Government of **Western Australia**
School Curriculum and Standards Authority

WACE
Western Australian Certificate of Education

Western Australian Certificate of Education Examination, 2012

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

Number of additional answer booklets used (if applicable):

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction tape/fluid, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations

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.

Ref: 12-024

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of total 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
				Total	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2012*. 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 then shade your new answer. Do not erase or use correction fluid/tape. 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 your answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to three significant figures and include appropriate units where applicable.

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.

6. The Chemistry Data Sheet is **not** handed in with your Question/Answer Booklet.

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 then shade your new answer. Do not erase or use correction fluid/tape. 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: 50 minutes.

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1. Two neutral atoms, L and M, have the electron configurations shown below:

   L: 2,8,5 M: 2,8,7

   Which one of the following describes the bonding and gives the formula of the compound most likely formed when L and M combine?

   (a) covalent; LM_3
   (b) covalent; L_3M
   (c) ionic; L_2M_5
   (d) ionic; L_7M_5

2. An element X has ions XO_2^- and XO_3^-. Which one of the following is X?

   (a) sulfur
   (b) nitrogen
   (c) chromium
   (d) phosphorus

3. Which one of the following describes the shape and molecular polarity for the NBr_3 molecule?

   (a) pyramidal; polar
   (b) pyramidal; non-polar
   (c) trigonal planar; polar
   (d) trigonal planar; non-polar

See next page

4. Consider the following statements.

In the Periodic Table,

(i) elements are arranged in increasing order of atomic mass.
(ii) elements with similar chemical properties are in groups.
(iii) atomic radii of elements decrease across the periods.
(iv) first ionisation energies of elements increase down the groups.

Which of the statements above are correct?

(a) (i) and (ii)
(b) (ii) and (iii)
(c) (iii) and (iv)
(d) (i), (ii) and (iii)

5. Which one of the following correctly lists the electronegativity of the given elements in increasing order?

(a) Br < Se < As < Ge
(b) Ge < As < Se < Br
(c) As < Se < Br < Ge
(d) Se < Br < Ge < As

6. Consider the following equation:

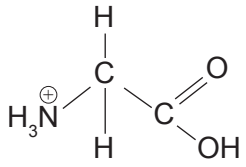
$$HS^-(aq) + CO_3^{2-}(aq) \rightleftharpoons S^{2-}(aq) + HCO_3^-(aq)$$

Which one of the following is **not** true of this equation?

(a) HCO_3^- is acting as a Brønsted-Lowry acid.
(b) CO_3^{2-} is acting as a conjugate base.
(c) HS^- is acting as a conjugate base.
(d) S^{2-} is acting as a Brønsted-Lowry base.

See next page

7. Consider the list below.

(i) PO_4^{3-}
(ii) NaH_2PO_4
(iii) 
(iv) $NH_2CH_2COO^-$
(v) Na_2HPO_4
(vi) $HC\ell$

Which two of the above species, when mixed together in water, form a buffer solution?

(a) (i) and (ii)
(b) (ii) and (v)
(c) (iii) and (iv)
(d) (i) and (vi)

8. Consider the following list of compounds:

(i) KNO_3
(ii) Na_3PO_4
(iii) Fe_2O_3
(iv) Na_2S
(v) $Ba(OH)_2$
(vi) $A\ell C\ell_3$
(vii) $Ca(NO_3)_2$

Which of the above compounds will dissolve in water to give a basic solution?

(a) (i), (ii), (iii), (iv) and (v)
(b) (ii), (iii), (iv), (v), (vii)
(c) (ii), (iv), (v)
(d) (ii), (iv)

9. Identify the oxidant in the following reaction:

$$2\ A\ell(s) + Cr_2O_3(s) \rightarrow A\ell_2O_3(s) + 2\ Cr(s)$$

(a) $A\ell$
(b) Cr_2O_3
(c) O
(d) Cr

See next page

10. Which one of the following is commonly used as an oxidising agent?

(a) $PbSO_4(s)$
(b) $H_2O(\ell)$
(c) $MnO_4^-(aq)$
(d) $CO_2(g)$

11. Which one of the reactions below is **most** likely to occur spontaneously?

(a) $H_2(g) + PbSO_4(s) \rightarrow 2\ H^+(aq) + Pb(s) + SO_4^{2-}(aq)$
(b) $Zn^{2+}(aq) + Fe(aq) \rightarrow Zn(s) + Fe^{2+}(aq)$
(c) $Cu^{2+}(aq) + Ni(s) \rightarrow Cu(s) + Ni^{2+}(aq)$
(d) $2\ Fe^{3+}(aq) + H_2O_2(aq) \rightarrow O_2(g) + 2\ Fe^{2+}(aq) + 2\ H^+(aq)$

12. Some solid magnesium carbonate is added to dilute hydrochloric acid. Which one of the following equations best represents the reaction that occurs?

(a) $MgCO_3 + 2\ HC\ell \rightarrow MgC\ell_2 + H_2O + CO_2$
(b) $MgCO_3 + 2\ H^+ \rightarrow Mg^{2+} + H_2O + CO_2$
(c) $CO_3^{2-} + 2\ HC\ell \rightarrow 2\ C\ell^- + H_2O + CO_2$
(d) $CO_3^{2-} + 2\ H^+ \rightarrow H_2O + CO_2$

13. Concentrated sulfuric acid is spilt on a bench top in a laboratory. Which one of the following would be the **most** suitable substance to use in the first step in safely cleaning up the spilt acid?

(a) 1.0 mol L^{-1} NaOH solution
(b) water
(c) $NaHCO_3$ powder
(d) 1.0 mol L^{-1} Na_2CO_3 solution

14. A student prepares two solutions, A and B. Solution A is prepared by dissolving 2.5 mole of $KC\ell$ in water, and Solution B is prepared by dissolving 2 mole of $Ca(NO_3)_2$ in water. Which one of the following statements is correct?

(a) A and B contain the same number of ions.
(b) A and B contain no ions.
(c) Solution A contains more ions than Solution B.
(d) Solution B contains more ions than Solution A.

See next page

15. Which one of the following is the formula of the ion that is formed when one chromium(III) ion reacts with six water molecules?

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

16. Which one of the following pairs of 0.1 mol L^{-1} solutions will form a white precipitate when mixed?

(a) KI and $Pb(NO_3)_2$
(b) K_2SO_4 and $NaNO_3$
(c) $(NH_4)_2SO_4$ and $NaNO_3$
(d) $Pb(NO_3)_2$ and Na_2CO_3

17. The reaction of iron(III) oxide with carbon monoxide gas is shown below:

$$Fe_2O_3(s) + 3\ CO(g) \rightleftharpoons 2\ Fe(\ell) + 3\ CO_2(g)$$

Which one of the following changes to the system will decrease the rate of the forward reaction?

(a) decreasing the volume of the reaction vessel
(b) decreasing the pressure of CO(g) in the vessel
(c) decreasing the $Fe_2O_3(s)$ particle size
(d) decreasing the concentration of $CO_2(g)$ in the system

18. Ammonium chloride ($NH_4C\ell$) dissolves readily in water at room temperature. If a sample of ammonium chloride is dissolved in a beaker of water, the beaker becomes cold to the touch. Which one of the following is the **best** explanation for this observation?

(a) The reaction is exothermic with a small activation energy.
(b) The reaction is exothermic with a large activation energy.
(c) The reaction is endothermic with a small activation energy.
(d) The reaction is endothermic with a large activation energy.

See next page

19. Consider the following properties of materials.

(i) electrical non-conductor in the solid state
(ii) electrical conductor in the molten state
(iii) electrical non-conductor when dissolved in water
(iv) malleable
(v) ductile
(vi) brittle
(vii) low melting point
(viii) low solubility in water

Which of these properties are **generally** associated with a covalent molecular substance?

(a) (iv), (v), (viii)
(b) (i), (iii), (iv), (vii)
(c) (ii), (iv), (v)
(d) (i), (iii), (vi), (vii), (viii)

20. An aluminium pot containing a volume of water is placed on a burner. When the water reaches approximately 45°C, some bubbles can be seen forming on the inner surface of the pot. Which one of the following explains the appearance of the bubbles?

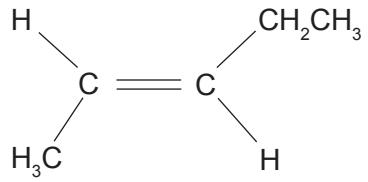
(a) Some of the water in the pot has begun to boil.
(b) The impurities in the water are reacting with the aluminium pot to form a gas.
(c) Some of the water is decomposing to H_2 and O_2 gases.
(d) As the temperature of the water increases, the solubility of dissolved gases decreases.

21. Which one of the following is a substitution reaction?

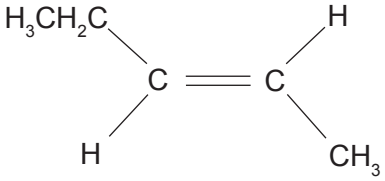
(a) $CH_3CH_2CH_2CH_2Br + Br_2 \rightarrow CH_3CH_2CH_2CHBr_2 + HBr$
(b) $CH_3CH_2CHCH_2 + Br_2 \rightarrow CH_3CH_2CHBrCH_2Br$
(c) $CH_3CH_2CH_2COOH + CH_3OH \rightarrow CH_3CH_2CH_2COOCH_3 + H_2O$
(d) $CH_3CH_2CHCH_2 + H_2 \rightarrow CH_3CH_2CH_2CH_3$

See next page

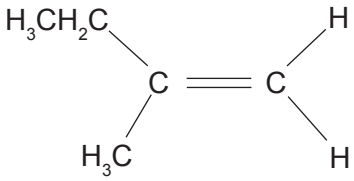
Examine the structures for compounds (i), (ii), (iii) and (iv) below to answer Questions 22 to 24.



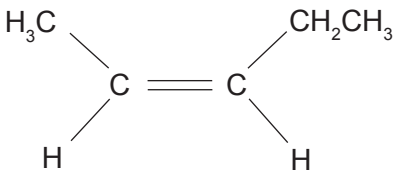
(i)



(ii)



(iii)



(iv)

22. Which of these compounds are geometric isomers?

(a) (i) and (ii)
(b) (i), (ii) and (iii)
(c) (i) and (iv)
(d) (iii) and (iv)

23. How many moles of oxygen will be consumed in the complete combustion of 1 mole of compound (i)?

(a) 1 mol
(b) 3.5 mol
(c) 5 mol
(d) 7.5 mol

24. Which one of the following is the product from the reaction of bromine with Compound (iii)?

(a) $CH_3CH_2CBr(CH_3)CH_2Br$
(b) $CH_3CH_2BrCH(CH_3)CH_3$
(c) $CH_3CH_2BrCH(CH_3)CH_2Br$
(d) $CH_3CH_2CH(CH_3)CH_2Br$

25. Which one of the following will react with acidified potassium dichromate to give a ketone?

(a) $CH_3CH_2CH_2OH$
(b) CH_3CH_2CHO
(c) $CH_3CH(OH)CH_3$
(d) $(CH_3)_3COH$

End of Section One

See next page

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

This section has **12** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to three significant figures and include appropriate units where applicable.

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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- 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: 60 minutes.

Question 26 **(6 marks)**

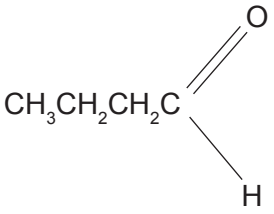
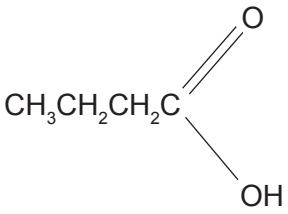
Consider the following substances, and place each in the appropriate column of the table below on the basis of their most significant type of intermolecular force.

CH_3OH
F_2
H_2S
C_6H_{12}
PF_3
HNO_3

Dispersion	Dipole-dipole	Hydrogen bonding	Ion-dipole

Question 27 **(4 marks)**

Examine the data in the table below. Use your knowledge of intermolecular forces to explain the differences in boiling points of the three compounds listed in the table.

Compound	Structure	Molar mass ($g\ mol^{-1}$)	Boiling point (°C)
Butan-1-ol	$CH_3CH_2CH_2CH_2OH$	74.24	118
Butanal		72.22	75
Butanoic acid		88.22	163

See next page

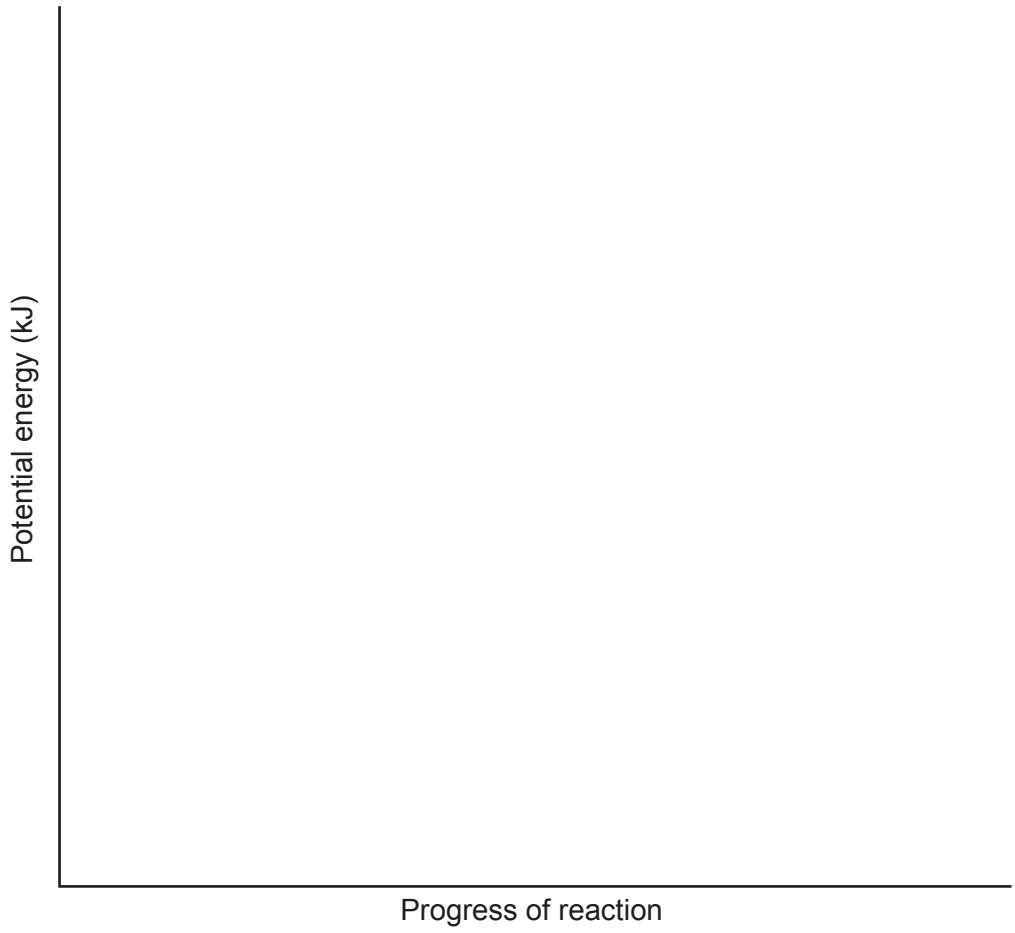
Question 28 **(7 marks)**

Consider the following reaction:

$$CO_2(g) + NO(g) \rightarrow CO(g) + NO_2(g) \qquad \Delta H = +226 \text{ kJ mol}^{-1},\ E_a = 360 \text{ kJ}$$

(a) On the axes below draw a potential energy diagram for this reaction. Label the activation energy (E_a) and enthalpy change (ΔH) for the reaction. Include a scale on the vertical axis.

On the same axes, use a dashed line to show a possible catalysed pathway. (5 marks)



(b) (i) How much energy is consumed when 2.5 mol of $CO_2(g)$ is reacted with 2.5 mol of NO(g)? (1 mark)

(ii) What is the activation energy when 2.5 mol of $CO_2(g)$ is reacted with 2.5 mol of NO(g)? (1 mark)

See next page

Question 29 **(6 marks)**

The white solid bismuth oxychloride reacts with concentrated hydrochloric acid to establish the following equilibrium:

$$BiOC\ell(s) + 2\ H^+(aq) \rightleftharpoons Bi^{3+}(aq) + C\ell^-(aq) + H_2O(\ell)$$

Three test tubes of the equilibrium system, 'A', 'B' and 'C' were prepared by adding excess $BiC\ell$ to concentrated hydrochloric acid.

Complete the table below by indicating the direction of the expected shift in equilibrium immediately following the changes stated in the table. Give the reason for the shift.

Test tube	Change	Direction of shift in equilibrium ('left', 'right' or 'no change')	Reason for shift
A	3 mL of water is added		
B	A few drops of concentrated nitric acid are added		
C	A few drops of concentrated silver nitrate solution are added		

See next page

Question 30 **(6 marks)**

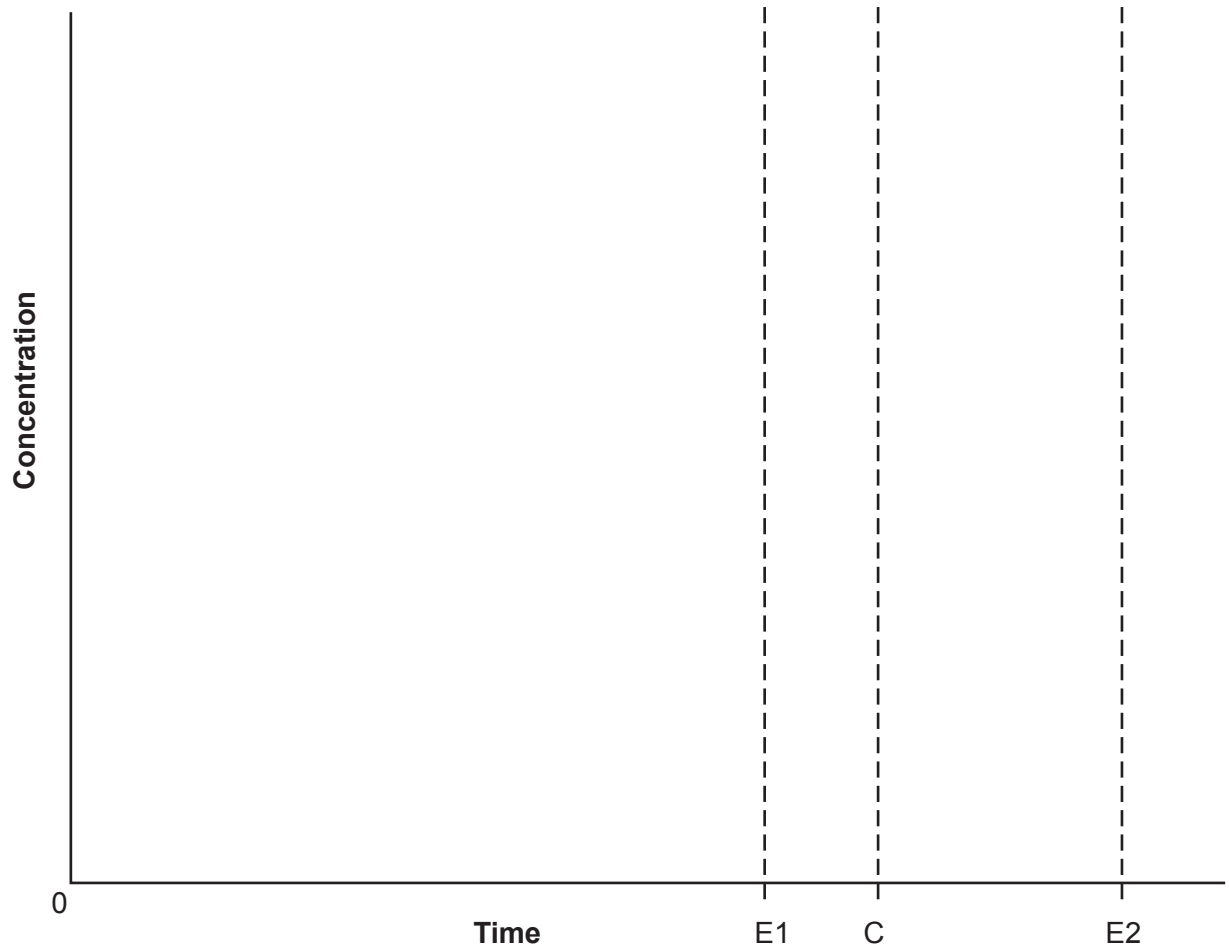
Silver chloride, $AgC\ell(s)$, is very sparingly soluble in water. However, it is soluble in ammonia solutions, due to the formation of the $[Ag(NH_3)_2]^+$ ion as shown in the equilibrium below:

$$AgC\ell(s) + 2\ NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq) + C\ell^-(aq)$$

The equilibrium constant, K, for this system is greater than 1 (>1).

A student mixes the reactants at time t = 0.

(a) On the axes below, draw separate curves to show how the concentrations of $NH_3(aq)$ and $[Ag(NH_3)_2]^+(aq)$ change with time as the system approaches, and finally reaches, equilibrium (Time E1). Clearly label your curve for $NH_3(aq)$ and your curve for $[Ag(NH_3)_2]^+(aq)$. Continue your curves from Time E1 to Time C. (3 marks)

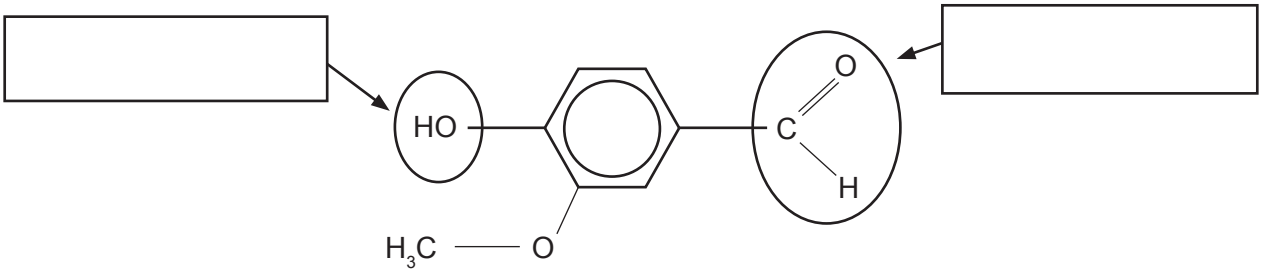


(b) At Time = C, as shown on the axis, a small quantity of concentrated $NaC\ell$ solution is added to the system, and the system is then again allowed to reach equilibrium at Time E2. On the same axes above, show how the concentrations of $NH_3(aq)$ and $[Ag(NH_3)_2]^+(aq)$ would change in response to the addition of $NaC\ell$ solution from Time C until equilibrium is reached at Time E2. (3 marks)

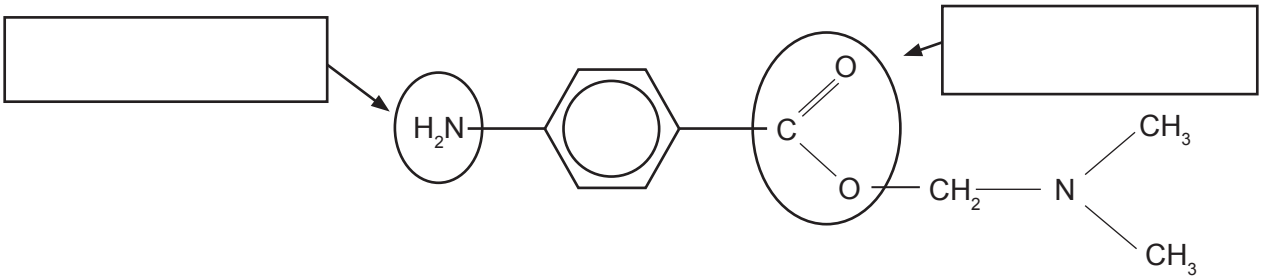
See next page

Question 31 **(4 marks)**

Examine the two compounds below. Compound 1 is the naturally occurring flavouring agent vanillin. Compound 2 is the local anaesthetic procaine. Name the functional groups circled in these two compounds.



Compound 1: Vanillin



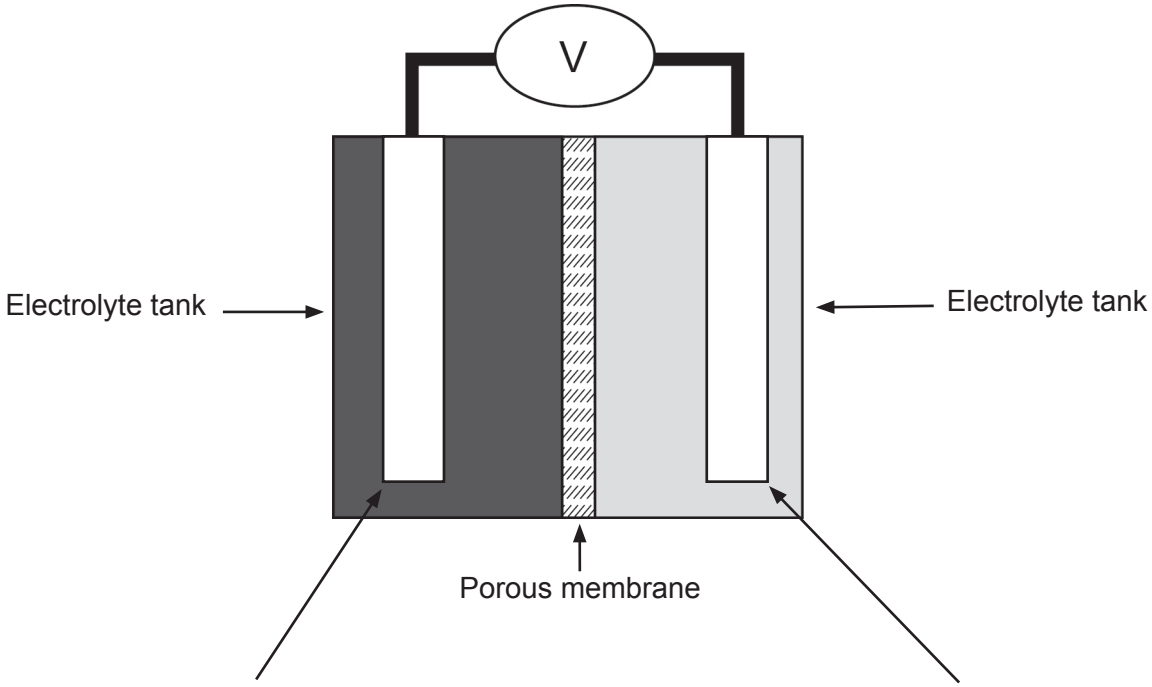
Compound 2: Procaine

See next page

Question 32 **(3 marks)**

The vanadium redox battery is an electrochemical cell that is being developed to store electricity produced by solar or wind power on a large scale.

The general structure of the vanadium redox battery is shown below. In this battery, $VO^{2+}(aq)$ is converted to $VO_2^{+}(aq)$ at one electrode, while $V^{3+}(aq)$ is converted to $V^{2+}(aq)$ at the other.



$H_2O(\ell) + VO^{2+}(aq) \rightarrow VO_2^{+}(aq) + 2\,H^{+}(aq) + e^{-}$

$V^{3+}(aq) + e^{-} \rightarrow V^{2+}(aq)$

(a) In the boxes above, identify and label both the anode and cathode. (1 mark)

(b) Draw an arrow on the diagram to indicate the direction of electron flow. (1 mark)

(c) State briefly how the porous membrane functions to complete the circuit. (1 mark)

See next page

Question 33 **(7 marks)**

When a few drops of concentrated sodium bismuthate solution, $NaBiO_3(aq)$, are added to a small volume of manganese(II) chloride solution, a deep purple solution is formed. The purple colour of the solution suggests that manganese is transformed to the +7 oxidation state as the permanganate ion, MnO_4^-. The colourless bismuth ion, $Bi^{3+}(aq)$, is also formed.

(a) Write the oxidation and reduction half equations, and the overall redox equation, for this reaction. (6 marks)

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

(b) In redox titrations involving permanganate or dichromate, the permanganate and dichromate must often be acidified. State why concentrated $HC\ell$ is not suitable for acidifying permanganate or dichromate solutions in redox titrations. (1 mark)

See next page

Question 34 **(6 marks)**

Write the equations and observations for each of the following. Include in your equations only those species that react. In each case, describe in full what you would observe, including:

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

(a) Excess sodium sulfide solution is mixed with copper(II) sulfate solution. (3 marks)

Equation	
Observation	

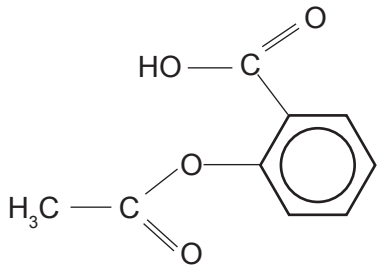
(b) Approximately 6 mol L^{-1} sulfuric acid is added to sodium acetate solution. (3 marks)

Equation	
Observation	

See next page

Question 35 **(6 marks)**

The active ingredient in aspirin tablets (acetylsalicylic acid) has the structure shown below. When acetylsalicylic acid is placed in water, some of it dissolves and ionises to form its conjugate base.



(a) Write the equation for the ionisation of acetylsalicylic acid in the space below, and identify the conjugate acid and base pairs in the reaction. Connect the acid-base pairs with a line, and label the conjugate acid in the pair 'A', and the conjugate base 'B'. (3 marks)

(b) Acetylsalicylic acid is a weak acid, and only partly ionises in water. It is poorly soluble in water, and far less soluble than a related compound, acetic acid (CH_3COOH). Explain why the water solubility of molecular acetylsalicylic acid is poor relative to that of CH_3COOH. (3 marks)

See next page

Question 36 **(6 marks)**

Water is able to react with itself in the process known as 'self-ionisation' or 'auto-ionisation'.

(a) Write the equation for the self-ionisation of water. (1 mark)

(b) At 25°C, the value of K_w is approximately 1.0×10^{-14}. At 10°C, the value of K_w is approximately 2.9×10^{-15}. (2 marks)

What are the relative concentrations of H^+ and OH^- ions in a neutral water solution at **25°C**? Circle the correct answer.

$[H^+] > [OH^-]$ $[H^+] < [OH^-]$ $[H^+] = [OH^-]$

What are the relative concentrations of H^+ and OH^- ions in a neutral water solution at **10°C**? Circle the correct answer.

$[H^+] > [OH^-]$ $[H^+] < [OH^-]$ $[H^+] = [OH^-]$

(c) Consider the values of K_w at 10°C and 25°C, and state whether the self-ionisation of water is an endothermic or exothermic process. Give a reason to support your answer. (3 marks)

See next page

Question 37 **(9 marks)**

Oxalic acid dihydrate ($H_2C_2O_4 \cdot 2H_2O$) is a primary standard used to standardise potassium permanganate solutions, which can be used for volumetric analysis.

(a) List **two** properties of oxalic acid that make it a good primary standard. (2 marks)

(b) A student was asked to prepare a standard solution of oxalic acid of approximate concentration 0.05 mol L^{-1}. The equipment listed below was available.

electronic balance	distilled water (20 L)
beakers (20 mL, 50 mL, 100 mL, 250 mL)	stirring rod
volumetric flasks (250 mL, 500 mL)	wash bottle
oxalic acid ($H_2C_2O_4 \cdot 2H_2O$) (5 g)	weighing boats

Give a step-by-step, detailed description of a procedure for preparing the standard oxalic acid solution. Perform and include any necessary calculations. (7 marks)

End of Section Two

See next page

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

This section contains **six (6)** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to three significant figures.

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: 70 minutes.

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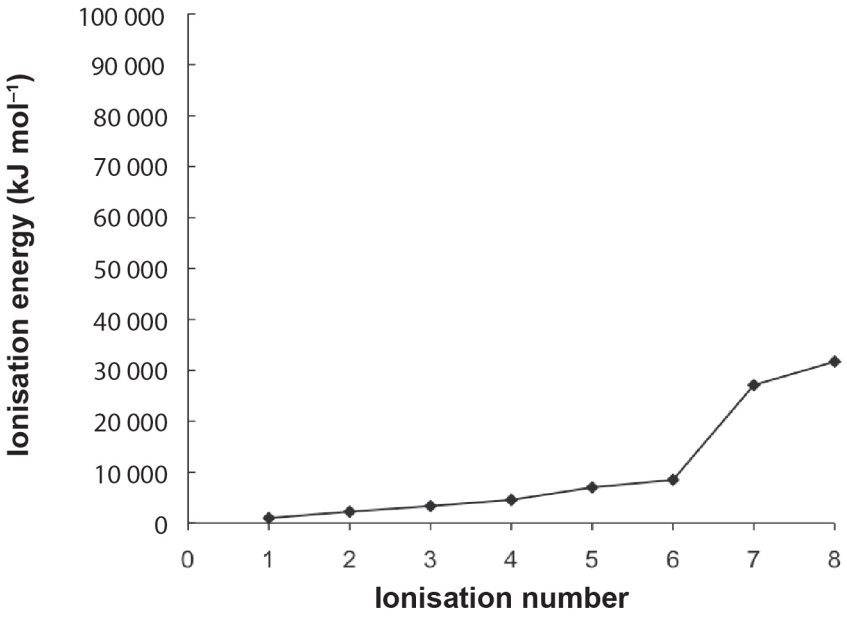
See next page

Question 38 **(6 marks)**

A plot showing the successive ionisation energies of sulfur is given below.



(a) Define ionisation energy, and explain the gentle increase in moving from the first ionisation energy to the sixth ionisation energy for sulfur. (2 marks)

(b) Explain the significant increase in moving from the sixth to the seventh ionisation energy for sulfur. (2 marks)

(c) On the same axes above, sketch the graph you would anticipate for the first eight successive ionisation energies of oxygen. (2 marks)

See next page

Question 39 **(18 marks)**

Qualitative analysis of an organic compound showed that it contained only carbon, hydrogen and oxygen. A quantitative study of the same compound was performed, in which a 0.5096 g sample was burnt in excess oxygen to produce 0.4160 g of water and 700.7 mL of carbon dioxide, collected at 100.0°C and 102.8 kPa.

(a) Determine the empirical formula of the compound. (10 marks)

See next page

(b) A second 0.4832 g sample of the compound was heated to 261°C. The vaporised sample was found to exert a pressure of 241 kPa in a 100.0 mL container. Use this information to determine the molecular formula of the compound. (4 marks)

(c) When the original compound was reacted with acidified ethanol it produced a fruity smelling liquid. Infer the structure of the original compound, and draw its structure in the box below. Name the original compound. (2 marks)

Name: _____

(d) Describe briefly and give observations for an additional chemical test to confirm the identity of the functional group in the original compound. (2 marks)

See next page

Question 40 **(16 marks)**

Sulfur dioxide is used as a preservative in wines because of its antimicrobial and antioxidant capacity. It dissolves readily in water, with a small quantity binding to compounds in wine but most, at the typical pH of wine of 3 to 4, existing as hydrogensulfite ion.

A winemaker wishes to keep the concentration of sulfur dioxide in wine at 180 ppm. During the manufacturing process, wine is periodically sampled and the concentration of sulfur dioxide measured using a redox titration.

The titration involves the reaction of the hydrogensulfite ion with iodine. The equation for the reaction is

$$HSO_3^-(aq) + I_2(aq) + H_2O(\ell) \rightarrow HSO_4^-(aq) + 2\ I^-(aq) + 2\ H^+(aq)$$

A 50.0 mL aliquot of wine is pipetted into a conical flask, indicator is added to the flask and it is then titrated against a standard 0.0107 mol L^{-1} iodine solution. This process is repeated. The results are shown in the table below.

	1	2	3	4
Final reading (mL)	13.81	26.62	39.48	13.53
Initial reading (mL)	0.83	13.81	26.62	0.74
Titre volume (mL)				

(a) Calculate the concentration of sulfur dioxide in the wine in grams per millilitre (g mL^{-1}). Assume all the sulfur dioxide exists as hydrogensulfite ion in solution, and express your answer to the appropriate number of significant figures. (6 marks)

See next page

(b) Given that the density of the wine is 0.975 g mL^{-1}, determine the concentration of sulfur dioxide in the wine in parts per million (ppm) and state whether the manufacturing process is producing wine with sulfur dioxide at the desired concentration. (4 marks)
Express your answer to three significant figures.
Note: You must show sufficient working to justify your answer.

While sulfur dioxide has many important uses, in the atmosphere it is a cause of acid rain. A fraction of the sulfur dioxide in the atmosphere is oxidised by reaction with oxygen to give sulfur trioxide gas.

(c) Draw the Lewis structures of SO_2 and SO_3 in the boxes below. You must show all valence electrons in your structure. (2 marks)

SO_2	SO_3

(d) Compare the water solubilities of these gases: that is, predict which one would be more soluble in water. Give reasoning to support your answer, and discuss briefly the relevance of their solubilities to acid rain. (4 marks)

See next page

Question 41 **(12 marks)**

The Pilbara iron ore industry uses vast amounts of ammonium nitrate explosive to break up the rock and ore. Much of the ammonium nitrate is produced in Kwinana, Western Australia, using the following process:

Step 1: Natural gas (from the North West Shelf) is reacted with steam.

$$CH_4(g) + H_2O(g) \rightleftharpoons 3\ H_2(g) + CO(g)$$

Step 2: Hydrogen produced in the above process is reacted with nitrogen from the air using the Haber Process.

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

Step 3: Ammonia is reacted with oxygen in air.

$$4\ NH_3(g) + 5O_2(g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(g)$$

Step 4: Nitrogen monoxide is reacted with oxygen in air.

$$2\ NO(g) + O_2(g) \rightleftharpoons 2\ NO_2(g)$$

Step 5: The nitrogen dioxide produced in the reaction above is reacted with water and oxygen to form nitric acid.

$$4\ NO_2(g) + 2\ H_2O(\ell) + O_2(g) \rightleftharpoons 4\ HNO_3(aq)$$

Step 6: Finally, nitric acid is reacted with ammonia to form ammonium nitrate.

$$HNO_3(aq) + NH_3(g) \rightleftharpoons NH_4NO_3(aq)$$

(a) How many moles of NH_4NO_3 are produced by the reaction of one mole of CH_4? (1 mark)

See next page

(b) Calculate the mass of CH_4 required to produce 2.50×10^5 tonnes of NH_4NO_3. Assume all reactions are 100% efficient, and express your answer to three significant figures. (6 marks)

(c) The equation for Step 3 of the process is reproduced below. It is an exothermic reaction ($\Delta H = -1130$ kJ) and is carried out at 900°C and atmospheric pressure. Use your understanding of reaction rates and Le Chatelier's principle to explain why these conditions are employed for this reaction. (5 marks)

$$4\ NH_3(g) + 5\ O_2(g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(g)$$

See next page

Question 42 **(12 marks)**

Large public swimming pools are often chlorinated using chlorine gas. The gas is bubbled through the water forming the equilibrium reaction shown below:

$$C\ell_2(aq) + H_2O(\ell) \rightleftharpoons HOC\ell(aq) + H^+(aq) + C\ell^-(aq) \qquad \text{(Reaction 1)}$$

The equilibrium constant for this reaction at 25.0°C is 3.94×10^4.

(a) Compare the relative amounts of chlorine and hypochlorous acid at equilibrium at 25°C. (1 mark)

The hypochlorous acid can dissociate as shown in the equilibrium below to give hypochlorite ion.

$$HOC\ell(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + OC\ell^-(aq) \qquad \text{(Reaction 2)}$$

(b) The pH of swimming pools is kept at approximately 7.5. A reason for this is to maximise the concentration of hypochlorous acid, the most effective disinfectant form of chlorine in water. Explain, using the appropriate chemistry concepts, why a pH of about 7.5 will maximise hypochlorous acid concentration. Your explanation should consider equilibrium Reactions 1 and 2. (3 marks)

See next page

(c) If the concentration of hypochlorous acid is to be 1.50 mg L^{-1}, what volume of chlorine gas, at standard pressure and 25°C, is required for an Olympic size swimming pool with a volume of water of 2.50×10^6 L? Assume that all the chlorine gas reacts to produce hypochlorous acid. (5 marks)

The hypochlorite ion can react with ammonia or amines in the water to form chloramines, which are responsible for the bad odour and eye irritation sometimes experienced in pools. Monochloramine is produced as shown in the reaction below:

$$NH_3(aq) + OC\ell^-(aq) \rightleftharpoons NH_2C\ell(aq) + OH^-(aq)$$

The removal of chloramines can be achieved by 'shock' chlorination – the addition of further chlorine to produce more hypochlorite ion, which oxidises chloramines to nitrogen trichloride, $NC\ell_3$. The nitrogen trichloride then decomposes to nitrogen gas and chlorine gas.

(d) Write a balanced equation showing the reaction of hypochlorite ion with ammonia to give nitrogen trichloride and hydroxide ion. (1 mark)

See next page

Question 42 (continued)

(e) Organic chloramines are produced by the reaction of an amine with hypochlorite ion. Give the structure of, and name, the primary amine with 2 carbon atoms. Show all atoms in your structure, and draw your structure in the box below. (2 marks)

Name: _____

Question 43 **(16 marks)**

Soaps function because their molecules dissolve in both grease and water. Water containing significant quantities of calcium and magnesium ions will not lather properly with soap, and will form an insoluble 'scum' according to the reaction below. Water that does not lather effectively is referred to as 'hard' water, and calcium ions are the primary cause of water hardness:

$$Ca^{2+}(aq) + 2\ CH_3(CH_2)_{16}COO^-(aq) \rightarrow (CH_3(CH_2)_{16}COO)_2Ca(s)$$

If water is hard due to the presence of calcium ions together with hydrogencarbonate ions (temporary hardness), then the hardness can be reduced by boiling the water. The calcium ions are removed from solution by precipitating as calcium carbonate:

$$Ca^{2+}(aq) + 2\ HCO_3^-(aq) \rightarrow CaCO_3(s) + H_2O(\ell) + CO_2(g)$$

Boiling hard water causes the build up of 'scale', and can lead to failure of the heating elements in kettles and other devices.

(a) The domestic water supply in Perth contains 65.0 mg L^{-1} calcium ions together with hydrogencarbonate ions. A large, tea-drinking family boils and consumes, on average, 4.20 L of water per day. Determine the mass of scale that will deposit in the household kettle during a 365-day year. Assume all calcium ions are removed from solution during boiling. (5 marks)

See next page

Question 43 (continued)

(b) What volume of $CO_2(g)$, measured at the boiling point of water, is produced during the boiling of 1.00 L of this water at standard pressure? (3 marks)

Water containing calcium and magnesium together with sulfates and/or chlorides cannot be made 'soft' by boiling. There are a number of methods that may be used to soften such water. One of these involves the addition of $Ca(OH)_2$ to the water in the process known as 'liming'.

In the liming process, the pH of water is raised when $Ca(OH)_2(s)$ is added.

(c) Calculate the pH of 1.05×10^3 L of water solution to which 125 mg of $Ca(OH)_2$ have been added. Assume all added $Ca(OH)_2$ dissolves. (3 marks)

See next page

The increase in pH (i.e., addition of OH^-) of the water shifts the equilibria of the carbonate species in the water so that first HCO_3^- predominates, and as the pH is raised further, CO_3^{2-} predominates.

Hard water containing HCO_3^- has significant buffering capacity.

(d) Explain what is meant by the term 'buffering capacity'. (1 mark)

(e) Write two equations that demonstrate the buffering capacity of hard water containing HCO_3^-. (2 marks)

(f) Write equations to show how the addition of OH^- shifts the equilibria of the carbonate species in water. (2 marks)

End of questions

Spare answer page

Question number: _____

Spare answer page

Question number: _____

Spare answer page

Question number: _____

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Question number: _____

Published by the School Curriculum and Standards Authority of Western Australia
27 Walters Drive
OSBORNE PARK WA 6017