UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2008/09

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.

A data sheet and a periodic table are attached

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Question 1 (25marks)

(a) (i) Calculate the smallest increment of energy that can be emitted or absorbed at a wavelength of 10.8 mm.

(ii) Calculate the energy of a photon from an FM radio station at a frequency of 101.1 MHz.

(iii) For what frequency of radiation will a mole of photons have energy 24.7 kJ? [8]

(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 lithium atom moving at 2.5×10^5 m/s. [7]

(c) The electron in the H atom is described by four quantum numbers.

(i) Define the four quantum numbers, give their possible values and explain the physical significance of each.

(ii) What does the Pauli Exclusion Principle say about the possible values of the four quantum numbers? [10]

Question 2 (25marks)

(a) How many possible values for l and m_l are there when $n = 3$ [2]

(b) Give the values for n, l, and m_l for

(i) each orbital in the *2p* subshell, (ii) each orbital in the *5d* subshell. [4]

(c) Which of the following are permissible sets of quantum numbers for an electron in a hydrogen atom? For those combinations that are permissible, write the appropriate designation for the subshell to which the orbital belongs (e.g. 1*s*, and so on). For those that are not permissible briefly explain why they are not permissible.

(i) $n = 2, l = 1, m_l = 1$; (ii) $n = 1, l = 0, m_l = -1$;

(iii) $n = 4, l = 2, m_l = -2$; (iv) $n = 3, l = 3, m_l = 0$? [8]

(d) Write the condensed electron configurations for the following atoms, using the appropriate noble-gas core abbreviations and indicate how many unpaired electrons each has:

(i) Cs (ii) Ni (iii) S (iv) Ga [8]

(e) Explain why a 2s and 2p subshells have the same energy in the H atom but have different energies in many electron atoms e.g. in Li. [3]

Question 3 (25marks)

(a) How do the sizes of atoms change as we move from left to right across a row in the periodic table and from top to bottom in a group in the periodic table?. Arrange the following atoms in order of increasing atomic radius: F, P, S, As [3]

(b) Why are monatomic cations smaller than their corresponding neutral atoms? Why are monatomic anions larger than their corresponding neutral atoms? [4]

(c) Arrange the following ions in order of increasing radius. [4]
(i) Co^{3+}, Fe^{2+}, Fe^{3+}; (ii) S^{2-}, Cl^{-}, K^{+}, Ca^{2+}

(d) Why does F have a larger first ionization energy than O? [3]

(e) Why does Li have a much larger second ionization energy than Be? [3]

(f) Write a Lewis formula for each of the following ionic salts
(i) Na_2O (ii) NH_4Cl [4]

(g) Use Lewis symbols and Lewis structures to diagram the formation of PF_3 from P and F atoms. [4]

Question 4 (25marks)

(a) Write one or more appropriate Lewis structures for the nitrite ion, NO_2^- and predict its shape. [5]

(b) Write the Lewis structure and predict the shape and polarity of SF_4[5]

(c) A fluoride of xenon is prepared by reacting 0.2045 g of Xe with excess F_2 to form 0.3229 g of product.
(i) Determine the molecular formula of the product.
(ii) What is the Lewis structure of the product?
(iii) Predict the shape of the molecule and its polarity [9]

(d) What type of intermolecular force accounts for the following differences in each case?
(i) CH_3OH boils at 65°C, CH_3SH boils at 6°C.
(ii) Xe is liquid at 1 atmosphere and 120 K, whereas Ar is a gas. [6]

Question 5 (25 marks)

(a) Name each of the following oxides, assuming that the compounds are ionic,
(i) MnO_2 (ii) V_2O_5 (iii) Al_2O_3 [3]

(b) Convert these descriptions into balanced equations:

(i) Boron sulphide, $B_2S_3(s)$, reacts violently with water to form dissolved boric acid, H_3BO_3, and hydrogen sulphide gas.
(ii) Phosphine, $PH_3(g)$, combusts in oxygen gas to form gaseous water and solid tetraphosphorus decoxide.
(iii) When liquid phosphorous trichloride is added to water, it reacts to form aqueous phosphorous acid, $H_3PO_3(aq)$, and aqueous hydrochloric acid. [6]

(c) Identify the following reactions as redox, precipitation or acid-base neutralization reaction. For the redox reactions identify the oxidizing and reducing agents. For the precipitation reactions, write the net ionic equation and for the neutralization reaction identify the acid and the base. [8]

(i) $Cu(OH)_2(s) + 2\,HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2\,H_2O(l)$

(ii) $Fe_2O_3(s) + 3\,CO(g) \rightarrow 2Fe(s) + 3\,CO_2(g)$

(iii) $Sr(NO_3)_2\,(aq) + H_2SO_4(aq) \rightarrow SrSO_4(s) + 2\,HNO_3(aq)$

(iv) $4\,Zn(s) + 10\,H^+(aq) + 2\,NO_3^-(aq) \rightarrow 4\,Zn^{2+}(aq) + N_2O(g) + 5\,H_2O(l)$

(d) You have a stock solution of 14.8 *M* NH_3. How many millilitres of this solution should you dilute to make 100.0 mL of 0.250 *M* NH_3? [3]

(e) In a titration, 3.25 g sample of an acid, HX, requires 68.8 mL of a 0.750 M NaOH(aq) solution for complete reaction. What is the molar mass of the acid? [5]

Question 6 (25 marks)

(a) Several brands of antacids use $Al(OH)_3$ to react with stomach acid, which contains primarily HCl:

$$Al(OH)_3(s) + HCl(aq) \rightarrow AlCl_3(aq) + H_2O(l)$$

(i) Balance this equation.
(ii) Calculate the number of grams of HCl that can react with 0.500 g of $Al(OH)_3$.
(iii) Calculate the number of grams of $AlCl_3$ and the number of grams of H_2O formed when 0.500 g of $Al(OH)_3$ reacts.
(iv) Show that your calculations in parts (ii) and (iii) are consistent with the law of conservation of mass. [8]

(b) A sample of 1.50 g of lead(II) nitrate is mixed with 125 mL of 0.100 M sodium sulphate solution.

(i) Write the chemical equation for the reaction that occurs.

(ii) Determine the limiting reactant in the reaction.

(iii) What are the concentrations of all the ions that remain in solution after the reaction is complete? [9]

(c) You are given a cube of silver metal that measures 1.000 cm on each side. The density of silver is 0.49 g cm^{-3}.

(i) How many silver atoms are in this cube?

(ii) Because atoms are spherical, they cannot occupy all the space of the cube. The silver atoms pack in the solid in such a way that 74% of the volume of the solid is actually occupied by silver atoms. Calculate the volume of a single silver atom.

(iii) Given that the volume of a sphere is $V = \frac{4\pi r^3}{3}$, calculate the radius in pm of a silver atom. [8]

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										Atomic mass → Symbol → Atomic No. →	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					TRANSITION ELEMENTS						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								

***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.