



Examination Question/Answer Booklet

CHEMISTRY STAGE 3AB Semester 1 sample paper

Please place your student identification label in this box

Time allowed for this paper

Reading time before commencing work: Ten minutes
Working time for paper: Three hours

Material required/recommended for this paper

To be provided by the supervisor

Question/answer booklet
Separate multiple-choice answer sheet
Data sheet

To be provided by the candidate

Standard items: Pens, pencils, eraser, correction fluid, ruler, highlighter
Special items: Scientific calculator

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.

Section	Out Of	
Multiple Choice	/50	
Short Answers	/69	
Extended response	/73	
Total	/192	%

Structure of this paper

Section	Suggested working time	Number of questions available	Number of questions to be attempted	% of paper	Marks
ONE Multiple choice	50 minutes	25	25	26	50
TWO Short response	60 minutes	12	12	36	69
THREE Extended response	70 minutes	6	6	38	73
			Total	100	192

Instructions to candidates

- The rules for the conduct of Curriculum Council examinations are detailed in the *Student Information Handbook*. Sitting this examination implies that you agree to abide by these rules.
- Answer the questions according to the following instructions.
Section One Answer all questions in the separate multiple-choice answer sheet provided.
Section Two Answer **all** questions in the spaces provided in this Question/Answer Booklet.
Section Three Answer **all** questions in the spaces provided in this Question/Answer Booklet
- A blue or black ballpoint or ink pen should be used.
- 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 $NH_3(g)$, $NH_3(aq)$, $CH_3COOH(l)$, $CH_3COOH(aq)$] or **solids** [for example $BaSO_4(s)$, $Cu(s)$, $Na_2SO_4(s)$].
- Additional information which may be necessary to answer questions is located on the separate Chemistry data sheet.

SECTION ONE—MULTIPLE-CHOICE

[50 marks]

This section has **TWENTYFIVE (25)** questions. Attempt **ALL** questions.

Answer all questions in Section 1 on the separate Multiple-Choice Answer Sheet provided, using a blue or black pen. Each question in this part is worth 2 marks.

Suggested working time: 50 minutes.

1. The ion $^{113}\text{In}^{3+}$ contains:

- a) 113 protons, 49 neutrons, 110 electrons
- b) 49 protons, 64 neutrons, 46 electrons
- c) 49 protons, 64 neutrons, 49 electrons
- d) 49 protons, 113 neutrons, 46 electrons

2. Which of the following 0.1 mol L^{-1} solutions when mixed will produce only a white precipitate?

- | | | | | |
|----|------------------|------------------|-------------------|---------------------|
| a) | zinc nitrate | copper sulfate | barium nitrate | potassium carbonate |
| b) | sodium chloride | zinc nitrate | sodium carbonate | ammonium nitrate |
| c) | copper nitrate | sodium chloride | aluminium nitrate | calcium hydroxide |
| d) | chromium nitrate | sodium hydroxide | zinc chloride | potassium carbonate |

3. According to the Bronsted-Lowry theory of acids and bases, select the alternative that is made up of bases only.

- | | | | |
|----|-------------------------|------------------------|---------------------------|
| a) | PO_4^{3-} | O^{2-} | NH_3 |
| b) | NH_3 | H_3O^+ | H_2CO_3 |
| c) | H_3PO_4 | NH_4^+ | CH_3COO^- |
| d) | NH_4^+ | H_3O^+ | H_2O |

4. To find the degree of ionisation of acetic (ethanoic) acid, the best method would be to:

- a) measure the density of a solution of known concentration.
- b) measure the volume of carbon dioxide (at STP) given off in a reaction with excess calcium carbonate.
- c) titrate a given number of mol against standard sodium hydroxide.
- d) use a pH meter.

5. Which of the following is a good primary standard for acid-base titrations?

- a) $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}(\text{s})$
- b) $\text{NaOH}(\text{s})$
- c) $\text{HCl}(\text{g})$
- d) $\text{Na}_2\text{CO}_3(\text{s})$

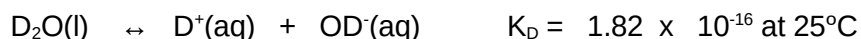
6. Metal X forms the following compounds:



Which one of the following is not true concerning element X?

- a) Element X is most likely a transition metal
- b) The oxidation number of X in the three compounds is +2, +3 and +4 respectively
- c) Element X could be a covalent network element
- d) The oxides and chloride of X would have high melting points

7. Deuterium (symbol D) is an isotope of hydrogen. Water made from deuterium has the symbol D_2O and has similar properties to normal water. D_2O ionises according to the equilibrium



In a neutral solution of pure D_2O at $25^\circ C$ the concentration of D^+ , in mole per litre, is

- a) 1×10^{-7}
- b) 1.35×10^{-8}
- c) 0.91×10^{-8}
- d) 1.82×10^{-16}

8. Which one of the following equilibria in aqueous solution would not be affected by diluting the solution with water?

- a) $[Co(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \leftrightarrow [CoCl_4]^{2-}(aq) + 6H_2O(l)$
- b) $Cr_2O_7^{2-}(aq) + 2OH^-(aq) \leftrightarrow 2CrO_4^{2-}(aq) + H_2O(l)$
- c) $Br_2(aq) + 2OH^-(aq) \leftrightarrow OBr^-(aq) + Br^-(aq) + H_2O(l)$
- d) $HPO_4^{2-}(aq) + SO_4^{2-}(aq) \leftrightarrow PO_4^{3-}(aq) + HSO_4^-(aq)$

9. Which one of the following could **not** be used to distinguish between solutions of sodium iodide and barium chloride?

- a) bromine water
- b) hydrochloric acid
- c) sulfuric acid
- d) copper(II) sulfate solution

10. Consider the three weak acids, tellurous acid, H_2TeO_3 , hydrazoic acid, HN_3 , and nitrous acid, HNO_2 . The conjugate bases of these acids would be

- a) TeO_3^{2-} , NH_4^+ and HNO_2^+
- b) $HTeO_3^-$, N_3^- and NO_2^-
- c) $HTeO_3^-$, HN_2^- and NO_2^-
- d) TeO_3^{2-} , NH_2^- and NO_3^-

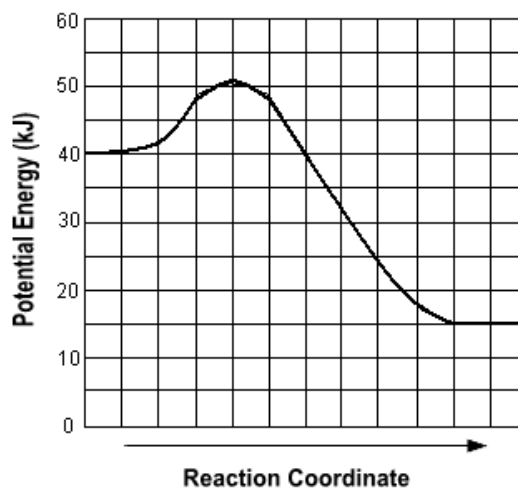
11. A student adds solid KCl to water in a flask. The flask is sealed with a stopper and thoroughly shaken until no more solid KCl dissolves. Some solid KCl is still visible in the flask. The solution in the flask is

- a) saturated and is at equilibrium with the solid KCl
- b) saturated and is not at equilibrium with the solid KCl
- c) unsaturated and is at equilibrium with the solid KCl
- d) unsaturated and is not at equilibrium with the solid KCl

12. Which symbol represents a particle that has the same total number of electrons as S^{2-} ?

- a) O^{2-}
- b) Se^{2-}
- c) Si
- d) Ar

13. Given the potential energy diagram for a chemical reaction:



Which statement correctly describes the energy changes that occur in the forward reaction?

- a) The activation energy is 10 kJ and the reaction is endothermic
- b) The activation energy is 10 kJ and the reaction is exothermic
- c) The activation energy is 50 kJ and the reaction is endothermic
- d) The activation energy is 50 kJ and the reaction is exothermic

14. If 0.025 gram of $\text{Pb}(\text{NO}_3)_2$ is dissolved in 100 grams of H_2O , what is the concentration of the resulting solution, in parts per million?

- a) 2.5×10^{-4} ppm
- b) 250 ppm
- c) 2.5 ppm
- d) 4.0×10^3 ppm

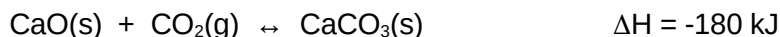
15. Which list consists of elements that have the most similar chemical properties?

- a) Mg, Al and Si
- b) K, Al and Ni
- c) Mg, Ca and Ba
- d) K, Ca and Ga

16. Which one of the following pairs of reactants will give a neutral solution when one mole of the first is mixed with one mole of the second?

- a) $\text{HCl}(\text{aq}) + \text{Pb}(\text{NO}_3)_2(\text{aq})$
- b) $\text{H}_2\text{SO}_4(\text{aq}) + \text{NaOH}(\text{aq})$
- c) $\text{H}_2\text{SO}_4(\text{aq}) + \text{K}_2\text{O}(\text{s})$
- d) $\text{CH}_3\text{COOH}(\text{aq}) + \text{NaOH}(\text{aq})$

17. Solid CaCO_3 and CaO and gaseous CO_2 are placed in a box and allowed to reach equilibrium.



The quantity of CaO in the box could be increased by

- a) adding more CaCO_3
 - b) adding more CO_2
 - c) raising the temperature
 - d) reducing the volume of the box
18. If an increase in temperature by 10°C doubles the rate of a reaction
- a) the average kinetic energy of reacting molecules doubles
 - b) the percentage of molecules having at least the minimum activation energy doubles
 - c) the rate of molecular collisions doubles
 - d) the average velocity of reacting molecules doubles
19. Which of the following will lead to an error when titrating a solution of sodium hydroxide (in the conical flask) with hydrochloric acid?
- a) Rinsing the conical flask with sodium hydroxide solution between titrations.
 - b) Rinsing the burette with hydrochloric acid before filling with acid for the first titration.
 - c) Adding 2 drops of phenolphthalein to the sodium hydroxide before pipetting 20.0 mL aliquots into the conical flask.
 - d) Washing down the side of the conical flask with distilled water during the titration.

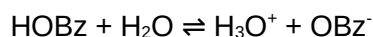
20. Consider the information in the table below.

Indicator	Colour in acid	Colour in base	pH range colour change
Methyl red	Red	Yellow	4.2 – 6.3
Thymol blue	Yellow	Blue	9.1 – 9.6
Alizarin yellow	Yellow	Red	10.1 – 12.0
Phenolphthalein	Colourless	Purple	8.2 – 10.0

A student carried out a titration to determine the percentage of ammonia in a household cleaner by adding the ammonia solution to 20.0 mL of a standard solution of nitric acid. She chose thymol blue as the indicator. Which of the following statements is correct?

- a) The equivalence point is basic.
- b) The end point occurs before the equivalence point.
- c) The equivalence point occurs within the endpoint pH range.
- d) Her calculated concentration of ammonia would be lower than the actual concentration.

21. For the following reactions of benzoic acid (HOBz) with water,



which of the following statements is correct?

- a) HOBz and H_3O^+ are a conjugate acid/base pair.
- b) HOBz and OBz^- are a conjugate acid/base pair.
- c) HOBz and H_2O are a conjugate acid/base pair.
- d) H_2O and H_3O^+ are the only conjugate acid/base pair in the reaction.

22. In a 1M solution of hydrofluoric acid (HF) which of the following will have the greatest concentration?

- a) HF
- b) H_3O^+
- c) F^-
- d) OH^-

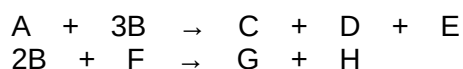
23. Acetic acid is a weak acid. A 0.1 mol L^{-1} solution produces a pH of 2.9. Approximately what proportion of the acetic acid molecules remain unconverted to ions?

- a) 1%
- b) 5%
- c) 60%
- d) 99%

24. An indicator is red if the pH is less than 4.4 and yellow if the pH is greater than 6.2. The indicator is placed in 0.10 mol L^{-1} solutions of KCN, H_2SO_4 and MgCl_2 . The colours of the solutions are

	KCN	H_2SO_4	MgCl_2
a)	Red	Yellow	Yellow
b)	Yellow	Red	Yellow
c)	Red	Yellow	Red
d)	Yellow	Red	Red

25. Consider a series of two reactions in a back titration, where B is the reactant in excess.



If 0.10 mol of F was required and 0.80 mol of B was added initially, the original amount of A was

- a) 0.10 mol
- b) 0.20 mol
- c) 0.30 mol
- d) 0.70 mol

END OF SECTION ONE

SECTION TWO—SHORT RESPONSE

[69 marks]

Section two contains **twelve (12)** questions. Attempt **ALL** questions in the spaces provided.

In this section, unless asked to write molecular equations, 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 $\text{NH}_3(\text{g})$, $\text{NH}_3(\text{aq})$, $\text{CH}_3\text{COOH}(\text{l})$, $\text{CH}_3\text{COOH}(\text{aq})$] or **solids** [for example $\text{BaSO}_4(\text{s})$, $\text{Cu}(\text{s})$, $\text{Na}_2\text{SO}_4(\text{s})$].

Suggested working time: 60 minutes

Question 1 [12 marks]

Write equations for any reactions that occur in the following procedures. If no reaction occurs write 'no reaction'.

In each case describe in full what you would observe, including any

- Colours
- Odours
- Precipitates (give the colour)
- Gases evolved (give the colour or describe as colourless)

If no change is observed, you should state this.

- a) phosphoric acid is added to a sodium carbonate solution.

Equation

Observation

(3 marks)

- b) hydrochloric acid is added to a lump of aluminium oxide

Equation

Observation

(3 marks)

- c) solutions of nickel(II) chloride and sodium phosphate are mixed

Equation

Observation

(3 marks)

- d) dilute hydrochloric acid is added to some silver metal

Equation

Observation

(3 marks)

Question 2 [8 marks]
Complete the table below

Name	Formula
	CO ₂
Carbon tetrachloride	
Potassium dichromate	
Helium gas	
	CuCl
	FeSO ₃
Sodium oxalate	
	NO

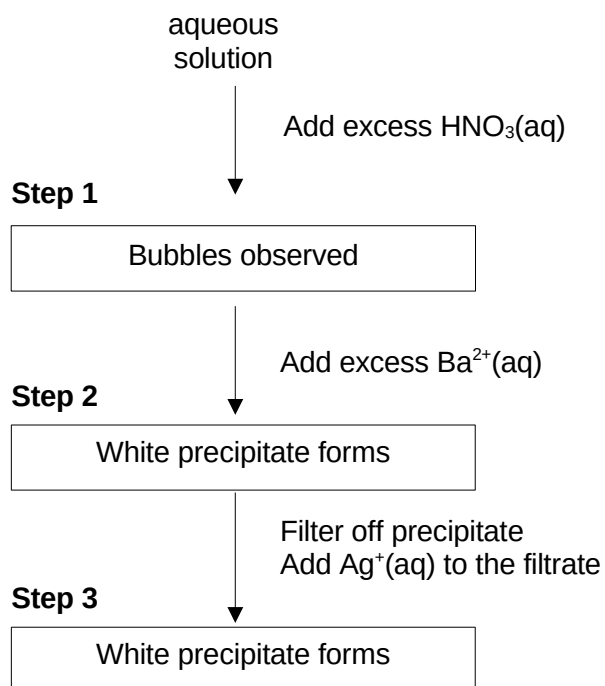
Question 3 [4 marks]

Write the electronic configuration for the following species

- a) an aluminium atom _____
- b) a calcium ion _____
- c) a neon atom _____
- d) an oxide ion _____

Question 4 [4 marks]

The flow diagram shows a series of tests that can be used to identify carbonate, chloride sulfate ions present in an aqueous solution.



- a) Identify the gas observed during Step 1.

_____ (1 mark)

- b) Explain why the analysis must be performed in the sequence given.

_____ (3 marks)

Question 5 [5 marks]

Chlorine forms a series of oxyacids including perchloric acid, HClO_4 , a powerful oxidant, and hypochlorous acid, HClO which is used in bleaching and as a disinfectant. The pH of 0.10 mol L^{-1} perchloric acid is 1.0 while the pH of 0.10 mol L^{-1} hypochlorous acid is 4.2.

- a) Write Bronsted-Lowry equations to illustrate the ionisation of these 2 acids in water.

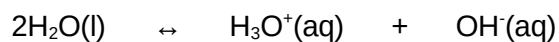
(2 marks)

- b) Explain, with the use of an equation, which of the salts sodium perchlorate, NaClO_4 , or sodium hypochlorite, NaClO , would you expect to be the most basic in solution.

(3 marks)

Question 6 [3 marks]

Pure water undergoes self-ionisation according to the following equilibrium:



The equilibrium constant for the ionisation of water (K_w) is 1.0×10^{-14} at 25°C

Write the equilibrium constant expression for this reaction.

$K =$

(1 mark)

As the temperature is decreased the value of K_w decreases.

Is pure water acidic, basic or neutral at 10°C ? Explain your answer.

(2 marks)

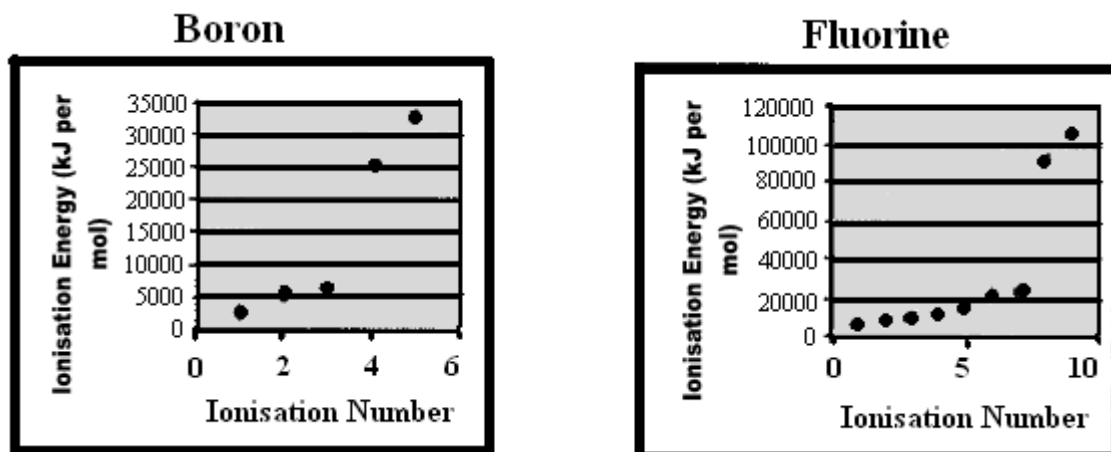
Question 7 [6 marks]

Three solutions in unlabelled bottles are known to be silver nitrate, zinc nitrate and sodium nitrate. Describe chemical tests you would carry out to determine the identity of each solution. Give equations for any reactions described.

[6 marks]

Question 8 [5 marks]

The successive ionisation energies of boron and fluorine are plotted in the following graphs:



- a) Why is there such a large increase in the ionisation energy required to remove the last two electrons?

(2 marks)

- b) Using the information on the graphs, explain how the position of the two elements in the Periodic Table can be determined.

(3 marks)

Question 9 [6 marks]

A pH buffer is a solution that tends to maintain a constant pH.

- a) What type of chemical species are present in a pH buffer?

(1 mark)

- b) Give the formula for two chemicals that might be found in a buffer solution

(2 marks)

- c) Describe how the buffer solution resists changes in pH. Use chemical equations to illustrate your answer.

(3 marks)

Question 10 [11 marks]

Hydrogen peroxide (H_2O_2) may be prepared in the laboratory by treating barium peroxide (BaO_2) with the dilute sulfuric acid, a white precipitate of barium sulfate also forms.

- a) Write a balanced molecular equation for the reaction of barium peroxide with sulfuric acid.

(2 marks)

7.664g of barium peroxide was treated with 50.0 mL of $0.9168 \text{ mol L}^{-1}$ sulfuric acid. The solid was removed by filtration and the filtrate made up to 100 mL in a volumetric flask.

- b) Which reagent, if any, is present in excess?

(3 marks)

- c) Determine the final concentration of the hydrogen peroxide solution in g L^{-1}

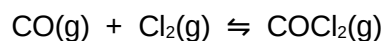
(3 marks)

- d) Over time hydrogen peroxide decomposes to form oxygen and water. What is the maximum volume of oxygen gas that would form from the decomposition of this solution at room temperature and pressure (298 K and 101.3 kPa)?

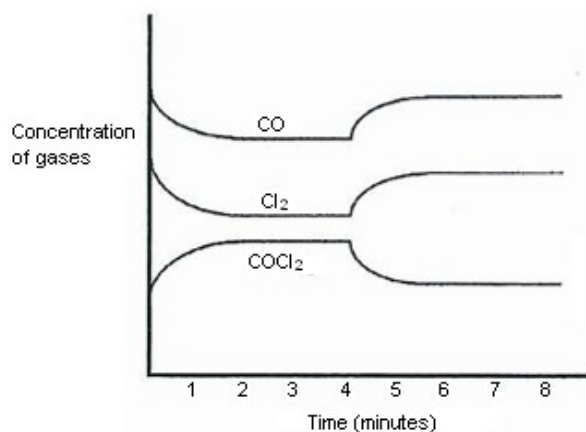
(3 marks)

Question 12 [5 marks]

Phosgene is prepared according to the following reversible reaction:



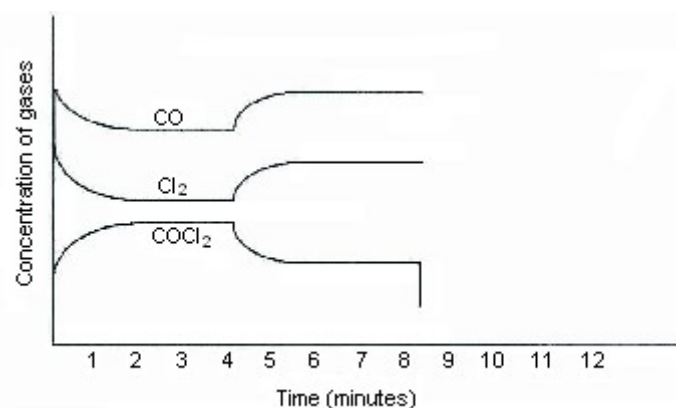
A mixture containing these three gases is introduced into a closed system in the presence of a catalyst. The following graph shows how the concentration of each of these gases varies with time.



- a) Describe the system three minutes after mixing and comment on the rates of reactions occurring in the system.

(2 marks)

- b) After 4 minutes the system is heated to higher temperature and allowed to reach equilibrium. At 8 minutes some $\text{COCl}_2\text{(g)}$ is removed. Show on the graph below how the concentrations of all the species would change over the next 4 minutes.



(3 marks)

SECTION THREE—EXTENDED RESPONSE

[73 marks]

Section Three has **SIX (6)** questions. Attempt **ALL** questions in the spaces provided below.

In descriptive responses, marks are awarded for relevant chemical content, including equations, diagrams and illustrative examples of the chemistry you are describing.

Calculations are to be set out in detail. Marks will be awarded for correct equations and clear setting out, even if you cannot complete the calculation. Express numerical answers to three (3) significant figures and provide units where appropriate.

Suggested working time: 70 minutes

Question 1 [3 marks]

Human blood is slightly basic and has a pH of approximately 7.4. If the pH falls, a condition known as acidosis can occur. Acidosis may occur as a result of strenuous exercise when glucose is converted into lactic acid. $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$. Lactic acid is a weak acid. Death may arise if the pH drops below 6.80.

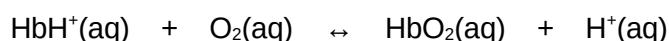
- a) Calculate the approximate hydrogen ion concentration of normal human blood.

(2 marks)

- b) Write an equation to show the ionisation of lactic acid and explain why it is classified as a weak acid

(2 marks)

Oxygen is transported around the body in the blood attached to haemoglobin(Hb) in the form of HbO_2 . The haemoglobin is involved in a series of equilibria which may be summarised by the following equation.



- c) (i) Write the equilibrium constant expression for the equilibrium summarised by the equation above

(1 mark)

- (ii) Is the equilibrium summarised above an example of a physical or chemical equilibrium? Explain your answer.

(2 marks)

(iii) Explain how an increase in the concentration of lactic acid (acidosis) influences this equilibrium and suggest why this might be fatal.

(3 marks)

(iv) During exercise a person's breathing rate increases and this increases the concentration of oxygen in the lungs. What effect would this have on the oxygen available to cells in muscle tissue? Explain your answer

(3 marks)

Question 2 [14 marks]

'Nitrochalk' is a widely used fertiliser which contains a mixture of ammonium nitrate and calcium carbonate.

A student attempted to determine the percentage by mass of nitrogen in Nitrochalk by the following procedure.

2.00 g of Nitrochalk was heated with 25.0 mL of 2.00 mol L⁻¹ sodium hydroxide until no more ammonia was evolved.



The mixture was filtered to remove the calcium carbonate and the filtrate was then made up to 250 mL by adding distilled water. The sodium hydroxide remaining was determined by titrating 25.0 mL aliquots of this solution against 0.101 mol L⁻¹ hydrochloric acid.

- a) Complete the table below and determine the average titre

Titration	1	2	3	4
Final Volume	33.20	31.00	35.15	32.85
Initial Volume	2.35	1.15	5.25	3.05
Titre				

(2 marks)

- b) Sketch a pH curve for the titration

(2 marks)

- c) Suggest a suitable indicator for this titration and justify your answer.

(2 marks)

c) the number of moles of ammonium nitrate present in the original 2.00 g of fertiliser

d) the percentage by mass of nitrogen in the fertiliser.

(6 marks)

(2 marks)

You have studied at least one process for the industrial manufacture of an important chemical in your course.

- (1 mark)

- [illegible]

(6 marks)

-
-
-
-

3AB Chemistry sample semester I exam paper

Question 4 [11 marks]

Serotonin is a compound that transmits nerve impulses between neurons in the body. It contains carbon, hydrogen, nitrogen and oxygen.

A 2.45 g sample of serotonin was combusted producing 6.122 g of carbon dioxide and 1.502 g of water.

A second sample of 1.112 g was analysed for its nitrogen content and found to contain 0.177 g of nitrogen.

- a) Determine the empirical formula of serotonin (8 marks)

- b) On vaporisation, 3.33 g of serotonin was found to occupy 0.633 L at 106.3 kPa and 155°C. Determine the molecular formula of the compound. (3 marks)

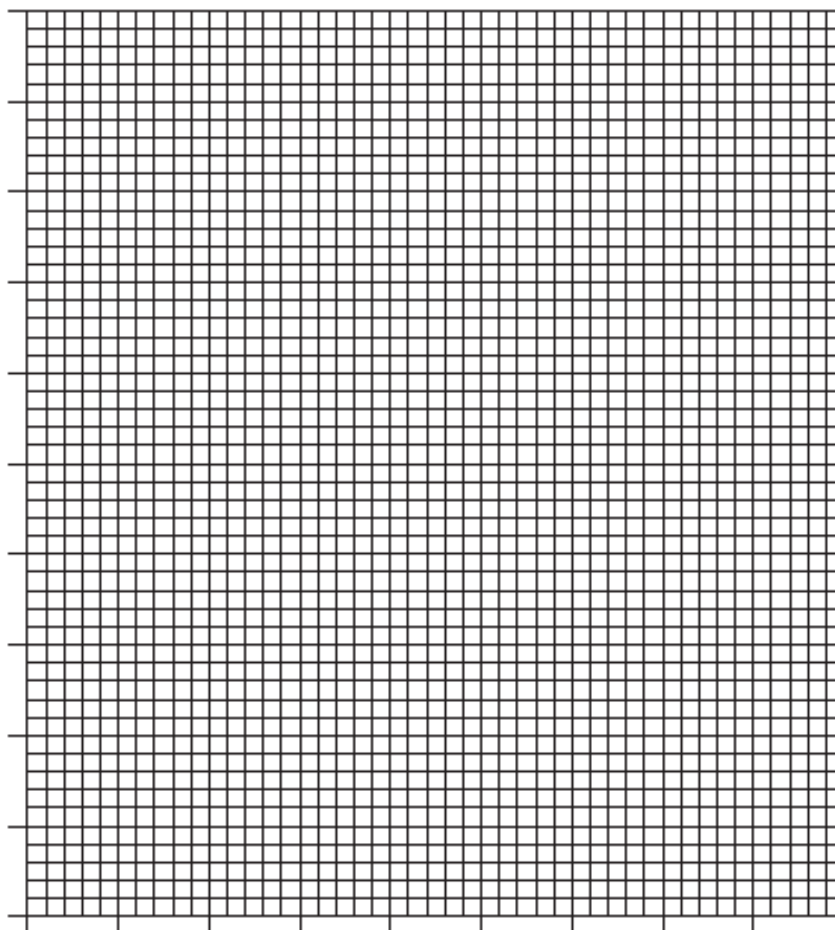
Question 5 [16 marks]

Airbags in cars are designed to prevent injuries in car crashes. They contain sodium azide (NaN_3) which produces nitrogen on impact. The nitrogen inflates the airbag very quickly.

- a) The table gives information on the volume of nitrogen gas produced at STP.

Time/microseconds	Volume of nitrogen gas produced/litres
0	0
5	46
10	64
15	74
20	82
25	88
30	88

- i) Draw a line graph of the results.



(3 marks)

- ii) Using your graph, predict the time taken to produce 70 litres of nitrogen gas.

_____ microseconds

(1 mark)

- b) The equation for the production of nitrogen gas is:



Balance the equation above.

(1 mark)

- c) Use the data from the graph to determine the mass of NaN_3 that is used in the airbag

(3 marks)

- d) Nitrogen is a non-toxic gas.

Suggest another property of nitrogen which makes it a suitable gas for use in airbags.

(1 mark)

- e) Maddy and Dionne wanted to investigate whether temperature would affect the rate of production of nitrogen gas.

- (i) What quantities will they need to measure?

(2 marks)

- (ii) What will be their independent variable?

(1 mark)

- (iii) Identify two variables they will need to control

(2 marks)

- (iii) How will they maximise the reliability of their results?

(2 marks)

The table below describes the pH and conductivity of a series of 0.1 mol L⁻¹ aqueous solutions

Explain fully the properties described above with reference to both acid-base and equilibrium theory.

[illegible]

END OF PAPER

Multiple choice answers

1. b
2. b (not a,c or d as they contain coloured cations)
3. a
4. d
5. a
6. c
7. b
8. d
9. b
10. b
11. a
12. d
13. b
14. b
15. c
16. c
17. c
18. b
19. a
20. d
21. b
22. a
23. d
24. b
25. b

SECTION TWO—SHORT RESPONSE

[69 marks]

Section two contains **twelve (12)** questions. Attempt **ALL** questions in the spaces provided.

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These species may be **ions** [for example Ag^+ (aq), **molecules** [for example $\text{NH}_3(\text{g})$, $\text{NH}_3(\text{aq})$, $\text{CH}_3\text{COOH}(\text{l})$, $\text{CH}_3\text{COOH}(\text{aq})$] or **solids** [for example $\text{BaSO}_4(\text{s})$, $\text{Cu}(\text{s})$, $\text{Na}_2\text{SO}_4(\text{s})$].

Suggested working time: 60 minutes

Question 1 [12 marks]

Write equations for any reactions that occur in the following procedures. If no reaction occurs write 'no reaction'.

In each case describe in full what you would observe, including any

- Colours
- Odours
- Precipitates (give the colour)
- Gases evolved (give the colour or describe as colourless)

If no change is observed, you should state this.

a) phosphoric acid is added to a sodium carbonate solution.

Equation $2\text{H}_3\text{PO}_4(\text{aq}) + 3\text{CO}_3^{2-}(\text{aq}) \rightarrow 3\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l}) + 2\text{PO}_4^{3-}(\text{aq})$

Observation Two colourless solutions are mixed and a colourless odourless gas is formed in a colourless solution.

(3 marks)

b) hydrochloric acid is added to a lump of aluminium oxide

Equation $\text{Al}_2\text{O}_3 + 6\text{H}^+ \rightarrow 3\text{H}_2\text{O} + 2\text{Al}^{3+}$

Observation A colourless solution is added to a white solid and a colourless solution is formed.

(3 marks)

c) solutions of nickel(II) chloride and sodium phosphate are mixed

Equation $3\text{Ni}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Ni}_3(\text{PO}_4)_2(\text{s})$

Observation A green solution is added to a colourless solution and a green solid is formed

(3 marks)

d) dilute hydrochloric acid is added to some silver metal

Equation no reaction

Observation

(3 marks)

Question 2 [8 marks]

Complete the table below

Name	Formula
Carbon dioxide	CO ₂
Carbon tetrachloride	CCl ₄
Potassium dichromate	K ₂ Cr ₂ O ₇
Helium gas	He
Copper I chloride	CuCl
Iron II sulfite	FeSO ₃
Sodium oxalate	Na ₂ C ₂ O ₄
Nitrogen monoxide	NO

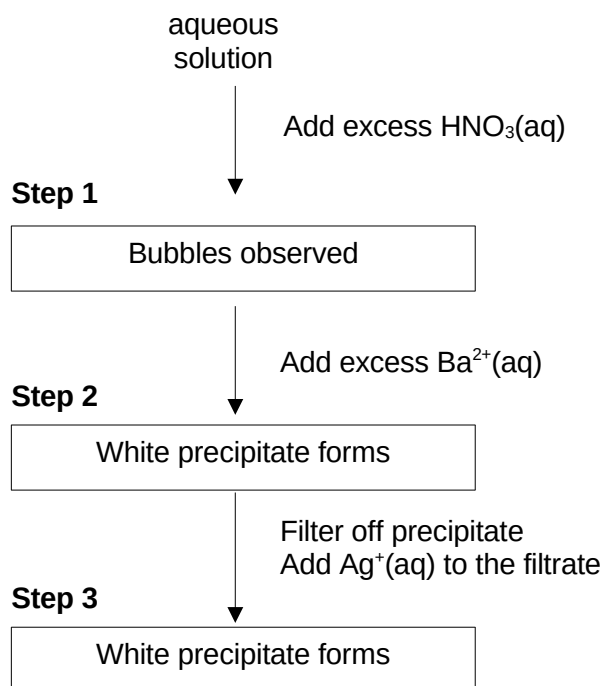
Question 3 [4 marks]

Write the electronic configuration for the following species

- a) an aluminium atom 2, 8, 3
- b) a calcium ion 2, 8, 8
- c) a neon atom 2, 8
- d) an oxide ion 2, 8

Question 4 [4 marks]

The flow diagram shows a series of tests that can be used to identify carbonate, chloride sulfate ions present in an aqueous solution.



- a) Identify the gas observed during Step 1.

Carbon dioxide

(1 mark)

- b) Explain why the analysis must be performed in the sequence given.

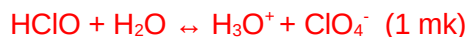
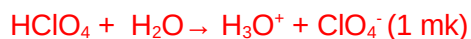
- If you added Ag⁺ first it would precipitate with carbonate and sulfate (1 mk)
- If you added Ba²⁺ first it would precipitate with carbonate and sulfate (1 mk)
- By adding the acid first it removes the carbonate from the solution (1 mk)

(3 marks)

Question 5 [5 marks]

Chlorine forms a series of oxyacids including perchloric acid, HClO_4 , a powerful oxidant, and hypochlorous acid, HClO which is used in bleaching and as a disinfectant. The pH of 0.10 mol L^{-1} perchloric acid is 1.0 while the pH of 0.10 mol L^{-1} hypochlorous acid is 4.2.

- a) Write Bronsted-Lowry equations to illustrate the ionisation of these 2 acids in water.



(2 marks)

- b)

perchlorate,
e the most basic

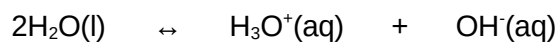
The most basic will be the one that accepts H^+ ions most easily

Hence ClO^- is most basic because the
 $\text{ClO}^- + \text{H}_3\text{O}^+ \rightarrow \text{HClO} + \text{H}_2\text{O}$ will occur to some extent because ClO^- is ion derived
from weak acid

(3 marks)

Question 6 [3 marks]

Pure water undergoes self-ionisation according to the following equilibrium:



The equilibrium constant for the ionisation of water (K_w) is 1.0×10^{-14} at 25°C

Write the equilibrium constant expression for this reaction.

$$K = [\text{H}_3\text{O}^+] [\text{OH}^-]$$

(1 mark)

As the temperature is decreased the value of K_w decreases.

Is pure water acidic, basic or neutral at 10°C ? Explain your answer.

Neutral (1 mk)

$$[\text{H}^+] = [\text{OH}^-] \text{ (1 mk)}$$

(2 marks)

Question 7 [6 marks]

Three solutions in unlabelled bottles are known to be silver nitrate, zinc nitrate and sodium nitrate. Describe chemical tests you would carry out to determine the identity of each solution. Give equations for any reactions described.

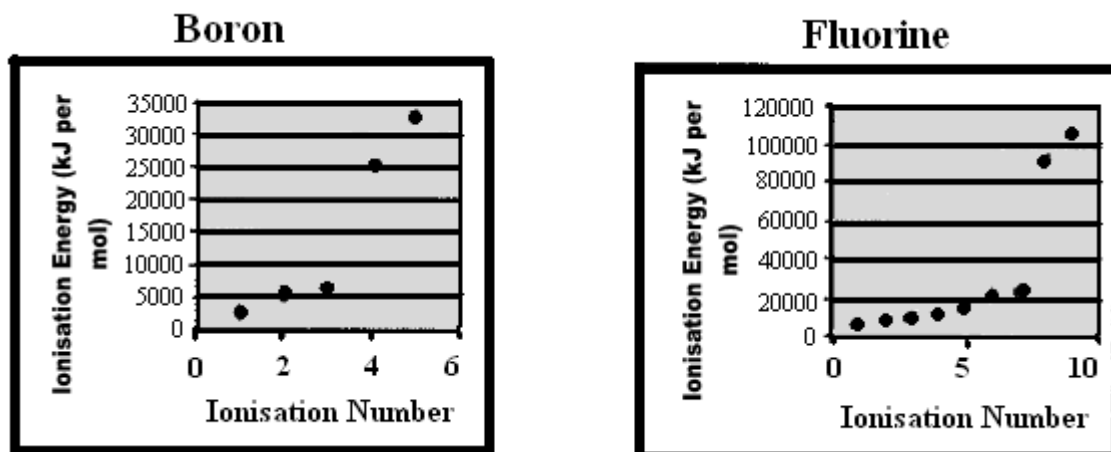
AgNO_3 $\text{Zn}(\text{NO}_3)_2$ NaNO_3

- Add sodium hydroxide solution and two of the unknowns form white precipitate and one doesn't (1 mk)
- The one that doesn't is $\text{NaNO}_3(\text{aq})$ (1 mk)
 $\text{Ag}^+ + \text{OH}^- \rightarrow \text{AgOH}(\text{s})$ (1 mk)
 $2\text{Ag}^+ + 2\text{OH}^- \rightarrow \text{Ag}_2\text{O}(\text{s}) + \text{H}_2\text{O}$
 $\text{Zn} + 2\text{OH}^- \rightarrow \text{Zn}(\text{OH})_2(\text{s})$ (1 mk)
- Add sodium chloride solution to both of the remaining unknowns and the one containing silver ions will form a white ppt (1 mk)
 $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}(\text{s})$ (1 mk)

[6 marks]

Question 8 [5 marks]

The successive ionisation energies of boron and fluorine are plotted in the following graphs:



- a) Why is there such a large increase in the ionisation energy required to remove the last two electrons?

Because you are removing electrons from a shell that is closer to the nucleus (1 mk)
Hence the electrons are closer to the positively charged nucleus and so more energy is needed (1 mk)

(2 marks)

- b) Using the information on the graphs, explain how the position of the two elements in the Periodic Table can be determined.

- Boron is in group three because it has 3 valence electrons removed before jump down to next shell (1 mk)
- Fluorine is in group 7 because it has 7 valence electrons removed before jump down to next shell (1 mk)

(3 marks)

Question 9 [6 marks]

A pH buffer is a solution that tends to maintain a constant pH.

- a) What type of chemical species are present in a pH buffer?

A conjugate acid/base pair

(1 mark)

- b) Give the formula for two chemicals that might be found in a buffer solution

$\text{CH}_3\text{COOH}/\text{CH}_3\text{COO}^-$

(2 marks)

- c) Describe how the buffer solution resists changes in pH. Use chemical equations to illustrate your answer.

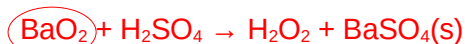
- If an acid is added to the buffer the CH_3COO^- will react with the hydrogen ions added (1 mk)
 $\text{CH}_3\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{COOH}$ (1 mk)
- If a base is added to the buffer the CH_3COOH will react with the hydroxide ions added (1 mk)
 $\text{CH}_3\text{COOH} + \text{OH}^- \rightarrow \text{H}_2\text{O} + \text{CH}_3\text{COO}^-$ (1 mk)

(3 marks)

Question 10 [11 marks]

Hydrogen peroxide (H_2O_2) may be prepared in the laboratory by treating barium peroxide (BaO_2) with the dilute sulfuric acid, a white precipitate of barium sulfate also forms.

- a) Write a balanced molecular equation for the reaction of barium peroxide with sulfuric acid.



(2 marks)

7.664g of barium peroxide was treated with 50.0 mL of $0.9168 \text{ mol L}^{-1}$ sulfuric acid. The solid was removed by filtration and the filtrate made up to 100 mL in a volumetric flask.

- b) Which reagent, if any, is present in excess?

$$n_{\text{BaO}_2} = \frac{7.664}{137.3 + 3 \times 16} = \frac{7.664}{169.3} = 0.0453 \text{ mol (1 mk)}$$

$$n_{\text{H}_2\text{SO}_4} = cv = (0.9168)(0.05) = 0.04584 \text{ mol (1 mk)}$$

$$\text{need } \frac{\text{BaO}_2}{\text{H}_2\text{SO}_4} = \frac{1}{1} \quad \text{given } \frac{\text{BaO}_2}{\text{H}_2\text{SO}_4} = \frac{0.0453}{0.04584} = \frac{0.988}{1}$$

$\therefore \text{BaO}_2$ is limiting reagent (1 mk)

(3 marks)

- c) Determine the final concentration of the hydrogen peroxide solution in g L^{-1}

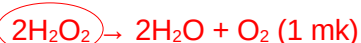
$$n_{\text{H}_2\text{O}_2} = \frac{1}{1} \times n_{\text{BaO}_2} = 0.0453 \text{ mol (1 mk)}$$

$$\text{mass } \text{H}_2\text{O}_2 = 0.0453 \times (2 \times 1.008 + 32) = 0.0453 \times 34.016 = 1.54 \text{ g (1 mk)}$$

$$c = \frac{\text{mass}}{\text{volume}} = \frac{1.54}{0.1} = 15.4 \text{ g L}^{-1} \text{ (1 mk)}$$

(3 marks)

- d) Over time hydrogen peroxide decomposes to form oxygen and water. What is the maximum volume of oxygen gas that would form from the decomposition of this solution at room temperature and pressure (298 K and 101.3 kPa)?



$$0.0453 \text{ mol}$$

$$n_{\text{O}_2} = \frac{1}{2} \times n_{\text{H}_2\text{O}_2} = \frac{1}{2} \times 0.0453 = 0.02265 \text{ (1 mk)}$$

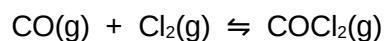
$$PV = nRT$$

$$(101.3) V = (0.02265)(298)(8.315) \Rightarrow V = 0.554 \text{ L (1 mk)}$$

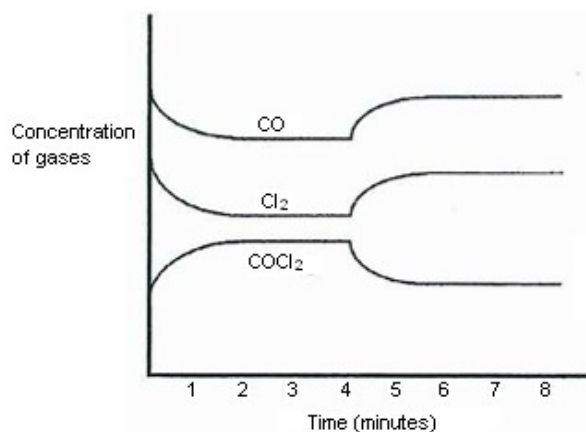
(3 marks)

Question 12 [5 marks]

Phosgene is prepared according to the following reversible reaction:



A mixture containing these three gases is introduced into a closed system in the presence of a catalyst. The following graph shows how the concentration of each of these gases varies with time.

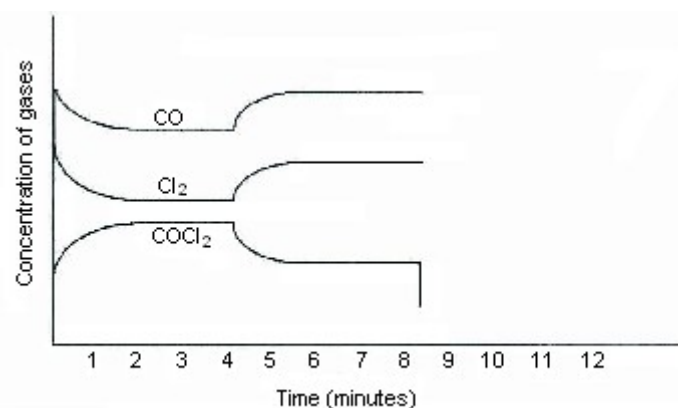


- a) Describe the system three minutes after mixing and comment on the rates of reactions occurring in the system.

The system is at equilibrium (1 mk) the rate of the forward reaction is equal to the rate of the backward reaction (1 mk)

(2 marks)

- b) After 4 minutes the system is heated to higher temperature and allowed to reach equilibrium. At 8 minutes some COCl₂(g) is removed. Show on the graph below how the concentrations of all the species would change over the next 4 minutes.



COCl₂ is removed so rate forward is greater than rate reverse reaction

(3 marks)

SECTION THREE—EXTENDED RESPONSE**[73 marks]**

Section Three has **SIX (6)** questions. Attempt **ALL** questions in the spaces provided below.

In descriptive responses, marks are awarded for relevant chemical content, including equations, diagrams and illustrative examples of the chemistry you are describing.

Calculations are to be set out in detail. Marks will be awarded for correct equations and clear setting out, even if you cannot complete the calculation. Express numerical answers to three (3) significant figures and provide units where appropriate.

Suggested working time: 70 minutes

Question 1 [3 marks]

Human blood is slightly basic and has a pH of approximately 7.4. If the pH falls, a condition known as acidosis can occur. Acidosis may occur as a result of strenuous exercise when glucose is converted into lactic acid. $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$. Lactic acid is a weak acid. Death may arise if the pH drops below 6.80.

- a) Calculate the approximate hydrogen ion concentration of normal human blood.

$$[\text{H}^+] = 10^{-7.4} = 3.98 \times 10^{-8} \text{ (2 mk)}$$

(2 marks)

- b) Write an equation to show the ionisation of lactic acid and explain why it is classified as a weak acid

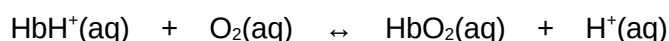


(1 mk for reversible arrow)

(1 mk for species)

(2 marks)

Oxygen is transported around the body in the blood attached to haemoglobin(Hb) in the form of HbO_2 . The haemoglobin is involved in a series of equilibria which may be summarised by the following equation.



- d) (i) Write the equilibrium constant expression for the equilibrium summarised by the equation above

$$K = \frac{[\text{HbO}_2][\text{H}^+]}{[\text{HbH}^+][\text{O}_2]}$$

(1 mark)

- (ii) Is the equilibrium summarised above an example of a physical or chemical equilibrium? Explain your answer.

Chemical equilibrium (1 mk)

New species is formed (1 mk)

(2 marks)

(iii) Explain how an increase in the concentration of lactic acid (acidosis) influences this equilibrium and suggest why this might be fatal.

More lactic acid increases $[H^+]$ (1 mk) which favours reverse reaction (1 mk) this reduces the oxygen transported by HbO_2 in the blood (1 mk)

(3 marks)

(iv) During exercise a person's breathing rate increases and this increases the concentration of oxygen in the lungs. What effect would this have on the oxygen available to cells in muscle tissue? Explain your answer

Increased oxygen in lungs will increase $O_2(aq)$ (1 mk) this will favour forward reaction (1 mk) hence more HbO_2 in blood transporting oxygen (1 mk)

(3 marks)

Question 2 [14 marks]

'Nitrochalk' is a widely used fertiliser which contains a mixture of ammonium nitrate and calcium carbonate.

A student attempted to determine the percentage by mass of nitrogen in Nitrochalk by the following procedure.

2.00 g of Nitrochalk was heated with 25.0 mL of 2.00 mol L⁻¹ sodium hydroxide until no more ammonia was evolved.



The mixture was filtered to remove the calcium carbonate and the filtrate was then made up to 250 mL by adding distilled water. The sodium hydroxide remaining was determined by titrating 25.0 mL aliquots of this solution against 0.101 mol L⁻¹ hydrochloric acid.

c) Complete the table below and determine the average titre

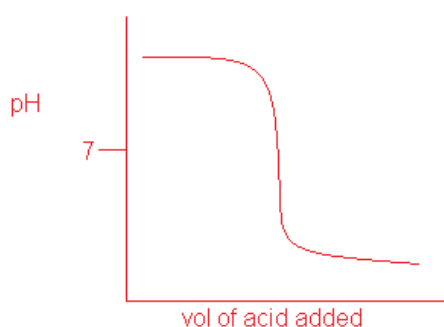
Titration	1	2	3	4
Final Volume	33.20	31.00	35.15	32.85
Initial Volume	2.35	1.15	5.25	3.05
Titre	30.95	29.85	29.9	29.8

$$\text{Average titre} = \frac{29.85 + 29.9 + 29.8}{3} = 29.85 \text{ mL}$$

(2 marks)

d) Sketch a pH curve for the titration

Strong acid vs strong base titration HCl is in the burette



(2 marks)

c) Suggest a suitable indicator for this titration and justify your answer.

Either methyl orange which changes colours in 3-4 range which is covered by equivalent point.

Or

Phenolphthalein which changes colour in 8-10 range which is covered by equivalence point.

(2 marks)

d) the number of moles of ammonium nitrate present in the original 2.00 g of fertiliser



$$v = 29.85 \text{ mL} \quad v = 25 \text{ mL}$$

$$c = 0.101 \text{ M}$$

$$\begin{aligned} n_{\text{H}^+} &= cv = (0.101)(0.02985) \\ &= 0.00301 \text{ mol} \\ &\quad (1 \text{ mk}) \end{aligned}$$

$$n_{\text{OH}^-} (\text{in } 25 \text{ mL}) = n_{\text{H}^+} = 0.00301 \quad (1 \text{ mk})$$

$$n_{\text{OH}^-} (\text{in } 250 \text{ mL}) = 0.00301 \times \frac{250}{25} = 0.0301 \quad (1 \text{ mk})$$

$$\begin{aligned} n_{\text{NaOH reacting with } n_{\text{H}_4\text{NO}_3}} &= (2)(0.025) = 0.0301 \\ &= 0.0199 \quad (1 \text{ mk}) \end{aligned}$$

$$n_{\text{NH}_4\text{NO}_3} = n_{\text{NaOH}} = 0.0199 \quad (1 \text{ mk})$$

$$\begin{aligned} \text{mass } \text{NH}_4\text{NO}_3 &= 0.0199 \times [(2 \times 14.01) + (4 \times 1.008) + (3 \times 16)] \\ &= 0.0199 \times 80.052 = 1.59 \text{ g} \quad (1 \text{ mk}) \end{aligned}$$

(6 marks)

e) the percentage by mass of nitrogen in the fertiliser.

$$\text{mass N} = \frac{2 \times 14.01}{80.052} \times 1.59 = 0.5565 \text{ g} \quad (1 \text{ mk})$$

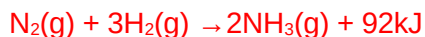
$$\begin{aligned} \% \text{ N} &= \frac{0.5565}{2} \times 100 \\ &= 27.8\% \quad (1 \text{ mk}) \end{aligned}$$

(2 marks)

Question 3 [9 marks]

You have studied at least one process for the industrial manufacture of an important chemical in your course.

- d) Write a balanced chemical equation or equations to describe the reactions occurring in this process



(1 mark)

- e) Describe the reaction conditions used to maximise yield and rate in this process and justify their use with reference to relevant chemical theory.

- High pressure favours forward rxn and increased yield (1 mk)
- High pressure also increases rate (1 mk)
- Low temp favours forward rxn as it is endothermic (1 mk)
- Need to compromise temp because a low temp will reduce rate (1 mk)
- Catalyst used to increase rate it will not affect yield (1 mk)

(6 marks)

- f) Explain two ways in which this process will impact the environment

- NH_3 is basic so will influence pH of local ecosystems if spilled (1 mk)

(2 marks)

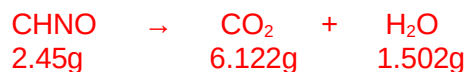
Question 4 [11 marks]

Serotonin is a compound that transmits nerve impulses between neurons in the body. It contains carbon, hydrogen, nitrogen and oxygen.

A 2.45 g sample of serotonin was combusted producing 6.122 g of carbon dioxide and 1.502 g of water.

A second sample of 1.112 g was analysed for its nitrogen content and found to contain 0.177 g of nitrogen.

- a) Determine the empirical formula of serotonin (8 marks)



	C	H	N	O
Mass	$\frac{12.01}{44.01} \times 6.122$ 1.67 (1 mk)	$\frac{2.016}{18.016} \times 1.502$ 0.168 (1 mk)	$\frac{0.177}{1.112} \times 2.45$ 0.38997 (1 mk)	$2.45 - (1.67 + 0.168 + 0.38997)$ $2.45 - 2.228$ 0.222 (1 mk)
Moles	$\frac{1.67}{12.01}$ 0.139	$\frac{0.168}{1.008}$ 0.1667	$\frac{0.38997}{14.01}$ 0.0278	$\frac{0.222}{16}$ 0.01387 (1 mk)
Ratio	$\frac{0.139}{0.01387}$ 10	$\frac{0.1667}{0.01387}$ 12	$\frac{0.0278}{0.01387}$ 2	$\frac{0.01387}{0.01387}$ 1 (1 mk)

\therefore EF is $\text{C}_{10}\text{H}_{12}\text{N}_2\text{O}$ (1 mk)

- b) On vaporisation, 3.33 g of serotonin was found to occupy 0.633 L at 106.3 kPa and 155°C. Determine the molecular formula of the compound. (3 marks)

$$PV = nRT$$

$$(106.3)(0.633) = n(8.315)(428)$$

$$n = 0.0189 \text{ (1 mk)}$$

$$n = \frac{\text{mass}}{\text{molar mass}}$$

$$0.0189 = \frac{3.33}{\text{molar mass}}$$

$$\Rightarrow \text{molar mass} = 176 \text{ (1 mk)}$$

$$\begin{aligned} \text{EF mass} &= (10 \times 12.01) + (12 \times 1.008) + (2 \times 14.01) + 16 \\ &= 176 \text{ (1 mk)} \end{aligned}$$

\therefore EF is same as MF

MF is $\text{C}_{10}\text{H}_{12}\text{N}_2\text{O}$

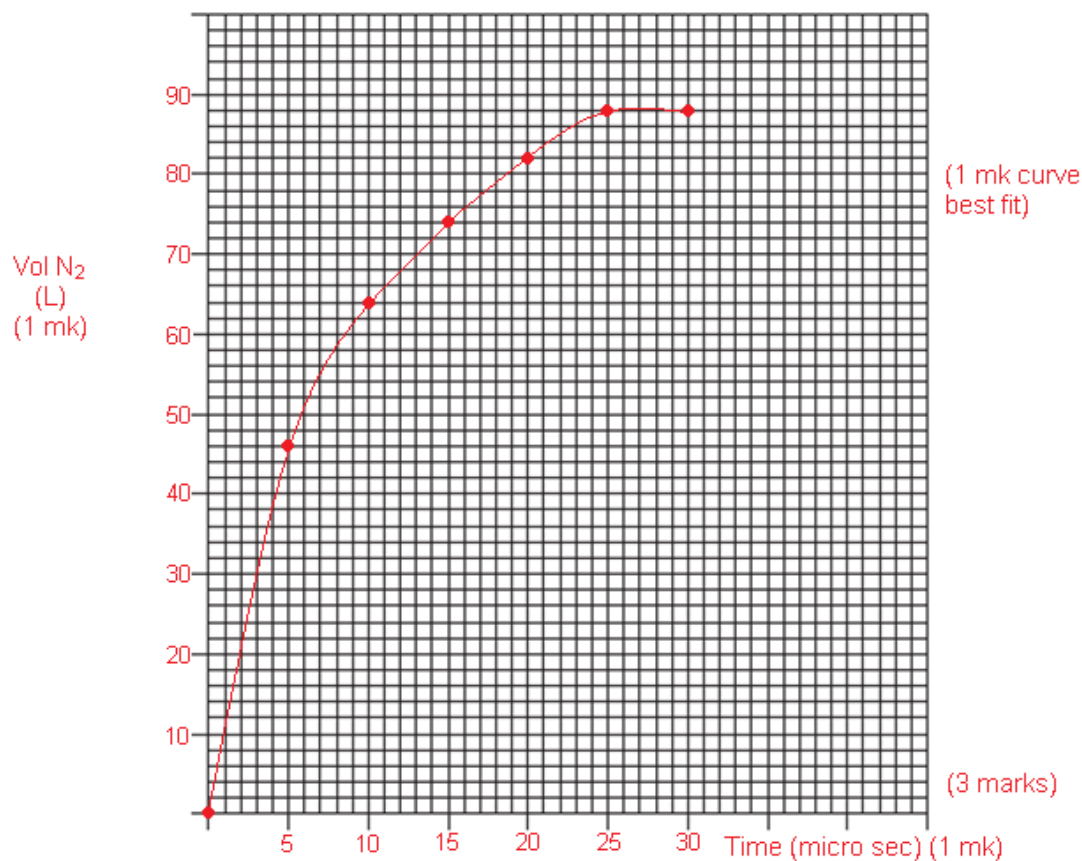
Question 5 [16 marks]

Airbags in cars are designed to prevent injuries in car crashes. They contain sodium azide (NaN_3) which produces nitrogen on impact. The nitrogen inflates the airbag very quickly.

- a) The table gives information on the volume of nitrogen gas produced at STP.

Time/microseconds	Volume of nitrogen gas produced/litres
0	0
5	46
10	64
15	74
20	82
25	88
30	88

- i) Draw a line graph of the results.



(3 marks)

- ii) Using your graph, predict the time taken to produce 70 litres of nitrogen gas.

12.5 microseconds

(1 mark)

- b) The equation for the production of nitrogen gas is:



Balance the equation above.

(1 mark)

- c) Use the data from the graph to determine the mass of NaN_3 that is used in the airbag

$$V_{\text{N}_2} = 88 \text{ L (1 mk)} \quad n = \frac{V}{22.4} = \frac{88}{22.4} = 3.93 \text{ mol (1 mk)}$$

$$n_{\text{NaN}_3} = \frac{2}{3} \times n_{\text{N}_2} = \frac{2}{3} \times 3.93 = 2.619 \text{ mol (1 mk)}$$

$$\text{mass NaN}_3 = 2.619 \times (22.99 + 3 \times 14.01) = 2.619 \times 65.02 = 170\text{g}$$

(3 marks)

- d) Nitrogen is a non-toxic gas.

Suggest another property of nitrogen which makes it a suitable gas for use in airbags.

It is inert

(1 mark)

- e) Maddy and Dionne wanted to investigate whether temperature would affect the rate of production of nitrogen gas.

- (ii) What quantities will they need to measure?

Temperature

Volume of nitrogen gas formed

Time

mass of NaN_3

(2 marks)

- (ii) What will be their independent variable?

Temperature

(1 mark)

- (iii) Identify two variables they will need to control

Mass of NaN_3

Pressure

(2 marks)

- (iii) How will they maximise the reliability of their results?

Conduct repeat trials

Discard any obvious outliers

(2 marks)

Question 6 [10 marks]

The table below describes the pH and conductivity of a series of 0.1 mol L⁻¹ aqueous solutions

Solution	pH	Conductivity
Ammonia (NH ₃)	11.1	Low
Ethanoic acid (CH ₃ COOH)	2.9	Low
Sodium carbonate (Na ₂ CO ₃)	11.7	High
Ammonium ethanoate (NH ₄ CH ₃ COO)	7.0	High
Hydrobromic acid (HBr)	1.0	High
Potassium hydroxide (KOH)	13.0	High

Explain fully the properties described above with reference to both acid-base and equilibrium theory.

- Those with pH less than 7 are acidic because they have a greater conc of H⁺ in solution than OH⁻ i.e. CH₃COOH, HBr (1 mk)
- HBr must ionise to greater extent than CH₃COOH because the lower pH indicates greater [H⁺] (1 mk)
 $\text{HBr} \rightarrow \text{H}^+ + \text{Br}^-$ (½ mk)
 $\text{CH}_3\text{COOH} \leftrightarrow \text{CH}_3\text{COO}^- + \text{H}^+$ (½ mk)
- Those with pH greater than 7 are basic because they produce greater [OH⁻] than [H⁺] i.e. NH₃, Na₂CO₃, KOH (1 mk)
NH₃ + Na₂CO₃ are weak bases (½ mk)
 $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$ (½ mk)
KOH is a strong base and completely dissociates (½)
 $\text{KOH} \rightarrow \text{K}^+ + \text{OH}^-$ (½ mk)
- Those with pH = 7 are neutral because [H⁺] = [OH⁻] i.e. NH₄CH₃COO (1 mk)
- Those with low conductivity only have a few charged particles in solution e.g. NH₃ in water equilibrium lies to the left (1 mk) also true for CH₃COOH
- Those with high conductivity have higher concentration of ions in solution – these equilibrium processes lie to the right (1 mk)

END OF PAPER