UNIVERSITY OF SWAZILAND
Faculty of Health Sciences
Department of Environmental Health Science
BACHELOR OF SCIENCE IN ENVIRONMENTAL HEALTH

**MAIN EXAMINATION PAPER 2021**

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|---|---|---|
| TITLE OF PAPER | : | CHEMISTRY FOR HEALTH SCIENCES |
| COURSE CODE | : | EHS 111 |
| DURATION | : | 2 HOURS |
| MARKS | : | 100 |
| INSTRUCTIONS | : | READ THE QUESTIONS & INSTRUCTIONS CAREFULLY |
| | : | THIS PAPER CONTAINS **TWO** SECTIONS |
| | : | SECTION A IS **COMPULSARY** AND CONTAINS MULTIPLE CHOICE QUESTIONS. TOTAL MARKS FOR THIS SECTION IS **50 MARKS** |
| | : | SECTION B CONTAINS THREE QUESTIONS, ANSWER **ANY TWO** QUESTIONS IN THIS SECTION. EACH QUESTION **CARRIES 25** MARKS. |
| | : | WRITE NEATLY & CLEARLY |
| | : | NO PAPER SHOULD BE BROUGHT INTO OR OUT OF THE EXAMINATION ROOM. |
| | : | BEGIN EACH QUESTION ON A SEPARATE SHEET OF PAPER. |

DO NOT OPEN THIS QUESTION PAPER UNTIL PERMISSION IS GRANTED BY THE INVIGILATOR.

## Section A (50 Marks)

This section is compulsory and it consists of multiple choice questions. A correct answer must be indicated by putting a circle around the letter for that answer on the answer sheet provided. If you change your answer, please cancel the wrong answer with a cross and then put a circle around the correct one. If more than one option has a circle around it a zero will be given for that question. Attempt all 50 questions.

1. A _____ $\Delta H$ corresponds to an _____ process.
   A) negative, endothermic
   B) negative, exothermic
   C) positive, exothermic
   D) zero, exothermic
   E) zero, endothermic

2. Express the temperature, 422.35 K, in degrees Celsius.
   A) 792.23 °C
   B) 149.20 °C
   C) 695.50 °C
   D) 50.89 °C
   E) 22.78 °C

3. Which one of the following reactions is a redox reaction?
   A) $NaOH + HCl \rightarrow NaCl + H_2O$
   B) $Pb^{2+} + 2Cl^- \rightarrow PbCl_2$
   C) $AgNO_3 + HCl \rightarrow HNO_3 + AgCl$
   D) None of the above is a redox reaction.

4. The length of the side of a cube having a density of 12.6 g/ml and a mass of 7.65 g is _____ cm.

   A) 3.20    B) 0.847    C) 1.02    D) 0.584    E) 1.32

5. A one degree of temperature difference is the smallest on the _____ temperature scale.
   A) Kelvin
   B) Celsius
   C) Fahrenheit
   D) Kelvin and Celsius
   E) Fahrenheit and Celsius

6. All atoms of a given element have the same _____ .

A) mass    B) number of protons    C) number of neutrons

D) number of electrons and neutrons    E) density

7. In the symbol below, x is _____.

$$_6^x C$$

A) the number of neutrons
B) the atomic number
C) the mass number
D) the isotope number
E) the elemental symbol

8. What volume (mL) of a concentrated solution of sodium hydroxide (6.00 M) must be diluted to 200. mL to make a 1.50 M solution of sodium hydroxide?

A) 0.0500    B) 50.0    C) 45.0    D) 800.    E) 0.800

9. Which one of the following statements is true?

A) Enthalpy is an intensive property.

B) The enthalpy change for a reaction is independent of the state of the reactants and products.

C) Enthalpy is a state function.

D) H is the value of q measured under conditions of constant volume.

E) The enthalpy change of a reaction is the reciprocal of the $\Delta H$ of the reverse reaction.

10. Which of the following is a statement of Hess's law?
   A) If a reaction is carried out in a series of steps, the $\Delta H$ for the reaction will equal the sum of the enthalpy changes for the individual steps.
   B) If a reaction is carried out in a series of steps, the $\Delta H$ for the reaction will equal the product of the enthalpy changes for the individual steps.
   C) The $\Delta H$ for a process in the forward direction is equal in magnitude and opposite in sign to the $\Delta H$ for the process in the reverse direction.
   D) The $\Delta H$ for a process in the forward direction is equal to the $\Delta H$ for the process in the reverse direction.
   E) The $\Delta H$ of a reaction depends on the physical states of the reactants and products.

11. An 8.29 g sample of calcium carbonate [$CaCO_3$ (s)] absorbs 50.3 J of heat, upon

which the temperature of the sample increases from 21.1 °C to 28.5 °C. What is the specific heat of calcium carbonate?

A) 0.63       B) 0.82       C) 1.1       D) 2.2       E) 4.2

12. The value of $\Delta H°$ for the reaction below is -790 kJ. The enthalpy change accompanying the reaction of 0.95 g of S is _____ kJ.

$$2S\ (s) + 3O_2\ (g) \rightarrow 2SO_3\ (g)$$
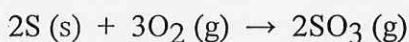
A) 23       B) -23       C) -12       D) 12       E) -790

13. Which one of the following types of elements is most likely to be a good oxidizing agent?
A) alkali metals
B) lanthanides
C) alkaline earth elements
D) transition elements
E) halogens

14. Chlorine is much more apt to exist as an anion than is sodium. This is because

_____.

A) chlorine is bigger than sodium

B) chlorine has a greater ionization energy than sodium does

C) chlorine has a greater electron affinity than sodium does

D) chlorine is a gas and sodium is a solid

E) chlorine is more metallic than sodium

15. Lanthanides differ mainly in the number of _____ electrons.

A) s       B) p       C) d       D) f       E) all of the above

16. Which of the following traits characterizes halogens?
A) very high melting point       B) existence as diatomic molecules
C) formation of dianions       D) the lowest first ionization energies in a period

E) the smallest atomic radius in a period

17. A 4.369 g sample of metal is placed in a flask. Water is added to the flask and the total volume in the flask is read to be 126.4 ml. The mass of the water, flask, and metal is 268.5 g. If the mass of the flask is 139.3 g and the density of water is 1.000 g/ml, the density of the solid is _____ $g/cm^3$.
A) 0.366
B) 1.56
C) 0.641
D) 2.73
E) 3.21

18. Ca reacts with element X to form an ionic compound with the formula CaX. Al will react with X to form _____ .

A) $AlX_2$ 　 B) AlX 　 　 C) $Al_2X_3$ 　 D) $Al_3X_2$ 　 　 　 　 E) $Al_3X$

19. The type of compound that is most likely to contain an ionic bond is _____ .

A) one that is composed of a metal from the far left of the periodic table and a nonmetal from the far right of the periodic table

B) a solid metal

C) one that is composed of only nonmetals

D) held together by the electrostatic forces between oppositely charged ions

E) there is no general rule to predict covalency in bonds.

20. Based on the octet rule, phosphorus most likely forms a _____ ion.

A) $P^{3+}$ 　 　 　 B) $P^{3-}$ 　 　 C) $P^{5+}$ 　 　 D) $P^{5-}$ 　 　 E) $P^+$

21. Which of the following compounds would you expect to be ionic?
A) $H_2O$
B) $CO_2$
C) $SrCl_2$
D) $SO_2$
E) $H_2S$

22. Of the atoms below, _____ is the least electronegative.

A) Ba 　 　 　 　 B) Be 　 　 　 C) Mg 　 　 　 D) Sr 　 　 　 E) Ca

23. In counting the electron domains around the central atom in VSEPR theory, a _____ is not included.

A) nonbonding pair of electrons        B) single covalent bond

C) core level electron pair        D) double covalent bond

E) triple covalent bond

24. Calculate the molarity of a 17.5% (by mass) aqueous solution of nitric acid.

A) 0.274 m        B) 2.74 m        C) 3.04 m        D) 4.33 m

E) The density of the solution is needed to solve the problem.

25. What is the conjugate base of $OH^-$?

A) $O_2$        B) $O^-$        C) $H_2O$        D) $O^{2-}$        E) $H_3O^+$

26. The $K_a$ of hypochlorous acid (HClO) is $3.00 \times 10^{-8}$. What is the pH at 25.0°C of an aqueous solution that is 0.0200 M in HClO?

A) +2.45        B) -2.45        C) -9.22        D) +9.22        E) +4.61

27. Which one of the following types of elements is most likely to be a good oxidizing agent?
A) alkali metals
B) lanthanides
C) alkaline earth elements
D) transition elements
E) halogens

28. In which of the following aqueous solutions does the weak acid exhibit the lowest percentage ionization?

A) 0.01 M $HC_2H_3O_2$ ($K_a = 1.8 \times 10^{-5}$)    B) 0.01 M $HNO_2$ ($K_a = 4.5 \times 10^{-4}$)

C) 0.01 M HF ($K_a = 6.8 \times 10^{-4}$)        D) 0.01 M HClO ($K_a = 3.0 \times 10^{-8}$)

E) These will all exhibit the same percentage ionization.

29. Barium reacts with a polyatomic ion to form a compound with the general formula $Ba_3(X)_2$. What would be the most likely formula for the compound formed between

sodium and the polyatomic ion X?
A) NaX
B) $Na_2X$
C) $Na_2X_2$
D) $Na_3X$
E) $Na_3X_2$

30. A BrØnsted-Lowry base is defined as a substance that _____.

A) increases $K_a$ when placed in $H_2O$     B) decreases $[H^+]$ when placed in $H_2O$

C) increases $[OH^-]$ when placed in $H_2O$   D) acts as a proton acceptor

E) acts as a proton donor

31. In the periodic table, the elements are arranged in _____.
   A) alphabetical order
   B) order of increasing atomic number
   C) order of increasing metallic properties
   D) order of increasing neutron content
   E) reverse alphabetical order

32. An element in the upper right corner of the periodic table _____.
   A) is either a metal or metalloid
   B) is definitely a metal
   C) is either a metalloid or a non-metal
   D) is definitely a non-metal
   E) is definitely a metalloid

33. The heavier noble gases are more reactive than the lighter ones because

   A) the lighter noble gases exist as diatomic molecules.
   B) the lighter noble gases have complete octets.
   C) the heavier noble gases are more abundant.
   D) the heavier noble gases have low ionization energies relative to the lighter ones.
   E) the heavier noble gases have greater electron affinities.

34. Of the following species, _____ will have bond angles of 120°.

   A) $PH_3$            B) $ClF_3$                 C) $NCl_3$                  D) $BCl_3$

   E) All of these will have bond angles of 120°.

35. What is the conjugate acid of $CO_3^{-2}$?

   A) $CO_2^{-2}$          B) $HCO_2^{-2}$              C) $H_2CO_3$                D) $HCO_3^-$

   E) none of the above

36. What is the oxidation number of sulfur in the $HSO_4^-$ ion?
    A) -2
    B) +1
    C) +2
    D) +4
    E) +6

37. What is the pH of an aqueous solution at 25.0 °C that contains $3.98 \times 10^{-9}$ M hydroxide ion?

    A) 8.40      B) 5.60        C) 9.00        D) 3.98        E) 7.00

38. Which one of the following is a metalloid?

    A) Ge            B) S            C) Br          D) Pb          E) C

39. The rate law for a reaction is

    $$rate = k\,[A][B]^2$$

    Which one of the following statements is <u>false</u>?
    A) The reaction is first order in A.
    B) The reaction is second order in B.
    C) The reaction is second order overall.
    D) $k$ is the reaction rate constant
    E) If [B] is doubled, the reaction rate will increase by a factor of 4.

40. For a given process at constant pressure, $\Delta H$ is negative. This means that the process
    is _____.
    A) endothermic          B) equithermic              C) exothermic
    D) a state function      E) energy

41. Each d-subshell can accommodate a maximum of _____ electrons.
    (A) 6              (B) 2            (C) 10            (D) 3            (E) 5

42. Which one of the following is a triprotic acid?
    A) nitric acid      B) chloric acid        C) phosphoric acid    D) hydrofluoric acid
    E) sulfuric acid

43. With thermodynamics, one cannot determine _____.
   A) the speed of a reaction
   B) the direction of a spontaneous reaction
   C) the extent of a reaction
   D) the value of the equilibrium constant
   E) the temperature at which a reaction will be spontaneous

44. The thermodynamic quantity that expresses the degree of disorder in a system is

   _____.
   A) enthalpy        B) internal energy     C) bond energy        D) entropy
   E) heat flow

45. The correct ground-state electron configuration for Palladium (Pd) is ____

   (A) $[Kr] 5s^1 4d^{10}$    (B) $[Kr] 5s^2 4d^4$           (C) $[Kr] 5s^1 4d^5$        (d) $[Kr] 5s^2 4d^5$

   (E) $[Kr] 5s^2 4d^8$

46. Which of the subshells below do <u>not</u> exist due to the constraints upon the angular
   momentum quantum number?
   A) 2d              B) 2s          C) 2p          D) all of the above
   E) none of the above

47. As the temperature of a reaction is increased, the rate of the reaction increases
   because the _____.
   A) reactant molecules collide less frequently
   B) reactant molecules collide more frequently and with greater energy per collision
   C) activation energy is lowered
   D) reactant molecules collide less frequently <u>and</u> with greater energy per collision
   E) reactant molecules collide more frequently with less energy per collision

48. The molar concentration of hydronium ion in pure water at 25°C is _____.
   A) 0.00      B) $1.0 \times 10^{-7}$      C) $1.0 \times 10^{-14}$      D) 1.00      E) 7.00

49. There are _____ atoms of oxygen are in 300 molecules of $CH_3CO_2H$.
   A) 300            B) 600      C) $3.01 \times 10^{24}$    D) $3.61 \times 10^{26}$
   E) $1.80 \times 10^{26}$

50. Of the following, _____ will lower the activation energy for a reaction.
A) increasing the concentrations of reactants
B) raising the temperature of the reaction
C) adding a catalyst for the reaction
D) removing products as the reaction proceeds
E) increasing the pressure

## Section B (50 Marks)

There are three questions in this section. Each question is worth 25 marks. Answer any two questions. In all calculations, answers must have the correct number of significant figures ( 4 significant figures) and correct units.

## Question 1

a. The following terms are used extensively in thermodynamics. For each term give one example;
   (i)     Exothermic process

   (ii)     endothermic process

   (iii)   System and surroundings

   (iv)   Specific heat capacity

   (v)    State function

   (vi)   Standard state

   (vii)  Enthalpy change

   (viii) Standard enthalpy of formation

   **[8 Marks]**

b. Arrange the energy of following orbitals in ascending order; $3s, 4p, 2s, 3d, 4s, 2p$

   **[3 Marks]**

c. Electronegativity _____ from left to right within a period and _____ from top to bottom within a group.    **[2 Marks]**

d. Calculate the molarity of a hydroxide solution that has a pOH of 4.08. (assume 70% ionization).    **[5 Marks]**

e. The average atomic weight of copper, which has two naturally occurring isotopes, is 63.5. One of the isotopes has an atomic weight of 62.9 amu and constitutes 69.1% of the copper isotopes. The other isotope has an abundance of 30.9%. The atomic weight (amu) of the second isotope is _____ amu.    **[7 Marks]**

**Total 25 marks**

## Question 2

a. Balance the following redox reaction equation in acidic medium

$$Fe_2S_3 + HNO_3 \longrightarrow Fe(NO_3)_3 + S + NO_2$$

[12 Marks]

b. Methanol, $CH_3OH$, can be produced from carbon monoxide and hydrogen using the chemical equation below;

$$CO\ (g)\ +\ 2H_2(g) \longrightarrow CH_3OH\ (l)$$

What is the mass of hydrogen required to produce 1.0L of methanol (d=0.791g/cm3) if this reaction has a 74% yield under certain conditions.

[8 Marks]

c. A coordinate covalent bond is _____.          [2 Marks]

d. The halogens, alkali metals, and alkaline earth metals have ___, ___ and ____ valence electrons, respectively.          [3 Marks]

**Total 25 marks**

## Question 3

a. A compound was found to contain 90.6% lead (Pb) and 9.4% oxygen. The empirical formula for this compound is _____.          [7 Marks]

b. The pH of a 0.60 M aqueous solution of formic acid, $HCHO_2$, at 25.0°C is 1.98. What is the value of $K_a$ for formic acid?          [6 Marks]

c. A certain alcohol contains only three elements, carbon, hydrogen, and oxygen. Combustion of a 30.00 gram sample of the alcohol produced 57.30 grams of $CO_2$ and 35.22 grams of $H_2O$. What is the empirical formula of the alcohol?

[9 Marks]

d. Chlorine is much more apt to exist as an anion while sodium is apt to form cations. Why is this?          [3 Marks]

**Total 25 marks**

# General data and fundamental constants

| Quantity | Symbol | Value |
|---|---|---|
| Speed of light | $c$ | $2.997\ 924\ 58 \times 10^8$ m s$^{-1}$ |
| Elementary charge | $e$ | $1.602\ 177 \times 10^{-19}$ C |
| Faraday constant | $F = N_A e$ | $9.6485 \times 10^4$ C mol$^{-1}$ |
| Boltzmann constant | $k$ | $1.380\ 66 \times 10^{-23}$ J K$^{-1}$ |
| Gas constant | $R = N_A k$ | $8.314\ 51$ J K$^{-1}$ mol$^{-1}$ |
| | | $8.205\ 78 \times 10^{-2}$ dm$^3$ atm K$^{-1}$ mol$^{-1}$ |
| | | $6.2364 \times 10$ L Torr K$^{-1}$ mol$^{-1}$ |
| Planck constant | $h$ | $6.626\ 08 \times 10^{-34}$ J s |
| | $\hbar = h/2\pi$ | $1.054\ 57 \times 10^{-34}$ J s |
| Avogadro constant | $N_A$ | $6.022\ 14 \times 10^{23}$ mol$^{-1}$ |
| Atomic mass unit | $u$ | $1.660\ 54 \times 10^{-27}$ Kg |
| Mass | | |
| electron | $m_e$ | $9.109\ 39 \times 10^{-31}$ Kg |
| proton | $m_p$ | $1.672\ 62 \times 10^{-27}$ Kg |
| neutron | $m_n$ | $1.674\ 93 \times 10^{-27}$ Kg |
| Vacuum permittivity | $\varepsilon_0 = 1/c^2\mu_0$ | $8.854\ 19 \times 10^{-12}$ J$^{-1}$ C$^2$ m$^{-1}$ |
| | $4\pi\varepsilon_0$ | $1.112\ 65 \times 10^{-10}$ J$^{-1}$ C$^2$ m$^{-1}$ |
| Vacuum permeability | $\mu_0$ | $4\pi \times 10^{-7}$ J s$^2$ C$^{-2}$ m$^{-1}$ |
| | | $4\pi \times 10^{-7}$ T$^2$ J$^{-1}$ m$^3$ |
| Magneton | | |
| Bohr | $\mu_B = e\hbar/2m_e$ | $9.274\ 02 \times 10^{-24}$ J T$^{-1}$ |
| nuclear | $\mu_N = e\hbar/2m_p$ | $5.050\ 79 \times 10^{-27}$ J T$^{-1}$ |
| g value | $ge$ | $2.002\ 32$ |
| Bohr radius | $a_0 = 4\pi\varepsilon_0\hbar/m_e c^2$ | $5.291\ 77 \times 10^{-11}$ m |
| Fine-structure constant | $\alpha = \mu_0 e^2 c/2h$ | $7.297\ 35 \times 10^{-3}$ |
| Rydberg constant | $R_\infty = m_e e^4/8h^3 c\varepsilon_0^2$ | $1.097\ 37 \times 10^7$ m$^{-1}$ |
| Standard acceleration of free fall | $g$ | $9.806\ 65$ m s$^{-2}$ |
| Gravitational constant | $G$ | $6.672\ 59 \times 10^{-11}$ N m$^2$ Kg$^{-2}$ |

## Conversion factors

| | | | | | |
|---|---|---|---|---|---|
| 1 cal | = | 4.184 joules (J) | 1 erg | = | $1 \times 10^{-7}$ J |
| 1 eV | = | $1.602\ 2 \times 10^{-19}$ J | 1 eV/molecule | = | $96\ 485$ kJ mol$^{-1}$ |

## Prefixes

| f | p | n | $\mu$ | m | c | d | k | M | G |
|---|---|---|---|---|---|---|---|---|---|
| femto | pico | nano | micro | milli | centi | deci | kilo | mega | giga |
| $10^{-15}$ | $10^{-12}$ | $10^{-9}$ | $10^{-6}$ | $10^{-3}$ | $10^{-2}$ | $10^{-1}$ | $10^3$ | $10^6$ | $10^9$ |

# PERIODIC TABLE OF ELEMENTS

## GROUPS

| PERIODS | 1 IA (1.008) | 2 IIA | 3 IIIB | 4 IVB | 5 VB | 6 VIB | 7 VIIB | 8 | 9 VIIIB | 10 | 11 IB | 12 IIB | 13 IIIA | 14 IVA | 15 VA | 16 VIA | 17 VIIA | 18 VIIIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | II 1 | | | | | | | | | | | | | | | | | 4.003 He 2 |
| 2 | 6.941 Li 3 | 9.012 Be 4 | | | | | | | | | | | 10.811 B 5 | 12.011 C 6 | 14.007 N 7 | 15.999 O 8 | 18.998 F 9 | 20.180 Ne 10 |
| 3 | 22.990 Na 11 | 24.305 Mg 12 | | | | | | | | | | | 26.982 Al 13 | 28.086 Si 14 | 30.974 P 15 | 32.06 S 16 | 35.453 Cl 17 | 39.948 Ar 18 |
| 4 | 39.098 K 19 | 40.078 Ca 20 | 44.956 Sc 21 | 47.88 Ti 22 | 50.942 V 23 | 51.996 Cr 24 | 54.938 Mn 25 | 55.847 Fe 26 | 58.933 Co 27 | 58.69 Ni 28 | 63.546 Cu 29 | 65.39 Zn 30 | 69.723 Ga 31 | 72.61 Ge 32 | 74.922 As 33 | 78.96 Se 34 | 79.904 Br 35 | 83.80 Kr 36 |
| 5 | 85.468 Rb 37 | 87.62 Sr 38 | 88.906 Y 39 | 91.224 Zr 40 | 92.906 Nb 41 | 95.94 Mo 42 | 98.907 Tc 43 | 101.07 Ru 44 | 102.91 Rh 45 | 106.42 Pd 46 | 107.87 Ag 47 | 112.41 Cd 48 | 114.82 In 49 | 118.71 Sn 50 | 121.75 Sb 51 | 127.60 Te 52 | 126.90 I 53 | 131.29 Xe 54 |
| 6 | 132.91 Cs 55 | 137.33 Ba 56 | 138.91 *La 57 | 178.49 Hf 72 | 180.95 Ta 73 | 183.85 W 74 | 186.21 Re 75 | 190.2 Os 76 | 192.22 Ir 77 | 195.08 Pt 78 | 196.97 Au 79 | 200.59 Hg 80 | 204.38 Tl 81 | 207.2 Pb 82 | 208.98 Bi 83 | (209) Po 84 | (210) At 85 | (222) Rn 86 |
| 7 | 223 Fr 87 | 226.03 Ra 88 | (227) **Ac 89 | (261) Rf 104 | (262) Ha 105 | (263) Unh 106 | (262) Uns 107 | (265) Uno 108 | (266) Une 109 | (267) Uun 110 | | | | | | | | |

TRANSITION ELEMENTS

Atomic mass → 10.811
Symbol → B 5
Atomic No. → 5

*Lanthanide Series

| 140.12 Ce 58 | 140.91 Pr 59 | 144.24 Nd 60 | (145) Pm 61 | 150.36 Sm 62 | 151.96 Eu 63 | 157.25 Gd 64 | 158.93 Tb 65 | 162.50 Dy 66 | 164.93 Ho 67 | 167.26 Er 68 | 168.93 Tm 69 | 173.04 Yb 70 | 174.97 Lu 71 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

**Actinide Series

| 232.04 Th 90 | 231.04 Pa 91 | 238.03 U 92 | 237.05 Np 93 | 238.03 Pu 94 | (243) Am 95 | (247) Cm 96 | (247) Bk 97 | (251) Cf 98 | (252) Es 99 | (257) Fm 100 | (258) Md 101 | (259) No 102 | (260) Lr 103 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

( ) indicates the mass number of the isotope with the longest half-life.