

For Examiners' use only:

Question	1-4	5-7	8-9	10-12	Total
Mark	/16	/11	/18	/15	/60

CHEM 113 TEST

Monday, 27 April, 2009

Name (Print clearly):

Student ID No:

Signature:

Instructions:

Attempt **all** questions. Enter answers in the spaces provided (continue on the back of the **opposite** sheet if necessary).

Total marks: 60

Time allowed: 60 minutes

Note:

At the end of this paper is:

1. a periodic table, and
2. a sheet containing physical chemistry formulae.

[Please check that both of these pages are provided before starting to answer the test paper!]

1. (6 marks)

(a) Define the meaning of the word 'isotope'

(1 mark)

(b) Give the number of neutrons and the number electrons in one atom of the boron isotope $^{11}_5\text{B}$.

(1 mark)

Number of neutrons =

Number of electrons =

(c) Write down the full electron configuration for this atom.

(1 mark)

(d) If the $^{11}_5\text{B}$ isotope of boron accounts for 80.1% of neutral B and the $^{10}_5\text{B}$ isotope accounts for the remainder, **calculate** the average molar mass for B to three significant figures.

(3 marks)

2. (4 marks)

- (a) Write **ALL** the possible values for the angular momentum quantum number, l , for the electron shell with principal quantum number $n = 3$

$l =$

- (b) For a d subshell, write **ALL** the possible values for the magnetic quantum number m_l

$m_l =$

- (c) Write **ALL** the possible values for the electron spin quantum number m_s

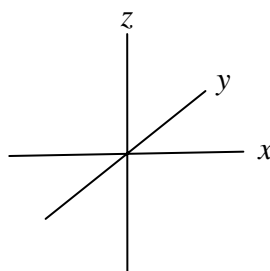
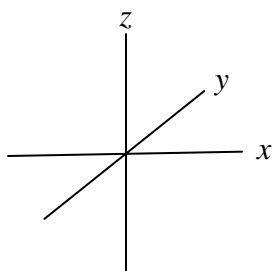
$m_s =$

3. (3 marks)

On the axes given below, sketch the shapes (or 'boundary surface' diagrams) of:

- (a) the $3s$ orbital

- (b) the $2p_z$ orbital



4. (3 marks)

Draw the Lewis structure for sulfuric acid, H_2SO_4 , then select, from the possibilities below, the number of single bonds, double bonds, lone pairs.

(a) 3, 3, 7

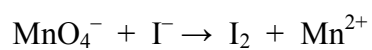
(b) 6, 1, 6

(c) 4, 2, 8

(d) 5, 1, 9.

5. (4 marks)

For the following redox reaction in an **acidic** solution, complete and balance the oxidation and reduction half-reactions and write the balanced equation for the full reaction.



6. (4 marks)

A helium gas thermometer is found to have a volume of 100.0 cm^3 when placed in an ice-water bath at $0 \text{ }^\circ\text{C}$. When the same thermometer is immersed in boiling liquid chlorine, the volume of helium at the same pressure is found to be 87.2 cm^3 . Calculate the temperature of the boiling point of chlorine in Kelvin (K).

[$0 \text{ }^\circ\text{C} = 273 \text{ K}$]

7. (3 marks)

How many H_2O molecules are there in a snowflake weighing 10 mg ?

Avogadro's number: $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

$M(\text{O}) = 16.0 \text{ g mol}^{-1}$; $M(\text{H}) = 1.00 \text{ g mol}^{-1}$

8. (3 marks)

The first law of thermodynamics may be written as

$$\Delta U = q + w$$

Briefly explain the meaning of each of the terms that appear in the above expression.

9. (15 marks)

A sample of liquid cyclohexane, $C_6H_{12}(l)$, of mass 0.842 g was mixed with excess oxygen and burned in a **constant-volume** calorimeter at 25 °C. It was observed that, after the combustion was over, the temperature of the calorimeter and its contents had increased by 3.91 °C (this information will not be required until part (e)).

(a) (3 marks)

Sketch a constant-volume calorimeter, labelling its essential features.

(b) (2 marks)

Write a balanced equation for the combustion of cyclohexane given that the products are $\text{CO}_2(\text{g})$ and $\text{H}_2\text{O}(\text{l})$.

(c) (3 marks)

Use the following information to calculate the standard enthalpy change, ΔH° , for the combustion of liquid cyclohexane.

Substance	ΔH_f° (kJ mol ⁻¹)
$\text{C}_6\text{H}_6(\text{l})$	49.0
$\text{C}_6\text{H}_{12}(\text{l})$	-156.0
$\text{C}_6\text{H}_{14}(\text{l})$	-198.7
$\text{CO}(\text{g})$	-110.5
$\text{CO}_2(\text{g})$	-393.5
$\text{H}_2(\text{g})$	0
$\text{H}_2\text{O}(\text{g})$	-241.8
$\text{H}_2\text{O}(\text{l})$	-285.8
$\text{O}(\text{g})$	249.4
$\text{O}_3(\text{g})$	142.2

(d) (3 marks)

Calculate the standard internal energy change, ΔU° , for the combustion of liquid cyclohexane. ($R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$)

[Hint: Use your answers to parts (b) and (c) above. If you were unable to obtain an answer in (c), use the **incorrect** value of $-4\,000 \text{ kJ mol}^{-1}$ here.]

(e) (4 marks)

Calculate the heat capacity of the complete calorimeter, including the water it contains. [$M(\text{C}_6\text{H}_{12}) = 84.2 \text{ g mol}^{-1}$]

[Hint: Use your answer to part (d) above. If you were unable to obtain an answer in (d), use the **incorrect** value of $-4\,000 \text{ kJ mol}^{-1}$ here.]

10. (2 marks)

Explain why the symbol \rightleftharpoons is used to denote chemical equilibrium.

(Go to question 11 on the next page.)

11. (6 marks)

The following questions, (a) to (e), each give an *equilibrium equation* and a *change* that may be made to such a system at equilibrium. You should use one of the following **letters** (A, B, C or D) to indicate how the (equilibrium) **system responds** to the change:

- (A) Net occurrence of forward reaction
- (B) No net reaction occurs
- (C) Net occurrence of reverse reaction
- (D) Cannot say

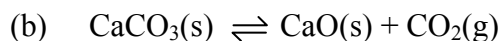
Only if you answer **D** for a particular question, you should then indicate the **additional information** that you would require in order to decide whether A, B or C in fact occurs.



Change: $\text{CO}_2(\text{g})$ is *removed* at constant volume and temperature

System response:

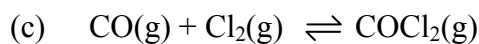
Additional information:



Change: $\text{CaCO}_3(\text{s})$ is *added* at constant pressure and temperature

System response:

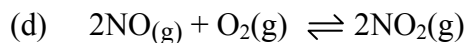
Additional information:



Change: $\text{He}(\text{g})$ is *added* at constant volume and temperature

System response:

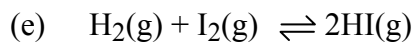
Additional information:



Change: Volume is *increased* at constant temperature

System response:

Additional information:



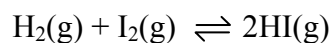
Change: Temperature is *decreased*

System response:

Additional information:

12. (7 marks)

At a particular temperature, the (thermodynamic) equilibrium constant is $K = 400$ for the reaction



11.0 mol of $\text{H}_2(\text{g})$ and 11.0 mol of $\text{I}_2(\text{g})$ are mixed and the above equilibrium is established at the temperature for which the given K is valid. The total pressure of the equilibrium system is 2.20 atm.

Calculate the equilibrium partial pressures of $\text{H}_2(\text{g})$, $\text{I}_2(\text{g})$ and $\text{HI}(\text{g})$.

Physical Chemistry Formulae

$$PV = nRT$$

$$P_A = x_A P_{\text{total}}$$

$$\text{where } P_{\text{total}} = P_A + P_B \quad \text{and} \quad x_i = \frac{n_i}{\sum_i n_i}$$

$$P_A = X_A P_A^\circ$$

$$P_B = (k_H)_B X_B$$

$$\Delta U = q + w$$

$$w_p = -P\Delta V$$

$$H = U + PV$$

$$\Delta H = \Delta U + RT\Delta n_{\text{gas}} \quad \text{when } \Delta T = 0$$

$$\Delta H(T_2) = \Delta H(T_1) + \Delta C_p(T_2 - T_1)$$

$$C_p = dH/dT \quad (\text{when } \Delta P = 0)$$

$$C_v = dU/dT \quad (\text{when } \Delta V = 0)$$

$$\Delta H_{\text{reaction}} = \sum_{\text{prods}} \nu_{\text{prod}} \Delta H_f(\text{prod}) - \sum_{\text{reacts}} \nu_{\text{react}} \Delta H_f(\text{react})$$

$$\text{For } aA + bB \rightarrow cC + dD,$$

$$\text{Rate} = \frac{-1}{a} \frac{d[A]}{dt} = \frac{-1}{b} \frac{d[B]}{dt} = \frac{1}{c} \frac{d[C]}{dt} = \frac{1}{d} \frac{d[D]}{dt}$$

$$\text{For Rate} = \frac{-d[A]}{dt} = k,$$

$$[A] = [A]_0 - kt$$

$$\text{For Rate} = \frac{-d[A]}{dt} = k[A],$$

$$[A] = [A]_0 e^{-kt} \quad \text{and} \quad t_{1/2} = (1/k) \log_e(2)$$

$$k = A e^{-E_a/RT}$$

$$\log_e \left(\frac{k_2}{k_1} \right) = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_b = \frac{[BH^+][OH^-]}{[B]}$$

$$\text{pH} = -\log_{10}[H^+]$$

$$\text{pH} = \text{p}K_a + \log_{10} \left(\frac{[A^-]}{[HA]} \right) = \text{p}K_a + \log_{10}(n(A^-)/n(HA))$$

$$\Delta S = \sum_{\text{prods}} \nu_{\text{prod}} S(\text{prod}) - \sum_{\text{reacts}} \nu_{\text{react}} S(\text{react})$$

$$\Delta S_{\text{phase change}} = \frac{\Delta H_{\text{phase change}}}{T_{\text{critical}}}$$

$$\Delta S_{\text{surr}} = \frac{-\Delta H_{\text{sys}}}{T}$$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G = \sum_{\text{prods}} \nu_{\text{prod}} \Delta G_f(\text{prod}) - \sum_{\text{reacts}} \nu_{\text{react}} \Delta G_f(\text{react})$$

$$\Delta G = \Delta G^\circ + RT \log_e Q$$

$$\Delta G^\circ = -RT \log_e K$$

$$\log_e K = \frac{-\Delta H^\circ}{RT} + \frac{\Delta S^\circ}{R}$$

$$\log_e \left(\frac{K_2}{K_1} \right) = \frac{\Delta H^\circ}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$E_{\text{cell}} = E_{\text{RHS}} - E_{\text{LHS}} = E_{\text{cathode}} - E_{\text{anode}}$$

$$w_{\text{elect}} = \Delta G = -nFE$$

$$\Delta G^\circ = -RT \log_e K = -nFE^\circ$$

$$E^\circ = \frac{RT}{nF} \log_e K = \frac{2.303RT}{nF} \log_{10} K$$

$$\text{At } 25^\circ\text{C: } E^\circ = \frac{0.0591 \text{ V}}{n} \log_{10} K$$

$$E = E^\circ - \frac{RT}{nF} \log_e Q = E^\circ - \frac{2.303RT}{nF} \log_{10} Q$$

$$\text{At } 25^\circ\text{C: } E = E^\circ - \frac{0.0591 \text{ V}}{n} \log_{10} Q$$

R Gas constant (8.314 J mol⁻¹ K⁻¹ or 0.082 L atm mol⁻¹ K⁻¹)

F Faraday constant (96489 C mol⁻¹)

Periodic Table

1 H 1.008																2 He 4.00	
3 Li 6.94	4 Be 9.01											5 B 10.8	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.9	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc (99)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57-71 see below	72 Hf 178.5	73 Ta 181.0	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89-103 see below	104 Rf (257)	105 Db (260)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110	111	112						

57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (147)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
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89 Ac (227)	90 Th 232.0	91 Pa (231)	92 U 238.1	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (245)	98 Cf (251)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lr (257)
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