1996

CHEMISTRY

UNIT 4

TRIAL EXAM

CHEMISTRY ASSOCIATES
P.O. BOX 2227
KEW, VIC., 3101
AUSTRALIA
TEL:(03) 9817 5374 FAX: (03) 9817 4334

email: chemas@vicnet.net.au

Internet: http://www.vicnet.net.au/~chemas/education.htm

STUDENT NUMBER

									Letter
Figures									
Words									

Victorian Chemistry 1996

CHEMISTRY

Common Assessment Task 3: Analysis and evaluation

1996 TRIAL CAT

(not to be used before Monday, October 7, 1996)

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*
12	12

Directions to students

Materials
Question and answer booklet of 19 pages with a detachable data sheet
Working space is provided throughout this booklet.
An approved calculator may be used.

The task
Detach the data sheet from this booklet during reading time.
Please ensure that you write your **student number** in the space provided on this page.
Answer **all** questions.
Questions should be answered in the spaces provided in this booklet
The suggested times and marks allotted to each question are indicated at the end of the question.
There is a total of 66 marks available.
All written responses should be in English.

At the end of the task
Hand in this question and answer booklet.

Chemistry CAT 3
Data Sheet

Physical constants

$F = 96\,500\ C\ mol^{-1}$

$R = 8.31\ J\ K^{-1}mol^{-1}$

1 atm = 101 325 Pa

$0^oC = 273\ K$

The electrochemical series

			E^o **in volt**
$H_2O_2(aq) + 2H^+(aq) + 2e^-$	→	$2H_2O(l)$	+1.77
$Au^+(aq) + e^-$	→	$Au(s)$	+1.68
$Cl_2(g) + 2e^-$	→	$2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^-$	→	$2H_2O(l)$	+1.23
$Br_2(l) + 2e^-$	→	$2Br^-(aq)$	+1.09
$Ag^+(aq) + e^-$	→	$Ag(s)$	+0.80
$Fe^{3+}(aq) + e^-$	→	$Fe^{2+}(aq)$	+0.77
$I_2(s) + 2e^-$	→	$2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^-$	→	$4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^-$	→	$Cu(s)$	+0.34
$S(s) + 2H^+(aq) + 2e^-$	→	$H_2S(g)$	+0.14
$2H^+(aq) + 2e^-$	→	$H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^-$	→	$Pb(s)$	-0.13
$Sn^{2+}(aq) + 2e^-$	→	$Sn(s)$	-0.14
$Ni^{2+}(aq) + 2e^-$	→	$Ni(s)$	-0.23
$Co^{2+}(aq) + 2e^-$	→	$Co(s)$	-0.28
$Cr^{3+}(aq) + e^-$	→	$Cr^{2+}(aq)$	-0.41
$Fe^{2+}(aq) + 2e^-$	→	$Fe(s)$	-0.44
$Zn^{2+}(aq) + 2e^-$	→	$Zn(s)$	-0.76
$2H_2O(l) + 2e^-$	→	$H_2(g) + 2OH^-(aq)$	-0.83
$Mn^{2+}(aq) + 2e^-$	→	$Mn(s)$	-1.03
$Al^{3+}(aq) + 3e^-$	→	$Al(s)$	-1.67
$Mg^{2+}(aq) + 2e^-$	→	$Mg(s)$	-2.34
$Na^+(aq) + e^-$	→	$Na(s)$	-2.71
$Ca^{2+}(aq) + 2e^-$	→	$Ca(s)$	-2.87
$K^+(aq) + e^-$	→	$K(s)$	-2.93
$Li^+(aq) + e^-$	→	$Li(s)$	-3.02

END OF DATA SHEET

Periodic table of the elements

1 H 1.0																	2 He 4.0
3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.1
11 Na 23.0	12 Mg 24.3											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 39.9
19 K 39.1	20 Ca 40.1	21 Sc 44.9	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.9	27 Co 58.9	28 Ni 58.7	29 Cu 63.6	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc 98.1	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 197.0	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)															

Lanthanides

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.3	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0

Actinides

90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.1	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (258)	102 No (255)	103 Lr (256)

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

Starch is called a **complex carbohydrate** while fructose is called a **simple carbohydrate**.

(a) Explain why starch and fructose are known as carbohydrates.

_____

_____

_____

_____

_____

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

_____

_____

_____

_____

_____

Question 1 (continued)

In some animals, cellulose 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.

_____

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 a lipid.

_____

1+1+1+1+2 = 6 marks
(suggested time: 8 minutes)

Question 2

Proteins are enzymes that help in the breakdown of complex molecules. One possible protein structure is

$$(\text{-NH - CH}_2\text{ - CO - NH - }\underset{\displaystyle \overset{|}{\text{Z}}}{\text{CH}}\text{ - COO-})_n$$

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**

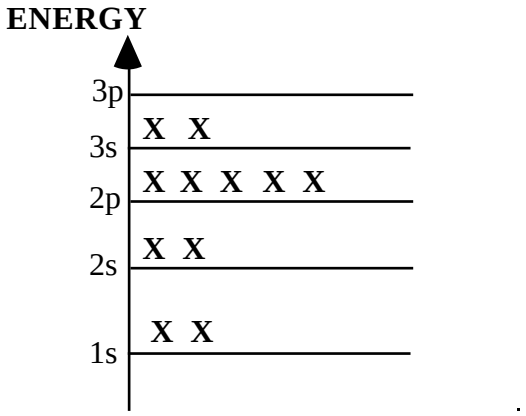
(c) What is the name given to this reaction?

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

1+2+1+1 = 5 marks
(suggested time: 7 minutes)

Question 3

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

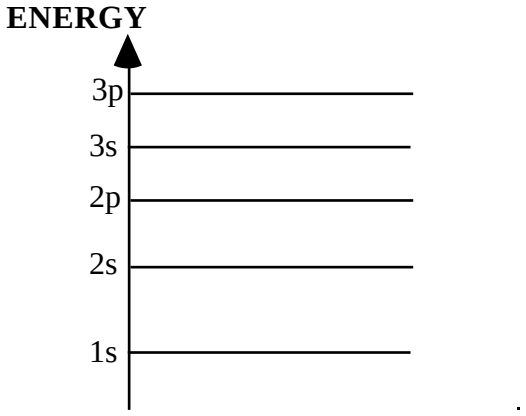


This is an electronic configuration of an ion with atomic number 13.

(a) Write the electronic configuration for this ion?

_____

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



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

Question 3 (continued)

(d) The ion Al^{3+} has the same ground electronic configuration as the ion Na^{+}. Will these ions have the same emission spectrum? Give a reason for your answer.

_____

_____

_____

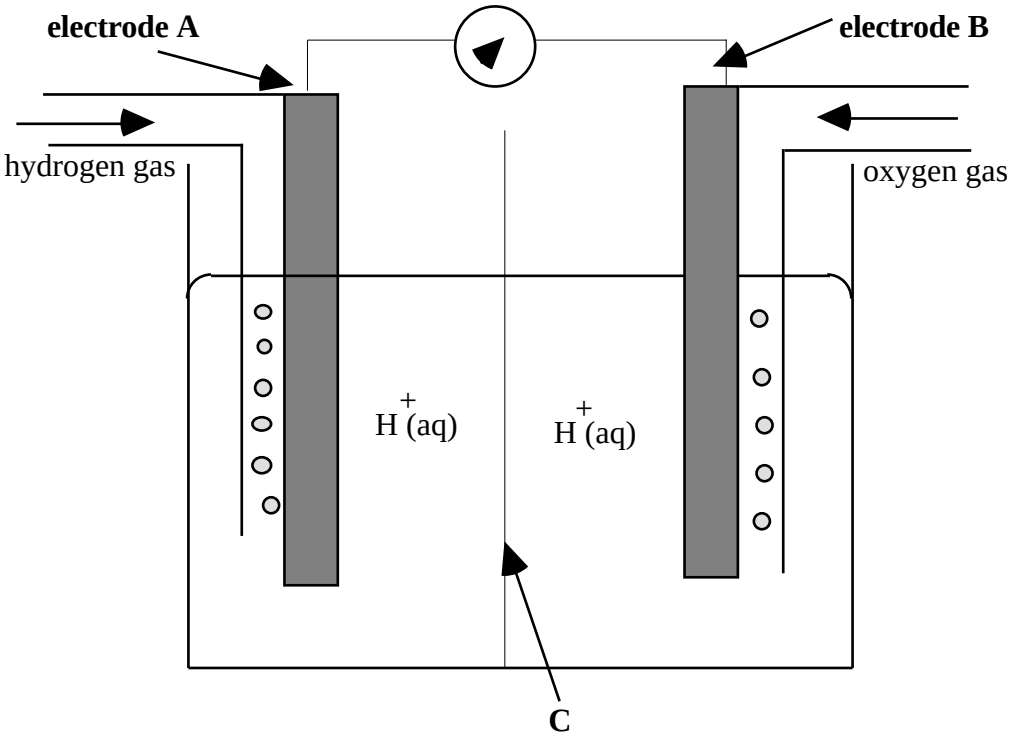
_____

_____

1+1+2+1 = 5 marks
(suggested time: 7 minutes)

Question 4

The cell shown below 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.



(a) Write the equations for the reactions occurring at the

(i) positive electrode _____

(ii) negative electrode _____

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

_____

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

_____

(d) Identify structure **C** in the diagram of the cell

_____

Question 4 (continued)

(e) Calculate the maximum possible potential for this cell by using E^0 values.

_____

_____

_____

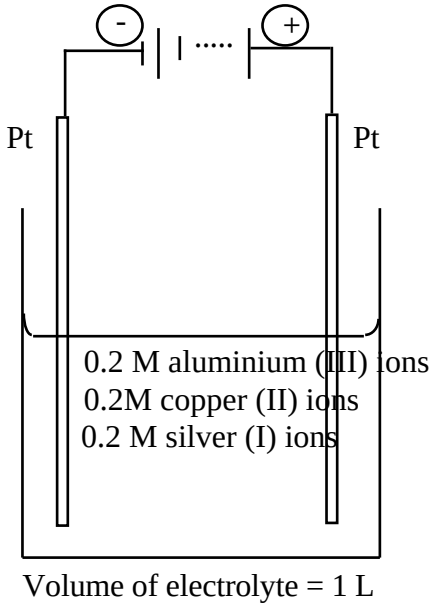
_____

_____

1+1+1+1+1+1 = 6 marks
(suggested time: 8 minutes)

Questions 5 and 6 refer to the following information

The following electrolytic cell is set up.



The electrolyte has a volume of 1 L and is a mixture of 0.2M $Al(NO_3)_3(aq)$, 0.2M $Cu(NO_3)_2(aq)$, and 0.2M $AgNO_3(aq)$. The electrodes are inert platinum.

Question 5

(a) Which metal will be deposited **last** 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.

_____

Question 5 (continued)

(d) The cell is run for a long time. Complete the table below.

	Initial Concentration	**Final Concentration**
Cu^{2+}		
Ag^{+}		
Al^{3+}		
NO_3^{-}		

1+1+1+ 2 = 5 marks
(suggested time: 7 minutes)

Question 6

A current of 0.2 A is passed through the electrolyte for 2 hours. Calculate the mass of silver 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: 7 minutes)

Question 7

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

_____

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

_____

_____

_____

_____

_____

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

hydrogen nucleus in star

hydrogen nucleus in water molecule

1+1+3 = 5 marks
(suggested time: 7 minutes)

Question 8

A packet of food has the following nutritional information printed on it.

serving size	25 g
energy content	400 kJ
total fat	0 g
total protein	1 g
total carbohydrate	17 g
fibre	1 g

The following experiment is carried out using a packet of this cereal and a bomb calorimeter.

(1) 25 g of cereal added to the calorimeter.

(2) Initial temperature of calorimeter = 24.720 ^{o}C.

(3) 12 kJ of electrical energy added to the calorimeter.

(4) Calorimeter temperature rises to 26.000 ^{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 = 60.400 ^{o}C.

(a) According to the nutritional information on the packet of food 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 food?

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

1+3+1 = 5 marks
(suggested time: 7 minutes)

Question 9

A carbohydrate has the molecular formula $C_{12}H_{22}O_{11}$.

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

_____

(b) 34.2 g of this carbohydrate 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 15 ^{o}C?

_____

_____

_____

_____

_____

1+ 3 = 4 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	$1s^2 2s^1$	+1
B	$1s^2 2s^2 2p^6 3s^1$	+2
C	$1s^2 2s^2 2p^6$	-1
D	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$	+1
E	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$	+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 forms an element that is a gas at room temperature and pressure?

_____

Question 10 (continued)

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 numbers.

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

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

(b) Which **one or more** of these expressions correctly state(s) the Periodic Law as it is understood in 1996? Explain your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

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

Question 11

(a) What is a common characteristic of the electronic configurations of the first row of transition elements?

_____

(b) These elements are all classified as metals.

Give one property they have in common with the main group metal, aluminium one property that they do not have in common with aluminium.

(i)_____

(ii)_____

(c) In aqueous solution, the element chromium forms simple ions and also ions containing oxygen. Choose four examples and complete the table below.

	Chromium	
two simple aqueous ions	(1)	(2)
two aqueous ions containing oxygen	(3)	(4)
colour of these two aqueous ions containing oxygen		
oxidation number of chromium in these two aqueous ions containing oxygen		

Question 11

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

_____

1+1+1+1+1+1+1+ 2 = 9 marks
(suggested time: 11 minutes)

Question 12

Write an equation in the table below to describe each of these energy sources.

Energy source	Equation
nuclear fission	
nuclear fusion	
combustion of fossil fuels	

2+1+1 = 4 marks
(suggested time: 6 minutes)

END OF QUESTIONS 1996 CHEMISTRY TRIAL CAT 3

CHEMISTRY ASSOCIATES
PO BOX 2227
KEW
VICTORIA 3101
AUSTRALIA
TEL: (03) 9817 5374 FAX: (03) 9817 4334

email: chemas@vicnet.net.au
INTERNET: http://www.vicnet.net.au/~chemas/education.htm

Question 1

(a) Fructose, $C_6H_{12}O_6$, and starch, $(C_6H_{10}O_5)_n$ 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 cellulose to simple carbohydrates is called digestion.

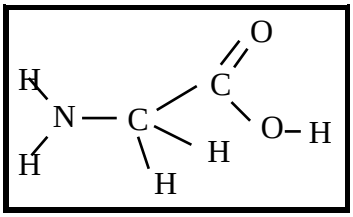
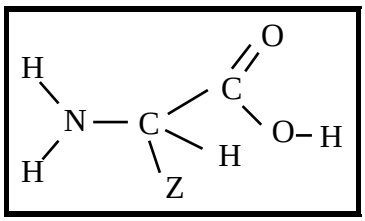
(ii) $(C_6H_{10}O_5)_n + nH_2O = n\,C_6H_{12}O_6$

(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**
	

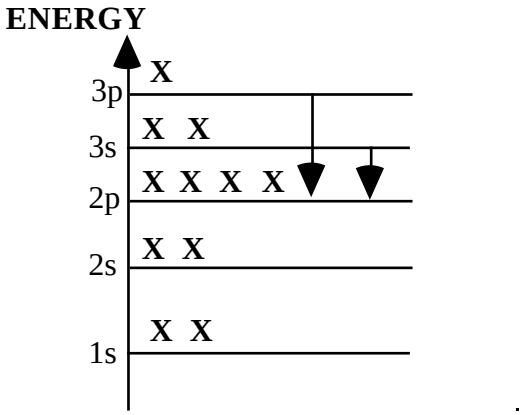
(c) This reaction is called condensation polymerisation.

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

Question 3

(a) This is the electronic configuration for an aluminium ion (Z = 13). It shows $1s^2 2s^2 2p^5 3s^2$.

(b) Since more energy is supplied, a 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 Al^{3+} has an atomic number of 13. Hence, the ions will not have the same emission spectrum.

Question 4

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

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

(b) The anode is the electrode at which oxidation takes place. $H_2(g)$ with oxidation number 0 is oxidised to $H_2O(l)$ in which hydrogen has an oxidation number of +1.
Hence, **A** 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) Structure **C** is a porous partition.

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

Question 5

(a) $Cu^{2+}(aq)$ has the less positive E^0 value. Hence, Cu(s) will be deposited after Ag(s). Aluminium is not deposited in aqueous solution.

(b) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

(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: $[Cu^{2+}(aq)] = 0.2$ M , $[Ag^+(aq)] = 0.2$ M,
$[Al^{3+}(aq)] = 0.2$ M, $[NO_3^-(aq)] = 0.4 + 0.2 + 0.6 = 1.2$ M.
During electrolysis, only $Cu^{2+}(aq)$ and $Ag^+(aq)$ are reduced. $Al^{3+}(aq)$ 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,
$[Al^{3+}(aq)] = 0.2$ M, $[NO_3^-(aq)] = 1.2$ M. Hence, the table is:

	Initial Concentration	**Final Concentration**
Cu^{2+}	0.2 M	≈ 0 M
Ag^+	0.2 M	≈ 0 M
Al^{3+}	0.2 M	0.2 M
NO_3^-	1.2 M	1.2 M

Question 6

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

Hence, $n(e^-) = \frac{0.2 \times 2 \times 60 \times 60}{96500} = \frac{1440}{96500} = 0.0148$ mole.
This is less than 0.2 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 = $\frac{1440}{96500}$.
Hence, the mass of silver = $\frac{1440 \times 107.9}{96500} = 1.6$ g **ANS**

Question 7

(a) The simple nuclear equation is: $4\ {}^{1}H_{1} \rightarrow {}^{4}He_{2}$

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

hydrogen nucleus in star

hydrogen nucleus in our star, the Sun

hydrogen atom (molecule) in the Earth which has formed from the sun

hydrogen reacts with oxygen to produce water $2H_2(g) + O_2(g) = 2H_2O(l)$

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

human consumption of plant

hydrogen nucleus in human cell

Question 8

(a) Energy content per gram = $\frac{400}{25}$ = 16.0 kJ/g **ANS**

(b) Calorimeter constant = $K = \frac{E}{\Delta T} = \frac{12}{(26.000 - 24.720)} = \frac{12}{1.280}$

Energy released on combustion of 25 g of food = $\frac{12}{1.280}$ x (60.400 - 24.500) = 337 kJ

Hence, energy content per gram = $\frac{337}{25}$ = 13.46 kJ/g **ANS**

(c) If the food had absorbed some moisture, this would give a lower than expected value for the energy content since the mass of food would be less than 25 g.

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: $n(CO_2) = 12 \times n(\text{carbohydrate}) = 12 \times \frac{34.2}{342} = 1.2$

$V(CO_2) = \frac{nRT}{P} = 1.2 \times \frac{8.31 \times (273 + 15) \times 1000}{101325}$ L = 28.3 L **ANS**

Question 10

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

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

(iii) The metal in Period 3 is **B** (Al^{2+})

(iv) The gas at room temperature and pressure is **C** (F^-) (F_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 (1) and (2) are correct. In summary,

atomic number $\longrightarrow$ outer shell electronic configuration $\longrightarrow$ chemical properties

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 aluminium, 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 aluminium. Unlike aluminium, they form a wide range of coloured compounds with variable oxidation numbers.

(c) One set of possible answers is:

	Chromium	
two simple aqueous ions	$Cr^{2+}(aq)$	$Cr^{3+}(aq)$
two aqueous ions containing oxygen	$CrO_4^{2-}(aq)$	$Cr_2O_7^{2-}(aq)$
colour of these two aqueous ions containing oxygen	yellow	orange
oxidation number of chromium in these two aqueous ions containing oxygen	+6	+6

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

Question 12

Energy source	One possible equation
nuclear fission	$^{1}n_{0} + {}^{235}U_{92} \rightarrow {}^{141}Ba_{56} + {}^{92}Kr_{36} + 3\ {}^{1}n_{0}$
nuclear fusion	$4\ {}^{1}H_{1} \rightarrow {}^{4}He_{2} + 2\ {}^{0}e_{1}$
combustion of fossil fuels	$C(s) + O_2(g) \rightarrow CO_2(g)$

END OF SUGGESTED SOLUTIONS 1996 CHEMISTRY TRIAL CAT 3

CHEMISTRY ASSOCIATES
PO BOX 2227
KEW
VICTORIA 3101
AUSTRALIA
TEL: (03) 9817 5374 FAX: (03) 9817 4334

email: chemas@vicnet.net.au
INTERNET: http://www.vicnet.net.au/~chemas/education.htm