**SEMESTER ONE EXAMINATION**

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**CHEMISTRY**

**UNIT 3**

**2018**

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

Teacher: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# TIME ALLOWED FOR THIS PAPER

## Reading time before commencing work: ten minutes

Working time for the paper: three hours

# MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

**To be provided by the supervisor:**

This Question/Answer Booklet

Multiple-choice Answer Sheet

Chemistry Data Book

**To be provided by the candidate:**

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener,

eraser, correction tape/fluid, ruler, highlighters

Special items: up to three 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 | /50 | /25 |
| Section Two:  Short answer | 8 | 8 | 60 | /70 | /35 |
| Section Three:  Extended answer | 5 | 5 | 70 | /80 | /40 |
|  | | | | | /100 |

**Instructions to candidates**

1. 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.

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

3. You must be careful to confine your responses to the specific question asked and to follow any instructions that are specific to a question.

4. 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.

5. The Chemistry Data Book is to be handed in with your Question/Answer Booklet.

**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 then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

1. Which of the following lists substances that are commonly used as an oxidising agent (oxidant) and a reducing agent (reductant)?

**Oxidising agent Reducing agent**

1. Cr2O72- MnO4-
2. MnO4- Cl -
3. Cl2 H2C2O4
4. Mg Cr2O72-

**Questions 2 and 3 relate to the following information.**

Naphthalene (C10H8) is a component of mothballs. It is a white, flaky solid that sublimes relatively easily, according to the equation below.

C10H8(s) ⇌ C10H8(g)

Two beakers had a sample of solid naphthalene placed in them. The first beaker was left as an ‘open system’, whilst a lid was placed on the second beaker making it a ‘closed system’.

naphthalene

The temperature of each beaker was then increased by gently heating over a Bunsen burner.

2. When the temperature of the open system was increased, which of the following would **not** be correct?

1. There would be less solid present.
2. The mass of the system would decrease.
3. The pressure inside the beaker would remain constant.
4. There would be an increase in the sublimation reaction rate.

3. When the temperature of the closed system was increased, which of the following would **not** be correct?

1. There would be more solid present.
2. The mass of the system would remain constant.
3. The pressure of the system would increase.
4. There would be an increase in the average kinetic energy of the particles.

4. The following equation represents the auto-ionisation of water.

2 H2O(l) + heat ⇌ H3O+(aq) + OH-(aq)

For pure water at 50 °C, which of the following is **correct**?

1. The H3O+ concentration is greater than 1.0 x 10-7 mol L-1.
2. The OH- concentration is less than 1.0 x 10-7 mol L-1.
3. The pH of water is greater than 7.
4. The Kw of water is less than 1.0 x 10-14.

5. The combustion of ethanol can be represented by the following equation;

C2H5OH(l) + 3 O2(g) → 2 CO2(g) + 3 H2O(g)

Which of the following statements is **correct** regarding this combustion equation?

1. Oxygen gas is the reductant.
2. The oxidation number of carbon increases.
3. The oxidation number of hydrogen decreases.
4. Ethanol is reduced.

6. When this half-equation is correctly balanced, what is the coefficient of H+(aq)?

ClO3-(aq) + H+(aq) → Cl2(g) + H2O(l)

(a) 4

(b) 6

(c) 8

(d) 12

7. A sample of barium sulfate powder is added to a beaker containing distilled water and stirred. The following chemical reactions occur;

① BaSO4(s) ⇌ Ba2+(aq) + SO42-(aq)

② SO42-(aq) + H2O(l) ⇌ HSO4-(aq) + OH-(aq)

If a few drops of HNO3(aq) was added to the beaker, which of the following statements are **correct**?

1. Equilibrium ① shifts to the left.
2. Equilibrium ② shifts to the right.
3. The pH of the solution would increase.
4. The amount of BaSO4(s) present would decrease.
5. The concentration of Ba2+(aq) in the solution would increase.
6. (i), (iii) and (v) only
7. (ii), (iv), and (v) only
8. (ii), (iii) and (iv) only
9. (i), (ii) and (v) only

**Questions 8 and 9 relate to the following information.**

The exothermic hydrogenation of propene gas to form propane gas requires a catalyst such as platinum or nickel to be present. This reaction occurs as shown in the equation below.

Pt

CH2=CHCH3(g) + H2(g) CH3CH2CH3(g)

Without a catalyst present this reaction only takes place at very high temperatures. The reaction is essentially irreversible.

8. Which of the following energy profile diagrams **best** represents the **uncatalysed** reaction? (You may assume each graph has the same scale on the axes.)

H

Progress of reaction

H

Progress of reaction

H

Progress of reaction

H

Progress of reaction

(a) (b)

(c) (d)

9. Which of the following would **not** occur if a platinum catalyst was used in the reaction?

1. The rate of reaction will increase.
2. The number of successful reactant collisions will increase.
3. The average kinetic energy of the reactant particles will increase.
4. The proportion of particles with enough kinetic energy to react will increase.

10. Which of the following solutions **could** be safely stored in the metal container stated?

(a) Copper(II) nitrate in a tin container.

(b) Potassium permanganate in a copper container.

(c) Nickel chloride in a lead container.

(d) Cobalt sulfate in an iron container.

11. Which of the following represents a loss of electrons?

1. H+(aq) forming H2(g).
2. Fe2+(aq) forming Fe3+(aq).
3. Mg2+(aq) forming Mg(s).
4. Cl2(g) forming Cl-(aq).

**Questions 12, 13 and 14 relate to the following information.**

The equilibrium shown below represents the endothermic decomposition of nitrogen tribromide into nitrogen and bromine vapours. Nitrogen tribromide and nitrogen are colourless gases, whereas bromine is a red vapour.

2 NBr3(g) ⇌ N2(g) + 3 Br2(g)

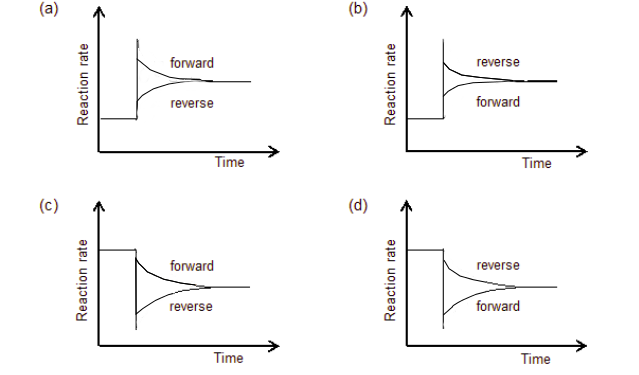
If some nitrogen tribromide is injected into an empty flask, which is then sealed;

12. Which of the following is **not necessarily true** of the system once equilibrium is established?

1. The pressure of the system would remain constant.
2. The partial pressure of NBr3 would remain constant.
3. The partial pressure of N2 would be half that of NBr3.
4. The partial pressure of Br2 would be three times that of N2.

Once equilibrium was established, the temperature of the system was increased.

13. Which of the following graphs is the **closest** representation of the effect of this temperature increase on reaction rate?



Once the system had re-established equilibrium, some N2(g) was removed.

14. Which of the following correctly states the effect of N2 removal on the equilibrium position, as well as the corresponding observations?

**Equilibrium position Observations**

1. favour reverse darker red
2. favour reverse lighter red
3. favour forward darker red
4. favour forward lighter red

15. A 1.00 mol L-1 H3PO4 solution has a pH of 1.08. Which of the following statements concerning this solution is **not** correct?

1. [H3PO4] > [PO43-]
2. [H3O+] > [H2PO4-]
3. [H2PO4-] > [HPO42-]
4. [H3O+] > [H3PO4]

16. A student is wishing to perform a titration between each of the following pairs of reactants. For which pairs would phenolphthalein be a suitable indicator choice to use, to correctly match the equivalence point of the reaction?

1. Na2CO3 and HCl
2. HCl and NaOH
3. NaOH and CH3COOH
4. NH3 and HNO3
5. (i) and (iv) only
6. (ii) and (iii) only
7. (ii), (iii) and (iv) only
8. (i), (ii) and (iii) only

17. Which of the following equations **cannot** be explained as being an “acid – base” reaction by any of the proposed theories attributed to Davey, Arrhenius or Bronsted-Lowry?

(a) H+ + OH- → H2O

(b) H2O + NH3 → NH4+ + OH-

(c) H2O + HNO2 → H3O+ + NO2-

(d) SO2 + CaO → CaSO3

18. If the equilibrium constant (K) value of a gaseous equilibrium system increases, which of the following **must be true**?

1. The pressure has been increased.
2. The temperature has been increased.
3. The concentration of reactants has been increased.
4. The ratio of product concentration to reactant concentration has been increased.

**Questions 19, 20 and 21 relate to the titration data below.**

A teacher accurately performed an acid-base titration and, using a pH meter, could graph the titration curve shown below.

Four groups of chemistry students (W, X, Y, Z) then attempted to replicate the same titration. Each group performed four trials, and their titre values are shown in the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 | Trial 4 |
| W | 16.10 mL | 16.05 mL | 16.00 mL | 16.05 mL |
| X | 19.40 mL | 19.35 mL | 19.45 mL | 19.40 mL |
| Y | 19.50 mL | 19.20 mL | 19.30 mL | 19.6 mL |
| Z | 35.20 mL | 35.25 mL | 35.15 mL | 35.25 mL |

19. Which group of students has performed the titration **most** **accurately**?

1. W
2. X
3. Y
4. Z

20. Which group of students is **most likely** to have incorrectly usedmethyl orange indicator?

1. W
2. X
3. Y
4. Z

21. Which experimental set up was used for this titration?

**Burette solution Conical flask solution**

1. KOH(aq) CH3COOH(aq)
2. CH3COOH(aq) KOH(aq)
3. NH3(aq) HCl (aq)
4. HCl (aq) NH3(aq)

22. In which of the following compounds does sulfur have an oxidation number of +4?

1. SO2
2. H2SO4
3. H2S
4. H2SO3
5. Na2S2O3
6. (i) only
7. (iii) only
8. (i) and (iv) only
9. (ii) and (v) only

23. Which of the following is **not** a redox reaction?

(a) HCrO4- + 3 H+ + NO → Cr3+ + 2 H2O + NO3-

(b) Cr2O72- + 2 H2O + NH4+ → 2 HCrO4- + NH3 + H3O+

(c) Cr2O72- + 5 H+ + 3 HNO2 → 2 Cr3+ + 4 H2O + 3 NO3-

(d) HCrO4- + H+ + 3 N2O → Cr + H2O + 6 NO

**Questions 24 and 25 relate to the following information.**

A chemist mixed 0.1 mol L-1 solutions of a weak, monoprotic acid and its sodium salt together in a beaker. The conjugate species formed a buffer as shown below;

weak acid(aq) + H2O(l) ⇌ conjugate base(aq) + H3O+(aq)

24. If a few drops of HCl (aq) are added to this system, which is **correct**?

1. The pH falls quickly.
2. The concentration of the weak acid equals the concentration of the conjugate base.
3. The concentration of the weak acid increases.
4. The concentration of the weak acid remains constant until the buffering capacity is exceeded.

25. Which of the following pairs of substances, when dissolved in water, could produce a buffer matching the above description?

1. KHCO3 and K­2CO3
2. H3PO4 and K2HPO4

1. HNO3 and NaNO3
2. CH3COOH and NaCH3COO

**End of Section One**

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

This section has **8** questions. Answer **all** questions. Write your answers in the spaces provided.

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

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Suggested working time: 60 minutes.

**Question 26 (10 marks)**

The first part of an energy profile diagram has been sketched on the axes below.

Reactants

If the activation energy of the **reverse** reaction is 70 kJ and the heat of reaction (enthalpy change) of the **forward** reaction is 210 kJ mol-1;

(a) Complete the energy profile diagram above. Label the products and the transition state (activated complex). (3 marks)

If a catalyst was added at the start of the reaction;

(b) Which of the following is the **most likely** new value of the activation energy for the **forward** reaction? (circle your answer) (1 mark)

180 kJ 230 kJ 290 kJ

If the temperature of this system was decreased;

(c) Explain, in terms of the collision theory, the effect this would have on the rate of reaction. (3 marks)

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(d) Assuming this is a reversible reaction, what effect would this temperature decrease have on the value of the equilibrium constant, K? Justify your answer. (3 marks)

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**Question 27 (10 marks)**

The main buffering system in blood is represented by the equation below:

CO2 (g) + H2O (l) ↔ H2CO3 (aq) ↔ HCO3 -1 (aq) + H3O+ (aq)

Studies of this system have become very important recently, as more people seek to undergo strenuous exercise to gain elite fitness levels. Blood pH must be maintained at a pH of 7.4. The danger of excessive exercise is that if blood pH levels fall below 6.8 or rises above 7.8, death can result.

(a) Considering that strenuous exercise converts blood-glucose into carbon dioxide, which dangerous pH range could this cause the person’s blood to enter?

Circle one of: 6.8 – 7.4 or 7.4 – 7.8 (1 mark)

It is possible to plot a titration curve for this buffer system, where the vertical axis shows the pH of the buffered solution (in this case, the blood). The horizontal axis shows the composition of the buffer: on the left-hand side of the plot, most of the buffer is in the form of carbonic acid or carbon dioxide, and on the right-hand side of the plot, most of the buffer is in the form of bicarbonate ion. (pK = pH)

|  |
| --- |
| http://www.chemistry.wustl.edu/~edudev/LabTutorials/Buffer/images/Titration.jpg |
|  |

(b) The solution acts as a buffer in the pH range of 5.1 to 7.1, as shown on the graph. With reference to the **chemicals** in the buffer, explain why this is the case. (1 mark)

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(c) This pH range, especially around the midpoint value of 6.1, enables the buffer to function most effectively. With reference to the **plotted pH curve** on the graph, explain why this is the case. (3 marks)

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As the graph shows, the normal blood pH of 7.4 is outside the optimal buffering range; therefore, chemical changes in the blood due to strenuous exercise may be too great for the buffer alone to effectively control the pH of the blood. When this happens, other organs must help control the amounts of CO2 and HCO3- in the blood.

(d) If the lungs help by removing excess CO2 from the blood, explain (with reference to the buffer equation) how this can alter the pH of the blood. (2 marks)

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(e) If the kidneys remove excess HCO3- from the body, explain (with reference to the buffer equation) how this can alter the pH of the blood. (2 marks)

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(f) If blood had a normal pH of 6.1 instead of 7.4, would you expect exercise to result in **heavier** or **lighter** breathing? (Use one highlighted word) (1 mark)

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**Question 28 (8 marks)**

Examine the diagram below, which shows some of the relevant equations involved in ocean equilibria, specifically the role of carbon-containing species.

CO2(g)

*air*

(aq) + H2O(l) (aq) (aq) + H+(aq)

CaCO3(s) Ca2+(aq) + (aq)

*ocean water*

*sediment*

+

H+(aq)

*dissolution*

*precipitation*

(a) Complete the equilibrium equations on the diagram above, by writing the chemical formula of the four (4) missing carbon-containing species in the boxes. (4 marks)

(b) Explain how higher atmospheric carbon dioxide levels cause a decrease in ocean pH, whereas the calcium carbonate present in sediment can counteract this to increase ocean pH. (4 marks)

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**Question 29 (10 marks)**

The ‘etching’ of silicon is performed in the production of semiconductor materials, which are used in all forms of modern technology, such as mobile phones and computers. This etching can be achieved using the reversible chemical reaction below.

Si(s) + 4 HF(g) ⇌ SiF4(g) + 2 H2(g) + heat

(a) Write an equilibrium constant (K) expression for this reaction. (1 mark)

|  |
| --- |
|  |

(b) Complete the following table, for each of the imposed changes stated. In each case, state the effect on the forward reaction rate and the equilibrium position. (6 marks)

|  |  |  |
| --- | --- | --- |
|  | Forward reaction rate  (increase, decrease, no change) | Equilibrium position shift  (left, right, no change) |
| Increase in total volume of the system |  |  |
| Removal of some H2(g) from system |  |  |
| Increase in temperature of the system |  |  |

(c) Rather than blocks or cubes of silicon (Si), the silicon used in etching is in the form of extremely thin pieces called ‘wafers’. Explain, in terms of the collision theory, what effect this has on **both** the forward reaction rate and yield of the reaction. (3 marks)

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**Question 30 (10 marks)**

Thymol blue is an indicator that has two distinct colour changes and displays three different colours over the pH range 0 to 14, as shown in the diagram below.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

pH

|  |  |  |
| --- | --- | --- |
| red | yellow | blue |

A few drops of thymol blue were added to the following 0.2 mol L-1 solutions;

* HNO3(aq)
* Mg(NO3)2(aq)
* NH4NO3(aq)
* KHCO3(aq)

(a) Which of these substances is most likely to turn blue? Use an equation to support your answer. (2 marks)

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(b) State two (2) solutions that **could not** be distinguished between by adding thymol blue. Justify your answer using appropriate chemical equations. (4 marks)

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(c) Two forms of thymol blue, at different pH, are shown in the table below. Complete the table, by writing which structure is blue in colour and which is yellow. (1 mark)

|  |  |  |
| --- | --- | --- |
| Thymol blue structure | SO3-  O  HO | SO3-  O  -O |
| Colour  (blue or yellow) |  |  |

(d) Justify your answer to (c). Include a brief description of how indicators function (i.e. how they are able to change colour). (3 marks)

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**Question 31 (7 marks)**

Six reactions (A-F) were carried out, as shown in the table below.

|  |  |
| --- | --- |
| A | Zn(s) + Ni(NO3)2(aq) |
| B | Br2(aq) + KI (aq) |
| C | HCl(aq) + KOH(s) |
| D | Br2(aq) + (l) |
| E | Fe(s) + H2O(l) + O2(g) |
| F | Ni(s) + HCl(aq) |

(a) Name the reaction that would occur in E. \_\_\_\_\_\_\_\_\_\_\_\_\_\_ (1 mark)

(b) In which reaction would halogen displacement occur? \_\_\_\_\_\_\_\_\_\_\_\_\_\_ (1 mark)

(c) Write the ionic equation for the reaction occurring in C. (1 mark)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(d) Give full observations for the reaction occurring in A. (2 marks)

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(e) Write two half-equations for the reaction occurring in B. (2 marks)

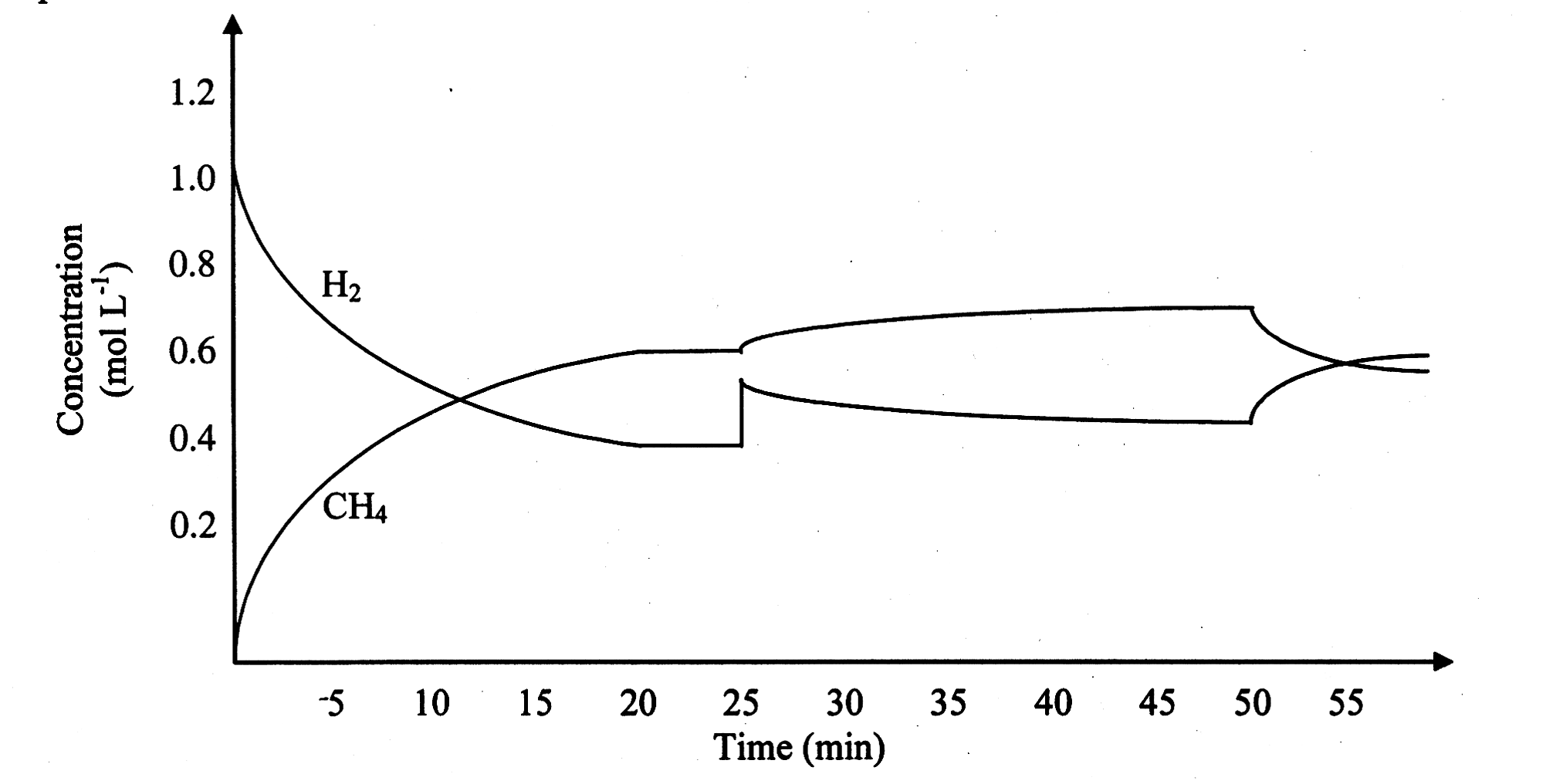
|  |  |
| --- | --- |
| oxidation |  |
| reduction |  |

**Question 32 (8 marks)**

The reaction between carbon and hydrogen gas to form methane can be represented by the following equation:

C(s) + 2H2 (g) ⮀ CH4 (g) + 75 kJ

The concentration of hydrogen and methane was plotted over time and the following graph produced.



(a) About what time was equilibrium first established? (1 Mark)

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(b) Suggest what could have caused the change at the 25-minute mark. (1 Mark)

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(c) Suggest what change occurred at the 50-minute mark. (1 Mark)

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(d) What would be the effect on the equilibrium if more C (s) were added to the system? (1 Mark)

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(e) Explain, using Le Chatelier’s Principle, what would be the effect of halving the volume of the

reaction container. (4 Marks)

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**Question 33 (7 marks)**

The Arrhenius theory of acids and bases introduced the relationship between acid behaviour and H+(aq) ions. Ethanoic acid (CH3COOH) is a common organic acid found in vinegar. It is a weak, monoprotic acid.

(a) Write an Arrhenius equation for the ionisation of ethanoic acid. (1 mark)

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(b) Define the term ‘monoprotic’ and explain why ethanoic acid is monoprotic, despite having four (4) hydrogen atoms per molecule. (2 marks)

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The Bronsted-Lowry theory of acids and bases introduced the concept of the hydronium ion, H3O+(aq), as well as conjugate acid-base pairs.

(c) Explain what the ‘H3O+(aq)’ notation is referring to and why it is often used in preference to the ‘H+(aq)’ notation. (2 marks)

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(d) **Label** and **link** the conjugate acid-base pairs in the equation below. (2 marks)

NO2-(aq) + HSO4-(aq) ⇌ SO42-(aq) + HNO2(aq)

**End of Section Two**

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

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

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

Final answers to calculations should be expressed to the appropriate number of significant figures.

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

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

Suggested working time: 70 minutes.

**Question 34 (15 marks)**

A solution of acidified iodic acid (HIO3) has some toxic carbon monoxide gas bubbled through it. A brown solution is observed to form, as the carbon monoxide is converted to the less harmful carbon dioxide gas.

(a) Write the oxidation and reduction half-equations and the overall redox equation for this reaction. States of matter are not required. (3 marks)

|  |  |
| --- | --- |
| Oxidation half-equation |  |
| Reduction half-equation |  |
| Working Space |  |
| Overall redox equation |  |

A chemistry student wants to determine the strength of the acid, but cannot find any information about the acidity constant (Ka) of iodic acid in her research.

(b) Write an acidity constant expression for iodic acid and explain what information a Ka value would provide regarding the acid. (2 marks)

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One method used to prepare iodic acid is by reacting aqueous iodine with aqueous chlorine. This produces a mixture of iodic and hydrochloric acids, as shown in the equation below;

I2(aq) + 5 Cl2(aq) + 6 H2O(l) → 10 HCl (aq) + 2 HIO3(aq)

(c) Identify the oxidising agent (oxidant) and reducing agent (reductant) in this reaction. Use oxidation numbers to support your answer. (4 marks)

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The chemistry student decided to prepare a sample of iodic acid according to the reaction above. She mixed 750 mL of 2.15 x 10-3 mol L-1 aqueous iodine (I2) with 830 mL of chlorine water (Cl2 (aq)) in a large beaker. Once the reaction had finished, a mixture of iodic and hydrochloric acids was present. She used a digital pH meter to measure the resulting pH of the solution and determined it to be 1.98.

(d) Determine and justify whether iodic acid is a strong or weak acid. Use appropriate calculations to support your answer. (You may assume that the chlorine water was in excess and that the reaction went to completion, consuming all the iodine.) (6 marks)

**Question 35 (15 marks)**

Dichlorine monoxide (Cl2O) is a brownish-yellow gas at room temperature. It is very soluble in water and when dissolved, it reacts with water to produce weak hypochlorous acid, according to the reversible reaction below;

Cl2O(g) + H2O(l) ⇌ 2 HClO (aq)

The solution of hypochlorous acid appears colourless. At room temperature (298.15 K) this reaction has an equilibrium constant (K) value of 0.090.

H2O(l)

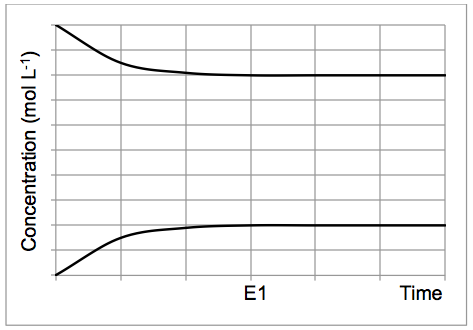
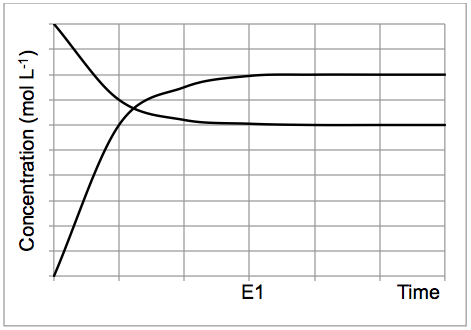
Cl2O

gas

A sample of Cl2O(g) was injected into a glass cylinder containing water, as shown in the diagram to the right, and allowed to establish equilibrium according to the equation above.

Several graphs have been sketched below, to show the changes in concentration of Cl2O(g) and HClO(aq) from Time 0, when the gas was injected into the system, until equilibrium was first established at Time E1. You may assume the scales on both axes of each graph are identical.

**Graph A Graph B**

Cl2O(g)

HClO(aq)

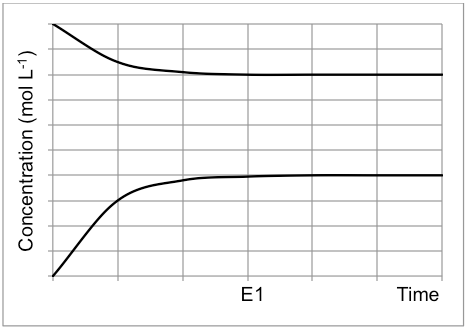
Cl2O(g)

HClO(aq)

Cl2O(g)

HClO(aq)

**Graph C**



(a) Which of these graphs (A, B or C) is **most likely** to illustrate the concentration changes that would occur, from the time the Cl2O(g) is injected into the system until the time that equilibrium is established at E1? Explain your choice below. (3 marks)

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Then, at some point after E1, the pressure on the system was increased, as shown in the diagram below.

Cl2O(g)

H2O(l) / HOCl (aq)

Cl2O(g)

H2O(l) / HOCl (aq)

(b) State the effect this would have on the equilibrium position and describe any corresponding observations that would be made because of this imposed change. (3 marks)

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(c) Explain what would happen to both the forward and reverse reaction rates, from the time the pressure was increased until the system re-establishes equilibrium. (3 marks)

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When the temperature of this equilibrium system is increased to 400 K, the new value of K is 1.98.

(d) Explain what information this provides about the heat of reaction (ΔH), including details of how you arrived at that conclusion. (3 marks)

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(e) Continue the graph below, showing the effect of a temperature increase on the system (imposed at Time Y) until equilibrium is re-established at E3. (You may assume water is still in the liquid state, because of the previous pressure increase.) (3 marks)

Cl2O(g)

HClO(aq)

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**Question 36 (19 marks)**

The ‘Kjeldahl method’ is a volumetric analysis process designed to measure the quantity of organic nitrogen (N) contained within a sample. One of the most common uses of the Kjeldahl method, is to determine the protein content in food and drink, since a measure of the nitrogen contained within a sample can be assumed to correspond directly to the amount of protein present.

Analysis by the Kjeldahl method is as follows;

1. A sample of the food or drink is dissolved in sulfuric acid, where all the nitrogen present in the protein is converted to ammonium sulfate, (NH4)2SO4. A small amount of sodium hydroxide is added to convert the ammonium ion to ammonia, which is then distilled off. All the nitrogen in the protein from the food/drink sample is now present as ammonia.

sample containing **N** → (**N**H4)2SO4 → **N**H3

1. The ammonia is then captured by (dissolved into) a solution containing a known, excess quantity of boric acid, i.e. all ammonia is captured and reacts according to the following equation;

B(OH)3(aq) + H2O(l) + **N**H3(g) → NH4+(aq) + B(OH)4-(aq)

1. A back titration is then performed, to determine the amount of boric acid remaining. This titration is performed using a sodium carbonate primary standard (Na2CO3) and the indicator methyl orange.

B(OH)3(aq) + H2O(l) + Na2CO3(aq) → NaHCO3(aq) + NaB(OH)4

1. The amount of ammonia captured can then be calculated. From this, the quantity of nitrogen, in the sample can be determined.
2. Once the mass of nitrogen in a food or drink sample is known, it is multiplied by a conversion factor according to the protein source. Some examples are shown in the table below.

|  |  |
| --- | --- |
|  | Conversion factor |
| peanuts | x 5.46 |
| rice | x 6.95 |
| meat, eggs | x 6.25 |
| dairy | x 6.38 |

e.g. if a sample of peanuts was determined to contain 3.5 g of nitrogen (N), they would therefore contain 3.5 g x 5.46 = 19.11 g of protein

Powdered baby formula (dairy milk powder) must be manufactured according to very strict specifications, to ensure it contains the correct nutritional balance to sustain the healthy growth of a baby. By law, whole milk powder for babies must contain a minimum of **26.44 g of protein per 100 g of milk powder**.

A sample of powdered baby formula was analysed for quality control purposes to determine the protein content. 3.75 grams of dairy milk powder was dissolved in 50.00 mL of sulfuric acid. The ammonium sulfate formed was distilled and the liberated ammonia was then captured and absorbed into 75.00 mL of a 0.200 mol L-1 boric acid solution.

Three 20.00 mL aliquots of the captured boric acid solution were then titrated against a standard 0.0650 mol L-1 sodium carbonate solution. The results of the titration are shown in the table below.

|  |  |  |  |
| --- | --- | --- | --- |
|  | 1 | 2 | 3 |
| Initial reading (mL) | 48.30 | 33.15 | 17.95 |
| Final reading (mL) | 33.15 | 17.95 | 2.75 |
| Titre (mL) |  |  |  |

(a) Use the titration results to calculate the number of moles of excess B(OH)3 remaining in the 75.00 mL sample **after** the capture of NH3. (4 marks)

(b) Use your answer from (a), as well as the **original** concentration of B(OH)3, to calculate the number of moles of NH3 that was captured in the boric acid solution. (3 marks)

(c) Calculate the percentage composition (by mass) of nitrogen in the sample of powdered baby formula. Express your answer to the correct number of significant figures. (4 marks)

(d) Use the appropriate conversion factor to calculate the protein content in the baby formula, and comment on whether this batch of milk powder meets the minimum requirement for protein content. (2 marks)

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As outlined previously, the back titration in the Kjeldahl method is performed using a sodium carbonate primary standard as well as the indicator methyl orange.

(e) Define the term ‘standard solution’ and state two (2) characteristics of Na2CO3 that allow it to be used as a primary standard. (3 marks)

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If the burette had been rinsed with distilled water at the start of the experiment;

(f) What effect would this error have on the value of the titre volumes obtained (i.e. higher volumes, lower volumes or unaffected)? (1 mark)

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(g) Is this a random or systematic error? Explain your answer. (2 marks)

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**Question 37 (16 marks)**

Hydrogen Peroxide (H2O2) is a chemical that undergoes “disproportionation” or self-redox, meaning it can be oxidised and reduced at the same time.

(a) Complete the following table with the balanced half-equations and full redox equation, if the two products of hydrogen peroxide disproportionation are water and oxygen gas. (3 marks)

|  |  |
| --- | --- |
| Reduction  Half-Equation |  |
| Oxidation  Half-Equation |  |
| Working space |  |
| Redox Equation |  |

Hydrogen Peroxide (H2O2) is a chemical that has many uses, including being used in aqueous solution as a hair bleaching agent, in a “20-volume” strength.

The volume strength refers to the litres of oxygen gas produced at STP when 1L of hydrogen peroxide solution disproportionates into water and oxygen gas (according to the redox equation above).

(b) Calculate the moles of oxygen gas that corresponds to the amount produced when 1L of

**20-volume** hydrogen peroxide disproportionates. (2 marks)

(c) Using the balanced redox equation from (a) above, calculate the moles of hydrogen peroxide that is required to produce this amount of oxygen gas. (1 mark)

(d) Calculate the concentration (in mol L-1) of this hydrogen peroxide solution. (1 mark)

(e) Calculate the concentration (% by mass) of this hydrogen peroxide solution, given that the density of a 20-volume solution is 1.02 gmL-1. (4 marks)

(f) A hairdresser wants to prepare 5L of 20-volume hydrogen peroxide solution from a concentrated (27.5% by mass, density of 1.13 gmL-1) stock solution. Calculate the volume of the concentrated stock solution she would need to measure out to prepare the desired 20-volume solution. (5 marks)

**Question 38 (15 marks)**

A chemistry student was investigating what type of solutions can be mixed together to form a buffer.

Firstly, he made two different hydrogensulfate / sulfate buffers. As illustrated in the diagrams below, one beaker contained a 1 L mixture of 0.5 mol L-1 NaHSO4(aq) and 0.5 mol L-1 Na2SO4(aq). The second beaker contained a 1 L mixture of 0.1 mol L-1 NaHSO4(aq) and 0.1 mol L-1 Na2SO4(aq).

0.1 mol L-1 HSO4-

mixed with

0.1 mol L-1 SO42-

0.5 mol L-1 HSO4-

mixed with

0.5 mol L-1 SO42-

Unfortunately, the student forgot to label the beakers, and could not remember which was which.

(a) Explain how the student could experimentally determine which beaker contained which buffer. Include a description of buffering capacity in your answer. Assume you have access to standard laboratory reagents and equipment. (6 marks)

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Next, the student decided to mix together solutions of sodium hydroxide, NaOH, and barium hydroxide, Ba(OH)2.

NaOH

mixed with

Ba(OH)2

(b) Why doesn’t this solution form a buffer? (1 mark)

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The original sodium hydroxide solution had a pH of 9.9 and the student measured 850 mL of this into a beaker. He then added 95 mL of a 0.075 mol L-1 barium hydroxide solution to the same beaker.

(c) Calculate the pH of the resulting solution. (8 marks)

**End of questions**

Spare answer page

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Spare answer page

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