MELBOURNE HIGH SCHOOL

UNIT 4 CHEMISTRY

TRIAL EXAMINATION

2011

Name: _____

Group: _____

Teacher: _____

QUESTION AND ANSWER BOOKLET
Wednesday 21st September 2011
Reading time : 15 minutes
Writing time : 90 minutes

Section	*Number of questions*	*Number of questions to be answered*	Number of marks	Suggested time (minutes)
A	20	20	20	23
B	10	10	60	67
		Total	80	90

Materials : * Question and answer booklet consisting of a cover page and 14 pages of questions - pages are numbered 2 to 15
* Answer sheet for multiple-choice questions.

Instructions : * Multiple choice items are to be answered by filling in the appropriate box which corresponds to the answer of your choice in the question booklet.
* Short answer questions are to be answered in the spaces provided.
* All written responses must be in English.
* Chemical equations and half equations must include symbols of state.
* Numerical answers are to be given to appropriate numbers of significant figures.
* A unit must be given in numerical answers that require a unit for complete specification.
***Students must bring in to the examination their own clean, stapled copy of the relevant pages of the data book.**
* Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, and a scientific calculator.
* **Students are NOT permitted to bring graphics calculators, mobile phones and/or any other electronic communication devices, or blank sheets of paper or white out liquid/tape into the examination room**.

Submission : * At the conclusion of the exam, place your Multiple Choice answer sheet inside this booklet.

Section A / 20

Section B / 60

Total / 80

2011 UNIT 4 - SECTION A

Specific instructions for Section A

- This section consists of 20 multiple choice items which are to be answered by shading the box on the answer sheet that corresponds to your answer in **lead pencil**.
- A correct answer scores 1 mark and an incorrect answer scores 0 marks.
- 1 × 20 = 20 marks, 23 minutes

1 Uranium can be used to generate electrical energy because

A nuclear fission reactions release large numbers of electrons.
B the nuclei of uranium atoms regularly release electrons.
C the fission of uranium releases vast amounts of thermal energy.
D the fusion of uranium atoms is a highly exothermic process.

2 Consider the reaction

$$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l) \qquad \Delta H = -2596 \text{ kJ mol}^{-1}$$

The heat of combustion of ethyne (acetylene) is

A -99.8 kJ g^{-1}.
B -49.9 kJ g^{-1}.
C +49.9 kJ g^{-1}.
D +99.8 kJ g^{-1}.

3 Consider the reaction

$$HCl(aq) + NaOH(aq) \rightarrow H_2O(l) + NaCl(aq) \qquad \Delta H = -57.0 \text{ kJ mol}^{-1}$$

When 20.0 mL of 0.150 M NaOH is reacted with 10.0 mL of 0.250 M HCl, the amount of heat released is

A. 28.5 J.
B. 143 J.
C. 171 J.
D. 314 J.

4 The amount of heat required to raise the temperature of 75.0 g of lead by 14.6 °C is 142 J. The specific heat capacity of lead in J g^{-1} $°C^{-1}$, is

A 1.30×10^{-4}
B 6.58×10^{-3}
C 0.130
D 7.71

5 The next **3** questions refer to the following information. One step in the production of sulfuric acid is the conversion of sulfur dioxide into sulfur trioxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{ kJ mol}^{-1}$$

The temperature in the converter is maintained in the range 450 ^oC to 500 ^oC. As the reaction rate would be greater at a higher temperature, the use of 450 ^oC to 500 ^oC temperatures is considered to be a compromise because:

A the products of the reaction would be different at higher temperatures.
B the cost of reaching higher temperatures would be prohibitive.
C the yield of sulfur trioxide would be less at higher temperatures.
D equilibrium can still be established at lower temperatures.

6 A reactor contains a mixture of sulfur dioxide, oxygen and sulfur trioxide at equilibrium. The volume of the reactor is allowed to increase while the temperature is held constant. The total number of molecules will

A remain the same and the concentrations will also remain constant.
B remain the same but the relative concentrations will change.
C decrease.
D increase.

7 A chemist investigating this equilibrium system at the lower temperature of 200 ^{o}C in the laboratory has a 2.00 L vessel in which equilibrium has been established. The vessel is found to contain 0.0200 mol of SO_2, 0.0100 mol of O_2 and 0.0400 mol of SO_3. The value of the equilibrium constant, K_c, under these conditions is

A 400 M^{-1}.
B 800 M^{-1}.
C 1.25×10^3 M.
D 2.50×10^3 M.

8 In which one of the following does sulfur have the same oxidation state as it has in sulfuric acid?

A oleum
B sulfur dioxide
C H_2SO_3
D H_2S

9 In the following reactions, sulfuric acid is acting as an oxidant:

$$Zn(s) + 2H_2SO_4(l) \rightarrow ZnSO_4(aq) + SO_2(g) + 2H_2O(l)$$
$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

Which one of the following statements about these reactions is **not** correct?

A The first reaction requires concentrated sulfuric acid whereas the second one will work with dilute sulfuric acid.
B The sulphur in the sulphate ion is acting as a reducing agent in the first reaction but not in the second reaction.
C The first reaction is redox but not acid/base whereas the second reaction is both acid/base and redox.
D The sulfur in the H_2SO_4 is being reduced in the first reaction whereas the hydrogen in the H_2SO_4 is being reduced in the second reaction.

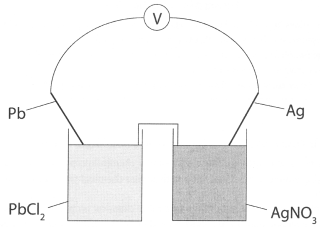
10 The K_a value for lactic acid is around 10^{-10}. In a 0.01 M solution of lactic acid, the substance present in the highest concentration will be

A H_2O
B lactic acid
C H_3O+
D the conjugate acid/base of lactic acid.

11 A galvanic cell is composed of a standard $Zn^{2+}(aq)/Zn(s)$ half cell coupled to a standard $Ni^{2+}(aq)/Ni(s)$ half cell connected by a salt bridge containing potassium nitrate solution. When current is being drawn from the cell, the reductant is

A nickel metal.
B nitrate ions.
C water.
D zinc metal.

12



Which of the following correctly describes the anode, cathode and direction of electron flow when the wires are connected at 25 °C?

	Anode	Cathode	Direction of electron flow
A	Pb	Ag	left to right
B	Pb	Ag	right to left
C	Ag	Pb	left to right
D	Ag	Pb	right to left

13 A chemist is preparing a standard $Cr^{3+}(aq)/Cr^{2+}(aq)$ half cell. A suitable electrode for use in the half cell would be made of [E^o $Cr^{3+}(aq)/Cr(s)$ = -0.91 V]

A chromium.
B copper.
C iron.
D platinum.

14 Both water molecules and iron(II) ions are able to act as either an oxidant or as a reductant, depending on the circumstances. Which one of the following reactions is likely to occur spontaneously?

A $2H_2O(l) \rightarrow O_2(g) + 2H_2(g)$
B $Fe(s) + 2Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq)$
C $2Fe^{2+}(aq) + 2H_2O(l) \rightarrow 2Fe(s) + O_2(g) + 4H^+(aq)$
D $2H_2O(l) + 4Fe^{3+}(aq) \rightarrow O_2(g) + 4Fe^{2+}(aq) + 4H^+(aq)$

15 The overall reaction for a discharging Ni-Cad cell is

$$2NiOOH(s) + Cd(s) + 2H_2O(l) \rightarrow 2Ni(OH)_2(s) + Cd(OH)_2(s)$$

with a concentrated solution of potassium hydroxide as the electrolyte. The anode reaction in a Nicad cell being recharged is

A $Ni(OH)_2(s) + OH^-(aq) \rightarrow NiOOH(s) + H_2O(l) + e^-$.
B $NiOOH(s) + H_2O(l) + e^- \rightarrow Ni(OH)_2(s) + OH^-(aq)$.
C $Cd(s) + 2OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$.
D $Cd(OH)_2(s) + 2e^- \rightarrow Cd(s) + 2OH^-(aq)$.

16 The combustion of methane, CH_4, can be used to generate electricity. The thermal energy released during combustion can be harnessed or methane can be oxidised directly in a fuel cell. When methane is oxidised in an acidic fuel cell, the half equation will be

A $CH_4(g) \rightarrow C(s) + 4H+(aq) + 4e^-$
B $CH_4(g) + 2H_2O(l) \rightarrow CO_2(g) + 8H^+(aq) + 8e^-$
C $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
D $CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2OH^-(aq) + 2e^-$

The next 2 refer to the following information.

The aluminum/air cell is an example of a commercial cell. The two reactants are aluminium metal and oxygen gas. An alkali environment is used in this cell. The half equation for the aluminium is

$$Al(s) + 4OH^-(aq) \rightarrow Al(OH)_4^-(aq) + 3e^-$$

17 Which one of the following correctly describes the electrodes?

	Anode	Polarity	Cathode	Polarity
A	aluminium	positive	oxygen	negative
B	aluminium	negative	oxygen	positive
C	oxygen	positive	aluminum	negative
D	oxygen	negative	aluminium	positive

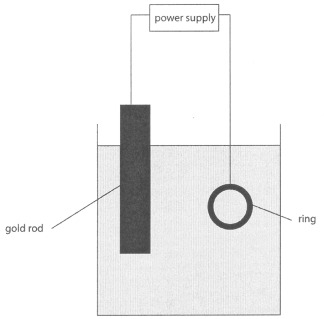
18 The half equation for the oxygen will be

A $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
B $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$
C $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$
D $O_2(g) + 4e^- \rightarrow 2O_2^-(aq)$

19 The products of the electrolysis of a 1.0 M solution of aluminium chloride at 25 °C are

A $Cl_2(g)$, Al(s)
B $O_2(g)$, $H_2(g)$
C $Cl_2(g)$, $H_2(g)$, $OH^-(aq)$
D Al(s), $O_2(g)$, $H^+(aq)$

20 An electrolytic cell is constructed to gold plate some jewellery.



Which one of the following is correct when the power is switched on?

A The gold rod acts as the cathode and the ring acts as the anode.
B The anode is negative and the cathode is positive.
C Anions in the electrolyte are attracted to the gold ring.
D Reduction occurs at the gold ring.

2011 UNIT 4 SECTION B

Specific instructions for Section B

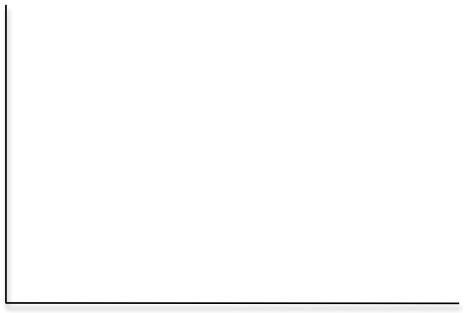
- This section consists of ***10*** short answer questions which are to be answered in the spaces provided.
- Numerical answers must be given to the appropriate number of significant figures.
- Symbols of state must be included in all equations and half equations.
- No credit will be given for an incorrect numerical answer unless it is supported by working.
- ***60*** marks, 67 minutes

1 [7 marks, 7 minutes]
The production of ammonia (NH_3) involves the following reaction.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0 \text{ kJmol}^{-1}$$

a Explain why this reaction has a high activation energy.

bi Sketch an energy profile for this reaction on the axes shown below. Clearly mark on the profile the energy of reactants and products, activation energy and ΔH for the reaction.



Reaction profile

bii On the same axes, using a dotted line, sketch the energy profile for the reaction in the presence of a catalyst

c Ammonia is a weak base. The conjugate acid of ammonia is the ammonium ion, NH_4^+. The ammonium ion reacts according to the following equation.

$$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$$

i Write an expression for the acidity constant, K_a, for the ammonium ion.

cii Determine the pH of a solution in which the concentration of ammonium ion is 0.10 M

(1 + (2 + 1) + (1 + 2) = 7)

2 [6 marks, 7 minutes]
The equilibrium reaction

$$2CO(g) + NH_3(g) \rightleftharpoons HCN(g) + CO_2(g) + H_2(g) \qquad \Delta H = +10 \text{ kJ mol}^{-1}$$

is established rapidly at temperatures exceeding 700 ^oC in the presence of alumina as a catalyst. The reaction is exceedingly slow at temperatures below 700 ^oC even when alumina is present. This reaction can be investigated by allowing a mixture of ammonia and carbon monoxide to establish equilibrium in the presence of alumina at 800 ^oC. A reference equilibrium system is prepared and a series of systems incorporating one change from the reference system are also set up. Each new equilibrium mixture is rapidly cooled to room temperature (quenched) so that the reaction is effectively stopped and concentrations do not change further.

a Predict the effect on the yield (**increase**, **decrease**, **no change** or **insufficient information to decide**) of hydrogen cyanide, HCN, when the specified change is made.

Change from the conditions in the reference system	Effect on yield of HCN(g) compared with reference system
1. The equilibrium mixture is maintained at 800 ^oC for twice the period of time before cooling.	
2. The same initial amount of ammonia but twice the original amount of carbon monoxide is used.	
3. The reaction temperature is 1100 ^oC instead of 800 ^oC.	
4. Palladium, a solid at 800 ^oC, is present in the reaction vessel. Palladium adsorbs hydrogen.	
5. Replacing the alumina with a more effective solid catalyst such as a transition metal oxide.	

b Explain your reasoning for Change 4.

((5 x 1) + 1 = 6)

3 [5 marks, 6 minutes]

a) A small piece of solid magnesium was placed in a conical flask with an excess of 1.20M nitric acid. The temperature recorded was 20.5^oC, and the pressure was 101.3 kPa. The hydrogen gas generated was collected in a gas syringe and its volume measured at regular intervals.

I. Label the axes below and sketch a graph of the volume of hydrogen gas generated over time. Label this graph with the letter "a"

II. An identical set up was used to perform the same reaction, but an identical mass of magnesium in powdered form was used instead. On the same axes below, sketch a graph of the volume of hydrogen gas generated over time. Label this graph with the letter "b".

III. A third identical set-up was then used to perform the same reaction, but this time the volume of acid was doubled. On the same axes below, sketch a graph of the volume of hydrogen gas generated over time. Label this graph with the letter "c".

b) What is the impact of increasing the temperature of the acid into which the small piece of magnesium was added (as in part a above)?

c) Explain in detail the reason why increase in temperature has the impact you described in b above.

((1 + 0.5+ 0.5) + 1 + 2 = 5)

4. [8 marks, 8 minutes]

200.0 ml of 0.15M hypobromous acid, HOBr, a weak acid, was placed in 3 separate beakers and subjected to the following additions:

Beaker 1	200ml of water added.
Beaker 2	10.0 ml of 0.0013M NaOH solution added
Beaker 3	A 0.450g piece of calcium carbonate added

The temperature of each beaker was kept at 23.0^{O}C

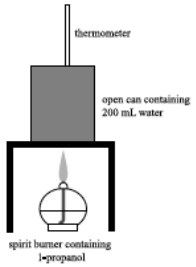
a. Determine the percentage ionisation of the acid before the addition of the other substances.

b Complete the table below using the terms "increased", "decreased" or "no change" to describe the effect of these additions on:
i) hydronium ion concentration
ii) hydroxide ion concentration
iii) K_a of the acid
iv) % ionisation

Beaker number	$[H_3O^+]$	$[OH^-]$	K_a	% ionisation
1				
2				
3				

(2 + 12 x 0.5 = 8)

5 [7 marks, 8 minutes]
A laboratory experiment is set up to determine the heat of combustion of 1-propanol. 1-propanol is burned in a 'spirit burner' and heat released is used to heat 200 mL of water. The equipment was set up as shown below.



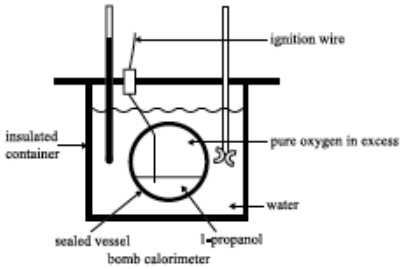
The following data was recorded.
Mass of spirit burner before heating: 125.62 g
Mass of spirit burner after heating: 122.89 g
Temperature of water before heating: 22.7°C
Temperature of water after heating: 85.6°C

a Use the change in the temperature of the water to determine the amount of energy, in kJ, added during heating.

b Determine an experimental value of the enthalpy of combustion, in kJ mol^{-1}, of 1-propanol.

c By comparing the experimentally determined value of the enthalpy of combustion with the theoretical one given in your data sheet, determine the percentage of chemical energy of the 1-propanol which ends up as heat energy in the water.

d The molar enthalpy of combustion of 1-propanol was then determined using a bomb calorimeter as shown below.



Give two reasons why the numerical value of the heat of combustion of 1-propanol obtained using a bomb calorimeter would be larger than that obtained using the 'spirit burner'.

_____

_____

_____

_____

(2+ 2 + 1 + 2 = 7)

6 [6 marks, 7 minutes]
When hydrochloric acid and sodium hydroxide are mixed an exothermic reaction occurs.

In one experiment, 400 mL of 0.20M HCl(aq) was mixed with 400 mL of 0.20M NaOH(aq) in a calorimeter and the energy released was measured as 4.56 kJ.

a Calculate the energy that would be released when 400 mL of 0.20M HCl is mixed with 600 mL of 0.20M NaOH. Show your working.

b Write a balanced ionic equation for this reaction and calculate the ΔH value.

_____

c Calculate the temperature rise that would occur in **a.**

_____

_____

_____

_____

(2 + 2 + 2 = 6)

7 [6 marks, 6 minutes]
An alkaline cell consists of a steel anode surrounded by zinc powder, a steel container in contact with a powdered mixture of manganese (IV) oxide and carbon, and a potassium hydroxide electrolyte. The cell reaction is:

$$Zn(s) + 2MnO_2(s) + H_2O(l) \rightarrow Zn(OH)_2(s) + Mn_2O_3(s)$$

a Why is a permeable separator between the zinc powder and the manganese (IV) oxide powder an essential part of the cell?

_____

_____

_____

b In this alkaline cell, which species is

i. the reductant _____

ii. the species being oxidised _____

iii. the product formed from the oxidant _____

iv. the spectator ion present? _____

c What are the anode and cathode processes (*ie* half equations) that occur when this type of alkaline cell is discharging?

anode: _____

cathode: _____

(2 + 2 + 2 = 6)

8 [7 marks, 8 minutes]
The starch and cellulose stored in plants can be converted into glucose which may then be the fuel used in a glucose/oxygen fuel cell. The overall reaction in such a fuel cell is:

$$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) \qquad \Delta H = -2803 \text{ kJ mol}^{-1}$$

The cell emf under standard conditions is 1.26 V and an acid electrolyte is used.

a Draw and label a simple fuel cell that could be used to obtain electrical energy by means of this reaction.

b What is the half equation for the oxidation process in the fuel cell?

_____

c Suggest a suitable electrolyte for this fuel cell.

_____

d A number of glucose/oxygen fuel cells are connected in series. How many fuel cells would be required to produce 12 V?

e Despite carbon dioxide being a product of the fuel cell reaction, suggest one advantage of using glucose as an energy source.

_____

_____

_____

(3 + 1 + 1+ 1 + 1 = 7)

9 [3 marks, 4 minutes]
Briefly explain the following chemical situation:
Both the charging and discharging of a lead-acid accumulator involve a change in the pH of the electrolyte.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

10 [5 marks, 5 minutes]
A solid oxide methane/oxygen fuel cell operates at temperatures in the range of 900 - 1000 ^{o}C. The half reactions in this fuel cell are:

anode $4O^{2-}(s) + CH_4(g) \rightarrow CO_2(g) + 2H_2O(g) + 8e^-$
cathode $O_2(g) + 4e^- \rightarrow 2O^{2-}(s)$

a Show that the reaction occurring in a solid oxide methane/oxygen fuel cell is the same as that of the complete combustion of methane.

b Give one advantage and one disadvantage of using a solid oxide methane/oxygen fuel cell to produce usable energy rather than using the combustion of methane.

Advantage: _____

_____

Disadvantage:

_____

_____

c What is one major operational difference between a generic fuel cell and a generic secondary cell?

____

____

____

(2 + 2 + 1 = 5)

END of PAPER