UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2007

TITLE OF PAPER: INTRODUCTORY CHEMISTRY II

COURSE NUMBER: C112

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) (i) What is meant by the term reaction rate?

(ii) Name three factors that affect the rate of a chemical reaction.

(iii) What information is necessary to relate the rate of disappearance of reactants to the rate appearance of the products? [6]

b) Consider the combustion of ethylene,

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

If the concentration of C_2H_4 is decreasing at the rate of 0.37 M/s, what are the rates of change in the concentration of CO_2 and O_2? [4]

c) The iodide ion reacts with hypochlorite ion (the active ingredient in chlorine bleaches) in the following reaction:

$I^-(aq) + OCl^-(aq) \rightarrow OI^-(aq) + Cl^-(aq)$.

This rapid reaction gives the following data:

Expt	$[OCl^-]$, M	I^-, M	Rate, M/s
1	1.5×10^{-3}	1.5×10^{-3}	1.36×10^{-4}
2	3.0×10^{-3}	1.5×10^{-3}	2.72×10^{-4}
3	1.5×10^{-3}	3.0×10^{-3}	2.72×10^{-4}

(i) Determine the rate law for this reaction.

(ii) Calculate the rate constant.

(iii) Calculate the rate when $[OCl^-] = 2.0 \times 10^{-3}$M and $[I^-] = 5.0 \times 10^{-3}$ M. [6]

d) The first order rate constant for the decomposition N_2O_5,

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

At 70 °C is $6.82 \times 10^{-3}\ s^{-1}$. Suppose we start with 0.0250 mol of $N_2O_5(g)$ in a volume of 2.0 l.

(i) How many moles of N_2O_5 will remain after 2.5 min?

(ii) How many minutes will it take for the quantity of N_2O_5 to drop to 0.010 mol?

(iii) What is the half-life of N_2O_5 at 70 °C? [6]

e) A certain first order reaction has a rate constant of $2.75 \times 10^{-2}\ s^{-1}$ at 20 °C. What is the value of k at 60 °C if the E_a = 75.5 kJ/mol. [4]

Question 2 (25marks)

a) The equilibrium $2\ NO(g) + Cl_2(g) \rightleftharpoons 2\ NOCl(g)$ is established at 500 K. An equilibrium mixture of the three gases has partial pressures of 0.095 atm, 0.171 atm, and 0.28 atm for NO, Cl_2 and NOCl, respectively. Calculate K_p for this reaction at 500 K. [5]

b) At 1000 K, $K_p = 1.85$ for the reaction

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

(i) What is the value of K_p for the reaction $2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$?

(ii) What is the value of K_p for the reaction $SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2} O_2(g)$?

(iii) What is the value of K_c for the reaction in part (i)? [7]

c) A mixture of 0.10 mol NO, 0.050 mol H_2 and 0.10 mol H_2O is placed in a 1.0 L vessel at 300 K and the following equilibrium is established:

$2\ NO(g) + 2\ H_2(g) \rightleftharpoons N_2(g) + 2\ H_2O(g)$

At equilibrium [NO] = 0.062 M.

(i) Calculate the equilibrium concentrations of H_2, N_2, and H_2O.

(ii) Calculate K_c. [7]

d) Consider the following equilibrium, for which $\Delta H < 0$:

$2\ SO_2(g) + O_29g) \rightleftharpoons 2\ SO_3(g)$

How will each of the following changes affect an equilibrium mixture of the three gases?

(i) $O_2(g)$ is added to the system.

(ii) The reaction mixture is heated.

(iii) The volume of the reaction vessel is doubled.

(iv) A catalyst is added to the mixture.

(v) The total pressure of the system is increased by adding a noble gas.

(vi) $SO_3(g)$ is removed from the system. [6]

Question 3 (25 marks)

a) The average pH of normal arterial blood is 7.40. At normal body temperature (37 °C), $K_w = 2.4 \times 10^{-14}$. Calculate $[H^+]$, $[OH^-]$ and pOH for blood at this temperature. [5]

b) Lactic acid ($HC_3H_5O_3$) has one acidic hydrogen. A 0.10 M solution of lactic acid has a pH of 2.44. Calculate its K_a. [5]

c) Calculate the molar concentration of OH^- ions in a 0.75 M solution of ethylamine ($C_2H_5NH_2$) given its K_b is 6.4×10^{-4}. [5]

d) Predict whether aqueous solutions of the following compounds are acidic, basic or neutral: (i) NH_4Br (ii) $FeCl_3$ (iii) Na_2CO_3 (iv) $KClO_4$ (v) $NaHC_2O_4$. In each case write a supporting equation. [5]

e) If the molar solubility of CaF_2 is 1.24×10^{-3} mol/L, what is its K_{sp} at this temperature? [5]

Question 4(25 marks)

a) (i) The hydrogen and nitrogen atoms in ammonia are joined together by covalent bonds. What is meant by the term ***covalent bond***?

(ii) By referring to the formation of the ammonium ion from ammonia give the meaning of the term coordinate bond.

(iii) Give the VSEPR model shape of the ammonium ion

(iv) Name the major force of attraction which exists between molecules in liquid ammonia and explain how this type of force arises. [10]

b) Account for the difference in the lattice enthalpies of $MgCl_2$ and $SrCl_2$ are 2326 and 2127 kJ/mol, respectively. [3]

c) Write the Lewis structure of ICl_3 and calculate the formal charge of iodine. [4]

d) (i) What is meant by the term polarizability?

(ii) Arrange the following atoms in order of increasing polarizability: O, S, Se, and Te.

(iii) Arrange the following molecules in order of increasing polarizability: CH_4, $GeCl_4$, $SiCl_4$, SiH_4, and $GeBr_4$.

(iv) Predict the order of boiling points of the substances in part (iii) [8]

Question 5 (25 marks)

a) Describe briefly how you would show the presence of the following elements in an organic compound:

(i) Chlorine

(ii) Sulphur

(iii) Nitrogen [6]

b) Analysis of 8.00 g of an organic compound showed that it contained 3.27g of carbon and 0.366 g of hydrogen. If the molecular mass of the compound is 176 g mol^{-1}, what is the molecular formula? [5]

c) Describe briefly how you would determine the percentage of carbon in an organic sample. [3]

d) Write the structures and the IUPAC names of the three types of alcohol which are isomers of C_4H_9OH. Indicate the type of alcohol for each isomer you write. [6]

e) Write the condensed structural formulae and names of all structural isomers of C_6H_{14}. [5]

Question 6(25 marks)

Write the formula and name of the major organic product for each of the following reactions:

(a) $CH_3CH_2CH_2COO^-Na^+ \quad + \quad NaOH \xrightarrow{Heat}$ (2)

(b) $CH_3COCH_3 \xrightarrow{Zn/HCl}$ (2)

(c) $CH_3CH_2OH \quad + \quad HCl \xrightarrow{ZnCl_2}$ (2)

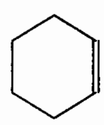
(d) $CH_3CH(Br)\ CH_2CH_3 \xrightarrow{Zn/HCl}$ (2)

(e) $CH_3CH(OH)\ CH_2CH_3 \quad + \quad H_2SO_4$ (2)

(f) $CH_3CH_2CH_2MgBr \quad + \quad H_2O \longrightarrow$ (2)

(g) $CH_3\ CH = CH_2 \quad + \quad HBr \longrightarrow$ (2)

(h)



$+ \ KMnO_4 \xrightarrow{OH^-}$ (2)

(i) $CH_3CH_2CH = CH_2 \xrightarrow[Heat]{Al_2(SO_4)_3}$ (2)

(j) $CH_3CH(Cl)\ CH_2Cl \quad + \quad 2KOH \xrightarrow[Heat]{Ethanol}$ (2)

(k)Bromoethane and bromopropane by Corey, Posner, Whiteside and House synthesis (3)

(l)One molecule of ethyne and two molecules of hydrogen chloride(2)

THE END

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

GROUPS

PERIODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	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								

Key: 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.