PRESBYTERIAN LADIES' COLLEGE
A COLLEGE OF THE UNITING CHURCH IN AUSTRALIA

Semester 1 Examination, 2017

Question/Answer Booklet

CHEMISTRY

Year 12 ATAR

Section 1: Multi-Choice /50	Section 2: Short response /70	Section 3: Extended Response /80	Total /200	%

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**
- **Chemistry ATAR Course Data Booklet 2017**

To be provided by the candidate

- **Standard items:** **pens, pencils, eraser, correction fluid, ruler, highlighters**
- **Special items:** **non-programmable calculators satisfying the conditions set by the Curriculum Council for this course**

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

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	50	25
Section Two: Short Response	9	9	60	70	35
Section Three: Extended Response	6	6	70	80	40
					100

Instructions to candidates

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

2. Answer the questions according to the following instructions.

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

   Sections Two: Write your answers in the space provided in this Question/Answer Booklet. Wherever possible, confine your answers to the line spaces provided. Use a **blue** or **black** pen (**not** pencil) for this section.

   Spare answer pages are provided at the end of this booklet. If you need to use these, indicate in the original answer space where the answer is continued, e.g. write 'continued on page 29'. Fill in the number of the question that you are continuing at the top of that page.

   The space provided for each question is an indication of the length of answer required.

   Section Three: Write your answers in this Question/Answer Booklet. Use a **blue** or **black** pen (**not** pencil) for this section. Do **not** copy the questions when answering.

   If your answer exceeds the three pages provided for each question, continue writing on the spare pages at the end of the booklet. Indicate at the end of the page that the answer is continued. E.g. write 'continued on page 29'. Fill in the number of the question that you are continuing at the top of that page.

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

Section One: Multiple-choice 25% (50 Marks)

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided.

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

Suggested working time for this section is 50 minutes.

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1. Old fashioned 'smelling salts' are made of ammonium carbonate crystals, which decompose in an endothermic reaction to produce the pungent-smelling ammonia gas. The decomposition equation is shown below.

$$(NH_4)_2CO_3(s) \rightleftharpoons 2\,NH_3(g) + CO_2(g) + H_2O(g)$$

Which of the following statements regarding this equilibrium is **not** correct?

(a) The reverse reaction rate would increase if the volume of the system was decreased.
(b) The forward reaction would be favoured by having more finely divided ammonium carbonate crystals.
(c) The reverse reaction rate would be increased on a warmer day.
(d) More ammonia would be produced on a warmer day.

2. The **five (5)** substances named below were dissolved in water and the pH of each was determined by adding a few drops of universal indicator. For which of these substances is the observed pH **unable** to be explained by the Arrhenius theory of acids and bases?

(i) Hydrochloric acid, HCl
(ii) Ethanoic acid, CH_3COOH
(iii) Ammonia, NH_3
(iv) Calcium carbonate, $CaCO_3$
(v) Sodium hydroxide, NaOH

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

3. Consider the incomplete chemical equation shown below.

$$Cr(s) + ClO_3^-(aq) + H^+(aq) \rightarrow Cr^{3+}(aq) + HClO_2(aq) + H_2O(l)$$

When this redox reaction is completed and balanced correctly (using whole numbers), the coefficient in front of $H^+(aq)$ will be;

(a) 1
(b) 3
(c) 6
(d) 9

4. The equation below shows the key step involved in the Contact process.

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) \qquad \Delta H = -198\ kJ\ mol^{-1}$$

Which of the following sets of conditions would increase both the rate and yield of $SO_3(g)$?

	Increased rate	**Increased yield**
(a)	High temperature	Low pressure
(b)	High pressure	Low temperature
(c)	Low temperature	High pressure
(d)	Low pressure	High temperature

5. Considering only the information given below, which reaction is **most likely** to proceed quickly in the reverse direction?

	ΔH(forward) (kJ mol^{-1})	**E_a(forward) (kJ mol L^{-1})**
(a)	+850	875
(b)	+120	645
(c)	-95	730
(d)	-545	90

6. Consider the information below, relating to malonic acid ($C_3H_4O_4$), which is a weak, organic, diprotic acid.

$$C_3H_4O_4(aq) + H_2O(l) \rightleftharpoons C_3H_3O_4^-(aq) + H_3O^+(aq) \qquad K_{a1} = 1.48 \times 10^{-3}$$

$$C_3H_3O_4^-(aq) + H_2O(l) \rightleftharpoons C_3H_2O_4^{2-}(aq) + H_3O^+(aq) \qquad K_{a2} = 1.10 \times 10^{-6}$$

Which of the following statements is **true** regarding **diprotic** acids?

(a) They have only 2 hydrogen atoms per molecule.
(b) They have a lower pH than monoprotic acids of the same concentration.
(c) They are all weak acids.
(d) The value of K_{a1} is always greater than the value of K_{a2}.

7. Rank the following substances in order of increasing **nitrogen** oxidation number (i.e. from the species with nitrogen in lowest oxidation state to highest oxidation state).

	NO_3^-		**N**$_2$O		H**N**O_2		**N**H_4^+		**N**$_2$
(a)	NH_4^+	<	N_2	<	N_2O	<	HNO_2	<	NO_3^-
(b)	NO_3^-	<	N_2O	<	HNO_2	<	N_2	<	NH_4^+
(c)	NH_4^+	<	HNO_2	<	N_2	<	NO_3^-	<	N_2O
(d)	N_2	<	NH_4^+	<	NO_3^-	<	N_2O	<	HNO_2

8. Consider 0.25 mol L^{-1} aqueous solutions of the following salts;

$NaHSO_4$ K_3PO_4 $Ca(NO_3)_2$

Rank these **three (3)** solutions in order of decreasing pH (i.e. highest to lowest).

(a) K_3PO_4 > $Ca(NO_3)_2$ > $NaHSO_4$
(b) $Ca(NO_3)_2$ > $NaHSO_4$ > K_3PO_4
(c) $NaHSO_4$ > $Ca(NO_3)_2$ > K_3PO_4
(d) $NaHSO_4$ > K_3PO_4 > $Ca(NO_3)_2$

Questions 9, 10 and 11 relate to the equilibrium system below.

At temperatures greater than 1000 °C, gaseous octasulfur (S_8) can undergo an endothermic decomposition to form gaseous disulfur (S_2) as shown in the equation below.

$$S_8(g) \rightleftharpoons 4\ S_2(g)$$

Some $S_8(g)$ was placed in an empty rigid container and allowed to establish equilibrium at 1052 °C. At this temperature the value of K for this equilibrium system is 324.

9. Once the system has established equilibrium, which of the following statements are **correct**?

(i) The total pressure inside the container will be constant.
(ii) The pressure inside the container will be higher than initially.
(iii) The colour of the gaseous mixture will be constant.
(iv) The rates of the forward and reverse reactions will be equal.
(v) The concentration of S_8 and S_2 will be equal.

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

10. Which of the following statements regarding K for this equilibrium system is **correct**?

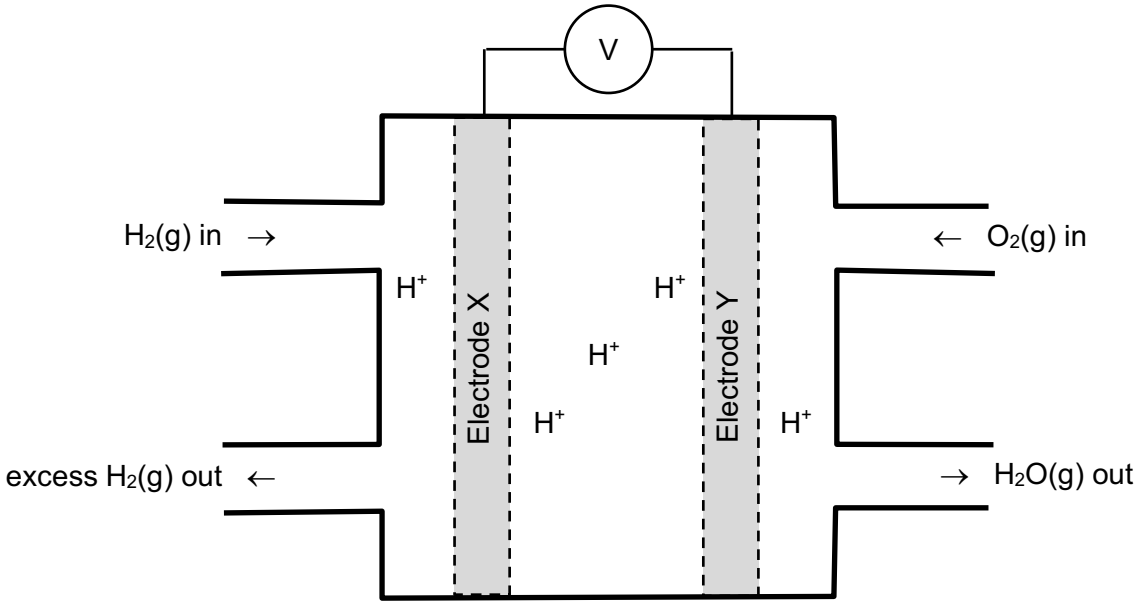
(a) At equilibrium there is a higher concentration of $S_8(g)$ present than $S_2(g)$.
(b) If the temperature of the system was decreased the value of K would increase.
(c) The equilibrium constant expression can be written $K = \frac{[S_8]}{[S_2]}$
(d) The equilibrium constant expression can be written $K = \frac{[S_2]^4}{[S_8]}$

11. Once the system had established equilibrium, various changes were imposed on the system and the effects of these changes were predicted using Le Chatelier's principle. Which of the following is **not** correct (i.e. the predicted effect on the equilibrium position does **not** match the imposed change stated)?

	Imposed change	**Effect on equilibrium position**
(a)	Pressure increase	$\leftarrow$
(b)	Removal of S_2	$\leftarrow$
(c)	Temperature increase	$\rightarrow$
(d)	Addition of S_8	$\rightarrow$

Questions 12 and 13 refer to the information below.

There are several different types of fuel cells, which mostly differ in terms of the fuel being utilised. One of the most common fuel cells is the hydrogen / oxygen fuel cell. A partially completed sketch of a hydrogen / oxygen fuel cell operating with an acid electrolyte is shown in the diagram below. The only overall chemical product of the hydrogen / oxygen fuel cell is water.



12. Which of the following statements are **correct**, regarding **fuel cells in general**?

(i) Fuel cells involve a redox reaction.
(ii) Fuel cells require continuous input of reactants to operate.
(iii) Fuel cells are a type of galvanic cell.
(iv) Fuel cells are a type of secondary cell.
(v) Fuel cells do not produce any sources of pollution.

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

13. Which of the following statements is **correct,** regarding the **hydrogen/oxygen fuel cell** shown in the diagram above?

(a) Reduction occurs at X.
(b) Electrons move from Y to X.
(c) Cations move towards Y.
(d) The EMF of this cell under standard conditions is 1.15 volts.

14. The hydrogencarbonate / carbonic acid buffering system in blood helps to maintain our blood at a pH of 7.4. Carbon dioxide (CO_2) can be exhaled by the lungs and hydrogen ions (H^+) can be excreted by the kidneys to help maintain the delicate balance of our blood chemistry. The equations for this buffer system are shown below, along with the concentration of the two main buffer components.

$$\underset{0.0245\ mol\ L^{-1}}{HCO_3^-(aq)} + H^+(aq) \rightleftharpoons \underset{0.0012\ mol\ L^{-1}}{H_2CO_3(aq)} \rightleftharpoons H_2O(l) + CO_2(g)$$

Which of the following statements regarding this buffer system is **not** correct?

(a) H_2CO_3/HCO_3^- are a conjugate acid-base pair.
(b) The buffering capacity is greater for a rise in H^+ concentration than for a fall in H^+ concentration.
(c) A rise in H^+ concentration in the blood would shift the equilibrium to the right.
(d) Increased breathing would decrease the pH of blood.

Questions 15 and 16 are based on the equilibrium reaction below.

In aqueous solution an equilibrium exists between dichromate and chromate ions as represented in the following equation:

$$Cr_2O_7^{2-}(aq) + 2\ OH^-(aq) \Leftrightarrow 2\ CrO_4^{2-}(aq) + H_2O(aq) \qquad \Delta H = -97\ kJ\ mol^{-1}$$

15. If concentrated sulfuric acid is added to an equilibrium system of chromate and dichromate ions then:

(a) the equilibrium position shifts to the left.
(b) the equilibrium position shifts to the right.
(c) there is no change in the colour.
(d) green chromium (III) sulfate forms.

16. If an equilibrium system of dichromate and chromate ions is heated:

(a) the equilibrium position shifts to the right.
(b) the colour becomes more yellow.
(c) there is no change in colour.
(d) the equilibrium position shifts to the left.

17. The equation for the autoionisation of water is shown below, along with two values for K_w at two corresponding temperatures.

$$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

$K_w = 1.0 \times 10^{-14}$ at 25°C
$K_w = 2.9 \times 10^{-14}$ at 40°C

Considering the information provided, which of the following statements is **not** correct?

(a) The autoionisation of water is an endothermic process.
(b) The concentration of H_3O^+ in water at 40°C is higher than water at 25°C.
(c) The pH of water at 40°C is lower than water at 25°C.
(d) The water at 40°C is slightly more acidic than water at 25°C.

18. Which of the following halogen displacement reactions would **not** occur under standard conditions?

(a) $Cl_2(aq) + 2\ Br^-(aq) \rightarrow 2\ Cl^-(aq) + Br_2(aq)$
(b) $I_2(aq) + 2\ Br^-(aq) \rightarrow 2\ I^-(aq) + Br_2(aq)$
(c) $Cl_2(aq) + 2\ I^-(aq) \rightarrow 2\ Cl^-(aq) + I_2(aq)$
(d) $Br_2(aq) + 2\ I^-(aq) \rightarrow 2\ Br^-(aq) + I_2(aq)$

19. A sample of ethanoic acid was placed in a beaker and several drops of universal indicator were added. To the beaker, aqueous sodium carbonate was added dropwise until it was in excess. Which of the following statements is **not** correct regarding the reaction that would have taken place?

(a) A colourless, odourless gas would have been produced.
(b) The colour of the solution would have changed from pink to green to blue.
(c) A neutralisation reaction would have taken place.
(d) A solid white salt would have been produced.

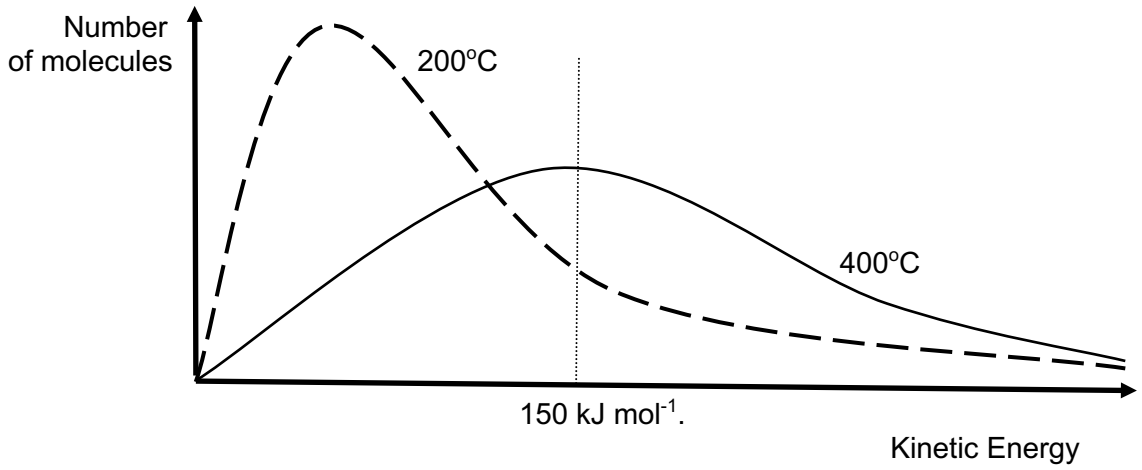
20. What is the concentration in parts per million of a solution of 0.0100 mol L^{-1} $NaOH_{(aq)}$ (molar mass (NaOH) = 40.00 g mol^{-1} and density of solution = 1.00 g mL)

(a) 4.0×10^2 ppm
(b) 2.5×10^3 ppm
(c) 4.0×10^3 ppm
(d) 1.0×10^{-2} ppm

21. Which of the following pairs of solutions would form a green precipitate when mixed?

(a) iron(III) nitrate and sodium hydroxide
(b) ammonium nitrate and chromium chloride
(c) copper(II) chloride and potassium nitrate
(d) nickel(II) sulfate and sodium carbonate

22. The graph shows the distribution of kinetic energy of molecules in a fixed quantity of gas at 200°C and 400°C involved in a reaction that has an activation energy of 150 kJ mol^{-1}



Which of the following statements about the graph is **false**?

(a) The average kinetic energy of the particles is greater at 400°C than at 200°C.
(b) The total area under each graph should be equal.
(c) The reaction will not occur at 200°C.
(d) Some molecules at 200°C will have higher velocities than some at 400°C.

23. Which one of the following correctly arranges 1.0 mol L^{-1} solutions of the substances in the order of increasing pH?

(a)	H_3PO_4	H_2SO_4	CH_3COONa	CH_3COOH	NH_4CH_3COO
(b)	H_2SO_4	H_3PO_4	CH_3COOH	NH_4CH_3COO	CH_3COONa
(c)	H_2SO_4	H_3PO_4	CH_3COOH	CH_3COONa	NH_4CH_3COO
(d)	H_3PO_4	H_2SO_4	NH_4CH_3COO	CH_3COOH	CH_3COONa

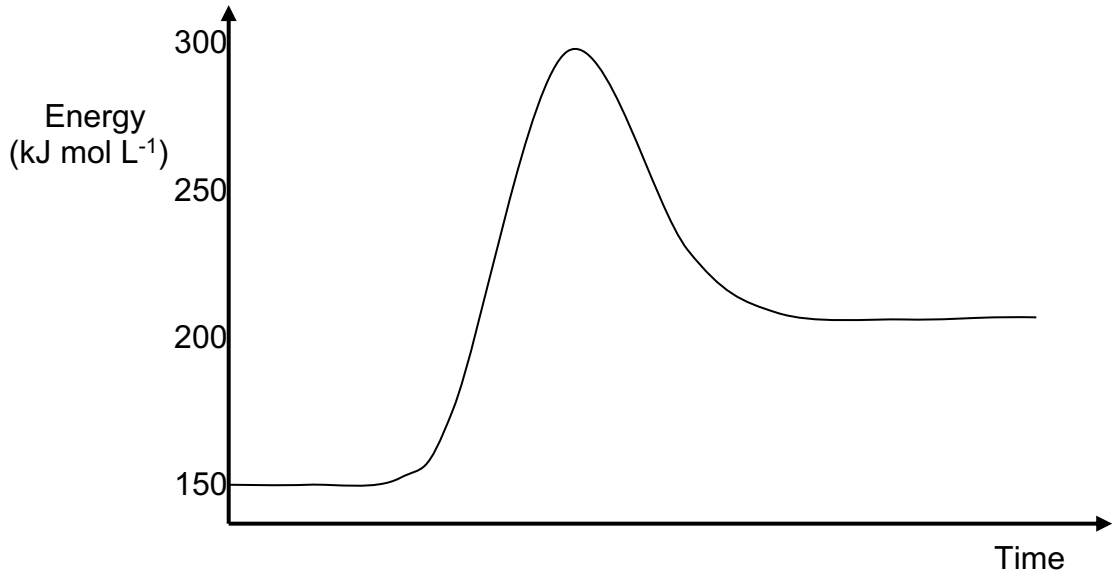
24. Consider the following equation:

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

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

(a) HCO_3^- is acting as a Bronsted-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 Bronsted-Lowry base.

25. An energy profile diagram for a chemical reaction is shown below.



The reaction is:

(a) Exothermic with an activation energy of +100 kJ mol L^{-1}
(b) Endothermic with an activation energy of +150 kJ mol L^{-1}
(c) Exothermic with an of enthalpy change +50 kJ mol L^{-1}
(d) Endothermic with an enthalpy change of +200 kJ mol L^{-1}

End of Section One

Section Two: Short Response 35% (70 Marks)

This section has **nine (9**) questions. Answer **all** questions. Write your answers in the space provided.

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

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

Suggested working time for this section is 60 minutes.

Question 26 **(7 marks)**

Hydrofluoric acid, HF(aq), is a colourless, highly corrosive solution, used in the manufacture of many pharmaceuticals. Hydrofluoric acid has a K_a value of 6.76×10^{-4}.

(a) Write an equilibrium constant (K_a) expression for the ionisation of HF in water and explain what information the value of K_a provides. (2 marks)

A student was given 0.500 L of a 0.250 mol L^{-1} hydrofluoric acid solution and instructed to produce a buffer.

(b) What substance could the student add to the HF(aq) to produce a buffer? Explain your answer. (2 marks)

(c) Write a chemical equation for the buffer system that would be formed and label the conjugate acid-base pairs. (3 marks)

Question 27 **(6 marks)**

Tin is a metallic element located in Group 14 of the periodic table. It is used to make many different alloys such as bronze and solder, as well as finding application in the plating of steel to produce 'tin cans' for storage.

A chemistry student had 1.0 mol L^{-1} solutions of the following **four (4)** substances;

$Ni(NO_3)_2$ $Zn(NO_3)_2$ $Pb(NO_3)_2$ $Mg(NO_3)_2$

(a) Which of these solutions could **not** be stored in a tin container? Explain your answer using a relevant chemical equation. (3 marks)

When tin metal is placed in an acidified solution containing the weak acid hydrogen chromate ($HCrO_4^-$) a deep green solution containing chromium(III) ions is formed, and the tin metal dissolves producing tin(II) ions.

(b) Write the oxidation and reduction half-equations and the overall redox equation for this reaction. (3 marks)

Oxidation half-equation	
Reduction half-equation	
Overall redox equation	

Question 28 **(8 marks)**

Ammonium carbamate can decompose in a reversible, endothermic reaction, according to the chemical equation shown below.

$$NH_4COONH_2(s) \rightleftharpoons 2\ NH_3(g) + CO_2(g)$$

(a) If the total volume of the system was decreased, state the effect this would have on the equilibrium position and note any observations. (3 marks)

equilibrium position: _____

_____

observation: _____

_____

(b) If the temperature of the system was decreased, explain the effect this would have on the equilibrium in terms of reaction rates. (3 marks)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(c) One of the products of this decomposition reaction is carbon dioxide gas. Write **two (2)** chemical equations that illustrate how increasing atmospheric CO_2 levels may contribute to ocean acidification. (2 marks)

1.
2.

Question 29 **(8 marks)**

(a) Calculate the pH of a solution of 1.25 mol L^{-1} nitric acid. (2 marks)

(b) A student was asked to dilute 75.0 mL of this solution to produce a solution of hydrochloric acid with a pH of 1.00. Calculate the volume of distilled water that she would need to add. (3 marks)

(c) 50 mL of this new acid solution was mixed with 50 mL of 0.025 mol L^{-1} $Ca(OH)_2$ solution. Calculate the pH of this new mixture. (3 marks)

Question 30 **(4 marks)**

The equilibrium constant for the following reaction is 0.67 at a particular temperature.

$$CO(g) + 3H_2(g) \rightarrow CH_4(g) + H_2O(g); \ \Delta H = +208 \text{ kJ mol}^{-1}$$

(a) A mixture of CO, H_2, CH_4 and H_2O at equilibrium is heated to this temperature. In the table below, mark with a tick what would happen to the concentration of each chemical as the reaction approaches equilibrium.

	Concentration increases	**Concentration does not change**	**Concentration decreases**
CO			
H_2			
CH_4			
H_2O			

(2 marks)

(b) When the temperature of the reaction mixture is increased by 10°C, the equilibrium constant for the reaction becomes 0.71. What conclusion can you make about the enthalpy change of this reaction? (1 mark)

_____

_____

_____

(c) Under high pressure what physical change could occur to **one (1)** of the products that would increase the rate of the forward reaction? (1 mark)

_____

_____

_____

Question 31 **(10 marks)**

(a) Sodium carbonate is used as a primary standard in acid-base titrations, while sodium hydroxide is not. Explain why this is so. (4 marks)

(b) Sodium hydrogen carbonate is often used to increase the pH in swimming pools. Explain, with the aid of suitable equations, how adding sodium hydrogencarbonate affects the pH of the water. (3 marks)

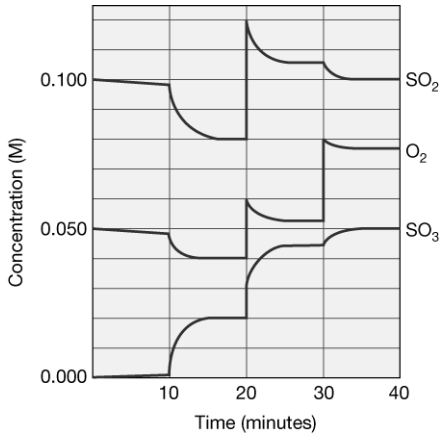
(c) Briefly explain why methyl orange is an inappropriate indicator to use in a titration between sodium hydroxide and acetic acid (ethanoic acid). (3 marks)

Question 32 **(7 marks)**

Sulfur dioxide gas and oxygen gas were mixed at 600°C to produce a gaseous equilibrium mixture:

$$2SO_2(g) + O_2(g) \leftrightharpoons 2SO_3(g)$$

A number of changes were then made, including the addition of a catalyst, resulting in the formation of new equilibrium mixtures. The graph below shows how the concentrations of the **three(3)** gases changed with time.



(a) Write an expression for the equilibrium constant, *K*, of the reaction. (1 mark)

_____

(b) During which time intervals was the reaction at equilibrium? (2 marks)

_____

_____

(c) At what time was the catalyst added? Explain your reasoning. (2 marks)

_____

_____

(d) What change was made to the system at:

(i) 20 minutes? (1 mark)

_____

_____

(ii) 30 minutes? (1 mark)

_____

_____

Question 33 **(9 marks)**

Write the equation and observation for the reaction that occurs in each of the following procedures. If no reaction occurs, write 'no reaction'. For full marks, chemical equations should refer only to those species consumed in the reaction and the new species produced. These species may be ions [for example $Ag^+(aq)$], molecules [for example $NH_3(g)$, $NH_3(aq)$, $CH_3COOH(l)$] or solids [for example $BaSO_4(s)$, $Cu(s)$, $Na_2CO_3(s)$].

(a) Hydrochloric acid solution is added to solid copper (II) oxide.

Equation:

_____

_____

Observation:

_____

_____

(3 marks)

(b) Solid calcium hydrogen carbonate is added to sulfuric acid solution.

Equation:

_____

_____

Observation:

_____

_____

(3 marks)

(c) Solid magnesium is added to phosphoric acid solution.

Equation:

_____

_____

Observation:

_____

_____

(3 marks)

Question 34 **(11 marks)**

Methanol is manufactured for use as a fuel for racing cars. It can be made by the reaction between carbon monoxide and hydrogen:

$$CO(g) + 2H_2(g) \leftrightharpoons CH_3OH(g); \ \Delta H = -103 \text{ kJ mol}^{-1}$$

(a) What conditions of temperature and pressure would be required for:

(i) a fast reaction rate? (1 mark)

_____

(ii) a high equilibrium yield of methanol? (1 mark)

_____

(b) Will a compromise be needed in the choice of temperature or pressure? Explain. (2 marks)

_____

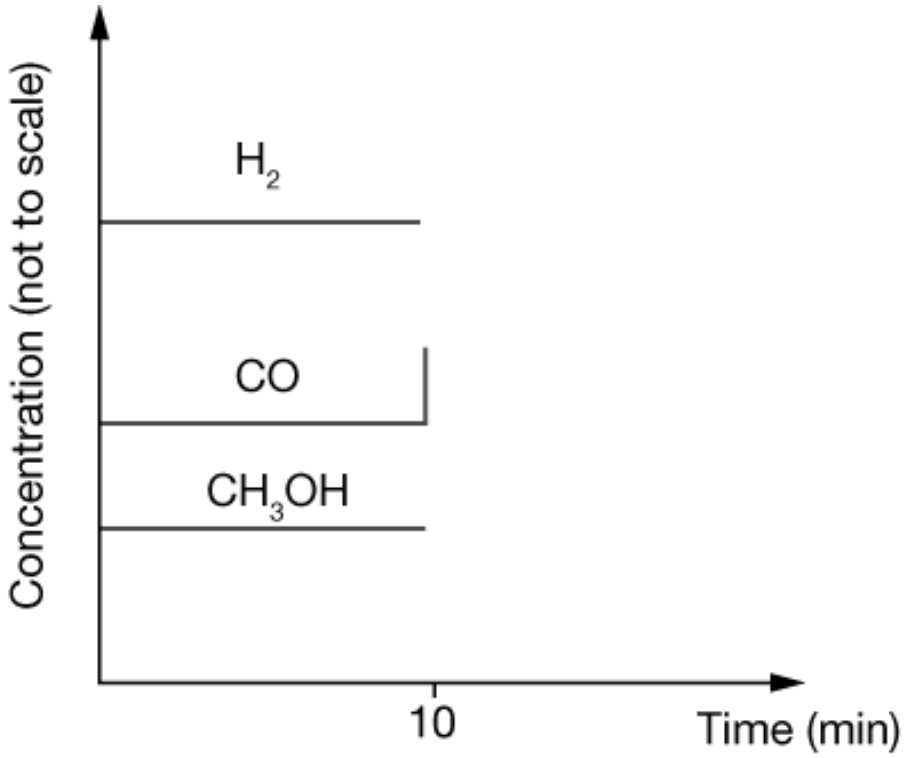
_____

(c) Suggest another method that could be employed at a manufacturing plant to increase the rate of methanol production. (1 mark)

_____

(d) As part of an investigation of this process, the concentrations of a mixture of CO, H_2 and CH_3OH were monitored continuously. The mixture was intially at equilibrium at 400°C and constant volume. After 10 minutes additional CO was added to the mixture, as shown in the graph below.

Graph of concentration versus time.



(i) Sketch on the graph to show how concentrations would change as a consequence of the addition of CO. (3 marks)

(ii) Following the addition of the CO the mixture again reaches equilibrium. Sketch a second set of lines on the graph to show the effect on the concentrations if the temperature was then increased to 450°C.

(3 marks)

End of Section Two

Section Three: Extended Response 40% (80 Marks)

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

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

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

Suggested working time for this section is 70 minutes.

Question 35 **(12 marks)**

To be used in wiring, copper must be at least 99.9% pure. To obtain 99.9% pure copper from its most common ore, chalcopyrite ($CuFeS_2$), two processes must take place.

(i) The first process occurs in a furnace where the chalcopyrite is converted to 'blister copper', which is approximately 98% pure due to impurities such as sand.
(ii) A second process occurs in an electrolytic cell where the 'blister copper' undergoes electrolysis to produce copper at or above 99.9% purity.

In the furnace, the ore is heated strongly with silica (silicon dioxide), calcium carbonate and air. The furnace reduces the copper (II) in the chalcopyrite first to copper (I) then to copper metal.

Below are the equations that represent the main processes occurring in the blast furnace.

Equation 1 : $2\ CuFeS_2 + 2\ SO_2 + 4\ O_2 \rightarrow Cu_2S + 2\ FeSiO_3 + 3\ SO_2$

Equation 2 : $Cu_2S + O_2 \rightarrow 2\ Cu + SO_2$

Equation **two (2)** can be represented as half-equations:

(a) Write the reduction half equation. (1 mark)

_____

_____

(b) Write the oxidation half equation. (1 mark)

_____

_____

In the electrolytic cell, the copper produced from the blast furnace is purified.

(c) Explain the electrolytic process used to purify copper. Include:

- a brief overview of the process
- a labelled diagram of the electrolytic cell
- the relevant oxidation and reduction half equations
- a discussion of impurities and how they are separated from the copper (10 marks)

Question 36 **(14 marks)**

A soluble fertiliser contains phosphorus in the form of phosphate ions (PO_4^{3-}). To determine the PO_4^{3-} content by gravimetric analysis, 5.97 g of the fertiliser powder was completely dissolved in water to make a volume of 250.0 mL. A 20.00 mL volume of this solution was pipetted into a conical flask and the PO_4^{3-} ions in the solution were precipitated as $MgNH_4PO_4$. The precipitate was filtered, washed with water and then converted by heating into $Mg_2P_2O_7$.

(The mass of $Mg_2P_2O_7$ was 0.0352 g.)

(a) Calculate the amount, in mole, of $Mg_2P_2O_7$ (1 mark)

(b) Calculate the amount, in mole, of phosphorus in the 20.00 mL volume of solution. (1 mark)

(c) Calculate the amount, in mole, of phosphorus in 5.97 g of fertiliser. (1 mark)

(d) Calculate the percentage of phosphate ions (PO_4^{3-}) by mass in the fertiliser. Ensure you express your answer to an appropriate number of significant figures. (3 marks)

(e) Several actions which could occur during this analytical procedure are listed below (**A**-**D**). For each action, indicate the likely effect on the calculated percentage of phosphate ions in the fertiliser by placing a tick in the appropriate box.

Action	Calculated result would be too low	No effect on calculated result	Calculated result would be too high
A. The $MgNH_4PO_4$ precipitate was not washed with water.			
B. The conical flask had been previously washed with water but not dried.			
C. A 25.00 mL pipette was unknowingly used instead of a 20.00 mL pipette.			
D. The mass of the fertiliser was recorded incorrectly. The recorded mass was 0.2 g higher than the actual mass.			

(4 marks)

Explain your reasoning for the answers that you have given in D part (e).

A. _____

B. _____

C. _____

D. _____

(4 marks)

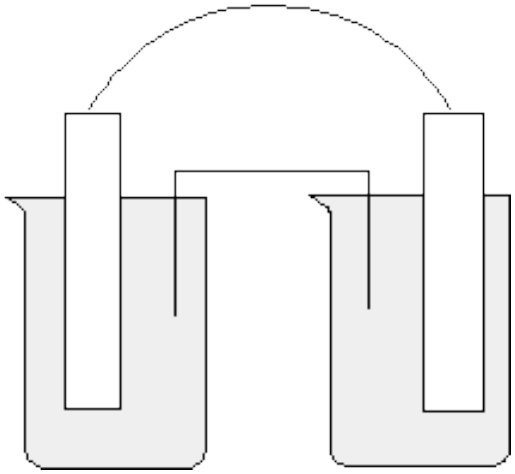
Question 37 **(18 marks)**

Lead-acid storage batteries use Pb and PbO_2 electrodes. Pb is the reducing agent, while PbO_2 is the oxidising agent. Sulfuric acid solution is used as the electrolyte.

(a) The overall battery reaction during discharge is given below. Write and balance the anode and cathode reactions for the lead-acid storage battery. (2 marks)

Anode reaction	
Cathode reaction	
Overall reaction	$Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

(b) A schematic diagram of the lead-acid battery showing the half-cells is shown below. Label the anode, cathode and salt bridge, and indicate the direction of electron flow with an arrow. (4 marks)



(c) (i) With reference to the 'electrical potential' of a galvanic cell, describe how the lead-acid storage battery produces current. (2 marks)

(ii) What determines the magnitude of the electrical potential of a cell? (1 mark)

(d) (i) Determine the number of moles of $H^+(aq)$ in a lead-acid battery that contains 4.50 L of 3.55 mol L^{-1} sulfuric acid solution. (1 mark)

(ii) Use the overall equation to determine the number of moles of $H^+(aq)$ consumed when discharge of this battery forms 138.1 g of $PbSO_4(s)$. The molar mass of $PbSO_4$ is 303.26 g mol^{-1}. (2 marks)

(iii) Use your answers to (i) and (ii) to determine the concentration of $H^+(aq)$ in the electrolyte in the discharge battery. Assume that the electrolyte volume remains constant and ignore any changes due to the formation of water. (2 marks)

(iv) Use your answers to (i) and (iii) to show that when this battery discharges, the change in pH of the electrolyte solution is negligible. Note that in any solution whose $H^+(aq)$ concentration is greater than 1 mol L^{-1}, the pH is negative. (3 marks)

(v) A flat (fully discharged) lead-acid battery can be ‘jump started’ by connecting it to a battery in a car whose engine is running. The current forced through the battery in this way causes the formation of a mixture of hydrogen and oxygen gas through the hydrolysis of water. State why the formation of the hydrogen and oxygen gas mixture may be dangerous. (1 mark)

Question 38 **(15 marks)**

Two chemists Ali and Kayley have to calculate the purity of a shipment of itaconic acid, which is produced from citric acid and is used to make polymers. Itaconic acid is a weak diprotic acid with the formula $C_5H_6O_4$. An experiment was set up to calculate the purity of the itaconic acid. It should be greater than 99% but since changing suppliers to Bozo Chemicals, they have their doubts.

A 1.250g of the itaconic acid was mixed with 50.00 mL of 0.750 mol L^{-1} $NaOH_{(aq)}$ and stirred thoroughly.

The resulting solution was filtered and immediately titrated against 1.25 mol L^{-1} $HCl_{(aq)}$.

The whole experiment was carried out **three (3)** times and the results shown below:

	Titrations		
	1	2	3
Final Reading (mL)	15.75	31.60	47.45
Initial Reading (mL)	0.00	15.75	31.60
Titre (mL)			

(a) Complete the table above and find the average titre of HCl used. (1 mark)

_____

(b) Calculate the number of moles of HCl used in each titration. (1 mark)

_____

_____

_____

(c) Calculate the number of moles of NaOH, which reacted with the HCl. (1 mark)

_____

_____

_____

(d) Calculate the number of moles of NaOH, which were added to the itaconic acid. (1 mark)

_____

_____

_____

(e) Calculate the number of moles of NaOH, which reacted with the itaconic acid. (2 marks)

(f) Calculate the number of moles of itaconic acid, in the original mass. (2 marks)

(g) Calculate the mass of itaconic acid, in the original mass. (2 marks)

(h) Calculate the percent purity of the itaconic acid. (2 marks)

(i) Do our two chemists have a right to be doubtful about Bozo Chemicals. Why? (2 marks)

_____

_____

_____

_____

_____

_____

(j) What assumption must be made about the composition of this brand of itaconic acid? (1 mark)

_____

_____

_____

Question 39 **(10 marks)**

A student was set a task of producing copper(II) nitrate crystals from copper(II) oxide and dilute nitric acid using the following reaction:

$$CuO_{(s)} + 2HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + H_2O_{(l)}$$

He added 5.00g of CuO to 50.0 mL of 1.00 mol L^{-1} HNO_3. The mixture was warmed until the reaction was complete, allowed to cool and the resulting solution was filtered.

He then left the filtrate to evaporate at room temperature until crystals of copper(II) nitrate formed.

(a) Calculate the mass of the copper(II) oxide that would have remained in the filter paper? (4 marks)

(b) How many moles of copper(II) nitrate should he have produced? (2 marks)

(c) If the copper(II) nitrate crystallised in the form of $Cu(NO_3)_2.6H_2O$, what will be the mass of crystals produced?

(2 marks)

(d) If the actual mass was 6.04g, what would be the formula of the hydrated copper (II) nitrate formed.

(2 marks)

Question 40 **(11 marks)**

Two students Sylvie and Maddie, have concerns about the vinegar they have purchased from a new supplier Vital Vinegar. Their concerns are further raised when they find out the company has been taken over by our old friends Bozo Chemicals. Commercial vinegar should be 5% by mass ethanoic acid.

An experiment was carried out to find the amount of ethanoic acid (CH_3COOH) in a sample of Vital Vinegar using the following method.

Pipette 25.00 mL of vinegar into a 250 mL volumetric flask. Add distilled water up to the mark. Using a pipette, transfer 20.00 mL aliquots of this diluted vinegar into a conical flask and titrate against 0.075 M NaOH in a burette, using phenolphthalein as an indicator.

Burette readings (mL)	Titrations			
	1	2	3	4
Final volume	9.50	18.60	27.65	36.75
Initial volume	0.00	9.50	18.60	27.65
Titre				

(a) Complete the table and calculate the titration volume.

(2 marks)

(b) Write an ionic equation for the reaction between ethanoic acid and sodium hydroxide

(2 marks)

(c) Calculate the concentration of ethanoic acid in the **diluted** vinegar in mol L^{-1}

(3 marks)

(d) Calculate the concentration of ethanoic acid in the **original** sample of vinegar in mol L^{-1}.

(2 marks)

(e) Convert the answer in (c) to give the concentration as a % by mass. (2 marks)

End of Section Three

Additional working space:

Question number: _____

Additional working space:

Question number: _____

Additional working space:

Question number: _____

Additional working space:

Question number: _____