UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF CHEMICAL SCIENCES

B Eng Tech in Engineering Metallurgy / Extraction Metallurgy

MODULE CETM1A1

CAMPUS DFC

PAPER 3

DATE: 2022

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INTERNAL MODERATOR	**DR P. F. MSOMI**
DURATION: 180 MINUTES	**TOTAL MARKS: 120**

NUMBER OF PAGES: **9 PAGES, INCLUDING 2 ANNEXURES**

INSTRUCTIONS: **ANSWER SECTION A ON THE MULTIPLE QUESTION ANSWER SHEET AND SECTION B IN DIFFERENT ANSWER SCRIPT PROVIDED.**

CONSULT THE DATA SHEET AND THE PERIODIC TABLE FOR ALL SUPPLEMENTARY INFORMATION.

CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT).

SECTION A

QUESTION 1

1.1 If matter is uniform throughout, cannot be separated into other substances by physical processes, but can be decomposed into other substances by chemical processes, it is called a (an) __________.

A) heterogeneous mixture
B) element
C) homogeneous mixture
D) compound
E) mixture of elements

1.2 Elements in Group 1A are known as the __________.

A) chalcogens
B) alkaline earth metals
C) alkali metals
D) halogens
E) noble gases

1.3 The n = 1 shell contains __________ p orbitals. All the other shells contain __________ p orbitals.

A) 3, 6
B) 0, 3
C) 6, 2
D) 3, 3
E) 0, 6

1.4 The first ionization energies of the elements __________ as you go from left to right across a period of the periodic table, and __________ as you go from the bottom to the top of a group in the table.

A) increase, increase
B) increase, decrease
C) decrease, increase
D) decrease, decrease
E) are completely unpredictable

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1.5 Atomic radius generally increases as we move __________.

A) down a group and from right to left across a period
B) up a group and from left to right across a period
C) down a group and from left to right across a period
D) up a group and from right to left across a period
E) down a group; the period position has no effect

1.6 Which equation correctly represents the first ionization of aluminium?

A) Al^- (g) → Al (g) + e-
B) Al (g) → Al^- (g) + e-
C) Al (g) + e- → Al^- (g)
D) Al (g) → Al^+ (g) + e-
E) Al^+ (g) + e- → Al (g)

1.7 How many unpaired electrons are there in an O^{2-} ion?

A) 0
B) 1
C) 2
D) 3
E) This cannot be predicted.

1.8 For a molecule with the formula AB_2 the molecular shape will be __________.

A) linear or bent
B) linear or trigonal planar
C) linear or T-shaped
D) T-shaped
E) trigonal planar

1.9 Which species below is the nitrate ion?

A) NO_2^-
B) NH_4^+
C) NO_3^-
D) N_3^-
E) N^{3-}

1.10 The hybridization of orbitals on the central atom in a molecule is sp^2. The electron-domain geometry about this central atom is __________.

A) octahedral
B) linear
C) trigonal planar
D) trigonal bipyramidal
E) tetrahedral

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1.11 According to VSEPR theory, if there are three electron domains in the valence shell of an atom, they will be arranged in a(n) __________ geometry.

A) octahedral
B) linear
C) tetrahedral
D) trigonal planar
E) trigonal bipyramidal

1.12 A typical triple bond __________.

A) consists of one σ bond and two π bonds
B) consists of three shared electrons
C) consists of two σ bonds and one π bond
D) consists of six shared electron pairs
E) is longer than a single bond

1.13 What is the empirical formula of a compound that contains 29% Na, 41% S, and 30% O by mass?

A) $Na_2S_2O_3$
B) $NaSO_2$
C) NaSO
D) $NaSO_3$
E) $Na_2S_2O_6$

1.14 How many moles of magnesium oxide are produced by the reaction of 3.82 g of magnesium nitride with 7.73 g of water?

$$Mg_3N_2 + 3\ H_2O \rightarrow 2\ NH_3 + 3\ MgO$$

A) 0.113
B) 0.0378
C) 0.429
D) 0.0756
E) 4.57

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1.15 Which of the following are strong acids?

HI
HNO_3
HF
HBr

A) HF, HBr
B) HI, H NO_3 , HF, HBr
C) HI, HF, HBr
D) HNO_3 , HF, HBr
E) HI, HNO_3 , HBr

1.16 A 17.5 mL sample of an acetic acid (CH_3CO_2H) solution required 29.6 mL of 0.250 M NaOH for neutralization. The concentration of acetic acid was __________ M.

A) 0.15
B) 0.42
C) 130
D) 6.8
E) 0.21

1.17 What is the coefficient of the permanganate ion when the following equation is balanced?

$$MnO_4^- + Br^- \rightarrow Mn^{2+} + Br_2 \text{ (acidic solution)}$$

A) 1
B) 2
C) 3
D) 5
E) 4

1.18 On a phase diagram, the critical temperature is __________.

A) the temperature below which a gas cannot be liquefied
B) the temperature above which a gas cannot be liquefied
C) the temperature at which all three states are in equilibrium
D) the temperature required to melt a solid
E) the temperature required to cause sublimation of a solid

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1.19 Which of the following expressions is the correct equilibrium-constant expression for the equilibrium between dinitrogen tetroxide and nitrogen dioxide?

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

A) $-\dfrac{[NO_2]}{[N_2O_4]}$

B) $\dfrac{[NO_2]^2}{[N_2O_4]}$

C) $\dfrac{[NO_2]}{[N_2O_4]^2}$

D) $[NO_2][N_2O_4]$

E) $[NO_2]^2[N_2O_4]$

1.20 How is the reaction quotient used to determine whether a system is at equilibrium?

A) The reaction quotient must be satisfied for equilibrium to be achieved.
B) At equilibrium, the reaction quotient is undefined.
C) The reaction is at equilibrium when Q < Keq.
D) The reaction is at equilibrium when Q > Keq.
E) The reaction is at equilibrium when Q = Keq.

[20 x 2] =40

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SECTION B

QUESTION 2

2.1 Consider the following isotopes.

2.1.1 Which two of the following are isotopes of the same element? (2)

$$^{31}_{16}X,\ ^{31}_{15}X,\ ^{32}_{16}X$$

2.1.2 What is the identity of the element whose isotopes you have selected? (2)

2.2

2.2.1 What are "valence electrons"? (2)

2.2.2 What are "core electrons"? (2)

2.2.3 What does each box in an orbital diagram represent? (1)

2.2.4 What quantity is represented by the half arrows in an orbital diagram? (2)

2.3 Using Lewis symbols and Lewis structures, sketch the formation of $SiCl_4$ from Si and Cl atoms. (4)

2.4 Draw the Lewis structures for each of the following molecules or ions. State if they obey the octet rule or not.

2.4.1 ICl_2^- (4)

2.4.2 $OPBr_3$ (the P is the central atom) (4)

2.4.3 XeF_4 (4)

[27]

QUESTION 3

3.1 Aluminium sulfide reacts with water to form aluminium hydroxide and hydrogen sulfide according to the reaction below:

$$Al_2S_2(s) + H_2O(l) \longrightarrow Al(OH)_3(s) + H_2S(g)$$

3.1.1 Balance the chemical equation for this reaction. (2)

3.1.2 How many grams of aluminium hydroxide are obtained from 14.2 g of aluminium sulfide? (4)

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QUESTION 3 (Continued)

3.2 Write a balanced net ionic equations for the reactions that occur in each of the following cases. indicate the spectator ion or ions in each reaction.

3.2.1 $Cr_2(SO_4)_3(aq) + (NH_4)_2CO_3(aq) \longrightarrow$ (4)

3.2.2 $Ba(NO_3)_2(aq) + K_2SO_4(aq) \longrightarrow$ (4)

3.3

3.3.1 Calculate the density of NO_2 gas at 0.970 atm and 35 $^{o\circ}$C. (3)

3.3.2 Calculate the molar mass of a gas if 2.50 g occupies 0.875 L at 685 torr and 35 $^{0\circ}$C. (4)

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QUESTION 4

4.1

4.1.1 Explain why surface tension and viscosity decease with increasing temperature. (3)

4.1.2 Why do substances with high surface tensions also tend to have high viscosities?

4.1.3 (3)

4.2 Referring to figure 1 below, describe all the phase changes that would occur in each of the following cases:

4.2.1 Water vapor originally at 0.005 atm and – 0.5 ^oC is slowly compresses at constant temperature until the final pressure is 20 atm. (4)

4.2.2 Water originally at 100.0 ^oC and 0.50 atm is cooled at constant pressure until the temperature is – 10 ^oC. (4)

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QUESTION 4 (Continued)

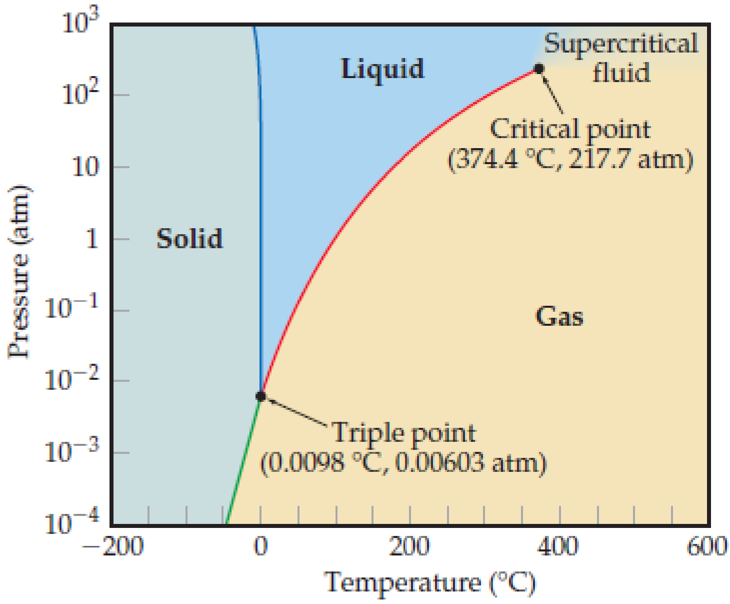

Figure 1: Phase diagram of H_2O.
Note that a linear scale is used to represent temperature and a logarithmic scale to represent pressure.

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QUESTION 5

5.1 A mixture of 0.10 mol of NO, 0.050 mol of H_2, and 0.10 mol of H_2O is placed in a 1.0 L vessel is placed in a 1.0 L vessel at 300 K. The following equilibrium is established:

$$2\ NO(g) + 2\ H_2(g) \rightleftharpoons N_2(g) + 2H_2O(g)$$

At equilibrium [NO] = 0.062 M.

5.1.1 Calculate the equilibrium concentrations of H_2, N_2, and H_2O. (8)
5.1.2 Calculate K_c. (3)

5.2 A solution is made containing 14.6 g of CH_3OH in 184 g H_2O.

5.2.1 Calculate the mole fraction of CH_3OH (3)
5.2.2 Calculate the mass percent of CH_3OH (3)
5.2.3 Calculate the molality of CH_3OH. (3)

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FULL MARKS = 122
TOTAL MARKS = 120

DATA INFORMATION

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Avogadro's number: N = 6.02 $\times 10^{23}$

$0^{o}C = 273.15$ K

Standard pressure = 1 atm = 101.325 kPa = 760 mmHg = 760 torr = 1.01325 bar

R = 8.31451 $L.kPa.K^{-1}.mol^{-1}$
= 8.31451 $\times 10^{-2}$ $L.bar.K^{-1}.mol^{-1}$
= 8.20578 $\times 10^{-2}$ $L.atm.K^{-1}.mol^{-1}$
= 62.364 $L.torr.K^{-1}.mol^{-1}$

<u>Equilibrium constants (Temperature = 25.0^{o}C)</u>

$K_w = 1 \times 10^{-14}$

UNIVERSITY OF JOHANNESBURG

Department of Chemical Sciences

Atomic Number | 2
He
4.0026 | Atomic Weight

1 **H** *1.0079*																	2 **He** *4.0026*
3 **Li** *6.941*	4 **Be** *9.0122*											5 **B** *10.811*	6 **C** *12.011*	7 **N** *14.007*	8 **O** *15.999*	9 **F** *18.998*	10 **Ne** *20.179*
11 **Na** *22.990*	12 **Mg** *24.305*											13 **Al** *26.982*	14 **Si** *28.086*	15 **P** *30.974*	16 **S** *32.064*	17 **Cl** *35.453*	18 **Ar** *39.948*
19 **K** *39.098*	20 **Ca** *40.078*	21 **Sc** *44.956*	22 **Ti** *47.88*	23 **V** *50.942*	24 **Cr** *51.996*	25 **Mn** *54.938*	26 **Fe** *55.847*	27 **Co** *58.933*	28 **Ni** *58.69*	29 **Cu** *63.546*	30 **Zn** *65.39*	31 **Ga** *69.723*	32 **Ge** *72.61*	33 **As** *74.922*	34 **Se** *78.96*	35 **Br** *79.904*	36 **Kr** *83.80*
37 **Rb** *85.47*	38 **Sr** *87.62*	39 **Y** *88.906*	40 **Zr** *91.224*	41 **Nb** *92.906*	42 **Mo** *95.94*	43 **Tc** *(98)*	44 **Ru** *101.07*	45 **Rh** *102.91*	46 **Pd** *106.42*	47 **Ag** *107.87*	48 **Cd** *112.41*	49 **In** *114.82*	50 **Sn** *118.71*	51 **Sb** *121.75*	52 **Te** *127.60*	53 **I** *126.90*	54 **Xe** *131.29*
55 **Cs** *132.91*	56 **Ba** *137.33*	57 **La** *138.91*	72 **Hf** *178.49*	73 **Ta** *180.95*	74 **W** *183.85*	75 **Re** *186.2*	76 **Os** *190.2*	77 **Ir** *192.22*	78 **Pt** *195.08*	79 **Au** *196.97*	80 **Hg** *200.59*	81 **Tl** *204.38*	82 **Pb** *207.2*	83 **Bi** *208.98*	84 **Po** *(209)*	85 **At** *(210)*	86 **Rn** *(222)*
87 **Fr** *(223)*	88 **Ra** *226.03*	89 **Ac** *227.03*															

58 **Ce** *140.12*	59 **Pr** *140.91*	60 **Nd** *144.24*	61 **Pm** *146.92*	62 **Sm** *150.36*	63 **Eu** *151.97*	64 **Gd** *157.25*	65 **Tb** *158.93*	66 **Dy** *162.50*	67 **Ho** *164.93*	68 **Er** *167.26*	69 **Tm** *168.93*	70 **Yb** *173.04*	71 **Lu** *174.97*
90 **Th** *232.04*	91 **Pa** *231.04*	92 **U** *238.03*	93 **Np** *237.05*	94 **Pu** *(244)*	95 **Am** *(234)*	96 **Cm** *(247)*	97 **Bk** *247*	98 **Cf** *(251)*	99 **Es** *(252)*	100 **Fm** *(257)*	101 **Md** *(258)*	102 **No** *(259)*	103 **Lr** *(260)*