CHEMICAL REACTIVITY - CHEM120

Section A - Multiple Choice Questions

Total Marks for Section A: 40
Total Marks for Examination: 100

Duration: 3 hours

Internal Examiners: V.O. Nyamori, H.G. Kruger, M.D. Bala, B.S. Martincigh, P.G. Ndungu and G.D. Dawson

Moderating Board: W.E. van Zyl, P.H. Coombes, A. Soares

INSTRUCTIONS:

1. Answer ALL questions.
2. There is only one correct answer for each question.
3. Your answers must be written on the multiple-choice answer sheet provided.
4. You must use HB pencil only on the answer sheet and make a dark heavy mark that fills the block completely.
5. This question paper consists of 12 pages and 40 questions. Please check that you have them all.
6. You are required to hand in this question paper at the end of the examination.
7. You will also require a copy of Section B of the examination paper.
8. You are advised not to spend more than 1 hour and 10 minutes on Section A.
9. A periodic table and a data sheet are provided.
For each of the following questions, select the correct answer from the list provided.

- There is only one correct answer for each question.
- Indicate your answer on the multiple choice answer sheet provided.
- Make a dark heavy mark with HB pencil that fills the block of the appropriate letter completely.

1. What is the correct name for the compound below?

   ![Chemical Structure](image)

   (A) 1-methylcyclohex-2-ene  
   (B) 3-methylcyclohexene  
   (C) 2-methylcyclohexene  
   (D) 1-methylcyclohex-5-ene

2. Which is the correct IUPAC name for the compound below?

   ![Chemical Structure](image)

   (A) 2-chloro-3-bromopropanoic acid  
   (B) 1-bromo-2-chloropropanoic acid  
   (C) 3-bromo-2-chloropropanoic acid  
   (D) 1-bromo-2-chloroethanoic acid

3. How many constitutional isomers are formed from C₅H₁₂?

   (A) 3  
   (B) 4  
   (C) 5  
   (D) 2
4. How many sigma-bonds and pi-bonds does 1-cyanocyclopenta-1,3-diene have?

(A) Six sigma-bonds and five pi-bonds
(B) Seven sigma-bonds and four pi-bonds
(C) Five sigma-bonds and six pi-bonds
(D) Eight sigma-bonds and three pi-bonds

5. Which Newman projection shown below has the most stable conformation of the following compound with the formula C_2H_4Br_2?

(A) 
(B) 
(C) 
(D) 

6. The best nomenclature for the geometry of the following compound is...

(A) R-
(B) S-
(C) E-
(D) Z-
7. Which of the following isomers will have the highest boiling point?

(A)\[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3\] \hspace{1cm} (B)\[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3\text{CH}_3\]

(C)\[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3\] \hspace{1cm} (D)\[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3\text{CH}_3\]

8. Which of the following is a tertiary amine?

(A)\[\text{CH}_3\text{N}\text{CH}_3\] \hspace{1cm} (B)\[\text{CH}_3\text{CH}_3\text{H}_3\text{C}-\text{HN}\text{CH}_3\]

(C)\[\text{H}_3\text{C}\text{H}_2\text{C}-\text{CH}_3\text{H}_3\text{C}\text{H}_2\text{C}-\text{CH}_3\] \hspace{1cm} (D)\[\text{H}_3\text{C}\text{CH}\text{NH}_2\text{CH}_3\]

9. Which statement about addition reactions between alkenes and HBr is false?

(A) The proposed mechanism involves radicals.

(B) The $\pi$ bond breaks in the course of the reaction.

(C) A hydrogen atom attaches itself to the alkene carbon atom possessing a partial negative charge.

(D) Bromine attacks the alkene carbon atom possessing a partial positive charge.
10. Which of the following is the most stable carbocation?

11. Which of the following is the major product of the following reaction?

12. Which structure below represents a ketone?

13. Which of the following is the best method for preparing CH₃Br?
   (A) CH₃OH + NaBr
   (B) CH₃OH + Br₂
   (C) CH₃OH + Br⁺
   (D) CH₃OH + HBr
14. What is the product of the following reaction?

\[
\text{H}_3\text{C} = \text{CH}_2 + \text{CH}_2 = \text{CH}_3 \quad 1. \text{O}_3 \\
2. \text{CH}_3 \text{S-CH}_3
\]

(A)  

15. Which of the following reagents can be used to reduce acetaldehyde to ethanol?

(A) LiAlH₄/H₃O⁺  
(B) K₂CrO₇/H⁺  
(C) SOCl₂  
(D) H₂O/H⁺

16. Which of the following is the best leaving group?

(A) CN⁻  
(B) I⁻  
(C) CH₃O⁻  
(D) HO⁻
17. Used sodium reacts with element X to form an ionic compound with the formula \( \text{Na}_3\text{X} \). Ca will react with X to form ________.
   (A) \( \text{Ca}_2\text{X}_3 \)
   (B) \( \text{CaX}_2 \)
   (C) \( \text{Ca}_3\text{X} \)
   (D) \( \text{Ca}_3\text{X}_2 \)

18. Consider the following properties of an element:
   (i) It is solid at room temperature.
   (ii) It easily forms an oxide when exposed to air.
   (iii) When it reacts with water, hydrogen gas evolves.
   (iv) It must be stored in oil.

Of the elements listed below which fits the above description the best?
   (A) Mercury
   (B) Sulfur
   (C) Sodium
   (D) Copper

19. Which one of the following is sodium sulfate?
   (A) \( \text{Na}_2\text{SO}_4 \)
   (B) \( \text{Na}_2\text{S}_4\text{O}_6 \)
   (C) \( \text{Na}_2\text{SO}_3 \)
   (D) \( \text{Na}_2\text{S}_2\text{O}_3 \)

20. Which equation correctly represents the reaction between carbon dioxide and water?
   (A) \( \text{CO}_2 \ (\text{aq}) + \text{H}_2\text{O} \ (l) \rightarrow \text{H}_2\text{CO} \ (\text{aq}) + \text{O}_2 \ (g) \)
   (B) \( \text{CO}_2 \ (\text{aq}) + \text{H}_2\text{O} \ (l) \rightarrow \text{H}_2\text{CO}_3 \ (\text{aq}) \)
   (C) \( \text{CO}_2 \ (\text{aq}) + \text{H}_2\text{O} \ (l) \rightarrow \text{H}_2 \ (g) + \text{CO} \ (g) + \text{O}_2 \ (g) \)
   (D) \( \text{CO}_2 \ (\text{aq}) + \text{H}_2\text{O} \ (l) \rightarrow \text{H}_2\text{O}_2 \ (\text{aq}) + \text{CO} \ (g) \)
21. The oxidation state of silicon in SiO$_4^{4-}$ is ________.
   (A) 0
   (B) +2
   (C) -4
   (D) +4

22. Which of the following elements has the largest first ionisation energy?
   (A) Al
   (B) Cl
   (C) Se
   (D) Na

23. Which of the following elements is the most electropositive?
   (A) Al
   (B) Cl
   (C) Se
   (D) Na

24. All of the halogens ________.
   (A) exist under standard conditions of temperature and pressure as diatomic gases
   (B) tend to form positive ions of several different charges
   (C) form salts with alkali metals with the formula MX
   (D) tend to form negative ions of several different charges

25. Which of the two elements would form the most ionic bond?
   (A) Rb and O
   (B) Rb and I
   (C) Li and Rb
   (D) O and I
26. Correctly list the five atoms in order of increasing size (smallest to largest):
   (A)  O < F < S < Mg < Ba
   (B)  O < F < S < Ba < Mg
   (C)  F < S < O < Mg < Ba
   (D)  F < O < S < Mg < Ba

27. Which substance dissolves in water to form an acidic solution?
   (A)  KCl
   (B)  Na₃PO₄
   (C)  NH₄Cl
   (D)  Na₂CO₃

28. Which of the following mixtures is not a true buffer? The total volume of solution is 1 dm³.
   (A)  1.0 mol NH₃ + 0.5 mol KOH
   (B)  1.0 mol NH₄Cl + 0.5 mol KOH
   (C)  1.0 mol NH₃ + 0.5 mol NH₄Cl
   (D)  1.0 mol NH₃ + 0.5 mol HCl

29. If a small amount of a strong base is added to a buffer made up of a weak acid, HA, and its sodium salt, NaA, the pH of the buffer does not change appreciably because:
   (A)  the Kₐ of HA changes.
   (B)  the base reacts with HA to give AOH and H⁺.
   (C)  the base reacts with A⁻ to give HA.
   (D)  the base reacts with HA to give A⁻.
30. For equal volumes of 0.10 mol dm$^{-3}$ solutions of HCO$_2$H (pH 2.6), NH$_4$Cl (pH 4.4) and HCN (pH 5.1), which solution requires the most 0.10 mol dm$^{-3}$ KOH to titrate to the equivalence point?

(A) HCN  
(B) NH$_4$Cl  
(C) HCO$_2$H  
(D) all the same

31. Which of the following slightly soluble salts is more soluble in 1.0 mol dm$^{-3}$ HClO$_4$?

(A) Hg$_2$Br$_2$  
(B) PbI$_2$  
(C) AgCl  
(D) PbSO$_3$

32. Which reaction has the largest positive entropy change per mole of product formed?

(A) S(s) + 3F$_2$(g) $\rightarrow$ SF$_6$(g)  
(B) SO$_2$(g) + Na$_2$O(s) $\rightarrow$ Na$_2$SO$_3$(s)  
(C) Fe$^{3+}$(aq) + SCN$^-$ (aq) $\rightarrow$ FeSCN$^{2+}$(aq)  
(D) H$_2$O(l) $\rightarrow$ H$_2$O(g)

33. A particular chemical reaction has a negative $\Delta H$ and negative $\Delta S$. Which statement is correct?

(A) The reaction is spontaneous at all temperatures.  
(B) The reaction is non-spontaneous at all temperatures.  
(C) The reaction becomes spontaneous as temperature increases.  
(D) The reaction becomes spontaneous as temperature decreases.
34. All of the following are colligative properties except:
   (A) osmotic pressure
   (B) boiling point elevation
   (C) freezing point depression
   (D) melting point determination

35. A cylinder fitted with a movable piston contains liquid water in equilibrium with water vapour at 25 °C. Which would cause a decrease in the equilibrium vapour pressure?
   (A) moving the piston downward a short distance
   (B) removing a small amount of vapour
   (C) removing a small amount of the liquid water
   (D) dissolving salt in the water

36. The addition of a non-volatile solute to water will always:
   (A) increase the boiling point.
   (A) increase the freezing point.
   (B) increase the temperature of the solution.
   (C) increase the vapour pressure at a specific temperature.

37. In every electrolytic and galvanic (voltaic) cell the anode is that electrode:
   (A) at which oxidation occurs.
   (B) which attracts cations.
   (C) at which electrons are supplied to the solution.
   (D) at which reduction occurs.
38. Which statement is true for the cell as it discharges?

\[ \text{Zn} \mid \text{Zn}^{2+}(1.0 \text{ mol dm}^{-3}) \mid\mid \text{Sn}^{2+}(1.0 \text{ mol dm}^{-3}) \mid \text{Sn} \]

(A) Oxidation occurs at the tin electrode.

(B) Electrons will flow from the tin electrode to the zinc electrode.

(C) The concentration of Zn\(^{2+}\) will increase.

(D) The mass of the tin electrode will decrease.

39. What would be the \(E^\circ\) value in volts for a zinc-silver galvanic cell?

<table>
<thead>
<tr>
<th>Standard Reduction Potentials</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{Zn}^{2+} + 2\text{e}^- = \text{Zn})</td>
</tr>
<tr>
<td>(\text{Ag}^+ + \text{e}^- = \text{Ag})</td>
</tr>
</tbody>
</table>

(A) 0.76 - 0.80

(B) 0.76 - (2 \times 0.80)

(C) 0.76 + 0.80

(D) 0.76 + (2 \times 0.80)

40. What is true in the galvanic cell in which the overall reaction is

\[ \text{Mg(s)} + \text{Br}_2(l) \rightarrow \text{Mg}^{2+}(aq) + 2\text{Br}^-(aq) \]

(A) The \(\text{Br}_2\)|\(\text{Br}^-\) electrode is the anode.

(B) Mg\(^{2+}\) ions migrate towards the cathode.

(C) An increase in concentration of Mg\(^{2+}\) would increase the cell voltage.

(D) The electrons enter the magnesium electrode from the external circuit.
CHEMICAL REACTIVITY - CHEM120

Section B

Total Marks for Section B: 60
Total Marks for Examination: 100

Internal Examiners: V.O. Nyamori, H.G. Kruger, M.D. Bala, B.S. Martincigh, P.G. Ndungu and G.D. Dawson

Moderating Board: W.E. van Zyl, P.H. Coombes, A. Soares

IMPORTANT: Complete this part immediately.

Student No: 

Seat Number: 

Surname (optional): Initials: 

INSTRUCTIONS:

1. Answer ALL questions.
2. Calculators may be used but all working must be shown.
3. The pages of this question paper must not be unpinned.
4. Your answers must be written on the question paper in the spaces provided.
   The left-hand pages may be used for extra space or for rough work.
5. Marks will be deducted for the incorrect use of significant figures and the omission of units.
6. You must write legibly in black or blue ink. Pencils and Tipp-Ex are not allowed.
7. This question paper consists of 17 pages. Please check that you have them all.
8. You will also require a copy of Section A: Multiple-Choice Questions.
9. You are advised not to spend more than 1 hours and 50 minutes on Section B.
10. A periodic table and a data sheet are provided.

| Question No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|--------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|
| Internal Mark|   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |
| External Mark|   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |
| Total Mark   | 3 | 5 | 4 | 6 | 2 | 4 | 5 | 6 | 4 | 5  | 3  | 3  | 2  | 2½ | 2  | 3½ |

Total Mark 60
QUESTION 1

Below is a line notation of a compound.

(a) Identify the hybridization of the numbered atoms (i) to (iii) in the compound above.

(b) Identify three different functional groups in the compound above.
QUESTION 2

(a) Write a structural formula for each of the following compounds: (2)

(i) 2-isopropylhexane

(ii) 4-chloro-5-hydroxypentanal

(b) Use the correct IUPAC nomenclature to name each of the following compounds: (3)

(i) \[ \text{structural formula} \]

(ii) \[ \text{structural formula} \]

(iii) \[ \text{structural formula} \]
QUESTION 3

(a) Below is one of the isomers of 2-bromobutan-1-ol, drawn using the perspective formula. Use Cahn-Prelog-Ingold $R, S$-nomenclature to designate its configuration in terms of ($R$-) or ($S$-).

\[ \text{Structure} \]

(b) Draw and clearly label the structure for the ‘$E$’ isomer of 2-chloro-3-methylpent-2-ene.

(2)
QUESTION 4

(a) Complete the following reactions by filling in the missing product(s) (no mechanism is required):

\[
\text{CH}_3\text{CH}_2\text{C}--\text{OH} \xrightarrow{\Delta, \text{H}^+} \text{CH}_3\text{CH}_2\text{OH}
\]

\[(\Delta = \text{heat or reflux})\]

\[
\text{R}--\text{C}--\text{OH} \xrightarrow{\text{NaOH, } \text{H}_2\text{O}}
\]

\[(1)\]

(b) Indicate what the partial charges (δ- or δ+) on the atoms of the two groups (i) and (ii) below are. Motivate your answer (hint: use electronegativity)

\[
\begin{align*}
\text{H} & \quad \text{F} \\
\text{H}--\text{C} & \quad \text{F}--\text{C} \\
\text{H} & \quad \text{F} \\
\text{(i)} & \quad \text{(ii)}
\end{align*}
\]

(c) Use the concept in (b) to explain what the term “inductive effect” means by describing the effect of the CH₃ and CF₃ groups on the neighbouring atom Y.

\[
\begin{align*}
\text{H} & \quad \text{F} \\
\text{H}--\text{C}--\text{Y} & \quad \text{F}--\text{C}--\text{Y} \\
\text{H} & \quad \text{F} \\
\text{(i)} & \quad \text{(ii)}
\end{align*}
\]
QUESTION 5

Alkenes can undergo addition reactions with acids. Below is an example of two possible products (3a and 3b) that can form in such an addition reaction.

(a) Indicate which product will be the major product.

(b) Motivate your answer.
QUESTION 6

Primary organic halides react with nucleophiles through an \( \text{S}_\text{N}2 \) mechanism. In the mechanism inversion of the carbon reaction centre is observed. Provide the mechanism of the \( \text{S}_\text{N}2 \) mechanism below.

\[
\begin{align*}
\text{H}_3\text{C} - \text{H}_2\text{C} & \quad \text{starting material} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{Br} \\
\text{H} & \quad \text{H} \\
\text{H}_3\text{C} - \text{H}_2\text{C} & \quad \text{product(s)} \\
\end{align*}
\]
QUESTION 7

(a) Superoxides of alkali metals are used to supply oxygen in emergency breathing apparatus. Write a balanced chemical equation to show the use of KO$_2$ for this purpose.

(2)

(b) Generally, first ionization energies (I$_1$) increase across a period from Group 1 to Group 18. State one important reason why the I$_1$ of Al (577.6 kJ mol$^{-1}$) is smaller than that of Mg (737.7 kJ mol$^{-1}$).

(1)

(c) Write a balanced chemical equation, including the phases, to show the effects of acid rain (H$_2$SO$_4$) on limestone (CaCO$_3$).

(1)

(d) State why the monoclinic form of sulfur has a higher melting point than the triclinic form.

(1)
QUESTION 8

(a) Give a reason why the black form of phosphorus is more stable than either the white or the red allotropes of the element.  

(1)

(b) Draw the Lewis structure of H₂SO₄ and determine the oxidation state of the central atom.  

(2)

(c) Nitric acid oxidizes most metals. Write a balanced chemical equation, including the phases, to show the action of concentrated nitric acid on chromium metal.  

(2)

(d) Write a balanced chemical equation to show the dehydrating property of H₂SO₄ on sugar (C₁₂H₂₂O₁₁).  

(1)
QUESTION 9

(a) Use a balanced chemical equation to explain why a high pressure is necessary in the Haber/Bosch Process for the production of ammonia.

(2)

(b) Write a balanced chemical equation, including any reaction conditions necessary, for the catalytic oxidation of sulfur dioxide in the Contact Process.

(2)
QUESTION 10

What is the pH of a buffer solution composed of 0.125 moles of ammonia, NH₃, and 0.200 moles of ammonium chloride, NH₄Cl, in enough water to make 0.750 dm³ of solution? K₆ for NH₃ is 1.8 x 10⁻⁵.
QUESTION 11

(a) Calculate the molar solubility of Ni(OH)₂ in a solution whose pH is 11.00. $K_{sp}$ for Ni(OH)₂ is $2.0 \times 10^{-15}$. 

(3)
QUESTION 12

Consider the following reaction and the data at 25 °C given below:

\[ \text{CH}_4(g) + 2\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O}(g) \]

<table>
<thead>
<tr>
<th>Compound</th>
<th>$\Delta H^\circ/ \text{kJ mol}^{-1}$</th>
<th>$S^\circ/ \text{J K}^{-1} \text{mol}^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_4$(g)</td>
<td>-74.87</td>
<td>186.1</td>
</tr>
<tr>
<td>O$_2$(g)</td>
<td>0</td>
<td>205.0</td>
</tr>
<tr>
<td>CO$_2$(g)</td>
<td>-393.5</td>
<td>213.7</td>
</tr>
<tr>
<td>H$_2$O$_2$(g)</td>
<td>-241.8</td>
<td>188.7</td>
</tr>
</tbody>
</table>

What is the value of $\Delta G^\circ$ (in kJ) at 25 °C for this reaction? (3)
Question 13

Determine the mass of a non-volatile, non-ionizing compound that must be added to 2.34 kg of water to lower the freezing point to -2.03 °C. The molar mass of the compound is 86.43 g mol\(^{-1}\) and the \(K_f\) for water is 1.86 °C mol\(^{-1}\) kg.
Question 14

Calculate the molality of C₂H₅OH in an aqueous solution that is prepared by mixing 50.0 cm³ of C₂H₅OH with 108.4 cm³ of H₂O at 20 °C. The density of the C₂H₅OH is 0.789 g cm⁻³ at 20 °C. Assume the density of water at this temperature is 1.00 g cm⁻³.

(2½)
Question 15

How many coulombs of electricity are required to completely convert 0.340 g of AgNO₃ into metallic Ag? How long will this process take if a 2 A power source is used?
Question 16

(a) Show the overall reaction for a Daniel cell, using the half-cell reactions below.

(b) Calculate the potential of a Daniel cell in which the $[\text{Zn}^{2+}]$ is $0.10 \text{ mol dm}^{-3}$ and $[\text{Cu}^{2+}]$ is $0.010 \text{ mol dm}^{-3}$.

<table>
<thead>
<tr>
<th>Standard Reduction Potentials</th>
</tr>
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<tbody>
<tr>
<td>$\text{Cu}^{2+}(aq) + 2e^- = \text{Cu}(s)$</td>
</tr>
<tr>
<td>$\text{Zn}^{2+}(aq) + 2e^- = \text{Zn}(s)$</td>
</tr>
</tbody>
</table>