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

WACE
Western Australian Certificate of Education

# Western Australian Certificate of Education Examination, 2015

## 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 | | | | | | | | | |

In words _____

_____

## 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 | 10 | 10 | 60 | 70 | 35 |
| Section Three: Extended answer | 5 | 5 | 70 | 77 | 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 2015*. 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.

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1. In which of the following compounds is the oxidation number of manganese **lowest**?

   (a) $Mn_2O_3$
   (b) $K_2MnO_4$
   (c) $NaMnO_4$
   (d) $MnO_2$

2. Which one of the following is **true** for a solution of silver chloride in equilibrium with some solid silver chloride, as illustrated by the equation below?

   $$Ag^+(aq) + C\ell^-(aq) \rightleftharpoons AgC\ell(s)$$

   (a) The silver chloride solution is saturated.
   (b) Use of a catalyst would allow more solid silver chloride to dissolve.
   (c) If more solid silver chloride is added to the mixture then this will change the concentrations of the silver ions and chloride ions in the solution.
   (d) The reaction in which silver ions and chloride ions precipitate to form solid silver chloride is not taking place.

3. An aqueous solution of ethanoic (acetic) acid can react with

   I magnesium to produce a solution of magnesium ethanoate and hydrogen gas.
   II solid potassium carbonate to produce a solution of potassium ethanoate, carbon dioxide gas and water.
   III sodium hydroxide solution to produce a solution of sodium ethanoate and water.
   IV acidified propan-1-ol to produce ethyl propanoate and water.

   Which of the above statements are correct?

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



**See next page**

4. Consider the following equilibrium.

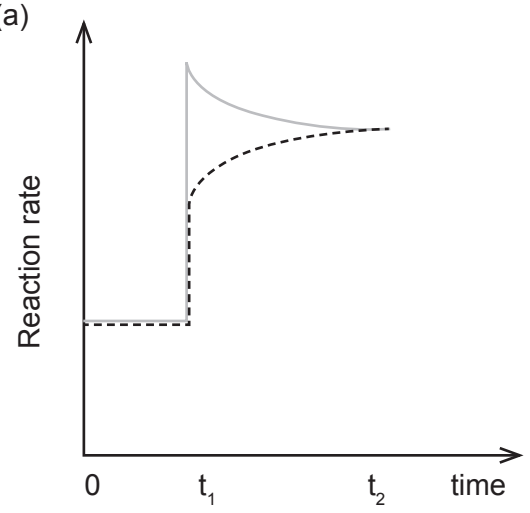
$$2\ C\ell F_3(g) \rightleftharpoons 3\ F_2(g) + C\ell_2(g) \qquad \Delta H = \text{negative}$$

The system is initially at equilibrium. At time $t_1$, the temperature of the system was increased. Which of the following **best** represents the changes in the forward and reverse reaction rates until equilibrium is re-established at time, $t_2$?

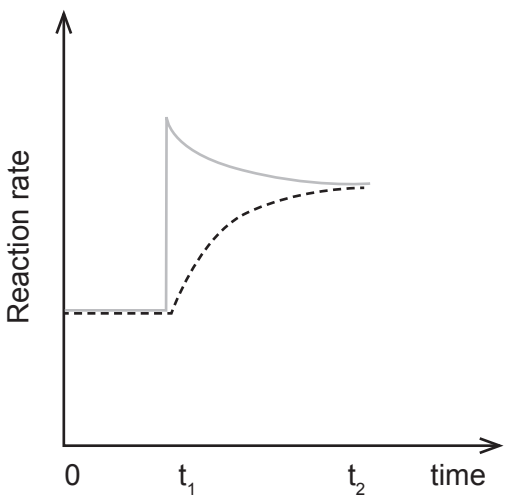
The forward reaction rate is represented by ——————

The reverse reaction rate is represented by - - - - - - - - - - - -

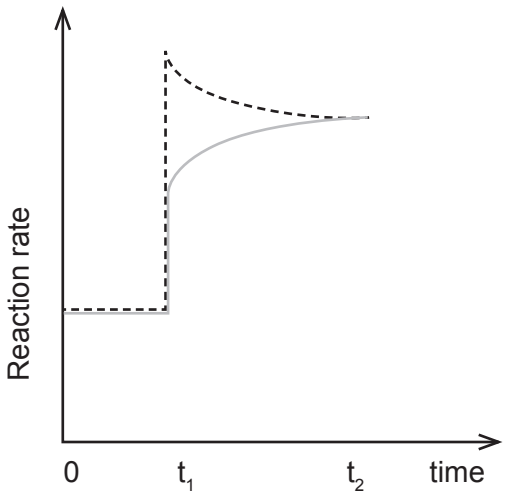
(a)



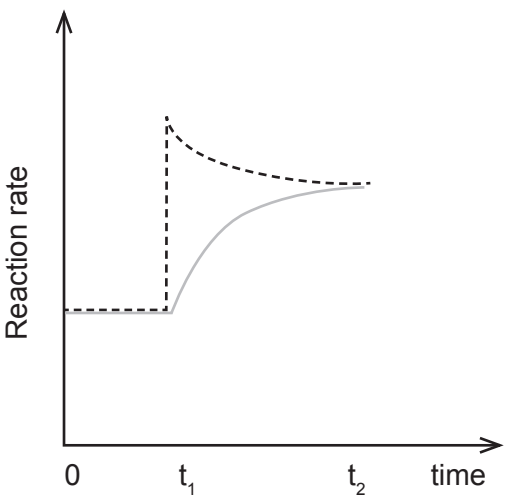

(b)




(c)




(d)

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5. Which one of the following reactions can occur spontaneously at 25.0 °C? (Assume the solutions have a concentration of 1.00 mol $L^{-1}$.)

(a) $C(s) + O_2(g) \rightarrow CO_2(g)$

(b) $2\ Fe^{2+}(aq) + C\ell_2(g) \rightarrow 2\ Fe^{3+}(aq) + 2\ C\ell^-(aq)$

(c) $Zn^{2+}(aq) + Cu(s) \rightarrow Zn(s) + Cu^{2+}(aq)$

(d) $Cu(s) + 2\ H^+(aq) \rightarrow Cu^{2+}(aq) + H_2(g)$

Questions 6 and 7 refer to the reaction represented by the equation shown below.

$$Pb(s) + PbO_2(s) + 4\ H^+(aq) + 2\ SO_4^{2-}(aq) \rightleftharpoons 2\ PbSO_4(s) + 2\ H_2O(\ell)$$

6. Which one of the following is the equilibrium law expression for this reaction?

(a) $K = \dfrac{1}{[H^+]^4[SO_4^{2-}]^2}$

(b) $K = \dfrac{[H_2O]^2}{[H^+]^4[SO_4^{2-}]^2}$

(c) $K = \dfrac{[PbSO_4]^2}{[H^+]^4[SO_4^{2-}]^2}$

(d) $K = \dfrac{1}{[H^+]^2[SO_4^{2-}]}$

7. Assuming equilibrium has been established, which one of the following will cause a decrease in pH?

(a) adding more solid lead
(b) adding solid sodium sulfate
(c) removing solid lead sulfate
(d) adding barium nitrate solution

8. In which one of the following situations will there be no visible reaction?

(a) Solutions of sodium fluoride and potassium chloride are mixed together.
(b) A clean strip of copper metal is placed into a silver nitrate solution.
(c) Bromine water and ethene are shaken together.
(d) Sodium metal is dropped into a beaker of distilled water.



See next page

9. For a covalent bond to be non-polar, the bonding atoms **must** have the same

(a) bonding capacity.
(b) electronegativity.
(c) number of valence electrons.
(d) atomic radius.

10. When a grey solid was added to a green solution, the **most** obvious observation was the decolourising of the solution.

Which one of the following might have been the reactants?

| | Solid | Solution |
|---|---|---|
| (a) | chromium | lead(II) nitrate |
| (b) | zinc | cobalt(II) nitrate |
| (c) | cadmium | nickel(II) nitrate |
| (d) | lead | chromium(III) nitrate |

11. In which of the following compounds do the cation and anion have the same electron configuration?

I magnesium oxide, MgO
II aluminium nitride, A$\ell$N
III sodium sulfide, $Na_2S$
IV lithium fluoride, LiF

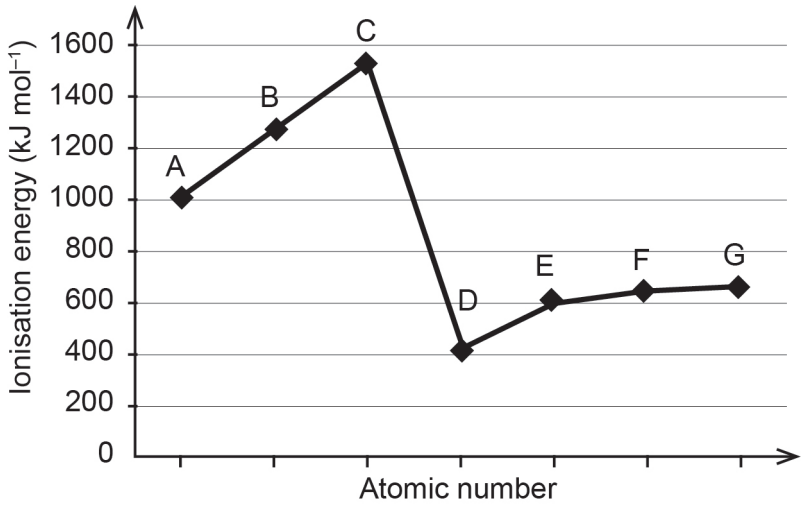
(a) I and II only
(b) I and III only
(c) III and IV only
(d) I, II and III only

12. Which one of the following lists the hydrides with **increasing** (from lowest to highest) melting points?

| | | | | |
|---|---|---|---|---|
| (a) | HI | HBr | HC$\ell$ | HF |
| (b) | $H_2S$ | $H_2Se$ | $H_2Te$ | $H_2O$ |
| (c) | $NH_3$ | $PH_3$ | $AsH_3$ | $SbH_3$ |
| (d) | $PH_3$ | $NH_3$ | $AsH_3$ | $SbH_3$ |

**See next page**

13. The first ionisation energy of **consecutive** elements (labelled A to G) of the Periodic Table is shown in the graph below.




Which of the following would be the **most** likely formula of a compound formed between two of the elements represented in the plot?

(a) BC
(b) $A_2B$
(c) $EB_2$
(d) $A_2D$

14. Which one of the following lists the solubilities of butane ($C_4H_{10}$), butan-2-ol ($CH_3CH(OH)CH_2CH_3$) and butanone ($CH_3COCH_2CH_3$) in water, from **most** soluble to **least** soluble?

| | | | |
|---|---|---|---|
| (a) | butan-2-ol | butanone | butane |
| (b) | butan-2-ol | butane | butanone |
| (c) | butanone | butan-2-ol | butane |
| (d) | butane | butanone | butan-2-ol |

15. Which one of the following is the same for equal volumes of 0.100 mol $L^{-1}$ solutions of ammonia and sodium hydroxide?

(a) pH of the solutions at 25.0 °C
(b) mass of the solute used to form each solution
(c) conductivity of the solutions at 25.0 °C and standard atmospheric pressure
(d) number of moles of hydrochloric acid needed for neutralisation

16. An aqueous solution at 25.0 °C with a pH less than zero

(a) contains neither $H^+(aq)$ or $OH^-(aq)$ ions.
(b) has a very high concentration of $H^+(aq)$ ions.
(c) contains no $OH^-(aq)$ ions.
(d) contains an equal concentration of $H^+(aq)$ and $OH^-(aq)$ ions.

**See next page**

17. A half-cell containing a metal electrode in a sodium nitrate solution is joined to another half-cell containing an inert electrode in a metal nitrate solution. Which one of the following combinations of electrode and metal nitrate solution will produce an electrochemical cell with the greatest electrical potential under standard conditions?

| | Electrode | Nitrate solution |
|---|---|---|
| (a) | Ag | $Sn^{2+}$ |
| (b) | Aℓ | $Cd^{2+}$ |
| (c) | Cr | $Fe^{2+}$ |
| (d) | Cu | $Fe^{3+}$ |

18. The reaction equilibrium between hydrogencarbonate ion and dihydrogen sulfide is represented by the equation shown below.

$$HCO_3^-(aq) + H_2S(aq) \rightleftharpoons H_2CO_3(aq) + HS^-(aq)$$

According to the Brønsted–Lowry theory of acids and bases, which one of the following shows the two species acting as bases in this equilibrium system?

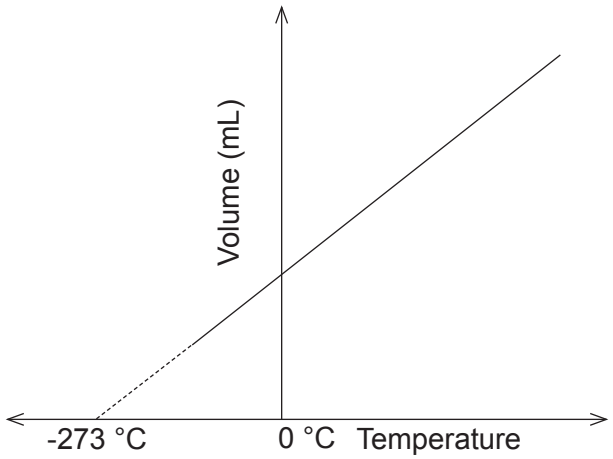
(a) $HCO_3^-$ and $H_2CO_3$
(b) $H_2S$ and $HS^-$
(c) $H_2S$ and $H_2CO_3$
(d) $HCO_3^-$ and $HS^-$

19. The following 1.00 mol $L^{-1}$ solutions are diluted by the addition of water. In which solution will the pH **not** change but the electrical conductivity will decrease?

(a) sodium carbonate
(b) ammonium chloride
(c) sodium chloride
(d) ethanoic (acetic) acid

See next page

20. The concept of absolute zero was developed from observations of the relationship between gas volume and temperature. This relationship is represented in the graph below.




Which one of the following conclusions **cannot** be drawn from this graph?

(a) A temperature exists where the volumes of gases fall to zero.
(b) Gas volumes double as the Celsius temperature doubles.
(c) The lowest temperature possible can be determined by extrapolating the graph.
(d) The value for absolute zero is -273 °C.

21. Five trials resulting in the following titres were obtained using a burette in an acid-base titration.

| Trial | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Titre volume (mL) | 37.52 | 36.98 | 36.95 | 36.76 | 37.03 |

Which of the trials should be used to calculate the average titre?

(a) 2, 3 only
(b) 2, 3, 4 only
(c) 2, 3, 5 only
(d) 1, 2, 3, 4, 5

22. Which one of the following lists the substances in order of **increasing** (from lowest to highest) boiling point?

| | | | | |
|---|---|---|---|---|
| (a) | $CH_3CH_3$ | $CH_3CH_2OH$ | $CH_3CHO$ | $CH_3COOH$ |
| (b) | $CH_3CH_3$ | $CH_3CHO$ | $CH_3CH_2OH$ | $CH_3COOH$ |
| (c) | $CH_3CH_2OH$ | $CH_3CH_3$ | $CH_3COOH$ | $CH_3CHO$ |
| (d) | $CH_3COOH$ | $CH_3CHO$ | $CH_3CH_2OH$ | $CH_3CH_3$ |

See next page

23. Under the right conditions, a compound containing two double bonds, buta-1,3-diene ($H_2C=CH–HC=CH_2$), can react with itself to make Buna rubber. This process is **best** referred to as

(a) saponification.
(b) condensation polymerisation.
(c) esterification.
(d) addition polymerisation.

24. What is the name of the organic compound produced when 2-fluoropent-1-ene reacts with fluorine gas?

(a) 2-fluoropentane
(b) 1,2-difluoropentane
(c) 1,1,2-trifluoropentane
(d) 1,2,2-trifluoropentane

25. Between which of the following pairs of substances can hydrogen bonding occur?

I $CH_3COCH_3$ and $CH_3NH_2$
II $CH_3CHO$ and HF
III $C_2H_6$ and $CH_3OH$
IV $CH_3F$ and $H_2O$

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

**End of Section One**

**See next page**

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See next page

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

This section has **10** 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.

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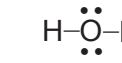
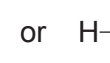
**Question 26** **(5 marks)**

Draw the Lewis structure (electron dot) diagram for both compounds listed in the table below.

For Lewis structures, all lone electron pairs must be shown.
All valence shell electron pairs should be represented either as **:** or as —

(for example, water  or  or  )

| Compound | Lewis structure (electron dot) diagram |
|---|---|
| $CF_4$ | (2 marks) |
| $NaC\ell O_3$ | (3 marks) |

**See next page**

**Question 27** **(8 marks)**

(a) The two substances $CS_2$ and HCN have linear molecules but $CS_2$ molecules are non-polar while HCN molecules are polar. Explain why these molecules have different polarities. Support your explanation with appropriate diagrams. (4 marks)

(b) Complete the table below by choosing **one** molecule from the following list to match the description given.

$H_2CO$ $PH_3$ $SO_3$ $CHBr_3$ $H_2$ CO $SiF_4$ (4 marks)

| Description | Molecule |
|---|---|
| a molecule which is tetrahedral and polar | |
| a diatomic molecule with only dispersion forces between its molecules | |
| a molecule which is trigonal planar and polar | |
| a molecule which is pyramidal and has dipole-dipole forces between its molecules | |

**See next page**

**Question 28** **(6 marks)**

(a) Explain why chlorine has a higher electronegativity than iodine. (3 marks)

(b) With reference to the nature of their bonding, explain why magnesium has a higher melting point than sodium. (3 marks)

**See next page**

**Question 29** **(7 marks)**

A 25.0 mL solution of nitric acid at 25.0 $^{o}$C contains 8.50 x $10^{-3}$ moles of hydrogen ions.

(a) Calculate the hydrogen ion concentration and the pH of the solution. (2 marks)

(b) Calculate the pH of the solution after 20.0 mL of 0.300 mol $L^{-1}$ potassium hydroxide solution is added to the original 25.0 mL of nitric acid. (5 marks)



**See next page**

**Question 30** **(6 marks)**

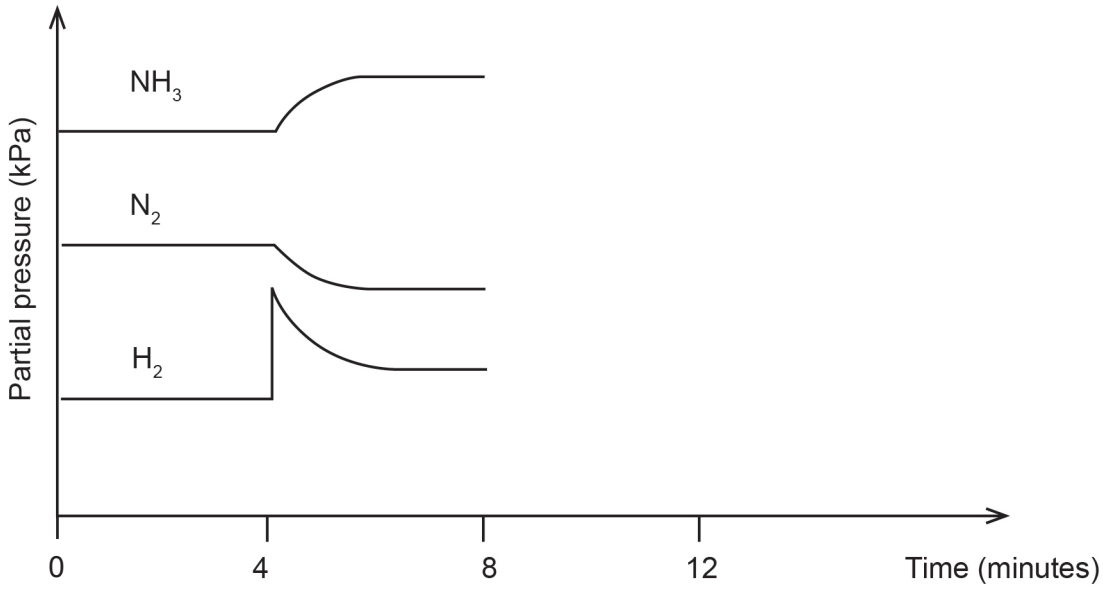
Ammonia exists in equilibrium with hydrogen and nitrogen as shown by the following exothermic equation.

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g) \quad \Delta H = -92\ kJ\ mol^{-1}$$

As they exist in the gaseous state, the relative concentrations can be given in terms of the partial pressure (kPa) of each gas.

Nitrogen, hydrogen and ammonia gases are placed in a rigid container and allowed to reach equilibrium. The graph below shows the partial pressures of the gaseous system initially at equilibrium. After the experiment operates for 4 minutes, a change is imposed upon it.

**Partial pressures of $NH_3$, $N_2$ and $H_2$ over time**




(a) What characteristic of equilibrium is indicated on the graph by the section from 0 to 4 minutes? (1 mark)

(b) A change was imposed on the system at the 4 minute mark. What imposed change could have produced the results indicated on the graph? (1 mark)

(c) The system was **suddenly** cooled at 8 minutes and then reached equilibrium again at 12 minutes. Using this information, complete the graph above from the 8 to the 12 minute mark. (4 marks)

**See next page**

**Question 31** **(6 marks)**

(a) Write a balanced ionic equation to represent the reaction described below. Include all state symbols.

0.100 mol $L^{-1}$ aqueous solutions of silver nitrate and potassium carbonate are mixed.

(3 marks)

(b) Describe a chemical test that can be used to distinguish between magnesium solid and cobalt solid. State the observations expected for each of the solids when tested.

(3 marks)

Chemical test

Observation with magnesium solid

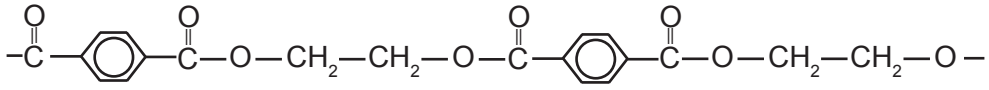
Observation with cobalt solid



**See next page**

**Question 32** **(7 marks)**

Dacron is the trade name for a common polyester used in making clothes and water bottles. Part of its structural formula is given below:



(a) Draw the structural formula for the **two** monomers that react to form this polymer. (2 marks)

Monomer one:

Monomer two:

(b) Name the other product of this polymerisation reaction. (1 mark)

**See next page**

(c) Predict and explain the effect on the polyester's rigidity and melting point as the polymer chains increase in length. (4 marks)



See next page

**Question 33** **(9 marks)**

Soaps and detergents are organic chemicals used to clean greasy material from surfaces.

(a) Draw the general structure of a typical detergent formula unit. (2 marks)

(b) Explain why detergents are soluble in both water and grease. (6 marks)

**See next page**

(c) State why detergents are more effective in hard water than soaps. (1 mark)



See next page

**Question 34** **(10 marks)**

Three different organic compounds were each tested with two reagents:
- acidified sodium permanganate solution and
- acidified propanoic acid.

Each organic compound has a molecular formula containing four carbon atoms, one oxygen atom and a number of hydrogen atoms.

The observations made are summarised in the following table.

| Unknown organic compound | Reagent added | |
|---|---|---|
| | **acidified sodium permanganate solution** | **acidified propanoic acid** |
| 1 | no observable change | fruity smell |
| 2 | purple solution decolourises | no observable change |
| 3 | no observable change | no observable change |

(a) Complete the table below, identifying the:
- functional group responsible for the observations made
- organic compound, by drawing its structural formula **or** giving its name. (6 marks)

| Unknown organic compound | Functional group | Structural formula or name of the organic compound |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |

**See next page**

(b) Draw the structural formula, showing all atoms of the organic product of the reactions of Compound 1 and Compound 2.

(i) Organic Compound 1 with the acidified propanoic acid. (2 marks)

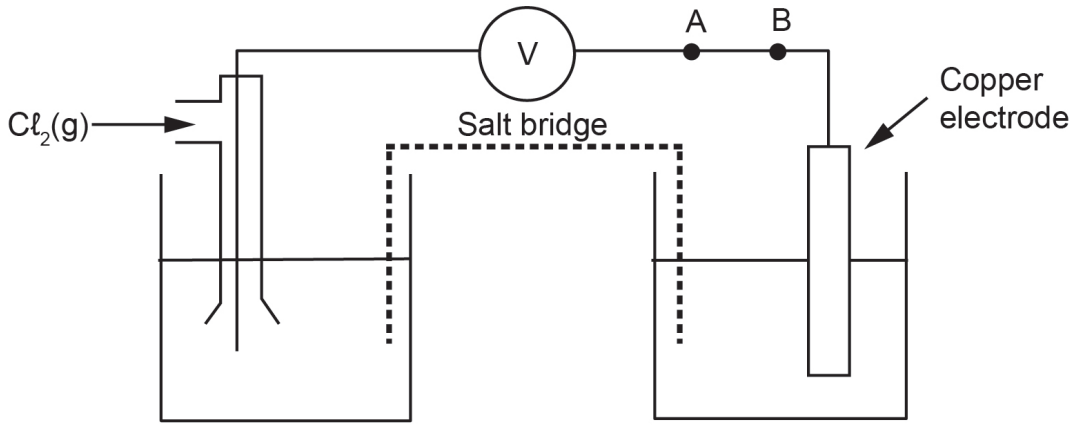
(ii) Organic Compound 2 with the acidified sodium permanganate solution. (2 marks)



See next page

**Question 35** **(6 marks)**

The following electrochemical cell was set up under standard conditions.




(a) Draw an **arrow** between **A** and **B** on the diagram to indicate the direction of electron flow. (1 mark)

(b) Write a balanced equation to represent the overall reaction occurring in this cell. (2 marks)

(c) State the reason for the reactants being kept in separate half-cells. (1 mark)

(d) State the observation predicted to occur in the $C\ell_2$/NaC$\ell$ half-cell. (1 mark)

(e) Predict a metal/metal ion cell that could be used in place of the $Cu/Cu^{2+}$ cell to give a higher emf (volts). (1 mark)

**End of Section Two**

**See next page**

**Section Three: Extended answer** **40% (77 Marks)**

This section contains **five (5)** 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 that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

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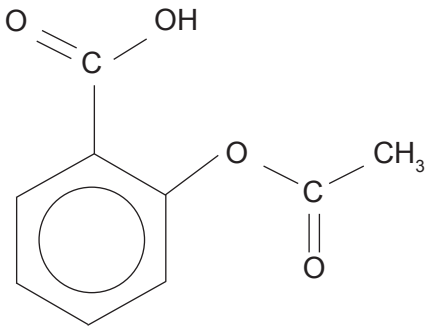
**Question 36** **(20 marks)**

Aspirin is one of the most popular and readily available pain-relieving drugs. The structure of aspirin is given below:




Aspirin contains two functional groups.

(a) (i) On the diagram of aspirin above, circle the **two** functional groups. Label them **A** and **B**. (2 marks)

(ii) Name each functional group. (2 marks)

Functional group **A**: _____

Functional group **B**: _____

**See next page**

**Question 36** (continued)

(b) In one commercial brand of aspirin, each '300 mg tablet' is claimed to contain 100% aspirin. To determine the actual percentage by mass of aspirin in an aspirin tablet, the following procedure, involving a back titration, was used.

Step 1: Three aspirin tablets, each with a mass of 300.0 mg, were crushed and dissolved in excess sodium hydroxide solution. Exactly 100.0 mL of 0.204 mol $L^{-1}$ solution of sodium hydroxide was used. The mixture was boiled to ensure complete reaction.

Step 2: The excess sodium hydroxide solution was titrated with hydrochloric acid as follows: 20.0 mL of the solution from step 1 was pipetted into a conical flask and 0.125 mol $L^{-1}$ hydrochloric acid was placed in the burette. The indicator, phenolphthalein, was used and an average titre of 17.89 mL of hydrochloric acid was required to reach the end-point.

Notes:

- Assume that any other chemicals present in an aspirin tablet are inert and will not react with either NaOH(aq) or HCℓ(aq).
- Phenolphthalein is colourless at a pH less than 8.3 and pink at a pH greater than 10.0.

(i) This is a titration between a strong acid and strong base. Strong acid–strong base titrations typically result in an equivalence point with a pH close to 7. Phenolphthalein was chosen as the indicator for this titration. Considering all of the species present in the solution at the equivalence point, explain why phenolphthalein is a suitable indicator to show the end-point. Support your answer with a suitable equation. (3 marks)



See next page

(ii) Calculate how many moles of hydroxide ions reacted with the aspirin. (5 marks)

(iii) Each aspirin molecule requires two hydroxide ions for complete reaction. Calculate the percentage by mass of aspirin in one aspirin tablet. (The molar mass of aspirin is 180.154 g $mol^{-1}$.) (4 marks)



An important procedure in volumetric analysis is the washing of equipment with the appropriate solution prior to the titration in order to minimise experimental error.

(c) Before performing the experiment, the glassware was washed with the solutions given in the table. Complete the table below by stating the effect of the washing. (4 marks)

| Washing procedure | Effect on the volume of hydrochloric acid used | Effect on the % of aspirin calculated |
|---|---|---|
| The conical flask was washed with distilled water. | | |
| The burette was washed with distilled water. | | |

**See next page**

**Question 37** **(16 marks)**

Sulfur compounds in sewerage and industrial processes can cause problems due to their odours, often because they eventually form dihydrogen sulfide gas, also known as rotten egg gas.

One class of sulfur compounds that need to be removed from sewerage is the thiosulfates. One step in their removal is the reaction of tetrathionate ions, $S_4O_6^{2-}$, with hydrogen peroxide, $H_2O_2$. The tetrathionate produces trithionate ions, $S_3O_6^{2-}$, and sulfate ions.

(a) (i) Complete the table below by writing balanced half-equations and the final redox equation for the reaction of tetrathionate and hydrogen peroxide. (6 marks)

| |
|---|
| Half-equation one<br><br>$S_4O_6^{2-} \rightarrow S_3O_6^{2-} + SO_4^{2-}$ |
| Half-equation two<br><br>$H_2O_2 \rightarrow$ |
| Redox |

(ii) Which substance is being oxidised? (1 mark)

In some industrial processes, dihydrogen sulfide is a waste product. If the quantity of gas is large, then it becomes economical to extract for other production processes. The Claus process is one such example where dihydrogen sulfide is used to produce elemental sulfur.

One of the key reactions occurring in the process is the Claus reaction represented by the equation shown below.

$$2\ H_2S(g) + SO_2(g) \rightarrow 3\ S(\ell) + 2\ H_2O(g)$$

Modern Claus plants, using three catalytic converters, may achieve up to 99.8% conversion but typically the conversion of dihydrogen sulfide to sulfur is between 95 and 97%.

**See next page**

In one particular industrial plant, the following initial conditions were used:

| | |
|---|---|
| dihydrogen sulfide ($H_2S$) | mass = 19.5 kg |
| sulfur dioxide ($SO_2$) | pressure = 68.3 kPa<br>temperature = 791 °C<br>volume = 43.4 kL |

(b) Calculate the maximum mass of sulfur that can be formed if the process is 96.8% efficient. Express your answer to **three** significant figures. (9 marks)



**See next page**

**Question 38** **(16 marks)**

The two different coloured cobalt(II) complex ions, $Co(H_2O)_6^{2+}$ and $CoCl_4^{2-}$, exist together in equilibrium in solution in the presence of chloride ions. This is represented by the equation below.

$$\underset{\text{pink}}{Co(H_2O)_6^{2+}(aq)} + 4\,Cl^-(aq) \rightleftharpoons \underset{\text{blue}}{CoCl_4^{2-}(aq)} + 6\,H_2O(\ell)$$

An experiment is conducted to investigate the effects on the equilibrium position by imposing a series of changes on the system. The shift in equilibrium position can be indicated by any colour change of the solution.

| Colour chart | |
|---|---|
| **Species** | **Colour** |
| $Co(H_2O)_6^{2+}(aq)$ | pink |
| $CoCl_4^{2-}(aq)$ | blue |
| Initial equilibrium mixture | purple |

After a 3.00 mL sample of an initial equilibrium mixture was placed in each of three test tubes, changes to each system were made by adding a different substance, as indicated in the table below.

| Test tube | Substance added to the test tube |
|---|---|
| 1 | 10 to 12 drops of distilled water |
| 2 | 20 to 25 drops of concentrated hydrochloric acid |
| 3 | 20 to 25 drops of 0.200 mol $L^{-1}$ silver nitrate solution, $AgNO_3(aq)$ |

(a) Complete the table below by predicting the:

- change in concentration, if any, of each of the ions in solution compared to the initial solution, after a new equilibrium position is reached.
- colour change, if any, that takes place from the initial purple-coloured solution.

(6 marks)

| **Additions to the test tube** | **Change in concentration from initial equilibrium to final equilibrium (increase, decrease, unchanged)** | | | **Colour favoured (pink, blue or unchanged)** |
|---|---|---|---|---|
| | **$[Co(H_2O)_6^{2+}]$** | **$[Cl^-]$** | **$[CoCl_4^{2-}]$** | |
| 1. add $H_2O(\ell)$ | | | | |
| 2. add $HCl(aq)$ | | | | |
| 3. add $AgNO_3(aq)$ | | | | |

**See next page**

(b) Other than a colour change, what else should be observed in test tube 3? (1 mark)

(c) Using Collision Theory, explain your predicted observations when hydrochloric acid is added to test tube 2. (3 marks)

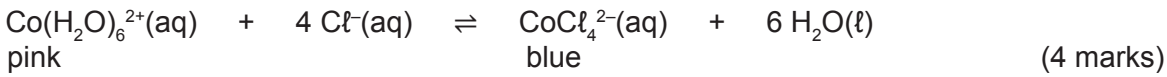


See next page

**Question 38** (continued)

Another experiment was conducted to investigate the effect that changing the temperature had on the equilibrium mixture. When 3.00 mL of the original equilibrium mixture was placed in a test tube and then in an ice bath, the solution became pink.

(d) Determine whether the forward reaction, as illustrated by the equation below, is exothermic or endothermic. Use Le Châtelier's Principle to justify your answer.




(4 marks)

(e) State **one** specific hazard to the environment that the disposal of chemicals from this experiment poses and state what could be done in the laboratory to reduce this hazard.

(2 marks)

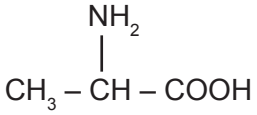
**See next page**

**Question 39** **(10 marks)**

Amino acids are biologically-important organic compounds containing both amine ($-NH_2$) and carboxylic acid (-COOH) functional groups.

An important amino acid is 2-aminopropanoic acid; usually known as alanine. It is a component in more than a thousand different proteins, found in an array of foods and can be produced within the body.

Structural formula for alanine



(a) Alanine is an alpha (α) amino acid. State the structural feature of alanine that allows it to be classified as an **alpha** (α) amino acid. (1 mark)

(b) Use the following information to demonstrate that the molecular formula of alanine is the same as its empirical formula.

When 1.86 g of alanine was vaporised at 550.0 °C and 50.0 kPa pressure, it occupied a volume of 2.86 L. (4 marks)



**See next page**

**Question 39** (continued)

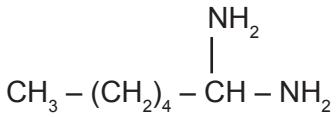
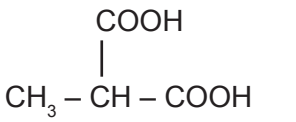
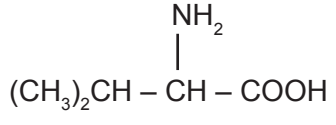
To consider the effect of having both an amine and a carboxylic acid functional group on the same molecule, amino acids can be compared with other organic compounds that have either:

- two amine functional groups on the same molecule (these compounds are called diamines)

**or**

- two carboxylic acid functional groups on the same molecule (these compounds are called dicarboxylic acids).

Amino acids have significantly higher melting points than diamines and dicarboxylic acids of similar mass and structure. This is illustrated in the table below.

| Compound type | Example | Molar mass g mol$^{-1}$ | Melting point °C |
|---|---|---|---|
| **diamine** |  hexane-1,1-diamine | 116.2 | 39 |
| **dicarboxylic acid** |  methylpropanedioic acid | 118.09 | 184 |
| **amine acid** |  2-amino-3-methylbutanoic acid (valine) | 117.15 | 298 |



**See next page**

(c) Explain why amino acids form crystalline solids and have significantly higher melting points than other organic molecules of similar mass and structure. Refer to the information provided in the table on page 34 and include a labelled diagram using the amino acid valine to illustrate your answer. (5 marks)



See next page

**Question 40** **(15 marks)**

Hydrogen fluoride, HF, is a highly dangerous and corrosive liquid that boils at near room temperature. It readily forms hydrofluoric acid in the presence of water and is an ingredient used to produce many important compounds, including medicines and polymers.

(a) (i) Name the electrostatic attractive force that holds the hydrogen and fluorine atoms together **within** hydrogen fluoride molecules. (1 mark)

(ii) Name the electrostatic attractive force **between** the hydrogen fluoride molecules. (1 mark)

(iii) Explain the origin of the attractive force **between** the hydrogen fluoride molecules. (2 marks)

(b) The equilibrium constant (K) for the dissociation of hydrofluoric acid is $6.8 \times 10^{-4}$, and for hydrochloric acid K is very large. To make a solution of hydrofluoric acid with the same pH as hydrochloric acid, a greater concentration of hydrofluoric acid is required. Explain why this is so. (3 marks)

**See next page**

(c) The salts, sodium chloride and sodium fluoride, readily dissolve in water. At 25.0 °C the pH of the sodium chloride solution is equal to 7 whereas the pH of the sodium fluoride solution is greater than 7. Explain this difference in pH. Include any relevant equation(s) to support your answer. (3 marks)

Propanoic acid, $CH_3CH_2COOH$, is also a weak monoprotic acid. When 0.500 mol of sodium propanoate is dissolved in 1.00 L of 0.500 mol $L^{-1}$ propanoic acid at 25.0 °C a buffer solution is formed.

(d) (i) Addition of 10.0 mL of 1.00 mol $L^{-1}$ HCℓ(aq) to this buffer does not significantly change its pH. Explain this observation, including any relevant equation(s). (3 marks)

(ii) State **two** conditions required to ensure that this system has a high buffering capacity. (2 marks)

One:

Two:

**End of questions**

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*Published by the School Curriculum and Standards Authority of Western Australia*
*303 Sevenoaks Street*
*CANNINGTON WA 6107*