THE SCHOOL FOR EXCELLENCE (TSFX)
UNIT 4 CHEMISTRY 2006

WRITTEN EXAMINATION 2

Reading Time: 15 minutes
Writing time: 1 hour 30 minutes

QUESTION AND ANSWER BOOKLET

Structure of Booklet

Section	*Number of Questions*	*Number of Questions to be Answered*	*Number of Marks*	*Suggested Times (minutes)*
A	20	20	20	20
B	7	7	70	70
			Total 90	**Total 90**

Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.

Students are **NOT** permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Students are **NOT** permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

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SECTION A: MULTIPLE CHOICE QUESTIONS

Instructions For Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1, an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

QUESTION 1
Lysine is an essential α-amino acid with the molecular formula $C_6H_{14}N_2O_2$. Which of the following best represents the molar mass of the tripeptide formed when lysine reacts with two glycine ($C_2H_5O_2N$) molecules?

A 225 $gmol^{-1}$

B 260 $gmol^{-1}$

C 380 $gmol^{-1}$

D 416 $gmol^{-1}$

QUESTION 2
Which of the following represents the product(s) of the oxidation of carbohydrates?

A CO_2 and H_2O
B $(NH_2)_2CO$
C $C_{12}H_{22}O_{11}$
D $C_6H_{12}O_6$

QUESTION 3
Which of the following conditions would result in the greatest rate of reaction for the hydrolysis of starch by the enzyme amylase in the human body?

A pH 2 and 57°C
B pH 2 and 37°C
C pH 8 and 57°C
D pH 8 and 37°C

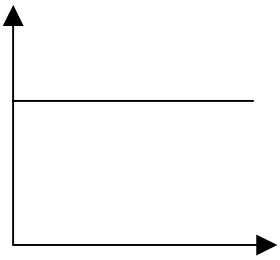
QUESTION 4
The functional group which makes the most significant contribution to the solubility of disaccharides is the

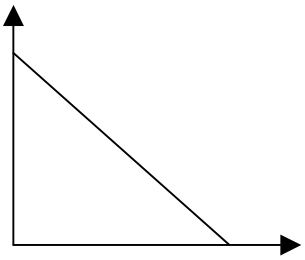
A ether group
B hydroxyl group
C carboxyl group
D ester group

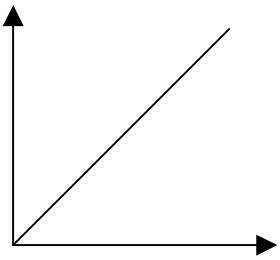
QUESTION 5
The scientist credited with having first proposed nuclear fission was

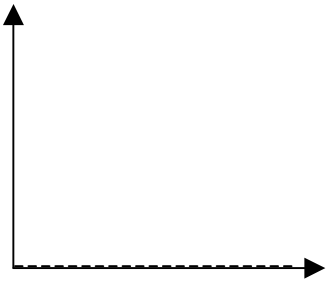
A Albert Einstein
B Marie Curie
C Ernest Rutherford
D Lise Meitner

QUESTION 6
Which of the following graphs correctly describes the general trend in reducing strength of elements as you move down a group of the periodic table?

A


B


C


D


QUESTION 7
In which of the following reactions is the metallic oxide behaving as an acidic oxide?

A $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$
B $SO_3(l) + H_2O(l) \rightarrow H_2SO_4(aq)$
C $Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2Al(OH)_4^-(aq)$
D $Al_2O_3(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2O(l)$

QUESTION 8
In which of the following reactions does nitrogen undergo reduction?

A $NH_3(aq) + H^+(aq) \rightarrow 2NH_4^+(aq)$
B $4NO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(aq)$
C $2NH_4^+(aq) + 3O_2(g) \rightarrow 2NO_2^-(aq) + 4H^+(aq) + 2H_2O(l)$
D $N_2(g) + 6H^+(aq) + 6e^- \rightarrow 2NH_3(aq)$

QUESTION 9
An adult has approximately 5 kg of fatty tissue which can be used as energy when required. The oxidation of palmitic acid is represented by the following equation:

$CH_3(CH_2)_{14}COOH(aq) + 23O_2(g) \rightarrow 16CO_2(g) + 16H_2O(l)$ $\Delta H = -10\ 035\ kJ\ mol^{-1}$

What amount of energy would be released from the oxidation of 200 g of palmitic acid?

A 7840 kJ
B 8259 kJ
C 9511 kJ
D 10035 kJ

QUESTION 10
Fuel cells do not store energy; they convert energy directly and continuously to electrical energy. A fuel cell may be constructed using methanol and oxygen contained in an alkaline electrolyte. The overall reaction for the methanol/oxygen fuel cell is

$$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$$

If the reaction at the cathode is $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ then the reaction at the anode would be

A $CH_3OH(l) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-$
B $CH_3OH(l) + 6OH^-(aq) \rightarrow 2CO_2(g) + 5H_2O(l) + 6e^-$
C $CH_3OH(l) + 3O_2(g) \rightarrow CO_2(g) + 3H_2O(l)$
D $CH_3OH(l) \rightarrow CO(g) + 4H+(aq) + 4e^-$

QUESTION 11
A commercially important secondary cell is the nickel-cadmium battery which is widely used in mobile phones. The discharge reaction for this cell is represented by the equation:

$Cd(s) + 2Ni_2O_3(s) + 3H_2O(l) \rightarrow Cd(OH)_2(s) + 2Ni(OH)_2(s)$

Which of the following correctly represents the reaction occurring at the negative electrode during the recharging process?

A $Cd(OH)_2(s) + 2e^- \rightarrow Cd(s) + 2OH^-(aq)$
B $Cd(s) + 2OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$
C $2Ni(OH)_2(s) + 2OH^-(aq) \rightarrow Ni_2O_3(s) + 3H_2O(l) + 2e^-$
D $Ni_2O_3(s) + 3H_2O(l) + 2e^- \rightarrow 2Ni(OH)_2(s) + 2OH^-(aq)$

QUESTION 12
The electron configuration of $_{25}Mn^{2+}$ changes from $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4\ 4p^1$ to $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$. In the process, the ion

A absorbs energy and increases in stability.
B releases energy and increases in stability.
C absorbs energy and decreases in stability.
D releases energy and decreases in stability.

QUESTION 13

Consider the reaction: $^{252}_{98}Cf + {}^{10}_{5}B \rightarrow 3\ {}^{1}_{0}n$ + ?

The missing particle in the above reaction is

A $^{259}_{103}Lr$ and the reaction is exothermic.

B $^{262}_{100}Fm$ and the reaction is exothermic.

C $^{259}_{103}Lr$ and the reaction is endothermic.

D $^{262}_{100}Fm$ and the reaction is endothermic.

QUESTION 14
An isotope of iodine $\left(^{131}_{53}I\right)$ undergoes radioactive decay by emitting beta particles; $^{0}_{-1}e$ (electrons). If the nucleus disintegrates through the loss of one electron, the new nucleus formed will have

A the same mass number but a different atomic number.
B a different mass number and atomic number.
C the same mass number and atomic number.
D the same atomic number but an increased nuclear charge.

QUESTION 15
In the electrolysis of a 500 ml aqueous solution containing a mixture of the following metal nitrates: $AgNO_3$, $Ca(NO_3)_2$ and $Cr(NO_3)_3$, 289,500 coulombs of charge was supplied to the cell. If the metal nitrates each have a concentration of 1.0 M, what would be the amount, in mole, of each metal deposited at the cathode?

	Ag	**Ca**	**Cr**
A	3.00 mol	0.00 mol	1.00 mol
B	0.50 mol	0.50 mol	0.50 mol
C	0.50 mol	0.00 mol	0.50 mol
D	3.00 mol	2.00 mol	1.00 mol

QUESTION 16
Which of the following bond types is responsible for maintaining the primary structure of proteins?

A Ion-dipole interactions
B Dipole-dipole bonding
C Hydrogen bonding
D Covalent bonding

QUESTION 17
A common food additive is **ascorbic acid** (Vitamin C). Ascorbic acid is used to prevent substances reacting with atmospheric oxygen, and thereby becoming rancid. Ascorbic acid would be classified as

A a preservative
B a stabilising agent
C an emulsifier
D an antioxidant

QUESTION 18
Which of the following could represent the products of the hydrolysis of a polyunsaturated fat?

A $C_3H_8O_3$ and $C_{15}H_{31}COOH$
B $C_6H_{12}O_6$ and $C_{15}H_{27}COOH$
C $C_3H_8O_3$ and $C_{15}H_{27}COOH$
D CO_2 and H_2O

QUESTION 19
If necessary, the body may use proteins as a source of energy, but only after first removing nitrogen. Excess nitrogen is removed from the body as

A NO_2
B NH_3
C $(NH_2)_2CO$
D NH_4^+

QUESTION 20
Which one of the following molecules would be **least** susceptible to rancidity under oxidising conditions?

A $C_{16}H_{32}O_2$
B $C_{16}H_{30}O_2$
C $C_{18}H_{34}O_2$
D $C_{18}H_{32}O_2$

SECTION B: SHORT ANSWER QUESTIONS

Instructions For Section B

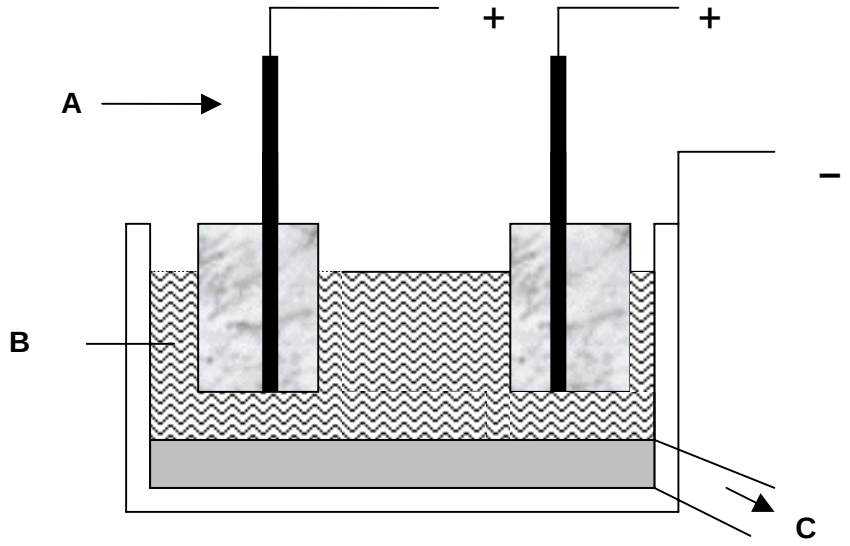
This section consists of 9 short answer questions. Section B is worth approximately 76% of the marks available. You should spend approximately 65 minutes on this section.

Answer **all** questions in the spaces provided.

To obtain full marks for your responses you should

- give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be give full marks.
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_{2(g)}$; $NaCl_{(s)}$.

QUESTION 1
Aluminium displays a number of properties that make it one of the most useful and largely produced metals in the world. The industrial production of aluminium is based on the Hall-Heroult Cell. A cross-section of such a cell is given below.



The equation representing the overall cell reaction in the Hall-Heroult Cell is:

$2Al_2O_{3(l)} + 3C_{(s)} \rightarrow 4Al_{(l)} + 3CO_{2(g)}$

a. Identify the following substances in the diagram above.

Substance A _____

Substance B _____

Substance C _____

b. Write the half-equation representing the reaction at the

(i) anode

_____

_____

(ii) cathode

_____

_____

c. Give a concise explanation as to why such electrolytic processes cannot produce aluminium metal using a solution of aluminium nitrate.

d. The anodes in the illustrated cell each weigh 20 kg and are connected in series. If a current of 180,000 A was passed through this cell, how long before each anode would have to be replaced?

e. The production of aluminium may contribute to increased levels of carbon dioxide in the atmosphere. Give an example of a reaction in the biosphere which **decreases** the atmospheric levels of carbon dioxide.

3 + 2 + 2 + 4 + 1 = 12 marks

QUESTION 2
The commonly used artificial sweetener, aspartame, is a dipeptide comprised of two α-amino acids. The name of this dipeptide is **gly-phe** and its semi-structural formula is given below:

$$^{+}H_3NCH(CH_2C_6H_5)CONHCH_2COO^{-}$$

a. What type of reaction is responsible for the formation of this dipeptide from its constituent amino acids?

_____

_____

b. What mass of water would be required to hydrolyse 2.5 g of this dipeptide?

_____

_____

_____

_____

_____

c. The dipeptide **gly-phe** is neutral at a pH of approximately 8.6.

If the pH of a solution of this dipeptide was decreased to 2 by the addition of hydrochloric acid, what would be the resultant charge on the dipeptide?

_____

_____

d. Phenylalanine is an essential amino acid whilst glycine is a non-essential amino acid. What is the difference between **essential** and **non-essential** amino acids?

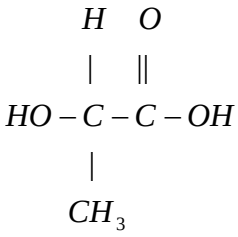
_____

_____

_____

_____

e. The dipeptide **gly-phe** and lactic acid can react to form two different compounds.



Lactic acid

State the type of functional group formed when these molecules react.

_____

_____

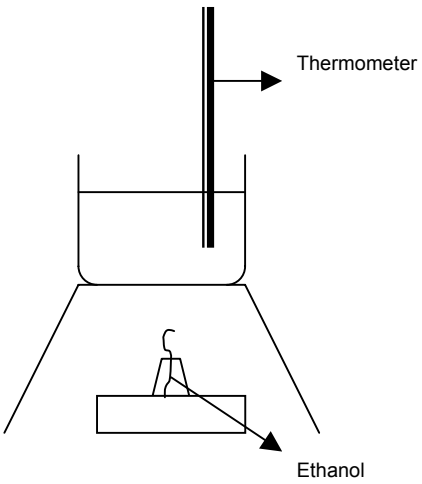
_____

1 + 2 +1+ 2 + 2 = 8 marks

QUESTION 3
The high cost of traditional hydrocarbon fuels has led to intense research into alternative fuels such as ethanol.

Ethanol is a common alcohol with molar mass 46 $gmol^{-1}$, density 0.789 g/ml and a heat of combustion of 1409.4 $kJmol^{-1}$.

a. A group of students decide to investigate the energy released during the combustion of ethanol using a form of calorimetry, as illustrated below.



The results obtained during this investigation include:

Volume of water in the beaker	500 ml
Volume of ethanol used during combustion	5.00 ml
Initial temperature of the water	22.4°C
Maximum temperature of the water	75.2°C
Note: Specific heat capacity of water	4.184 $J^{-1}g^{-1}°C^{-1}$

(i) What amount of energy was released when the ethanol was burned?

_____

_____

(ii) Why is the measured heat of combustion in this investigation lower than the true heat of combustion for ethanol?

_____

_____

(iii) Use the results of this experiment to write the corresponding thermochemical equation for the combustion of ethanol.

b. Assume that all the heat released during the combustion of the ethanol sample in this investigation was transferred to the water.

(i) Determine the calibration factor of this "calorimeter" in $kJ°K^{-1}$.

(ii) A 15.0 ml sample of pure olive oil contains 505 kJ of energy. What temperature change should the students observe during the complete combustion of a 2.50 ml sample using the illustrated "calorimeter"?

c. Olive oil contains 55-85% oleic acid ($CH_3(CH_2)_7CHCH(CH_2)_7COOH$) by weight.

(i) What type of fatty acid is oleic acid?

(ii) State one difference that would be observed in the physical properties of olive oil if it contained 85% stearic acid ($CH_3(CH_2)_{16}COOH$) by weight?

(1 + 1 + 4) + (2 + 2) + (1 + 1) = 12 marks

QUESTION 4
Elements display trends across periods and down groups of the periodic table. One trend is that of first ionisation energy. The first ionisation energies of the elements of Period 3 are given in the table below.

Element	1st Ionisation Energy (kJ/mol)
Sodium	496
Magnesium	738
Aluminium	578
Silicon	789
Phosphorus	1012
Sulfur	1000
Chlorine	1251
Argon	1521

a. (i) Give a concise explanation for why the 1st ionisation energies generally increase across a period.

_____

_____

_____

_____

(ii) Name another trend which shows an increase moving across a period.

_____

b. (i) Write the electron configuration for the element sulfur.

_____

_____

(ii) Discuss why the 1st ionisation energy of magnesium is slightly higher than that of aluminium.

_____

_____

_____

_____

(iii) Write an equation to show that the oxide of sulfur is acidic.

_____

_____

c. The element sulfur has four naturally occurring isotopes:

Relative Isotopic Mass	% Abundance
31.97	94.93
32.97	0.760
33.97	4.29
35.97	0.0200

(i) The above information was obtained using a mass spectrometer. What is the basis of separation of particles in the mass spectrometer?

_____

_____

(ii) Use the given information to calculate the relative atomic mass of sulfur.

_____

_____

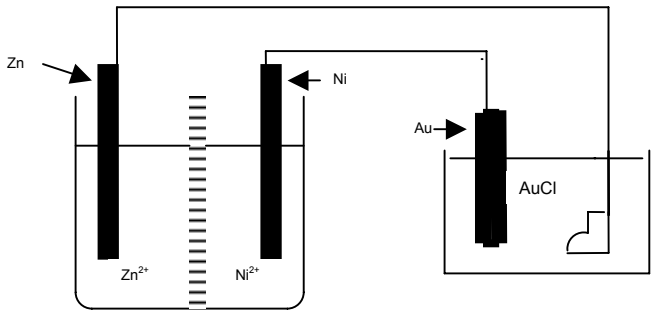
_____

_____

(2 + 1) + (1 + 2 + 1) + (1 + 2) = 10 marks

QUESTION 5

A chemistry teacher decides to simultaneously demonstrate the principles of galvanic and electrolytic cells by coating a baby's bootie with gold. He sets up a galvanic cell with electrodes of zinc and nickel suspended in solutions of their corresponding ions, and that are separated by a porous barrier. This cell is connected to a small bath containing a gold electrode and a solution of acidified gold chloride, AuCl.



a. (i) Which electrode in the galvanic cell should be assigned a positive polarity?

(ii) What is the polarity of the baby bootie in the second cell?

(iii) What is the purpose of the barrier in the galvanic cell?

(iv) What would be the theoretical voltage generated by the galvanic cell?

(v) Write the equation for the reaction occurring in the galvanic cell.

_____

_____

_____

b. Calculate the time it would take to coat the bootie if the process requires 10.0 g of gold for complete coverage and if the galvanic cell produces a current of 2.50 amperes.

_____

_____

_____

_____

_____

_____

(1 + 1 + 2 + 1 + 1) + 3 = 9 marks

QUESTION 6
Ionic salts may be derived from complex metal ions which may be anionic or cationic.

An example of such an ion is pentaaminechlorocobalt (III) which combines with sulfate to form $[Co(NH_3)_5Cl]SO_4$.

a. Draw a diagram of the complex metal ion. In your diagram, state the names of the bonds between the central metal ion and the ligand(s) and indicate the charge on the central metal ion as well as the overall complex.

b. What characteristic must a substance possess in order to act as a ligand?

_____

_____

_____

c. A distinguishing feature of many transition metals is their ability to form ions in varying oxidation states.

(i) Name the transition metal other than zinc from the first series of the periodic table that can only produce ions of one oxidation state.

_____

(ii) Explain why transition metals lose electrons from the 4s energy level before losing electrons from the 3 d energy level.

_____

_____

_____

_____

_____

(iii) State one other characteristic of transition metals that differentiate them from Group I and II metals.

_____

_____

_____

_____

(5) + 1 + (1 + 2 + 1) = 10 marks

QUESTION 7

a. Give an explanation for why an enzyme loses its biological activity following denaturation.

_____

_____

_____

_____

_____

_____

b. Write an equation representing the reaction involved in the production of a fertiliser.

_____

_____

c. Give the equation for the reaction that occurs when hydrogen gas is bubbled through a solution of $KOH_{(aq)}$ and $CuSO_{4(aq)}$.

_____

_____

_____

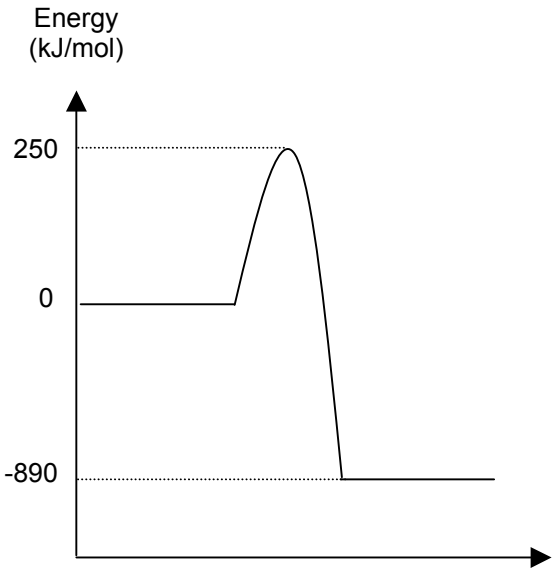
_____

_____

_____

d. The energy profile for the combustion of methane gas is given below.

$$CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)} \quad \Delta H = -890\,kJ\,/\,mol$$



If the heat of vaporisation of water is $44\,kJ\,/\,mol$, draw the enthalpy profile for the reaction $CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$ on the graph above, clearly labelling the energies of the reactants and products.

2 + 1 + 3 + 3 = 9 marks