INSTRUCTIONS:

1. Answer **ALL** questions.
2. There is only **one correct answer** for each question.
3. There is **negative marking**. You will lose ¼ mark for every wrong answer. Therefore it is not advisable to guess any answer.
4. Your answers **must** be written on the **multiple-choice answer sheet** provided.
5. You must use **HB pencil only** on the answer sheet and make a dark heavy mark that fills the block completely.
6. This question paper consists of 9 pages including a periodic table. Please check that you have them all.
7. You are required to hand in this question paper at the end of the examination.
8. You will also require a copy of **Section B** of the examination paper.
9. You are **advised** not to spend more than **45 minutes** on Section A.
10. A **periodic table** is 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. For the transition: 
\[ \text{H}_2\text{O}(l) \quad \text{\textcircled{}} \quad \text{H}_2\text{O}(s) \]
at 273 K predict whether the entropy, \( S \), will:
   a) increase 
   b) decrease 
   c) show a small increase 
   d) remain the same

2. For an electrolysis cell, which of the following statements is correct?
   a) oxidation takes place at the positive anode 
   b) oxidation takes place at the negative anode 
   c) reduction takes place at the positive anode 
   d) reduction takes place at the negative anode

3. The 'triple point' may be defined as the:
   a) temperature and pressure at which the solid, liquid and gas phases coexist at equilibrium. 
   b) volume and temperature at which the solid, liquid and gas phases coexist at equilibrium. 
   c) temperature and pressure at which solids, liquids and gases cannot be distinguished from each other. 
   d) none of the above.
4. Colligative properties depend upon the:
   a) identity of the solute particles.
   b) number of solute particles.
   c) physical properties of the solute particles.
   d) boiling point and freezing point of the solution.

5. According to the Brønsted–Lowry definition, bases, when reacting with acids will:
   a) give up protons
   b) accept protons
   c) lose electrons
   d) accept electrons

6. Why is manganese(IV) oxide incorporated into a Leclanche cell?
   a) to consume hydrogen gas
   b) to increase the voltage
   c) to maintain a balance of charges
   d) none of the above

7. The reaction quotient, Q, is calculated:
   a) before equilibrium has been reached
   b) at equilibrium
   c) after equilibrium has been reached
   d) when all the reactants have been converted to products
8. A cellophane bag, which acts as a membrane permeable only to water, contains a 2 M sugar solution. The bag is immersed in a 1 M sugar solution. What will happen?
   a) The bag will soon contain more solution that will be more concentrated than 2 M.
   b) The bag will soon contain more solution that will be less concentrated than 2 M.
   c) The bag will lose sugar and the solution in it will become less concentrated.
   i. The bag will lose water and the solution in it will become more concentrated.

9. How many chiral carbons (stereogenic centres) does compound (A) have?

   ![Compound (A)](image)

   a) 3
   b) 1
   c) 4
   d) none

10. How many structural isomers can the formula C₄H₁₀ have?
    a) 2
    b) 4
    c) 3
    d) 1
11. Which of the following is **not** true about stereoisomers?
   a) They have the same chemical formula but have a different atom orientation in space.
   b) They can be non-superimposable mirror images of each other.
   c) They do not all necessarily have chiral centres.
   d) They have different chemical formulae but similar structures.

12. Which is the correct IUPAC name for compound (B)?

   ![Compound (B) diagram]

   a) (Z)-4-chloro-3-methylhept-3-ene
   b) (E)-3-methyl-4-chlorohept-3-ene
   c) (E)-4-chloro-3-methylhept-3-ene
   d) (Z)-3-methyl-4-chlorohept-3-ene

13. The following is **true** about heterolytic fission:
   a) it is a process whereby the atom splits into two equal parts
   b) a process where radicals are formed
   c) a process where anions and cations are formed
   d) involves the use of a single hooked arrow

14. The following is **true** about a nucleophile:
   a) it reacts with a negatively charged species
   b) it is electron deficient
   c) it will react with an electron deficient species
   d) it cannot be a neutral molecule
15. The secondary radical is more stable than the primary radical (shown below) because there are more

\[
\begin{align*}
\text{H} & \quad \text{C} - \text{CH}_3 \\
\text{CH}_3 & \quad \text{CH}_3 \text{CH}_2 \text{CH}_2 \text{CH}_2
\end{align*}
\]

a) electron withdrawing groups stabilising the radical
b) carbon atoms in a secondary radical
c) alkyl groups stabilising the radical
d) hydrogen atoms stabilising the radical

16. Which of the following is **not true** about electrophilic addition reactions?
   a) It involves the movement of \(\pi\) (pi) electrons.
   b) It involves a carbocation intermediate.
   c) An example is a hydrohalogenation reaction.
   d) It results in only one isomer being formed.

17. A Lewis base can be considered to be
   a) an electrophile.
   b) a nucleophile.
   c) an electron acceptor.
   d) a radical initiator.

18. Metals are generally
   a) good conductors of heat and electricity.
   b) brittle solids.
   c) known to behave as semi-conductors.
   d) nonconductors of heat and electricity.
19. Which sequence of ionic radii is not correct?
   a) Na<sup>+</sup> < K<sup>+</sup> < Rb<sup>+</sup>
   b) F<sup>-</sup> < Cl<sup>-</sup> < Br<sup>-</sup>
   c) Al<sup>3+</sup> < Mg<sup>2+</sup> < Na<sup>+</sup>
   d) N<sup>3-</sup> < O<sup>2-</sup> < F<sup>-</sup>

20. The oxidation state of I in IO<sub>3</sub><sup>-</sup> is
   a) +1
   b) +5
   c) -1
   d) -5

21. Which statement is correct?
   a) Ionisation energy generally increases from left to right across the periodic table.
   b) Ionisation energy generally decreases from left to right across the periodic table.
   c) Ionisation energy generally increases going down a group in the periodic table.
   d) Ionisation energy does not correlate with effective nuclear charge in any way.

22. An example of a polyprotic acid is
   a) HCl
   b) HNO<sub>3</sub>
   c) H<sub>2</sub>CO<sub>3</sub>
   d) NaOH

23. The anion ClO<sub>2</sub><sup>-</sup> is called
24. Which element reacts most vigorously with water?
   a) Li  
   b) Cs  
   c) Mg  
   d) Ca

25. The element that commonly has both the +1 and +3 oxidation number (or oxidation state) is
   a) B  
   b) Pb  
   c) Al  
   d) Tl

[25]

End of Section A
University of KwaZulu-Natal, Westville Campus, Durban
Examinations : November 2009
CHEM120 - CHEMICAL REACTIVITY

University of KwaZulu-Natal, Westville Campus, Durban
Examinations : November 2009
CHEMICAL REACTIVITY - CHEM120

Section B

Total Marks for Section B: 75
Total Marks for Examination: 100

Duration: 3 hours


Moderating Board: W. van Zyl, M. Bala, I. Nikolaenko, R. Robinson

IMPORTANT: Complete this part immediately.

Student No: ____________________________

Seat Number: ____________________________

Name (optional): ____________________________

INSTRUCTIONS:

11. Answer ALL questions.
12. Calculators may be used but all working must be shown.
13. The pages of this question paper must not be unpinned.
14. 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.
15. Marks will be deducted for the incorrect use of significant figures and the omission of units.
16. You must write legibly in black or blue ink. Pencils and Tipp-Ex are not allowed.
17. This question paper consists of 17 pages including a periodic table. Please check that you have them all.
18. You will also require a copy of Section A: Multiple-Choice Questions.
19. You are advised not to spend more than 2 hours and 15 minutes on Section B.
20. A periodic table and a data sheet are provided.

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QUESTION 1

a) Write a balanced equation that shows the formation of 1 mole of MgO(s) from its elements.

b) Calculate $\Delta G^\circ$ at 25 °C for the equilibrium below, if at this temperature the equilibrium constant $K = 0.15$.

$$N_2O_4(s) \rightleftharpoons 2NO_2(g)$$
QUESTION 2

A buffer solution contains 0.0600 mol L\(^{-1}\) of acetic acid (CH\(_3\)COOH) and 0.0350 mol L\(^{-1}\) of acetate ion (CH\(_3\)COO\(^{-}\)). Calculate the pH the buffer solution after 0.0025 mol HCl had been added to the buffer. (Hint: You may assume that the addition of HCl does not cause a change in volume and that the change in concentration, x, is small compared to initial concentrations.)

\[ K_a \text{ for acetic acid} = 1.80 \times 10^{-5} \]
QUESTION 3

a) Define the term “osmosis”.  

(2)

b) The osmotic pressure for 500 mL of an aqueous solution containing 2.86 g of bovine haemoglobin was found to be $2.51 \times 10^{-3}$ atm at 50 °C. Determine the molar mass of the haemoglobin.  

(3)
QUESTION 4

a) Calculate the pOH of a sample of water from the Umgeni river if $[\text{H}_3\text{O}^+] = 2.3 \times 10^{-9}\text{ mol L}^{-1}$.

(1)

b) The $K_{sp}$ for silver chloride, AgCl(s), is $6.20 \times 10^{-12}$ at 30 °C. Calculate the solubility of silver chloride in pure water in:

i) moles per litre

(2½)

ii) grams per litre

(1)
QUESTION 5

a) Calculate $\Delta G^\circ$ for the reaction:

$$\text{Mn}^{2+}(aq) + \text{Pb}(s) \rightleftharpoons \text{Mn}(s) + \text{Pb}^{2+}(aq)$$

**DATA**

\begin{align*}
\text{Pb}^{2+}(aq) + 2e^- & \rightleftharpoons \text{Pb}(s) \quad E^\circ = -0.13 \text{ V} \\
\text{Mn}^{2+}(aq) + 2e^- & \rightleftharpoons \text{Mn}(s) \quad E^\circ = -1.18 \text{ V}
\end{align*}

(2½)

b) i) Give the Nernst equation.

(1)
QUESTION 5 (continued)

ii) Calculate the concentration of Ca^{2+}(aq) required to give a cell potential of 0.55 V at 25 °C for the reaction:

\[ \text{Ca(s)} + \text{Mg}^{2+}(\text{aq}) \rightarrow \text{Ca}^{2+}(\text{aq}) + \text{Mg(s)} \]

where: \([\text{Mg}^{2+}] = 0.005 \text{ mol L}^{-1} \).

DATA

\[ \text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ca(s)} \quad E^o = -2.87 \text{ V} \]

\[ \text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Mg(s)} \quad E^o = -2.37 \text{ V} \]
QUESTION 6

a) What is the hybridization of the carbon atoms labelled 1, 2 and 3 in compound (A)?

(1½)

Compound (A)

1. 
2. 
3. 

b) Give the geometry around each of the carbon atoms labelled 1, 2 and 3.

(1½)

1. 
2. 
3. 

c) Name the three functional groups in compound (A).

(1½)

1. 
2. 
3. 
QUESTION 7

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

i) 3-chlorobutan-2-ol

ii) 2-amino-3-methylbutan-2-ene

b) Give the IUPAC name for each of the following compounds:

i) ![Structural formula of a compound]

ii) ![Structural formula of a compound]
QUESTION 8
The structure of compound (B) is a derivative of cyclopentane.

\[
\begin{align*}
\text{F} & \quad \text{OH} \\
\text{Compound (B)} & \quad \\
\end{align*}
\]

a) Use an asterisk symbol (*) to identify the chiral carbons. (2)

b) Use the perspective formula (dash-wedge) with the template given below to draw the (S)-configuration of 2-chlorobutane. (1½)
QUESTION 9

a) Write down the product for each of the following reactions:

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CHCH}_3 \xrightarrow{\text{OH, CrO}_3/\text{H}^+} \]

\[
\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}_3 \xrightarrow{\text{Br}_2} \]

b) Fill in the missing reagents and/or reaction conditions for the reactions below:

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{CCH}_3 \xrightarrow{\text{OH}} \text{CH}_3\text{CHCH}_2\text{CHCH}_3 \]

\[
\text{H}_3\text{C}_2\text{C}=\text{C}^\text{=C}_\text{H} \xrightarrow{} \text{H}_3\text{CH}_2\text{C}=\text{O} + \text{HO}_\text{C}=\text{O} \]
Question 10

a) Which of the following two carbocations is more stable and why?

\[ \text{H}^+ \text{C} = \text{CH}_3 \quad \text{H}^+ \text{C} = \text{CH}_3 \]

A \quad B

More stable carbocation: ____________
Reason:

b) Identify the nucleophile and electrophile in the following reaction:

\[ \text{CO} \text{OCH}_3 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{C} = \text{O} + \text{CH}_3\text{OH} \]

(1)

(1)

(1)

Why is a strong nucleophile not crucial in a S_N1 reaction?
Question 11

a) Identify whether the alkyl halide below will undergo an $S_{N1}$ or $S_{N2}$ reaction on the addition of $\text{H}_2\text{N}^-$. Then give the mechanism clearly showing the transition state and the products. (Hint: Make use of curly arrows in your answer.)

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl} \xrightarrow{\text{H}_2\text{N}^-} \text{CH}_3\text{CH}_2\text{CH}_2\text{N}^- \xrightarrow{\text{Cl}_2/\text{heat or light}} \text{CH}_3\text{Cl} + \text{HCl}
\]

(5)

b) Give the propagation steps for the following reaction:

\[
\text{CH}_4 \xrightarrow{\text{Cl}_2/\text{heat or light}} \text{CH}_3\text{Cl} + \text{HCl}
\]

(2)
Question 12

a) Complete the following reactions:

i) \(6\text{Li} + \text{N}_2\) □

ii) \(2\text{K} + \text{O}_2\) □

iii) \(\text{CaO} + \text{H}_2\text{O}\) □

iv) \(\text{CaCO}_3 \xrightarrow{\Delta} \text{□} \) □

(2)

b) Complete and balance the following reactions:

i) \(\text{Na} + \text{H}_2\text{O}\) □

ii) \(\text{Li} + \text{O}_2\) □

iii) \(\text{B(OH)}_3 + \text{H}_2\text{O}\) □

iv) \(\text{Al} + \text{Fe}_2\text{O}_3\) □

(4)

c) Write equations that show that aluminium hydroxide is amphoteric.

(2)

d) Explain, clearly showing your reasoning, whether \(\text{H}_3\text{PO}_4\) or \(\text{HClO}_3\) is the stronger acid.

(4)
Question 13

a) Outline the reaction sequence of the Ostwald Process, starting with NH₃ and air. All equations must be balanced and the reagents shown.  

(3)

b) Write detailed balanced equations that clearly show how sulfuric acid is made industrially starting from sulfur.  

(5)

c) Give the four major components of industrial smog.  

(2)

End of Section B