CHEMISTRY

Written examination 1

Tuesday 10 June 2003

Reading time: 11.45 am to 12.00 noon (15 minutes)
Writing time: 12.00 noon to 1.30 pm (1 hour 30 minutes)

QUESTION AND ANSWER BOOK

<table>
<thead>
<tr>
<th>Structure of book</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Section</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td><strong>Total</strong></td>
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</tbody>
</table>

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, an approved graphics calculator (memory cleared) and/or one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied
- Question and answer book of 17 pages, with a detachable data sheet in the centrefold.
- Answer sheet for multiple-choice questions.

Instructions
- Detach the data sheet from the centre of this book during reading time.
- Write your student number in the space provided above on this page.
- Check that your name and student number as printed on your answer sheet for multiple-choice questions are correct, and sign your name in the space provided to verify this.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.

Students are NOT permitted to bring mobile phones and/or any other electronic communication devices into the examination room.
SECTION A – Multiple-choice questions

Instructions for Section A
Answer all questions in pencil on the answer sheet provided for multiple-choice questions. A correct answer scores 1, an incorrect answer scores 0. Marks will not be deducted for incorrect answers. No mark will be given if more than one answer is completed for any question.

Question 1
Ethanol can be manufactured by the reaction between ethene and water. This is represented by the equation

\[ \text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightarrow \text{C}_2\text{H}_5\text{OH}(\text{g}) \quad \Delta H = -46 \text{ kJ mol}^{-1} \]

Which conditions would produce the highest percentage yield of ethanol at equilibrium?
A. low pressure and low temperature
B. high pressure and low temperature
C. low pressure and high temperature
D. high pressure and high temperature

Question 2
The rate of decomposition of hydrogen peroxide is increased by the presence of a catalyst.
The catalyst
A. increases the equilibrium constant for the reaction.
B. provides a reaction pathway with a lower activation energy.
C. provides a reaction pathway with a greater activation energy.
D. increases the average kinetic energy of the hydrogen peroxide molecules.

Question 3
At 25ºC, the pH of 0.0050 M Ba(OH)\textsubscript{2} is
A. 2.0
B. 2.3
C. 11.7
D. 12.0

Questions 4 and 5 refer to the following information.

0.12 g of a metal was reacted with excess hydrochloric acid. 125 mL of hydrogen gas was collected at 27ºC and 100 kPa.

Question 4
The amount of hydrogen gas, in mol, would be closest to
A. 5.0
B. 0.52
C. 0.052
D. 0.0050
**Question 5**
The metal involved could be
A. zinc.
B. sodium.
C. calcium.
D. magnesium.

**Question 6**
Consider the reaction

\[
\text{CH}_3\text{CH} = \text{CHCH}_3 + \text{Br}_2 \rightarrow Z
\]

Z would be represented by
A. \(\text{CH}_3\text{CHBrCHBrCH}_3\)
B. \(\text{CH}_2\text{BrCH}_2\text{CHBrCH}_3\)
C. \(\text{CH}_3\text{CHBrCH}_2\text{CH}_2\text{Br}\)
D. \(\text{CH}_2\text{BrCH}_2\text{CH}_2\text{CH}_2\text{Br}\)

**Question 7**
Consider the addition polymerisation of \(\text{CH}_3\text{CH} = \text{CHCH}_3\).
The structure of the resulting polymer would be
A. \(\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \quad \text{C. CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}_3\)
B. \(\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}_3\)
C. \(\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}_3\)
D. \(\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}_3\)

**Question 8**
Consider the reaction

\[
\text{CH}_3\text{CH} = \text{CHCH}_3 + \text{H}_2\text{O} \rightarrow X
\]

\[
X + \text{CH}_3\text{COOH} \rightarrow Y
\]
The structure of \(Y\) would be
A. \(\text{CH}_3\text{CH}_2\text{CHCOOCH}_3\)
B. \(\text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}_3\)
C. \(\text{CH}_3\text{CH}_2\text{CH}_2\text{COOCH}_3\)
D. \(\text{CH}_3\text{OOCH}_2\text{CH}_2\text{CH}_2\text{CH}_3\)
Questions 9 and 10 refer to the following information.

Consider the equilibrium

\[ 2\text{ClF}_3(\text{g}) \rightleftharpoons 3\text{F}_2(\text{g}) + \text{Cl}_2(\text{g}) \quad \Delta H = \text{negative} \]

**Question 9**

An expression for the equilibrium constant for this reaction is

A. \( \frac{[\text{ClF}_3]^2}{[\text{F}_2]^3 [\text{Cl}_2]} \)

B. \( \frac{3[\text{F}_2] [\text{Cl}_2]}{2[\text{ClF}_3]} \)

C. \( \frac{[\text{F}_2]^3 [\text{Cl}_2]}{[\text{ClF}_3]^2} \)

D. \( \frac{2[\text{ClF}_3]}{3[\text{F}_2] [\text{Cl}_2]} \)

**Question 10**

For a particular equilibrium mixture, the temperature is lowered and the amount of ClF\(_3\) changes by 0.010 mol.

The changes occurring would be

<table>
<thead>
<tr>
<th></th>
<th>ClF(_3)</th>
<th>F(_2)</th>
<th>Cl(_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>increase by 0.010 mol</td>
<td>decrease by 0.015 mol</td>
<td>decrease by 0.0050 mol</td>
</tr>
<tr>
<td>B.</td>
<td>increase by 0.010 mol</td>
<td>decrease by 0.0067 mol</td>
<td>decrease by 0.020 mol</td>
</tr>
<tr>
<td>C.</td>
<td>decrease by 0.010 mol</td>
<td>increase by 0.015 mol</td>
<td>increase by 0.0050 mol</td>
</tr>
<tr>
<td>D.</td>
<td>decrease by 0.010 mol</td>
<td>increase by 0.0067 mol</td>
<td>increase by 0.020 mol</td>
</tr>
</tbody>
</table>

**Question 11**

Catalytic cracking of alkanes is carried out by passing the hydrocarbon vapour over a heated catalyst in the absence of air.

Which of the following is **not** a possible product of the catalytic cracking of hexane?

A. propene
B. methane
C. hydrogen
D. carbon dioxide

**Question 12**

The compound that is a structural isomer of \( \text{CH}_3\text{CH}_2\text{COOH} \) is

A. \( \text{HCOOCH}_2\text{CH}_3 \)
B. \( \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \)
C. \( \text{CH}_3\text{COOCH}_2\text{CH}_3 \)
D. \( \text{CH}_3\text{CHOHCH}_2\text{OH} \)
Question 13
How many hydrogen atoms are there in a molecule of 3-nonanol?
A. 9
B. 19
C. 20
D. 21

Question 14
The number of structural isomers with the formula C₄H₉Cl is
A. 1
B. 2
C. 3
D. 4

Question 15
Oxides of nitrogen are formed in air at the high temperatures generated in lightning flashes according to the equation
\[ \text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{NO}(g) \quad K_1 = 5 \times 10^{-3} \text{ at } 3000^\circ \text{C} \]
At 3000°C, the equilibrium constant \( K_2 \) for the reaction
\[ 4\text{NO}(g) \rightleftharpoons 2\text{N}_2(g) + 2\text{O}_2(g) \]
would be
A. \( 4 \times 10^4 \)
B. \( 1 \times 10^2 \)
C. \( 1 \times 10^{-2} \)
D. \( 5 \times 10^{-3} \)

Question 16
A group of chemists complain about the smell that they noticed when reading new copies of a particular journal. The publishers of the journal decide to try to identify the substance, or substances, responsible for this smell. Which of the following analytical methods would be the most likely choice for the first stage of an analysis?
A. flame tests
B. paper chromatography
C. gas-liquid chromatography
D. atomic absorption spectroscopy

Question 17
Equal masses of each of the following substances are dissolved in separate samples of water to give 500 mL of solution.
Which substance would produce the solution with the lowest pH?
A. \( \text{NH}_3 \)
B. \( \text{HCl} \)
C. \( \text{HNO}_3 \)
D. \( \text{HClO}_4 \)
Question 18
The oxidation number of Cl in HClO$_4$ is
A. +7
B. +5
C. +3
D. −1

Question 19
A sample of hydrocarbon contains 81.8% carbon by mass.
The empirical formula of the compound would be
A. CH$_2$
B. CH$_3$
C. C$_2$H$_5$
D. C$_3$H$_8$

Question 20
Concentrated sulfuric acid reacts with glucose. One of the chemical reactions that can occur may be represented as
\[
\text{C}_6\text{H}_{12}\text{O}_6(\text{s}) + 6\text{H}_2\text{SO}_4(\text{l}) \rightarrow 6\text{C}(\text{s}) + 6\text{H}_3\text{O}^+(\text{aq}) + 6\text{HSO}_4^-(\text{aq})
\]
This reaction is best described as being
A. dehydration only.
B. acid-base and redox only.
C. dehydration and acid-base only.
D. dehydration, acid-base and redox.

END OF SECTION A
SECTION B – Short-answer questions

Instructions for Section B

Answer all questions in the spaces provided.
To obtain full marks for your responses you should
• give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
• show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
• make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$; NaCl(s).
Question 1
Sodium is an essential element in our diets. However, the amount of sodium present in some foods is often much higher than levels recommended by doctors. A sauce was analysed using atomic absorption spectroscopy to determine the sodium content.
A 25.00 mL sample of the sauce was diluted to 1.00 L with deionised water.
Four aqueous samples of known NaCl concentration were also prepared as standard solutions. The absorbances of the four standard solutions and the diluted sauce solution were measured. The results are given in the table below.

<table>
<thead>
<tr>
<th>concentration of Na⁺(aq)</th>
<th>absorbance</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mg L⁻¹</td>
<td>0.051</td>
</tr>
<tr>
<td>200 mg L⁻¹</td>
<td>0.100</td>
</tr>
<tr>
<td>300 mg L⁻¹</td>
<td>0.149</td>
</tr>
<tr>
<td>400 mg L⁻¹</td>
<td>0.199</td>
</tr>
<tr>
<td>diluted sauce</td>
<td>0.185</td>
</tr>
</tbody>
</table>

a. Use the above data for the Na⁺(aq) standards to plot a calibration line on the graph below.

SECTION B – Question 1 – continued
b. Use your calibration graph to determine the sodium ion concentration in the diluted sample of the sauce and in the original sauce. Enter your answers in the table below.

<table>
<thead>
<tr>
<th>concentration of Na⁺(aq) in diluted solution of sauce in mg L⁻¹</th>
<th>concentration of Na⁺(aq) in original (undiluted) sauce in mg L⁻¹</th>
</tr>
</thead>
</table>

2 marks

c. i. What important assumption must you make in order to calculate the NaCl content of the sauce from the Na⁺ concentration?

ii. Calculate the concentration of NaCl in the original (undiluted) sauce in g L⁻¹.

iii. The maximum recommended daily NaCl intake for a healthy adult is 2.5 g. What percentage of a maximum daily recommended intake would be consumed by a person who eats 10 mL of the original (undiluted) sauce?

1 + 3 + 2 = 6 marks

d. Why is it that atomic absorption spectroscopy will measure only the sodium ion concentration in your sample and not the concentration of some other substance or substances as well?

2 marks

Total 11 marks
Question 2

Part of the Contact Process for the manufacture of sulfuric acid involves the conversion of sulfur dioxide to sulfur trioxide, as shown by the equation

$$2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g) \quad \Delta H = -192 \text{ kJ mol}^{-1}$$

As part of a laboratory study of this process, a container was filled with an equilibrium mixture of sulfur dioxide, sulfur trioxide and oxygen in the presence of a catalyst. The container was initially at 450°C. The container had a fixed volume and was thermally well insulated. Concentrations during a following experiment are shown on the diagram below.

a. What change occurred at the 10 minute point?

b. Which components of the equilibrium mixture are represented by X and Y?

X =

Y =

1 mark

1 mark
c. Give explanations for the changes in concentration that occur in X, Y and O₂ between 10 and 20 minutes.

3 marks

d. Would the temperature of the mixture increase, decrease or remain the same between 10 and 20 minutes? Explain your reasoning.

2 marks
Total 7 marks
Question 3

Esters are the basis of many naturally occurring odours and are therefore widely used in the creation of artificial flavours. Methyl butanoate is a component of the smell of pineapple. A manufacturer decides to test the use of some of this compound in an ice-cream mix.

Chromium trioxide is an oxidising agent that can convert a simple alcohol to the corresponding carboxylic acid.

a. Give a simple structure for the ester methyl butanoate.

b. Using 1-butanol and methanol as starting materials give chemical equations showing the steps in the preparation of methyl butanoate. Give the name of any catalyst used.

1 mark

3 marks

Total 4 marks
Question 4
Methanoic acid HCOOH is a weak acid present in the sting of some ants. It ionises in water according to

\[ \text{HCOOH}(aq) \rightleftharpoons \text{HCOO}^- (aq) + \text{H}^+ (aq) \quad K_a = 1.8 \times 10^{-4} \text{ at } 25^\circ\text{C} \]

a. Explain the meaning of the terms 'weak acid' and 'strong acid'.

b. Write the expression for the $K_a$ of methanoic acid.

c. Assuming a small degree of dissociation, calculate the concentrations of $\text{H}^+ (aq)$ and $\text{HCOO}^- (aq)$ in 0.10 M methanoic acid at 25°C.

2 marks

1 mark

2 marks

Total 5 marks
Question 5
Chromatography is often used for the analysis of the mixture of amino acids that is formed when proteins are broken down. The small protein methionine enkephalin has some pain killing activity. An aqueous solution of methionine enkephalin is broken down into its constituent amino acids and the resultant solution of amino acids is subjected to paper chromatography. A strip from such a chromatogram is shown below.

Amino acids are colourless, but the position of an amino acid spot on the strip can be seen by spraying the strip with a solution of ninhydrin, a substance that reacts with amino acids to produce an intense purple colour.

a. The identities of the four amino acids in this particular mixture have been determined by measuring their $R_f$ values.
   i. Explain how an $R_f$ value is calculated.
   ii. Calculate the $R_f$ of the methionine spot.

1 + 2 = 3 marks
b. Describe how the sample containing the mixture of the four amino acids was added to the paper in order to begin the procedure.

__________________________________________________________________________

__________________________________________________________________________

1 mark

c. What factors determine the different $R_f$ values of the different amino acids?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

2 marks
Total 6 marks
Question 6

a. The Earth’s oceans contain significant amounts of dissolved carbon dioxide. The dissolving process can be described by the following chemical equilibria.

\[
\text{CO}_2(g) \rightleftharpoons \text{CO}_2(aq) \\
\text{CO}_2(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}^+(aq) + \text{HCO}_3^-(aq)
\]

Use this information to explain the likely effect of the increasing concentration of atmospheric \( \text{CO}_2 \) on the pH of seawater at the ocean surface.

3 marks

b. Several different acid-base systems contribute to the hydrogen ion concentration in blood. One of these systems is represented by the equilibrium

\[
\text{CO}_2(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}^+(aq) + \text{HCO}_3^-(aq) \quad K_a = 7.9 \times 10^{-7}
\]

The concentration of \( \text{CO}_2(aq) \) in freshly oxygenated blood is approximately \( 1.3 \times 10^{-5} \) M and the pH of blood is 7.4.

i. Calculate the concentration of the hydrogen ion, \( \text{H}^+ \), in fresh blood.

ii. Calculate the concentration of the hydrogen carbonate ion, \( \text{HCO}_3^- \), in fresh blood.

1 + 2 = 3 marks

Total 6 marks

SECTION B – continued
Question 7

Pyrolusite, an ore of manganese, contains manganese in the form of MnO\(_2\). A sample of pyrolusite from a newly discovered deposit is analysed to determine the degree of purity of the deposit.

To determine the amount of Mn in the pyrolusite sample, 1.25 g of dried pyrolusite was heated with 100 mL of 0.150 M oxalic acid (H\(_2\)C\(_2\)O\(_4\)). The oxalic acid was in excess, so that all of the MnO\(_2\) reacted according to

\[
\text{MnO}_2(s) + \text{H}_2\text{C}_2\text{O}_4(aq) + 2\text{H}^+(aq) \rightarrow \text{Mn}^{2+}(aq) + 2\text{CO}_2(g) + 2\text{H}_2\text{O}(l)
\]

20.00 mL of the resulting solution is then titrated with an 0.0510 M solution of the triiodide ion

\[
\text{I}_3^-(aq) + \text{H}_2\text{C}_2\text{O}_4(aq) \rightarrow 2\text{CO}_2(g) + 2\text{H}^+(aq) + 3\text{I}^-(aq)
\]

22.00 mL of the 0.0510 M triiodide solution was needed to react with the remaining oxalic acid.

a. Calculate the amount in mole of oxalic acid remaining in the original 100 mL solution after the pyrolusite had been reacted with the oxalic acid.

3 marks

b. Calculate the amount in mole of oxalic acid used to reduce the MnO\(_2\) in the 1.25 g of pyrolusite.

2 marks

c. Calculate the amount in mole of MnO\(_2\) present in the original 1.25 g of pyrolusite and hence the percentage of MnO\(_2\) by mass present in the pyrolusite.

2 marks

Total 7 marks