UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION 2011/12

TITLE OF PAPER: INTRODUCTORY CHEMISTRY II

COURSE NUMBER: C112

TIME: THREE (3) HOURS

INSTRUCTIONS:

Answer **any four questions**. Each question is worth 25 marks.

Non-programmable electronic calculators may be used.

A data sheet and periodic table are attached

Graph paper is provided

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Question 1 25 marks)

(a) A fixed quantity of gas at 21 °C exhibits a pressure of 752 torr and occupies a volume of 4.38 L.

i. Use Boyle's law to calculate the volume the gas will occupy if the pressure is increased to 1.88 atm while the temperature is held constant.

ii. Use Charles's law to calculate the volume the gas will occupy if the temperature is increased to 175 °C while the pressure is held constant. [4]

(b) i. Write the ideal-gas equation, and give the units used for each term in the equation when $R = 0.0821\ L\cdot atm\cdot mol^{-1}\cdot K^{-1}$.

ii. What is an ideal gas? [4]

(c) Many gases are shipped in high-pressure containers. Consider a steel tank whose volume is 65.0 L and which contains O_2 gas at a pressure of 16,500 kPa at 23 °C.

i. What mass of O_2 does the tank contain?

ii. What volume would the gas occupy at STP?

iii. At what temperature would the pressure in the tank equal 150.0 atm? [9]

(d) A mixture of gases contains 10.25 g of N_2, 1.83 g of H_2 and 7.95 g of NH_3. If the total pressure of the mixture is 1.85 atm, what is the partial pressure of each component? [8]

Question 2 (25 marks)

(a) i. Calculate the amount of energy needed to raise the temperature of 10.0 g of iron (specific heat capacity, 0.45 $Jg^{-1}\ {}^{o}C^{-1}$) from 25 °C to 500 °C.

ii. What mass of gold (specific heat capacity, 0.13 $J\ g^{-1}\ {}^{o}C^{-1}$) can be heated through the same temperature difference when supplied with the same amount of energy as in (i)? [5]

(b) The vaporization of 0.235 mol of liquid CH_4 requires 1.93 kJ of heat. What is the enthalpy of vaporization of methane? [4]

(c) Calculate the reaction enthalpy for the formation of anhydrous aluminium chloride

$2\ Al(s) + 3Cl_2(g) \longrightarrow 2AlCl_3(s)$ $\quad \Delta H^o = ?$

From the following data:

$2Al(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$ $\quad \Delta H^o = -1049$ kJ

$HCl(g) \longrightarrow HCl(aq)$ $\quad \Delta H^o = -73.5$ kJ

$H_2(g) + Cl_2(aq) \longrightarrow 2HCl(g)$ $\quad \Delta H^o = -185$ kJ

$AlCl_3(s) \longrightarrow AlCl_3(aq)$ $\quad \Delta H^o = -323$ kJ [5]

(d) Calculate the standard reaction enthalpy for the formation of boron trifluoride, which is widely used as a catalyst in the chemical industry:

$$B_2O_3(s) + 3CaF_2(s) \longrightarrow 2BF_3(g) + 3CaO(s)$$

Use the standard enthalpies of formation given in the table below: [5]

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

Substance	$\Delta_f H^o$/kJ mol^{-1}
$B_2O_3(s)$	-1272.8
$BF_3(g)$	-1137.0
$CaF_2(s)$	-1219.6
$CaO(s)$	-635.09

(e) When 3.245 g of lead(IV) oxide is formed from lead metal and oxygen, 3.76 kJ of heat is released. What is the enthalpy of formation of $PbO_2(s)$? [6]

Question 3 (25 marks)

(a) The rate of formation of the dichromate ions is 0.14 mol L^{-1} s^{-1} in the reaction $2CrO_4^{2-}(aq) + 2H^+(aq) \rightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$. What is the rate of reaction of the chromate ion in the reaction? What is the reaction rate? [4]

(b) A 100 mg sample of NO_2, confined to a 200-mL reaction vessel, is heated to 300 °C, when k=0.54 L mol^{-1} s^{-1}.

i. What is the initial reaction rate?

ii. How does the reaction rate change (and by what factor) if the mass of NO_2 present in the container is increased to 200 mg? [8]

(c) The following data were collected for the reaction $C_2H_6(g) \rightarrow 2\,CH_3(g)$ at 700 °C:

Time, s	0	1000	2000	3000	4000
$[C_2H_6]$, mmol L^{-1}	1.59	0.92	0.53	0.31	0.18

i. Plot the data to confirm that the reaction is first order.

ii. From the graph, determine the reaction rate constant. [7]

(d) The rate constant of the first-order reaction $2N_2O(g) \rightarrow 2N_2(g) + O_2(g)$ is 0.38 s^{-1} at 1000 K and 0.87 s^{-1} at 1030 K. What is the activation energy of the reaction? [6]

Question 4 (25 marks)

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

i. $2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$

ii. $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$

iii. $\frac{1}{2}N_2(g) + \frac{1}{2}Cl_2(g) + 2H_2(g) \rightleftharpoons NH_4Cl(s)$ [3]

(b) When the reversible reaction

$2\,A + B \rightleftharpoons 2\,C$

Reached equilibrium, the following concentrations were measured: [A] = 0.40 M, [B] = 0.30 M, and [C] = 0.55 M. What is the value of K_c for this reaction? [4]

(c) Write the expressions for the equilibrium constants for the following reactions:

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

$\frac{1}{2}N_2(g) + \frac{3}{2}H_2(g) \rightleftharpoons NH_3(g)$

i. If $K_c = 0.49$ for the first reaction, what is the value of K_c for the second reaction at the same temperature.

ii. Determine the value of the equilibrium constant for the following reaction at the same temperature:

$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$ [6]

(d) Calculate K_p for the dissociation of PCl_5 at 250 °C.

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

At this temperature, K_c is 0.00900 [4]

(e) For the reaction:

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$

the equilibrium constant is $K_p = 4.00$ at a certain temperature. Suppose 1.00 atm CO and 2.00 atm H_2O are introduced into a vessel. What is the pressure of CO_2 at equilibrium? [6]

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

i. $2Cl_2(g) + 2H_2O(g) \rightleftharpoons 4HCl(g) + O_2(g)$
An increase in temperature: $\Delta H^o = +113$ kJ

ii. $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$
An increase in the amount of NH_4HS [2]

Question 5 (25 marks)

(a) What are the concentrations of $H_3O^+(aq)$ and $OH^-(aq)$ in a solution prepared from 0.0250 mol of $Ba(OH)_2$ dissolved in 105 mL of water? [3]

(b) The pOH of a 0.120 M solution of formic acid, HCO_2H is 11.67.

i. What is the acid ionization constant of formic acid?
ii. What is the percent ionization of formic acid in this solution? [7]

(c) The ionization constant for HCN is 4.0×10^{-10}. What is the CN^- concentration in a 0.125 M solution of hydrocyanic 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? ($K_a = 1.8 \times 10^{-5}$ for acetic acid) [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. $(CH_3)_2CHCH(CH_3)_2$
ii. $CH_3C{\equiv}CCH_3$
iii. $CH_3(CH_2)_4COOH$
iv. CH_3NH_2
v. o-$CH_3C_6H_4OH$ [10]

(b) Write a shortened (condensed) formula of

i. 3-phenyl-1-butene
ii. cis-4-methyl-2-hexene
iii. 5-methlyoctanal
iv. 2-heptanol [8]

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

i. 2-butanol is heated with concentrated sulphuric acid.
ii. 1-butanol is heated with propanoic acid. [4]

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

USEFUL DATA

1 atm = 101325 Pa = 760 Torr

$K_w = 1.00 \times 10^{-14}$

First order integrated equation $\ln[A]_t = \ln[A]_0 - kt$

Second order integrated equation $\frac{1}{[A]_t} = \frac{1}{[A]_0} + kt$

Arrhenius equation $k = Ae^{-E_a/RT}$

Quadratic equation: $ax^2 + bx + c = 0$ solution is $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

PERIODIC TABLE OF ELEMENTS

GROUPS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PERIODS	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										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.

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}