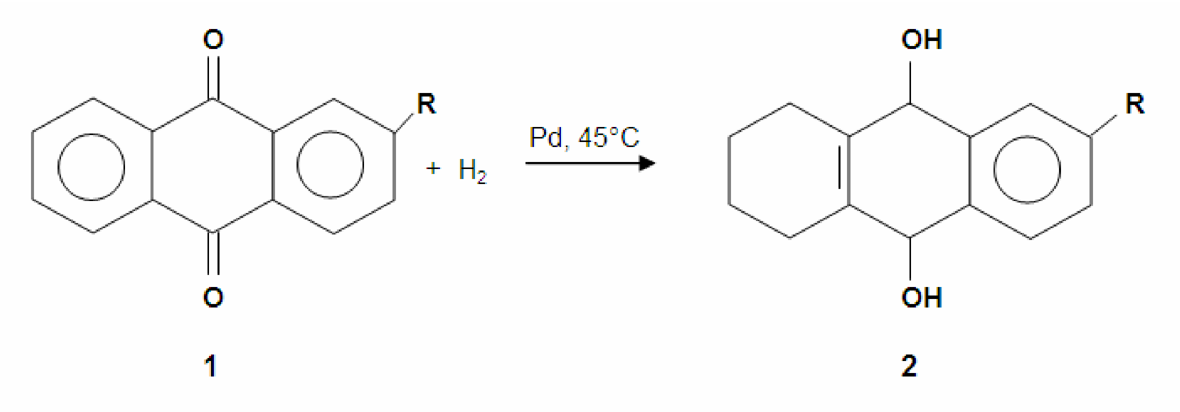
Colourless

Mark	Description
1	Colourless (N.B. blue is not acceptable)
0	Question incorrectly answered or not attempted

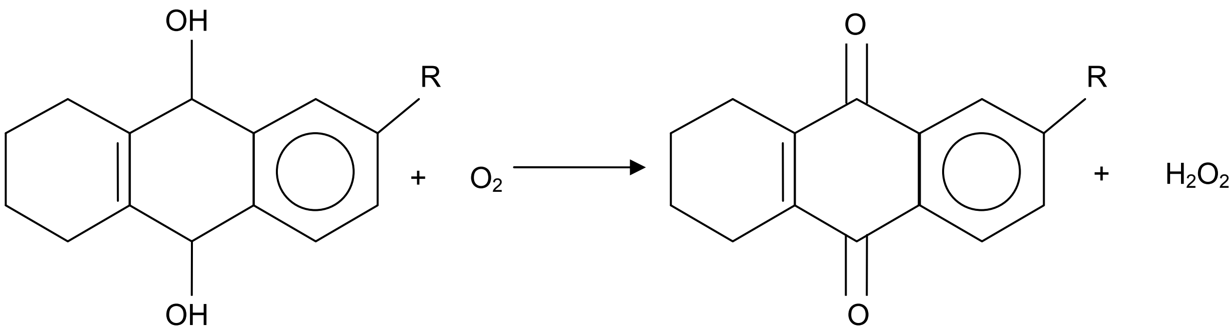
Question 39 **(21 marks)**

Hydrogen peroxide (H_2O_2) is an important industrial oxidising agent. Its manufacture can be summarised into the steps outlined below.

Step 1 – Hydrogenation
Hydrogen gas is bubbled through a solution containing an alkyl anthraquinone in two solvents, one polar (in which very little anthraquinone dissolves) and the other non-polar. Finely divided alumina particles loaded with palladium catalyst are added to the solution. A number of hydrogenation reactions occur to convert the alkyl anthraquinone (**1**) (a diketone) into tetrahydro-alkyl anthrahydroquinone (**2**) as shown below. The palladium catalyst is removed by filtration before step 2.



Step 2 – Oxidation
The hydrogenated anthraquinone mixture is oxidised by bubbling air through the solution. Oxygen from the air oxidises the tetrahydro-alkyl anthrahydroquinone (**2**) producing compound **3** and hydrogen peroxide, which is dissolved in the organic phase. The reaction is shown below.



2 **3**

Step 3 – Hydrogen peroxide extraction
Deionised water is added from the top of a liquid-liquid extraction tower. The water flows down the tower while the organic solution containing the hydrogen peroxide is pumped up the tower. The water reaching the bottom of the tower has a composition of 25 to 35 % by mass crude hydrogen peroxide, whilst the organic solution leaving the top of the tower is free of hydrogen peroxide and is recycled.

The crude hydrogen peroxide is purified and vacuum distilled to give a solution that is 70 % hydrogen peroxide by mass.

(a) Explain why two solvents, one polar and the other non-polar, are needed in the hydrogenation step. (2 marks)

Dihydroxyanthraquinones 2 and 3 dissolve in polar solvent and are removed from the reactants as they are formed. These compounds are required for the oxidation step (plus some reasonable explanation as to why the dihydroxyanthraquinones 2 and 3 dissolve in polar solvent).

or

The non-polar solvent dissolves the alkyl anthraquinone while the polar solvent dissolves the dihydrianthraquinones 2 and 3 (plus some explanation as to why the dihydroxyanthraquinones 2 and 3 dissolve in polar solvent while the alkyl anthraquinone dissolves in non-polar solvent).

Mark	Description
2	Correct answer with suitable explanation
1	Correct answer with little explanation
0	Question incorrectly answered or not attempted

(b) In the hydrogenation step of this process, what effect does the palladium have on the rate at which equilibrium is attained? Explain, by applying Collision Theory, how the palladium has this effect. (3 marks)

Palladium is a catalyst in this reaction, and is used to increase the rate of the reaction (i.e the rate at which equilibrium is attained), but is not consumed. Equilibrium is attained more rapidly. The palladium acts by providing a reaction pathway with a smaller activation energy than the activation energy for the uncatalysed reaction. Consequently, at any given temperature more collisions will result in a reaction, as a greater fraction of particles will collide with energy above the lower activation energy.

Mark	Description
3	Three of the following important points: i) increases rate at which equilibrium is attained, ii) provides an alternative pathway with lower activation energy, iii) lower activation energy means a greater fraction of collisions will be sufficiently energetic for reaction
2	Two of the three important points
1	One of the three important points
0	Question incorrectly answered or not attempted

(c) Explain why the palladium in the hydrogenation step is finely divided. (2 marks)

This relates to the increased surface area that is created by finely dividing the palladium. The greater the surface area in a heterogeneous system, the greater the reaction rate. Since catalysis occurs at the solid surface in a heterogenous system, an increase in surface area causes more of the substance to be exposed for catalysis; this is how the reaction rate is increased.

Mark	Description
2	Two of the following three important points: i) increased surface area, ii) increased reaction rate, iii) catalysis takes place at the surface in heterogeneous systems
1	One of the three important points noted
0	Question incorrectly answered or not attempted

(d) Explain why the hydrogen peroxide initially dissolved in the organic solution preferentially dissolves in the water when they mix in the extraction tower. (2 marks)

Hydrogen peroxide is a hydrogen bond donor and acceptor (*i.e.* it is capable of hydrogen bonding) and will be solvated by water in preference to less polar solvents

Mark	Description
2	Two important points: i) hydrogen peroxide is capable of hydrogen bonding and therefore ii) will be solvated by water
1	One of the two important points
0	Question incorrectly answered or not attempted.

A sample of the distilled and purified hydrogen peroxide solution was taken to a quality control laboratory to check the concentration of the hydrogen peroxide in the solution. A 10.0 mL sample of the product was diluted to 500.0 mL in a volumetric flask. Acidified aliquots of 10.0 mL of this diluted solution were then titrated against a standard 0.112 mol L^{-1} potassium permanganate solution.

The burette readings obtained are shown in the table below.

Titration result	Trials (mL)			
	1	2	3	4
Final reading	19.32	37.73	18.84	37.54
Initial reading	0.03	18.98	0.14	18.84
Titre	**19.29**	**18.75**	**18.70**	**18.70**

(e) Write a balanced redox equation for the reaction between the hydrogen peroxide and permanganate ion. (2 marks)

$2\ MnO_4^-(aq) + 6\ H^+(aq) + 5\ H_2O_2(aq) \rightarrow 2\ Mn^{2+}(aq) + 8\ H_2O(aq) + 5\ O_2(g)$

Mark	Description
2	Correct reaction equation
1	Equation not balanced
0	Question incorrectly answered or not attempted

(f) Determine the average titre value. (1 mark)

18.72 mL

Mark	Description
1	18.72 mL (19.29 mL is rejected as an outlier)
0	Question incorrectly answered or not attempted

(g) Calculate the concentration of the hydrogen peroxide, in mol L^{-1}, in the original sample taken from the production process. (5 marks)

n ($KMnO_4^-$) = cV = 0.112 mol L^{-1} × 0.01872 L = 2.10 × 10^{-3} mol

n(H_2O_2) reacting = $5 \times \frac{2.09664 \times 10^{-3}\ mol}{2} = 5.24 \times 10^{-3}\ mol$

c(H_2O_2, diluted solution) = $\frac{5.25 \times 10^{-3}\ mol}{0.01 L} = 0.525 mol L^{-1}$

∴ c(H_2O_2, original solution) = $0.525 mol L^{-1} \times \frac{500}{10} = 2.62 \times 10^{1} mol L^{-1}$

Fast mark

Cumulative marks	Description
5	2.62 × 10^1mol L^{-1} (or an answer between 2.59 × 10^1 mol L^{-1} and 2.65 × 10^1 mol L^{-1})
0	Question incorrectly answered or not attempted

Part mark

Mark	Description
1	Calculates number of moles of $KMnO_4^-$ = 2.10 × 10^{-3} mol
3	Calculates n(H_2O_2) reacting = 5.24 × 10^{-3} mol
4	Calculates concentration of dilute H_2O_2 solution = 0.525 mol L^{-1}
5	2.62 × 10^1mol L^{-1} (or an answer between 2.59 × 10^1 mol L^{-1} and 2.65 × 10^1 mol L^{-1})
0	Question incorrectly answered or not attempted

(h) What mass of hydrogen peroxide is in 100 mL of this original solution? (2 marks)

$n(H_2O_2)$ in 100 mL of original solution = $2.625 \times 10^{1}\ mol\ L^{-1} \times \frac{1000}{100} = 2.625\ mol$

$\therefore mass(H_2O_2) = 2.625\ mol \times 34.0148\ g\ mol^{-1} = 89.3\ g$

Mark	Description
2	89.3 g (or an answer between 88.4 g and 90.2 g)
1	Correctly calculates number of moles but incorrectly calculates mass
0	Question incorrectly answered or not attempted

(i) What is the mass of 100 mL of the original peroxide solution if it has a density of 1.29 g mL^{-1}? (1 mark)

$\rho = \frac{m}{v} \Rightarrow m = \rho v = 1.29\ g\ mL^{-1} \times 100\ mL = 129\ g$

Mark	Description
1	129 g (or an answer between 127 g and 130 g)
0	Question incorrectly answered or not attempted

(j) The concentration of hydrogen peroxide from the production process should be 70 % w/w (or 70 % by mass). This means that in 100 g of hydrogen peroxide solution there should be 70 g H_2O_2. From your answers to (j) and (k), calculate the concentration of the hydrogen peroxide solution as a % w/w and state whether the production process is operating appropriately. (1 mark)

$m(H_2O_2)\ in\ 100\ g = \frac{89.3\ g \times 100\ g}{129\ g} = 69.2\ g$

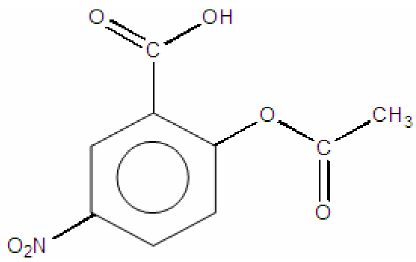
69.22g H_2O_2 in 100 g solution *i.e.* solution is 69.22 % w/w (or % by mass) H_2O_2. Compares reasonably well with the aimed for 70 % w/w ⇒ process is operating well.

Mark	Description
1	69.2 % w/w (or by mass) (or an answer between 68.5 % and 69.9 %) AND statement that process is operating appropriately
0	Question incorrectly answered or not attempted

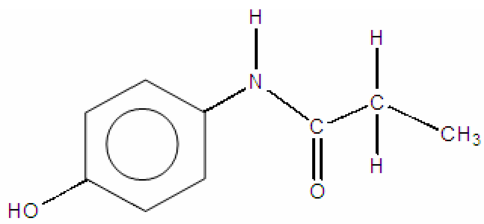
Question 40 **(11 marks)**

You are the senior chemist working in an analytical laboratory, and the local veterinarian contacts you and is dealing with an anxious client whose dog has eaten a very large quantity of an unidentified 'painkiller'. A small amount of the substance has been salvaged, and the veterinarian has asked you to analyse the sample to determine its identity.

(a) The painkiller was one of those whose structural formulae are shown below. Identify the elements that are present in the substance swallowed by the dog. (1 mark)



Aspirintro



Paracetamolo

carbon, hydrogen, nitrogen, oxygen

Mark	Description
1	All elements identified
0	Question incorrectly answered or not attempted

(b) You perform a combustion analysis of the 0.229 g sample, which produces 0.5508 g CO_2, 0.1368 g H_2O and 0.0639 g of NO_2. Determine which one of the 'painkillers' the dog swallowed. (10 marks)

$$n(CO_2) = \frac{0.5508 g}{44.01 g mol^{-1}} = 1.25 x 10^{-2}$$

$$\therefore n(C) = 1.25 x 10^{-2} mol$$

$$m(C) = 1.25 x 10^{-2} mol x 12.01 g mol^{-1} = 0.15306 g$$

$$n(H_2O) = \frac{0.1368 g}{18.01 g mol^{-1}} = 7.5957 x 10^{-3} mol$$

$$\therefore n(H) = 2 x 7.5957 x 10^{-3} mol = 1.52 x 10^{-2} mol$$

$$m(H) = 1.52 x 10^{-2} mol x 1.008 g mol^{-1} = 0.1532 g$$

$$n(NO_2) = \frac{0.0639 g}{46.01 g mol^{-1}} = 1.389 x 10^{-3} mol$$

$$\therefore n(N) = 1.389 x 10^{-3} mol$$

$$m(N) = 1.389 x 10^{-3} mol x 14.01 g mol^{-1} = 0.01946 g$$

m(O) = 0.229 - (0.15024 + 0.01532 + 0.019446) = 0.043994 g

Element	C	H	N	O
Moles	1.25×10^{-2}	1.52×10^{-2}	1.39×10^{-3}	2.75×10^{-3}
Mole ratio	$\frac{1.25 \times 10^{-2}}{1.39 \times 10^{-3}} = 8.99$	$\frac{1.52 \times 10^{-2}}{1.39 \times 10^{-3}} = 10.94$	$\frac{1.39 \times 10^{-3}}{1.39 \times 10^{-3}} = 1$	$\frac{2.75 \times 10^{-3}}{1.39 \times 10^{-3}} = 1.98$
Round	9	11	1	2

Empirical formula is $C_9H_{11}NO_2$

$\therefore$ **Substance swallowed by the dog was paracetamolo.**

Alternative approach:

Asprinitro is $C_9H_7NO_6$, Paracetamolo is $C_9H_{11}NO_2$,

Mol C = mol CO_2 = 0.5508/44.01 = 0.0125
Mol N = mol NO_2 = 0.0639/46.01 = 0.00139
C:N ratio is 0.0125/ 0.00139 = 9:1. Need H analysis.

Mol H = 2 × mol H_2O = 2 × 0.1368/18.016 = 0.01519
H:N ratio is 0.01519/0.00139 = 11:1. Therefore the drug is paracetamolo.

Fast mark

Mark	Description
10	$C_9H_{11}NO_2$ = paracetamolo. Full marks for any valid method of identifying the drug.
0	Question incorrectly answered or not attempted

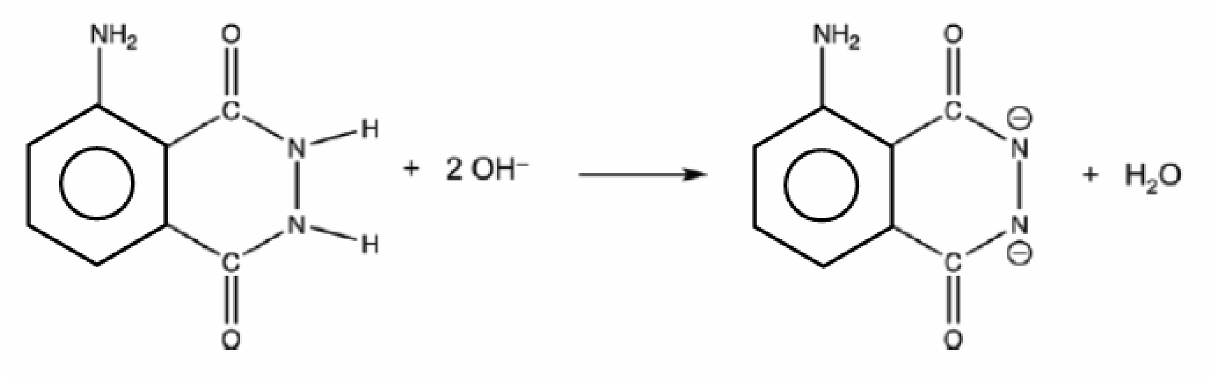
Part mark

Cumulative Marks	Description
3	1 mark each for number of moles of CO_2 (**1.25×10^{-2}**), H_2O (**7.59×10^{-3}**) and NO_2 (**1.39×10^{-3}**) (for 3 marks in total if all correct)
6	1 mark each for number of moles of C (**1.25×10^{-2}**), H (**1.52×10^{-2}**) and N (**1.39×10^{-3}**) (for 3 marks in total if all correct)
7	1 mark for calculation of mass of O (**4.40×10^{-2} g**)
8	1 mark for calculation of moles of O (**2.75×10^{-3} mol**)
9	1 mark for molar ratio, rounding and empirical formula
10	1 mark for identification of paracetamolo

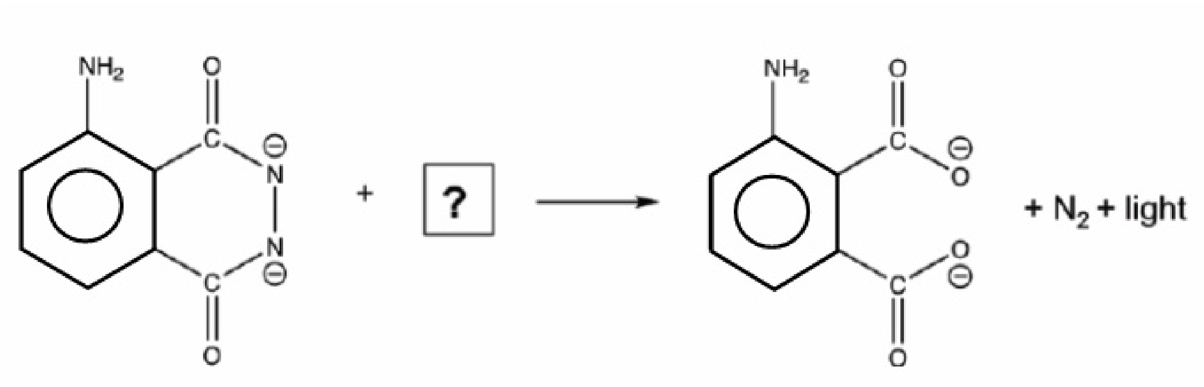
Question 41 **(13 marks)**

A chemiluminescent reaction generates energy in the form of light. This property can be used in forensic analysis to detect traces of blood. Luminol (chemical name 3-aminophthalyl hydrazide) is commonly used for this purpose, where the luminol and other reagents necessary for the reaction (potassium hydroxide and hydrogen peroxide) are available in a small portable kit for the forensic scientist to carry to a crime scene. The luminol chemiluminescence overall reaction, which requires a catalyst, may be broken down into two parts, as shown below.

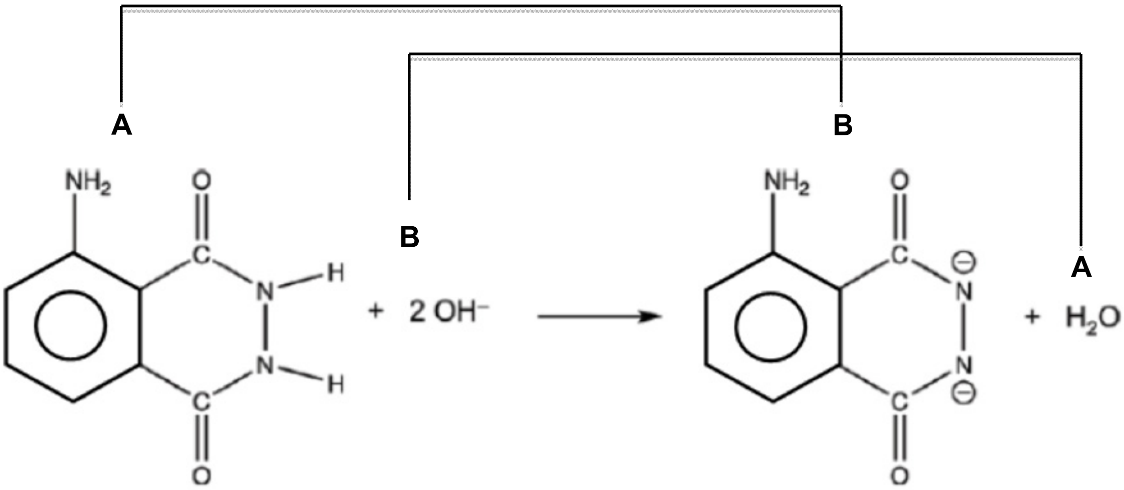
Part A:



Part B:



(a) Identify all conjugate acid and base pairs in Part A of the reaction. Join each pair with a line, and label the conjugate acid and base of each pair appropriately. (2 marks)



A = conjugate acid
B = conjugate base

Mark	Description
2	Both conjugate pairs identified and correctly labelled (any valid means of labelling)
1	One conjugate pair identified and correctly labelled
0	Question incorrectly answered or not attempted

(b) The decomposition of H_2O_2 is an important part of Part B of the process. Write the equation for the decomposition of H_2O_2. (1 mark)

$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$

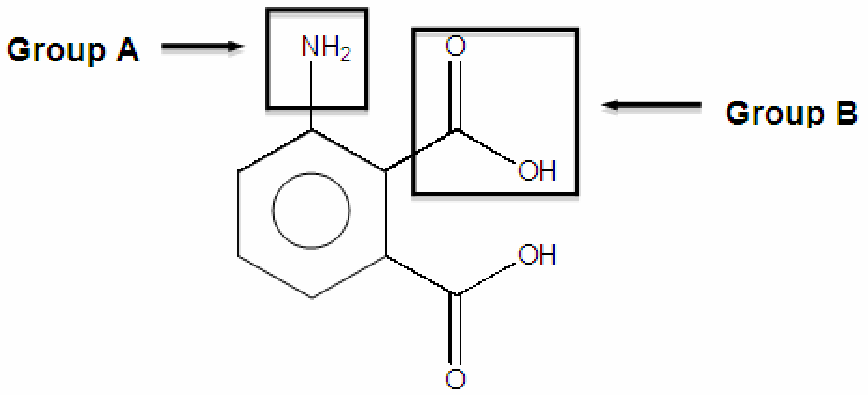
Mark	Description
1	Correct equation ($2\ H_2O_2 \rightarrow 2\ H_2O + O_2$)
0	Question incorrectly answered or not attempted

(c) Which one of the H_2O_2 decomposition products is involved in Part B of the process, as indicated by the question mark? (1 mark)

O_2

Mark	Description
1	O_2
0	Question incorrectly answered or not attempted

(d) Name the functional groups (A and B) present if the final product is acidified, as shown below. (2 marks)



Group A: **amino**

Group B: **carboxylic acid**

Mark	Description
2	Both functional groups correctly identified. Amine also acceptable for group A.
1	One correct functional group only identified
0	Question incorrectly answered or not attempted

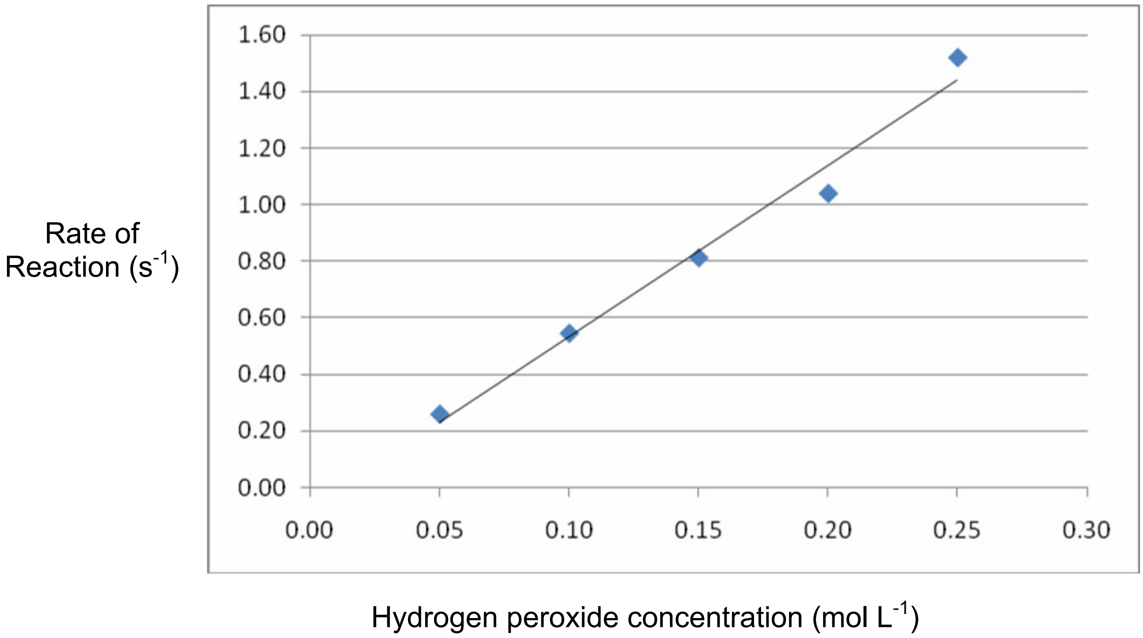
(e) Some of the luminol kits taken from storage in a forensic laboratory are slow to form luminescence. This could be due to loss of hydrogen peroxide through decomposition during storage. A forensic scientist performed some experiments to establish quantitatively the effect of hydrogen peroxide concentration on reaction rate. She recorded three trials at each hydrogen peroxide concentration she tested, measuring the time taken for the reaction to complete using a stopwatch. The table below shows the results.

Hydrogen peroxide concentration (mol L^{-1})	**Time for reaction to be complete, t (s)**	**Mean time for reaction to be complete, t_m (s)**	**Mean rate of reaction, $\frac{1}{t_m}$ (s^{-1})**
0.05	(i) 3.85 (ii) 3.82 (iii) 3.89	3.85	0.260
0.10	(i) 1.85 (ii) 1.83 (iii) 1.81	1.83	0.546
0.15	(i) 1.21 (ii) 1.25 (iii) 1.22	1.23	0.813
0.20	(i) 0.94 (ii) 0.96 (iii) 0.99	0.96	1.04
0.25	(i) 0.67 (ii) 0.63 (iii) 0.68	0.66	1.52

Complete the table (i.e. calculate the mean time for the reaction to be compete [t_m] and the mean rate of reaction $\left(\frac{1}{t_m}\right)$ for each hydrogen peroxide concentration), and plot the data on the graph below. (3 marks)

See table.

(3 marks)



Mark	Description
3	Three of the following three correct: (i) 'Mean time for reaction to be complete' column **AND** (ii) 'Mean reaction rate' column correct **AND** (iii) a correct plot (independent and dependent variables on correct axis, axes labelled, data accurately plotted)
2	Two of three items correct (a correct plot of incorrect data achieves 1 mark)
1	One of three items correct (a correct plot of incorrect data achieves one mark)
0	Question incorrectly answered or not attempted

(e) Name **one** variable that must be kept constant during this experiment. (1 mark)

Temperature OR concentration of hydroxide OR amount of catalyst OR state of subdivision of catalyst OR any valid response.

Mark	Description
1	Any valid response (see above)
0	Question incorrectly answered or not attempted

(f) How could the reaction endpoint be identified in this experiment? (1 mark)

Appearance of luminescence

Mark	Description
1	Appearance of luminescence (or any valid method)
0	Question incorrectly answered or not attempted

(g) What can the scientist conclude about the reaction rate from this experiment? (2 marks)

Increasing H_2O_2 concentration increases the rate of reaction. The results also show that the relationship is (very close to) linear over the concentration range studied *i.e.* rate $\propto$ $[H_2O_2]$.

Mark	Description
2	Increasing H_2O_2 concentration increases the rate of reaction **AND** relationship is linear
1	Either increasing H_2O_2 concentration increases the rate of reaction **OR** relationship is linear
0	Question incorrectly answered or not attempted

Question 42 **(14 marks)**

Manned spacecraft require that the level of carbon dioxide in the vehicle not exceed certain limits. The optimal working limit for carbon dioxide is a pressure of 5.06×10^{-2} kPa.

(a) If the temperature in a Russian Soyuz space vehicle is 20.0 °C, and the volume of its flight cabin is 3.60×10^{4} L, calculate the number of moles of carbon dioxide that will give this optimal pressure. (2 marks)

$$PV = nRT \Rightarrow n = \frac{PV}{RT} = \frac{(5.06 x 10^{-2} kPa)(3.60 x 10^{4} L)}{8.315 J K^{-1} mol^{-1} x 293 K} = 7.48 x 10^{-1} mol CO_2$$

OR

1 mole in 22.41 L at 273.1 K has a pressure of 101.3 kPa

Number of moles is directly proportional to pressure and to volume and inversely proportional to temperature.

$$\therefore 1 x \frac{5.06 x 10^{-2} kPa}{101.3 kPa} x \frac{3.60 x 10^{4} L}{22.41 L} x \frac{273.1 K}{293.1 K} = 7.48 x 10^{-1} mol$$

Mark	Description
2	7.48×10^{-1} mol (or an answer between 7.40×10^{-1} mol and 7.55×10^{-1} mol)
1	Incorrect answer, but some logic shown somewhere
0	Question incorrectly answered or not attempted

(b) The concentration of carbon dioxide in exhaled air is 3.7 % by volume. If the space craft has 3 crew who on average breathe 15 times per minute and exhale 500 mL each breath how many mole of carbon dioxide will be produced by the crew on an 8 day mission? Assume a pressure of 101.3 kPa within the lungs and body temperature of 37.8 °C. (4 marks)

V(exhaled air in 8 days) = $3 crew \times 15 \frac{exhalations}{min} \times 1440 \frac{min}{day} \times 8 days \times 500 \frac{mL}{exhalation} = 2.59 \times 10^5 L$

$v(CO_2) = 2.59 \times 10^5 L \times 3.7\% = 9590.4 L = 9.59 \times 10^3 L (3 s.f.)$

$$n = \frac{PV}{RT} = \frac{(101.3 kPa)(9590.4 L)}{8.315 JK^{-1}mol^{-1} \times 310.8 K} = 375.91 mol = 3.76 \times 10^2 mol CO_2$$

Mark	Description
4	3.76×10^2 mol (or an answer between 3.72×10^2 mol and 3.79×10^2 mol)
3	1.01×10^4 mol [Incorrect volume of CO_2 used (uses 2.59 x 10^5 L)]
2	Does not correctly calculate volume of air (and therefore $v(CO_2)$, but attempts to and completes the question otherwise correctly)
1	Question incorrectly answered, but some logic shown somewhere
0	Question incorrectly answered or not attempted

(c) What additional pressure of carbon dioxide would this give in the cabin of the space vehicle if none was removed? (2 marks)

$$P = \frac{nRT}{V} = \frac{(3.76 \times 10^2 mol)(8.315 JK^{-1} mol^{-1})(293 K)}{3.60 \times 10^4 L} = 25.44 kPa = 2.54 \times 10^1 kPa (3 s.f.)$$

Mark	Description
2	2.54×10^1 kPa (or an answer between 2.51×10^{-1} mol and 2.56×10^{-1} mol) [**or** question correctly completed with an incorrect number of moles of CO_2 derived in part (b) of the question]
1	Incorrect answer, but some logic shown somewhere
0	Question incorrectly answered or not attempted

(d) How many mole of carbon dioxide need to be removed from the air of the cabin during the 8-day mission to achieve the optimal working pressure of 5.06×10^{-2} kPa for the carbon dioxide? (1 mark)

$n(CO_2)$ to be removed = 375.9 – 0.0748 = 375.1 mol = 375 (3 s.f.)

Mark	Description
1	375 mol (or an answer between 371 mol and 379 mol)
0	Question incorrectly answered or not attempted

The carbon dioxide can be removed by passing it through a series of scrubbers.

(e) The Russian Soyuz spacecraft has potassium superoxide, KO_2, in its scrubbers. When air in spacecraft passes through scrubbers containing potassium superoxide the carbon dioxide in the air reacts with KO_2 producing oxygen gas. The equation for this reaction is below.

$$4\ KO_2(s) \quad + \quad 2\ CO_2 \quad \rightarrow \quad 2\ K_2CO_3(s) \quad + \quad 3\ O_2(g)$$

What mass of potassium superoxide is needed to remove 345 moles of carbon dioxide?

(2 marks)

2 mol KO_2 removes 1 mol CO_2

Require 2 × 345 mol KO_2 = 690 mol

∴ mass required = 690 mol × 71.1 g mol^{-1} = 4.9059 × 10^4 g = 49.1 kg (3 s.f.)

Mark	Description
2	49.1 kg (or an answer between 44.2 kg and 54.0 kg)
1	Number of moles of KO_2 correct but mass calculated incorrectly **OR** number of moles KO_2 incorrect but mass calculated correctly
0	Question incorrectly answered or not attempted

(f) Additional scrubbers containing lithium hydroxide are also used in the Soyuz spacecraft to help keep the pressures of carbon dioxide and oxygen at the appropriate levels. Lithium hydroxide reacts with carbon dioxide according to the following equation.

$$2\ LiOH(s) \quad + \quad CO_2(g) \quad \rightarrow \quad LiCO_3(s) \quad + \quad H_2O(\ell)$$

These scrubbers have an efficiency of about 54 %. What mass of lithium hydroxide will be needed to absorb 5.18 mol carbon dioxide from the air in the space vehicle cabin?

(3 marks)

2 mol LiOH removes 1 mol CO_2

∴ 2 × 5.18 = 10.36 mol LiOH removes 5.18 mol CO_2

mass LiOH required if scrubbers 100 % efficient = 10.36 × 23.94 = 248 g

Scrubbers 54 % efficient

∴ mass required = $\frac{100}{54} x\ 248.02 = 459.29g = 459g(3s.f.)$

Mark	Description
3	459 g (or an answer between 454 g and 463 g)
2	Mass LiOH if scrubbers 100 % efficient calculated
1	Number of moles of LiOH calculated
0	Question incorrectly answered or not attempted

Question 43 **(12 marks)**

Select a row (an example is Period 3) of the Periodic Table, and describe and explain the relationship between the number of valence electrons and an element's

i. bonding capacity
ii. position on the Periodic Table
iii. physical and chemical properties
iv. ionisation energy

Your answer should be approximately one to two pages in length.

Marks should be awarded for relevant chemistry, and the ability to write coherent sentences. It is not expected that all points listed below be covered, but each part of the question must be addressed for full marks to be awarded.

Diagrams, graphs and equations may be used to help where appropriate.
Some candidates may prefer to write 4 paragraphs, one for each part.
Other candidates may prefer to integrate the various parts of the question.

Points:
Bonding capacity

- **The number of valence electrons that an element can gain, lose or share in a bond**
- ***E.g.*** **Na has 1 valence electron, so it has a bonding capacity of 1; it tends to lose this to form a +1 ion.**
- **Mg has 2 valence electrons, so it has a bonding capacity of 2; it tends to lose these to form a +2 ion.**
- **S has 6 valence electrons, and it has a bonding capacity of 2 as it tends to gain two electrons to form a –2 ion.**
- **Cℓ has 7 valence electrons, and it has a bonding capacity of 1 as it tends to gain one electron to form a –1 ion.**
- **This results in compounds such as NaCℓ, $MgC\ell_2$, MgO**
- **Some students may discuss the high stabilities of the noble gases such as Ar.**

Position in the Periodic Table

- **Elements are placed in order of atomic number, which means in order of increasing number of electrons. Successive elements along a row have successively increasing numbers of valence electrons.**
- ***E.g.*** **Row 3 Na electron configuration 2,8,1**
  Mg electron configuration 2,8,2, etc
- **The number of valence (outer shell) electrons has a strong effect on the element's bonding, and therefore chemical, properties.**
- **Students may also comment on the elements on the left and the elements on the right and perhaps relate first ionisation energy to the metallic characteristics of the element.**

Physical and chemical properties

- **The number of valence electrons influences the element's physical and chemical properties**
- **Group 1 elements (*e.g.* Na 2,8,1) have one valence electron. Since this is weakly held, it can move under the influence of an electric field, and so conduct electricity. This loosely held valence electron is also responsible for the ability of metals like Na to conduct heat.**
- **Na tends to lose its one valence electron and form ionic bonds with non metals such as oxygen (which tends to gain 2 electrons to form a –2 ion)**

(Points similar to the above may also be discussed in relation to the non-metallic elements on the right of the Periodic Table.)

Ionisation Energy

- **Graph of first ionisation energy (IE) of elements from Na to Ar**
- **Na has one valence electron which is easily lost so Na has a relatively low first IE and a very high second IE**
- **Mg has two valence electrons; so Mg has a relatively low first IE, a higher second IE but a very high third IE**
- **Thus, first IE generally increases across a row of the Periodic Table**
- **Therefore the more valence electrons possessed by an element, the greater the first IE.**
- **Group 16 and 17 elements such as S and Cℓ are involved in covalent bonding because of their high first IEs.**

Mark	Description
10-12	Coherently describes and explains all parts, at least 15 points made, some with supporting examples and/or diagrams.
7-9	All parts clearly addressed but only 10-14 points made; or at least 15 points made but only three parts addressed; few examples or diagrams
4-6	5-9 points made but only three parts addressed; or 8-12 points made but only two parts addressed; no, or one or two, examples or diagrams
1-3	Maximum of four points in two parts addressed
0	Question incorrectly answered or not attempted

End of questions