UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2006

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) Define atomic number and mass number. Which of these can vary without changing the identity of the element? [3]

b) Copy and fill in the gaps of the following table, assuming each column represents a ***neutral atom.*** [8]

Symbol	^{52}Cr				
Protons		25			82
Neutrons		30	64		
Electrons			48	86	
Mass number				222	207

c) Naturally occurring magnesium has the following isotopic abundances:

Isotope	Abundance %	Atomic mass g/mol
^{24}Mg	78.99	23.98504
^{25}Mg	10.00	24.98584
^{26}Mg	11.01	25.98259

What is the average atomic mass of magnesium? [4]

d) Predict the chemical formula and name of the compound formed by the following elements:
(i) Ga and F (ii) Li and H (iii) K and S [6]

e) Name the following compounds:
(i) $HBrO_3$ (ii) P_4F_6 (iii) IF_5 (iv) N_2O [4]

Question 2 (25 marks)

a)

compound	ΔH_f^o/kJmol^{-1}
$NO_2(g)$	+34
$CO_2(g)$	-394
$H_2O(g)$	-242

$$C_3H_5N_3O_9(l) + \frac{11}{4}O_2(g) \rightarrow 3CO_2(g) + \frac{5}{2}H_2O(g) + 3NO_2(g) \quad \Delta H^o = -1540 \text{ kJmol}^{-1}$$

(i) Standard enthalpy of formation is defined using the term ***standard state.*** What does the term ***standard state*** mean? [2]

(ii) Use the data given above to calculate the standard enthalpy of formation of nitroglycerine, $C_3H_5N_3O_9$. [5]

(iii) Calculate the standard enthalpy change for the following decomposition of nitroglycerine.

$$C_3H_5N_3O_9(l) \rightarrow 3CO_2(g) + \frac{5}{2}H_2O(g) + \frac{3}{2}N_2(g) + \frac{1}{4}O_2(g)$$ [4]

(iv) Given that the enthalpy of formation of liquid water is -286 kJ mol^{-1}, calculate the enthalpy change for the process $H_2O(l) \rightarrow H_2O(g)$ and explain the sign of ΔH^o in your answer. [3]

b) 45.00 mL of 0.010 M HCl(aq) was mixed with 65.00 mL of 0.010 M $Ba(OH)_2$(aq) in a styrofoam cup calorimeter at 26.21 °C and allowed to react.

(i) Write a balanced chemical equation for the reaction and identify the reaction type. [3]

(ii) Which reactant is in excess? [3]

(iii) Assuming the solutions have the same specific heat capacity as water, i.e. 4.184 J $°C^{-1}g^{-1}$ and density 1.0 g/cm^3, calculate the final temperature of the mixture after reaction has gone to completion. The reaction enthalpy is -55.84 kJ/mol H_3O^+. [5]

Question 3(25 marks)

a) You know that an unlabelled bottle contains a solution of one of the following: $AgNO_3$, $CaCl_2$ or $Al_2(SO_4)_3$. A friend suggests you test a portion of each solution with $Ba(NO_3)_2$ and then with NaCl solutions. Explain, with supporting equations, how these two tests together would be sufficient to determine which salt is present in the solution. [6]

b) Write balance molecular and net ionic equations for the reaction that occurs when

(i) Solid $CaCO_3$ reacts with an aqueous solution of nitric acid. [2]

(ii) Solid iron(II) sulphide reacts with an aqueous solution of hydrobromic acid. [2]

c) Which of the following are redox reactions? For those that are, indicate which element is oxidized and which is reduced. For those that are not indicate whether they are precipitation or acid-base reactions.

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

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

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

(iv) $Zn(s) + 10H^+(aq) + 2NO_3(aq) \rightarrow 4Zn^{2+}(aq) + N_2O(g) + 5H_2O(l)$ [6]

d) 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. [2]
   (ii) Which is the limiting reactant in the reaction? [3]
   (iii) What is the concentration of sulphide ions that remain in solution after the reaction is complete? [4]

Question 4(25 marks)

a) One type of sunburn occurs on exposure to uv light of wavelength in the vicinity of 325 nm.
   (i) What is the energy of a photon of this wavelength?
   (ii) What is the energy of a mole of these photons?
   (iii) How many photons are in a 2.00 mJ burst of this radiation? [6]

b) Among the elementary subatomic particles of physics is the muon, which decays within a few nanoseconds after formation. The muon has a rest mass 206.8 times that of an electron. Calculate the de Broglie wavelength of a muon travelling at 8.85×10^5 cm/s. [5]

c) What is the maximum number of electrons in an atom that can have the following quantum numbers:
   (i) $n = 2, m_s = -½$ (ii) $n = 5, l = 3$ (iii) $n = 4, l = 3, m_l = -3$
   (iv) $n = 4, l = 1, m_l = 1, m_s = ½$ [8]

d) Identify the specific element that corresponds to each of following electron configurations:
   (i) $1s^2 2s^2 2p^6 3s^2$, (ii) $[Ne]3s^2, 3p^1$, (iii) $[Ar]3d^5 4s^1$ [6]

Question 5(25 marks)

a) Write the electron configurations of the following species:
   (i) Sr (ii)Fe (iii) As^+ (iv) S^{2-} [8]

b) Explain why atomic radii increase down a group. [3]

c) Identify the species with the larger radius in the following pairs. In each case give a brief explanation:
   (i) Na or Mg (ii) Mg^{2+} or Al^{3+} (iii) N^{3-} or O^{2-} (iv) Cl or Br [8]

d) Explain why
   (i) The electron affinity of chlorine is greater than that of bromine [3]
   (ii) The electron affinity of the sulphur atom is greater than that of the S^{2-} ion. [3]

Question 6(25 marks)

a) A sample of an unknown liquid weighing 0.495 g is collected as vapour in a 127 mL flask at 98 °C. The pressure of the vapour in the flask is then measured and found to 691 Torr. What is the molar mass of the liquid? [5]

b) A cement company uses 1.00 x 10^5 kg of limestone daily. The limestone decomposes on heating forming lime and carbon dioxide:

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

What volume of carbon dioxide at 735 Torr and 25 °C is released into the atmosphere daily by this company? [5]

c) A 2.00 L container contains a mixture of 72.0 g N_2 and 66.0 g Ar. Calculate the partial pressure of each gas and the total pressure if the temperature is 45.0 °C. [5]

d) Nitrous oxide can be formed by thermal decomposition of ammonium nitrate:

$$NH_4NO_3(s) \xrightarrow{\Delta} N_2O(g) + 2\ H_2O(g)$$

What mass of ammonium nitrate would be required to produce 145 L of N_2O at 3.79 atm and 42 °C? [5]

e) Two identical balloons are separately filled with hydrogen and helium gas. When half the hydrogen has been lost by effusion, how much helium will have been lost? [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	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.