UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2005

TITLE OF PAPER: GENERAL CHEMISTRY

COURSE NUMBER: C101

TIME: THREE (3) HOURS

INSTRUCTIONS: There are six (6) questions each worth 25 marks.
Answer any four (4) questions.
A data sheet and periodic table are attached.
Non-programmable calculators may be used.

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Question 1

(a) A natural sample of bromine consists of 50.54% ^{79}Br (mass 78.918 amu) and 49.46% ^{81}Br (mass 80.916 amu).

(i) What is an isotope? *[1]*

(ii) Calculate the average molar mass of bromine from the above data. *[2]*

(iii) Give the electronic configuration of the bromine atom. *[2]*

(b) Calculate the enthalpy change of the reaction

$$2C(s) + H_2(g) \rightarrow C_2H_2(g)$$

From the following data

$$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g)(l) \qquad \Delta H^{\circ} = -2600kJ$$

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^{\circ} = -393kJ$$

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) \qquad \Delta H^{\circ} = -483.6kJ$$

$$H_2O(l) \rightarrow H_2O(g) \qquad \Delta H^{o} = +44kJ$$

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(c) Write thermochemical equations to show:

(i) the standard enthalpy of formation of ammonium chloride is -31.3kJ mol^{-1}. *[2]*

(ii) the standard enthalpy of sublimation of iodine is -49 J mol^{-1}. *[1]*

(iii) when 0.51 g methanol, CH_3OH, burns in excess oxygen it gives off 5840.6 Joules of heat. *[2]*

(d) Describe briefly how you would test for the presence of each of the following elements in an organic compound.

(i) carbon (ii) nitrogen (iii) sulphur
(iv) chlorine (v) hydrogen (vi) phosphorus *[12]*

Question 2

(a) Give four reasons why carbon forms large number of compounds. *[6]*

(b) (i) Name any six types of organic reactions.

(ii) Describe each of the reactions named above and write an equation to illustrate.

[12]

(c) There are three unlabelled gas cylinders in a laboratory. One contains ethane, another one contains ethane while the third one contains ethyne. Describe briefly experiments you would perform to identify and label the cylinders. *[7]*

Question 3

(a) There are three different definations of acids that we used: Arrhenius, Brønsted and the Lewis definition. Briefly distinguish between these. *[4]*

(b) Hydrochloric acid, HCl, is a strong acid whereas hydrocyanic acid, HCN, is a weak acid with an ionization constant of 4.0×10^{-10}.

(i) Briefly distinguish between a strong acid and a concentrated acid. *[1]*

(ii) Calculate the pH of a 0.1 M HCl and the pH of a 0.1 M HCN. *[8]*

(c) Suppose we carryout titrations with 25.00 mL of each acid as the analytes. What is the pH of each analyte solution after the addition of 5.00 mL of 0.250 M NaOH as the titrant? *[12]*

Question 4

(a) A molecular compound is found to have 60.4% Xe, 22.1% O and 17.5% F by mass. The molecular mass is 217.3 g/mol.

(i) Deduce the molecular formula of the compound *[4]*

(ii) What is its Lewis structure? (Xe is the central atom). *[3]*

(iii) Using the VSEPR theory, predict the molecular shape of the compound. *[2]*

(b) The following redox reaction occurs in acidic solution.

$$Cu(s) + NO_3^-(aq) \rightarrow Cu^{2+}(aq) + NO(g)$$

(i) Balance the equation. *[3]*

(ii) Name the reducing and the oxidising agent *[2]*

(c) Chlorine gas can be prepared by heating sodium chloride, sulphuric acid and manganese (IV) oxide together according to the reaction

$$4NaCl(aq) + 2H_2SO_4(aq) + MnO_2(s) \rightarrow 2Na_2SO_4(aq) + MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$$

In a particular preparation, 10.00g MnO_2 was added to 100.0 mL of 1.71 M NaCl and heated with 20.0 mL of 15.0 M sulphuric acid.

(i) Determine the limiting reagent. *[5]*

After the reaction, a total of 758 mL of Cl_2 gas at 25.0 °C and 1.20 atmospheres was obtained.

(ii) Calculate the percentage yield for this reaction. *[5]*

Question 5

(a) Consider the gases NH_3 (g), SO_2 (g) and H_2 (g).

(i) Classify each one as acidic, basic or neutral. *[1½]*

(ii) Arrange them in increasing order of rate of effusion. *[1½]*

(b) Consider the reversible reaction

$$4NH_3(g) + 5O_2(g) \qquad 4NO(g) + 6H_2O(g)$$

Based on Le Chatelier's principle, predict whether each of the following changes would favour the forward or reverse direction. Justify your answer.

(i) addition of H_2O

(ii) addition of a catalyst

(iii) a decrease in pressure (achieved by increasing the volume) *[6]*

(c) The equilibrium constant for the water-gas shift reaction has a value of 0.227 at 2000K.

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

Supposed 0.0500 mol CO and 0.0500 mol H_2O are placed in a 2.00 L flask. What are the equilibrium concentrations of all the species. *[10]*

(d) Consider the reaction of sulphur dioxide and oxygen to give sulphur trioxide.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g), \qquad \Delta H^{\circ} = -198kJ$$

Calculate the heat evolved from a reaction mixture of 13.4L of sulphur dioxide at 1.00 atm and 273 K and 14.0g of oxygen. *[6]*

Question 6

(a) A green aqueous solution was labelled "nickel(II) chloride".

(i) What ions are present in the solution *[1]*

(ii) Write the chemical formulae of the salt dissolved in this solution. *[1]*

(b) Calculate the number of molecules of water, H_2O, present in a cube of ice that measures 5.00 cm on each side. (Assume the density of ice = 0.92 g/cm^3 and that of water = 1.00 g/cm^3). *[2]*

(c) Vinegar is a solution of acetic acid, CH_3COOH in water. In a titration experiment, a student finds that a 5.00 mL sample of vinegar requires 16.96 mL of 0.240 M NaOH solution to reach the end point.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

(i) Calculate the molar concentration of acetic acid in the vinegar. *[3]*

(ii) Calculate the mass percent of acetic acid in the vinegar, if the density of the vinegar is 1.005 g/cm^3. *[3]*

(d) Predict whether a reaction will occur in each of the following cases, write a balanced equation for the reaction which occur and their net ionic equations. If no reaction occurs, write an arrow then "NR" after the chemical symbols of the reactants.

(i) An aqueous solution of sodium carbonate is added to nitric acid.

(ii) An aqueous solution of sodium phosphate is added to an aqueous solution of copper(II) sulphate.

(iii) An aqueous solution of silver(I) nitrate and an aqueous solution of sodium carbonate are mixed. *[6]*

(e) You are given the following colourless solutions with no labels.

(i) silver(I) nitrate (ii) barium hydroxide (iii) copper(II) sulphate

Describe **three** qualitative tests that will help confirm the identity of each substance. In each test proposed, describe the expected result and write the chemical equation for the test, where necessary.

[6]

(f) Complete the following

(i) Of the ions Cl^-, F^- and Br^-, the ion with the smallest radius is _____

(ii) Of the atoms Ar, K and Ca the atom with the largest ionization energy is _____

(iii) Of the atoms As, Sn and S, the atom with the highest electronegativity is _____

[3]

PERIODIC TABLE OF ELEMENTS

PERIODS	GROUPS 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	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

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
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

*Lanthanide Series

**Actinide Series

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

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}