Government of **Western Australia**
Curriculum Council

WACE
Western Australian Certificate of Education

Western Australian Certificate of Education
Sample Examination, 2010

Question/Answer Booklet

CHEMISTRY
Stage 3

Please place your student identification label in this box

Student Number: In figures | | | | | | | | |

In words _____

_____

Time allowed for this paper
Reading time before commencing work: ten minutes
Working time for paper: three hours

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Multiple-choice Answer Sheet
Chemistry Data Sheet

To be provided by the candidate
Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set out by the Curriculum Council for this course

Important note to candidates
No other items may be taken into the examination room. It is your responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor before reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	25	25
Section Two: Short answer	12	12	60	70	35
Section Three: Extended answer	6	6	70	80	40
					100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010.* Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly unless instructed otherwise.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. 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.

See next page

Section One: Multiple-choice **25% (25 Marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time for this section is 50 minutes.

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1. Which of the following **best** explains why calcium and barium are chemically similar to each other and different from sodium?

   (a) They are both metals.
   (b) Their nuclei have the same number of protons.
   (c) They each have two valence electrons.
   (d) They both react with water giving hydrogen.

2. The element X belongs to Group 16 of the periodic table. Which one of the following statements is true about the element X?

   (a) X will be present as X^{2+} in ionic compounds.
   (b) X will be present as X^{2-} in ionic compounds.
   (c) X will mostly likely exist as uncombined atoms in its elemental state.
   (d) X will not in general form compounds.

3. Which one of the following lists the elements in order of decreasing first ionisation energy, that is, from highest to lowest?

   (a) Rb > K > Na > Li
   (b) Li > Mg > B > Aℓ
   (c) Ne > Cℓ > P > Aℓ
   (d) Li > C > N > Ne

4. An element X has the following five successive Ionisation Energies (in kJ mol^{-1})

   502, 4569, 6919, 9550, 13356

   What would be the formula of the compound formed when X reacts with sulfur?

   (a) X_2S
   (b) XS
   (c) XS_2
   (d) X_2S_3

5. Which one of the following statements is **false** regarding elements in the periodic table?

   (a) The number of protons increases across a period.
   (b) Atomic radius decreases across a period.
   (c) Group 18 elements are generally unreactive.
   (d) Electronegativity increases down a group.

See next page

6. Which one of the following **is not** a property of ionic compounds?

   (a) Generally higher melting points than covalent molecular substances
   (b) Strong conductors of electricity in the solid state
   (c) Dissociation of ions accompanies their dissolution in water
   (d) They are brittle solids

7. Which one of the following pairs of substances forms a buffer in aqueous solution?

   (a) H_2CO_3 and CO_3^{2-}
   (b) H_3O^+ and OH^-
   (c) $HC\ell$ and $C\ell^-$
   (d) HPO_4^{2-} and $H_2PO_4^-$

8. Which one of the following statements **does not** apply to a strong acid?

   (a) It has a weak conjugate base.
   (b) Its ionisation equilibrium lies to the right.
   (c) It has a strong conjugate base.
   (d) It is an electrolyte.

9. Which one of the following solids, when dissolved in water, would form a solution with a pH less than 7?

   (a) $NaCH_3COO$
   (b) RbF
   (c) NH_4NO_3
   (d) $Mg(OH)_2$

10. Which one of the following 0.01 mol L^{-1} solutions would give the fewest ions in solution?

    (a) NH_3
    (b) $NaC\ell$
    (c) H_2SO_4
    (d) $BaC\ell_2.2H_2O$

11. A chemist wishes to prepare a soluble fertiliser containing ions that are a source of nitrogen, phosphorus and potassium. Which one of these mixtures will produce a completely soluble fertiliser when added to water?

(a)	Na_3PO_4	$Ca(NO_3)_2$	$KC\ell$
(b)	K_2CO_3	$Ba(NO_3)_2$	K_3PO_4
(c)	K_2SO_4	$NH_4C\ell$	Na_3PO_4
(d)	$Ca(NO_3)_2$	KNO_3	Na_3PO_4

See next page

12. Which one of the following statements is **false** about Kinetic Theory as it relates to gas molecules?

    (a) It defines the temperature at which gas atoms or molecules have zero motion as absolute zero.
    (b) It assumes the distance between molecules increases with temperature.
    (c) It assumes that absolute zero is the lowest possible temperature attainable.
    (d) It assumes that molecular motion decreases with temperature.

13. Group 2 metals react vigorously with water according to the following molecular equation.

$$M(s) + 2\,H_2O(\ell) \rightarrow M(OH)_2 + H_2(g)$$

    In a particular experiment, equal masses of each of the following metals are added to an excess of water. Which metal will produce the greatest volume of hydrogen?

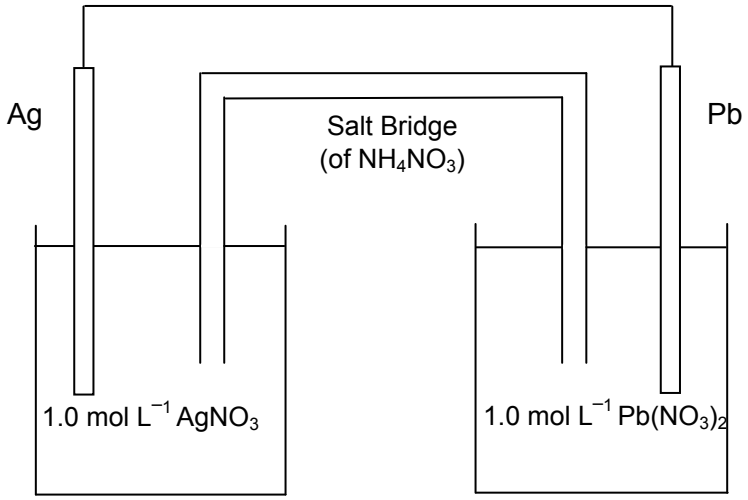
    (a) Mg
    (b) Ca
    (c) Sr
    (d) Ba

14. Which of the four elements (Fe, S, O or Cr) shown in bold below has the highest oxidation state?

    (a) **Fe**$C\ell_3$
    (b) Na_2**S**O_3
    (c) K_2Cr_2**O**$_7$
    (d) **Cr**$_2O_3$

See next page

15. A short rod of silver metal dips into a 1.0 mol L^{-1} solution of silver nitrate to create an Ag/Ag^+ half-cell. Similarly, a rod of lead metal dips into a 1.0 mol L^{-1} solution of lead(II) nitrate. The two rods are joined by a piece of copper wire. A salt bridge of ammonium nitrate, as shown in the diagram below, joins the two solutions.



Which one of the following will occur?

(a) Lead deposits from solution onto the lead rod.
(b) Electrons flow through the wire from the lead rod to the silver rod.
(c) Nitrate ions migrate through the salt bridge from the Pb/Pb^{2+} half-cell to the Ag/Ag^+ half-cell.
(d) The silver rod starts to dissolve.

16. Chlorine gas is bubbled through a solution of a salt, and the solution turns brown. A separate solution of the same salt is added to a solution of lead(II) nitrate, and a bright yellow precipitate is formed. Which of the following is the most likely identity of the ion causing the colour changes?

(a) iron(III)
(b) bromide
(c) iodide
(d) chromate

17. Which combination of the statements that follow applies to a primary standard?

I. It has a high molar mass.
II. It is easily oxidised.
III. It is not hygroscopic.
IV. It is either a strong acid or a strong base.

(a) Only I and III
(b) Only I and IV
(c) Only II and III
(d) Only III and IV

See next page

18. Which one of the following is the formula of the ion that is formed when one aluminium ion reacts with six water molecules?

(a) $[A\ell(H_2O)_6]^{3+}$
(b) $[A\ell(H_2O)_6]^{+}$
(c) $[A\ell(H_2O)_6]^{3-}$
(d) $[A\ell(H_2O)_6]^{-}$

19. Ethanol can be manufactured industrially by the reaction of ethene and water in the presence of acid catalyst as shown by the equilibrium below.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) + \text{energy}$$

Which one of the following changes to the system would increase the **yield** of the ethanol?

(a) Increasing the temperature at which the reaction is carried out
(b) Increasing the partial pressure of ethanol in the reaction chamber
(c) Using a larger quantity of catalyst in the reaction
(d) Using high pressure steam in the reaction

20. Which one of the following molecules is non-polar, but has polar covalent bonds?

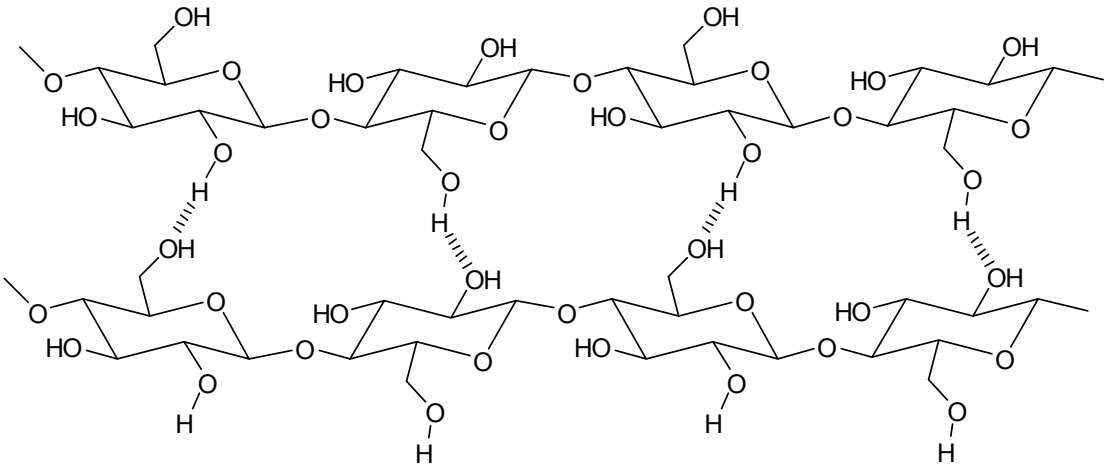
(a) tetrafluoromethane, CF_4
(b) ammonia, NH_3
(c) chlorine, $C\ell_2$
(d) water, H_2O

21. Which one of the following observations **could not** be explained in terms of hydrogen bonding?

(a) The boiling point of NH_3 is greater than that of CH_4.
(b) Water mixes readily with C_2H_5OH.
(c) Potassium iodide is more soluble in water than potassium fluoride.
(d) Propanol has a higher boiling point than propanal.

See next page

22. Fibres such as cotton and paper are made up of neighbouring polymeric chains of cellulose, which have many hydroxyl groups (OH) as illustrated below.



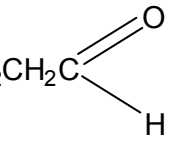
The strength of these fibres arises from the attractive forces, shown as dashed lines, between neighbouring cellulose chains. What is the name given to these forces of attraction?

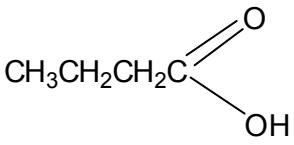
(a) covalent bonds
(b) hydrogen bonds
(c) ionic bonds
(d) dispersion forces

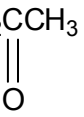
See next page

Questions 23 to 25 are related to the compounds I – IV shown below.

I $CH_3CH_2CH_2CH_2OH$

II 

III 

IV 

23. Which one of these compounds would have the suffix ‘oic acid’ included in its IUPAC name?

(a) I
(b) II
(c) III
(d) IV

24. Which two compounds may be described as structural isomers?

(a) I and II
(b) II and III
(c) I and III
(d) II and IV

25. Which two compounds could react to form an ester?

(a) I and III
(b) II and III
(c) III and IV
(d) II and IV

End of Section One

Section Two: Short answer **35% (70 Marks)**

This section has **12** 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.

- 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 60 minutes.

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	

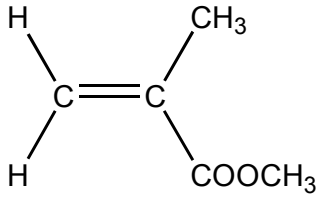
(1 mark)

Equation	$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$
Equilibrium constant expression	

(1 mark)

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)

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

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

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

Structure	Name

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

Structure	Name

See next page

Question 29 **(6 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)

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

(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

Explanation:

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: _____

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

Equation: _____

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: _____

_____

_____

_____

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

Observation: _____

_____

_____

_____

See next page

Question 32 **(7 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) _____

(ii) _____

(iii) _____

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. (2 marks)

_____

_____

_____

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)

_____

_____

_____

_____

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.

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

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)

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

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

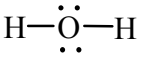
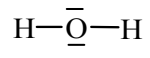
_____

(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)

See next page

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.

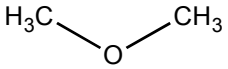
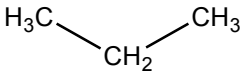
(for example, water  or  or  bent

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

See next page

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)
		
		
CH_3CH_3		
CH_3CH_2OH		

Question 36 **(10 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: _____

(ii) Reduction: _____

(iii) Overall: _____

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)

_____

_____

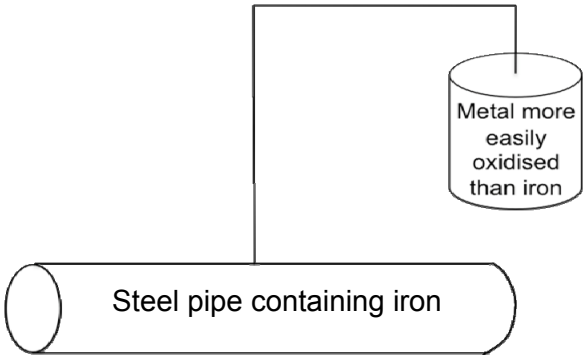
_____

_____

_____

See next page

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 one other metal that may be connected to a steel pipe as a cathodic protectant. (1 mark)

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

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

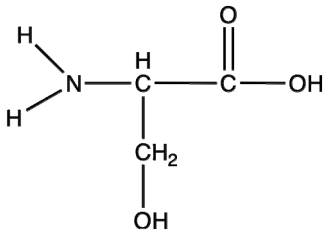
Anodic reaction: $Fe(s) \rightarrow Fe^{2+}(aq) + 2\ e^-$

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)

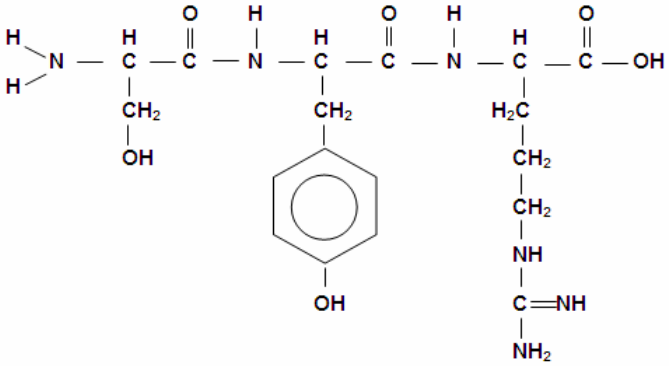
See next page

Question 37 **(3 marks)**

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



(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)



End of Section Two

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Section Three: Extended answer **40% (80 Marks)**

This section contains **six (6)** 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.

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Suggested working time for this section is 70 minutes.

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) Complete and balance the equation for the reaction that occurs after the powders are mixed with water. (2 marks)

Equation: $Ca(OH)_2(aq) + CuSO_4(aq) \rightarrow$ _____

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

See next page

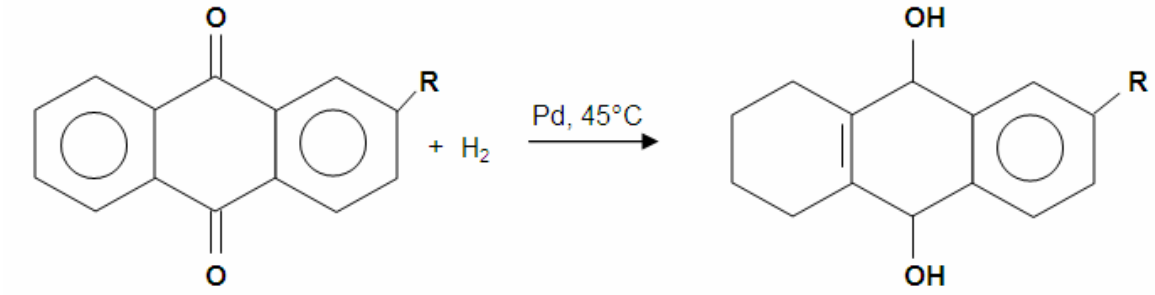
(c) Calculate the mass of reagent in excess. (2 marks)

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

Question 39 **(21 marks)**

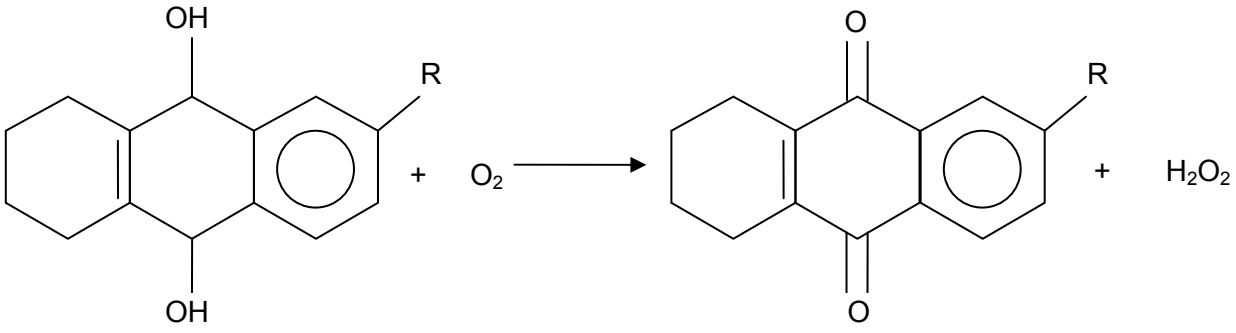
Hydrogen peroxide (H_2O_2) is an important industrial oxidising agent. Its manufacture can be summarised into the steps outlined below.

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.



1 **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**

See next page

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)

(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)

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

(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)

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				

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

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

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

See next page

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

(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)

(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 (h) and (i), calculate the concentration of the hydrogen peroxide solution as a % w/w and state whether the production process is operating appropriately. (1 mark)

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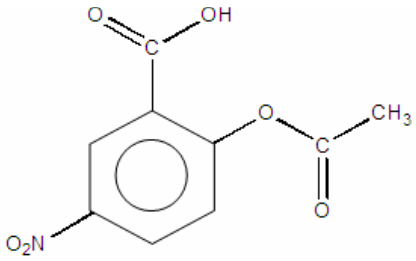
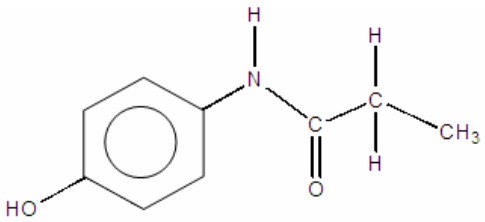
Question 40 **(11 marks)**

You are the senior chemist working in an analytical laboratory and the local veterinarian contacts you. He 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

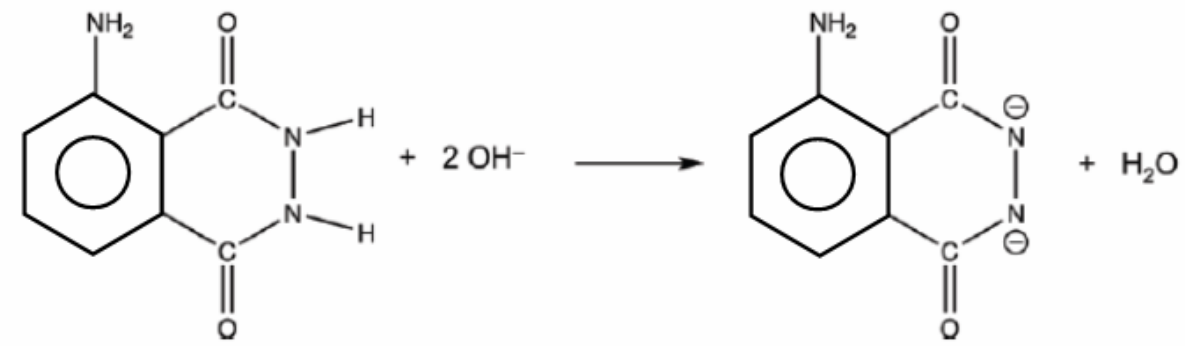
(b) You perform a combustion analysis of the 0.229 g sample, which produces 0.5508 g CO_2, 0.1368 g H_2O and 0.0639 g of NO_2. Determine which one of the painkillers the dog swallowed. (10 marks)

See next page

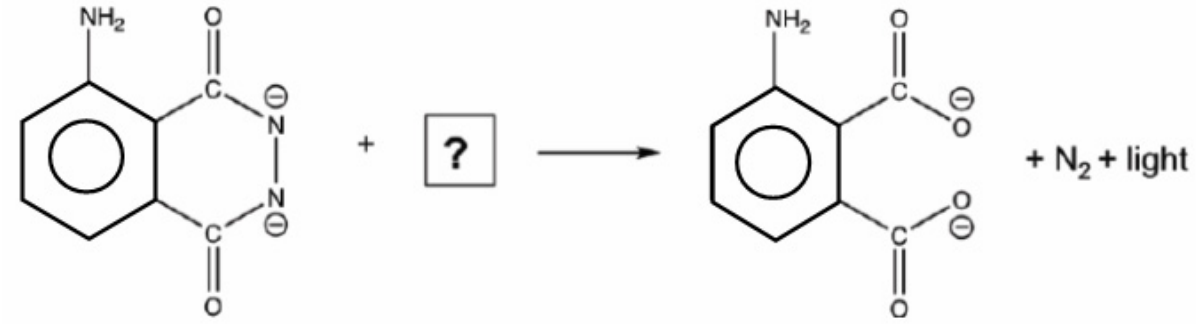
Question 41 **(13 marks)**

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:



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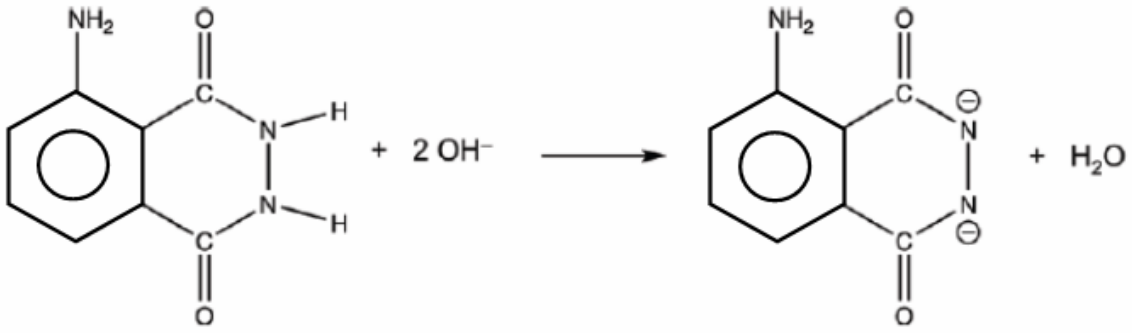
(a) Identify all conjugate acid and base pairs in Part A of the reaction. Join each pair with a line, and label the conjugate acid and base of each pair appropriately. The equation for this reaction is repeated below. (2 marks)



(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)

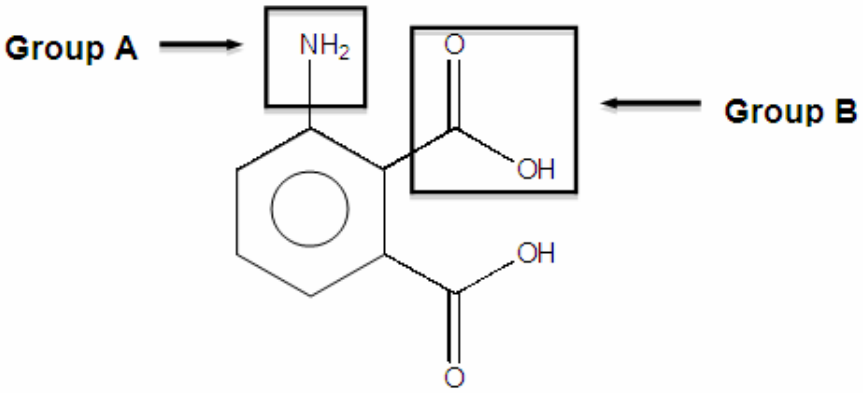
Hint: In this reaction, H_2O_2 is both oxidised and reduced.

Equation: _____

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

_____

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



Group A: _____

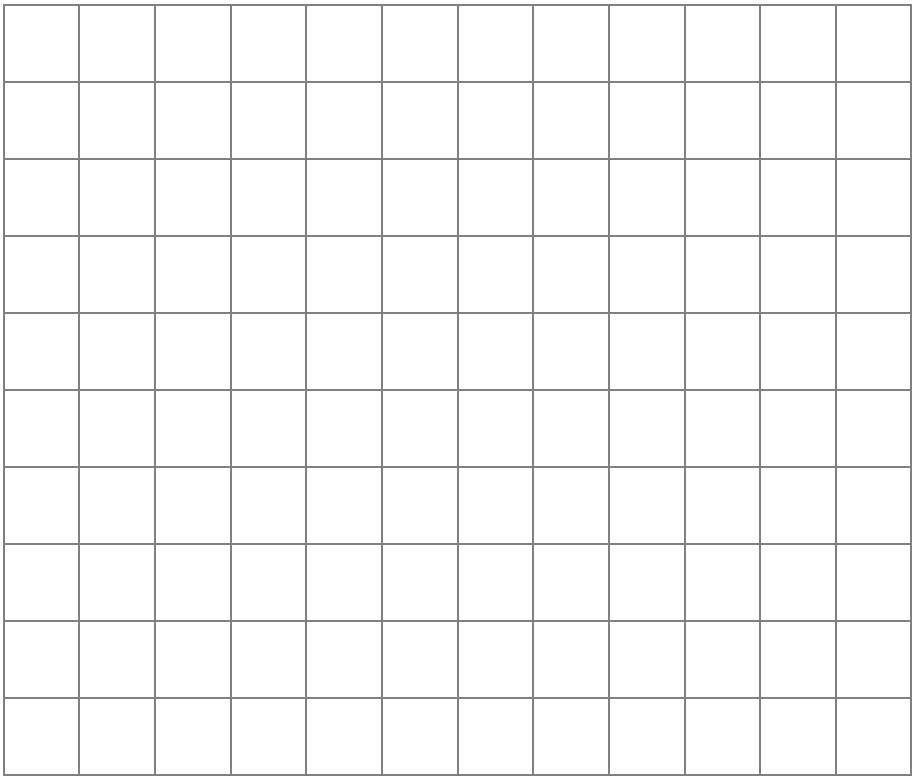
Group B: _____

See next page

(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 with luminol 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		
0.10	(i) 1.85 (ii) 1.83 (iii) 1.81		
0.15	(i) 1.21 (ii) 1.25 (iii) 1.22		
0.20	(i) 0.94 (ii) 0.96 (iii) 0.99		
0.25	(i) 0.67 (ii) 0.63 (iii) 0.68		

Complete the table (i.e. calculate the mean (average) 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)



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

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

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

See next page

Question 42 **(14 marks)**

Manned spacecraft require that the level of carbon dioxide in the vehicle does 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)

(b) The concentration of carbon dioxide in exhaled air is 3.7 % by volume. If the spacecraft has 3 crew who on average breathe 15 times per minute and exhale 500 mL each breath, how many moles 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)

See next page

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

(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)

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 the 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.

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

What mass of potassium superoxide is needed to remove 345 moles of carbon dioxide? (2 marks)

See next page

(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.

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

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)

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.

End of questions

Additional working space

Additional working space

Additional working space

Additional working space

Additional working space

Additional working space

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