**ATAR course examination, Semester 1, 2024**

**Question/Answer booklet**

**CHEMISTRY**

**Year 12 Unit 3**

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

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

**Time allowed for this paper**

Reading time before commencing work: ten minutes

Working time: three hours

**Materials required/recommended for this paper**

***To be provided by the supervisor***

This Question/Answer booklet

Multiple–choice answer sheet

Chemistry Data booklet

***To be provided by the candidate***

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination

**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 material. 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 examination | Your mark |
| Section OneMultiple–choice | 25 | 25 | 50 | 25 | 25 |  |
| Section TwoShort answer | 8 | 8 | 60 | 74 | 35 |  |
| Section ThreeExtended answer | 5 | 5 | 70 | 86 | 40 |  |
|  |  |  |  | **Total** | 100 |  |

**Instructions to candidates**

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2024: Part II Examinations.*  Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

Section One: Answerall 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. Do not use erasable or gel pens. 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 preferably using blue/black pen. Do not use erasable or gel pens.

3. When calculating numerical answers, show your working or reasoning clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

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

5. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

6. The Chemistry Data booklet is not to be handed in with your Question/Answer booklet.

**Section One: Multiple–choice 25% (25 Marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple–choice answer sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. Do not use erasable or gel pens. 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. In which one of the following does molybdenum have the highest oxidation number?

(a) MoCℓ5

(b) Mo2S3

(c) MoO42–

(d) Mo6Cℓ12

2. When hydrogen gas is passed over a heated metal oxide, the metal and steam are formed as shown in the diagram below.



Which one of the following shows the changes to the hydrogen and metal oxide?

|  |  |  |
| --- | --- | --- |
|  | **hydrogen** | **metal oxide** |
| (a) | oxidised | reduced |
| (b) | oxidised | oxidised |
| (c) | reduced | oxidised |
| (d) | reduced | reduced |

3. Which one of the following equations best represents acids as defined by Davy?

(a) NH3(aq) + H2O(ℓ) ⇌ NH4+(aq) + OH–(aq)

(b) HCℓ(aq) → H+(aq) + Cℓ–(aq)

(c) CO2(aq) + H2O(ℓ) ⇌ H2CO3(aq

(d) 2 HCℓ(aq) + Mg(s) → MgCℓ2(aq) + H2(g)

4. A student stirs a heated mixture of ammonium chloride and calcium hydroxide solids.

Which of the following observations are correct?

(i) No observable reaction occurs.

(ii) A yellow-green gas is evolved.

(iii) A pungent gas is evolved.

(iv) The mixture becomes moist.

(a) i only

(b) iii only

(c) ii and iv only

(d) iii and iv only

**Questions 5 and 6 relate to the following information.**

5. The following equilibrium system is involved in maintaining blood pH at 7.40 ± 0.05.

 1 CO2(aq) + H2O(ℓ) ⇌ H2CO3(aq)

 2 H2CO3(aq) + H2O(ℓ) ⇌ H3O+(aq) + HCO3–(aq)

Which one of the following correctly shows the equilibrium expression for reaction 1?

(a) 

(b) 

(c) 

(d) 

6. Which one of the following immediate actions can be taken by the body if blood pH falls below 7.35?

(a) more water flows from the cells into the blood

(b) rapid breathing to reduce CO2 levels

(c) excreting more H+(aq) in urine

(d) more CO2 moves from the cells into the blood

7. Which one of the following is correct if solution X has a pH of 3 and solution Y has a pH of 6?

(a) [H+(aq)] in solution X is 30 times that of [H+(aq)] in solution Y.

(b) [H+(aq)] in solution X is half that of [H+(aq)] in solution Y.

(c) [H+(aq)] in solution X is 1000 times that of [H+(aq)] in solution Y.

(d) Solution X must contain a stronger acid than solution Y.

8. Which one of the following statements concerning ethanoic acid (Ka = 1.7 × 10–5) is correct?

(a) It is weakly ionised in water existing mainly as the molecular species CH3COOH(aq).

(b) It completely ionises in water and exists mainly as H+(aq) and CH3COO–(aq).

(c) It does not ionise at all in water.

(d) It has a higher pH than the same concentration of hydrochloric acid because OH–(aq) is produced in the hydrolysis of CH3COO–(aq) ions.

**Questions 9 and 10 refer to the following information.**

A buffer solution is made using H2S(aq) and NaHS(aq).

9. Which one of the following equations correctly represents this buffer?

(a) H2S(aq) **⇌** 2 H+(aq) + S2–(aq)

(b) H2S(aq) + H2O(ℓ) ⇌ H3O+(aq) + HS–(aq)

(c) H2S(aq) + NaHS(aq) ⇌ Na+(aq) + HS–(aq) + H2O(ℓ)

(d) H2S(aq) + H2O(ℓ) ⇌ H3S+(aq) + OH–(aq)

10. Which one of the following limits the amount of sodium hydroxide solution that can be added before a significant change in pH occurs?

(a) [HS–(aq)]

(b) [OH–(aq)]

(c) [H3O+(aq)]

(d) [H2S(aq)]

11. Sulfur dioxide gas is catalytically converted to SO3(g) as shown in the equation below.

2 SO2(g) + O2(g) $\overset{V\_{2}O\_{5}}{⇌}$ **S**O3(g)

The function of the catalyst in the reaction is to

(a) increase the equilibrium proportion of SO3(g).

(b) decrease the equilibrium proportion of SO2(g)

(c) increase the rate of formation of SO3(g).

(d) decrease the rate of the reverse reaction.

12. Which one of the following correctly describes the following solutions?

|  |  |  |  |
| --- | --- | --- | --- |
|  | **LiNO3(aq)** | **NaHSO4(aq)** | **NH4Cℓ(aq)** |
| (a) | Acidic | basic | neutral |
| (b) | Basic | acidic | basic |
| (c) | Neutral | acidic | acidic |
| (d) | Neutral | neutral | acidic |

13. Consider the following partial pressure-time graph for an equilibrium mixture of three gases A, B and C which was heated at t1.



Which one of the following best shows the balanced equation and nature of the forward reaction?

|  |  |  |
| --- | --- | --- |
|  | **Equation** | **Forward reaction** |
| (a) | A(g) ⇌ 2 B(g) + C(g) | exothermic |
| (b) | 2 B(g) ⇌ A(g) + C(g) | endothermic |
| (c) | 2 B(g) + A(g) ⇌ C(g) | exothermic |
| (d) | A(g) + 2 B(g) ⇌ C(g) | endothermic |

**Questions 14 and 15 refer to the graph shown below.**

14. Which one of the following statements is correct about the reverse of the combustion reaction shown in the graph below?



(a) The reaction is exothermic with activation energy Y.

(b) The reaction is endothermic with activation energy Z.

(c) The reaction is exothermic with activation energy X.

(d) The reaction is endothermic with activation energy X + Y.

15. Consider the two reactions separately.

Forward reaction: reactants → products

Reverse reaction: products → reactants

Which one of the following statements is correct about the rate of these reactions?

(a) The rate of both reactions will be the same.

(b) The rate of the forward reaction will be faster than the reverse reaction.

(c) The rate of the reverse reaction will be faster than the forward reaction.

(d) The rate of each reaction cannot be compared using this graph.

**Questions 16 and 17 refer to the information below.**

Consider a reaction between calcium carbonate and dilute hydrochloric acid where the loss in mass is measured as shown in the graph below.



16. Which one of the following best explains the change in results between experiments 1 and 2?

(a) A catalyst is used in 1.

(b) A higher temperature is used in 2.

(c) Larger pieces of calcium carbonate are used in 2.

(d) The hydrochloric acid is more concentrated in 1.

17. Which one of the following best explains why the loss in mass is the same for both experiments?

(a) Only a certain mass of CO2(g) can be produced.

(b) The dilute hydrochloric acid reacts very slowly limiting the loss in mass.

(c) The calcium carbonate is the limiting reagent.

(d) The students measured the loss in mass over the same time period.

18. Identify the reducing agent in the following chemical equation.

2 HNO2(aq) + 4 H+(aq) + 4 Ag(s) + 2 SO42-(aq) → N2O(g) + 2 Ag2SO4(s) + 3 H2O(l)

(a) HNO2(aq)

(b) H+(aq)

(c) Ag(s)

(d) SO42-(aq)

19. Consider the following equilibrium reaction.

H2(g) + I2(g) **⇌ 2 HI(g)**

**Two separate experiments are set up at the same temperature. The lid is removed and the contents left to come to equilibrium.**

****

Which one of the following statements is true about the equilibrium concentrations?

(a) [H2(g)] = [HI(g)] in experiment A

(b) [HI(g)] = 2[H2(g)] in experiment A

(c) [HI(g)] in experiment A = [HI(g)] in experiment B

(d) [HI(g)] in experiment A = ½ [I2(g)] in experiment B

20. Which one of the following equations shows CH3NH2(aq) acting as a Brønsted-Lowry base?

(a) CH3NH2(aq) + H2O(ℓ) ⇌ CH3NH3+(aq) + OH–(aq)

(b) CH3NH2(aq) + H2O(ℓ) ⇌ CH3NH–(aq) + H3O+(aq)

(c) CH3NH2(aq) + H2O(ℓ) ⇌ CH3NH2OH–(aq) + H+(aq)

(d) CH3NH2(aq) + H2O(ℓ) ⇌ CH3+(aq) + NH3(aq) + OH–(aq)

21. Which one of the following graphs best shows the effect of adding a small quantity of acid, at t1, to a buffer solution?

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| (a) |  |  | (b) |  |
| (c) |  |  | (d) |  |

22. Which of the following is the best explanation as to how this system acts as a buffer when a small amount of NaOH solution is added to it?

(a) The equilibrium shifts right to produce more H3O+ ions to bring the pH back up.

(b) C6H5COOH reacts with the added OH– to prevent significant changes in the pH.

(c) C6H5COO– reacts with the OH– to produce C6H5COOH and resist pH change.

(d) OH– ions react with the H3O+ in the system to be neutralised and prevent pH change.

23. Which one of the following is the final correct step in the preparation of a burette for volumetric analysis?

(a) Rinse with distilled water.

(b) Rinse with the solution to be used.

(c) Rinse with the solution to be used and then distilled water.

(d) Dry thoroughly.

**Questions 24 and 25 refer to the information below.**

Consider the information provided in the diagrams below, regarding the set-up of two different titrations, A and B.

 **Titration A Titration B**



24. In Titration A, the

1. nitric acid is the primary standard.
2. nitric acid is the standard solution.
3. pH of the solution in the conical flask will decrease as the titration proceeds.
4. end point occurs when an equal number of moles of NH3(aq) and HNO3(aq) have reacted.

25. In Titration B, which of the following correctly identifies an error, along with its correct classification as random or systematic?

|  |  |  |
| --- | --- | --- |
|  | **Error** | **Random or systematic** |
| (a) | Rinsing the pipette with distilled water prior to titration. | systematic |
| (b) | Rinsing the conical flask with distilled water prior to titration. | systematic |
| (c) | Rinsing the burette with distilled water prior to titration. | random |
| (d) | Washing down the sides of the conical flask with distilled water during the titration. | random |

**End of section 1**

**Section Two: Short answer 35% (74 Marks)**

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

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes

**Question 26 (6 marks)**

Write a balanced ionic equation for any reactions occurring between the following substances and state any observations that would be noted as the reaction takes place.

(a) Excess 1 mol L-1 nitric acid is poured into a beaker containing chromium(III) carbonate powder. (3 marks)

|  |
| --- |
| Equation |

 Observations

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(b) A 1molL-1 potassium hydroxide solution is mixed with a 1molL-1 ammonium chloride solution. (3 marks)

|  |
| --- |
| Equation |

 Observations

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**Question 27 (15 marks)**

A reaction is set up to investigate the following equilibrium at 100.0 °C.

 2 CO(g) + O2(g) ⇌ 2 CO2(g) ΔH = +564 kJ mol–1

(a) What assumption must be made about the reaction vessel? Explain your answer. (2 marks)

(b) Complete the table indicating what will happen if the following changes are made. Assume sufficient time is allowed to reach a new equilibrium each time. (6 marks)

|  |  |  |
| --- | --- | --- |
| **Change made to equilibrium** | **Effect on ppO2(g)** | **Effect on value of K** |
| Temperature is reduced to 50.0 °C. |  |  |
| Volume of reaction vessel is decreased |  |  |
| A catalyst is added |  |  |

(c) Use collision theory and your knowledge of reaction rates to explain how the addition of O2(g) at 100.0 °C affects the equilibrium system and the partial pressures of each gas from just before the O2(g) is added until just after equilibrium is re-established. (7 marks)

**Question 28 (7 marks)**

Methyl orange is substance that can act as an acid–base indicator. It ionises slightly in water as shown in the equation below. The two forms have different colours.

 red (pH ˂ 3.1) yellow (pH ˃ 4.4)



(a) Label the conjugate acid–base pairs on the equation. (2 marks)

(b) Using a suitable example of an acid and base, explain why this indicator is used in titrations between weak bases and strong acids. (5 marks)

**Question 29 (12 marks)**

Consider a pH monitored titration between previously standardised 0.1000 mol L-1 solutions of sodium hydroxide and hydrochloric acid, with 20.00 mL of sodium hydroxide in the conical flask.

(a) Calculate the pH of the mixture when 19.00 mL of acid has been added from the burette.
 (6 marks)

(b) Use your answer to part (a) (use pH = 11 if you did not obtain an answer) and the following information to construct a pH curve for the titration from initially 20.00 mL of sodium hydroxide until 30.00 mL of hydrochloric acid has been added. (6 marks)

pH of the mixture when 21.00 mL of acid has been added ≈ 2.6

pH of the mixture when 30.00 mL of acid has been added ≈ 1.7



A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

**Question 30 (9 marks)**

One of the chemicals used in the process of leather tanning is sodium formate, NaHCOO. It acts as a pH regulator and a preservative.

Sodium formate is added to the tanning solution, where the crystals dissolve and react with the sulfuric acid present from previous steps. This neutralises the sulfuric acid, whilst producing formic acid.

H2SO4(aq) + 2 NaHCOO(s) → 2 HCOOH(aq) + Na2SO4(aq)

 *sodium formate formic acid*

The aim is to add excess sodium formate to the tanning solution, so that all the sulfuric acid is neutralised, and the remaining sodium formate forms a buffer solution with the newly produced formic acid.

Consider a 285 L batch of tanning solution containing 0.135 mol L-1 H2SO4(aq). The leathermakers wish to produce a final solution containing an equal number of moles of formic acid and sodium formate.

(a) Calculate the mass of sodium formate that should be dissolved in the tanning solution. Assume no change in final volume. (4 marks)

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(b) Write the chemical equation for the buffer system that would be formed in the tanning solution. (2 marks)

|  |
| --- |
|  |

(c) If the amount of sodium formate added was **greater than** that calculated in part (a), explain the effect this would have on the buffering capacity of the tanning solution. Include a definition of buffering capacity in your answer. (3 marks)

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**Question 31 (11 marks)**

Consider the following information about phosphoric acid (H3PO4(aq)).

1 H3PO4(aq) + H2O(ℓ) **⇌** H2PO4–(aq) + H3O+(aq) Ka = 7.1 × 10-3

2 H2PO4–(aq) + H2O(ℓ) ⇌ HPO42–(aq) + H3O+(aq) Ka = 6.3 × 10-8

3 HPO42–(aq) + H2O(ℓ) ⇌ PO43–(aq) + H3O+(aq) Ka = 4.2 × 10-13

**(a) Is phosphoric acid strong or weak? Explain your answer. (3 marks)**

**(b) Write equation 2 as an Arrhenius acid equation and use it to differentiate between the Arrhenius and Brønsted-Lowry theories of acids. (4 marks)**

(c) Write a balanced ionic equation for the reaction between phosphoric acid and excess sodium hydroxide solution. Explain whether this reaction will go to completion. (4 marks)

**Question 32 (5 marks)**

A student was investigating the rate of reaction between zinc metal and hydrochloric acid.

Zn(s) + 2 HCl(aq) → ZnCl2(aq) + H2(g)

The student performed three (3) different tests, which are summarised below.

|  |  |
| --- | --- |
| **Test 1** | 20 g of Zn(s) was ground into small pieces, and was then mixed with 50 mL of 0.2 mol L-1 HCl(aq) |
| **Test 2** | 20 g of Zn(s) in large chunks, was mixed with50 mL of 0.2 mol L-1 HCl(aq) |
| **Test 3** | 20 g of Zn(s) was ground into small pieces, and was then mixed with 50 mL of 0.1 mol L-1 HCl(aq) |

In each test, the zinc was present in excess.

The data collected by the student involved monitoring the mass of the beaker upon mixing of the reactants. The results of the 3 tests are displayed on the graph below.

Time (s)

Mass of beaker (g)

Test 1

Consider the curve labelled **Test 1**.

(a) Explain, in terms of collision theory, what information the **shape** of this curve provides, regarding the rate of reaction. (4 marks)

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(b) On the graph above, label the other curves to indicate which represents **Test 2** and which represents **Test 3**. (1 mark)

**Question 33 (9 marks)**

Litmus is a weak acid and is one of the oldest forms of pH indicator. It is used to test materials for acidity. The structure of one of the litmus components is shown below.



Litmus is a complicated molecule which we will simplify to “HLit”. The "H" is the proton which can be lost. The "Lit–" is the rest of the weak acid molecule. There will be an equilibrium established when this acid dissolves in water. Taking the simplified version of this equilibrium:

HLit(aq) + H2O(ℓ) ⇌ Lit–(aq) + H3O+(aq)

(a) Given that litmus appears blue in alkaline conditions and red in acidic conditions predict the colours of the HLit molecules and the Lit–ion justifying your answer using Collision Theory.

 (5 marks)

Phenolphthalein is another acid–base indicator often used in titrations. Unlike litmus it changes colour at a pH of approximately 9. A student wanted to standardise a solution of sodium hydroxide using either a 0.100 mol L–1 solution of oxalic acid or a 0.100 mol L–1 solution of nitric acid.

(b) Given that the student only has access to phenolphthalein for this titration which standard solution should she use for the titration? The oxalic acid or the nitric acid? Explain your answer using at least one equation to assist. (4 marks)

**End of section two**

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**Section Three: Extended answer 40% (86 Marks)**

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

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

Final answers to calculations should be expressed to theappropriate numberofsignificant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original question where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes

**Question 34 (14 marks)**

The pH of a swimming pool should be kept between 7.20 and 7.80.

Consider a swimming pool with a volume of 35,000 L.

(a) Calculate the volume of commercial hydrochloric acid (10.2 mol L**–1**) required to reduce the pH of the pool from 7.80 to 7.20. (5 marks)

A sodium hydrogen carbonate buffer (as shown in the equation below) is normally used in a swimming pool.

H2CO3(aq) + H2O(ℓ) ⇌ HCO3–(aq) + H3O+(aq)

(b) Use the buffer equation to describe, with reference to Le Châtelier’s principle, how the calculated volume in part (a) is incorrect. (6 marks)

The buffer concentration in the pool should be between 80 and 120 ppm but after heavy rain it decreased to 75 ppm and the pH decreased to 7.00

The instructions on the pool buffer are shown below.

|  |
| --- |
| Directions for use |
| Water Level | 50,000 litres | 1,000 L |
| Buffer | add 1 kg | add 20 g |
| Increase to alkalinity | 10 ppm | 10 ppm |

(c) Calculate the mass of pool buffer required to raise its concentration to from 75 to 105 ppm assuming the pool volume is unchanged at 35,000 L. (3 marks)

**Question 35 (13 marks)**

Sulfuric (H2SO4) and sulfurous (H2SO3) acids are closely related in terms of their chemical composition, however they display different chemical properties and consequently have very different uses.

Both acids are polyprotic, and the acidity constants for each are provided in the table below.

|  |  |  |
| --- | --- | --- |
|  | H2SO4 | H2SO3 |
| Ka1 | 1.0 x 103 | 1.4 x 10-2 |
| Ka2 | 1.2 x 10-2 | 1.0 x 10-7 |

(a) Define the term polyprotic. (1 mark)

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Compare 1 mol L-1 solutions of H2SO4(aq) and H2SO3(aq).

(b) State which solution would have the higher pH. Include a definition of pH, and use the Ka data provided, to justify your answer. (4 marks)

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(c) Define an acid, according to the Arrhenius theory. Write successive ionisation equations showing **sulfuric** acid behaving as an Arrhenius acid. (4 marks)

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(d) Define an acid, according to the Bronsted-Lowry theory. Write successive ionisation equations showing **sulfurous** acid behaving as a Bronsted-Lowry acid in aqueous solution. (4 marks)

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**Question 36 (14 marks)**

Consider the following reversible system, that has been allowed to establish equilibrium.

2 NO(g) + Cl2(g) ⇌ 2 NOCl(g)

 *colourless greenish-yellow yellow*

A change was imposed on this system at Time T1. The subsequent effects of this change are illustrated by both the rate and concentration graphs below.



Between Time E1 and Time T1, the system was in equilibrium.

(a) Describe the information provided by each of the graphs above, which supports the assertion that the system was in equilibrium. (2 marks)

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At Time T1, a change was imposed on the system.

(b) Describe the change in appearance of the system between Time T1 and Time E2. (1 mark)

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(c) Identify the change imposed on the system at Time T1. Explain your answer, using evidence from the graphs above, and referring to collision theory. (5 marks)

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(d) Identify the sign of the enthalpy change for the forward reaction. Justify your answer, using evidence from the graphs above, and referring to Le Chatelier’s principle. (4 marks)

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(e) Compare the values of Kc at Time E1 and Time E2. Justify your answer. (2 marks)

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**Question 37 (23 marks)**

One method of extracting titanium dioxide from beach sand uses the method described in the following steps.

|  |
| --- |
| beach sand containing 3.00% titanium ore – ilmenite (FeTiO3(s)) (between 45.0% - 65.0% pure titanium dioxide (TiO2(s)) |
| **↓** |
| ore dissolved in sulfuric acid to form (TiOSO4(s)) and impurities removed |
| **↓** |
| hydrated titanium dioxide produced and acidic wastes removed |
| **↓** |
| anhydrous titanium dioxide (TiO2(s)) (99.8% pure) produced by heating to remove water |

(a) Starting with 1.00 tonne of beach sand, calculate the minimum mass of anhydrous titanium dioxide (TiO2(s)) (99.8% pure) that can be produced. State your answer to the appropriate number of significant figures. (4 marks)

(b) What assumption must be made about the production of titanium dioxide from beach sand for the value you obtained in part (a) to be correct. (1 mark)

(c) Calculate the minimum volume of concentrated sulfuric acid (65.0% by weight) required to completely react with 100.0 kg of beach sand containing 3.00% ilmenite (FeTiO3(s)).

 (1.55 g of this sulfuric acid occupies 1.00 mL at 20.0°C

**OR**

 1.00g occupies 0.645 mL)

 (7 marks)

 FeTiO3(s) + 2 H2SO4(aq) → TiOSO4(s) + FeSO4(s) + 2 H2O(ℓ)

Titanium dioxide is used as a pure white pigment in paint.

(d) Explain why it is important to remove any FeSO4(s) from the mixture. (2 marks)

A titration is carried out to determine the exact concentration of the sulfuric acid. To achieve this 10.00 mL of the acid is carefully diluted to 250.0 mL in a volumetric flask. Aliquots of 10.00 mL of diluted acid are placed in a conical flask and titrated against a previously standardised 0.5780 mol L-1 sodium hydroxide solution. An average titre of 14.74 mL of sodium hydroxide is required.

(e) Calculate the concentration of the sulfuric acid in mol L-1. (4 marks)

(f) If 1.55 g of the concentrated acid solution in part (e) occupies a volume of 1.00 mL confirm by calculation it is a 65.0% by weight sulfuric acid solution. (Use 10.0 mol L-1 if you did not obtain an answer in part (e)) (5 marks)

**Question 38 (22 marks)**

Barium hydroxide solution, Ba(OH)2(aq), is also known as ‘baryta water’. It is used primarily in analytical chemistry, but also for certain organic synthesis processes.

A chemist wanted to use a sample of ‘baryta water’ to analyse the CO2(g) content of air. However, the concentration of Ba(OH)2(aq) had to first be determined by titration.

The ‘baryta water’ was titrated against a standard solution of potassium hydrogenphthalate, KHC8H4O4(aq). Potassium hydrogenphthalate is a weak, monoprotic acid, which is commonly used as a primary standard.

(a) Briefly describe why each of the following are important characteristics of a primary standard. (2 marks)

|  |  |
| --- | --- |
| High molar mass |  |
| Not deliquescent or hygroscopic |  |

A standard 0.1282 mol L-1 KHC8H4O4(aq) solution was made by dissolving KHC8H4O4(s) in distilled water, and making it up to 500.0 mL in a volumetric flask.

(b) Calculate the mass of KHC8H4O4(s) that was dissolved to prepare a 500.0 mL solution of the primary standard. (3 marks)

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A 20.00 mL sample of ‘baryta water’ was diluted to 100.0 mL in a volumetric flask. The diluted solution was then used to fill a burette. A few drops of phenolphthalein were added to a conical flask containing 15.00 mL of 0.1282 mol L-1 KHC8H4O4(aq). After several trials, the chemist determined an average titre of 18.38 mL.

The chemical equation for the titration reaction is as follows;

HC8H4O4-(aq) + OH-(aq) → C8H4O42-(aq) + H2O(l)

(c) Explain why phenolphthalein is a suitable indicator for this titration. Support your answer with a relevant chemical equation. (4 marks)

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(d) Calculate the concentration of the undiluted ‘baryta water’. State your answer to the appropriate number of significant figures. (7 marks)

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Once the ‘baryta water’ was standardised, the chemist was able to carry out their analysis to determine the concentration of CO2(g) in a sample of air.

When CO2(g) comes into contact with ‘baryta water’ a film of white barium carbonate powder, as well as water, forms.

(e) Write a balanced ionic equation for this reaction, including state symbols. (2 marks)

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**End of questions**

Supplementary page

Question number:

Supplementary page

Question number:

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Spare grid for question 29