UNIVERSITY OF BOTSWANA

C110 (B.Sc. YEAR ONE) GENERAL CHEMISTRY FINAL EXAMINATION
22 April 1999. Time Allowed: 3 hours.

Student's ID # :---------- Group and Serial Number: ----------

Constants:

$K_W = 1.0 \times 10^{-14}$ at 25 °C

$c = 3.00 \times 10^{8}$ m/s

1 nm = 10^{-9} m

$h = 6.63 \times 10^{-34}$ J.s = 6.63×10^{-34} kg m^2/s

$R_H = 1.097 \times 10^{7}$ m^{-1}

Gas constant, R = 0.08206 L. atm.K^{-1}.mol^{-1} = 8.314 J.K^{-1}.mol^{-1}.

1 atm = 760 mm Hg = 1.01×10^{5} N.m^{-2}

DO NOT WRITE IN THIS TABLE.

M.C.	1	2	3	4	5	6	7	Total

SECTION A: MULTIPLE CHOICE QUESTIONS [60 Marks]

This section has 30 questions. Circle the letter for the one correct answer in each question.

1. The expression for the solubility product of $Ba_3(AsO_4)_2$ is,

   a. $[Ba^{2+}]^3[AsO_4^{3-}]^2$
   b. $[3Ba^{2+}]^3[2AsO_4^{3-}]^2$
   c. $3[Ba^{2+}] \times 2[AsO_4^{3-}]$
   d. $3[Ba^{2+}]^3 + 2[AsO_4^{3-}]^2$
   e. $[Ba^{2+}]_3[AsO_4^{3-}]_2$

2. The solubility of silver sulphate (Ag_2SO_4), in moles per litre, can be expressed in terms of the resulting ion concentrations. Which one of the following relationships is correct?

   a. Solubility = $2[Ag^+]$
   b. Solubility = $[Ag^+]$
   c. Solubility = $[2Ag^+]$
   d. Solubility = $2[SO_4^{2-}]$
   e. Solubility = ½ [Ag+]

3. A solution has an H^+ concentration of 4.0×10^{-2} mol.L^{-1}. What is the OH^- concentration in the same solution, in moles per litre?

   a. 4.0×10^{-2}
   b. 4.0×10^{-9}
   c. 4.0×10^{-12}
   d. 2.5×10^{-13}
   e. 25.0

4. Which one of the following is the correct name for the compound $FeBr_3$?

   a. Ferrous bromide
   b. Iron (III) bromide
   c. Iron bromite
   d. Iron bromide
   e. Iron tribromine

5. A freshly prepared compound contains potassium, hydrogen, phosphorus, and oxygen. The assay values are: potassium, 44.895%; hydrogen, 0.5787%; phosphorus, 17.783%. The empirical formula of this compound is:

   a. $K_2H_4PO_4$
   b. K_2HPO_4
   c. $K_2H_2PO_4$
   d. $K_2HP_2O_5$
   e. KH_2PO_4

6. When the chemical equation, $AsF_3 + CCl_4 \rightarrow AsCl_3 + CCl_2F_2$, is correctly balanced, the sum of the (smallest set of integer) coefficients will be:

   a. 4
   b. 5
   c. 10
   d. 14
   e. 20

7. In the redox reaction,

   $$\mathbf{C_4H_{10}\,(g) + Cr_2O_7^{2-}(aq) + H^+\,(aq) \rightarrow H_6C_4O_4\,(aq) + Cr^{3+}\,(aq) + H_2O,}$$

   the reducing species is:

   a. C_4H_{10}
   b. $Cr_2O_7^{2-}$
   c. H^+
   d. $H_6C_4O_4$
   e. Cr^{3+}

8. Light has a frequency (ν) of $3.75 \times 10^{15}\ s^{-1}$; its wavelength ($\lambda$) is:

   a. 98.1 nm
   b. 120 nm
   c. 364 nm
   d. 255 nm
   e. 79.9 nm

9. Given that the energy ($\bar{\nu}$) of a Paschen line ($n_1 = 3$) in the H spectrum is $9.142 \times 10^5\ m^{-1}$, what is the value of n for the higher state?

   a. 4
   b. 5
   c. 6
   d. 7
   e. 8

10. How many grams of lead(II) iodate, $Pb(IO_3)_2$, are precipitated when 32.0 mL of 2.85 M $Pb(NO_3)_2$ (aq) are mixed with 38.6 mL of 5.12 M KIO_3 (aq) solution? The reaction is:
    $Pb(NO_3)_2(aq) + 2KIO_3(aq) \rightarrow Pb(IO_3)_2(s) + 2KNO_3(aq)$

    a. 25.4 g
    b. 29.8 g
    c. 48.3 g
    d. 50.8 g
    e. 51.9 g

11. The following electron configurations are given for a cation (M^{2+}) and an anion (A^-). What is the formula for the compound formed from these ions ?

    M^{2+} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$ A^- $1s^2\ 2s^2\ 2p^6$

    a. ZnO
    b. ZnF_2
    c. CuF_2
    d. $NiCl_2$
    e. NiO

12. Which one of the following molecules is **non-polar**?

    a. CO
    b. CH_3Cl
    c. SO_3
    d. NH_3
    e. SO_2

13. Describe the geometry of the $\mathbf{IF_4^-}$ ion.

    a. Square planar
    b. Tetrahedral
    c. See-saw molecule
    d. Square pyramid
    e. T-shaped molecule.

14. What is the hybridization of the **As** atom in the ion, AsF_4^- ?

a. sp
b. sp^3
c. sp^3d
d. sp^2
e. sp^3d^2

15. How many sigma (σ) bonds, pi (π) bonds, and unshared/lone pairs of electrons are there in the molecule, HONO?

a. 3 σ, 1 π, and 5 lone pairs.
b. 2 σ, 2 π, and 4 lone pairs.
c. 4 σ, 0 π, and 5 lone pairs.
d. 2 σ, 2 π, and 5 lone pairs.
e. 4 σ, 0 π, and 4 lone pairs.

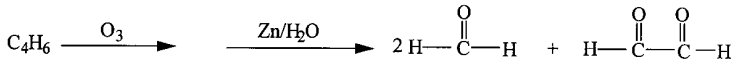
16. The order of increasing boiling points for the compounds, 1-butanol, 1-pentanol, pentane, 2-methylbutane and hexane is:

a. hexane < 2-methylbutane < pentane < 1-pentanol < 1-butanol
b. 2-methylbutane < pentane <1-butanol 1-pentanol < hexane
c. pentane < 2-methylbutane < 1-butanol < hexane < 1-pentanol
d. 1-butanol < 1-pentanol < 2-methylbutane < pentane < hexane
e. 2-methylbutane < pentane < hexane < 1-butanol < 1-pentanol

17. Isopropanol reacts with butanoic acid in the presence of sulfuric acid to produce a sweet smelling compound called:

a. butyl isopropanoate
b. isopropyl butanoaote
c. butyl propanoate
d. 2-isopropylbutanal
e. 5-methyl-2-hexanone

18. An unknown compound of molecular formula C_4H_6 was subjected to ozonolysis followed by treatment with zinc in water to obtain the products shown in the equation:



The structure of the unknown compound is

a. $CH_2{=}CH{-}CH{=}CH_2$

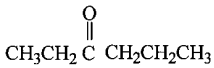
b. $CH_2{=}C(CH_3){-}CH_3$

c. $CH_2{=}C{=}CH{-}CH_3$

d. $CH{\equiv}C\,CH_2CH_3$

e. $CH_3\,C{\equiv}C\,CH_3$

19. An unknown compound P, of molecular formula C_6H_{10} reacts with 2 moles of bromine. Hydration of the same compound, P, gives a product with the structure



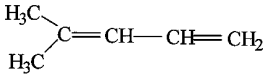
The unknown compound is:

a. $HC{\equiv}CCH_2CH_2CH_2CH_3$

b. $CH_3C{\equiv}CCH_2CH_2CH_3$

c. $CH_2{=}CH{-}CH_2{-}CH{=}CH{-}CH_3$

d. $CH_2{=}CH{-}CH{=}CH{-}CH_2CH_3$

e. 

20. A 100g mass of hydrocarbon is composed of 85.7g carbon and 14.3g hydrogen. The compound does not decolorize bromine water but gives only one monochlorination product. The hydrocarbon is

    a. methylcyclohexene
    b. cycloheptane
    c. 2,3-dimethylpentane
    d. 1,3-dimethylcyclopentene
    e. 1,2,3-trimethylcyclopropane

21. Given the equilibrium:

    $2SO_3\,(g) \rightleftharpoons 2\,SO_2(g) + O_2\,(g)$

    Initially 1.20 moles of SO_3 are placed in a 1.00 L vessel. When the system reaches equilibrium at 700 °C , $[SO_3] = 0.420$ M. Calculate K_c at 700 °C.

    a. 0.725
    b. 3.45
    c. 1.75
    d. 2.78
    e. 1.35

22. The four gases NH_3, O_2, NO, H_2O are mixed in a reaction vessel and allowed to reach equilibrium in the reaction at a certain temperature:

    $4\,NH_3\,(g) + 5O_2\,(g) \rightleftharpoons 4NO(g) + 6\,H_2O\,(g)$.

    To the system at equilibrium, some more oxygen gas is introduced. Which one of the following statements is true?

    a. The value of K_c increases as a result of adding oxygen.
    b. The value of K_c decreases as a result of adding oxygen.
    c. The concentration of NH_3 starts decreasing as the system moves towards a new equilibrium.
    d. The concentration of NH_3 starts increasing as the system moves towards a new equilibrium.
    e. The concentration of NO starts decreasing as the system moves towards a new equilibrium.

23. The oxidation of carbon monoxide shown below is an exothermic process:

$2CO\ (g) + O_2\ (g) \rightleftharpoons 2\ CO_2\ (g)$

Which one of the following will cause an **increase** in the equilibrium concentration of **CO(g)**?

a. Increasing the total pressure of the system at constant temperature.
b. Adding more O_2 (g) to the system.
c. Removing CO_2 from the system.
d. Increasing the temperature of the system.
e. Decreasing the volume of the system.

24. The enthalpy change (ΔH_r) for the following reaction:
$C_2H_4\ (g) + H_2O\ (g) \rightarrow C_2H_5OH\ (g)$ can be estimated from the bond enthalpies (denoted by BE) as follows:

a. $\Delta H_r = BE(C{=}C) - 2BE(C\text{-}C) - BE(C\text{-}O)$
b. $\Delta H_r = BE(C{=}C) + BE(O\text{-}H) - 2BE(C\text{-}C) - BE(C\text{-}O)$
c. $\Delta H_r = BE(C\text{-}O) + BE(C\text{-}C) - BE(O\text{-}H) - BE\ (C{=}C)$
d. $\Delta H_r = BE(C\text{-}H) + BE(C\text{-}O) + BE(C\text{-}C) - BE(O\text{-}H) - BE(C{=}C)$
e. $\Delta H_r = BE(O\text{-}H) + BE(C{=}C) - BE(C\text{-}H) - BE(C\text{-}O) - BE(C\text{-}C)$

25. Use the information given to calculate ΔH^o for the reaction:

$2\ ZnS\ (s) + 3O_2(g) \rightarrow 2ZnO(s) + 2\ SO_2(g)$

Given:

$Zn(s) + \frac{1}{2}\ O_2(g) \rightarrow ZnO(s)$	$\Delta H^o = -348$ kJ
$Zn(s) + S(s) \rightarrow ZnS(s)$	$\Delta H^o = -206$ kJ
$S(s) + O_2(g) \rightarrow SO_2(g)$	$\Delta H^o = -297$ kJ

a. –581 kJ
b. –247 kJ
c. –878 kJ
d. –1140 kJ
e. –961 kJ

26. A 10.0 L vessel contains 893 g of nitrogen gas. What is the pressure exerted by the gas at 25 °C?

a 2.80 atm
b 12.8 atm
c 32.2 atm
d 66.4 atm
e 8.0 atm

27. A gas mixture contains gases with the following partial pressures, given in mm Hg:

$P(O_2) = 510,\ P(N_2) = 336,\ P(CO_2) = 38.1,\ P(Ne) = 427.$

What is the mole fraction of oxygen, $X(O_2)$, in the mixture?

a. 0.326
b. 0.563
c. 0.389
d. 0.408
e. 0.631

28. Which one of the following plots for an ideal gas will not be a straight line, (all other variables are constant)?

a. P against T
b. V against T
c. P against V
d. V against n
e. All the plots will be straight lines.

29. For the reaction, $2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$, the proposed mechanism is:

step (1): $2NO \rightleftharpoons N_2O_2$ (fast)

step (2): $N_2O_2 + H_2 \rightarrow N_2O + H_2O$ (slow)

step (3) $N_2O + H_2 \rightarrow N_2 + H_2O$ (fast)

The rate law for this mechanism is:

a. rate = $k\,[N_2O][\,H_2]$
b. rate = $k[NO]^2$
c. rate = $k[NO]^2\,[\,H_2]^2$
d. rate = $k[NO]^2\,[\,H_2]$
e. impossible to know from just the given mechanism.

30. For the reaction, $H_2(g) + I_2(g) \rightarrow 2HI(g)$, the slope of a graph of ***ln*** k vs 1/T is -20450 K. Calculate the activation energy, E_a, for the reaction.

a. 170 kJ/mol
b. 246 kJ/mol
c. 151 kJ/mol
d. 74.8 kJ/mol
e. 273 kJ/mol

---------- End of Section A ----------

SECTION B

There are 7 questions in this Section. Answer each question in the space provided.

Question 1.

Given the reaction:

$$3\ Cd(NO_3)_2\ (aq) + 2\ Na_3PO_4\ (aq) \rightarrow Cd_3(PO_4)_2\ (s) + 6\ NaNO_3\ (aq).$$

The reaction of 0.520 g of $Cd(NO_3)_2$ (MM = 236.4 g/mol) with 1.70 g of Na_3PO_4 (MM = 164.0 g/mol) produces 0.250 g of $Cd_3(PO_4)_2$ (MM = 527.2 g/mol).

a. Identify the limiting reagent.

b. Calculate the % yield of $Cd_3(PO_4)_2$.

[5 Marks]

Question 2.

a. Write the ground state electron configuration for the following atoms or ions. Use the [rare gas] abbreviation for completely filled electron shells. **[2 marks]**

$_{43}Tc$ _____

$_{31}Ga^{3+}$ _____

b. List the following species in order of **decreasing radius** (largest first)

Al , Al^{3+} , Ca , Mg **[1 Mark]**

Question 3.

Calculate the pH of a 2.5×10^{-2} $Ba(OH)_2$ (aq) solution. **[4 Marks]**

Question 4.

a. Write three (3) different **non-equivalent resonance structures** for the SO_2F_2 molecule, where the S atom is the central atom.

b. Then calculate the **Formal Charges** on each of the atoms.

c. Finally, draw **the best possible resonance structure** for the SO_2F_2 molecule, which may or may not be one of your three structures already drawn.

[7 Marks]

Question 6.

For the reaction

$N_2(g) + O_2(g) \rightleftharpoons 2\ NO(g)$ $K_c = 0.810$, at a certain temperature.
In a 1.00 L vessel, 0.200 mol N_2, and 0.200 mol $O_2(g)$ were introduced and allowed to come to equilibrium at this temperature.

a. Calculate the equilibrium concentrations of N_2 , O_2, and NO.
b. After the system has reached equilibrium, its pressure is increased by decreasing the volume of the reaction vessel. What effect will this increase in pressure have on the amount of NO(g)?

[6 Marks]

Question 7.

The following results were obtained for a reaction between A and B at room temperature.

[A]/ mol.L^{-1}	**[B]/mol.L^{-1}**	**Initial rates/mol.L^{-1}.s^{-1}**
0.5	1.0	2
0.5	2.0	8
0.5	3.0	18
1.0	3.0	36
2.0	3.0	72

(i) What is the order of the reaction with respect to A and with respect to B?
(ii) What is the rate equation for the reaction?
(iii) Calculate the rate constant, and clearly indicate its units.

[6 Marks]

PERIODIC CHART OFTHE ELEMENTS

1	2											3	4	5	6	7	8
1 H 1.00794																1 H 1.00794	2 He 4.00260
3 Li 6.941	4 Be 9.01218											5 B 10.81	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.998403	10 Ne 20.179
11 Na 22.98977	12 Mg 24.305						TRANSITION METALS					13 Al 26.98154	14 Si 28.0855	15 P 30.97376	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.0983	20 Ca 40.08	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.69	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.22	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.9055	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.9045	54 Xe 131.29
55 Cs 132.9054	56 Ba 137.33	71 Lu 174.967	72 Hf 178.49	73 Ta 180.9479	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.9665	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.9804	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0254	103 Lr (260)	104 § (261)	105 § (262)	106 § (263)	107 §		109 §									

§The International Union for Pure and Applied Chemistry has not adopted official names or symbols for these elements.

Note: Atomic masses shown here are 1981 IUPAC values.

* Lanthanides

57	58	59	60	61	62	63	64	65	66	67	68	69	70
*La 138.9055	Ce 140.12	Pr 140.9077	Nd 144.24	Pm (145)	Sm 150.36	Eu 151.96	Gd 157.25	Tb 158.9254	Dy 162.50	Ho 164.9304	Er 167.26	Tm 168.9342	Yb 173.04

' Actinides

89	90	91	92	93	94	95	96	97	98	99	100	101	102
'Ac 227.0278	Th 232.0381	Pa 231.0359	U 238.0289	Np 237.0482	Pu (244)	Am (243)	Cm (247)	Bk (247)	Cf (251)	Es (252)	Fm (257)	Md (258)	No (259)