UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2006

TITLE OF PAPER: INTRODUCTORY CHEMISTRY

COURSE NUMBER: C101

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) Write thermochemical equations for the following

(i) The standard enthalpy of formation of gaseous sulphur hexafluoride is -1209 kJ/mol.

(ii) The standard enthalpy of combustion of methane is -890. kJ/mol. [4]

(b) Given that the standard enthalpies of formation of sulphur dioxide and sulphur trioxide are -296.83 kJ/mol and -395.72 kJ/mol, respectively calculate the standard enthalpy of reaction for the reaction of sulphur dioxide with oxygen to form sulphur trioxide. [4]

(c) A 200. mL sample of hydrogen chloride at 690. Torr and 20. °C is dissolved in 100. mL of water. The solution was titrated to the stoichiometric point with 15.7 mL of sodium hydroxide solution. What is the molar concentration of the NaOH solution? [5]

(d) The analysis of a hydrocarbon revealed that it was 85.7% C and 14.3% H by mass. When 1.77 g of the gas was stored in a 1.500 L flask at 17 °C, it exerted a pressure of 508 Torr. What is the molecular formula of the hydrocarbon? [5]

(e) Iron pyrite, FeS_2, is the form in which much of the sulphur occurs in coal. In the combustion of the coal, oxygen reacts with iron pyrite to produce iron(III) oxide and sulphur dioxide.

(i) Write a balanced equation for the reaction of iron pyrite with oxygen.

(ii) Calculate the mass of Fe_2O_3 that is produced from the reaction of 75.0 L of oxygen at 2.33 atm and 150. °C with an excess of iron pyrite.

(iii) If the sulphur dioxide that is produced is dissolved to form 5.00 L of aqueous solution, what is the molar concentration of the resulting sulphurous acid, H_2SO_3, solution? [7]

Question 2 (25marks)

(a) Consider the following elements: magnesium, carbon, and chlorine.

(i) Write the ground state electron configuration of each element

(ii) Use an appropriate pair of the above elements and their Lewis symbols to illustrate covalent bond formation.

(iii) Use an appropriate pair of the above elements and their Lewis symbols to illustrate ionic bond formation. [7]

(b) Consider the following molecules: CF_4 and SF_4

(i) Write the Lewis structure of each.

(ii) Predict the shape of the molecule using VSEPR model.

(iii) Predict, giving reasons, which molecule has the higher boiling point. [10]

(c) For the molecule N_2O

(i) Write the Lewis structures that contribute to its resonance hybrid. (skeleton is N-N-O)

(ii) Calculate the formal charges on all atoms in the above structures.

(iii) Select the structure that is likely to make a dominant contribution to the resonance hybrid. [8]

Question 3 (25marks)

(a) Which of the following steps might you take to increase the yield of nitrate ion in the endothermic reaction of NO_2 with liquid water;

$3\ NO_2(g) + 3\ H_2O(l) \rightleftharpoons 2\ H_3O^+(aq) + 2\ NO_3^-(aq) + NO(g)$

(i) Decrease the volume

(ii) Add sodium hydroxide to the solution

(iii) Reduce the temperature

(iv) Dilute the solution

Explain your answers. [4]

(b) In a gas phase equilibrium mixture of PCl_3, PCl_5, and Cl_2 at 500 K, $P_{PCl_5} = 0.15$atm $P_{Cl_2} = 0.20$ atm. What is the partial pressure of PCl_3, given that $K_p = 25$ for the reaction

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$? [4]

(c) A reaction mixture that consisted of 0.400 mol H_2 and 1.60 mol I_2 was prepared in a 3.00 L flask and heated. At equilibrium, 60.0% of hydrogen gas had reacted. What is the equilibrium constant for the reaction

$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$ at this temperature. [5]

(d) The activation energy of the reaction in (c) is reduced from 184 kJ/mol to 59 kJ/mol in the presence of a catalyst. By what factor is the rate constant increased by the catalyst at 600. K, all other factors being equal? [5]

(e) The half life for the first order decomposition of azomethane, $CH_3N{=}NCH_3$, in the reaction

$CH_3N{=}NCH_3(g) \rightarrow N_2(g) + C_2H_6(g)$

is 1.02 s at 300 °C. A 45.0 mg sample of azomethane is placed in a 300. mL reaction vessel and heated to 300 °C.

(i) What mass (in milligrams) of azomethane remains after 10.0 s?

(ii) Determine the partial pressure exerted by the $N_2(g)$ in the reaction vessel after 10.0 s. [7]

Question 4 (25marks)

a. Explain why solutions of weak acids have higher pH values than solutions of strong acids at the same concentration. [3]

b. Calculate the pH of the following solutions
   (i) 0.150 M HCl(aq) [3]
   (ii) 0.150 M $Ba(OH)_2$(aq) [4]
   (iii) 0.150 M CH_3COOH(aq) [5]
   (iv) A solution containing 0.20 M CH_3COOH(aq) and 0.10 M CH_3COONa(aq) K_a for acetic acid is 1.8×10^{-5}. [5]

c. Will Ag_2CO_3 precipitate from a solution formed from a mixture of 100.0 mL of 1.0×10^{-4} M $AgNO_3$(aq) and 100.0 mL of a solution containing 1.0×10^{-4} M CO_3^{2-}(aq)? $K_{sp} = 6.2 \times 10^{-12}$ for Ag_2CO_3. [5]

Question 5 (25marks)

a. The velocity of an electron that is emitted from a metallic surface is 2.2×10^3 km/s. What is the wavelength of the electron? [3]

b. Identify which of the following sets of four quantum numbers {n, l, m_l, m_s} cannot exist for an electron in an atom and explain why.
   (i) {5, 0, -1, ½} (ii) {2, 2, -1, ½} [4]

c. Predict the ground state electron configuration of
   (i) Pb^{2+} (ii) P^{3-} (iii) Fe^{3+} [6]

d. Describe briefly how you would determine the percentage composition of each of the following elements in an organic compound:
   (i) Carbon
   (ii) Hydrogen
   (iii) Oxygen
   (iv) Nitrogen [12]

Question 6 (25marks)

a. An alkane contains five carbon atoms per molecule. Write the structures and names of all the possible isomers of the compound. [5]

b. Write the structures and names of the products of the following reactions:
(i) $CH_3CH{=}CH_2 + HBr$
(ii) $CH_3CH(OH)CH_2CH_3 + H_2SO_4$(concentrated)
(iii) $CH_3CH{=}CH_2 + O_3$
(iv) $CH_3COO^- Na^+ + NaOH(Ca\ O) + Heat$ [8]

c. What do you understand by the following terms? Illustrate with an equation or structure where possible.
(i) Octane number
(ii) Polymerisation
(iii) Substitution reaction
(iv) Hydrolysis
(v) Hybridisation
(vi) Addition reaction [12]

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	*ge*	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