

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

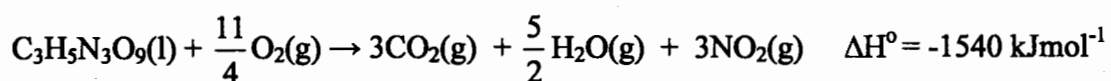
What is the average atomic mass of magnesium? [4]

- d) Predict the chemical formula and name of the compound formed by the following elements: [6]
- (i) Ga and F (ii) Li and H (iii) K and S
- e) Name the following compounds: [4]
- (i) HBrO₃ (ii) P₄F₆ (iii) IF₅ (iv) N₂O

Question 2 (25 marks)

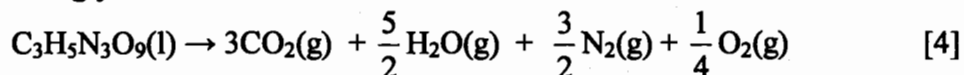
a)

compound	$\Delta H_f^\circ / \text{kJmol}^{-1}$
NO ₂ (g)	+34
CO ₂ (g)	-394
H ₂ O(g)	-242



- (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, C₃H₅N₃O₉. [5]

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



- (iv) Given that the enthalpy of formation of liquid water is -286 kJ mol^{-1} , calculate the enthalpy change for the process $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$ and explain the sign of ΔH° in your answer. [3]

- b) 45.00 mL of 0.010 M $\text{HCl}(\text{aq})$ was mixed with 65.00 mL of 0.010 M $\text{Ba}(\text{OH})_2(\text{aq})$ 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. $4.184 \text{ J }^\circ\text{C}^{-1}\text{g}^{-1}$ and density 1.0 g/cm^3 , calculate the final temperature of the mixture after reaction has gone to completion. The reaction enthalpy is $-55.84 \text{ kJ/mol H}_3\text{O}^+$. [5]

Question 3(25 marks)

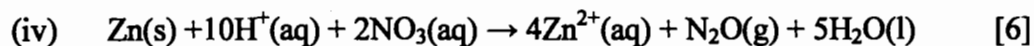
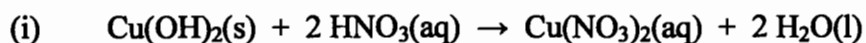
- a) You know that an unlabelled bottle contains a solution of one of the following: AgNO_3 , CaCl_2 or $\text{Al}_2(\text{SO}_4)_3$. A friend suggests you test a portion of each solution with $\text{Ba}(\text{NO}_3)_2$ and then with NaCl solutions. Explain, with supporting equations, how these two tests 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.



- d) A sample of 1.50 g of lead(II) nitrate is mixed with 125 mL of 0.100 M sodium sulphate solution.
- Write the chemical equation for the reaction that occurs. [2]
 - Which is the limiting reactant in the reaction? [3]
 - What is the concentration of sulphide ions that remain in solution after the reaction is complete? [4]

Question 4(25 marks)

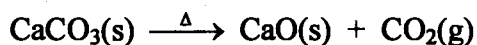
- a) One type of sunburn occurs on exposure to uv light of wavelength in the vicinity of 325 nm.
- What is the energy of a photon of this wavelength? [2]
 - What is the energy of a mole of these photons? [3]
 - How many photons are in a 2.00 mJ burst of this radiation? [6]
- b) Among the elementary subatomic 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:
- $n = 2, m_s = -\frac{1}{2}$
 - $n = 5, l = 3$
 - $n = 4, l = 3, m_l = -3$
 - $n = 4, l = 1, m_l = 1, m_s = \frac{1}{2}$
- [8]
- d) Identify the specific element that corresponds to each of following electron configurations:
- $1s^2 2s^2 2p^6 3s^2$,
 - $[\text{Ne}]3s^2 3p^1$,
 - $[\text{Ar}]3d^5 4s^1$
- [6]

Question 5(25 marks)

- a) Write the electron configurations of the following species:
- Sr
 - Fe
 - As^+
 - 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:
- Na or Mg
 - Mg^{2+} or Al^{3+}
 - N^{3-} or O^{2-}
 - Cl or Br
- [8]
- d) Explain why
- The electron affinity of chlorine is greater than that of bromine [3]
 - The electron affinity of the sulphur atom is greater than that of the S^{2-} ion. [3]

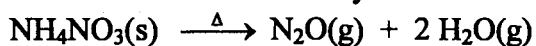
Question 6(25 marks)

- 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 1.00×10^5 kg of limestone daily. The limestone decomposes on heating forming lime and carbon dioxide:



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 N₂ 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:



What mass of ammonium nitrate would be required to produce 145 L of N₂O 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	$2.997\,924\,58 \times 10^8 \text{ m s}^{-1}$
Elementary charge	e	$1.602\,177 \times 10^{-19} \text{ C}$
Faraday constant	$F = N_A e$	$9.6485 \times 10^4 \text{ C mol}^{-1}$
Boltzmann constant	k	$1.380\,66 \times 10^{-23} \text{ J K}^{-1}$
Gas constant	$R = N_A k$	$8.314\,51 \text{ J K}^{-1} \text{ mol}^{-1}$ $8.205\,78 \times 10^{-2} \text{ dm}^3 \text{ atm K}^{-1} \text{ mol}^{-1}$ $6.2364 \times 10 \text{ L Torr K}^{-1} \text{ mol}^{-1}$
Planck constant	h $\hbar = h/2\pi$	$6.626\,08 \times 10^{-34} \text{ J s}$ $1.054\,57 \times 10^{-34} \text{ J s}$
Avogadro constant	N_A	$6.022\,14 \times 10^{23} \text{ mol}^{-1}$
Atomic mass unit	u	$1.660\,54 \times 10^{-27} \text{ Kg}$
Mass		
electron	m_e	$9.109\,39 \times 10^{-31} \text{ Kg}$
proton	m_p	$1.672\,62 \times 10^{-27} \text{ Kg}$
neutron	m_n	$1.674\,93 \times 10^{-27} \text{ Kg}$
Vacuum permittivity	$\epsilon_0 = 1/c^2 \mu_0$ $4\pi\epsilon_0$	$8.854\,19 \times 10^{-12} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$ $1.112\,65 \times 10^{-10} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$
Vacuum permeability	μ_0	$4\pi \times 10^{-7} \text{ J s}^2 \text{ C}^{-2} \text{ m}^{-1}$ $4\pi \times 10^{-7} \text{ T}^2 \text{ J}^{-1} \text{ m}^3$
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	$9.274\,02 \times 10^{-24} \text{ J T}^{-1}$
nuclear	$\mu_N = e\hbar/2m_p$	$5.050\,79 \times 10^{-27} \text{ J T}^{-1}$
g value	g_e	2.002 32
Bohr radius	$a_0 = 4\pi\epsilon_0 \hbar^2 / m_e e^2$	$5.291\,77 \times 10^{-11} \text{ m}$
Fine-structure constant	$\alpha = \mu_0 e^2 c / 2h$	$7.297\,35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_e e^4 / 8h^3 c \epsilon_0^2$	$1.097\,37 \times 10^7 \text{ m}^{-1}$
Standard acceleration of free fall	g	$9.806\,65 \text{ m s}^{-2}$
Gravitational constant	G	$6.672\,59 \times 10^{-11} \text{ N m}^2 \text{ Kg}^{-2}$

Conversion factors

1 cal	=	4.184 joules (J)	1 erg	=	$1 \times 10^{-7} \text{ J}$
1 eV	=	$1.602\,2 \times 10^{-19} \text{ J}$	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	GROUPS																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	IA	IIA	IIIB	IVB	VB	VIB	VIIIB	VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA	VIIIA	
1	1.008 H 1																		
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 →
Symbol →
Atomic No. →

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.