



# Western Australian Certificate of Education Examination, 2014

## Question/Answer Booklet

### CHEMISTRY

#### Stage 3

Place one of your candidate identification labels in this box.  
Ensure the label is straight and within the lines of this box.

Student Number: In figures

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In words

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#### Time allowed for this paper

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

Number of additional  
answer booklets used  
(if applicable):

#### 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 (blue/black preferred), pencils (including coloured), sharpener,  
correction fluid/tape, 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.



## 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	11	11	60	72	35
Section Three: Extended answer	6	6	70	82	40
				<b>Total</b>	100

## Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2014*. 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 that you are continuing to answer at the top of the page.
6. The Chemistry Data Sheet is **not** to be 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.

1. Which one of the following is a representation of a lead(IV) ion with 125 neutrons?
- (a)  $^{125}_{4}\text{Pb}$
- (b)  $^{207}_{82}\text{Pb}^{4+}$
- (c)  $^{82}_{125}\text{Pb}^{4+}$
- (d)  $^{125}_{82}\text{Pb}^{4+}$
2. Which one of the following species does **not** have an electron configuration of 2,8,8?
- (a)  $\text{Cl}^{-}$
- (b)  $\text{S}^{2-}$
- (c)  $\text{Ar}$
- (d)  $\text{Na}^{+}$
3. The successive ionisation energies for an element, X, are shown below.

Equation for process	Ionisation energy (kJ mol <sup>-1</sup> )
$\text{X}(\text{g}) \rightarrow \text{X}^{+}(\text{g}) + \text{e}^{-}$	1012
$\text{X}^{+}(\text{g}) \rightarrow \text{X}^{2+}(\text{g}) + \text{e}^{-}$	1903
$\text{X}^{2+}(\text{g}) \rightarrow \text{X}^{3+}(\text{g}) + \text{e}^{-}$	2914
$\text{X}^{3+}(\text{g}) \rightarrow \text{X}^{4+}(\text{g}) + \text{e}^{-}$	4958
$\text{X}^{4+}(\text{g}) \rightarrow \text{X}^{5+}(\text{g}) + \text{e}^{-}$	6276
$\text{X}^{5+}(\text{g}) \rightarrow \text{X}^{6+}(\text{g}) + \text{e}^{-}$	21270
$\text{X}^{6+}(\text{g}) \rightarrow \text{X}^{7+}(\text{g}) + \text{e}^{-}$	25400
$\text{X}^{7+}(\text{g}) \rightarrow \text{X}^{8+}(\text{g}) + \text{e}^{-}$	29860

The element **most** likely to be X is

- (a) aluminium.
- (b) nitrogen.
- (c) chlorine.
- (d) phosphorus.

See next page

4. The ability of an atom in a chemical bond to draw electrons toward itself is responsible for the phenomenon of polar covalent bonding and is known as
- electron density.
  - electronegativity.
  - ionisation energy.
  - dipole moment.
5. Which of the following is the **most** polar bond?
- C-N
  - N-O
  - O-F
  - P-Cl
6. Which of the following pairs of elements will be **most** similar in their chemical properties?
- Si and Sn
  - K and Ca
  - P and S
  - Na and Cs
7. The following table lists the phases of some group 16 hydrides at room temperature.

Group 16 hydride	Phase at room temperature
H <sub>2</sub> O	liquid
H <sub>2</sub> S	gas
H <sub>2</sub> Se	gas
H <sub>2</sub> Te	gas

- Which of the following statements **best** explains why H<sub>2</sub>O is liquid at room temperature and the other group 16 hydrides are gases?
- The polarity of the group 16 hydrides increases going down the group.
  - There are greater dispersion forces between the molecules with higher molar masses.
  - Dipole-dipole forces vary in their strength for these molecules due to the different electronegativities of the group 16 elements.
  - The size and shape of the molecules can influence phase.
8. Which one of the following covalent compounds has polar molecules?
- CH<sub>2</sub>F<sub>2</sub>
  - CF<sub>4</sub>
  - SO<sub>3</sub>
  - CO<sub>2</sub>

9. Absolute zero may be regarded as the temperature at which
- (a) water changes to a solid.
  - (b) all substances become solid.
  - (c) all particle motion ceases.
  - (d) particles have vibrational energy only.

10. Consider the following endothermic reaction



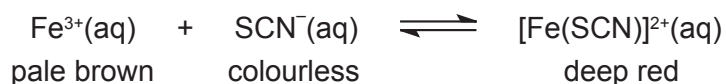
Which one of the following changes to the system at equilibrium will increase the value of its equilibrium constant,  $K$ ?

- (a) increased pressure
  - (b) addition of a catalyst
  - (c) increased temperature
  - (d) decreased temperature
11. Which one of the following is the equilibrium law expression for the equilibrium represented below?



- (a)  $\frac{[\text{Cr}_2\text{O}_7^{2-}]}{[\text{CrO}_4^{2-}]^2[\text{H}^+]^2}$
- (b)  $\frac{[\text{CrO}_4^{2-}]^2[\text{H}^+]^2}{[\text{Cr}_2\text{O}_7^{2-}]}$
- (c)  $\frac{[\text{CrO}_4^{2-}]^2[\text{H}^+]^2}{[\text{Cr}_2\text{O}_7^{2-}][\text{H}_2\text{O}]}$
- (d)  $\frac{[\text{Cr}_2\text{O}_7^{2-}][\text{H}_2\text{O}]}{[\text{CrO}_4^{2-}]^2[\text{H}^+]^2}$

12. Aqueous solutions of iron(III) ions and thiocyanate ions form the equilibrium represented below.



The reaction is exothermic.

Which one of the following statements about changes to the system and the effect on the colour of the solution is true?

- (a) Adding water will make it turn darker red.  
(b) Cooling the solution will make it turn darker red.  
(c) Adding a small volume of aqueous  $\text{Na}_2\text{CO}_3$  solution will turn it darker red.  
(d) Adding solid iron(III) chloride to the solution will make it lighter red.
13. Which of the following is the strongest acid?

	Acid	Acid dissociation (equilibrium) constant
(a)	$\text{CH}_3\text{COOH}$	$1.8 \times 10^{-5}$
(b)	$\text{HCO}_3^{-}$	$5.6 \times 10^{-11}$
(c)	HF	$6.8 \times 10^{-4}$
(d)	$\text{H}_2\text{C}_2\text{O}_4$	$5.4 \times 10^{-2}$

14. Which of the following  $0.1 \text{ mol L}^{-1}$  aqueous solutions has the highest pH?

- (a) ammonium sulfate  
(b) hydrochloric acid  
(c) potassium phosphate  
(d) sodium nitrate

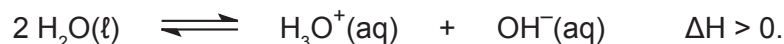
15. Consider the following reaction.



Which one of the following represents an acid-base conjugate pair for this reaction?

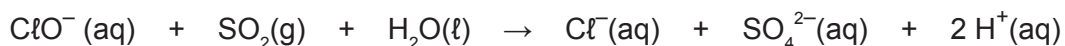
- (a)  $\text{OBr}^{-}/\text{H}_2\text{O}$   
(b)  $\text{HOBr}/\text{OH}^{-}$   
(c)  $\text{OBr}^{-}/\text{OH}^{-}$   
(d)  $\text{H}_2\text{O}/\text{OH}^{-}$

16. Consider the self-ionisation of water:



Which of the following statements about aqueous solutions is true?

- I All aqueous solutions contain  $\text{H}_3\text{O}^+$  and  $\text{OH}^-$  ions.
  - II In any neutral aqueous solution at any temperature,  $[\text{H}_3\text{O}^+] = [\text{OH}^-]$
  - III In aqueous solutions with pH greater than 7,  $[\text{H}_3\text{O}^+] > [\text{OH}^-]$
  - IV A neutral aqueous solution at  $100^\circ\text{C}$  has a  $\text{pH} < 7$
- (a) I only  
(b) I and II only  
(c) I, II and III only  
(d) I, II and IV only
17. The equation below shows the reaction when sulfur dioxide gas ( $\text{SO}_2$ ) is bubbled through a solution containing hypochlorite ions ( $\text{ClO}^-$ ).



Which of the following statements about this reaction is correct?

- I The sulfur in sulfur dioxide is oxidised.
  - II The hydrogen in water is reduced.
  - III The hypochlorite ion is the reducing agent.
  - IV The water is the oxidising agent.
- (a) I only  
(b) II and III only  
(c) III and IV only  
(d) I and IV only
18. Consider the following mixtures:

- I solid  $\text{I}_2$  is added to a solution of  $\text{H}_2\text{S}$
- II liquid  $\text{Br}_2$  is added to a solution of  $\text{Fe}^{2+}$
- III freshly exposed Al metal is added to a solution of  $\text{HCl}$
- IV a piece of cobalt metal is placed in an aqueous solution of  $\text{Cr}^{3+}$ .

Based on  $E^\circ$  values, in which of the above mixtures will a chemical reaction occur?

- (a) II only  
(b) I and III only  
(c) I, II and III only  
(d) III and IV only

19. A buffer solution is made by dissolving ammonium chloride in a dilute solution of ammonia. The following equilibrium exists in the prepared solution:

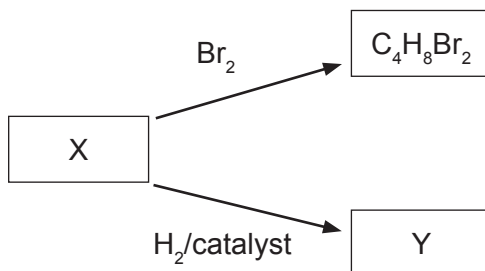


A small amount of a strong acid is added to the buffer solution. Once the equilibrium has been re-established, the effect would be

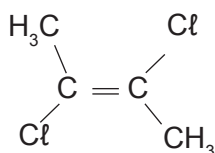
- (a) an overall decrease in the  $\text{H}^+$  ion concentration.
  - (b) that the equilibrium has shifted to the left.
  - (c) an overall increase in the  $\text{NH}_4^+$  ion concentration.
  - (d) an overall increase in the  $\text{OH}^-$  ion concentration.
20. Which of the following compounds has the highest boiling point?
- (a) 1-chloropropane
  - (b) propan-1-ol
  - (c) propanal
  - (d) methylpropane
21. How many isomers are there with the molecular formula  $\text{C}_2\text{H}_2\text{Br}_2$ ?
- (a) 2
  - (b) 3
  - (c) 4
  - (d) 5
22. Which one of the following is **not** a primary amine?
- (a)  $\text{CH}_3\text{NH}_2$
  - (b)  $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_3$
  - (c)  $\text{CH}_3\text{NHCH}_3$
  - (d)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$



23. In the following diagram what are the molecular formulae of substances X and Y likely to be?



- |     | X                         | Y                         |
|-----|---------------------------|---------------------------|
| (a) | $\text{C}_4\text{H}_8$    | $\text{C}_4\text{H}_6$    |
| (b) | $\text{C}_4\text{H}_8$    | $\text{C}_4\text{H}_{10}$ |
| (c) | $\text{C}_4\text{H}_{10}$ | $\text{C}_4\text{H}_8$    |
| (d) | $\text{C}_4\text{H}_6$    | $\text{C}_4\text{H}_8$    |
24. Which one of the following is the IUPAC name for the compound below?



- (a) 2,3-dichloro-*trans*-but-2-ene  
 (b) 2,3-dichloro-*cis*-but-2-ene  
 (c) 1,2-dichloro-*trans*-but-2-ene  
 (d) 1,2-dichloro-*cis*-but-2-ene
- Question 25 refers to the structures shown below.
- |  |   |
|--|---|
| <p>I <math>\text{CH}_3\text{CH}_2\text{CH}_2\overset{\text{O}}{\parallel}\text{C}\text{OH}</math></p>              | <p>II <math>\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}</math></p> |
| <p>III <math>\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\overset{\text{O}}{\parallel}\text{C}\text{OH}</math></p> | <p>IV <math>\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3</math></p>          |
25. Which one of the following gives their increasing order of solubility in water?

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

End of Section One

See next page

## Section Two: Short answer

35% (72 Marks)

This section has 11 questions. Answer **all** questions. Write your answers in the spaces provided.

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

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

Suggested working time: 60 minutes.

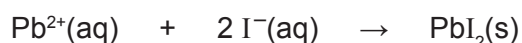
## Question 26

(4 marks)

For the following reactions, describe fully the observed changes, including any:

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

- (a) Lead(II) nitrate solution is added to potassium iodide solution. (1 mark)

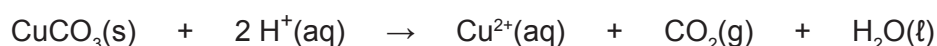


Observation:

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- (b) Solid copper(II) carbonate is added to dilute nitric acid solution. (3 marks)



Observation:

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## Question 27

(4 marks)

Write balanced ionic equations to represent the reactions described below.

- (a) Chlorine gas is bubbled through an aqueous solution of sodium bromide. (2 marks)

See next page

(b) Solid nickel oxide is added to dilute hydrochloric acid solution.

(2 marks)

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**Question 28****(8 marks)**

Complete the table below by **either** drawing the Lewis structures **or** naming the shape of the molecules. For Lewis structures, any lone pairs must be shown.

All electron shell pairs should be represented as either : or as —.

Molecule/ion	Lewis structure	Name of shape
$\text{NCl}_3$	<pre>       :Cl:N:Cl:        :   :        :Cl:           </pre>	
$\text{H}_2\text{S}$	<pre>       H:S:H        :           </pre>	
$\text{SiH}_4$		Tetrahedral
$\text{O}_3$		Bent (V-shaped)
$\text{NO}_3^-$		Trigonal planar

## Question 29

(9 marks)

Ethanol,  $C_2H_5OH$ , and hexane,  $C_6H_{14}$ , are two common industrial solvents.

- (a) (i) Identify the polarity of molecules that are soluble in each of these solvents. (2 marks)

	Polarity of molecules/substances that are soluble in solvent
Ethanol	(circle one only) Polar                  Non-polar
Hexane	(circle one only) Polar                  Non-polar

- (ii) Explain the interactions between solute and solvent particles in solutions of these two solvents. (3 marks)

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- (b) Ethanol and water are often mixed together in the manufacture of a range of substances. The following data were recorded during one production process.

Substance	Volume (mL)
water	50
ethanol	50
mixture of water and ethanol	96

The 'loss' of 4 mL on mixing water with ethanol implies strong interactions between the water and ethanol molecules. Describe these interactions and explain the origin of their strength. (4 marks)

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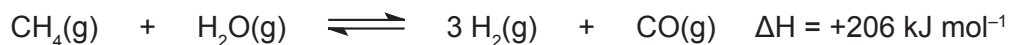
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## Question 30

(9 marks)

Hydrogen can be made by reacting methane (natural gas) with water (steam). The reaction can form the chemical equilibrium represented below.



State the conditions of temperature and pressure that would optimise the yield of hydrogen at a reasonable rate of reaction. Using collision theory and principles of chemical equilibrium, explain your choice of conditions.

	Optimum conditions	Explanation
Temperature	(circle one only)  high  moderate  low  (1 mark)	(3 marks)
Pressure	(circle one only)  high  moderate  low  (1 mark)	(4 marks)

See next page

## Question 31

(5 marks)

- (a) State the role of the standard hydrogen half-cell in determining the table of Standard Reduction Potentials. (2 marks)

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- (b) State **three** limitations of Standard Reduction Potential tables. (3 marks)

One: \_\_\_\_\_

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Two: \_\_\_\_\_

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Three: \_\_\_\_\_

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## Question 32

(6 marks)

Nitrogen gas from the atmosphere undergoes a series of redox reactions to transform it into nitrate ions that are absorbed by plants. The process can be simplified into the following three steps.

Step 1 – Nitrogen-fixing soil bacteria reduce nitrogen gas to ammonium ions.

Step 2 – Nitrifying bacteria then oxidise ammonium ions to nitrite ions.

Step 3 – Nitrifying bacteria then oxidise nitrite ions to nitrate ions.

Write the half-equations for each of these steps. Assume acidic conditions.

Step 1

Step 2

Step 3

See next page

## Question 33

(9 marks)

- (a) Methanoic acid,  $\text{HCOOH}$ , may be produced by oxidation of an alcohol with acidified potassium permanganate,  $\text{MnO}_4^-$ , solution.

Write the oxidation and reduction half-equations and the final redox equation for this reaction. (5 marks)

Oxidation half-equation	
Reduction half-equation	
Final redox equation	

- (b) Methanoic acid reacts with ethanol in the presence of sulfuric acid to produce a sweet smelling compound.

Write the balanced equation for the reaction of methanoic acid with ethanol. (2 marks)

- (c) Draw the structural formula for the sweet smelling compound and give its IUPAC name. Show **all** H atoms in the structure. (2 marks)

Name: \_\_\_\_\_

See next page



## Question 34

(5 marks)

Alcohols can be classified as primary, secondary or tertiary.

Complete the table below by drawing the structure for a primary alcohol, a secondary alcohol and a tertiary alcohol, each with the molecular formula  $C_5H_{12}O$ . Show **all** H atoms in your structures.

Give the IUPAC names for the primary and secondary alcohols you have drawn.

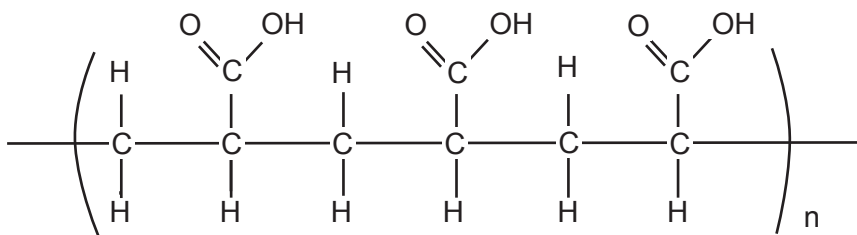
	Structure	Name
Primary alcohol		
Secondary alcohol		
Tertiary alcohol		Name not required.

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## Question 35

(4 marks)

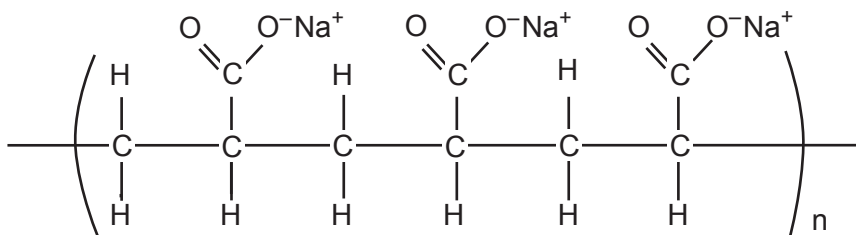
- (a) The structure below represents a segment of polyacrylic acid.



Draw the structure for the monomer of this addition polymer.

(1 mark)

- (b) The structure below represents sodium polyacrylate made by reacting polyacrylic acid with sodium hydroxide.



Sodium polyacrylate is a superabsorbent polymer that can absorb approximately 800 times its own weight in water. It is a white powder that swells when water is added. The sodium ions are removed from the polymer structure by interactions with water molecules and then other water molecules move into the swollen structure, where they are held.

- (i) What is the name of the interactions occurring between water molecules and sodium ions to enable the removal of the latter from the polymer? (1 mark)

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- (ii) Explain how the polymer sodium polyacrylate can absorb large quantities of water. (2 marks)

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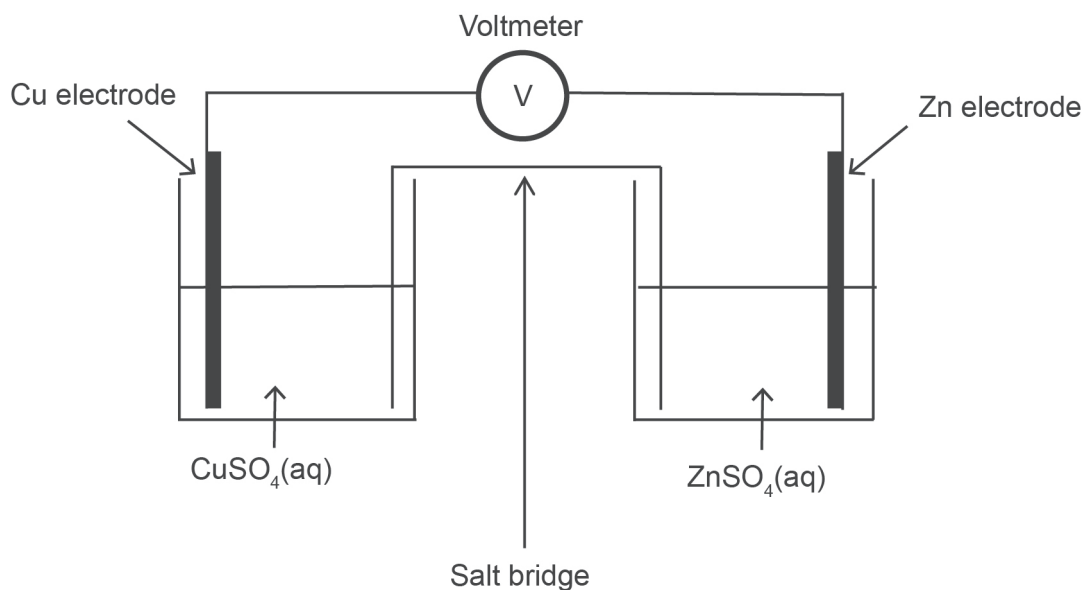
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## Question 36

(9 marks)

A student investigated the effect of concentration of the electrolyte on the electrical potential of electrochemical cells. The student measured the electrical potential for the cell shown in the diagram below. In all trials the volumes of solutions and their temperatures were the same and the surface areas of the copper and zinc electrodes were the same.

The overall cell reaction is as follows:



- (a) What is the independent variable in this investigation? (1 mark)

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- (b) What is the dependent variable in this investigation? (1 mark)

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- (c) Why did the volumes and temperatures of solutions and surface areas of the electrodes need to be the same in each trial? (1 mark)

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See next page

The student found that as the concentration of  $\text{Cu}^{2+}$  ions increased, electrical potential increased, but as concentration of  $\text{Zn}^{2+}$  ions increased, electrical potential decreased, as shown in the table below.

Trial	$\text{Cu}^{2+}$ concentration (mol L <sup>-1</sup> )	$\text{Zn}^{2+}$ concentration (mol L <sup>-1</sup> )	Electrical potential, E (V)
1	0.00001	1.00	1.01
2	0.010	1.00	1.04
3	1.00	1.00	1.09
4	1.00	0.010	1.16
5	1.00	0.00001	1.26

- (d) Explain the increase in electrical potential as the concentration of  $\text{Cu}^{2+}$  ions increased and the decrease in electrical potential as the concentration of  $\text{Zn}^{2+}$  ions increased. (2 marks)

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- (e) The student also observed that as the cells were allowed to run for a while their electrical potential slowly decreased from its maximum value. Why did this happen? (2 marks)

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The student concluded:

‘As the concentration of the oxidant increases, so does the cell voltage (electrical potential).’

- (f) List **two** ways to improve the investigation. (2 marks)

One: \_\_\_\_\_

Two: \_\_\_\_\_

End of Section Two

See next page

## Section Three: Extended answer

40% (82 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.
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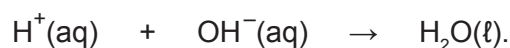
Suggested working time: 70 minutes.

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**Question 37****(9 marks)**

Aqua regia is a mixture of concentrated hydrochloric acid and nitric acid that is able to dissolve gold. One of its uses is in the analysis of gold content in gold ore.

As part of quality control processes, a chemist in a gold analysis laboratory analysed aqua regia to ensure the required 3:1 mole ratio of hydrochloric acid to nitric acid. The chemist found that 20.0 mL of aqua regia needed 28.6 mL of 8.00 mol L<sup>-1</sup> sodium hydroxide for complete neutralisation. The reaction for the neutralisation reaction between the sodium hydroxide and acid is represented by the equation below:



- (a) Calculate the moles of hydrogen ions present in the 20.0 mL sample of aqua regia. (2 marks)

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See next page

The chemist analysed the chloride content of the aqua regia by adding excess silver nitrate solution to a separate 20.0 mL sample of aqua regia. This resulted in the precipitation of 24.6 g of solid.

- (b) Write the balanced ionic equation for precipitation of silver chloride from aqua regia. (1 mark)

- (c) Calculate the moles of hydrochloric acid in the 20.0 mL of aqua regia. (3 marks)

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- (d) Determine whether the aqua regia had the required ratio of hydrochloric acid to nitric acid. State clearly whether the ratio was as required and support your answer with clear workings. (3 marks)

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## Question 38

(12 marks)

Below is a table showing the atomic radius, first ionisation energy and melting point for the Second Period elements.

Element	Atomic number	Atomic radius (nm)	First ionisation energy(kJ mol <sup>-1</sup> )	Melting point (°C)
Lithium	3	0.152	520	180
Beryllium	4	0.112	900	1 278
Boron	5	0.085	801	2 300
Carbon	6	0.077	1 086	3 727
Nitrogen	7	0.075	1 402	-210
Oxygen	8	0.073	1 314	-219
Fluorine	9	0.072	1 681	-220
Neon	10	0.071	2 081	-249

- (a) State and explain the trend in atomic radius across the Second Period. (3 marks)

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- (b) State and explain the trend in first ionisation energy across the Second Period. (4 marks)

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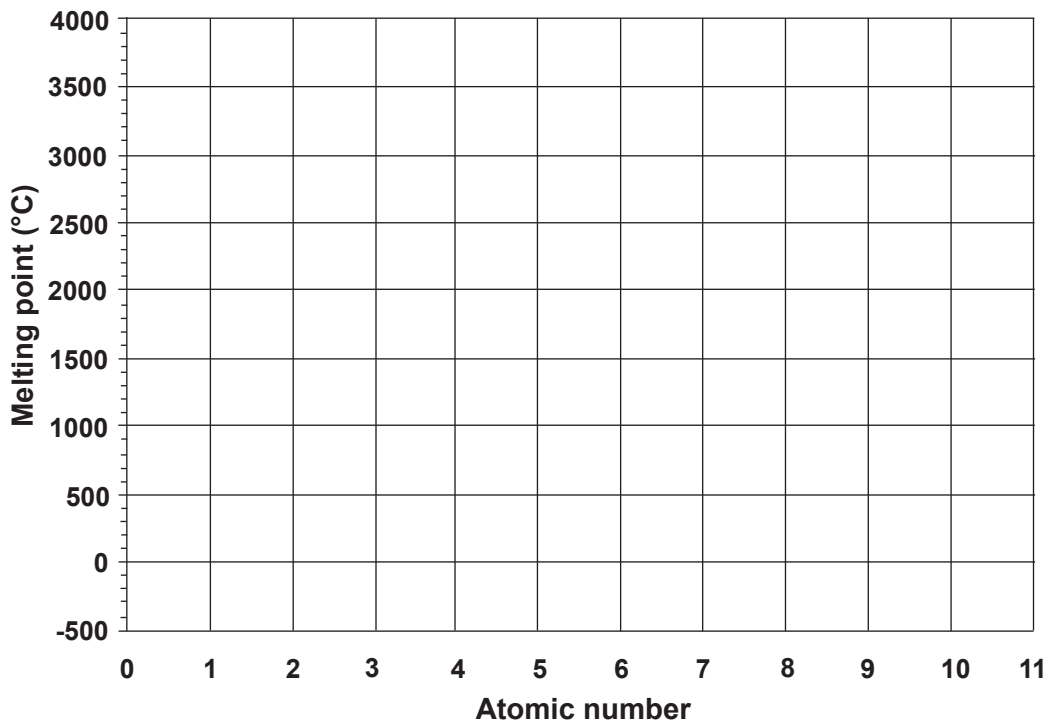
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- (c) Plot a graph of atomic number against melting point for the Second Period elements. (2 marks)

(If you need to make a second attempt at this grid item, the grid is repeated at the end of this Question/Answer Booklet. Cancel the graph on this page.)



- (d) Based on their bonding when solid, explain the difference in melting points of lithium, carbon and neon. (3 marks)

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- (b) 1.95 g of the compound was vaporised and was found to occupy 0.387 L at 95.0 kPa and 105 °C. Determine the molecular formula of the compound. (2 marks)

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- (c) Further analysis of the organic compound revealed that it had a carboxylic acid functional group. Draw a possible structural formula of the organic compound. (2 marks)

## Question 40

(15 marks)

Citric acid is the active ingredient in some bathroom and kitchen cleaning solutions. A student determined the content of citric acid in a cleaner by titration with sodium hydroxide solution.

The sodium hydroxide solution first needed to be standardised. To do this, the student dissolved approximately 4 g of sodium hydroxide pellets in water, to give an approximately  $0.1 \text{ mol L}^{-1}$  solution. This solution was standardised by titrating 20.00 mL of the NaOH solution with a  $0.105 \text{ mol L}^{-1}$  standard hydrochloric acid solution. The average titration volume was 17.45 mL.

- (a) Explain why sodium hydroxide is not suitable as a primary standard. (2 marks)

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- (b) Show that the concentration of the sodium hydroxide solution is  $0.0916 \text{ mol L}^{-1}$ . Show sufficient workings to justify your answer. (3 marks)

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The student then weighed a 10.00 mL aliquot of the cleaner and found it weighed 10.4 g. This 10.00 mL aliquot was next diluted to 100.0 mL in a volumetric flask. Against the standardised sodium hydroxide solution, 20.00 mL aliquots of the diluted cleaner were titrated. The table below shows the results of the titrations.

Titre	1	2	3	4
Final reading (mL)	25.30	23.55	22.40	22.25
Initial reading (mL)	3.50	2.70	1.50	1.30
Titre volume (mL)				

- (c) Calculate the average titre volume to be used in the calculation of the citric acid content. (2 marks)

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- (d) Given that citric acid ( $C_6H_8O_7$ ) is a weak triprotic acid, determine the percentage composition by mass of citric acid in the cleaner. The molar mass of citric acid is  $192.124 \text{ g mol}^{-1}$ . (6 marks)

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- (e) Select a suitable indicator for this titration from the table below. Explain your choice. (2 marks)

Indicator	Colour change (low pH – high pH)	pH range
Methyl yellow	red-yellow	2.4 – 4.0
Litmus	red-blue	5.0 – 8.0
Bromothymol blue	yellow-blue	6.0 – 7.6
Thymol blue	yellow-blue	8.0 – 9.6

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## Question 41

(24 marks)

Rock phosphate is a non-renewable source of phosphate fertiliser. Because of concerns about its eventual depletion, urine is being investigated as an alternative renewable source for phosphate.

The phosphate in urine will precipitate as calcium hydroxyapatite,  $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$ , and struvite,  $\text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}$ , as the pH of the urine increases. The pH increases due to the hydrolysis of urea,  $\text{CO}(\text{NH}_2)_2$ , in urine to ammonia and carbon dioxide.

- (a) Write the balanced equation for the hydrolysis of urea. (2 marks)

- (b) Explain briefly why hydrolysis of urea causes an **increase** in pH. Include an appropriate balanced equation in your answer. (2 marks)

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To determine phosphorus concentration in urine, a researcher collected 5.00 L of urine. After allowing the pH to increase to about 9 and adding excess magnesium ions to complete precipitation, 25.3 g of calcium hydroxyapatite and struvite precipitate were collected.

Analysis showed that 82.3% by mass of the precipitate was struvite and the rest calcium hydroxyapatite.

- (c) Determine the concentration, in grams per litre, of the phosphorus in the urine. Express your answer to **three** significant figures. (Assume all phosphorus has been precipitated.) (9 marks)

Molar masses (in  $\text{g mol}^{-1}$ ): struvite 245.418; calcium hydroxyapatite 1004.636.

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Once all the phosphorus has been removed, the nitrogen present can be recovered from the urine in the form of ammonium ions and converted to a nitrogen fertiliser. Recovery of the nitrogen can be achieved as follows:

**Step 1**

Sodium hydroxide is added to the phosphorus-depleted urine to increase its pH.

**Step 2**

The solution is heated to 40 °C to convert the aqueous ammonia to the gas phase and a stream of air is passed through the solution.

**Step 3**

The ammonia-enriched air is allowed to come into contact with a room-temperature solution of sulfuric acid. The ammonia is absorbed by the solution to react with the acid to give ammonium sulfate.

- (d) Explain, using collision theory, why increasing the pH of the phosphorus-depleted urine converts the ammonium ions to ammonia. Support your answer with a balanced equation. (3 marks)

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Question 41 (continued)

- (e) State the purpose of heating the solution to 40 °C. (1 mark)

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- (f) Write a balanced equation for the reaction in Step 3. (2 marks)

- (g) The amount of ammonium sulfate recovered from the 5.00 L of urine in this experiment is 72.65 g. If the process is 78% efficient, what is the concentration of nitrogen, in grams per litre, in the phosphorus-depleted urine? (5 marks)

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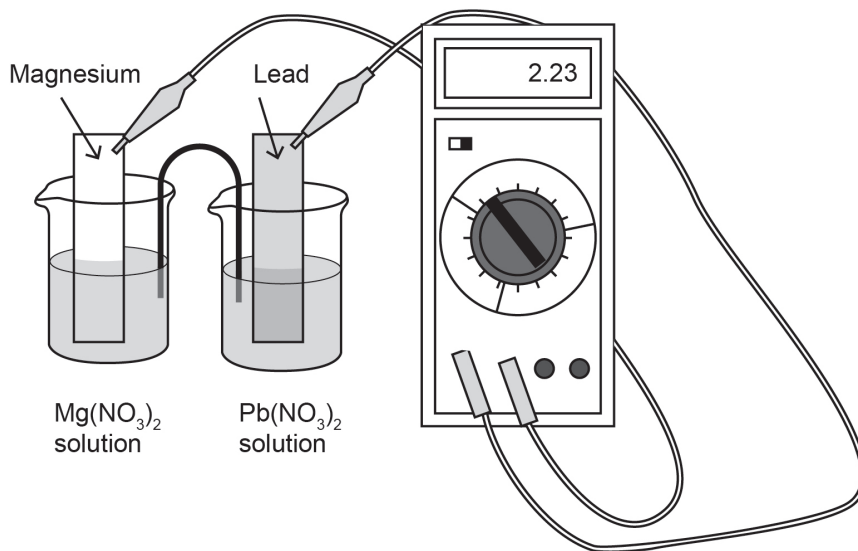


Question 42

(8 marks)

Using the diagram below, explain the role of the following in the operation of an electrochemical (galvanic) cell:

- anode process
- cathode process
- lead(II) nitrate electrolyte
- salt bridge
- electron flow in external circuit.



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End of questions



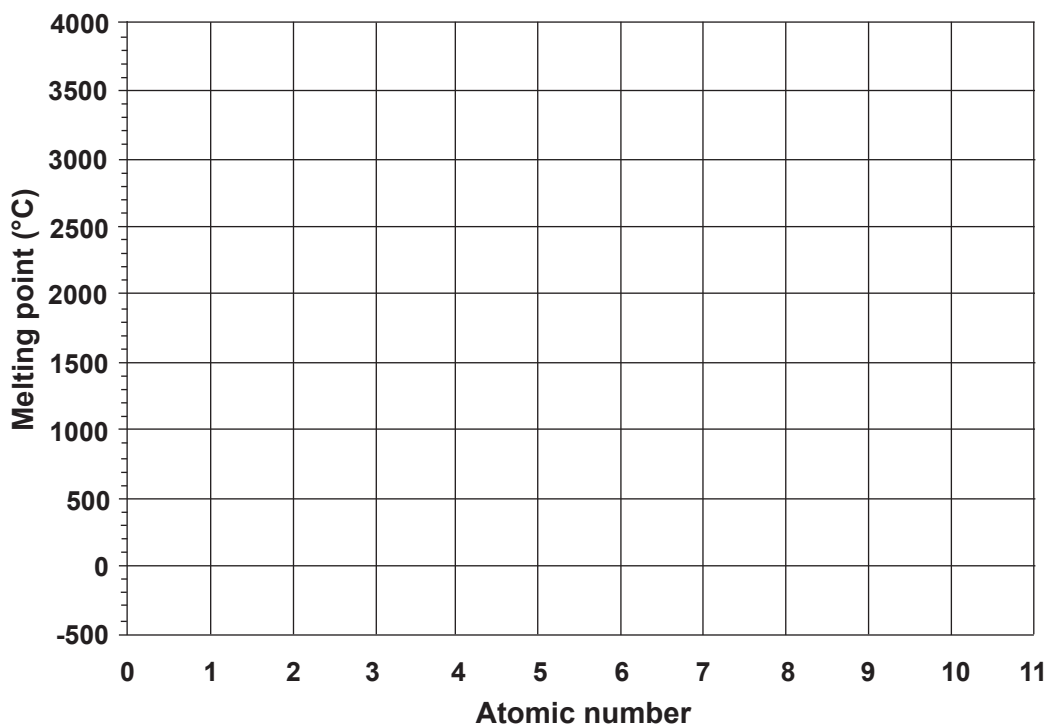








Spare grid.



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## ACKNOWLEDGEMENTS

### Section Three

#### Question 42

Adapted from: Megna, R. *Electrochemical cell* [Image]. Retrieved June 23, 2014, from [http://photo.photoshelter.com/search?I\\_DSC=45859901-2RM&\\_ACT=search](http://photo.photoshelter.com/search?I_DSC=45859901-2RM&_ACT=search)

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