UNIVERSITY OF SWAZILAND

FINAL EXAMINATION – 2015, MAY

TITLE OF PAPER : Introductory Chemistry II

COURSE NUMBER : C112

TIME : Three Hours

INSTRUCTIONS :

1. **Answer all questions in Section A** (Total 50 marks)
2. **Answer any TWO questions in Section B** (each question is 20 marks)

NB: Non-programmable electronic calculators may be used

A data sheet, a periodic table and answer sheet (for **Section A**) are attached

Useful data and equations:

1 atm = 760 Torr = 760 mmHg

1 atm = 101325 Pa

Arrhenius equation: $k = Ae^{-E_a/RT}$ or $lnk = lnA - \frac{E_a}{RT}$

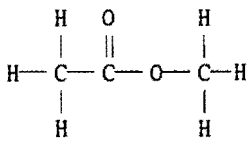
Van der Walls equation: $P = \frac{nRT}{V-nb} - \frac{n^2a}{V^2}$

This Examination Paper Contains Twelve Printed Pages Including This Page

You are not supposed to open the paper until permission to do so has been granted by the Chief Invigilator.

Section A

1. A 1.44-g sample of an unknown pure gas occupies a volume of 0.335 L at a pressure of 1.00 atm and a temperature of 100.0°C. The unknown gas is _____.
   A) argon
   B) helium
   C) krypton
   D) neon
   E) xenon
2. What is the enthalpy change (in kJ) of a chemical reaction that raises the temperature of 250.0 mL of solution having a density of 1.25 g/mL by 7.80 °C? (The specific heat of the solution is 3.74 joules/gram-K.)
   A) -7.43
   B) -12.51
   C) 8.20
   D) -9.12
   E) 6.51
3. The compound below is a(n) _____.



   A) carboxylic acid
   B) ketone
   C) aldehyde
   D) ester
   E) amine
4. The rate constant for a second-order reaction is 0.13 $M^{-1}s^{-1}$. If the initial concentration of reactant is 0.26 mol/L, it takes _____ s for the concentration to decrease to 0.11 mol/L.
   A) 0.017
   B) 0.68
   C) 9.1
   D) 40.
   E) 5.2
5. Nitrosyl bromide decomposes according to the following equation.

   $2NOBr\ (g) \longrightarrow 2NO\ (g) + Br_2\ (g)$

   A sample of NOBr (0.64 mol) was placed in a 1.00-L flask containing no NO or Br_2. At equilibrium the flask contained 0.36 mol of NOBr. How many moles of NO and Br_2, respectively, are in the flask at equilibrium?
   A) .28,.28
   B) .36,.18
   C) .28,.14
   D) .14,.23
   E) .36,.36
6. The volume occupied by 0.50 mol of gas at 35°C and 2.0 atm pressure is _____ L.
   A) 38
   B) 6.3
   C) .72
   D) .053
   E) .026
7. The ΔH for the solution process when solid sodium hydroxide dissolves in water is 44.4 kJ/mol. When a 10.1-g sample of NaOH dissolves in 250.0 g of water in a coffee-cup calorimeter, the temperature increases from 23.0 °C to _____°C. Assume that the solution has the same specific heat as liquid water, i.e., 4.18 J/g-K.
   A) 35.2
   B) 24.0
   C) 33.7
   D) 33.3
   E) 40.2
8. Ethers can be made by condensation of two _____ molecules by splitting out a molecule of water.
   A) alkyne
   B) alcohol
   C) ketone
   D) aldehyde
   E) olefin
9. A first-order reaction has a rate constant of 0.33 min^{-1}. It takes _____ min for the reactant concentration to decrease from 0.13 M to 0.095 M.
   A) 0.085
   B) 0.13

C) 0.41 D) 1.2
E) 0.95

10. Which one of the following will change the value of an equilibrium constant?
A) changing temperature
B) adding other substances that do not react with any of the species involved in the equilibrium
C) varying the initial concentrations of reactants
D) varying the initial concentrations of products
E) changing the volume of the reaction vessel

11. A sample of gas (1.9 mol) is in a flask at 21°C and 697 mm Hg. The flask is opened and more gas is added to the flask. The new pressure is 782 mm Hg and the temperature is now 26°C. There are now _____ mol of gas in the flask.
A) 1.6 B) 2.1
C) 2.9 D) 3.5
E) 0.28

12. In the presence of excess oxygen, methane gas burns in a constant-pressure system to yield carbon dioxide and water:

$$CH_4\,(g) + 2O_2\,(g) \longrightarrow CO_2\,(g) + 2H_2O\,(l) \qquad \Delta H = -890.0\ kJ$$

Calculate the value of q (kJ) in this exothermic reaction when 1.70 g of methane is combusted at constant pressure.
A) -94.6 B) 0.0306
C) -0.0106 D) 32.7
E) -9.46×10^4

13. _____ could be the formula of an alkene.
A) C_3H_8 B) C_3H_6
C) C_6H_6 D) $C_{17}H_{36}$
E) CH_8

14. Nitrogen dioxide decomposes to nitric oxide and oxygen via the reaction:

$$2NO_2 \longrightarrow 2NO + O_2$$

In a particular experiment at 300 °C, $[NO_2]$ drops from 0.0100 to 0.00550 M in 100 s. The rate of appearance of O_2 for this period is _____ M/s.
A) 2.3×10^{-5} B) 4.5×10^{-5}
C) 9.0×10^{-5} D) 4.5×10^{-3}
E) 9.0×10^{-3}

15. The equilibrium-constant expression depends on the _____ of the reaction.
A) stoichiometry B) mechanism
C) stoichiometry and mechanism D) the quantities of reactants and products initially present
E) temperature

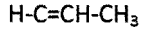
16. At a temperature of _____°C, 0.444 mol of CO gas occupies 11.8 L at 912 torr.
A) 379 B) 73.0
C) 14.0 D) 32.0
E) 116

17. The value of $\Delta H°$ for the reaction below is -126 kJ. The amount of heat that is released by the reaction of 20.0 g of Na_2O_2 with water is _____ kJ.

$$2\,Na_2O_2\,(s) + 2\,H_2O\,(l) \longrightarrow 4NaOH\,(s) + O_2\,(g)$$

A) 16.2 B) 32.3
C) 67.5 D) 64.6
E) -126

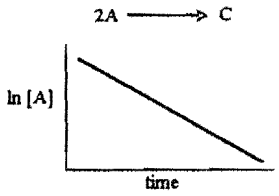
18. The compound below is an _____.



A) alkyne B) alkene
C) alkane D) aromatic compound

E) olefin

19. The graph shown below depicts the relationship between concentration and time for the following chemical reaction.



The slope of this line is equal to _____.

A) k
B) -1/k
C) $\ln[A]_0$
D) -k
E) 1/k

20. The equilibrium constant for reaction 1 is K. The equilibrium constant for reaction 2 is _____.

(1) $SO_2(g) + (1/2)\,O_2(g) \longrightarrow SO_3(g)$
(2) $2SO_3(g) \longrightarrow 2SO_2(g) + O_2(g)$

A) K^2
B) 2K
C) 1/2K
D) $1/K^2$
E) $-K^2$

21. A sample of He gas (2.35 mol) occupies 57.9 L at 300.0 K and 1.00 atm. The volume of this sample is _____ L at 423 K and 1.00 atm.

A) 0.709
B) 41.1
C) 81.6
D) 1.41
E) 57.9

22. The value of ΔE for a system that performs 168 kJ of work on its surroundings and loses 79 kJ of heat is _____ kJ.

A) +247
B) -247
C) +55
D) -55
E) -168

23. Gasoline and water do not mix because gasoline is _____.

A) less dense than water
B) less viscous than water
C) nonpolar and water is polar
D) volatile and water is not
E) polar and water is nonpolar

24. The following reaction occurs in aqueous solution:

$NH_4^+(aq) + NO_2^- \longrightarrow N_2(g) + 2H_2O(l)$

The data below is obtained at 25°C.

$[NH_4^+]$ (M)	$[NO_2^-]$ (M)	Initial rate (M/s)
0.0100	0.200	3.2×10^{-3}
0.0200	0.200	6.4×10^{-3}

The order of the reaction in NH_4^+ is _____.

A) -2
B) -1
C) +2
D) +1
E) 0

25. The equilibrium expression for K_p for the reaction below is _____.

$2O_3(g) \longrightarrow 3O_2(g)$

A) $\dfrac{3PO_2}{2PO_3}$
B) $\dfrac{2PO_3}{3PO_2}$
C) $\dfrac{3PO_3}{2PO_2}$
D) $\dfrac{PO_3^{\,2}}{PO_2^{\,2}}$
E) $\dfrac{PO_2^{\,3}}{PO_3^{\,2}}$

26. If 3.21 mol of a gas occupies 56.2 L at 44°C and 793 torr, 5.21 mol of this gas occupies _____ L under these conditions.

A) 14.7
B) 61.7
C) 30.9
D) 91.2

E) 478

27. The kinetic energy of a 12.5-g object moving at a speed of 81.9 m/s is _____ J.
A) 145 B) 0.950
C) 41.9 D) 41900
E) 1450

28. Alkynes always contain a _____.
A) C-C bond B) C≡C bond
C) C=C bond D) C-H bond
E) C≡H bond

29. A reaction was found to be zero order in A. Increasing the concentration of A by a factor of 3 will cause the reaction rate to _____.
A) remain constant B) increase by a factor of 27
C) increase by a factor of 9 D) triple
E) decrease by a factor of the cube root of 3

30. According to the Arrhenius concept, an acid is a substance that _____.
A) is capable of donating one or more H^+
B) causes an increase in the concentration of H^+ in aqueous solutions
C) can accept a pair of electrons to form a coordinate covalent bond
D) reacts with the solvent to form the cation formed by autoionization of that solvent
E) tastes bitter

31. A sample of gas (24.2 g) initially at 6.00 atm was compressed from 8.00 L to 2.00 L at constant temperature. After the compression, the gas pressure was _____ atm.
A) 12.0 B) 16.0
C) 18.0 D) 20.0
E) 24.0

32. Given the data in the table below and $\Delta H°_{rxn}$ for the reaction

$SO_2Cl_2\,(g) + 2\,H_2O\,(l) \rightarrow H_2SO_4\,(l) + 2HCl\,(g)$ $\Delta H° = -62$ kJ

$\Delta H°_f$ of HCl (g) is _____ kJ/mol.

Substance	$\Delta H_f°$ (kJ/mol)
SO_2 (g)	-297
SO_3 (g)	-396
SO_2Cl_2 (g)	-364
H_2SO_4 (l)	-814
H_2O (l)	-286

A) -184 B) 60
C) -92 D) 30
E) Insufficient data are given.

33. Hydrocarbons containing only single bonds between the carbon atoms are called _____.
A) alkenes B) alkynes
C) aromatics D) alkanes
E) ketones

34. The kinetics of the reaction below were studied and it was determined that the reaction rate increased by a factor of 9 when the concentration of B was tripled. The reaction is _____ order in B.

$A + B \rightarrow P$

A) zero B) first
C) second D) third
E) one-half

35. Which one of the following is a BrØnsted -Lowry acid?
A) $(CH_3)^3NH^+$ B) CH_3COOH

C) HF D) HNO_2

E) all of the above

36. Using the van der Waals equation, the pressure in a 22.4 L vessel containing 1.50 mol of chlorine gas at 0.00°C is _____ atm. (a = 6.49 L^2-atm/mol^2, b = 0.0562 L/mol)

A) 0.993 B) 1.50

C) 0.676 D) 1.91

E) 1.48

37. Given the following reactions

$N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta H = +180.7$ kJ

$2\,N_2O(g) \rightarrow O_2(g) + 2N_2(g)$ $\Delta H = -163.2$ kJ

the enthalpy of reaction for

$2\,N_2O(g) \rightarrow 2NO(g) + N_2(g)$

is _____ kJ.

A) 145.7 B) 343.9

C) -343.9 D) 17.5

E) -145.7

38. Hybridization of the carbon atom indicated by (*) in CH_3-* CH_2- CH_3, *CH_2=CH_2, and CH_3-*C≡CH is _____, _____, and _____, respectively.

A) sp^3, sp^2, sp B) sp^3, sp, sp^2

C) sp, sp^2, sp^3 D) sp, sp^3, sp^2

E) sp^2, sp^3, sp

39. The overall order of a reaction is 2. The units of the rate constant for the reaction are _____.

A) M/s B) $M^{-1}s^{-1}$

C) 1/s D) 1/M

E) s/M^2

40. In basic solution, _____.

A) $[H_3O^+] = [OH^-]$ B) $[H_3O^+] > [OH^-]$

C) $[H_3O^+] < [OH^-]$ D) $[H_3O^+]$ = 0 M

E) $[OH^-] > 7.00$

41. CO (5.00 g) and CO_2 (5.00 g) were placed in a 750.0 mL container at 50.0°C. The partial pressure of CO in the container was _____ atm.

A) 6.29 B) 4.02

C) 10.3 D) 0.292

E) 1.60

42. Given the following reactions

$N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta H = +180.7$ kJ

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = -113.1$ kJ

the enthalpy for the decomposition of nitrogen dioxide into molecular nitrogen and oxygen

$2NO_2(g) \rightarrow N_2(g) + 2\,O_2(g)$

is _____ kJ.

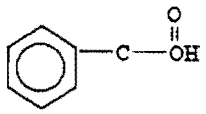
A) 67.6 B) -67.6

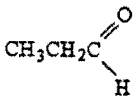
C) 293.8 D) -293.8

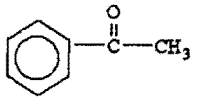
E) 45.5

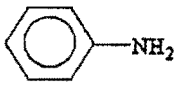
43. Which structure below is not correctly drawn?

A) $CH_3CH_2 — O — CH_2CH_3$

B) 

C) 

D) 

E) 

44. If the rate law for the reaction

2A + 3B → products

is second order in A and first order in B, then the rate law is rate = _____.

A) k[A][B]
B) $k[A]^2[B]^3$
C) $k[A][B]^2$
D) $k[A]^2[B]$
E) $k[A]^2[B]^2$

45. Nitric acid is a strong acid. This means that _____.

A) aqueous solutions of HNO_3 contain equal concentrations of $H^+(aq)$ and $OH^-(aq)$
B) HNO_3 does not dissociate at all when it is dissolved in water
C) HNO_3 dissociates completely to $H^+(aq)$ and $NO_3^-(aq)$ when it dissolves in water
D) HNO_3 produces a gaseous product when it is neutralized
E) HNO_3 cannot be neutralized by a weak base

46. A gas mixture of N_2 and CO_2 has a total pressure of 8.00 atm and contains 12.5 mol of gas. If the partial pressure of N_2 is 3.69 atm, how many moles of CO_2 are in the mixture?

A) 5.77
B) 3.69
C) 4.31
D) 11.0
E) 6.73

47. The temperature of a 15-g sample of lead metal increases from 22 °C to 37 °C upon the addition of 29.0 J of heat. The specific heat capacity of the lead is _____ J/g-K.

A) 7.8
B) 1.9
C) 29
D) 0.13
E) -29

48. Which of the following compounds do <u>not</u> contain an sp^3 hybridized oxygen atom?

A) ketones
B) alcohols
C) ethers
D) esters
E) water

49. A reaction was found to be second order in carbon monoxide concentration. The rate of the reaction _____ if the [CO] is doubled, with everything else kept the same.

A) doubles
B) remains unchanged
C) triples
D) increases by a factor of 4
E) is reduced by a factor of 2

50. Which one of the following is the weakest acid?

A) HF ($K_a = 6.8 \times 10^{-4}$)
B) HClO ($K_a = 3.0 \times 10^{-8}$)
C) HNO_2 ($K_a = 4.5 \times 10^{-4}$)
D) HCN ($K_a = 4.9 \times 10^{-10}$)
E) Acetic acid ($K_a = 1.8 \times 10^{-5}$)

Section B

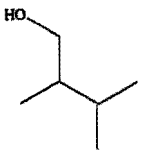
Question 1

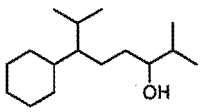
a) Name any six classes of organic compounds (3)

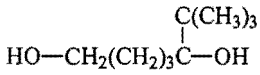
b) Give the functional group and a named example for each of the classes of compounds named above. (6)

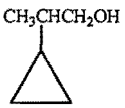
c) Draw all the structural and geometric isomers of pentene, C_5H_{10}, that have an unbranched hydrocarbon chain. (3)

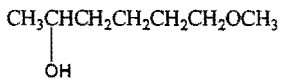
d) Name the following compounds (8)

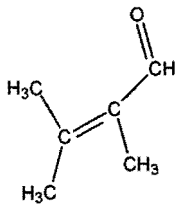
i) 

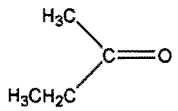
ii) 

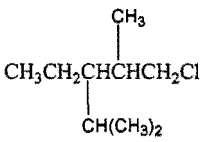
iii) 

iv) 

v) 

vi) 

vii) 

viii) 

Question 2

a) State whether the following statements are true or false:

i) In an exothermic equilibrium reaction, increasing the reaction temperature favors the formation of reactants.

ii) At constant temperature, reducing the volume of a gaseous equilibrium mixture causes the reaction to shift in the direction that increases the number of moles of gas in the system

iii) The effect of a catalyst on a chemical reaction is to react with product, effectively removing it and shifting the equilibrium to the right. Work equals force times distance.

iv) One joule equals 1 kg m^2/s^2. A gas is considered "ideal" if one mole of it in a one-liter container exerts a pressure of exactly 1 atm at room temperature.

v) According to the kinetic-molecular theory, molecules of different gases at the same temperature always have the same average kinetic energy.

vi) Two deviations of real gases from ideal gases which are treated in the van der Waals equation are finite molecular volume and non-zero molecular attractions.

vii) The instantaneous rate of a reaction can be read directly from the graph of molarity versus time at any point on the graph.

viii) The overall reaction order is the sum of the orders of each reactant in the rate law.

ix) The half-life for a first order rate law depends on the starting concentration.

x) An acid containing the COOH group is called a carbo-oxy acid.

Question 3

a) What does Hess's Law state? (2)

b) Given the following standard enthalpy changes of formation, calculate the standard enthalpy change of combustion of silane, SiH_4 at 298 K: (6)

$SiH_4(g) + 2O_{2(g)} \longrightarrow SiO_{2(g)} + 2H_2O_{(l)}$

Substance	$SiH_{4(g)}$	$SiO_{2(g)}$	$2H_2O_{(l)}$
$\Delta H°_f$ (KJ/mol)	+34.0	-910.9	-285.8

c) From the following equations and their corresponding standard enthalpy changes, calculate the $\Delta H°_{rxn}$, for the following reaction at 298 K. (6)

$C_{(s)} + 2H_{2(g)} \longrightarrow CH_{4(g)}$

Given:						ΔH° (KJ)
$C_{(s)}$	+	$O_{2(g)}$	$\longrightarrow$	$CO_{2(g)}$		-393.5
$H_{2(g)}$	+	$\frac{1}{2} O_{2(g)}$	$\longrightarrow$	$H_2O_{(l)}$		-285.8
$CO_{2(g)}$	+	$2H_2O_{(l)}$	$\longrightarrow$	$CH_{4(g)}$	+ $2O_{2(g)}$	+890.3

d. In the first step in the industrial process for making nitric acid, ammonia reacts with oxygen in the presence of a suitable catalyst to form nitric oxide and water vapor:

$4\ NH_{3(g)} + 5\ O_{2(g)} \rightarrow 4\ NO_{(g)} + 6H_2O_{(g)}$

How many liters of $NH_{3(g)}$ at 850 °C and 5.00 atm are required to react with 3.50 M of $O_2(g)$ in this reaction? (6)

SI Units and Conversions

Unit	Symbol	SI units
Newton	N	$kg.m.s^{-2}$
Pascal	Pa	$kg.m^{-1}.s^{-2}$ or $N.m^{-2}$
Joule	J	$kg.m^{2}.s^{-2}$ or N.m or AVs
Watt	W	$kg.m^{2}.s^{-3}$ or $J.s^{-1}$
Coulomb	C	A.s
Volt	V	$kg.m^{2}.s^{-3}.A^{-1}$ or $J.C^{-1}$
Ohm	Ω	$kg.m^{2}.s^{-3}.A^{-2}$ or $v.A^{-1}$
Amp	A	$1Cs^{-1}$

Pressure Units and conversion factors

Pa	I Pa = 1 $N.m^{-2}$
Bar	1 bar = 10^{5} Pa
Atmosphere	1 atm = 101.325 kPa
Torr	760 Torr = 1 atm
	760 Torr = 760 mmHg= 101.325 kPa

General data and Fundamental Constants

Gas constant	R	8.314 51 $J.K^{-1}.mol^{-1}$ 8.314 51 x 10^{-2} $L.bar.K^{-1}.mol^{-1}$ 8.205 78 x 10^{-2} $L.atm.K^{-1}.mol^{-1}$ 62.364 $L.Torr.K^{-1}.mol^{-1}$
Avogadro constant	N_A	6.022169 x 10^{23} mol^{-1}
Molar volume of an ideal gas at 0°C and 1 atm	V_m	22.414 dm^3

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