UNIVERSITY OF BOTSWANA
DEPARTMENT OF CHEMISTRY

B.Sc Year I: GENERAL CHEMISTRY (C110)
SECOND SEMESTER EXAMINATION: 20 APRIL 2000

Time Allowed: 3 hours

INSTRUCTIONS:

Fill in the following information:

Student ID No:_____

Tutorial Group and No:_____

The paper has two parts. For Section A (multiple-choice questions), circle the letter for the correct answer for each question.
For questions in Section B, use the space provided to write your answers. If you need additional space, write on the back of the printed pages.

WRITE ALL ANSWERS ON THIS QUESTION PAPER.

Constants:

$K_W = 1.0 \times 10^{-14}$ at 25 °C

Avogadro constant = 6.022×10^{23} mol^{-1}

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

1 atm = 760 mm Hg.

Do not write in this table.

MC	1	2	3	4	5	6	7	Total

SECTION A: MULTIPLE CHOICE (60 Marks)

1. The combustion of methanol takes place according to the equation:

   $2CH_3OH\ (l) + 3\ O_2\ (g) \rightarrow 2CO_2(g) + 4\ H_2O\ (l)$

   What is the value of ΔH for the combustion of one mole of methanol? The standard heats of formation are:

   $\Delta H_f^\circ\ CH_3OH\ (l) = -238.5\ kJ.\ mol^{-1}$
   $\Delta H_f^\circ\ H_2O\ (l) = -285.6\ kJ.\ mol^{-1}$
   $\Delta H_f^\circ\ CO_2\ (g) = -393.8\ kJ.\ mol^{-1}$

   a. –485.6 kJ
   b. +581.4 kJ
   c. –937.1 kJ
   d. –274.6 kJ
   e. –726.5 kJ

2. Given the thermochemical equation:

   $2\ Al(s) + 1.5O_2\ (g) \rightarrow Al_2O_3\ (s)$ $\Delta H = -1600\ kJ$,
   what is ΔH for the reaction:
   $2\ Al_2O_3\ (s) \rightarrow 4Al\ (s) + 3O_2\ (g)$?

   a. –1600 kJ
   b. 1600 kJ
   c. –3200 kJ
   d. 3200 kJ
   e. 800 kJ

3. What is the molality of a solution of benzene, C_6H_6, in toluene, $C_6H_5CH_3$, in which the mole fraction of benzene is 0.150?

   a. 2.26 m
   b. 1.92 m
   c. 0.150 m
   d. 0.850 m
   e. 3.14 m

4. How much water should be added to 25.00 mL of 6.00 M HNO_3 to prepare 0.500 M HNO_3? Assume all volumes to be additive.

   a. 350 mL
   b. 325 mL
   c. 300 mL
   d. 275 mL
   e. 250 mL.

5. What are the values of K_p and K_c for the reaction:
   $H_2O(l) \leftrightharpoons H_2O(g)$ at 25 °C? The vapour pressure of water at 25 °C is 23.8 mm Hg.

   a. 23.8 and 0.766
   b. 3.13×10^{-2} and 1.28×10^{-3}
   c. 23.8 and 0.973
   d. 3.13×10^{-2} and 0.766
   e. 23.8 and 23.8.

6. When 1.000 g of I_2 is heated to 1000 K in a 1.00 L container, the resulting equilibrium mixture contains 0.830 g of I_2. For the reaction:
   $I_2(g) \leftrightharpoons 2I(g)$,
   K_c will be:

   a. 4.20×10^{-3}
   b. 3.94×10^{-3}
   c. 3.27×10^{-3}
   d. 1.34×10^{-4}
   e. 5.49×10^{-4}

7. For the reaction:

   $H_2(g) + I_2(g) \leftrightharpoons 2\ HI(g)$, $K_c = 50.2$ at 445 °C. If 0.200 mol of $H_2(g)$ and 0.200 mol of I_2 (g) are placed in a 4.00 L container, what will be the equilibrium concentration of [HI] at 445 °C?

   a. 0.078 M
   b. 0.051 M
   c. 0.101 M
   d. 0.0962 M
   e. 0.021 M.

8. Four gases, NH_3, O_2, NO and H_2O are mixed in a reaction vessel and allowed to reach equilibrium in the reaction:

$4\ NH_3\ (g) + 5O_2\ (g) \leftrightharpoons 4NO(g) + 6H_2O\ (g)$.
To the system at equilibrium, some more NO(g) is introduced. Which one of the following statements is true?

a. The value of K_c increases as a result of adding NO(g).
b. The value of K_c decreases as a result of adding NO(g).
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 oxygen starts decreasing as the system moves towards a new equilibrium.

9. If $K_c = 4.4 \times 10^9$ at 1000 K for the reaction:

$CCl_4\ (g) + ½\ O_2\ (g) \leftrightharpoons COCl_2\ (g) + Cl_2\ (g)$,

what will be K_c' for the following reaction?

$2\ COCl_2\ (g) + 2\ Cl_2\ (g) \leftrightharpoons 2CCl_4\ (g) + O_2\ (g)$.

a. 4.5×10^{-19}
b. 5.2×10^{-20}
c. 2.5×10^{18}
d. 6.4×10^9
e. -8.8×10^9

10. For the equilibrium reaction:

$2SO_3(g) \leftrightharpoons O_2(g) + 2SO_2(g)$, $\Delta H = 198$ kJ
which one of the following will cause the value of the equilibrium constant to increase?

a. Increase the temperature.
b. Decrease the temperature.
c. Add $SO_3(g)$
d. Increase the volume.
e. Equilibrium constant does not change with any of the above.

11. Which one of the following mixtures is a buffer solution?

a. 50 mL of 1.0 M HCl + 25 mL of 1.0 M NaOH.
b. 50 mL of 1.0 M HCl + 50 mL of 1.0 NaCl.
c. 50 mL of 1.0 M CH_3COOH + 50 mL of 1.0 M NaOH.
d. 50 mL of 1.0 M CH_3COONa + 25 mL of 1.0 M NaOH.
e. 50 mL of 1.0 M CH_3COOH + 25 mL of 1.0 M NaOH

12. Methyl red indicator is a weak acid with $K_a = 1 \times 10^{-5}$. The weak acid molecule (HIn) is red, and the corresponding anion, (In^-), is yellow. What will be the colour of a solution containing the indicator if the pH of the solution is 3.

a. Red.
b. Yellow.
c. Orange (a mixture of red and yellow.)
d. Blue
e. Colourless.

13. The K_{sp} for $La(IO_3)_3$ is 6.2×10^{-12}. What is the molar solubility of $La(IO_3)_3$ in water?

a. 6.9×10^{-4} M
b. 9.3×10^{-4} M
c. 1.7×10^{-5} M
d. 7.2×10^{-5} M
e. 2.4×10^{-6} M

14. Which of the following salt solutions is **wrongly** identified.

a. $FeCl_3$ (aq) - neutral
b. NH_4ClO_4 (aq)– acidic
c. LiBr (aq) – neutral.
d. KCN (aq)– basic.
e. Na_3PO_4(aq) – basic.

15. A 50.0 mL sample of 0.25 M CH_3NH_2 (aq) solution is titrated with 0.35 M HCl. For CH_3NH_2, $K_b = 3.6 \times 10^{-4}$. What is the pH after addition of 15.0 mL of 0.35 M HCl?

a. 9.26
b. 9.83
c. 10.19
d. 10.70
e. 11.05

16. A 50.0 mL sample of 0.010 M $Ba(OH)_2$ is titrated with 0.0100 M HCl. At the stoichiometric point, the solution is;

a. 1.0×10^{-2} M $BaCl_2$ (aq)
b. 6.6×10^{-3} M $BaCl_2$ (aq).
c. 3.3×10^{-3} M $BaCl_2$ (aq).
d. 5.0×10^{-3} M $BaCl_2$ (aq)
e. pure water.

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

$2NO \leftrightharpoons N_2O_2$ (fast)
$N_2O_2 + H_2 \rightarrow N_2O + H_2O$ (slow)
$N_2O + H_2 \rightarrow N_2 + H_2O$ (fast)

The rate law for this mechanism is:

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

18. For the reaction between chlorine and nitric oxide
$Cl_2(g) + 2NO(g) \rightarrow 2NOCl(g)$,
it is found that doubling the concentration of both reactants increases the rate by a factor of 8. If only the concentration of Cl_2 is doubled, while keeping the concentration of nitric oxide constant, the rate increases by a factor of 2. The order of the reaction with respect to NO is:

a. 3.
b. 2.
c. 1.
d. 0
e. ½

19. The reaction, cyclopropene → propene is a first order reaction. At a given temperature, 85.0 % of a sample of cyclopropene changes into propene in 79.0 min. What is the value of the rate constant, k?

a. 8.74×10^{-3} min^{-1}.
b. 0.0113 min^{-1}
c. 0.0152 min^{-1}
d. 0.0201 min^{-1}
e. 0.0240 min^{-1}.

20. The reaction $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$, is suspected to be second order in NO_2. Which of the following graphs would be the best to confirm that the reaction is indeed second order?

a. A graph of $[NO_2]$ vs t.
b. A graph of $[NO_2]^{-1}$ vs t.
c. A graph of ln $[NO_2]$ vs t.
d. A graph of $[NO_2]^2$ vs t.
e. A graph of ln $([NO_2]^{-1})$ vs t.

21. For a first order reaction, which one of the following statements is true?

a. The graph of ln k vs T is a straight line.
b. The reactant is fully consumed after two half lives.
c. A graph of the rate of reaction vs concentration of the reactant is a straight line with a positive slope.
d. A graph of ln k vs 1/T is a straight line with a positive slope.
e. The half-life of the reaction is independent of the rate constant.

22. The half-life for the first order decomposition of a substance A is 200 s. How much time is required for the concentration of A to decrease to one ninth of its initial value?

a. 634 s.
b. 1.58×10^{-3} s.
c. 412 s
d. 1800 s
e. 22.2 s.

23. How many monochlorination products are possible from chlorination of a C_7H_{16} hydrocarbon with fifteen primary hydrogens?

a. 4
b. 6
c. 7
d. 3
e. 15.

24. What alkene upon acid hydration would give 3-hexanol only?

a. 1-hexene
b. 3-methyl-2-hexene
c. Trans-3-hexene
d. 2-hexene
e. 3-methyl-3-hexene

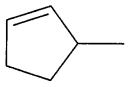
25. What does one need (conditions and/or reagents) to change ethane to chloroethane?

a. Hydrochloric acid
b. Chlorine and light
c. Chlorine and water
d. Sodium chloride
e. Chlorine only

26. Which of the following species is an electrophile?

a. Carbocation.
b. Carbanion
c. An alkene
d. A base
e. Water.

27. Name the compound whose structure is given below

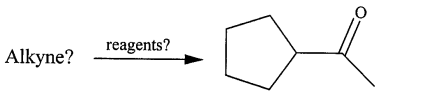


a. 1-Methyl-2-cyclopentene
b. 1-Methyl-4-cyclopentene
c. 2-Methyl-1-cyclopentene
d. 3-Methyl-1-cyclopentene
e. 5-Methyl-1-cyclopentene

28. Chlorination of propyne with excess chlorine gives

a. 3-Chloropropyne
b. 1, 2-Dichlorocyclopropane
c. 1, 1, 2, 2-Tetrachloropropane
d. 1, 2, 3-Trichloropropane
e. 1, 2, 3, 3-Tetrachloropropane.

29. Complete the reaction given below by giving the name of the alkyne and reagents required to do the transformation



Cyclopentyl methyl ketone

a. Cyclopentylethyne with acidic water in presence of mercuric sulphate.
b. Cyclopentylethyne with aqueous mercuric sulphate.
c. Cyclopentylethyne with sodium amide
d. Ethynylcyclopentane with hydrogen in presence of a platinum catalyst.
e. Ethynylcyclopentane with hydrogen and Lindlar's catalyst.

30. Which of the following does not exhibit positional isomerism?

a. An alkene
b. An aldehyde
c. An alkyl halide
d. A ketone
e. An alcohol

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

SECTION B

Answer the following questions in the space provided. If you need additional space, use the back of the page.

Question 1

80.0 mL of 0.030 M HCN(aq) is mixed with 20.0 mL of 0.050 M NaCN(aq). Calculate the pH of the resulting solution. K_a for HCN is 4.9×10^{-10}

(6 marks)

Question 2.

Calculate the solubility of lead (II) chloride in a 0.10 M $CaCl_2$ solution. K_{sp} for $PbCl_2 = 1.6x10^{-5}$ at 25 °C.

(5 marks)

Question 3.

When solid NH_4HS and 0.200 mol of gaseous NH_3 were placed in 2.0-L vessel at 24 °C, the equilibrium:
$NH_4HS(s) \leftrightharpoons NH_3(g) + H_2S(g)$
was reached. $K_c = 1.6 \times 10^{-4}$. What are the equilibrium concentrations of NH_3 and H_2S?

(5 marks)

Question 4.

A solution of an unknown compound dissolved in 25.0 g benzene (C_6H_6) has the boiling point, $T_b = 82.55\ ^oC$. The boiling point of pure benzene is 80.10 °C, and $k_b = 2.53\ ^oC.\ kg.\ mol^{-1}$. Calculate the molar mass of this compound.

(4 marks)

Question 5.

When 0.231 g of phosphorus reacts with chlorine to form PCl_3 in a calorimeter of heat capacity 216 J. $(^{o}C)^{-1}$, the temperature of the calorimeter rose by 11.06 ^{o}C. Write the thermochemical equation for the reaction.

(4 marks)

Question 6.

For the hydrolysis of methyl methanoate at 298 K, occurring according to the equation:
$HCOOCH_3 + H_2O \rightarrow HCOOH + CH_3OH$,
the following results were obtained:

$[HCOOCH_3]$	$[H^+]$	Initial Rate
0.50 M	1.00 M	0.56×10^{-3} mol.L^{-1}.s^{-1}
1.00 M	1.00 M	1.11×10^{-3} mol.L^{-1}.s^{-1}
2.00M	1.00 M	2.24×10^{-3} mol.L^{-1}.s^{-1}
2.00M	0.50 M	1.13×10^{-3} mol.L^{-1}.s^{-1}
2.00M	2.00 M	4.49×10^{-3} mol.L^{-1}.s^{-1}

a. Deduce the rate expression and calculate the rate constant.
b. The rate constant at 323 K is 8.63×10^{-3} L.mol^{-1}.s^{-1}, and at 313 K, it is 8.63×10^{-3} L.mol^{-1}.s^{-1}. Find the value of the activation energy for the reaction.

(6 marks)

Question 7.

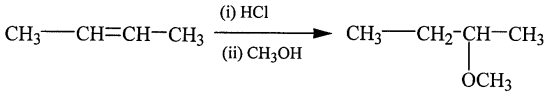
A. Provide line formulae for all the compounds with the given names (4 marks)

(a) 6-Ethyl-4, 8-dimethyl-1, 6-nonadiene

(b) 4-Oxopentanoic acid

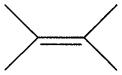
(c) Ethyl hexanoate

B. Provide a mechanism for the following reaction (3 marks)



C. Provide the name of the product obtained from the following reactions (3 marks)

(i) 3-Octene $\xrightarrow{H_2, Pt}$

(ii)  $\xrightarrow[\text{(ii) Zn/ H2O}]{\text{(i) } O_3}$

(iii) $CH_3—CH_2-C\equiv CH \xrightarrow{2\ HBr}$

PERIODIC TABLE OF THE ELEMENTS

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** 18.9984	10 **Ne** 20.179
11 **Na** 22.9898	12 **Mg** 24.305	**Transition Metals**										13 **Al** 26.9815	14 **Si** 28.0855	15 **P** 30.9738	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** 83.8
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** 102.906	46 **Pd** 106.42	47 **Ag** 107.868	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.29
55 **Cs** 132.905	56 **Ba** 137.33	71 **Lu** 174.967	72 **Hf** 178.49	73 **Ta** 180.948	74 **W** 183.85	75 **Re** 186.207	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.967	80 **Hg** 200.59	81 **Tl** 204.383	82 **Pb** 207.2	83 **Bi** 208.908	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.025	103 **Lr** (260)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh**	108 **Hs**	109 **Mt**	110	111	112	113					

Lanthanides:	57 **La** 138.906	58 **Ce** 140.12	59 **Pr** 140.908	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.925	66 **Dy** 162.50	67 **Ho** 161.930	68 **Er** 167.26	69 **Tm** 166.934	70 **Yb** 173.04
Actinides:	89 **Ac** 227.028	90 **Th** 232.038	91 **Pa** 231.036	92 **U** 238.029	93 **Np** 237.048	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)