UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2011/12

TITLE OF PAPER: INTRODUCTORY CHEMISTRY II

COURSE NUMBER: C112

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

Graph paper is provided

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Question 1 (25 marks)

(a) How does a gas differ from a liquid with respect to each of the following properties?

i. Density
ii. Compressibility
iii. Ability to mix with other substances of the same phase to form homogenous mixtures? [3]

(b) Assume that you have a cylinder with a movable piston. What would happen to the gas pressure inside the cylinder if you do the following:

i. Decrease the volume to one-fourth the original volume while holding the temperature constant.
ii. Reduce the Kelvin temperature to half its original value while holding the volume constant.
iii. Reduce the amount of gas to half while keeping the volume and temperature constant. [3]

(c) An aerosol spray can with a volume of 250 mL contains 2.30 g of propane gas (C_3H_8) as a propellant.

i. If the can is at 23^{o}C, what is the pressure in the can?
ii. What volume would the propane occupy at STP?
iii. The can says that exposure to temperatures above 66 ^{o}C may cause the can to burst. What is the pressure in the can at this temperature? [7]

(d) i. Calculate the density of NO_2 gas at 0.970 atm and 35 ^{o}C.
ii. Calculate the molar mass of a gas if 2.50 g occupies 0.875 L at 685 torr and 35 ^{o}C. [8]

(e) Both Jacques Charles and Joseph Louis Guy-Lussac were avid balloonists. In his original flight in 1783, Jacques Charles used a balloon that contained approximately 31,150 L of H_2. He generated the H_2 using the reaction between iron and hydrochloric acid:

$$Fe(s) + 2\,HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$$

How many kilograms of iron were needed to produce this volume of H_2 if the temperature was 22 ^{o}C? [4]

Question 2 (25 marks)

(a) The specific heat capacity of water is 4.18 J g^{-1} $^{o}C^{-1}$ and that of stainless steal is 0.51 J g^{-1} $^{o}C^{-1}$. Calculate the heat that must be supplied to a 500.0-g stainless steel vessel containing 450.0 g of water to raise its temperature from 25 ^{o}C to the boiling point of water, 100 ^{o}C. What percentage of the heat is used to raise the temperature of the water? [5]

(b) A 50.0-mL sample of 0.500 M $NaOH(aq)$ and 50.0 mL of 0.500 M $HNO_3(aq)$, both initially at 18.6 °C, were mixed and stirred in a calorimeter having a calorimeter constant equal to 525.0 J $°C^{-1}$. The temperature of the mixture rose to 21.3 °C.

i. What is the change in enthalpy for the neutralization reaction?
ii. What is the change in enthalpy for the neutralization in kilojoules per mole of HNO_3? [5]

(c) Strong sunshine delivers about 1 kW/m^2. Calculate the maximum mass of pure ethanol that can be vaporized in 10 min from a beaker left in strong sunshine, assuming the surface area of the ethanol to be 50 cm^2. Assume all heat results in vaporization, not an increase in temperature. ($\Delta H_{vap} = 43.5$ kJ mol^{-1}) [5]

(d) Calculate the enthalpy of reaction for the synthesis of hydrogen chloride gas

$$H_2(g) + HCl(g) \rightarrow 2HCl(g) \qquad \Delta H^o = ?$$

From the following data:

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s) \qquad \Delta H^o = -176 \text{ kJ}$$

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) \qquad \Delta H^o = -92.22 \text{ kJ}$$

$$N_2(g) + 4H_2(g) + Cl_2(g) \rightarrow 2NH_4Cl(s) \qquad \Delta H^o = -628.86 \text{ kJ}$$ [5]

(e) Calculate the standard reaction enthalpy of the oxidation of ammonia:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

Using the enthalpies of formation given in the table below:

Table 1: Standard enthalpies of formation, $\Delta_f H^o$

Substance	$\Delta_f H^o$/kJ mol^{-1}
$H_2O(g)$	-241.8
$NH_3(g)$	-46.11
$NO(g)$	+90.25

[5]

Question 5

(a) Manganate ions, MnO_4^{2-}, form permanganate ions and manganese(IV) oxide in an acidic solution at a rate of 2.0 mol/(L.min):

$$3MnO_4^{2-}(aq) + 4H^+(aq) \rightarrow 2MnO_4^-(aq) + MnO_2(l) + 2H_2O(l).$$

What is the rate of formation of permanganate ions? What is the rate of reaction of $H^+(aq)$? [4]

(b) A 0.15g sample of H_2 and 0.32g sample of I_2 are confined to a 500-mL reaction vessel and heated to 700 K, when k = 0.063 L mol^{-1} s^{-1}.

i. What is the initial reaction rate?

ii. By what factor does the reaction rate increase if the mass H_2 present in the mixture is doubled? [7]

(c) Sulfuryl chloride, SO_2Cl_2, decomposes by first order kinetics, and at k = 2.81 x 10^{-3} min^{-1} at a certain temperature.

i. Write the rate law for the reaction.

ii. Determine the half-life for the reaction.

iii. If a 14.0g sample of SO_2Cl_2 is sealed in a 2500-L reaction vessel and heated to the specified temperature, what mass will remain after 1.5 h? [6]

(d) i. Calculate the activation energy for the conversion of cyclopropane to propene from an Arrhenius plot of the following data:

T,K	750	800	850	900
k, s^{-1}	1.8 x 10^{-4}	2.7 x 10^{-3}	3.0 x 10^{-2}	0.26

ii. What is the value of the reaction rate constant at 600 °C? [8]

Question 4 (25 marks)

(a) Write the expression for the equilibrium constant, K_p, for each of the following reactions:

i. $3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$

ii. $2NH_3(g) \rightleftharpoons 3H_2(g) + N_2(g)$

iii. $3/2H_2(g) + \frac{1}{2}N_2(g) \rightleftharpoons NH_3(g)$ [3]

(b) An equilibrium mixture at a certain temperature for the reaction

$2H_2S(g) \rightleftharpoons 2H_2(g) + S_2(g)$

has 2.00 atm pressure of H_2S, 0.400 atm H_2 and 1.60 atm S_2. What is K_p for this reaction? [4]

(c) Given the following equilibrium constants:

i. $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$ $K_1 = 0.62$

ii. $FeO(s) + H_2(g) \rightleftharpoons Fe(s) + H_2O$ $K_2 = 0.42$

Find the equilibrium constant, K, at the same temperature for the reaction:

$FeO(s) + CO(g) \rightleftharpoons Fe(s) + CO_2(g)$ [5]

(d) K_c has a value of 12.9 for the following reaction at a temperature of 1550K.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

What is the value of K_P for this reaction? [5]

(e) For the reaction

$$2NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

The equilibrium constant K_p is 3.90×10^{-4} at 50 °C. A 5.0 g sample of $NaHCO_3$ is placed in a closed evacuated flask, and the temperature is raised to 50 °C. What will be the total gas pressure at equilibrium? [5]

(f) In which direction will each of the following reactions shift after the specified stress is applied?

i. $N_2O_4(g) \rightleftharpoons 2NO(g)$
A decrease in the total pressure (an increase in volume)

ii. $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$
An increase in the concentration of CO_2

iii. $2Cl_2(g) + 2H_2O(g) \rightleftharpoons 4HCl(g) + O_2(g)$
An decrease in temperature: $\Delta H^o = +113$ kJ [3]

Question 5

(a) What are the concentrations of $H_3O^+(aq)$ and $OH^-(aq)$ in a solution prepared from 0.100 mol of NHO_3 dissolved in 125 mL of water. [3]

(b) The pOH of a 0.100 M solution of aqueous ammonia, $NH_3(aq)$ or NH_4OH is 2.87. What is the percent ionization of this solution of ammonia? What is the base-ionization constant? [7]

(c) The ionization constant for HOCl is 3.0×10^{-8}. What is the OCl^- concentration in a 0.0350 M solution of hypochlorous acid? [7]

(d) What is the pH of the mixture resulting from the reaction of 25.0 mL of 0.200 M KOH and 25.0 mL of 0.200 M CH_3CO_2H? [8]

Question 6 (25 marks)

(a) Give the systematic name of the following compound and identify the class i.e. alkane, alkene, alcohol, ketone, aldehyde, carboxylic acid etc:

i. $CH_3(CH_2)_3CH_3$

ii. $CH_3CH_2CH{=}CH_2$

iii. CH_3OCH_3

iv. P-$CH_3C_6H_4CHO$

v. $CH_3(CH_2)_3CH(OH)CH_3$ [10]

(b) Write a shortened (condensed) formula of

i. 3-methyl-1-pentene

ii. 4-ethyl-3,3-dimethyheptane

iii. 2-octanone

iv. butanoic acid [8]

(c) Write the structural formula of the major product formed when

i. 2-butanol is heated with hydrobromic acid

ii. ethanoic acid reacts with methanol [4]

(d) Suggest two compounds that may be used to prepare ethyl ethanoate and write a balanced equation for the reaction. [3]

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	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								

Key: Atomic mass → 10.811; Symbol → B; Atomic No. → 5

*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.