For Examiners' use only:

Question	1-4	5-7	8-9	10-13	Total
Mark	/16	/11	/18	/15	/60

CHEM 111 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 $^{11}_{5}\mathrm{B}$. (1 mark)

Number of neutrons =

Number of electrons =

(c) Write down the full electron configuration for this atom. (1 mark)

(d) If the $^{11}_{5}\mathrm{B}$ isotope of boron accounts for 80.1% of neutral B and the $^{10}_{5}\mathrm{B}$ 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, $\boldsymbol{l}$, for the electron shell with principal quantum number $\boldsymbol{n = 3}$

$\boldsymbol{l}$ =

(b) For a *d* subshell, write **ALL** the possible values for the magnetic quantum number $\boldsymbol{m_l}$

$\boldsymbol{m_l}$ =

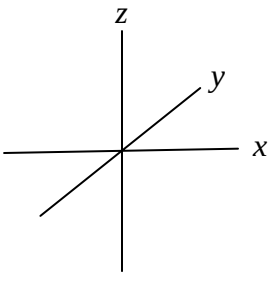
(c) Write **ALL** the possible values for the electron spin quantum number $\boldsymbol{m_s}$

$\boldsymbol{m_s}$ =

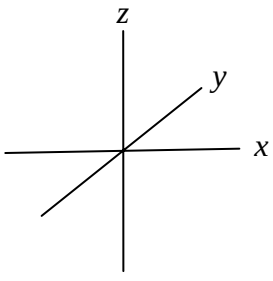
3. (3 marks)

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

(a) the 3*s* 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.

$$MnO_4^- + I^- \rightarrow I_2 + Mn^{2+}$$

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 °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 °C = 273 K]

7. (3 marks)

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

Avogadro's number: $N_A = 6.022 \times 10^{23}$ mol^{-1}
$M(O) = 16.0$ g mol^{-1}; $M(H) = 1.00$ 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 $CO_2(g)$ and $H_2O(l)$.

(c) (3 marks)

Use the following information to calculate the standard enthalpy change, $\Delta H°$, for the combustion of liquid cyclohexane.

Substance	$\Delta H_f°$ (kJ mol^{-1})
$C_6H_6(l)$	49.0
$C_6H_{12}(l)$	–156.0
$C_6H_{14}(l)$	–198.7
$CO(g)$	–110.5
$CO_2(g)$	–393.5
$H_2(g)$	0
$H_2O(g)$	–241.8
$H_2O(l)$	–285.8
$O(g)$	249.4
$O_3(g)$	142.2

(d) (3 marks)

Calculate the standard internal energy change, $\Delta U°$, for the combustion of liquid cyclohexane. (R = 8.314 J mol^{-1} 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 kJ mol^{-1} here.]

(e) (4 marks)

Calculate the heat capacity of the complete calorimeter, including the water it contains. [M(C_6H_{12}) = 84.2 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 kJ mol^{-1} here.]

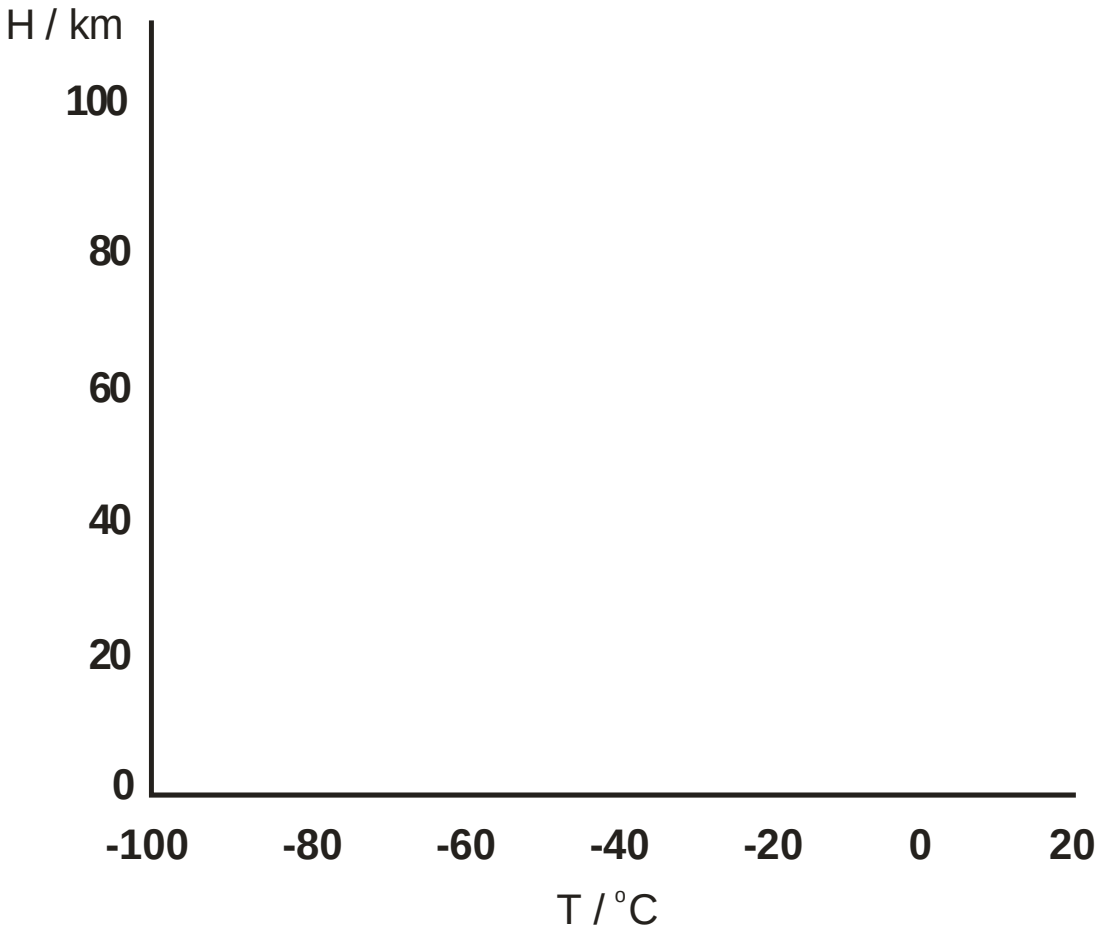
10. (7 marks)

Using the plot of altitude, H in km, versus temperature, T in ^{o}C, below, add the following features:

(a) a curve to show the temperature profile for the atmosphere of Earth;

(b) names of the four main regions of the atmosphere (draw horizontal lines at the appropriate altitudes);

(c) temperature and altitude corresponding to each of the three turning points.



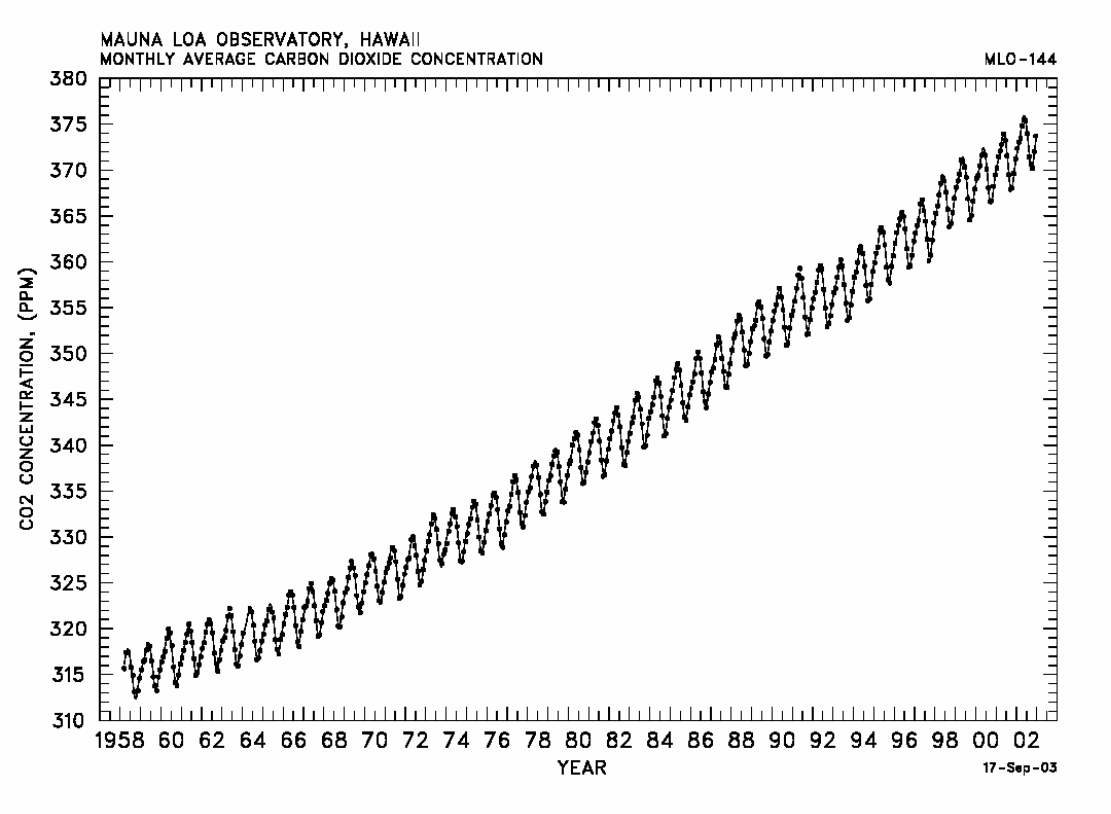
11. (4 marks)

(a) Write the names and chemical formulae of two halogen-containing molecules known to participate in the photochemical destruction of ozone in the stratosphere.

(b) It has been shown experimentally that approximately 100,000 O_3 molecules are destroyed for every Cl atom released by photochemical dissociation of a chlorofluorocarbon molecule in the stratosphere. Write the reaction sequence (2 steps) responsible for this O_3 destruction process.

12. (2 marks)

(a) Explain the **annual variation** of tropospheric carbon dioxide superimposed on the long-term increase shown in the plot below for the Northern Hemisphere.



(b) What is the present (2009) level of CO_2 in the atmosphere in ppm?

13. (2 marks)

List the four essential ingredients for the formation of photochemical smog.

1.
2.
3.
4.

Physical Chemistry Formulae

$PV = nRT$

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

$P_A = X_A P_A^\circ$

$P_B = (k_H)_B X_B$

$\Delta U = q + w$

$w_P = -P\Delta V$

$H = U + PV$

$\Delta H = \Delta U + RT\Delta n_{gas}$ when $\Delta T = 0$ $\quad \Delta H(T_2) = \Delta H(T_1) + \Delta C_P(T_2 - T_1)$

$C_P = \mathrm{d}H/\mathrm{d}T$ (when $\Delta P = 0$) $\quad C_V = \mathrm{d}U/\mathrm{d}T$ (when $\Delta V = 0$)

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

For $a\mathrm{A} + b\mathrm{B} \rightarrow c\mathrm{C} + d\mathrm{D}$, $\quad \mathrm{Rate} = \frac{-1}{a}\frac{\mathrm{d[A]}}{\mathrm{d}t} = \frac{-1}{b}\frac{\mathrm{d[B]}}{\mathrm{d}t} = \frac{1}{c}\frac{\mathrm{d[C]}}{\mathrm{d}t} = \frac{1}{d}\frac{\mathrm{d[D]}}{\mathrm{d}t}$

For $\mathrm{Rate} = \frac{-\mathrm{d[A]}}{\mathrm{d}t} = k$, $\quad [\mathrm{A}] = [\mathrm{A}]_0 - kt$

For $\mathrm{Rate} = \frac{-\mathrm{d[A]}}{\mathrm{d}t} = k[\mathrm{A}]$, $\quad [\mathrm{A}] = [\mathrm{A}]_0 e^{-kt}$ and $t_{1/2} = (1/k)\log_e(2)$

$k = Ae^{-E_a/RT}$ $\quad \log_e\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$

$K_a = \frac{[\mathrm{H^+}][\mathrm{A^-}]}{[\mathrm{HA}]}$ $\quad K_b = \frac{[\mathrm{BH^+}][\mathrm{OH^-}]}{[\mathrm{B}]}$

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

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

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

$\Delta S_{phase\ change} = \frac{\Delta H_{phase\ change}}{T_{critical}}$ $\quad \Delta S_{surr} = \frac{-\Delta H_{sys}}{T}$

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

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

$\Delta G = \Delta G^\circ + RT\log_e Q$ $\quad \Delta G^\circ = -RT\log_e K$

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

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

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

$E^\circ = \frac{RT}{nF}\log_e K = \frac{2.303RT}{nF}\log_{10} K$ $\quad$ At 25°C: $E^\circ = \frac{0.0591\ \mathrm{V}}{n}\log_{10} K$

$E = E^\circ - \frac{RT}{nF}\log_e Q = E^\circ - \frac{2.303RT}{nF}\log_{10} Q$ $\quad$ At 25°C: $E = E^\circ - \frac{0.0591\ \mathrm{V}}{n}\log_{10} Q$

R Gas constant (8.314 J $\mathrm{mol^{-1}}$ $\mathrm{K^{-1}}$ or 0.082 L atm $\mathrm{mol^{-1}}$ $\mathrm{K^{-1}}$)

F Faraday constant (96489 C $\mathrm{mol^{-1}}$)

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

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)