1993

CHEMISTRY

UNIT 4
TRIAL EXAM

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STUDENT NUMBER Letter

Figures									
Words									

Victorian Certificate of Education 1993

CHEMISTRY

Common Assessment Task 3: Analysis and evaluation

1993 TRIAL CAT

(not to be used before Friday October 8, 1993)

Reading time: 15 minutes

Total writing time: 1 hour 30 minutes

QUESTION AND ANSWER BOOKLET

Structure of booklet

Number of questions	*Number of questions to be answered*
11	11

Directions to students

Materials

Question and answer booklet of 16 pages.
Double-sided data sheet
An approved calculator may be used.

The task

Answer **all** questions.
Questions should be answered in the spaces provided in this booklet
The marks allotted to each question are indicated at the end of the question.
There is a total of 75 marks available.
All written responses should be in English.

At the end of the task

Please ensure that you write your **student number** in the space provided on this page.
Hand in this question and answer booklet.

DATA

TABLE 1: RELATIVE ATOMIC MASS ($^{12}C = 12.00$)

Element	*Symbol*	*Relative Atomic Mass*
Aluminium	Al	27.0
Calcium	Ca	40.1
Carbon	C	12.0
Copper	Cu	63.5
Hydrogen	H	1.0
Magnesium	Mg	24.3
Nitrogen	N	14.0
Oxygen	O	16.0
Sodium	Na	23.0
Zinc	Zn	65.4

TABLE 2: PHYSICAL CONSTANTS

Avogadro constant (N_A) 6.023×10^{23} mol^{-1}

Faraday (F) 96 500 C mol^{-1}

Ideal gas molar volume at STP (0^oC and 1 atmosphere pressure) = 22.4 L

Universal gas constant (R) 8.31 J K^{-1} mol^{-1}

TABLE 3: THE ELECTROCHEMICAL SERIES
(the states of the substances have been omitted deliberately)

Ag^+	+	e^-	=	Ag	+0.80
Al^{3+}	+	$3e^-$	=	Al	-1.67
Au^{3+}	+	$3e^-$	=	Au	+1.29
Br_2	+	$2e^-$	=	$2Br^-$	+1.08
Ca^{2+}	+	$2e^-$	=	Ca	-2.87
Cd^{2+}	+	$2e^-$	=	Cd	-0.403
Ce^{4+}	+	e^-	=	Ce^{3+}	+1.44
Cl_2	+	$2e^-$	=	$2Cl^-$	+1.36
Co^{2+}	+	$2e^-$	=	Co	-0.28
$Cr_2O_7^{2-}$ + $14H^+$	+	$6e^-$	=	$2Cr^{3+}$ + $7H_2O$	+1.36
Cu^{2+}	+	$2e^-$	=	Cu	+0.34
Cu^{2+}	+	e^-	=	Cu+	+0.158
Cu^+	+	e^-	=	Cu	+0.522

(continued over page)

TABLE 3: THE ELECTROCHEMICAL SERIES (continued)
(the states of the substances have been omitted deliberately)

F_2 + $2e^-$	=	$2F^-$	+2.87
Fe^{3+} + e^-	=	Fe^{2+}	+0.77
Fe^{2+} + $2e^-$	=	Fe	-0.44
$2H^+$ + $2e^-$	=	H_2 (defined)	0.00
$2H_2O$ + $2e^-$	=	H_2 + $2OH^-$	-0.83
H_2O_2 + $2H^+$ + $2e^-$	=	$2H_2O$	+1.77
I_2 + $2e^-$	=	$2I^-$	+0.54
K^+ + e^-	=	K	-2.93
Li^+ + e^-	=	Li	-3.02
Mg^{2+} + $2e^-$	=	Mg	-2.34
MnO_4^- + $8H^+$ + $5e^-$	=	Mn^{2+} + $4H_2O$	+1.52
Mn^{2+} + $2e^-$	=	Mn	-1.03
Na^+ + e^-	=	Na	-2.71
Ni^{2+} + $2e^-$	=	Mi	-0.25
NO_3^- + $4H^+$ + $3e^-$	=	NO + $2H_2O$	+0.96
NO_3^- + $2H^+$ + e^-	=	NO_2 + H_2O	+0.81
O_2 + $4H^+$ + $4e^-$	=	$2H_2O$	+1.23
O_2 + $2H^+$ + $2e^-$	=	H_2O_2	+0.68
O_2 + $2H_2O$ + $4e^-$	=	$4OH^-$	+0.40
Pb^{2+} + $2e^-$	=	Pb	-0.13
PbO_2 + HSO_4^- + $3H^+$ + $2e^-$	=	$PbSO_4$ + $2H_2O$	+1.69
$PbSO_4$ + H^+ + $2e^-$	=	Pb + HSO_4^-	-0.36
S + $2H^+$ + $2e^-$	=	H_2S	+0.14
SO_2 + $4H^+$ + $4e^-$	=	S + $2H_2O$	+0.45
SO_4^{2-} + $4H^+$ + $2e^-$	=	SO_2 + $2H_2O$	+0.20
Sn^{4+} + $2e^-$	=	Sn^{2+}	+0.15
Sn^{2+} + $2e^-$	=	Sn	-0.14
Sr^{2+} + $2e^-$	=	Sr	-2.89
Zn^{2+} + $2e^-$	=	Zn	-0.76

Instructions for students

Answer **all** questions.

To obtain full credit for your responses you should

(1) give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full credit.

(2) show all working in your answers to numerical questions. No credit can be given for an incorrect answer unless it is accompanied by details of the working.

(3) 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

(a) The chemical properties of an element depend on the electron configuration of its atoms. For example, the element sodium has atomic number 11 and the electron configuration $1s^2 2s^2 2p^6 3s^1$.
Complete the following table for each of the elements listed.

TABLE 1.1

Element	*Atomic number*	*Electron configuration*
HELIUM	2	
CARBON	6	
MAGNESIUM	12	
SULFUR	16	
SCANDIUM	21	

(b) An element can form ions by gaining or losing electrons. For example, an atom of the element sodium can lose one electron to form the ion Na^+. Three elements from **TABLE 1.1** which **readily** form ions are listed. Write the symbol for the ion and the electron configuration of the ion in **TABLE 1.2**.

TABLE 1.2

Element	*Ion formed*	*Electron configuration*
MAGNESIUM		
SULFUR		
SCANDIUM		

$2\frac{1}{2} + 1\frac{1}{2}$ = 4 marks

(suggested time: 5 minutes)

QUESTION 2

(a) Most carbon atoms are carbon-12. The element carbon also forms a radioactive isotope, carbon-14. Explain the difference between carbon-12 and carbon-14.

(b) It is believed that carbon nuclei are formed from helium nuclei in the Sun. Write a balanced nuclear equation for this reaction.

(c) The Sun is 1.5×10^8 km from the Earth. No one has been there to collect samples for analysis! Explain how we know of the existence of the elements helium and carbon in the Sun?

2 + 1 + 3 = 6 marks

(suggested time: 7 minutes)

The following information refers to Questions 3 and 4

The element chlorine is the second element in Group VII of the Periodic Table and the second last member of Period 3. In combination with another Period 3 element, sodium, it forms one of the most important of all compounds, common salt.

QUESTION 3

Use your knowledge of the elements sodium and chlorine to illustrate briefly the trends in properties of the elements within Period 3 of the Periodic Table under the following headings.

(a) Electronegativity.

(b) Melting temperature.

(c) Structures of the elements.

3 + 3 + 3 = 9 marks

(suggested time: 11 minutes)

QUESTION 4

Use your knowledge of the compounds of sodium and chlorine to illustrate briefly the trends in properties within Period 3 of the Periodic Table under the following headings.

(a) Hydrides of the elements.

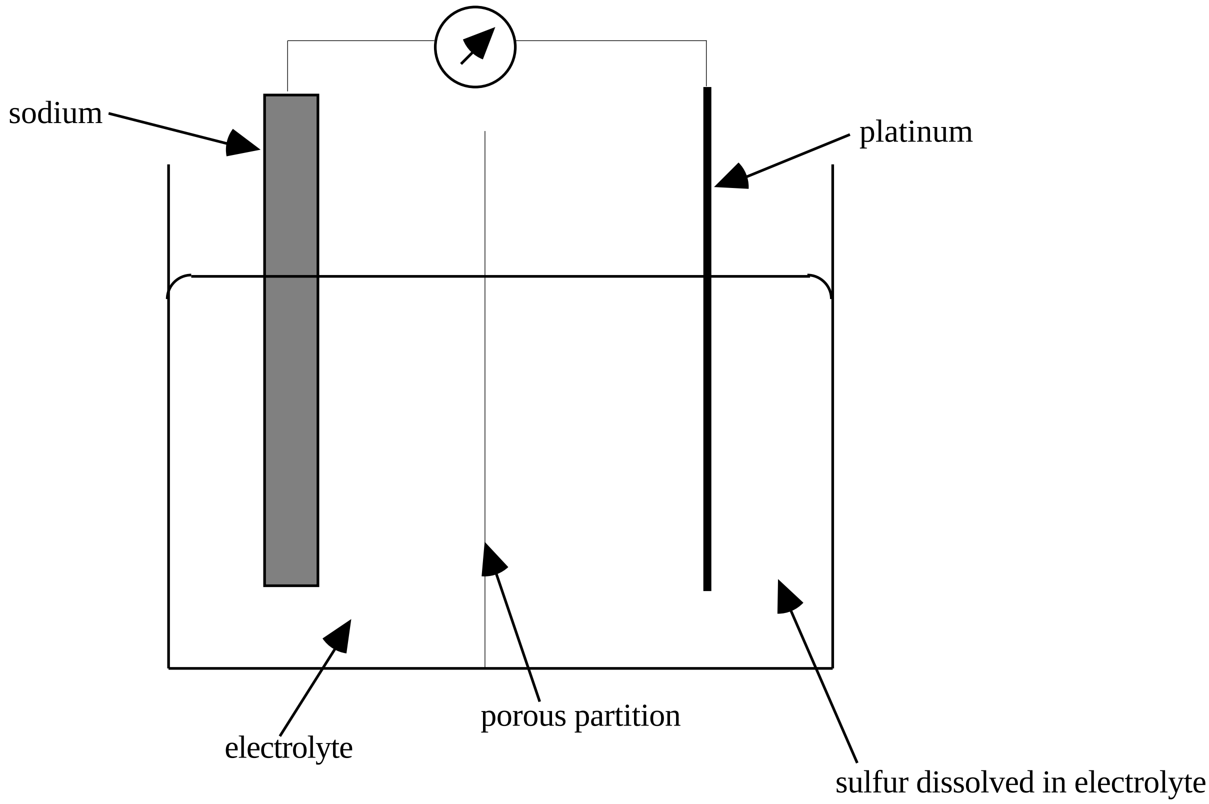
(b) Oxides of the elements.

3 + 3 = 6 marks

(suggested time: 7 minutes)

QUESTION 5

It has been suggested that the elements sodium and sulfur could be used in a galvanic cell to produce electrical energy as illustrated below.



(a) Write an equation for a half-reaction which could occur at the sodium electrode.

(b) Write an equation for a half-reaction which could occur at the platinum electrode.

(c) Write the overall reaction occurring in the galvanic cell.

(d) What is the maximum potential that could be generated by this galvanic cell?
(use the values given in TABLE 3 of the DATA)

(e) The electrolyte plays a vital role in the operation of this cell. Describe some of the characteristics required of the electrolyte in this cell so that the cell could operate properly.

1 + 1 + 1 + 1 + 3 = 7 marks

(suggested time: 8 minutes)

The following information refers to Questions 6, 7 and 8

A chemist in an industrial laboratory is asked to produce small samples of each of the elements: sodium, chlorine, hydrogen and oxygen for a customer. The chemist has access to the following list of materials.

CHEMICALS	*APPARATUS*
(1) solid sodium chloride	(1) container to hold molten materials
(2) water	(2) heat source to melt solids
(3) platinum electrodes	(3) source of electrical energy
(4) concentrated sulfuric acid	(4) container to hold aqueous solutions

QUESTION 6

Describe, with the aid of a diagram, how both sodium metal and chlorine gas could be produced from **one** electrolytic cell.

diagram

6 marks

(suggested time: 7 minutes)

QUESTION 7

Describe, with the aid of a diagram, how both hydrogen and and oxygen gas could be produced from **one** electrolytic cell.

diagram

6 marks

(suggested time: 7 minutes)

QUESTION 8

The customer requires exactly 10 g of sodium metal. For how long would the chemist have to pass a current of 10 A through the electrolytic cell to produce this amount of sodium?

3 marks

(suggested time: 4 minutes)

QUESTION 9

Many people like their coffee or tea to taste sweet. Sarah uses sucrose, Ross prefers glucose while Emilia chooses "Equal" which contains the chemical Aspartame with the molecular formula $C_{14}H_{18}N_2O_5$.

(a) Describe the differences between the structures of the two sugars glucose and sucrose.

Glucose	***Sucrose***

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(b) Write the balanced chemical equation that occurs when the sucrose used by Sarah undergoes hydrolysis.

(c) Write the balanced chemical equation when the product formed in (b) is used in respiration.

(d) Emilia reads the following nutritional information on her packet of "Equal".

> *"Natural Sugar Taste.*
> *Equal in sweetness to 2 teaspoons of sugar but provides less than 16 kJ"*

Emilia has a rather skeptical nature so she decides to investigate the energy content of her packet of "Equal". She uses a bomb calorimeter with a calorimeter constant of 40.0 kJ $^{o}C^{-1}$. The packet of "Equal" contains 0.5 g of Aspartame and reacts completely with oxygen in the calorimeter. What is the maximum temperature rise in the calorimeter if the energy content of the packet is to be less than 16 kJ?

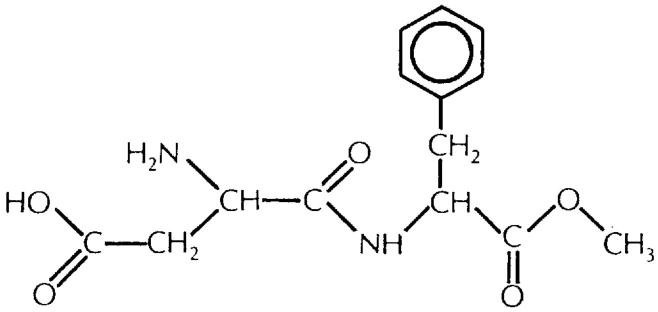
(e) Emilia finds that her packet of "Equal" has an energy content of 15 kJ. If the molecular mass of Aspartame is 294 g mol^{-1}, what is the heat released when 1 mol of Aspartame is burnt in oxygen?

4 + 2 + 2 + 3 + 2 = 13 marks

(suggested time: 16 minutes)

QUESTION 10

The sweetener Aspartame has the structural formula shown below.



(a) Circle the 'peptide link' in the structure above.

(b) In the space below, draw the structures of the two molecules formed when Aspartame undergoes hydrolysis.

Molecule 1	***Molecule 2***

(c) If the nitrogen atoms in the Aspartame molecule are not required for the manufacture of other molecules, they must be eliminated from the body. Briefly describe how this happens.

1 + 2 + 2 = 5 marks

(suggested time: 6 minutes)

QUESTION 11

The energy key to life in the world to-day is the generation of electrical energy but there are many different ways of obtaining this energy. One method in common use is nuclear fission. One method suggested for future use is nuclear fusion. Briefly describe how each of these two methods can be used to produce electrical energy. Use a diagram in each of your explanations.

(a) Nuclear fission.

Diagram

QUESTION 11 (continued)

(b) Nuclear fusion.

Diagram

5 + 5 = 10 marks

(suggested time: 12 minutes)

END OF 1993 VCE CHEMISTRY TRIAL CAT 3

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SUGGESTED SOLUTIONS

Question 1

(a)

Element	*Atomic number*	*Electron configuration*
HELIUM	2	$1s^2$
CARBON	6	$1s^2 2s^2 2p^2$
MAGNESIUM	12	$1s^2 2s^2 2p^6 3s^2$
SULFUR	16	$1s^2 2s^2 2p^6 3s^2 3p^4$
SCANDIUM	21	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$

(b)

Element	*Ion formed*	*Electron configuration*
MAGNESIUM	Mg^{2+}	$1s^2 2s^2 2p^6 3s^6$
SULFUR	S^{2-}	$1s^2 2s^2 2p^6 3s^2 3p^6$
SCANDIUM	Sc^+ or Sc^{3+}	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ $1s^2 2s^2 2p^6 3s^2 3p^6$

$2\frac{1}{2} + 1\frac{1}{2} = 4$ marks

(suggested time: 5 minutes)

Question 2

(a) Carbon-12 has 6 protons and 6 neutrons in its nucleus. It has an atomic number of 6 and a mass number of 12. Carbon-14 has 6 protons and 8 neutrons in its nucleus. It has an atomic number of 6 and a mass number of 14. Carbon-12 and carbon-14 are isotopes. The extra neutrons in carbon-14 make its nucleus unstable and it undergoes radioactive decay.

(b) The simple nuclear equation is: $3\ {}^4He_2 \rightarrow {}^{12}C_6$

(c) Every element shows a unique pattern of spectral lines. These lines may be either coloured (emission spectrum) or black (absorption spectrum). The examination of the emission and absorption spectra of atoms provides easy identification of these atoms.

When helium and carbon atoms atoms are given energy, some electrons are promoted to higher energy levels. When these electrons drop back into lower energy levels, energy is emitted in the form of electromagnetic radiation. This energy is emitted only in discrete packets called quanta and is equal to the difference in energy between the energy levels in the atom. Each of these discrete energy packets corresponds with one particular wavelength (or frequency) of light since $E_2 - E_1 = \Delta E = hf$.

2 + 1 + 3 = 6 marks

(suggested time: 7 minutes)

SUGGESTED SOLUTIONS

Question 3

(a) Electronegativity.

Electronegativity is a measure of the electron attracting power of an atom. Sodium has a low electronegativity and chlorine has a high electronegativity. Electronegativity increases steadily across Period 3 as the the number of protons in the nucleus increases while electrons are being added to the same outershell. Hence, sodium easily loses one electron to form Na^+ and chlorine easily gains one electron to form Cl^-.

(b) Melting temperature. ***(actual values of temperatures not required)***

Sodium has a relativively low melting temperature (98^{o}C) since the positive sodium ions in the metal structure are only loosely held together by the mobile outershell electrons. Chlorine is a gas at room temperature and pressure with very weak forces of attraction between the diatomic chlorine molecules. Hence, the melting temperature is low at -101^{o}C. The melting temperatures for the Period 3 elements increase to a maximum with silicon at 1423^{o}C and then decrease (although not in a perfectly regular fashion) to argon at -189^{o}C.

(c) Structures of the elements.

Sodium, magnesium and aluminium have metallic structures with a three dimensional lattice of positive ions in a 'sea of electrons'. Silicon has a three dimensional lattice structure with strong covalent bonding. Phosphorus P_4, sulfur S_8, and chlorine Cl_2 are molecular solids (at sufficiently low temperatures) with strong covalent bonding within the molecules but weak dispersion forces between the molecules. Phosphorus and sulfur have a variety of allotropic forms with different structures. Argon is a monatomic solid (below its melting temperature) with weak dispersion forces between the atoms.

3 + 3 + 3 = 9 marks

(suggested time: 11 minutes)

Question 4

(a) Hydrides of the elements.

(This answer contains much more than would be required to gain full marks.)

Sodium hydride (NaH) is an ionic white solid that reacts violently with water according to the equation: $NaH(s) + H_2O(l) \rightarrow NaOH(aq) + H_2(g)$. The solution produced is strongly basic. On the other hand, hydrogen chloride (HCl) is a colourless, molecular, covalently bonded gas at room temperature and pressure.

It dissolves readily in water to produce a strongly acidic solution according to the equation: $HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$.$MgH_2$ is similar in structure and reactions to NaH. AlH_3 is partly covalent and reacts with water similarly to NaH.

SiH_4 , PH_3 and H_2S are colourless, molecular, covalently bonded gases at room temperature and pressure. SiH_4 is neutral. PH_3 is slightly basic. H_2S is poisonous and produces a weakly acidic solution in water. The element argon does not form a hydride.

(b) Oxides of the elements.

(This answer contains much more than would be required to gain full marks.)

Sodium oxide (Na_2O) is an ionic white solid with a high melting temperature that dissolves in water to form a basic solution according to the equation:
$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$. In sharp contrast to this, dichlorine heptoxide (Cl_2O_7) is a colourless, molecular, covalently bonded liquid at room temperature and pressure. It dissolves readily in water to form a highly acidic solution according to the equation: $Cl_2O_7(l) + H_2O(l) \rightarrow 2HClO_4(aq)$. MgO is an ionic white solid with a very high melting temperature and forms a basic solution in water. Al_2O_3 is an ionic white solid with a very high melting temperature. It is insoluble in water but reacts with both acids and alkalis. SiO_2 is a colourless solid with a high melting temperature. It is insoluble in water but reacts with concentrated NaOH. P_4O_{10} is a white, molecular, covalently bonded solid with a much lower melting temperature. It dissolves in water to form a strong acid (H_3PO_4). SO_3 is a colourless, molecular, covalently bonded liquid at room temperature and pressure. It dissolves in water to form a strong acid (H_2SO_4).

3 + 3 = 6 marks

(suggested time: 7 minutes)

Question 5

(a) $Na(s) \rightarrow Na^+(_{electrolyte}) + e-$

Notice that it is **not** correct to write $Na^+(aq)$ since there is no water present.

(b) $S(_{electrolyte}) + 2H^+(_{electrolyte}) + 2e- \rightarrow H_2S(_{electrolyte})$

(c) $2Na(s) + S(_{electrolyte}) + 2H^+(_{electrolyte}) \rightarrow 2Na^+(_{electrolyte}) + H_2S(_{electrolyte})$

(d) The maximum potential = E^o(oxidant) - E^o(reductant) = +0.14 - (-2.71) = 2.85 V **ANS**

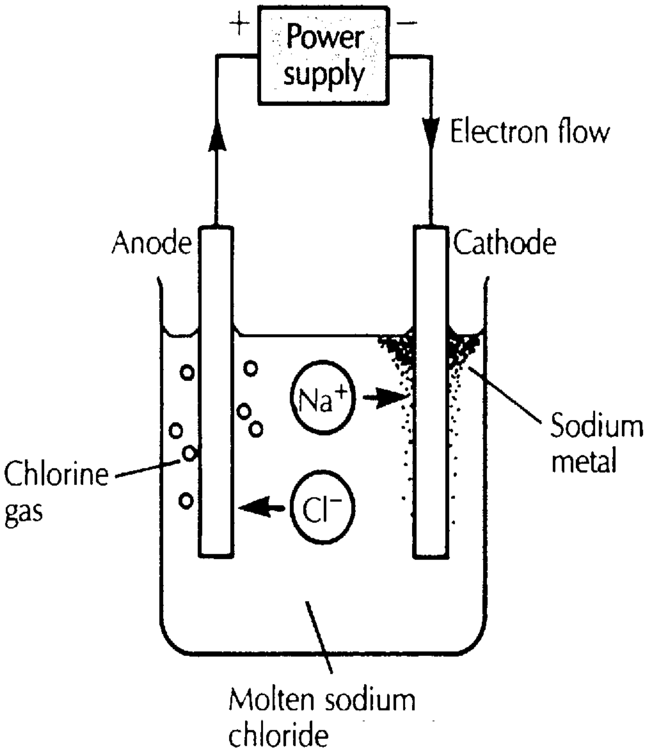
(e) The electrolyte in this cell must
(1) allow charge to pass through it to complete the electrical circuit.
(2) be able to dissolve sulfur.
(3) not contain any water since sodium metal reacts violently with water.
(4) not react with the products of the electrode reactions.

1 + 1 + 1 + 1 + 3 = 7 marks

(suggested time: 8 minutes)

SUGGESTED SOLUTIONS

Question 6

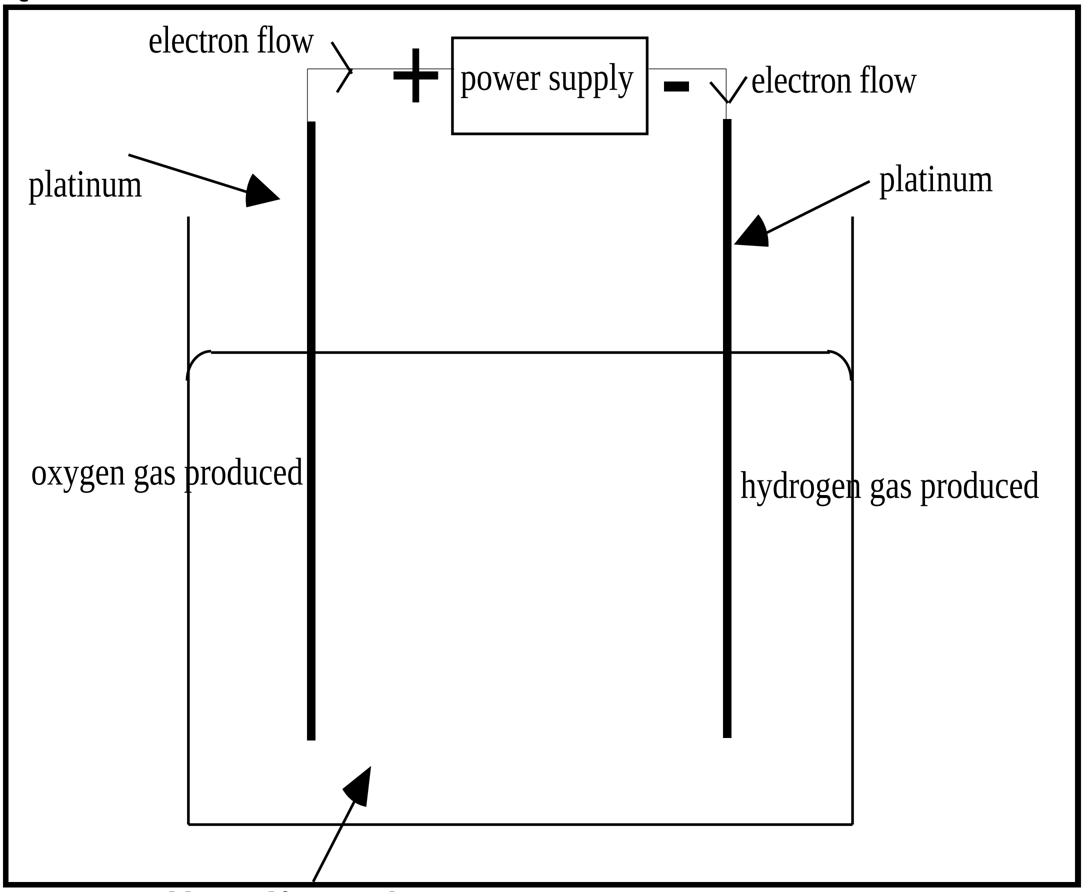


The solid sodium chloride must be made molten by the application of heat. Two platinum electrodes are connected to the power supply and then immersed in the molten NaCl. The chlorine gas is produced at the positive electrode by oxidation according to the equation: $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$. This is the anode. Sodium metal is produced at the negative electrode by reduction according to the equation: $Na^+(l) + e^- \rightarrow Na(l)$. This is the cathode.

6 marks
(suggested time: 7 minutes)

SUGGESTED SOLUTIONS

Question 7



dilute sulfuric acid

Use the concentrated sulfuric acid and water to produce a dilute solution of sulfuric acid. Immerse the platinum electrodes in the dilute sulfuric acid and connect the power supply. Oxygen gas is produced at the positive electrode by oxidation according to the equation: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$. This is the anode. Hydrogen gas is produced at the negative electrode by reduction according to the equation:

$2H^+(aq) + 2e^- \rightarrow H_2(g)$. This is the cathode.

6 marks

(suggested time: 7 minutes)

SUGGESTED SOLUTIONS

Question 8

From the balanced equation $Na^+(l) + e^- \rightarrow Na(l)$,

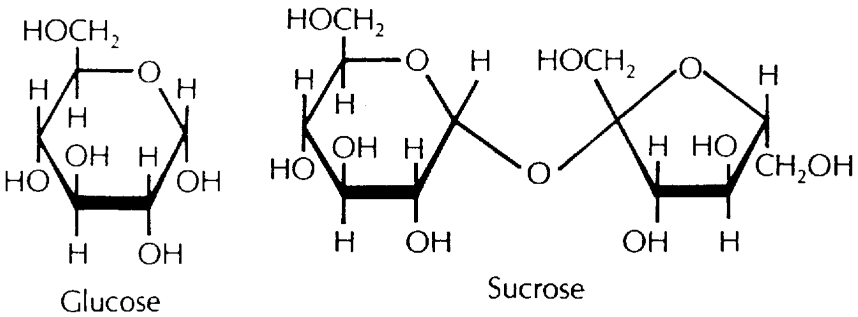
the number of mole of electrons = the number of mole of sodium = $\frac{10}{23}$.

Now, the quantity of electricity = $Q = I \times t = n(e^-) \times 96\,500$.

Hence, t (seconds) = $\frac{10}{23} \times \frac{96\,500}{10}$ = 4196 s = 1.2 hours **ANS**

3 marks
(suggested time: 4 minutes)

Question 9



(a) Glucose has the molecular formula $C_6H_{12}O_6$ while sucrose has the molecular formula $C_{12}H_{22}O_{11}$. Glucose is a monosaccharide. Sucrose is a disaccharide formed by the condensation reaction between glucose and fructose. In this condensation reaction, a link is established between the two monosaccharides through an oxygen atom (ether linkage) and a water molecule is eliminated in the process. The structures of glucose and sucrose are shown above.

(b) The hydrolysis equation for sucrose is:

$$C_{12}H_{22}O_{11}(aq) + H_2O(l) \rightarrow 2\,C_6H_{12}O_6(aq)$$

(c) The respiration equation is:

$$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

(d) Maximum energy = 40 x ΔT (maximum) = 16 kJ.

Hence, ΔT (maximum) = $\frac{16}{40}$ = 0.4 ^oC. **ANS**

(e) If 0.5 g of "Equal" produces 15 kJ,

then 294 g will produce $\frac{15 \times 294}{0.5}$ = 8820 kJ **ANS**

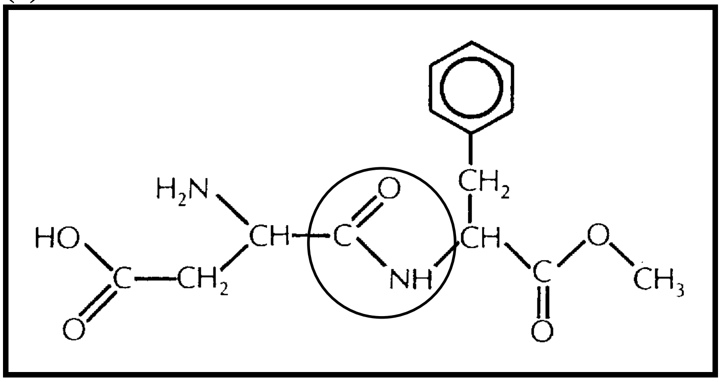
4 + 2 + 2 + 3 + 2 = 13 marks

(suggested time: 16 minutes)

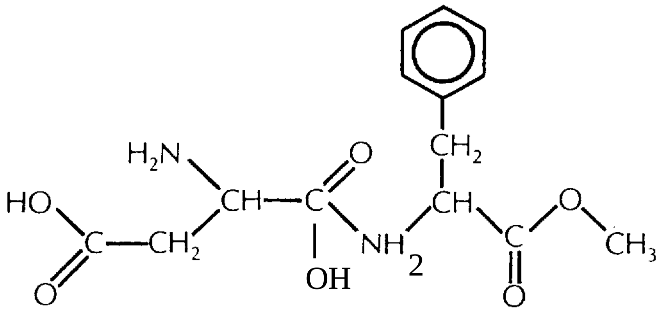
SUGGESTED SOLUTIONS

Question 10

(a)



(b)When Aspartame undergoes hydrolysis, water is added and the peptide link is broken to give the two molecules below.



Molecule 1 Molecule 2

(c) The nitrogen atoms are converted to ammonia which in turn is changed to urea. Urea has the formula $(NH_2)_2CO$. Urea is non-toxic, readily soluble in water and is easily eliminated from the body.

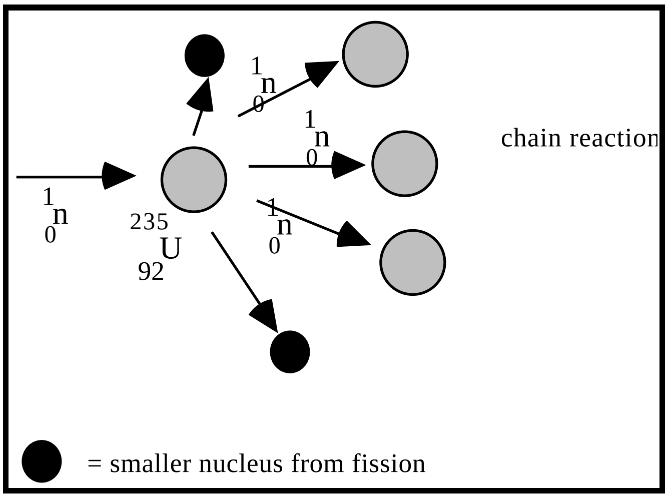
1 + 2 + 2 = 5 marks

(suggested time: 6 minutes)

SUGGESTED SOLUTIONS

Question 11

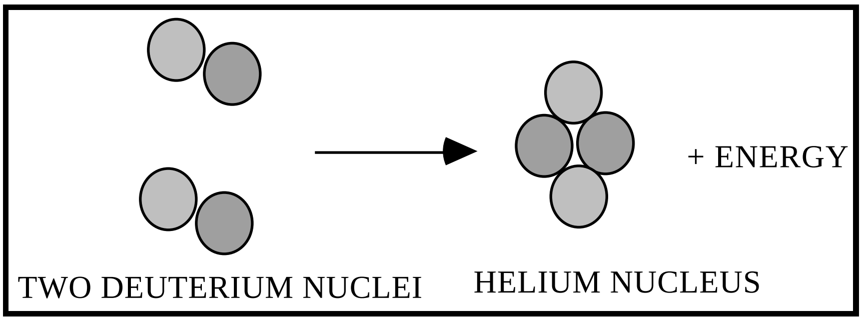
(a) Nuclear fission



When a heavy nucleus such as $^{235}U_{92}$ absorbs a neutron, the nucleus splits into smaller nuclei and releases energy and more neutrons. When a sufficient amount of $^{235}U_{92}$ is present, a chain reaction can occur. In a controlled chain reaction, the energy released is used to turn water into steam which drives a turbine to produce electricity. Nuclear fission gives a net energy gain when large nuclei are split.

SUGGESTED SOLUTIONS

(b) Nuclear fusion



In a nuclear fusion reaction such as $2\,^{2}H_{1} \rightarrow\ ^{4}He_{2}$, energy is released which is equivalent to the mass difference between the reactants and product according to the equation $E = \Delta mc^2$ where E = energy, Δm = difference in mass and c = speed of light. The energy released could be used to produce steam to drive a turbine to produce electricity. However, fusion reactions have not yet been produced in a controlled way.
Nuclear fusion gives a net energy gain when small nuclei are combined.

5 + 5 = 10 marks

(suggested time: 12 minutes)

END OF 1993 VCE CHEMISTRY TRIAL CAT 3 SOLUTIONS

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