UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION 2006

TITLE OF PAPER: INTRODUCTORY CHEMISTRY

COURSE NUMBER: C101

TIME: THREE (3) HOURS

INSTRUCTIONS:

There are **six** questions. Each question is worth 25 marks. Answer **any four** questions.

Non-programmable electronic calculators may be used.

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Question 1 (25marks)

a. An apparatus consists of a 4.0 L flask containing nitrogen gas at 25°C and 803 kPa, joined to a 10.0 L flask containing argon gas at 25 °C and 47.2 kPa. The stopcock on the connecting tube is opened and the gases mix.
   (i) What is the partial pressure of each gas in the combined volume of the two flasks after mixing?
   (ii) What is the total pressure of the gas mixture? [5]

b. Calculate the mass of ammonium nitrate that should be heated to obtain 100. mL of dinitrogen oxide, N_2O, at 1.00 atm and 298 K in the reaction $NH_4NO_3(s) \rightarrow N_2O(g) + 2H_2O(g)$. [5]

c. Calculate the standard enthalpy of formation of $PCl_5(s)$from the the enthalpy of formation of $PCl_3(l)$ (-319.7 kJ/mol) and
$PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s)$ $\Delta H^\circ = -124$ kJ [3]

d. Calculate the standard reaction enthalpy of of the reduction of iron(II) oxide, a step in the production of iron, $FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$, given the following thermochemical equations:
$3\ Fe_2O_3(s) + CO(g) \rightarrow 2\ Fe_3O_4(s) + CO_2(g)$ $\Delta H^\circ = -47.2$ kJ
$Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$ $\Delta H^\circ = -24.7$ kJ
$Fe_3O_4(s) + CO(g) \rightarrow 3\ FeO(s) + CO_2(g)$ $\Delta H^\circ = +35.9$ kJ [5]

e. Calculate the heat evolved from a mixture of 13.4 L of sulphur dioxide at 1.00 atm and 273 K and 15.0 g oxygen in the reaction
$2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$ $\Delta H^\circ = -198$ kJ. [5]

Question 2 (25marks)

a. Consider the following elements: potassium, sulphur, and fluorine.
   (i) Write the ground state electron configuration of each element
   (ii) Use an appropriate pair of the above elements and their Lewis symbols to illustrate covalent bond formation.
   (iii) Use an appropriate pair of the above elements and their Lewis symbols to illustrate ionic bond formation. [7]

b. Consider the following molecules: BF_3 and ClF_3
   (i) Write the Lewis structure of each.
   (ii) Predict the shape of the molecule using VSEPR model.
   (iii) Predict, giving reasons, which molecule has the higher boiling point. [10]

c. Explain why the lattice enthalpy of MgO (3850 kJ/mol) is greater than that of MgS (3406 kJ/mol) [4]

d. Arrange the cations K^+, Mg^{2+}, Al^{3+}, Cs^+ in order of increasing polarizing power. Explain the reasons for your arrangement. [4]

Question 3 (25marks)

a. Let the equilibrium constants for the reactions

$2\,H_2O(g) \rightleftharpoons 2\,H_2(g) + O_2(g)$ and

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

be K_{p1} and K_{p2}, respectively. Show that the equilibrium constant for the reaction $CO_2(g) + H_2(g) \rightleftharpoons H_2O(g) + CO(g)$ is $K_{p3} = (K_{p2}/K_{p1})^{½}$, and evaluate it at 1565 K, at which temperature $K_{p1} = 1.6 \times 10^{-11}$ and $K_{p2} = 1.3 \times 10^{-10}$. [5]

b. A mixture of 0.0560 mol O_2 and 0.0200 mol N_2O is placed in a 1.00 L reaction vessel at 25 °C. When the reaction $2\,N_2O(g) + O_2(g) \rightleftharpoons 4\,NO_2(g)$ is at equilibrium, 0.0200 mol NO_2 is present.

(iii) What are the equilibrium concentrations of N_2O and O_2

(iv) What is the value of K_c at this temperature. [5]

c. The following kinetic data were obtained for the reaction $A(g) + 2\,B(g) \rightarrow$ Product:

Experiment	Initial concentration, mol/L		Initial rate, Mol L^{-1} s^{-1}
	$[A]_0$	$[B]_0$	
1	0.60	0.30	12.6
2	0.20	0.30	1.4
3	0.60	0.10	4.2
4	0.17	0.25	?

(i) What is the order with respect to each reactant, and the overall order?

(ii) Write the rate law for the reaction.

(iii) Determine the value of the rate constant

(iv) Predict the reaction rate for experiment 4. [8]

d. Dinitrogen pentoxide, N_2O_5, decomposes by first order kinetic with a rate constant 3.7×10^{-5} s^{-1} at 298 K.

(i) What is the half life in hours for the decomposition of N_2O_5 at 298 K?

(ii) If the initial concentration of N_2O_5 is 2.33×10^{-2} mol/L, what will be the concentration remaining after 2.0 h?

(iii) How much time will elapse before the N_2O_5 concentration decreases from 23.3 mmol/L to 17.6 mmol/L? [7]

Question 4 (25marks)

a. Calculate the pH and pOH of a solution containing 14.0 mg NaOH in 250.0 mL of solution. ($K_w = 1.00 \times 10^{-14}$) [4]

b. When the pH of a 0.10 M $HClO_2(aq)$ was measured, it was found to be 1.2. What are the values of the K_a and pK_a? [5]

c. A 100.0 mL buffer solution is 0.15 M $CH_3CO_2H(aq)$ and 0.10 M $NaCH_3CO_2(aq)$. $K_a = 1.8 \times 10^{-5}$ for acetic acid.
   (i) What is the pH of the buffer solution?
   (ii) What will be the pH of the solution after the addition of 3.0 mmol NaOH.? [8]

d. What molar concentration of Ag^+ ions is required for the formation of a precipitate when added to 1.0×10^{-5} M NaCl(aq). What mass of $AgNO_3$ needs to be added for the onset of precipitation in 100.0 mL of this solution. $K_{sp} = 1.6 \times 10^{-10}$ for AgCl. [8]

Question 5 (25marks)

a. Calculate the wavelength of a hydrogen atom travelling at 10.0 m/s. [4]

b. Write the ground state electron configuration of the following species:
   (i) Tl^+ (ii) S^{2-} (iii) Mn^{2+} [6]

c. Explain why, in a many electron atom, a 3s electron is bound more strongly than a 3p electron. [3]

d. Describe briefly how you would show the presence of the following elements in an organic compound:
   (i) Carbon
   (ii) Hydrogen
   (iii) Sulphur
   (iv) Nitrogen
   (v) Chlorine
   (vi) Phosphorus (12)

Question 6 (25marks)

a. An alkene contains five carbon atoms per molecule. Write the structures and names of all the possible isomers of the alkene. [10]

b. Name any five types of organic reactions and for each reaction named, describe the reaction and write an equation to illustrate. [10]

c. Describe briefly a reaction you would perform in a laboratory to differentiate between the following pairs of substances and write equation for any reaction described:
   (i) Cyclohexane and cyclohexene
   (ii) Ethene and ethyne [5]

General data and fundamental constants

Quantity	Symbol	Value
Speed of light	c	$2.997\ 924\ 58 \times 10^{8}$ m s^{-1}
Elementary charge	e	$1.602\ 177 \times 10^{-19}$ C
Faraday constant	$F = N_A e$	9.6485×10^{4} C mol^{-1}
Boltzmann constant	k	$1.380\ 66 \times 10^{-23}$ J K^{-1}
Gas constant	$R = N_A k$	8.314 51 J K^{-1} mol^{-1}
		$8.205\ 78 \times 10^{-2}$ dm^3 atm K^{-1} mol^{-1}
		6.2364×10 L Torr K^{-1} mol^{-1}
Planck constant	h	$6.626\ 08 \times 10^{-34}$ J s
	$\hbar = h/2\pi$	$1.054\ 57 \times 10^{-34}$ J s
Avogadro constant	N_A	$6.022\ 14 \times 10^{23}$ mol^{-1}
Atomic mass unit	u	$1.660\ 54 \times 10^{-27}$ Kg
Mass		
electron	m_e	$9.109\ 39 \times 10^{-31}$ Kg
proton	m_p	$1.672\ 62 \times 10^{-27}$ Kg
neutron	m_n	$1.674\ 93 \times 10^{-27}$ Kg
Vacuum permittivity	$\varepsilon_o = 1/c^2\mu_o$	$8.854\ 19 \times 10^{-12}$ J^{-1} C^2 m^{-1}
	$4\pi\varepsilon_o$	$1.112\ 65 \times 10^{-10}$ J^{-1} C^2 m^{-1}
Vacuum permeability	μ_o	$4\pi \times 10^{-7}$ J s^2 C^{-2} m^{-1}
		$4\pi \times 10^{-7}$ T^2 J^{-1} m^3
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	$9.274\ 02 \times 10^{-24}$ J T^{-1}
nuclear	$\mu_N = e\hbar/2m_p$	$5.050\ 79 \times 10^{-27}$ J T^{-1}
g value	g_e	2.002 32
Bohr radius	$a_o = 4\pi\varepsilon_o\hbar/m_e e^2$	$5.291\ 77 \times 10^{-11}$ m
Fine-structure constant	$\alpha = \mu_o e^2 c/2h$	$7.297\ 35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_e e^4/8h^3 c\varepsilon_o^2$	$1.097\ 37 \times 10^{7}$ m^{-1}
Standard acceleration of free fall	g	9.806 65 m s^{-2}
Gravitational constant	G	$6.672\ 59 \times 10^{-11}$ N m^2 Kg^{-2}

Conversion factors

1 cal	=	4.184 joules (J)	1 erg	=	1×10^{-7} J
1 eV	=	$1.602\ 2 \times 10^{-19}$ J	1 eV/molecule	=	96 485 kJ mol^{-1}

Prefixes

f	p	n	μ	m	c	d	k	M	G
femto	pico	nano	micro	milli	centi	deci	kilo	mega	giga
10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}	10^{9}

PERIODIC TABLE OF ELEMENTS

PERIODS	GROUPS 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1.008 **H** 1																	4.003 **He** 2
2	6.941 **Li** 3	9.012 **Be** 4											10.811 **B** 5	12.011 **C** 6	14.007 **N** 7	15.999 **O** 8	18.998 **F** 9	20.180 **Ne** 10
3	22.990 **Na** 11	24.305 **Mg** 12											26.982 **Al** 13	28.086 **Si** 14	30.974 **P** 15	32.06 **S** 16	35.453 **Cl** 17	39.948 **Ar** 18
4	39.098 **K** 19	40.078 **Ca** 20	44.956 **Sc** 21	47.88 **Ti** 22	50.942 **V** 23	51.996 **Cr** 24	54.938 **Mn** 25	55.847 **Fe** 26	58.933 **Co** 27	58.69 **Ni** 28	63.546 **Cu** 29	65.39 **Zn** 30	69.723 **Ga** 31	72.61 **Ge** 32	74.922 **As** 33	78.96 **Se** 34	79.904 **Br** 35	83.80 **Kr** 36
5	85.468 **Rb** 37	87.62 **Sr** 38	88.906 **Y** 39	91.224 **Zr** 40	92.906 **Nb** 41	95.94 **Mo** 42	98.907 **Tc** 43	101.07 **Ru** 44	102.91 **Rh** 45	106.42 **Pd** 46	107.87 **Ag** 47	112.41 **Cd** 48	114.82 **In** 49	118.71 **Sn** 50	121.75 **Sb** 51	127.60 **Te** 52	126.90 **I** 53	131.29 **Xe** 54
6	132.91 **Cs** 55	137.33 **Ba** 56	138.91 ***La** 57	178.49 **Hf** 72	180.95 **Ta** 73	183.85 **W** 74	186.21 **Re** 75	190.2 **Os** 76	192.22 **Ir** 77	195.08 **Pt** 78	196.97 **Au** 79	200.59 **Hg** 80	204.38 **Tl** 81	207.2 **Pb** 82	208.98 **Bi** 83	(209) **Po** 84	(210) **At** 85	(222) **Rn** 86
7	223 **Fr** 87	226.03 **Ra** 88	(227) ****Ac** 89	(261) **Rf** 104	(262) **Ha** 105	(263) **Unh** 106	(262) **Uns** 107	(265) **Uno** 108	(266) **Une** 109	(267) **Uun** 110								

Atomic mass → 10.811
Symbol → **B**
Atomic No. → 5

TRANSITION ELEMENTS

***Lanthanide Series**	140.12 **Ce** 58	140.91 **Pr** 59	144.24 **Nd** 60	(145) **Pm** 61	150.36 **Sm** 62	151.96 **Eu** 63	157.25 **Gd** 64	158.93 **Tb** 65	162.50 **Dy** 66	164.93 **Ho** 67	167.26 **Er** 68	168.93 **Tm** 69	173.04 **Yb** 70	174.97 **Lu** 71
****Actinide Series**	232.04 **Th** 90	231.04 **Pa** 91	238.03 **U** 92	237.05 **Np** 93	(244) **Pu** 94	(243) **Am** 95	(247) **Cm** 96	(247) **Bk** 97	(251) **Cf** 98	(252) **Es** 99	(257) **Fm** 100	(258) **Md** 101	(259) **No** 102	(260) **Lr** 103

( ) indicates the mass number of the isotope with the longest half-life.