UNIVERSITY OF BOTSWANA
DEPARTMENT OF CHEMISTRY

B.Sc Year I: GENERAL CHEMISTRY (C110)
EXAMINATION PAPER 2: MAY 2002

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.

IMPORTANT: It is the student's responsibility to check that no page is missing in this paper. The paper has 15 pages in addition to the Periodic Table.

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 Torr.

Do not write in this table.

| MC	1	2	3	4	5	6	7	Total

SECTION A: MULTIPLE CHOICE (60 %)

1. Calculate the molality of urea (MM = 60g/mol) in a solution prepared by dissolving 16 g of urea in 39 g of water.
   a. 96
   b. 6.8
   c. 0.68
   d. 0.41
   e. 0.15

2. Given the reaction enthalpies:

   $2P(s) + 3Cl_2(g) \rightarrow 2PCl_3(g)$ $\Delta H° = -574$ kJ
   $2P(s) + 5Cl_2(g) \rightarrow 2PCl_5(l)$ $\Delta H° = -887$ kJ

   what is $\Delta H°$ for the reaction:
   $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(l)$ $\Delta H° = ?$

   a. -157 kJ
   b. -313 kJ
   c. -1461 kJ
   d. +1461 kJ
   e. +222 kJ

3. Calculate the mole fraction of urea (MM = 60g/mol) in a solution prepared by dissolving 16 g of urea in 39 g of water.

   a. 0.58
   b. 0.37
   c. 0.13
   d. 0.11
   e. 9.1

4. The equilibrium constant for the reaction (1) is K. What is the equilibrium constant for the equation (2)?

   (1) $SO_2(g) + \frac{1}{2} O_2(g) \rightleftharpoons SO_3 (g)$

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

   a. K^2
   b. $2K$
   c. $1/2K$
   d. $1/K^2$
   e. $-K^2$

5. When a chemical reaction has reached equilibrium,

   a. No further reaction takes place in either direction.
   b. The rate of the forward reaction is equal to the rate of the backward reaction.
   c. All the reactants have been used up.
   d. The concentrations of reactants and products are equal.
   e. The rate constant becomes equal to the equilibrium constant.

6. K_c for the reaction below at 25 °C is 4.8×10^{-6}. Calculate the equilibrium concentration (mol/L) of Cl_2 (g) if the initial concentration of ICl(g) is 1.33 mol/L. There is no I_2 or Cl_2 initially present.

   $$2ICl\ (g) \rightleftharpoons I_2(g) + Cl_2\ (g)$$
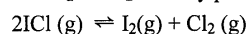
   a. 2.9×10^{-3}
   b. 5.8×10^{-3}
   c. 3.2×10^{-6}
   d. 6.4×10^{-6}
   e. 343

7. Consider the following reaction at equilibrium

   $$2\ CO_2\ (g) \rightleftharpoons 2\ CO\ (g) + O_2\ (g) \qquad \Delta H° = -514\ kJ$$
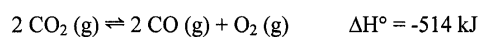
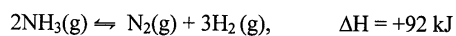   Increasing the temperature will _____.

   a. increase the concentration of $O_2(g)$.
   b. decrease the concentration of $CO_2(g)$.
   c. decrease the value of the equilibrium constant.
   d. shift the reaction to the right.
   e. increase the concentration of $CO(g)$.

8. Consider the reaction:

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

   Determine the value of the equilibrium constant for this reaction if an initial concentration of $N_2O_4(g)$ of 0.0400 mol/L is reduced to 0.0055 mol/L at equilibrium. There is no $NO_2(g)$ present at the start of the reaction.

   a. 0.87
   b. 13
   c. 0.22
   d. 0.022
   e. 22×10^{-4}

9. Consider the equilibrium reaction:

    $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g),$ $\Delta H = +92 \text{ kJ}$

    This reaction will shift to the right with _____.
   a. increasing temperature and decreasing volume.
    b. increasing both temperature and volume.
    c. decreasing both temperature and volume
    d. decreasing temperature and increasing volume.
    e. The addition of extra nitrogen gas to the container.

10. Which one of the following substances, when added to a solution of hydrofluoric acid, could be used to prepare a buffer solution?

    a. HCl.
    b. $NaNO_3$.
    c. NaF
    d. NaCl.
    e. NaBr.

11. In a titration experiment it was found that 15.38 mL of 0.139 M NaOH was required to neutralize a 25.00 mL sample of HCl. What was the molarity of the HCl sample?

    a. 11.7
    b. 0.00214
    c. 0.0855
    d. 0.267
    e. 0.139

12. The K_{sp} for Ag_2S is 1.0×10^{-51}. What is the molar solubility of Ag_2S?

    a. 1.0×10^{-17} M
    b. 7.9×10^{-18} M
    c. 6.3×10^{-18} M
    d. 8.3×10^{-53} M
    e. 1.0×10^{-51} M

13. Of the following substances, an aqueous solution of ------------- will form basic solutions.

NH_4Cl $Cu(NO_3)_2$ K_2CO_3 NaF

a. NH_4Cl, $Cu(NO_3)_2$
b. NH_4Cl, K_2CO_3
c. NaF only.
d. K_2CO_3, NaF
e. NH_4Cl only

14. Which of the following does NOT act as a weak base in water?

a. $(CH_3)_3 N$
b. $HCOO^-$
c. NO_2^-
d. ClO_4^-
e. NH_3

15. What is the pH of a 0.015 mol/L solution of barium hydroxide?

a. 12.48
b. 12.18
c. 1.82
d. 1.52
e. Could be any of the above, depending on the concentration used.

16. In general, as temperature goes up, reaction rate

a.   goes up if the reaction is exothermic
b.   goes up if the reaction is endothermic
c   goes up regardless of whether the reaction is exothermic or endothermic
d   stays the same regardless of whether the reaction is exothermic or endothermic.
e   stays the same if the reaction is first order

17. The K_a of HClO is 3.0×10^{-8}. What is the pH at 25 °C of 0.020 M aqueous solution of HClO?

a.   2.45
b.   -2.45
c.   -9.22
d   9.22
e.   4.61

18. The following data show how the initial rate of reaction changes with initial concentration of reactants for the reaction:

$$2ClO_2(aq) + 2OH^-(aq) \rightarrow ClO_3^- (aq) + ClO_2^-(aq) + H_2O(l)$$
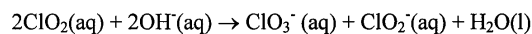
Experiment	$[ClO_2]_o$	$[OH^-]_o$	initial Rate
1	0.060 M	0.030 M	0.0248 M/s
2	0.020	0.030	0.00276
3	0.020	0.090	0.00828

The order of the reaction with respect to $[ClO_2]$ and $[OH^-]$ is, respectively:

a. 1, 1
b. 2, 1
c. 1, 2
d. 2, 2
e. 3, 2

19. For the reaction shown, what is the rate of disappearance of H_2 when the rate of appearance of N_2 is 5.2 mmol $L^{-1}s^{-1}$?

$$2NO(g) + 2H_2(g) \rightarrow 2 H_2O (g) + N_2(g)$$
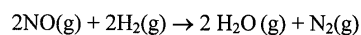
a. 1.3 mmol $L^{-1}s^{-1}$
b. 2.6 mmol $L^{-1}s^{-1}$
c. 5.2 mmol $L^{-1}s^{-1}$
d. 21 mmol $L^{-1}s^{-1}$
e. 10.4 mmol $L^{-1}s^{-1}$

20. The rate constant of a certain reaction is 1.3×10^{-4} L $mol^{-1}s^{-1}$ at 100 °C and 1.1×10^{-3} L $mol^{-1}s^{-1}$ at 150 °C. What is the activation energy of the reaction?

a. 16 kJ/mol
b. 56 kJ/mol
c. 99 kJ/mol
d. 132 kJ/mol
e. 22 kJ/mol

21. What is the rate constant of a first order process that has a half-life of 225 s?

a. 0.693 s^{-1}
b. 3.08×10^{-3} s^{-1}
c. 1.25 s^{-1}
d. 12.5 s^{-1}
e. 4.44×10^{-3} s^{-1}

22. For a first order reaction, a plot of _____ against _____ is a straight line.

    a. ln $[A]_t$, $1/t$
    b. ln $[A]_t$, t
    c. $1/[A]$, t
    d. $[A]$, t
    e. t, $1/[A]$

23. The hydrocarbons with general molecular formula, C_nH_{2n}, belong to the class of
    a. open chain alkanes and alkenes
    b. alkenes and alkynes
    c. cycloalkanes and cycloalkenes
    d. open chain alkenes and cycloalkanes
    e. alkenes and cycloalkynes

24. Monochlorination of the branched alkane, $(CH_3)_2CHCH_2CH_3$, may lead to the formation of
    a. only one monochlorination product
    b. two monochlorination products
    c. three monochlorination products
    d. four monochlorination products
    e. five monochlorination products

25. Select the correct statement with regard to the following reaction.
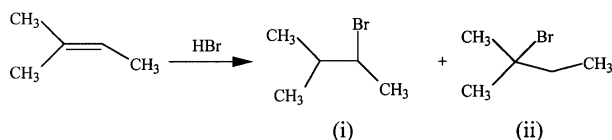

    a. (i) will be the major product and (ii) the minor
    b. (ii) will be the major product and (i) the minor
    c. Both the products will be formed in equal amounts.
    d. The reaction will not occur without aid of light.
   e. The reaction may also give 1-bromo-2-methyl-2-butene besides (i) and (ii).

26. Which one of the following is true for **both** alkanes and alkenes
    a. both readily decolorize bromine water
    b. both have sp – hybridized carbons
    c. both undergo addition reactions
    d. both burn with smokeless flames
   e. both burn in excess oxygen to give carbon dioxide and water

27. The compound shown below belongs to the class of allenes. What is the hybridization of C-3 in this molecule?
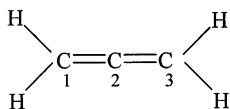
   a. sp^3
   b. sp
   c. sp^2
   d. sp^{3}d
   e. sp^{3}d^2

28. The reaction of propene with hydrogen (in the presence of a catalyst) to give propane may be described as
   a. substitution
   b. hydrogenation
   c. hydration
   d. neutralization
   e. dehydrogenation

29. The correct name of the compound shown below is
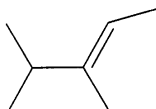
   a. 3,4-dimethyl-2-pentene
   b. 3,4-dimethylpentane
   c. 3,4-dimethyl-3-pentene
   d. 2,3-dimethyl-3-pentene
   e. 2,3-dimethyl-4-pentene

30. The functional group in the molecule shown below is:
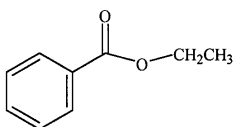
   a. aldehyde
   b. ether
   c. ester
   d. carboxylic acid
   e ketone

SECTION B

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

Question 1.

(a) What is a buffer?
(b) Give one example each of an acid and a base buffer.
(c) Write the chemical equilibrium that exists in the solution of each of the buffers.
(d) Explain how a buffer works.

(6 marks)

Question 2.

For HClO, $K_a = 2.9 \times 10^{-8}$ at 25 °C.
a. What is K_b for ClO⁻ ?
b. Calculate the pH of a 0.088 mol/L KClO(aq) at 25 °C.

(6 marks)

Question 3.

For the equilibrium:

C_2H_6 (g) $\rightleftharpoons$ C_2H_4 (g) + H_2 (g), K_p = 0.050 at 900 K. Pure C_2H_6 at 2.0 atm is placed in a flask and allowed to come to equilibrium at 900 K. What is the partial pressure of each of the three gases at equilibrium?

(5 Marks)

Question 4.

When 0.515 g of methanol, CH_3OH burns in excess oxygen in a calibrated calorimeter with a heat capacity of 551 J/°C, the temperature of the calorimeter rises by 10.6 °C. Calculate the reaction enthalpy for:

$$2CH_3OH \text{ (l)} + 3O_2\text{(g)} \rightarrow 2CO_2\text{(g)} + 4H_2O\text{(l)}$$
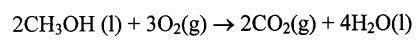
And write the thermochemical equation.

(5 Marks)

Question 5.

What is the vapour pressure, at 25 °C, of the solution that results from adding 60.0 g of glucose ($C_6H_{12}O_6$; MM = 180.2) to 500. g water? The vapour pressure of pure water at 25 °C is 23.8 Torr. Assume Raoult's law is followed.

(5 Marks)

Question 6
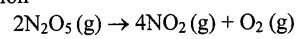
For the reaction
$$2N_2O_5 (g) \rightarrow 4NO_2 (g) + O_2 (g)$$
the rate expression is: Rate = $k[N_2O_5]$, with $k = 5.2 \times 10^{-3}$ s^{-1} at 65° C.
If the initial concentration of N_2O_5 was 0.040 mol L^{-1}, what would be the concentration of N_2O_5 remaining after 600. s?

(3 marks)

Question 7

a. Write the IUPAC names for the following structures   (2 marks)

b. Draw the structural formulas of the following compounds   (2 marks)
    (i)   N-Ethyl –N-methyl butyl amine (N-Ethyl –N-methyl-1-butanamine)
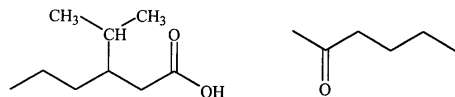
    (ii)   Ethyl 2-methylbutanoate

c.   Draw the structures of all possible isomers of dimethyl cyclobutane. (3 marks)

d.   Shown below is the mechanism for addition of HCl to an alkene. The mechanism
    is not complete, as it does not show the movement of electrons and charges on
    some species. Complete the mechanism by showing the movement of electrons
    with arrows and indicate the appropriate charges.

                                                            (3 marks)
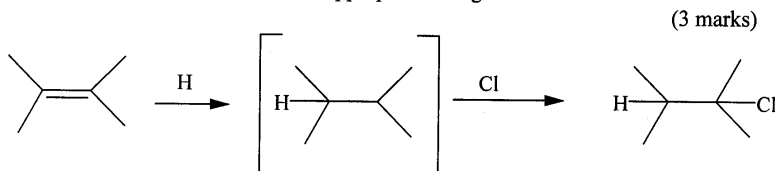
PERIODIC TABLE OF THE ELEMENTS

http://www.chem.qmw.ac.uk/iupac/atwt/table.html

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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											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** (264)	108 **Hs** (265)	109 **Mt** (268)	110 **Uun** (269)	111 **Uuu** (272)	112 **Uub** (269)		114 **Uuq**		116 **Uuh**		118 **Uuo**

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)