CHEMISTRY DEPARTMENT
UNIVERSITY OF BOTSWANA

CHE 102 GENERAL CHEMISTRY II FINAL EXAMINATION
APRIL 2004. TIME ALLOWED: 3 hours

Name of the student: .................................................................

ID #:----------------------------- Group and Serial Number: ---------------

WRITE ALL ANSWERS ON THIS QUESTION PAPER.

The paper has two parts. For Section A (multiple-choice questions), circle the letter for the correct answer for each question.
For questions in Section B, use the space provided to write your answers. If you need additional space, write on the back of the printed pages.

You may detach the Periodic Table, but you may NOT write anything on it during the examination.

IMPORTANT: It is the student’s responsibility to report if any page is missing in this paper. The paper has 14 pages in addition to the Periodic Table.

Specific heat capacity of H₂O (l) = 4.184 J/(°C.g)
Kw = 1.0 x 10⁻¹⁴ at 25 °C
Avogadro constant = 6.022 x 10²³ mol⁻¹
R = 8.314 J. K⁻¹. mol⁻¹ = 0.08206 L. atm. K⁻¹ mol⁻¹
1 atm = 760 Torr.
Unless otherwise stated, all solutions are aqueous and all temperatures are 25 °C.

Do not write in this table.

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<tr>
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Section A: Multiple Choice Questions (60%)

1. Which of the following is the structure of 3,3-dimethyl-1-pentene

```
a)

b)

c)

d)

e)
```

2. Select the sequence of reagents from the given list which will best accomplish the following transformation:

```
CH₃ C≡C CH₃ → CH₃CH-CH₂CH₃
```

a. H₂SO₄/H₂O/ HgSO₄

b. H₂/ Lindlar, then H₂SO₄/H₂O

H₂/Ni, then H₂SO₄/H₂O

d. H₂O₂ /OH

e. H₂/Pt, then H₂O/ H₂SO₄

3. The addition of two moles of hydrogen bromide to 1-pentyne will yield-

```
a. 1,1-dibromopentane
b. 1,2-dibromopentane
c. 1,3-dibromopentane
d. 2,2-dibromopentane
e. 3,3-dibromopentane
```
4. How many monochlorination products will be produced from the following reaction?

\[
\text{H}_3\text{C} - \text{C}_8\text{H}_3\text{C} - \text{CH}_3 \xrightarrow{\text{Cl}_2 \ \text{Light}}
\]

a. 8
b. 6
c. 3
d. 4
e. 2

5. The addition of water to cyclooctyne catalysed by sulphuric acid and mercury (II) sulphate will afford-

![Diagrams of cyclooctyne and its probable products]

a)  

b) ![Diagrams of cyclooctyne and its probable products]

c) ![Diagrams of cyclooctyne and its probable products]

d) ![Diagrams of cyclooctyne and its probable products]

e) ![Diagrams of cyclooctyne and its probable products]

6. Which of the following is the structure of 3,5-dibromophenol?

![Diagrams of various phenol structures with different bromine positions]

a) ![Diagrams of various phenol structures with different bromine positions]

b) ![Diagrams of various phenol structures with different bromine positions]

c) ![Diagrams of various phenol structures with different bromine positions]

d) ![Diagrams of various phenol structures with different bromine positions]

e) ![Diagrams of various phenol structures with different bromine positions]

7. The following compounds are-

\[
\text{CH}_3\text{C} = \text{CH}_3 \quad \text{and} \quad \text{CH}_3\text{CH}_2\text{CH}
\]

a. functional isomers
b. skeletal isomers
c. the same molecule
d. positional isomers
e. geometric isomers
8. The functional groups contained in the following structure are-

- ketones, alcohol and carboxylic acid
- ketones, alcohol and acid anhydride
- ketones, cyclopropyl, alcohol and aldehyde
- ketones, cyclopropyl, alcohol and ether
- ketones, alcohol, and ester

9. Calculate $\Delta H^\circ$ (in kJ) for reaction 3 below:

(1) $2\text{NO} \rightarrow \text{N}_2 + \text{O}_2 \quad \Delta H^\circ = -180 \text{ kJ}$
(2) $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2 \quad \Delta H^\circ = -112 \text{ kJ}$
(3) $\text{N}_2 + 2\text{O}_2 \rightarrow 2\text{NO}_2 \quad \Delta H^\circ = ?$

- a. 68
- b. -68
- c. -292
- d. 292
- e. -146

10. Given the following $\Delta H^\circ_f$ values:

<table>
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<tr>
<th>Substance</th>
<th>$\Delta H^\circ_f$ (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_2$(g)</td>
<td>34.0</td>
</tr>
<tr>
<td>H$_2$O(l)</td>
<td>-286</td>
</tr>
<tr>
<td>HNO$_3$ (aq)</td>
<td>-207</td>
</tr>
<tr>
<td>NO(g)</td>
<td>90.0</td>
</tr>
</tbody>
</table>

Calculate the value of $\Delta H^\circ$ (in kJ) for the reaction:

$3 \text{NO}_2$(g) + H$_2$O(l) $\rightarrow$ 2 HNO$_3$ (aq) + NO(g)

- a. 64
- b. 140
- c. -140
- d. -508
- e. -64
1. An unsaturated solution is one that ____________
   a. has no double bond.
   b. contains maximum concentration of solute possible, and is in equilibrium with undissolved solute.
   c. has a concentration lower than the molar solubility.
   d. contains more dissolved solute than the solubility allows.
   e. contains no solute.

12. The vapour pressure of pure water at 25 °C is 23.8 torr. Raoult’s law predicts that a solution prepared by dissolving 18 g of glucose (MM = 180 g/mol) in 95 g of water will have a vapour pressure of ____________ torr.
   a. 24.3
   b. 23.8
   c. 0.451
   d. 0.443
   e. 23.4

13. For an aqueous solution of a non-electrolyte, the vapour pressure will be ____________, the boiling point will be ____________, and the freezing point will be ____________ than for pure water.
   a. lower, lower, lower
   b. lower, higher, lower
   c. lower, higher, higher
   d. higher, higher, lower
   e. higher, lower, higher

4. For the reaction below:
   \[ \text{N}_2\text{O}_4 (g) \rightleftharpoons 2\text{NO}_2 (g) \]
   determine the value of \( K_c \) if an initial concentration of \( \text{N}_2\text{O}_4 \) (g) of 0.0400 mol/L is reduced to 0.0055 mol/L at equilibrium. There is no \( \text{NO}_2 \) present at the start of the reaction.
   a. 0.87
   b. 13
   c. 0.22
   d. 0.022
   e. \( 2.2 \times 10^{-4} \)
15. The value of $K_c$ for the equilibrium

$$H_2 \ (g) + I_2 \ (g) \rightleftharpoons 2HI \ (g)$$

is 54.0 at 427 °C. At this temperature, what is the value of $K_c$ for

$$HI \ (g) \rightleftharpoons \frac{1}{2} H_2 \ (g) + \frac{1}{2} I_2 \ (g)?$$

a. 27  
b. 7.35  
c. 0.136  
d. 2.92 \times 10^3  
e. 3.43 \times 10^{-4}$

16. The value of $K_c$ for the reaction below is 0.016. Under a set of equilibrium conditions, 

$[HI] = 0.10 \ M$ and $[H_2] = [I_2]$. Calculate the concentration of $I_2$ (mol/L):

$$2HI \ (g) \rightleftharpoons H_2 \ (g) + I_2 \ (g)$$

a. $1.2 \times 10^{-2}$  
b. $4.0 \times 10^{-2}$  
c. $3.1 \times 10^{-1}$  
d. 1.3  
e. 0.31

7. The endothermic reaction

$$\text{Propene (g)} \rightleftharpoons \text{Cyclopropane (g)}$$

is at equilibrium. Which action(s) below will shift the equilibrium to the left and cause the amount of propene(g) to increase?

a. increasing the system temperature  
b. decreasing the system temperature  
c. increasing the system pressure  
d. decreasing the system pressure  
e. increasing both the system temperature and the system pressure.

18. The $[OH^-]$ and pH of a 0.035 M NaOH solution at 25 °C are

$$M \ and \ _____$$

respectively.

a. 0.035, 1.46  
b. 0.035, -1.46  
c. $2.9 \times 10^{-13}$, -12.54  
d. 0.035, 12.54  
e. $2.9 \times 10^{-13}$, 12.54
19. Of the acids in the table below, is the strongest acid

<table>
<thead>
<tr>
<th>Acid</th>
<th>$K_a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC$_2$H$_3$O$_2$</td>
<td>$1.8 \times 10^{-5}$</td>
</tr>
<tr>
<td>HCHO$_2$</td>
<td>$1.8 \times 10^{-4}$</td>
</tr>
<tr>
<td>HClO</td>
<td>$3.0 \times 10^{-8}$</td>
</tr>
<tr>
<td>HF</td>
<td>$6.8 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

a. HC$_2$H$_3$O$_2$
b. HCHO$_2$
c. HClO
d. HF
e. HC$_2$H$_3$O$_2$ and HCHO$_2$

20. The $K_a$ of HClO is $3.0 \times 10^{-8}$ at 25°C. What is the pH at 25 °C of an aqueous solution that is 0.020 M HClO?

a. 2.45
b. -2.45
c. -9.22
d. 9.22
e. 4.61

21. An aqueous solution of will have pH greater than 7.0 at 25 °C.

a. NH$_4$NO$_3$
b. KBr
c. NaI
d. CH$_3$COONa
e. FeCl$_3$

22. In which of the following aqueous solutions would you expect AgCl to have the highest solubility?

a. pure water
b. 0.020 M BaCl$_2$
c. 0.020 M NaCl
d. 0.020 M AgNO$_3$
e. 0.020 M KCl

23. Which of the following pairs of substances can be dissolved to form a buffer solution?

a. NaI, HI
b. KCl, HBr
c. NH$_4$Cl, NH$_4$NO$_3$
d. NaF, HF
e. None of these
24. A reaction is found to be second order in carbon monoxide. If the concentration of CO is doubled, the rate of the reaction will ________.
   a. double
   b. remain unchanged
   c. triple
   d. increase by a factor of 4
   e. decrease by a factor of 2.

25. The rate constant of a first order reaction is $0.0271 \text{ s}^{-1}$. The half-life of the reaction is ________.
   a. 0.451 s
   b. 40.9 s
   c. 25.6 s
   d. 0.625 s
   e. initial concentration is required in order to determine the half-life.

26. The initial concentration of a reactant in a first-order reaction is 0.27 M. The rate constant for the reaction is $0.75 \text{ s}^{-1}$. What is the concentration (mol/L) of reactant after 1.5 s?
   a. 3.8
   b. 1.7
   c. $8.8 \times 10^{-2}$
   d. $2.0 \times 10^{-2}$
   e. 0.135

27. In general, as temperature goes up, the rate of a reaction ________.
   a. goes up if the reaction is exothermic.
   b. goes up if the reaction is endothermic.
   c. goes up regardless of whether the reaction is exothermic or endothermic.
   d. stays the same regardless of whether the reaction is exothermic or endothermic.
   e. stays the same if the reaction is first order.

28. A catalyst increases reaction rate ________.
   a. by decreasing the heat of the reaction.
   b. by increasing the equilibrium constant.
   c. by changing the order of the reaction.
   d. by providing a reaction path with a lower activation energy.
   e. none of these could increase the reaction rate.
29. When the temperature of a reaction is increased from 303 K to 333K, the rate constant increases by a factor of 10. \( \frac{k_2}{k_1} = 10 \). What is the activation energy (kJ/mol) of the reaction?

a. 30  
b. 33  
c. 46  
d. 64  
e. 89

30. Which of the following graphs shows the correct relationship between concentration and time for a reaction that is second order in [A]?

a.  

b.  

c.  

d.  

e.  
Question one (10 marks)

(a) Hydrogenation of $C_4H_6$, catalysed by Pt consumed two moles of $H_2$ to give $C_4H_{10}$.

$$C_4H_6 + 2H_2 \xrightarrow{\text{Pt}} C_4H_{10}$$

Draw all the isomers of $C_4H_6$ in this reaction, and give their systematic names.

(b) Write the equation of the reaction in which 1-pentyne is hydrated in presence of sulphuric acid and $\text{HgSO}_4$. Write the structure and the name of the major product.

c) The compound 2-methyl-2-butene reacted with water in presence of sulphuric acid to give an alcohol. Write the reaction, give the structure and the name of the alcohol produced. What class (primary, secondary, tertiary etc) does the alcohol belong to?
Question two (9 marks)

For the reaction $2\text{ClO}_2(\text{aq}) + 2\text{OH}^- (\text{aq}) \rightarrow \text{ClO}_3^- (\text{aq}) + \text{ClO}_2^- (\text{aq}) + \text{H}_2\text{O}(l)$, the following experimental data were obtained:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>$[\text{ClO}_2]$</th>
<th>$[\text{OH}^-]$</th>
<th>Initial rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.060 M</td>
<td>0.030 M</td>
<td>0.0248 M/s</td>
</tr>
<tr>
<td>2</td>
<td>0.020</td>
<td>0.030</td>
<td>0.00276</td>
</tr>
<tr>
<td>3</td>
<td>0.020</td>
<td>0.090</td>
<td>0.00828</td>
</tr>
</tbody>
</table>

a. Find the order of the reaction with respect to $\text{ClO}_2$.
b. What is the order of the reaction with respect to $\text{OH}^-$
c. What is the overall order?
d. What is the value of the rate constant? Include the units of the rate constant with your answer.
Question Three. (7 marks)

a. Assume that the molar solubility of CaF₂ in water is s. Express Kₚₛ of CaF₂ in terms of s.

b. Given for PbS, Kₛᵖ = 8.0 x 10⁻²⁸. Calculate the molar solubility of PbS in water.

c. What is the molar solubility of PbS in a 0.0180 M solution of Na₂S? (for PbS, Kₛᵖ = 8.0 x 10⁻²⁸).
Consider a 0.10 M solution of potassium benzoate, KC₆H₅CO₂ (aq)
Write the equilibrium that exists in the solution, and write the expression for the equilibrium constant.
Set up an equilibrium table.
Kₘ of benzoic acid, C₆H₅COOH = 6.5 x 10⁻⁵, calculate Kₜ for benzoate ion, C₆H₅CO₂⁻
Calculate the pH of the given solution.
Question Five

Consider the equilibrium:

\[ 2\text{SO}_2 (g) + \text{O}_2 (g) \rightleftharpoons 2\text{SO}_3 (g) \quad \Delta H^\circ = -198 \text{ kJ} \]

a. What happens to the partial pressure of \(\text{SO}_3\) when the partial pressure of \(\text{SO}_2\) is decreased?

b. What happens to the partial pressure of \(\text{SO}_2\) if the partial pressure of \(\text{O}_2\) is increased?

c. If the volume of the container is increased, what happens to the amount of \(\text{SO}_3\)?

d. If the temperature of the system is increased, what happens to \(K_c\)?

e. If a catalyst is added to the system, what happens to \(K_p\)?

f. If the partial pressure of \(\text{SO}_3\) is increased, what happens to \(K_p\)?
# PERIODIC TABLE OF THE ELEMENTS

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**Lanthanides:**

- La (138.906)
- Ce (140.12)
- Pr (140.908)
- Nd (144.24)
- Sm (150.36)
- Eu (151.96)
- Gd (157.25)
- Tb (158.925)
- Dy (162.50)
- Ho (161.930)
- Er (167.26)
- Tm (166.934)
- Yb (173.04)

**Actinides:**

- Ac (227.028)
- Th (232.038)
- Pa (231.036)
- U (238.029)
- Np (237.048)
- Pu (244)
- Am (243)
- Cm (247)
- Bk (247)
- Cf (251)
- Es (252)
- Fm (257)
- Md (258)
- No (259)