UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION – 2015, JUNE

TITLE OF PAPER : Introductory Chemistry II

COURSE NUMBER : C112

TIME : Three Hours

INSTRUCTIONS :

1. **Answer all questions in Section A** (Total 40 marks)
2. **Answer any three 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 THIRTEEN Printed Pages Including This Page

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

1. A sample of gas (1.3 mol) occupies _____ L at 22°C and 4.5 atm.
   A) .079 B) .52
   C) 7.0 D) 13
   E) .032
2. A 6.50-g sample of copper metal at 25.0 °C is heated by the addition of 84.0 J of energy. The final temperature of the copper is _____°C. The specific heat capacity of copper is 0.38 J/g-K.
   A) 29.9 B) 25.0
   C) 9.0 D) 59.0
   E) 34.0
3. The general formula of a carboxylic acid is _____.
   A) R-O-R' B) R-CO-R'
   C) R-CO-OH D) R-H
   E) R-CO-OR'
4. The initial concentration of reactant in a first-order reaction is 0.27 M. The rate constant for the reaction is 0.75 s^{-1}. What is the concentration (mol/L) of reactant after 0.50 s?
   A) 0.64 B) 1.7
   C) 0.19 D) 0.11
   E) 0.39
5. In the coal-gasification process, carbon monoxide is converted to carbon dioxide via the following reaction:

   $$CO\ (g) + H_2O\ (g) \rightleftharpoons CO_2\ (g) + H_2\ (g)$$

   In an experiment, 0.35 mol of CO and 0.40 mol of H_2O were placed in a 1.00-L reaction vessel. At equilibrium, there were 0.16 mol of CO remaining. K_{eq} at the temperature of the experiment is _____.
   A) 5.5 B) 0.75
   C) 0.93 D) 1.1
   E) 1.0
6. The density of krypton gas at 1.21 atm and 50.0°C is _____ g/L.
   A) 0.0456 B) 0.262
   C) 0.295 D) 3.82
   E) 7.65
7. The specific heat capacity of methane gas is 2.20 J/g-K. How many joules of heat are needed to raise the temperature of 5.00 g of methane from 36.0 °C to 75.0 °C?
   A) 88.6 B) 429
   C) 1221 D) 0.0113
   E) 22.9
8. The addition of HBr to 2-butene produces _____.
   A) 1-bromobutane B) 2-bromobutane
   C) 1,2-dibromobutane D) 2,3-dibromobutane
   E) no reaction
9. At elevated temperatures, methylisonitrile (CH_3NC) isomerizes to acetonitrile (CH_3CN):

   $$CH_3NC\ (g) \rightarrow CH_3CN\ (g)$$

At the start of an experiment, there are 0.200 mol of reactant and 0 mol of product in the reaction vessel. After 25 min, 0.106 mol of reactant (CH_3NC) remain. There are _____ mol of product (CH_3CN) in the reaction vessel.

A) 0.022 B) 0.106
C) 0.200 D) 0.306
E) 0.094

10. Which of the following expressions is the correct equilibrium-constant expression for the following reaction?

$$CO_2\,(g) + 2H_2\,(g) \longrightarrow CH_3OH\,(g)$$

A) $\dfrac{[CH_3OH]}{[CO_2]}$ B) $\dfrac{[CH_3OH]}{[CO_2][H_2]}$

C) $\dfrac{[CO_2][H_2]^2}{[CH_3OH]}$ D) $\dfrac{[CO_2][H_2]}{[CH_3OH]}$

E) $\dfrac{[CH_3OH]}{[CO_2][H_2]^2}$

11. A 0.325 L flask filled with gas at 0.851 atm and 19°C contains _____ mol of gas.

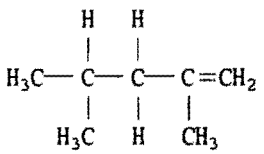
A) .0116 B) .0148
C) 9.42 D) 12.4
E) 80.7

12. The value of $\Delta H°$ for the reaction below is -482 kJ. Calculate the heat (kJ) released to the surroundings when 6.00 g of CO (g) reacts completely.

$$2CO\,(g) + O_2\,(g) \rightarrow 2CO_2\,(g)$$

A) 1450 B) 103
C) 51.6 D) 482
E) -482

13. What is the name of the compound below?



A) 2,4-methylbutene B) 2,5-dimethylpentane
C) 2,4-ethylbutene D) 2,4-dimethyl-1-pentene
E) 2,4-dimethyl-4-pentene

14. The combustion of ethylene proceeds by the reaction

$$C_2H_4\,(g) + 3O_2\,(g) \rightarrow 2CO_2\,(g) + 2H_2O\,(g)$$

When the rate of disappearance of O_2 is 0.23 Ms^{-1}, the rate of disappearance of C_2H_4 is _____ Ms^{-1}.

A) 0.15 B) 0.077

C) 0.69 D) 0.35
E) 0.46

15. The value of K_{eq} for the following reaction is 0.25:

$$SO_2\,(g) + NO_2\,(g) \rightleftharpoons SO_3\,(g) + NO\,(g)$$

The value of K_{eq} at the same temperature for the reaction below is _____.

$$2SO_2\,(g) + 2NO_2\,(g) \rightleftharpoons 2SO_3\,(g) + 2NO\,(g)$$

A) 0.50 B) 0.063
C) 0.12 D) 0.25
E) 16

16. A sample of an ideal gas (3.00 L) in a closed container at 25.0°C and 76.0 torr is heated to 340°C. The pressure of the gas at this temperature is _____ torr.
A) 912 B) 156
C) 76.5 D) 39.5
E) 0.0253

17. Calculate the value of ΔE in joules for a system that loses 73 J of heat and has 150 J of work performed on it by the surroundings.
A) -73 B) -77
C) +77 D) +223
E) -223

18. Alkenes have the general formula _____.
A) C_nH_{2n}. B) C_nH_{2n-2}.
C) C_nH_{2n+2} D) C_nH_n.
E) $C_{2n}H_n$.

19. For a first-order reaction, a plot of _____ versus _____ is linear.
A) ln $[A]_t$, $\frac{1}{t}$ B) ln $[A]_t$, t
C) $\frac{1}{[A]_t}$, t D) $[A]_t$, t
E) t, $\frac{1}{[A]_t}$

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

$$N_2\,(g) + O_2\,(g) \rightleftharpoons 2NO\,(g)$$

A) $\frac{(2PO_2)(2PN_2)}{2P\mathrm{NO}}$ B) $\frac{(PO_2)(PN_2)}{2P\mathrm{NO}}$
C) $\frac{(PO_2)(PN_2)}{P\mathrm{NO}}$ D) $\frac{(2P\mathrm{NO})}{(2PN_2)(2PO_2)}$
E) none of the above

21. A gas originally at 27°C and 1.00 atm pressure in a 3.9 L flask is cooled at constant pressure until the temperature is 11°C. The new volume of the gas is _____ L.

A) 0.27 B) 3.7
C) 3.9 D) 4.1
E) 0.24

22. The kinetic energy of a 23.2-g object moving at a speed of 93.6 m/s is _____ J.

A) 145 B) 102
C) 1450 D) 0.950
E) 102000

23. The general formula of an alkane is _____.

A) $C_{2n}H_{2n+2}$ B) C_nH_{2n}
C) C_nH_{2n+2} D) C_nH_{2n-2}
E) C_nH_n

The data in the table below were obtained for the reaction:

$A + B \rightarrow P$

Experiment Number	[A] (M)	[B] (M)	Initial Rate (M/s)
1	0.273	0.763	2.83
2	0.273	1.526	2.83
3	0.819	0.763	25.47

24. The order of the reaction in A is _____.

A) 1 B) 2
C) 3 D) 4
E) 0

25. The order of the reaction in B is _____.

A) 1 B) 2
C) 3 D) 4
E) 0

26. The overall order of the reaction is _____.

A) 1 B) 2
C) 3 D) 4
E) 0

27. The Keq for the equilibrium below is 7.52 × 10-2 at 480.0°C.

$2Cl_2\,(g) + 2H_2O\,(g) \rightleftharpoons 4HCl\,(g) + O2\,(g)$

What is the value of Keq at this temperature for the following reaction?

4HCl (g) + O2 (g) 2Cl2 (g) + 2H2O (g)

A) 0.0752
B) -0.0752
C) 13.3
D) 5.66 × 10-3
E) 0.150

28. A balloon originally had a volume of 4.39 L at 44°C and a pressure of 729 torr. The balloon must be cooled to _____°C to reduce its volume to 3.78 L (at constant pressure).
A) 38.0
B) 0.00
C) 72.9
D) 273
E) 546

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

$$PCl_3\,(g) + 3\,HCl\,(g) \rightarrow 3\,Cl_2\,(g) + PH_3\,(g)$$

is _____ kJ.

Compound	$\Delta H_f°$ (kJ/mol)
PCl_3 (g)	-288.07
HCl (g)	-92.30
PH_3 (g)	5.40

A) -570.37
B) -385.77
C) 570.37
D) 385.77
E) The $\Delta H°_f$ of Cl_2 (g) is needed for the calculation.

30. A Brønsted-Lowry base is defined as a substance that _____.
A) increases $[H^+]$ when placed in H_2O
B) decreases $[H^+]$ when placed in H_2O
C) increases $[OH^-]$ when placed in H_2O
D) acts as a proton acceptor
E) acts as a proton donor

31. The molecular geometry of each carbon atom in an alkane is _____.
A) octahedral
B) square planar
C) trigonal planar
D) tetrahedral
E) trigonal pyramidal

32. The kinetics of the reaction below were studied and it was determined that the reaction rate did not change 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

33. A fixed amount of gas at 25.0°C occupies a volume of 10.0 L when the pressure is 629 torr. Use Charles's law to calculate the volume (L) the gas will occupy when the temperature is increased to 121°C while maintaining the pressure at 629 torr.
A) 10.9
B) 13.2

C) 2.07 D) 7.56
E) 48.4

34. The value of $\Delta H°$ for the following reaction is -3351 kJ:

$2Al\ (s) + 3O_2\ (g) \rightarrow 2\ Al_2O_3\ (s)$

The value of $\Delta H_f°$ for Al_2O_3 (s) is _____ kJ.

A) -3351 B) -1676
C) -32.86 D) -16.43
E) +3351

35. A substance that is capable of acting as both an acid and as a base is _____.

A) autosomal B) conjugated
C) amphoteric D) saturated
E) miscible

36. Hydrocarbons containing carbon-carbon triple bonds are called _____.

A) alkanes B) aromatic hydrocarbons
C) alkynes D) alkenes
E) olefins

37. If the rate law for the reaction

$2A + 3B \rightarrow$ products

is first order in A and second order in B, then the overall 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) $k[A]^2[B]^2$

38. 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_2 in the container was _____ atm.

A) 4.02 B) 10.3
C) 1.60 D) 0.292
E) 6.31

39. Given the following reactions:

$2S\ (s) + 3O_2\ (g) \rightarrow 2SO_3\ (g)$ $\Delta H = -790$ kJ

$S\ (s) + O_2\ (g) \rightarrow SO_2\ (g)$ $\Delta H = -297$ kJ

the enthalpy of the reaction in which sulfur dioxide is oxidized to sulfur trioxide

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

is _____ kJ.

A) 196 B) -196
C) 1087 D) -1384
E) -543

40. The molar concentration of hydronium ion in pure water at 25°C is _____.

A) 0.00 B) 1.0×10^{-7}
C) 1.0×10^{-14} D) 1.00
E) 7.00

41. Which of the following compounds does <u>not</u> contain a C=O bond?

A) ketones B) aldehydes
C) esters D) amides

E) ethers

42. At elevated temperatures, dinitrogen pentoxide decomposes to nitrogen dioxide and oxygen:

$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$

When the rate of formation of NO_2 is 5.5×10^{-4} M/s, the rate of decomposition of N_2O_5 is _____ M/s.

A) 2.2×10^{-3} B) 1.4×10^{-4}

C) 10.1×10^{-4} D) 2.8×10^{-4}

E) 5.5×10^{-4}

43. SO_2 (5.00 g) and CO_2 (5.00 g) were placed in a 750.0 mL container at 50.0°C. The total pressure in the container was _____ atm.

A) 0.192 B) 4.02

C) 2.76 D) 6.78

E) 1.60

44. The specific heat capacity of lead is 0.13 J/g-K. How much heat (in J) is required to raise the temperature of 15 g of lead from 22 °C to 37 °C?

A) 2.0 B) -0.13

C) 5.8×10^{-4} D) 29

E) 0.13

45. Which solution below has the highest concentration of hydroxide ions?

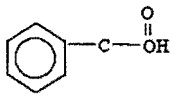
A) pH = 3.21 B) pH = 12.6

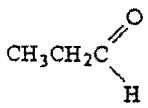
C) pH = 7.93 D) pH = 9.82

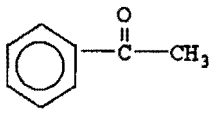
E) pH = 7.00

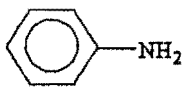
46. Which structure below represents an aldehyde?

A) $CH_3CH_2 — O — CH_2CH_3$

B) 

C) 

D) 

E) 

47. In a gas mixture of He, Ne, and Ar with a total pressure of 8.40 atm, the mole fraction of Ar is _____ if the partial pressures of He and Ne are 1.50 and 2.00 atm, respectively.

A) 0.179 B) 0.238

C) 0.357 D) 0.583

E) 0.417

48. The value of $\Delta H°$ for the reaction below is -1107 kJ:

$2Ba(s) + O_2(g) \rightarrow 2BaO(s)$

How many kJ of heat are released when 15.75 g of Ba (s) reacts completely with oxygen to form BaO (s)?

A) 20.8 B) 63.5

C) 114 D) 70.3

E) 35.1

49. Which statement about hydrocarbons is false?

A) The smallest alkane to have structural (constitutional) isomers has 4 carbon atoms.

B) Cyclic alkanes are structural isomers of alkenes.

C) Alkanes are more reactive than alkenes.

D) Alkanes can be produced by hydrogenating alkenes.

E) Alkenes can be polymerized.

50. What is the general formula for a ketone?

A) R-O-R

B) R-CO-R'

C) R-CO-OH

D) R-OH

E) R-CHO

Section B

Question 1

a. Calculate the pH of 5×10^{-8} M NaOH at 25°C. (Hint: note the concentration of NaOH and show all the steps in your calculation.) (8)

b. 10.00 ml of 0.200 M NH_3 is titrated with 0.150 M HCl (K_a for $NH_4^+ = 5.70 \times 10^{-10}$), calculate the pH of the solution after 5.00 ml of HCl was added. (6)

c. Calculate the concentration of H^+ (*aq*) in:

i. a solution in which $[OH^-]$ is 0.010 *M*, (3)

ii. a solution in which $[OH^-]$ is 1.8×10^{-9} *M* (3)

State whether these solutions are neutral, acidic or basic

Question 2

a. Give the systematic name of the following compound and identify the class i.e. alkane, alkene, alcohol, ketone, aldehyde, carboxylic acid etc: (10)

	Name	Class
i) $CH_3(CH_2)_3CH_3$		
ii) $CH_3CH_2CH{=}CH_2$		
iii) CH_3OCH_3		
iv) CH_3NH_2		
v) $CH_3(CH_2)_3CH(OH)CH_3$		

b) Draw the structures of the following compounds: (10)

i. Cis-2-butene
ii. Octa-2,5-diene
iii. 4,6-Dimethyl-hept-1-yne
iv. 1-methylcyclohexene
v. 2-Bromo-4-hydroxy-pentanoic acid

Question 3

a. A 1.000-L flask is filled with 1.000 mol of $H_2(g)$ and 2.000 mol of $I_2(g)$ at 447 °C. The value of the equilibrium constant K_c for the reaction

b. $$H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$$

at 448 °C is 50.5.What are the equilibrium concentrations of H_2, I_2, and HI in moles per liter? (8)

b. The initial rate of a reaction A + B → C was measured for several different starting concentrations of A and B, and the results are as follows:

Experiment Number	[A] (*M*)	[B] (*M*)	Initial Rate (*M*/s)
1	0.100	0.100	4.0×10^{-5}
2	0.100	0.200	4.0×10^{-5}
3	0.200	0.100	16.0×10^{-5}

Using these data, determine

i. the rate law for the reaction, (2)

ii. the rate constant, (5)

iii. The rate of the reaction when [A] = 0.050 *M* and [B] = 0.100 *M*. *(5)*

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

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