**YEAR 12 SEMESTER ONE EXAM, 2021**

**CHEMISTRY**

MULTIPLE CHOICE QUESTION BOOKLET

# Time allowed for this paper

## Reading time before commencing work: ten (10) minutes

Working time: three (3) hours

# Materials required/recommended for this paper

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

This Multiple Choice Question Booklet

Multiple-choice Answer Sheet & Question/Answer Booklet

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 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 |
| Section One  Multiple-choice | 25 | 25 | 50 | / 25 | / 25 |
| Section Two  Short answer | 10 | 10 | 60 | / 70 | / 35 |
| Section Three  Extended answer | 5 | 5 | 70 | / 80 | / 40 |
|  | | | | | / 100 |

**Instructions to candidates**

1. Write your answers in the Question/Answer booklet provided preferably using a blue/black pen. Do not use erasable or gel pens.

2. Answer the questions according to the following instructions.

Section One: Answer all questions on the separate Multiple-choice answer sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. 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 the Question/Answer Booklet.

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 the 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. It is **your responsibility** to ensure ALL booklets are collected by the examiners at the conclusion of this exam.

**Section One: Multiple-choice 25% (25 marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

1. Which of the following factors would increase the reaction rate by increasing the proportion of successful collisions between reactant particles?

1. Increasing the concentration of reactant species.
2. Decreasing the volume of a gaseous system.
3. Increasing the subdivision of a solid reactant.
4. Increasing the temperature of a reacting system.

2. Which of the following 500.0 mL samples of 1.0 mol L-1 solution meet all of the following criteria?

1. Have a pH below 7.
2. Can be completely neutralised by the addition of 0.5 moles of NaOH(s).
3. Have a Ka value less than 1.
4. NH3
5. HCl
6. CH3COOH
7. H2SO3

**Questions 3 and 4 refer to the equilibrium below.**

Consider the following physical equilibrium involving bromine.

Br2 *(l)* ⇌ Br2 *(g)*

3. If this system had established equilibrium, which of the following wouldbe correct?

1. The rate of evaporation would equal the rate of condensation.
2. The rate of evaporation would be greater than the rate of condensation.
3. The rate of condensation would be greater than the rate of evaporation.
4. The rate of evaporation and condensation would be zero.

4. If the temperature of this system was increased by 5°C, this would

(a) have no effect on the position of equilibrium.

(b) decrease the rate of condensation.

(c) decrease the rate of evaporation.

(d) increase the value of K.

5. Which of the following solution mixtures would be the poorest electrolyte at equivalence point?

1. Hydrochloric acid and sodium hydroxide.
2. Sulfuric acid and barium hydroxide.
3. Ethanoic acid and ammonia.
4. All of the above.

6. Carbon monoxide and chlorine gases react to form phosgene (COCl2). The reaction is reversible.

CO(g) + Cℓ2(g) ⇌ COCℓ2(g) + 35 kJ

Which of the following conditions will increase the rate of formation of phosgene?

1. Increasing the temperature
2. Increasing the pressure
3. Removal of phosgene
4. Decreasing the temperature
5. Decreasing the pressure
6. i and iv only
7. iii, iv and v only
8. i, ii and iii only
9. i and ii only

7. In an acid-base titration, which of the following is **least** likely to cause an error in the

calculated concentration?

1. Each person in the group taking turns to measure the burette.
2. Measuring the volume at the bottom of the meniscus.
3. Rinsing the burette with distilled water before each titration.
4. Using a funnel in the burette and leaving it in the same place for each titration.

8. Consider the following data regarding the monoprotic acids below.

HSO4-(aq) Ka = 1.3 x 10-2 at 25 °C

HC2O4-(aq) Ka = 5.4 x 10-5 at 25 °C

Compare 0.2 mol L-1 solutions of both NaHSO4 and NaHC2O4. The NaHC2O4 solution would have a

1. higher concentration of Na+(aq).
2. higher conductivity.
3. higher pH.
4. higher concentration of anions with a (-2) charge.

**Questions 9, 10 and 11 refer to the following equilibrium system.**

Consider the following gaseous system, which has attained equilibrium at 85 °C.

CO(g) + Br2(g) ⇌ COBr2(g) + heat

*colourless red colourless*

9. If the volume of the system was reduced by 50%, it would be observed that

1. the red colour would gradually lighten.
2. the red colour would gradually darken.
3. the red colour would immediately darken and then gradually lighten.
4. the red colour would immediately lighten and then gradually darken.

The reacting system was then cooled from 85 °C to 35 °C where COBr2 condenses into a liquid.

10. Comparing to the system at 85 °C, the new system at 35 °C would contain

1. a smaller mass of COBr2.
2. a larger mass of COBr2.
3. the same mass of COBr2.
4. the comparative mass of COBr2 cannot be predicted from this information.

11. If the system is cooled to 35 °C, it would then be classified as

1. an open system, because some of the COBr2 has condensed.
2. an open system, because there would be fewer gas particles.
3. a closed system, because the position of equilibrium has not changed.
4. a closed system, because the number of atoms in the system has not changed.

12. A chemistry student attempted to identify a 0.5 mol L-1 salt solution by performing several chemical tests.

1. A few drops of phenolphthalein were added to a sample of the solution, and the mixture turned pink.
2. A few drops of 2.0 mol L-1 HCℓ(aq) were added to a separate sample of the solution, and this resulted in bubbles of colourless, odourless gas forming.

The identity of the salt solution could be

1. NaCH3COO.
2. KHCO3.
3. LiF.
4. NH4NO3.

13. An acid-base titration is performed to determine the concentration of a sodium hydroxide solution. The flask contains sodium hydroxide solution. Standardised ethanoic acid is delivered from the burette. A student incorrectly uses the indicator bromophenol blue, which has an endpoint at a pH of about pH 4. Because of this incorrect choice

1. Not enough acid will be delivered and the calculated sodium hydroxide concentration will be too low.
2. Not enough acid will be delivered and the calculated sodium hydroxide concentration will be too high.
3. Too much acid will be delivered and the calculated sodium hydroxide concentration will be too low.
4. Too much acid will be delivered and the calculated sodium hydroxide concentration will be too high.

14. The solubility of CO2(g) in water can be represented by the following equilibria:

CO2(g) ⇌ CO2(aq)

CO2(aq) + H2O(l) ⇌ HCO3 –(aq) + H +(aq)

Which of the following would increase the solubility of CO2 gas in water?

(a) Adding HNO3 solution.

(b) Adding solid KHCO3.

(c) Increase the volume of the container.

(d) Adding solid NaOH.

15. The magnitude of the equilibrium constant (K), for the equilibrium reaction below is

1.3 x 10-3at 25ºC.

H2O(l) ⇌ H2O(g)

In an experiment, a sealed flask containing water at 25ºC shows a water vapour concentration reading of 6.0 x 10-5 mol L-1. Which of the following statements best describes the rates of reactions at that instant?

(a) The rate of the forward reaction is greater than the rate of the reverse reaction.

(b) The rate of the reverse reaction is greater than the rate of the forward reaction.

(c) The rate of the forward reaction equals the rate of the reverse reaction.

(d) Both the forward and reverse reaction rates equal 0 as the reaction has reached completion.

16. Consider the data shown in the table below, which relates to a particular reversible reaction.

|  |  |  |
| --- | --- | --- |
|  | Uncatalysed reaction | Catalysed reaction |
| Ea(forward) (kJ mol-1) | 551 | **W** |
| Ea(reverse) (kJ mol-1) | **X** | 129 |
| H(forward) (kJ mol-1) | +373 | **Y** |
| H(reverse) (kJ mol-1) | **Z** |  |

The correct values of W, X, Y and Z are

**W X Y Z**

1. 502 178 +373 - 373
2. 924 178 - 373 +373
3. 244 924 - 422 - 373
4. 502 422 +373 +924

17. Which of the acidic solutions below could be completely neutralised by the addition of 1 mole of NH3(aq)?

1. 1 mole of CH3COOH(aq)
2. 1 mole of H2SO4(aq)
3. 1 mole of HCℓ (aq)
4. 1 mole of H2CO3(aq)
5. i only.
6. iii only.
7. i and iii only.

(d) ii and iv only.

**Questions 18 and 19 refer to the information below.**

An aqueous solution was formed by dissolving an equal number of moles of solid Zn(NO3)2 and solid Cr(NO3)3 in a beaker containing water.

Ten drops of concentrated NaOH solution was added to this solution mixture. The following equations describe the subsequent equilibrium reactions in this solution mixture.

Zn2+(aq) + 4 OH-(aq) ⇌ Zn(OH)42-(aq) K = 4.6 x 1017

Cr3+(aq) + 4 OH-(aq) ⇌ Cr(OH)4-(aq) K = 8.0 x 1029

18. **Immediately** after the NaOH solution was added, which of the following statements would be correct regarding the two equilibria above?

1. Both the forward reaction rates and the reverse reaction rates increased straight away.
2. The forward reaction rates increased while the reverse reaction rates decreased.
3. The forward reaction rates increased while the reverse reaction rates remained unchanged.
4. The reverse reaction rates increased while the forward reaction rates decreased.

19. Once both equilibria had been established, which of the following would be **most likely**?

1. [Zn2+(aq)] < [Cr3+(aq)]
2. [Cr(OH)4-(aq)] < [Cr3+(aq)]
3. [Zn(OH4)2- (aq)] < [Zn2+(aq)]
4. [Zn(OH)42-(aq)] < [Cr(OH)4-(aq)]

20. A gaseous equilibrium is represented by the following equation.

**x** A(g) ⇌ **y** B(g) Note: ‘**x**’ and ‘**y**’ represent numerical values.

The graph below shows the relationship between the mass of gas B and temperature and pressure.

Mass of gas B (grams)

Pressure of system (atm)

l l l l l l l

10 20 30 40 50 60

600 –

500 –

400 –

300 –

200 –

100 –

–

300 °C

200 °C

Using the data provided in this graph, which of the following must be true for this reaction?

1. x > y and H is positive.
2. x > y and H is negative.
3. x < y and H is positive.
4. x < y and H is negative.

21. Consider the dihydrogen phosphate ion, **H2PO4 –**

Which of the pairings below correctly show the conjugate species for this ion.

**Conjugate acid Conjugate base**

1. H3PO4 HPO­42-
2. HPO42- H3PO4
3. PO43-  H3PO4
4. H3PO4 PO43-

22. An acid-base indicator

1. only displays two different colours.
2. changes colour in response to pH.
3. always distinguishes an acid from a base.
4. only changes colour in solutions having concentration of 1.0 molL-1 and at 25oC.

23. Which of the following are redox reactions?

1. N2(g) + 3 H2(g) → 2 NH3(g)
2. CaCO3(s) + 2 HBr(aq) → CaBr2(aq) + H2O(l) + CO2(g)
3. Zn(s) + 2 HCℓ(aq) → ZnCℓ2(aq) + H2(g)

iv. S(s) + O2(g) → SO2(g)

1. Reactions i, ii and iii.
2. Reactions i, ii and iv.
3. Reactions i, iii and iv.
4. Reactions ii, iii and iv.

**Questions 24 and 25 refer to the following chemicals.**

Consider the four (4) pairs of chemicals listed below under standard conditions.

i. Pb(s) and Cd(NO3)2(aq)

ii. Sn(s) and Ni(NO3)2(aq)

iii. Ni(s) and Pb(NO3)2(aq)

iv. Cd(s) and Sn(NO3)2(aq)

24. If these chemical combinations were mixed in separate beakers, which would result in a metal displacement reaction?

1. Reactions i and ii only.
2. Reactions i and iii only.
3. Reactions ii and iv only.
4. Reactions iii and iv only.

25. Which of the following pairs contains the strongest oxidising agent and the strongest reducing agent in the order as written under standard conditions?

1. Pb2+(aq) and Cd(s)
2. Cd2+(aq) and Pb(s)
3. Pb2+(aq) and Pb(s)
4. Cd2+(aq) and Cd(s)

**End of Section One**

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

This section has 10 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 (7 marks)**

(a) Classify the following salts as acidic, basic or neutral and write them in the appropriate column below.

K2S , NH4Br , Mg(NO3)2 , NaI, NaHCO3 , CH3COOK (or KCH3COO) , KCℓ , Na2CO3

(4 marks)

|  |  |  |
| --- | --- | --- |
| **Acidic** | **Basic** | **Neutral** |
|  |  |  |

(b) Use the Brønsted-Lowry model to explain why the pH of ammonia (NH3) solution is greater than 7.0 at 25 °C. Include at least one appropriate equation in your answer (3 marks)

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**Question 27 (6 marks)**

Consider the following gaseous equilibrium system.

2 NO2(g) ⇌ N2O4(g) + heat

*brown colourless*

Complete the following table by stating how each of the imposed changes would affect;

1. the rate of the forward reaction,
2. the position of equilibrium, and
3. the concentration of NO2(g)

Note: consider the effect of each imposed change to the existing equilibrium.

|  |  |  |
| --- | --- | --- |
|  | Increase in temperature  of system | Increase in volume  of system |
| (i) Rate of forward reaction  (Write increase, decrease or  no change) |  |  |
| (ii) Position of equilibrium  (Write shift left, shift right or  no change) |  |  |
| (iii) Concentration of NO2(g)  (Write increase, decrease or  no change) |  |  |

**Question 28 (9 marks)**

A chemistry student poured 325.0 mL of 0.55 mol L-1 hydrochloric acid (HCℓ) into a beaker. They then added exactly 200 drops of 2.0 mol L-1 nitric acid (HNO3) whilst measuring the pH of the mixture throughout.

(a) Calculate the initial pH of the hydrochloric acid solution. (1 mark)

(b) Calculate the resultant pH of the solution mixture after the 200 drops of nitric acid was added. Assume 1 drop = 0.05 mL (6 marks)

The student concluded that the hydrochloric acid (HCℓ) was a buffer, since the pH change caused by the additional 200 drops of nitric acid had been minimal. However, their teacher said this was incorrect, and the hydrochloric acid solution was **not** a buffer.

(c) Use relevant chemical theory to justify the teacher’s statement, with reference to the results obtained. (2 marks)

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**Question 29 (6 marks)**

The sulfur cycle involves the transformation of sulfur atoms through various oxidation states. The sequence of change is as follows:

(i) Hydrogen sulfide (H2S) released from hydrothermal vents is converted to elemental sulfur (S8) by photosynthetic green and purple bacteria. The half- equation for this process is shown below:

8H2S(g) → S8(s) + 16H+(aq) + 16è

(ii) The elemental sulfur is then converted to sulfate ions (SO42-).

(iii) Sulfate ions are transformed into sulfite ions (SO32-) by another type of bacteria.

(iv) Sulfite ions change back into hydrogen sulfide.

The cycle then starts again.

Write the half-equations representing the remaining three (3) changes (i.e. ii to iv) in the sulfur cycle described above, assuming acidic conditions. Classify each step as a reduction (R) or oxidation (O) process.

|  |  |  |
| --- | --- | --- |
|  | Half-equation | Reduction or Oxidation |
| (ii) |  |  |
| (iii) |  |  |
| (iv) |  |  |

**Question 30 (9 marks)**

Consider the information provided in the table below for a particular chemical reaction that is taking place at 25 °C.

|  |
| --- |
| Ea = 8 kJ |
| H = -33 kJ mol-1 |
| K = 1  [Pb2+] [I-]2 |
| K = 2.27 x 108 |

(a) Write a balanced chemical equation for the reaction occurring. (2 marks)

|  |
| --- |
|  |

(b) Sketch an energy profile diagram for this reaction on the axes below. Label the activation energy (EA) and change in enthalpy (△H). (5 marks)

Progress of reaction

Enthalpy (kJ mol-1)

(c) Comment, with reference to the data table above, on whether the forward or reverse reaction is more likely to occur at 25 °C. (2 marks)

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**Question 31 (4 marks)**

The following graph illustrates the relationship between the temperature of pure water and its electrical conductivity.

l l l l l l

0 20 40 60 80 100

Temperature (°C)

Conductivity (S cm-1)

(a) State the relationship between the independent and the dependent variables. (1 mark)

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(b) With reference to relevant chemical theory, explain the trend shown by the graph. Include a relevant chemical equation in your answer. (3 marks)

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**Question 32 (6 marks)**

For each of the following pairs of compounds, identify a chemical test (i.e. reaction) that can be used to **visibly** distinguish between them. Provide a brief description of the chemical test and the resultant observation, but equations are not required.

|  |  |  |
| --- | --- | --- |
| **Substances** | **Your chemical test**  **(describe fully)** | **What visible change would be observed?** |
| 1.0 mol L-1 sodium hydroxide solution  and  1.0 mol L-1 sodium carbonate solution |  | With 1.0 mol/L sodium hydroxide solution  With 1.0 mol/L sodium carbonate solution |
| A freshly cleaned strip of silver metal  and  A freshly cleaned strip of chromium metal |  | With silver metal  With chromium metal |

**Question 33 (4 marks)**

The following gaseous system had established equilibrium.

N2(g) + O2(g) + 181 kJ ⇌ 2 NO(g)

A change was then imposed on the system, the effect of which is represented by the graph below.

Reaction rate

reverse

forward

(a) Which of the changes below was imposed on the system? (circle your choice) (1 mark)

|  |  |  |
| --- | --- | --- |
| addition of nitrogen gas  to the system | decrease in total volume  of the system | increase in temperature  of the system |

(b) Use Le Chatelier’s principle to justify the resultant shift that was observed. (3 marks)

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**Question 34 (11 marks)**

Write balanced **ionic** equations for any reactions occurring between the following substances and

state **­one** observation for each of the reactions.

If there is no reaction, write ‘no reaction’ for the equation and if there is no change observed,

write ‘no visible reaction’ for the observation. Where applicable, use the colours stated in the

Chemistry Data Booklet.

(a) Dilute ethanoic acid is mixed with 1.0 mol/L sodium hydrogencarbonate solution. (2 marks)

|  |
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|  |

State one observation that would be noted for this reaction. (1 mark)

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(b) A small piece of magnesium metal is placed in a 1.0 mol/L hydrochloric acid solution

(2 marks)

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State one observation that would be noted for this reaction. (1 mark)

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(c) A small piece of barium metal is dropped into a large bowl of warm water. (2 marks)

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State one observation that would be noted for this reaction. (1 mark)

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Write the equilibrium constant expression (K) for this reaction. (2 marks)

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**Question 35 (8 marks)**

A chemistry class was asked to determine the identity of an unknown acid. The students were told that the answer was either the weak acid potassium hydrogen phthalate, KHC8H4O4, or the weak acid potassium hydrogen iodate, KH(IO3)2.

A group of students dissolves 4.962 g of the unknown acid in distilled water, and making the solution up to 250.0 mL in a volumetric flask.

20.00 mL aliquots of this solution are then titrated against a standardised 0.06723 mol L-1 NaOH solution. The students’ results are provided in the table below.

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| --- | --- | --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 |
| Final (mL) | 48.03 | 42.78 | 39.45 | 37.45 | 31.66 |
| Initial (mL) | 18.44 | 13.91 | 10.07 | 8.53 | 2.73 |
| Titre (mL) |  |  |  |  |  |

The stoichiometric ratio for the neutralisation reaction between each of the acids and sodium hydroxide solution is the same, as shown in the following equations.

|  |  |  |
| --- | --- | --- |
| Potassium hydrogen phthalate | KHC8H4O4(s) | M = 204.22 g mol-1 |
| KHC8H4O4(aq) + NaOH(aq) → C8H4O4KNa(aq) + H2O(l) | | |
| Potassium hydrogen iodate | KH(IO3)2(s) | M = 389.908 g mol-1 |
| KH(IO3)2(aq) + NaOH(aq) → NaK(IO3)2(aq) + H2O(l) | | |

Note: The molar mass values for the two acids are also provided in the table above.

(a) State whether the indicator methyl orange or phenolphthalein would be suitable for this titration.

(1 mark)

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(b) Use the data provided to calculate the molar mass of the original powdered acid.

(6 marks)

(c) Identify and state whether the primary standard used was potassium hydrogen phthalate or potassium hydrogen iodate. Note: Your answer **must** be supported by the calculation shown in part (b) (1 mark)

**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.

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 the appropriate number of significant figures.

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: 70 minutes.

**Question 36 (17 marks)**

When solutions of iron(III) nitrate and potassium thiocyanate are mixed, the iron thiocyanate complex ion, FeSCN2+ is formed, and an aqueous equilibrium system is established as shown below.

Fe3+(aq) + SCN-(aq) ⇌ FeSCN2+(aq) + heat

*very pale brown colourless blood-red*

The appearance of the equilibrium mixture is determined by the concentration of FeSCN2+, which displays a characteristic blood-red colour.

A group of chemistry students sets up this equilibrium as described;

Step 1: 0.01 mol L-1 of Fe(NO3)3 and 0.006 mol L-1 of KSCN solutions are mixed in a beaker.

Step 2: The solution mixture is allowed to sit for 10 minutes until equilibrium is established.

Due to the characteristic blood-red colour, the concentration of FeSCN2+(aq)can be determined by a technique called Optical Spectrometry.

After 10 minutes, a sample of the equilibrium mixture is taken and its absorbance measured using light at 447 nm.

This absorbance value is then compared to a calibration curve to determine the concentration of FeSCN2+ at equilibrium.

The calibration curve for FeSCN2+(aq) is shown below.

(a) If the absorbance was determined to be 0.96, determine the concentration of FeSCN2+ present at equilibrium. (1 mark)

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(b) Sketch a concentration vs time graph for all relevant species, to show the relative changes to their concentration when solutions of Fe(NO3)3 and KSCN were mixed at Time 0. Assume chemical equilibrium was established at Time E1.

(5 marks)

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Time

Concentration (mol L-1)

0.010 –

0.009 –

0.008 –

0.007 –

0.006 –

0.005 –

0.004 –

0.003 –

0.002 –

0.001 –

During their research, the students found other reactions that can affect the equilibrium reaction that they have been examining. The chemical equations for these other reactions are:

i. Fe3+(aq) + 6 F-(aq) ⇌ FeF63-(\*aq)

ii. SCN-(aq) + H3O+(aq) ⇌ HSCN(aq) + H2O(l)

iii. Fe3+(aq) + 3 OH-(aq) ⇌ Fe(OH)­3(s)

The students poured their solution into several smaller beakers, and decided to perform various experiments with them.

Each of the beakers contain the equilibrium mixture shown below:

Fe3+(aq) + SCN-(aq) ⇌ FeSCN2+(aq) + heat

*very pale brown colourless blood-red*

(c) In one of the beakers (labelled Beaker 1), the students added a few drops of concentrated hydrochloric acid and in another beaker (labelled Beaker 2), they added a few drops of concentrated sodium hydroxide solution.

They found that in both beakers, the blood-red colour becomes lighter than before.

Justify these results by using Le Chatelier’s principle and making reference to any appropriate equations provided. (6 marks)

Beaker 1: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Beaker 2: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(d) State **one** observation that would have distinguished between Beaker 1 and Beaker 2 described in part (c). (1 mark)

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In another beaker (labelled Beaker 3) containing the equilibrium mixture, the students added a few drops of concentrated potassium fluoride (KF) solution.

(e) Using Collision theory and reaction rates, explain the effect this would have on the equilibrium position. (4 marks)

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**Question 37 (16 marks)**

Coca-Cola was first released in 1886 in the USA. Its current formula still remains a trade secret, but the listed ingredients are;

*Carbonated water, sugar, caffeine, phosphoric acid,*

*caramel colouring, natural flavourings.*

Phosphoric acid adds a tangy taste to the Coca-Cola. A chemistry class was assigned the task of determining the concentration of phosphoric acid, H3PO4(aq), in Coca-Cola.

Once the concentration of H3PO4 has been obtained, it can then be used **to determine the phosphorus content** of the soft drink.

Research by the students led to the development of the following method;

1. Obtain a 150.0 mL aliquot of Coca-Cola.

2. Heat for 20 minutes, to just below the boiling point.

3. Allow to cool.

4. Insert a pH meter into the solution.

5. Titrate against a 0.1005 mol L-1 NaOH standard solution, until a pH of 9.50 is reached.

Phosphoric acid is a weak, triprotic acid. This means there are three different equivalence points for the titration reaction. The titration curve for this reaction is shown below.

Volume of NaOH solution added

pH

14 -

12 -

10 -

8 -

6 -

4 -

2 -

0 -

first equivalence point (EP1)

second equivalence point (EP2)

third equivalence point

The pH at the third equivalence point is too basic to titrate accurately, and so the titration is only performed to the **second equivalence point** (EP2), according to the following equation;

**H3PO4(aq) + 2 NaOH(aq) → Na2HPO4(aq) + 2 H2O(l)**

or

H3PO4(aq) + 2 OH-(aq) → HPO42- (aq) + 2 H2O(l)

(a) Explain why the pH at the first equivalence point (EP1) is acidic, whilst the pH at the second equivalence point (EP2) is basic. Include relevant chemical equations in your answer.

(4 marks)

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The students performed the titration and found an average titration volume of 16.65 mL of NaOH solution was required to reach the **second** equivalence point (EP2).

(b) Calculate the mass of phosphorus present in a 375 mL can of Coca-Cola. Calculate the mass of phosphorus present in a 375 mL can of Coca-Cola. Write your final answer with the correct number of significant figures.

The relevant titration chemical equation is provided again for your convenience.

H3PO4(aq) + 2 NaOH(aq) → Na2HPO4(aq) + 2 H2O(l) (6 marks)

In Steps 2 and 3 of the method, the Coca-Cola sample is heated and then cooled. This removes the carbonic acid present in the soft drink. The equation is as follows:

H2CO3(aq) → H2O(l) + CO2(g)

(c) Explain why this step is important for the **validity** of the experiment. (2 marks)

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(d) Use your knowledge of Brønsted-Lowry theory, write the chemical formula for:

1. the conjugate base of H2CO3 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. the conjugate acid of the ion CO3 2- \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(2 marks)

One group of students forgot to heat their Coca-Cola samples before performing their titration.

(e) i. Classify this error as either random or systematic. (1 mark)

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ii. State the likely effect this would have on the students’ calculated phosphorus content

(i.e. higher, lower or no effect). (1 mark)

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**Question 38 (20 marks)**

The buffering capacity of seawater results from the presence of the hydrogencarbonate ions, HCO3- and carbonate ions, CO32-. The equilibrium chemical equation for this buffer is given below.

HCO3-(aq) + H2O(l) ⇌ CO32-(aq) + H3O+(aq)

(a) Define a buffer. (2 marks)

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(b) Using knowledge of ocean acidification, describe how the large increase in the concentration of carbon dioxide gas in the atmosphere due to human activity, results in a higher H3O+ concentration in seawater. (Note: chemical equations are **not** required in your answer). (3 marks)

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(c) Justify, using Le Chatelier’s principle, how the equilibrium buffer responds to an increase in the concentration of H3O+. (2 marks)

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A group of chemistry students collected a sample of seawater and decided to investigate its buffering capacity. They placed two 100.0 mL samples of the seawater into separate beakers and measured their initial pH.

To one beaker they added 0.005 mol L-1 HCl solution in 1.0 mL aliquots, whilst measuring the pH. To the other beaker, they added 0.005 mol L-1 NaOH solution in 1.0 mL aliquots, whilst measuring the pH.

Their results are shown in the table below.

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|  | | Volume of acid or base added (mL) | | | | | | | | | | |
|  | | 0.0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 |
| pH | HCl(aq) | 8.2 | 8.2 | 8.1 | 8.1 | 8.0 | 7.8 | 7.5 | 7.0 | 6.2 | 5.0 | 3.0 |
| NaOH(aq) | 8.2 | 8.2 | 8.3 | 8.3 | 8.4 | 8.4 | 8.5 | 8.5 | 8.6 | 8.7 | 8.9 |

(d) Plot both sets of pH data on the same pair of axes, using the grid below. (5 marks)

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(e) Does seawater contain a higher concentration of HCO3- ions or CO32- ions? Explain your answer, by referring to the data collected in this investigation. (4 marks)

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In addition to an increased H3O+ ion concentration in sea water, the increase in atmospheric CO2 gas also has a negative impact on many marine calcifying species, such as cuttlefish (an animal similar to squid).

(f) State two (2) negative consequences associated with the cuttlefish not being able to form its internal calcium carbonate shell. (2 marks)

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(g) State two (2) ways humans can reduce their production of CO2 gas. (2 marks)

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**Question 39 (15 marks)**

Gold is a precious metal that humankind has used for thousands of years. Over the centuries there have been many methods used to extract gold from its ore. In 1783, the ‘gold cyanidation’ process was developed, which is still widely used today.

In the ‘gold cyanidation’ process, the ore is first grounded and crushed to a powder and then mixed with a liquid containing water and sodium cyanide solution (NaCN) for 16 – 48 hours. Oxygen gas is also pumped into the mixture.

During this time ‘gold leaching’ occurs. This process results in the gold being oxidised to the (+1) oxidation state and dissolved into solution to form the aurocyanide ion, Au(CN)2 -.

The process can be summarised by the ‘Elsner equation’.

4 Au(s) + 8 CN-(aq) + O2(g) + 2 H2O(l) → 4 Au(CN)2-(aq) + 4 OH-(aq)

In a laboratory procedure, a sample of gold-containing ore was crushed and placed in a tank, along with 25.0 kL of leaching solution. The initial concentration of NaCN in the leach solution was measured to be 0.478 g L-1. After 48 hours, this concentration had fallen to 0.083 g L-1.

(a) Calculate the mass of gold that was dissolved in the procedure. (6 marks)

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(b) Calculate the final pH of the leaching solution. (Assuming that only the OH- ions produced by the procedure contribute to the overall pH). (4 marks)

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One of the techniques used to separate the gold from the leaching solution is the Merill-Crowe process. In this process, zinc powder is added to the leaching solution to precipitate the gold. The chemical equation for the Merill-Crowe process is shown below.

2 Au(CN)2-(aq) + 3 Zn(s) → 3 Zn2+(aq) + 8 CN-(aq) + 2 Au(s)

(c) State the oxidising agent (oxidant) and the reducing agent (reductant) in this process. (2 marks)

Oxidant: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Reductant: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(d) Explain, in terms of the collision theory, why zinc **powder** is used to precipitate the gold out of solution. (3 marks)

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**Question 40 (12 marks)**

Barium is a soft silvery metallic alkaline earth metal. It is never found in nature in its pure form due to its high reactivity with air.

Barium reacts with air to form a metal oxide known as **baryta**. As baryta readily reacts with water and carbon dioxide in the air, it is rarely found as a mineral.

(a) Write a balanced chemical equation for the formation of **baryta** (include state subscripts). (2 marks)

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The most common found barium-containing minerals in nature are barium sulfate (barite), and barium carbonate (witherite).

In a laboratory experiment, a student attempts to produce barium sulfate by precipitation reaction. After careful research, the student decides to dissolve 2.00 g of barium nitrate in 20.0 mL of 0.10 mol L-1 solution of aluminium sulfate. The molecular chemical equation for this reaction is as follows:

Aℓ2(SO4)3 (aq) + 3 Ba(NO3)2 → 3 BaSO4(s) + 2 Aℓ(NO3)3(aq)

(b) Determine the limiting reactant. (4 marks)

(c) Assuming the volume of the original solution does not change, calculate the concentration of aluminium ions in the final solution. (2 marks)

(d) The following table shows relevant information about **witherite** (BaCO3).

|  |  |
| --- | --- |
| Dissolution equilibrium constant (K) at 25oC | 5.1 x 10-9 |
| Solubility at various temperatures | 16 mg/L (8.8°C)  22 mg/L (18 °C)  24 mg/L (20 °C)  24 mg/L (24.2 °C) |

In a chemistry experiment, a student dissolves a small sample of barium carbonate powder in 100.0 mL of water in a sealed container.

The chemical equation for the dissolution of BaCO3 is as follows:

BaCO3(s) ⇌ Ba2+(aq) + CO32-(aq)

Complete the following table by stating how each of the imposed changes would affect:

* the concentration of the carbonate ions (CO32-) and
* the equilibrium constant (K)

(4 marks)

|  |  |  |
| --- | --- | --- |
| Imposed change | Effect on the concentration of CO32- ions  (Write increase, decrease or no change) | Effect on the value of equilibrium constant (K) (Write increase, decrease or no change) |
| Temperature is decreased |  |  |
| A small sample of barium nitrate powder is added |  |  |

**END OF QUESTIONS**

**Supplementary page:**

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