UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION 2007

TITLE OF PAPER: INTRODUCTORY CHEMISTRY I

COURSE NUMBER: C111

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) The element oxygen has three naturally occurring isotopes with 8, 9, and 10 neutrons in the nucleus.
   (i) Write the full chemical symbols for these three isotopes.
   (ii) Describe the similarities and differences between the three kinds of atoms of oxygen. [4]

b) From the following list of elements –Ar, H, Ga, Al, Ca, Br, Ge, K, O-pick the one that best fits each description; use each element once:
   (i) An alkali metal (ii) A noble gas
   (iii) A halogen (iv) An alkaline earth metal
   (v) A metal that forms a 3+ ion (vi) A non-metal that forms a 2- ion
   (vii) A element that resembles aluminium (viii) A metalloid. [8]

c) Calculate the average molar mass of bromine in a natural sample, which consists of 50.54% ^{79}Br (molar mass 78.918 g) and 49.46% ^{81}Br (molar mass 80.916 g/mol). [5]

d) Give the correct formula for the following species:
   (i) Calcium sulphide (ii) Bromic acid
   (iii) Aluminium nitride (iv) Potassium hydrogen sulphite
   (v) Hypoiodite ion (vi) Dinitrogen tetraoxide
   (vii) Sulphur hexafluoride (viii) Copper sulphate pentahydrate [8]

Question 2 (25 marks)

a) Define the term standard molar enthalpy change of formation. [3]

b) The equation below shows the reaction between ammonia and fluorine;

$$NH_3(g) + 3F_2(g) \rightarrow 3HF(g) + NF_3(g)$$

Use the standard enthalpy change of formation (ΔH_f°) data in the table below to calculate the enthalpy change for this reaction. [6]

Compound	$NH_3(g)$	$HF(g)$	$NF_3(g)$
ΔH_f°/kJmol^{-1}	-46	-269	-114

c) From the enthalpies of reaction

$H_2(g) + F_2(g) \rightarrow 2\,HF(g)$ $\Delta H = -537$ kJ
$C(s) + 2\,F_2(g) \rightarrow CF_4(g)$ $\Delta H = -680$ kJ
$2\,C(s) + 2\,H_2(g) \rightarrow C_2H_4(g)$ $\Delta H = +52.3$ kJ

Calculate ΔH for the reaction of ethene with F_2:

$$C_2H_4(g) + 6\,F_2(g) \rightarrow 2\,CF_4(g) + 4HF(g)$$ [6]

d) In a combustion analysis of a 0.152 g sample of the artificial sweetener aspartame, it was found that 0.318 g of carbon dioxide, 0.084 g of water and 0.0145 g of nitrogen were produced.

(i) What is the empirical formula of aspartame? [8]

(ii) The molar mass of aspartame is 294 g/mol. What is its molecular formula? [2]

Question 3 (25 marks)

a) Separate samples of an unknown solution are treated with dilute solutions of HBr, H_2SO_4, and NaOH. A precipitate forms in all three cases. Which of the following cations could the solution contain: K^+, Pb^{2+}, Ba^{2+}? Support your answer with appropriate equations. [4]

b) Which of the following solutions is most basic? 0.5 M NH_3; 0.1 M KOH; 0.1 M $Ca(OH)_2$. Explain [3]

c) Which element is oxidized and which is reduced in the following reactions?

(i) $Ni(s) + Cl_2(g) \rightarrow NiCl_2(s)$

(ii) $PbS(s) + 4\,H_2O_2(aq) \rightarrow PbSO_4(s) + 4\,H_2O(l)$ [4]

d) A 3.455 g sample of a mixture was analysed for barium ion by adding a small excess of sulphuric acid to an aqueous solution of the sample. The resultant reaction produced a precipitate of Barium sulphate, which was collected by filtration, washed, dried and weighed. If 0.2815 g of the barium sulphate was obtained, what was the mass percentage of barium in the sample? [5]

e) The following redox reactions are important in the refining of certain elements.

$\mathbf{SiCl_4} + H_2(g) \rightarrow Si(s) + HCl(g)$

$\mathbf{SnO_2}(s) + C(s) \rightarrow Sn(s) + CO_2(g)$

$\mathbf{V_2O_5}(s) + Ca(l) \xrightarrow{\Delta} V(s) + CaO(s)$

(i) Balance the above equations. [3]

(ii) Name the source compound or ore of the element (in boldface). [3]

(iii) What is the oxidation state of the element being extracted? [3]

Question 4(25 marks)

a) (i) Calculate the smallest increment of energy (a quantum) that can be emitted or absorbed at a wavelength of 438 nm.
(ii) Calculate the energy of a photon of frequency $6.75 \times 10^{12}\ s^{-1}$.
(iii) What wavelength of radiation has photons of energy 2.87×10^{-18}? [6]

b) Use the de Broglie relationship to determine the wavelengths of the following objects:
(i) A 10.0 g bullet fired at 250 m/s.
(ii) A neutron moving at 2.5×10^{6} m/s. [4]

c) Which of the following sets of quantum numbers are permissible for an electron in an atom? For those that are not permissible give a reason.
(i) $n = 2, l = 1, m_l = 1, m_s = ½$
(ii) $n = 5, l = 3, m_l = 4, m_s = ½$
(iii) $n = 2, l = 3, m_l = -1, m_s = -½$
(iv) $n = 1, l = 0, m_l = -1, m_s = ½$ [4]

d) Write the electron configurations of the following species
(i) Se (ii) Ni (iii) Co^{2+} (iv) P^{3-} [8]

e) What is the maximum number of electrons that can occupy the following subshells?
(i) 5p (ii) 3s (iii) 5f

Question 5(25 marks)

a) Write the symbol for each of the following ions, the formula for the compound that the ion would form with oxygen and name the compound
(i) A cobalt iom, $[Ar]3d^6$
(ii) A molybdenum ion, $[Kr]4d^3$
(iii) A thallium ion, $[Xe]4f^{14}5d^{10}6s^2$ [9]

b) Select the element/ion with
(i) Highest first ionization energy Se, S, Te
(ii) Smallest radius Cl^-, Br^-, F^-
(iii) Lowest second ionization energy Ar, K, Ca
(iv) Largest ionic radius Ca^{2+}, Cl^-, K^+
In each give a reason for your choice. [8]

c) In terms of electron configurations obtained from the building up principle, explain why the ionization energies of group 16 elements are smaller than those of group 15 elements. [4]
d) What is a diagonal relationship? Give two examples to illustrate the concept. [4]

Question 6 (25 marks)

a) Oxygen can be produced by thermal decomposition of mercury(II) oxide:

$$2\,HgO(s) \xrightarrow{\Delta} 2Hg(l) + O_2(g)$$

What volume of oxygen is produced at 50.0 °C and 0.947 atm by the decomposition of 27.0 g HgO? [5]

b) If 22.0 L of nitrogen gas at STP is heated to 167 °C and compressed to a volume of 7.00 L, what will be the final pressure? [5]

c) A tank contains 78.0 g N_2 and 42.0 g Ne at a total pressure of 3.75 atm and a temperature of 50.0 °C. Calculate the partial pressure of each gas and the volume of the tank. [5]

d) What mass of ammonia will exert the same pressure as 12 mg of hydrogen sulphide, H_2S, in the same container under the same conditions? [5]

e) What is the molar mass of a compound that takes 2.7 times longer to effuse through a porous plug than it did for the same amount of XeF_2 at the same temperature and pressure. [5]

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 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

*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.