1994

CHEMISTRY

UNIT 4

TRIAL EXAM

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STUDENT NUMBER Letter

Figures
Words

Victorian Certificate of Education 1994

CHEMISTRY

Common Assessment Task 3: Analysis and evaluation

1994 TRIAL CAT

(not to be used before Tuesday October 4, 1994)

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 19 pages.
Data sheets
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*
Carbon	C	12.0
Copper	Cu	63.5
Hydrogen	H	1.0
Magnesium	Mg	24.3
Nitrogen	N	14.0
Oxygen	O	16.0
Silver	Ag	107.9
Sodium	Na	23.0

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
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
Na^+	+	e^-	=	Na	-2.71
Ni^{2+}	+	$2e^-$	=	Ni	-0.25
$NO_3^- + 4H^+ + 3e^-$			=	$NO + 2H_2O$	+0.96
$NO_3^- + 2H^+ + e^-$			=	$NO_2 + H_2O$	+0.81
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

Glucose is called a **simple carbohydrate** while starch and cellulose are called **complex carbohydrates.**

(a) Explain why glucose, starch and cellulose are known as carbohydrates.

_____

_____

_____

_____

_____

(b) Use chemical formulae to explain the difference between a **simple carbohydrate** and a **complex carbohydrate**.

_____

_____

_____

_____

_____

Starch can be converted into simple carbohydrates by the action of enzymes.

(c) (i) What is the name given to this process?

_____

(ii) Write a balanced chemical equation to describe this reaction.

_____

QUESTION 1 (continued)

Lipids are complex molecules which are broken down into simpler molecules in the body.
A lipid can be represented by the general formula $C_3H_5(RCOO)_3$, where R is a long chain of carbon and hydrogen atoms.

(d) Write a balanced chemical equation for the hydrolysis of $C_3H_5(RCOO)_3$ and name one of the products formed in the reaction.

_____

PRODUCT _____

2+2+1+1+3 = 9 marks
(suggested time: 10 minutes)

QUESTION 2
The enzymes that help in the breakdown of complex molecules are proteins. One possible protein structure is

$$(\text{-NH - CH}_2\text{ - CO - NH - CH - COO-})_n$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad |$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad \text{CH}_3$$

where *n* represents the number of these units that are joined together.

This protein is a polymer of smaller units called monomers.

(a) What is the general name given to the monomers that combine to produce proteins?

_____

(b) Draw the structures of the two different monomers that have combined to produce the protein above.

STRUCTURE 1	**STRUCTURE 2**

QUESTION 2 (continued)

(c) What is the name given to the type of reaction that occurs when these two monomers combine?

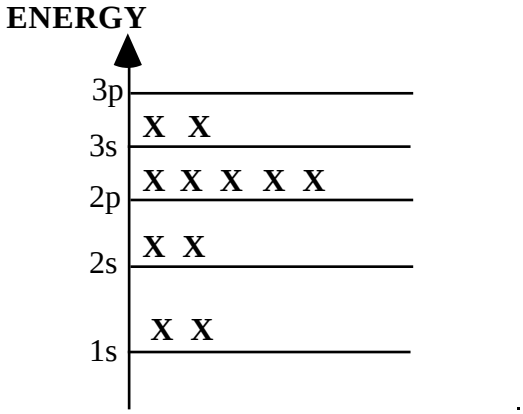
_____

(d) Give the chemical formula of another substance produced by this reaction.

_____

1+2+2+1+1 = 7 marks
(suggested time: 9 minutes)

QUESTION 3
In the diagram below (not to scale), **X** represents an electron.



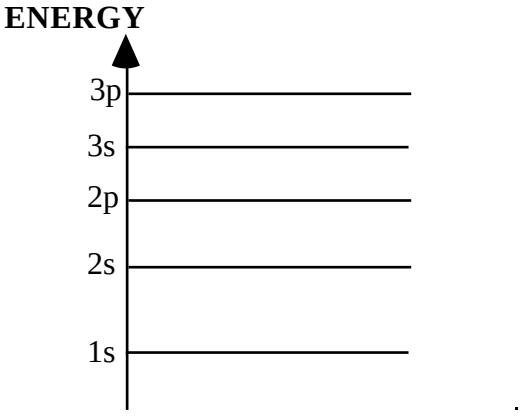
This is an electronic configuration of an atom with atomic number 11.

(a) What is the name given to this kind of electronic configuration?

_____

QUESTION 3 (continued)

(b) More energy is supplied to this atom. On the diagram below, draw another (different) possible electronic configuration for this atom.



(c) Also on the diagram above, show **two** possible electronic transitions that would be part of the emission spectrum for this atom.

(d) The ion Mg^{2+} has the same ground electronic configuration as the ion Na^{+}. Will these ions have the same emission spectrum? Give a reason for your answer.

_____

_____

_____

_____

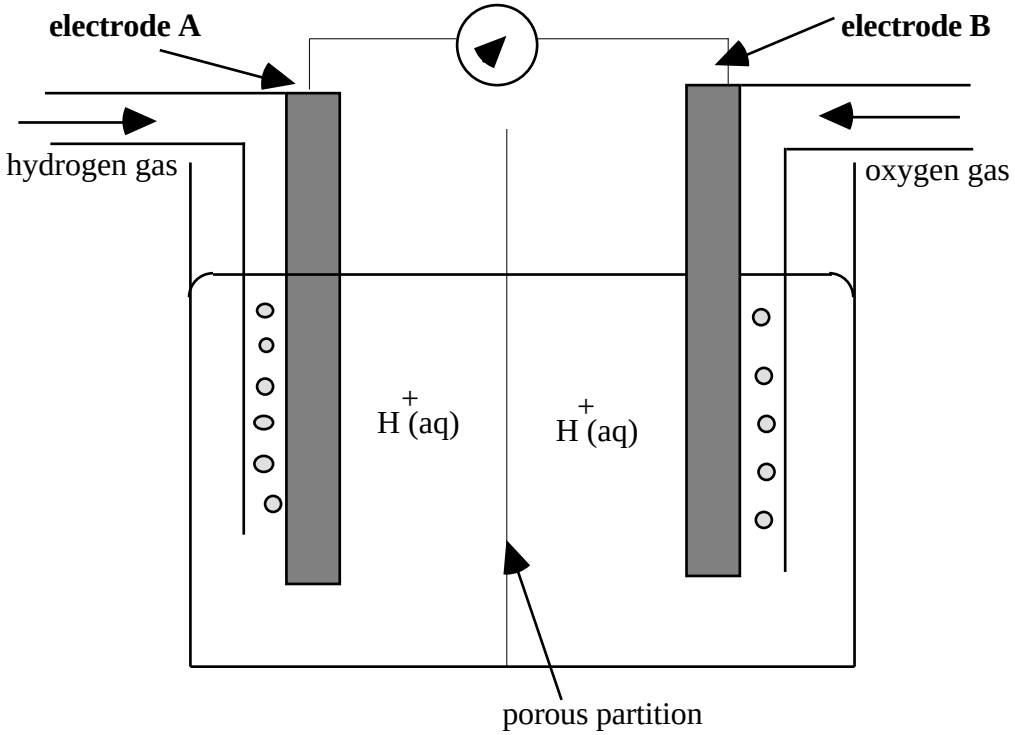
_____

1+1+2+2 = 6 marks

(suggested time: 7 minutes)

QUESTION 4

The hydrogen/oxygen fuel cell is a means of producing an electric current from the reaction between hydrogen gas and oxygen gas which are supplied continuously to electrodes A and B as shown in the diagram below.



(a) Write the equations for the reactions occurring at

(i) cathode _____

(ii) anode _____

(b) Which electrode in this fuel cell is the cathode?

_____

(c) Write the balanced chemical equation for the overall reaction occurring in the fuel cell.

_____

(d) If the E^0 for the cathode reaction is 0 V and the E^0 for the anode reaction is +1.23 V, what is the maximum possible voltage for this fuel cell?

_____

QUESTION 4 (continued)

(e) Give one reason why the actual voltage of this fuel cell is less than the possible maximum.

_____

_____

_____

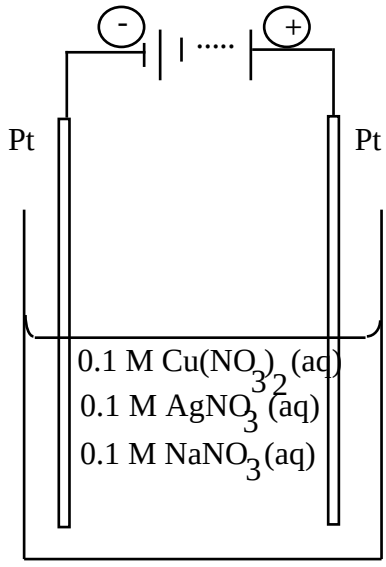
_____

_____

1+1+1+1+1+1 = 6 marks
(suggested time: 7 minutes)

QUESTIONS 5 and 6 REFER TO THE FOLLOWING INFORMATION

A student is supplied with the following electrolytic cell.



Volume of electrolyte = 1 L

The electrolyte has a volume of 1 L and is a mixture of 0.1M $Cu(NO_3)_2$(aq), 0.1M $AgNO_3$(aq) and 0.1M $NaNO_3$(aq). The electrodes are inert platinum.

QUESTION 5

(a) Which metal will be deposited first on the cathode when the cell is operated?

_____

_____

_____

_____

_____

(b) Write a balanced equation for this electrode reaction.

_____

(c) Write a balanced equation for the reaction at the anode.

_____

(d) The cell is run for a long time. Use the following code to complete the table below.
E = equal to 0.1 M, **G** = much greater than 0.1 M, **L** = much less than 0.1 M.

	Initial Concentration	**Final Concentration**
Cu^{2+}		
Ag^{+}		
Na^{+}		
NO_3^{-}		

1+1+1+4 = 7 marks
(suggested time: 9 minutes)

QUESTION 6

A current of 0.1 A is passed through the electrolyte for 60 minutes. Calculate the mass of metal deposited on the cathode in this time. (You should assume that one metal is deposited completely before any other reaction begins.)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

5 marks

(suggested time: 6 minutes)

QUESTION 7

The carbon atoms in human bodies had their origin in nuclear reactions in distant stars (according to the theory of nucleogenesis).

(a) Write a balanced nuclear equation for the formation of a carbon nucleus from a helium nucleus.

_____

(b) Is this reaction exothermic or endothermic? Give a reason for your answer.

_____

_____

_____

_____

_____

(c) Draw a flowchart to show how a carbon nucleus formed in the stars could now be a part of a glucose molecule in a human cell.

carbon nucleus in star

carbon nucleus in glucose molecule

1+1+4 = 6 marks

(suggested time: 7 minutes)

QUESTION 8

A single serving of breakfast cereal has the following nutritional information printed on the packet.

serving size	19 g
energy content	294 kJ
total fat	0 g
total protein	1 g
total carbohydrate	17 g
fibre	1 g

A scientist carries out the following procedures and makes the following measurements using a packet of this cereal and a bomb calorimeter.

(1) 19 g of cereal added to the calorimeter.

(2) Initial temperature of calorimeter = 24.820 ^{o}C.

(3) 10 kJ of electrical energy added to the calorimeter.

(4) Calorimeter temperature rises to 25.995 ^{o}C.

(5) Calorimeter cooled to 24.500 ^{o}C.

(6) Excess oxygen gas added to the calorimeter.

(7) Complete combustion of the cereal.

(8) Final calorimeter temperature = 57.400 ^{o}C.

(a) According to the nutritional information on the packet of cereal, what is the energy content per gram (in kJ/g)?

_____

_____

_____

_____

_____

QUESTION 8 (continued)

(b) What is the experimentally determined value (in kJ/g) of the energy content of the cereal?

(c) Assuming that all figures quoted are accurate, give a possible explanation for the difference between the values in (a) and (b).

1+4+1 = 6 marks
(suggested time: 7 minutes)

QUESTION 9

Maltose is a carbohydrate with the molecular formula $C_{12}H_{22}O_{11}$.

(a) Write a balanced chemical equation for the combustion of maltose in excess oxygen to produce carbon dioxide and water.

_____

(b) 17 g of maltose reacts completely with oxygen according to the equation above. What volume of carbon dioxide in litres will be produced by this reaction at 101,325 Nm^{-2} and 25 ^{o}C?

_____

_____

_____

_____

_____

1+4 = 5 marks
(suggested time: 6 minutes)

QUESTION 10

The electronic configurations of five ions are given below. The charge on the ion is given after the electronic configuration.

ION	Electronic Configuration	Charge
A	$1s^2$	+2
B	$1s^2 2s^2 2p^6$	+3
C	$1s^2 2s^2 2p^6 3s^2 3p^6$	-1
D	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$	+1
E	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$	+4

(a) From the above ions, **A**,**B**,**C**,**D** and **E**,

(i) Which one is an element in Group II of the Periodic Table?

_____

(ii) Which one is a Transition Element?

_____

(iii) Which one is a metal in Period 3 of the Periodic Table?

_____

(iv) Which one is an element that forms a gas at room temperature and pressure?

_____

Over the years, the Periodic Law has been expressed in different ways.

(1) "The chemical properties of the elements are a periodic function of their atomic weights."

(2) "The chemical properties of the elements are a periodic function of their atomic numbers."

(3) "The chemical properties of the elements are a periodic function of their electronic configurations."

(b) Which one or more of these expressions correctly state(s) the Periodic Law as it is understood in 1994? Explain your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

1+1+1+1+3 = 7 marks
(suggested time: 9 minutes)

QUESTION 11

The following questions refer to some of the elements in the first series of transition elements.

(a) What is the common characteristic of the electronic configurations of these ten elements?

_____

(b) These elements are all classified as metals. List (i) one property they have in common with the main group metal, sodium and (ii) one property that they do not have in common with sodium.

(i)_____

(ii)_____

(c) In aqueous solution, the elements chromium and manganese form simple ions and also ions containing oxygen. Choose two examples for each element and complete the table below.

	Chromium	Manganese
simple aqueous ion		
colour of simple ion		
aqueous ion containing oxygen		
oxidation number of the metal in this aqueous ion containing oxygen		

QUESTION 11

(d) Write a balanced half-equation that shows the aqueous chromium ion containing oxygen, from the table above, acting as an oxidant.

_____

(e) The element iron is produced in a blast furnace by reduction. Write a balanced chemical equation for this reaction.

_____

1+1+1+1+1+1+1+ 2+2 = 11 marks
(suggested time: 13 minutes)

END OF 1994 VCE CHEMISTRY TRIAL CAT 3

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SUGGESTED SOLUTIONS

Question 1

(a) Glucose, $C_6H_{12}O_6$, and cellulose, $(C_6H_{10}O_5)_n$ are carbohydrates because they are compounds of carbon, hydrogen and oxygen with the general formula of $C_x(H_2O)_y$.

(b) A simple carbohydrate is a monomer such as glucose or fructose with the formula $C_6H_{12}O_6$. A complex carbohydrate, such as starch or cellulose, has the general formula $(C_6H_{10}O_5)_n$ where *n* is variable. Complex carbohydrates are condensation polymers of simple carbohydrates.

(c) (i) The process of converting starch to simple carbohydrates is called digestion.

(ii) $(C_6H_{10}O_5)_n + nH_2O = n\,C_6H_{12}O_6$

(d) $C_3H_5(RCOO)_3 + 3\,H_2O = C_3H_5(OH)_3 + 3RCOOH$

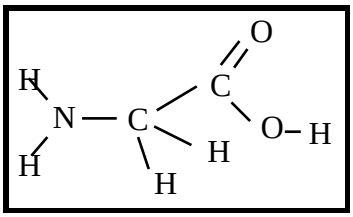
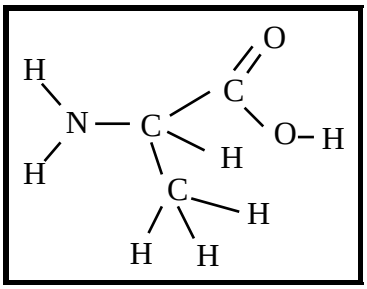
lipid **glycerol** **fatty acid**

Hydrolysis means reaction with water.

Question 2

(a) The monomers that combine to produce proteins are called amino acids.

(b)

STRUCTURE 1	**STRUCTURE 2**
	

(c) This reaction is called condensation polymerisation.

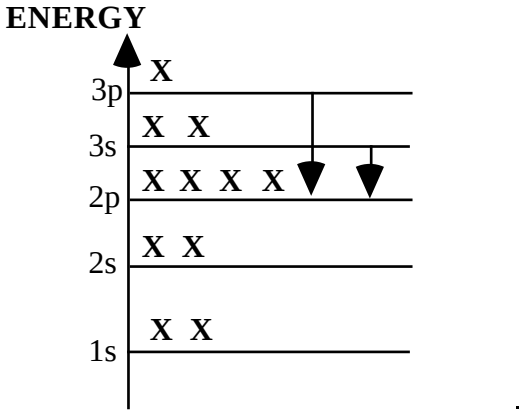
(d) Water, H_2O, is produced in this reaction.

SUGGESTED SOLUTIONS

Question 3

(a) This is the electronic configuration for a sodium atom (Z = 11). It shows $1s^2 2s^2 2p^5 3s^2$. This is an **excited** electronic configuration.

(b) Since more energy is supplied, another higher excited state must be produced. An example is shown below.



(c) To produce an emission spectrum, the electrons must move to a lower energy level. This is **one** possible answer for (b) and (c)

(d) The emission spectrum of an ion depends on the electronic configuration and also on the nuclear charge. Na^+ has an atomic number of 11 while Mg^{2+} has an atomic number of 12. Hence, the ions will not have the same emission spectrum.

Question 4

(a) (i) $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

(ii) $H_2(g) \rightarrow 2H^+(aq) + 2e^-$

(b) The cathode is the electrode at which reduction takes place. $O_2(g)$ with oxidation number 0 is reduced to $H_2O(l)$ in which oxygen has an oxidation number of -2. Hence, **B** is the cathode.

(c) The overall reaction for the fuel cell is $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$. This equation is obtained by multiplying (ii) by 2 and adding it to equation (i).

(d) The maximum potential = E^o(oxidant) - E^o(reductant) = 1.23 - 0 = 1.23 V **ANS**

(e) The electrodes are of critical importance in a fuel cell. Lack of perfect contact of the reactants with the electrodes results in a lower than expected voltage.

SUGGESTED SOLUTIONS

Question 5

(a) $Ag^+(aq)$ has the more positive E^0 value. Hence, Ag(s) will be deposited before Cu(s).

(b) $Ag^+(aq) + e^- \rightarrow Ag(s)$

(c) At the anode, water reacts according to the equation $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$
This is an oxidation reaction.

(d) The initial concentrations are: $[Cu^{2+}(aq)] = 0.1$ M , $[Ag^+(aq)] = 0.1$ M,
$[Na^+(aq)] = 0.1$ M, $[NO_3^-(aq)] = 0.2 + 0.1 + 0.1 = 0.4$ M.
During electrolysis, only $Cu^{2+}(aq)$ and $Ag^+(aq)$ are reduced. $Na^+(aq)$ does not react since $E^0(H_2O)$ is greater than $E^0(Na^+(aq))$. $NO_3^-(aq)$ does not react in aqueous solution. Hence, the final concentrations are: $[Cu^{2+}(aq)] \approx 0$ M , $[Ag^+(aq)] \approx 0$ M,
$[Na^+(aq)] = 0.1$ M, $[NO_3^-(aq)] = 0.4$ M. Hence, the table is:

	Initial Concentration	**Final Concentration**
Cu^{2+}	E	L
Ag^+	E	L
Na^+	E	E
NO_3^-	G	G

Question 6

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

Hence, $n(e^-) = \frac{0.1 \times 60 \times 60}{96500} = \frac{360}{96500} = 0.0037$ mole. This is less than 0.1 mole.
Hence, all of the metal deposited will be silver.

From the balanced equation $Ag^+(aq) + e^- \rightarrow Ag(s)$,
the number of mole of silver = the number of mole of electrons = $\frac{360}{96500}$.
Hence, the mass of silver = $\frac{360 \times 107.9}{96500} = 0.4$ g **ANS**

SUGGESTED SOLUTIONS

Question 7

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

(b) When low atomic number elements undergo fusion, energy is released.
The reaction is exothermic.

carbon nucleus in star

carbon nucleus in our star, the Sun

carbon atom in the Earth which has formed from the sun

carbon atom reacts with oxygen to produce carbon dioxide $C(s) + O_2(g) = CO_2(g)$

green plant photosynthesis to produce glucose $6CO_2(g) + 6H_2O(l) = C_6H_{12}O_6(aq) + 6O_2(g)$

human consumption of plant

carbon nucleus in glucose molecule

Question 8

(a) Energy content per gram = $\frac{294}{19}$ = 15.47 kJ/g **ANS**

(b) Calorimeter constant = $K = \frac{E}{\Delta T} = \frac{10}{(25.995 - 24.820)} = \frac{10}{1.175}$

Energy released on combustion of 19 g of cereal = $\frac{10}{1.175}$ x (57.400 - 24.500) = 280 kJ

Hence, energy content per gram = $\frac{280}{19}$ = 14.74 kJ/g **ANS**

(c) If the cereal had absorbed some moisture, this would give a lower than expected value for the energy content since the mass of cereal would be less than 19 g.

SUGGESTED SOLUTIONS

Question 9

(a) The balanced equation is $C_{12}H_{22}O_{11}(aq) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(l)$

(b) From the balanced equation: $n(CO_2) = 12 \times n(\text{maltose}) = 12 \times \frac{17}{342} = \frac{204}{342}$.

$V(CO_2) = \frac{nRT}{P} = \frac{204}{342} \times \frac{8.31 \times (273 + 25) \times 1000}{101325}$ L = 14.6 L **ANS**

Question 10

(a) (i) The Group II element is **A** (Be^{2+})

(ii) The transition element is **D** (Sc^{+})

(iii) The metal in Period 3 is **B** (Al^{3+})

(iv) The gas at room temperature and pressure is **C** (Cl_2)

(b) It is not correct to say that the chemical properties of the elements are a periodic function of their atomic weights since atomic weight is not the cause of chemical properties. The chemical properties of the elements are a result of the outer shell electronic configurations of the atom. These electronic configurations, in turn, arise from the atomic numbers of the elements. Hence, only (2) and (3) are correct. In summary,

atomic number → outer shell electronic configuration → chemical properties

SUGGESTED SOLUTIONS

Question 11

(a) The first series of transition elements correspond to the filling of the 3d subshell.

$3d^1$ (Sc) to $3d^{10}$(Zn)

(b) (i) Like sodium, the transition metals are good conductors of heat and electricity. They are also malleable and ductile.

(ii) The transition metals are harder and have higher melting temperatures and boiling temperatures than sodium. Unlike sodium, they form a wide range of coloured compounds with variable oxidation numbers.

(c) One set of possible answers is:

	Chromium	Manganese
simple aqueous ion	$Cr^{2+}(aq)$	$Mn^{2+}(aq)$
colour of simple ion	blue	colourless
aqueous ion containing oxygen	$Cr_2O_7^{2-}(aq)$	$MnO_4^-(aq)$
oxidation number of the metal in this aqueous ion containing oxygen	+6	+7

(d) One possible half-equation is: $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- = 2Cr^{3+}(aq) + 7H_2O(l)$

(e) $Fe_2O_3(s) + 3CO(g) = 2Fe(l) + 3CO_2(g)$

END OF 1994 VCE CHEMISTRY TRIAL CAT 3 SOLUTIONS

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