UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION 2007/8

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) Explain in molecular terms why the pressure of a gas increases with increasing temperature when the volume is held constant. [3]

b) A quantity of N_2 gas originally held at 4.75 atm pressure in a 1.00 L container at 26 °C is transferred into a 10.0 L container at 20 °C. A quantity of O_2 gas originally at 5.25 atm and 26 °C in a 5.00 L container is transferred to the same container.
   (i) Calculate the partial pressures of N_2 and O_2 in the new container.
   (ii) Calculate the total pressure. [6]

c) Vessel A contains CO(g) at 0 °C and 1 atm. Vessel B contains SO_2(g) at 20 °C and 0.5 atm. The two vessels have the same volume.
   (i) Which vessel contains more molecules?
   (ii) Which contains more mass?
   (iii) In which vessel is the average kinetic energy of the molecules higher? [6]

d) Hexane burns according to the following equation:

$$2\,C_6H_{14}(g) + 19\,O_2(g) \rightarrow 12CO_2(g) + 14\,H_2O(g)$$

   (i) What volume of CO_2 will be formed by burning 9.00 L hexane, with the two volumes being measured under the same conditions?
   (ii) What volume of oxygen will be needed? [5]

e) Copper oxide can be reduced to copper metal by heating in a stream of hydrogen gas:

$$CuO(s) + H_2(g) \xrightarrow{\Delta} Cu(s) + H_2O(l)$$

What volume of hydrogen at 27 °C and 722 Torr would be required to react with 95.0 g of CuO? [5]

Question 2 (25 marks)

a) Distinguish between theoretical yield, actual yield and percent yield. [3]

b) Phenol (C_6H_5OH), often used as a disinfectant in stables and drains is a common water pollutant. It can be converted to less harmful oxalic acid ($H_2C_2O_4$) by reaction with ozone:

$$C_6H_5OH + 11\,O_3 \rightarrow 3\,H_2C_2O_4 + 11\,O_2$$

   (i) What mass of ozone would be required to react with 125.0 g of phenol?
   (ii) What mass of oxalic acid would be produced? [7]

c) Cadmium hydroxide, used in storage battery electrodes, is prepared by precipitation from a solution containing cadmium chloride and potassium hydroxide:

$$CdCl_2(aq) + 2\,KOH(aq) \rightarrow Cd(OH)_2(s) + 2\,KCl(aq)$$

What mass of cadmium hydroxide could be prepared from 125 mL of 0.250 M $CdCl_2$ mixed with 125 mL of 0.450 M KOH? [7]

d) Oxygen difluoride can be prepared by bubbling gaseous fluorine into 0.5 M solution of NaOH:

$$2\,F_2(g) + 2\,NaOH(aq) \rightarrow OF_2(g) + 2NaF(aq) + H_2O(l)$$

Oxygen difluoride can be used to prepare compounds such as O_2AsF_6, containing the dioxygen cation, O_2^+, by the following reaction:

$$4\,OF_2 + 2\,AsF_5 \rightarrow 2\,O_2AsF_6 + 3F_2$$

If 14.0 g F_2 is bubbled through 650 mL of 0.500 M NaOH to prepare OF_2 with a 78.0% yield, how many grams of O_2AsF_6 can be prepared? [8]

Question 3 (25 marks)

a) (i) What is the frequency of gamma rays having a wavelength 2.00×10^{-5} nm?
(ii) What is the energy (in kJ/mol) of this radiation? [5]

b) Calculate the wavelength of a proton of mass 1.67×10^{-24}g having a velocity of 1.80×10^{8} cm/s. [3]

c) For Cl in its ground state, indicate how many electrons have each of the following quantum number values:
(i) $n = 2$ (ii) $l = 3$ (iii) $m_l = 0$ (iv) $n = 2$ $m_s = ½$
(v) $l = 1$ $m_l = -1$ (vi) $n = 1$ $l = 0$ [6]

d) Write the electron configurations of the following species
(i) Sb (ii) Cr^{2+} (iii) C^{4-} (iv) S [8]

e) Identify the atom represented by the following electron configuration
(i) $[Ar]4s^2 3d^1$ (ii) $[Kr]\,5s^2 4d^{10} 5p^5$ (iii) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$. [3]

Question 4 (25 marks)

a) Arrange the following species in order of increasing size. In each case give a brief explanation:
   (i) C, N, S, O
   (ii) Fe^{2+}, Fe^{3+}
   (iii) Br^-, Cl^-, I^-, F^- [6]

b) Which of each pair should have the greater first ionization energy? Justify your choice:
   (i) O or F (ii) Si or Ge (iii) N or O [6]

c) Arrange the following species in order of increasing (more negative) electron affinity: O, S, Se, Cl. Explain briefly. [3]

d) Which element should be more reactive, O or S? Explain your answer. [3]

e) Name an element that can be classified as a member of each of the following groups:
   (i) noble gases (ii) alkali metals (iii) halogens (iv) nonmetals

   (v) transition metals (vi) metalloids (vii) alkaline earth metals [7]

Question 5 (25 marks)

a) Define the terms (i) specific heat capacity (ii) molar heat capacity. [3]

b) Metallic copper can be produced from copper(II) oxide by the reaction with hydrogen:

$$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l) \qquad \Delta H^o = -128.8 \text{ kJ}$$

If the standard enthalpy of formation of liquid water is -285.83 kJ/mol, what is the standard enthalpy of formation of copper(II) oxide? [4]

c) Calculate the heat evolved from a reaction mixture of 13.4 L of sulphur dioxide at 1.00 atm and 273 K and 15.0 g oxygen in the reaction

$$2\,SO_2(g) + O_2(g) \rightarrow 2\,SO_3(g) \qquad \Delta H^o = -198 \text{ kJ}$$ [8]

d) Dinitrogen tetroxide reacts with carbon monoxide to form carbon dioxide and a gaseous oxide of nitrogen, which contains 63.65% N and 36.35% O by mass. Known enthalpies of formation are:

Compound	ΔH_f^o, kJ/mol
$N_2O_4(g)$	9.7
$CO(g)$	-110
$CO_2(g)$	-393

Under standard conditions, reaction of a mixture of 40.35 g N_2O_4 and 51.16 g CO in a calorimeter raised the temperature of 3255.0 g water by 25.09 °C. The specific heat of water is 4.184 J g^{-1} $°C^{-1}$.

(i) Determine the formula of the oxide of nitrogen and name it.
(ii) Write a balanced equation for the reaction.
(iii) Determine how much of the oxide of nitrogen is formed.
(iv) How much heat is produced by the reaction?
(v) Calculate the standard heat of formation of the oxide of nitrogen. [10]

Question 6 (25 marks)

a) Write a complete balanced equation for each of the following reactions:

(i) When solid sodium hydride is added to water, hydrogen gas is released and aqueous sodium hydroxide is formed

(ii) Solid calcium phosphate reacts with a mixture of solid silicon dioxide and solid carbon to form solid phosphorus, solid calcium silicate and gaseous carbon monoxide. [6]

b) Copy the following table and fill in the gaps [5]

Symbol	$^{75}As^{3-}$			
Protons		28	53	
Neutrons		31	74	118
Electrons		26		76
Net Charge			-1	3+

c) Give the name or chemical formula, as appropriate of the following compounds

(i) cobalt(III) sulphate (ii) $HClO_3(aq)$ (iii) sulphurous acid

(iv) barium carbonate (v) ICl_3 (vi) S_2Cl_2

(vii) magnesium hydrogen carbonate (viii) MnO_2 [8]

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

(i) $Cd(s) + 2\,AgCl(s) \rightarrow Cd^{2+}(aq) + 2Ag(s) + 2\,Cl^{-}(aq)$

(ii) $2\,Fe^{3+}(aq) + 2\,Hg(l) + 2Cl^{-}(aq) \rightarrow 2\,Fe^{2+}(aq) + Hg_2Cl_2(s)$

(iii) $2Na(s) + S(s) \rightarrow Na_2S(s)$ [6]

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	$F = N_Ae$	9.6485×10^{4} C mol^{-1}
Boltzmann constant	k	$1.380\,66 \times 10^{-23}$ J K^{-1}
Gas constant	$R = N_Ak$	$8.314\,51$ 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	$a_o = 4\pi\varepsilon_o\hbar/m_ee^2$	$5.291\,77 \times 10^{-11}$ m
Fine-structure constant	$\alpha = \mu_oe^2c/2h$	$7.297\,35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_ee^4/8h^3c\varepsilon_o^{\,2}$	$1.097\,37 \times 10^{7}$ 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 VIIIB	9	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										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.