For Examiners' use only:

Question	1 – 3	4 – 7	8	9 - 13	Total
Mark	/9	/19	/17	/15	/60

CHEM 111 TEST

Monday, 28 April, 2008

Name (Print clearly): .....

Student ID No: ANSWERS

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 attached before starting to answer the test paper!]

1. (4 marks)

For the elements below, give the full electron configurations. (Use Ne ($Z = 10$) $(1s)^2\ (2s)^2\ (2p)^6$ as a model.)

Ca ($Z = 20$)

$Ca\ (1s)^2 (2s)^2 (2p)^6\ (3s)^2 (3p)^6 (4s)^2$

Cu ($Z = 29$)

$Cu\ (1s)^2\ (2s)^2\ (2p)^6\ (3s)^2\ (3p)^6\ (4s)^1\ (3d)^{10}$

2. (3 marks)

Bromine is an element that has two stable isotopes in roughly equal abundance. For the isotopic cation $^{79}Br^+$, give the following:

(a) The number of protons per ion — 35

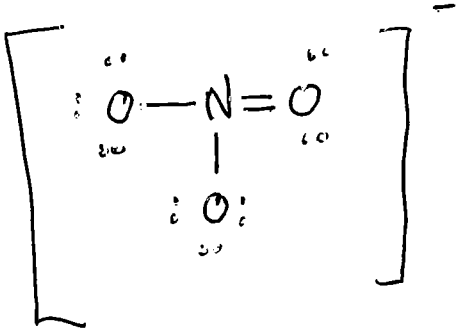
(b) The number of electrons per ion — 34

(c) The number of neutrons per ion — 44

3. (2 marks)

Draw the Lewis dot structure for the nitrate anion, NO_3^-, and select from the possibilities below the number of single bonds, double bonds and lone pairs.

(a) 2,1,10 (b) 3,1,9 (c) 3,0,10 (d) 1, 2, 7 (e) 2,1,8



4. (4 marks)

Write a balanced half equation for the following (incomplete) ion-electron reaction occurring in **basic** solution

MnO_4^- ⟶ MnO_2

Acid $MnO_4^- + 4H^+ + 3e \longrightarrow MnO_2 + 2H_2O$ Add $4OH^-$ to both sides

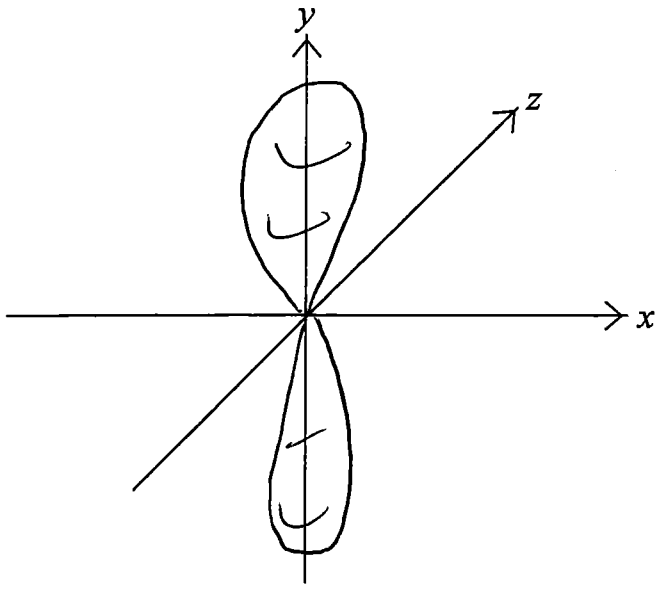
$MnO_4^- + 2H_2O + 3e \longrightarrow MnO_2 + 4OH^-$

What are the two oxidation states of Mn in the reaction? +7, +4

What colour change would you see? Purple ⟶ dark brown

5. (2 marks)

Sketch a probability distribution for a $2p_y$ atomic orbital.



6. (7 marks)

A 3.2 L flask at 20 °C contains a mixture of two gases and a small quantity (< 1 mL) of liquid water at equilibrium. The gases are N_2 at a partial pressure of 0.79 atm and O_2 at a partial pressure of 0.20 atm.

At 20 °C, the vapour pressure of water is 17.5 mm of Hg; 1 atm = 760 mm of Hg = 1.013 × 10^5 Pa; R = 8.314 J mol^{-1} K^{-1}.

(a) What is the total pressure in the flask in atm.?

$P_{total} = P = P_{N_2} + P_{O_2} + P_{H_2O}$ Daltons Law

$= 0.79 + 0.20 + \frac{17.5}{760} = 1.013$ atm $= 1.01$ atm (2 sf)

(b) Of the gas, what is the mole fraction of O_2, X_{O_2} in the flask?

$$X_{O_2} = \frac{P_{O_2}}{P} = \frac{0.20}{1.013} = 0.197 = 0.20 \text{ (2sf)}$$

(c) What is the partial pressure of O_2 in the flask in units of Pa?

$P_{O_2} = 0.20$ atm

$= 0.20$ atm $\times 1.013 \times 10^5$ Pa $atm^{-1} = 2.026 \times 10^4$ Pa

$= 2.0 \times 10^4$ Pa (2sf)

(d) Calculate the number of moles of O_2 in the flask. (For the purposes of this calculation ignore the small volume occupied by the liquid water).

$P_{O_2} V = n_{O_2} RT$

$$n_{O_2} = \frac{P_{O_2} V}{RT} = \frac{2.026 \times 10^4 \times 3.2 \times 10^{-3}}{8.314 \times 293.15}$$

$= 0.0266$ mols $\cong 0.027$ mols

OR

$$n_{O_2} = \frac{0.20 \text{ atm} \times 3.2 \text{ L}}{0.082 \text{ L atm mol}^{-1} \text{K}^{-1} \times 293.15 \text{ K}}$$

$= 0.0266$ mols $= 0.027$ mols.

7. (6 marks)

25.7 mL of a solution of 0.015 mol L^{-1} sodium thiosulfate ($S_2O_3^{2-}$) reacts to completion with 15.5 mL of iodine solution in neutral conditions to give as products tetrathionate ($S_4O_6^{2-}$) and iodide (I^-).

(a) Write a balanced ion-electron half equation for

$S_2O_3^{2-} \longrightarrow S_4O_6^{2-}$

$2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e^-$

(b) Write a balanced ion-electron half equation for

$I_2 \longrightarrow I^-$

$I_2 + 2e^- \rightarrow 2I^-$

(c) Write a balanced equation for the overall redox reaction.

$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$

(d) Calculate the concentration of the iodine solution.

$$\frac{\text{mols } S_2O_3^{2-}}{\text{mols } I_2} = \frac{2}{1}$$

$$[S_2O_3^{2-}] \times V_{S_2O_3^{2-}} = 2 \times [I_2] \times V_{I_2}$$

$$0.015 \text{ mol } L^{-1} \times 25.7 \text{ mL} = 2 \times [I_2] \times 15.5 \text{ mL}$$

$$[I_2] = 0.012 \text{ M}$$

(e) What indicator would you use to enhance the colour change of this reaction?

Starch.

8. (17 marks)

$\Delta U^\circ = -5\,172$ kJ mol^{-1} for the combustion of solid naphthalene, $C_{10}H_{8(s)}$.

(a) (i) Define the change in internal energy, ΔU, for a reaction.

$\Delta U = U_{products} - U_{reactants}$ (= difference in Energy, U, of products + reactants)

$= q + w$ (Heat absorbed from surrounding + work done on system as the reaction proceeds)

(ii) Write the balanced chemical equation for the combustion of 1 mol of naphthalene at 298 K.

$C_{10}H_{8(s)} + 12\,O_{2(g)} \rightarrow 10\,CO_{2(g)} + 4H_2O_{(l)}$

(iii) Calculate ΔH° for the combustion of naphthalene.

$[R = 8.314\ \text{J K}^{-1}\ \text{mol}^{-1}]$ $\Delta n = 10 - 12 = -2$

$\Delta H^\circ = \Delta U^\circ + RT.\Delta n$

$= -5172 + [8.314 \times 298 \times (-2)/1000]$ (kJ)

$= -5172 - 4.955$

$= -5177$ kJ mol^{-1}

(iv) Calculate q_P (i.e., q at constant pressure) for combustion of 0.1 mol of naphthalene at 298 K.

$q_p = \Delta H$ For 0.1 mol of Naphth.

$\therefore q_p = 0.1 \times (-5177) = -517.7$ kJ

(v) Calculate w_P (i.e., w at constant pressure) for combustion of 1 mol of naphthalene at 298 K.

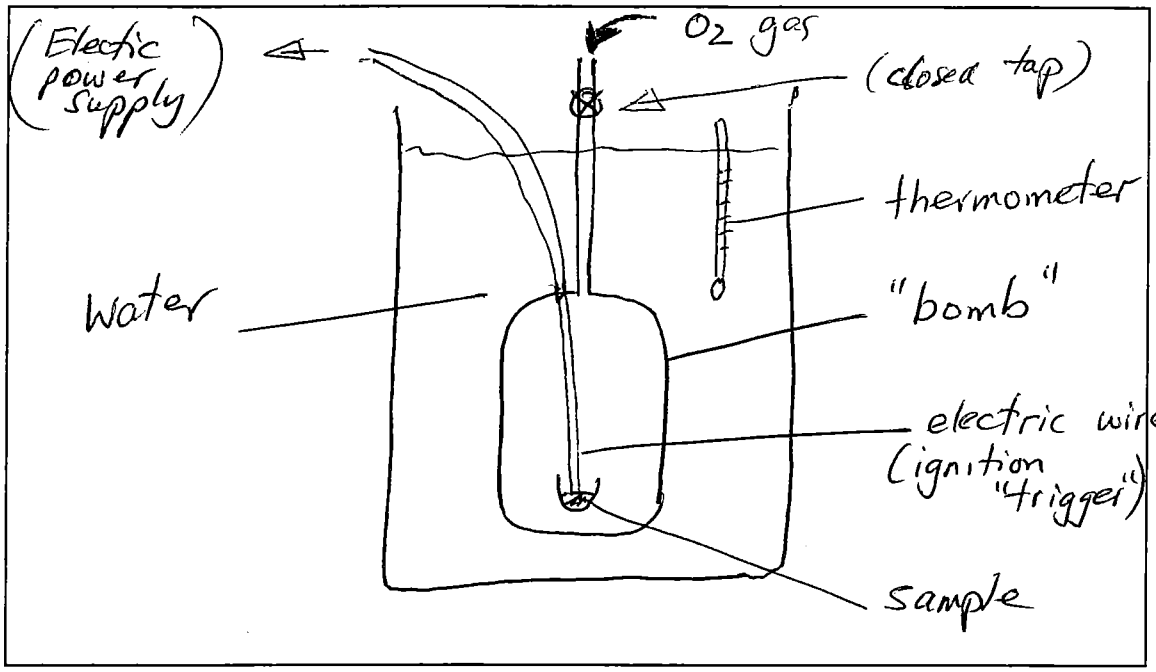
$w_p = -P.\Delta V = -RT.\Delta n$

$= +4.955$ kJ mol^{-1}

(b) A constant-**volume** calorimeter containing 1.000 kg of water is calibrated by combustion of 1.28 g of naphthalene in it at 298 K. A temperature rise of 6.56 °C is observed.

[Useful information: $M(C_{10}H_8) = 128$ g mol^{-1}; specific heat of water: 4.184 J g^{-1} K^{-1}; $\Delta U°$ for combustion of naphthalene is given at start of question]

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



(ii) Calculate the heat capacity of the complete calorimeter, including the water.

$$\Delta U_{total} = C_{V(total)} \cdot \Delta T = -\Delta U_{combustion}$$

$$\Delta U_{combustion} = \frac{1.28}{128} \times \Delta U° = 0.01 \times (-5172)\ kJ$$

$$\therefore\ C_{V(total)} = \frac{+0.01 \times 5172}{6.56}$$

$$= 7.884\ kJ\ K^{-1}$$

$$= 7884\ J\ K^{-1}$$

(iii) Calculate the heat capacity of the empty calorimeter, excluding the water.

$$C_{V(total)} = C_{V(water)} + C_{V(calorimeter)}$$

$$\therefore\ 7884 = 1000 \times 4.184 + C_{V(calorimeter)}$$

$$\therefore\ C_{V(calorimeter)} = 7884 - 4184$$

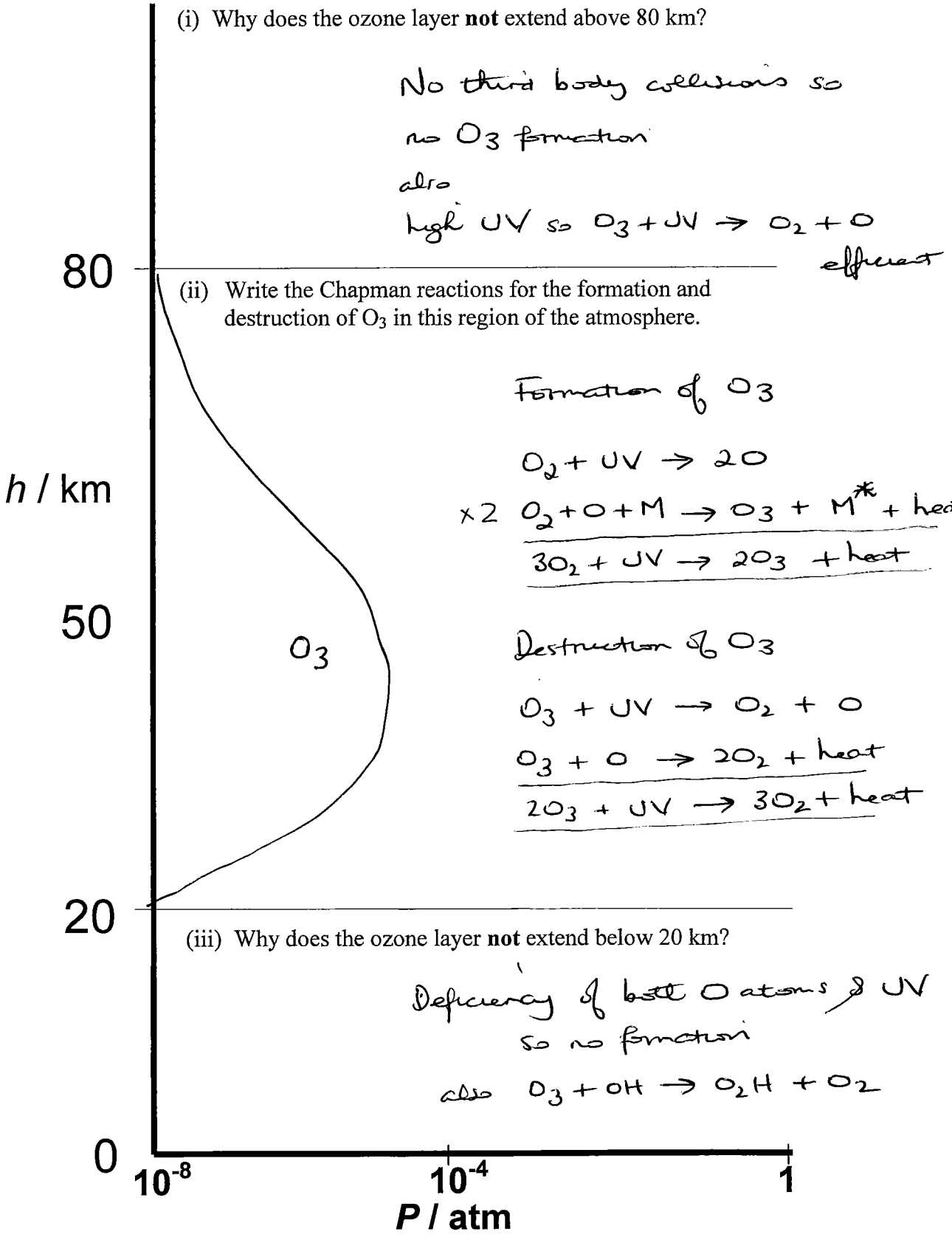
$$= 3700\ J\ K^{-1}$$

9. (7 marks)

Complete the plot of Earth's atmosphere below, where *h* is altitude:

(a) sketch the partial pressure profile for the ozone layer;

(b) answer the questions in the spaces provided.



(i) Why does the ozone layer **not** extend above 80 km?

No third body collisions so no O_3 formation

also

high UV so $O_3 + UV \rightarrow O_2 + O$ efficient

(ii) Write the Chapman reactions for the formation and destruction of O_3 in this region of the atmosphere.

Formation of O_3

$O_2 + UV \rightarrow 2O$

$\times 2$ $O_2 + O + M \rightarrow O_3 + M^* + heat$

$3O_2 + UV \rightarrow 2O_3 + heat$

Destruction of O_3

$O_3 + UV \rightarrow O_2 + O$

$O_3 + O \rightarrow 2O_2 + heat$

$2O_3 + UV \rightarrow 3O_2 + heat$

(iii) Why does the ozone layer **not** extend below 20 km?

Deficiency of both O atoms & UV so no formation

also $O_3 + OH \rightarrow O_2H + O_2$

10. (3 marks)

Over Antarctica in the late Autumn and Winter, HCl and $ClONO_2$, which are formed in the gas phase, are adsorbed onto ice crystals in the polar stratospheric clouds. Write chemical equations to show

(a) the reaction of these species on the ice crystals over Winter, and

(b) the effect of sunlight on the products when Spring returns to the Antarctic continent.

(a) $HCl + ClONO_2 \rightarrow Cl_2 + HNO_3$

$H_2O + ClONO_2 \rightarrow HOCl + HNO_3$

(b) $Cl_2 + UV \rightarrow 2Cl$

$HOCl + UV \rightarrow OH + Cl$

11. (2 marks)

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

1.	Sunlight
2.	NOx
3.	Hc
4.	Temp Inversion

12. (2 marks)

Write chemical equations to explain how ozone is produced under conditions favourable for the development of photochemical smog.

1) engine $N_2 + O_2 + \text{heat} \rightarrow 2NO$

2) w/ air $2NO + O_2 \rightarrow 2NO_2$

3) sunlight $NO_2 + UV \rightarrow NO + O$

4) $O + O_2 + M \rightarrow O_3 + M^*$

13. (1 mark)

Circle the number, in each of the columns below, that **most closely** matches the average level of CO_2 in the Earth's atmosphere, expressed in units of ppm, for the year 1800 (pre-industrial revolution) and the present time.

from close to --- ppm in the year 1800	to --- ppm in 2008
220	330
240	360
260	(380)
(280)	390