1995

CHEMISTRY

UNIT 4

TRIAL EXAM

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STUDENT NUMBER Letter

Figures
Words

Victorian Certificate of Education 1995

CHEMISTRY

Common Assessment Task 3: Analysis and evaluation

1995 TRIAL CAT

(not to be used before Monday October 2, 1995)

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*
9	9

Directions to students

Materials

Question and answer booklet of 17 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 marks allotted to each question are indicated at the end of the question.
There is a total of 60 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}

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
$Cd^{2+}(aq) + 2e^-$	→	$Cd(s)$		-0.40
$Fe^{2+}(aq) + 2e^-$	→	$Fe(s)$		-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

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 (255)

END OF DATA SHEET

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) In the twenty-first century, it is likely that energy will be available from a combination of the following energy sources.

(i) the combustion of fossil fuels,
(ii) nuclear fission,
(iii) nuclear fusion,
(iv) fuel cells
(v) silicon (solar cells).

Match each of the equations in the table below with the correct energy source.

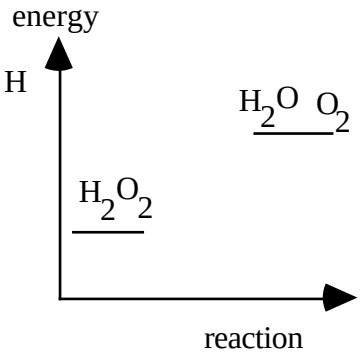
Equation	Energy source
$4\ {}^{1}H_{1} \rightarrow {}^{4}He_{2} + 2\ {}^{0}e_{1}$	
$C(s) + O_2(g) \rightarrow CO_2(g)$	
${}^{1}n_{0} + {}^{235}U_{92} \rightarrow {}^{141}Ba_{56} + {}^{92}Kr_{36} + 3\ {}^{1}n_{0}$	

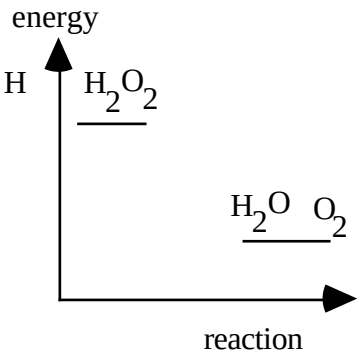
QUESTION 1 (continued)

When a solution of hydrogen peroxide is allowed to stand for a time, decomposition occurs slowly according to the equation $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$.
This is an exothermic reaction.

(b) Choose **one** of the diagrams below and complete it by showing

(i) the energy profile of the reaction
(ii) the ΔH value of the reaction.





If a small amount of the catalyst, manganese dioxide, $MnO_2(s)$, is added to the hydrogen peroxide, the solution bubbles vigorously as oxygen is rapidly produced.

(c) Draw the new energy profile for the reaction. On your diagram you must show:

(i) the activation energy for the original reaction.

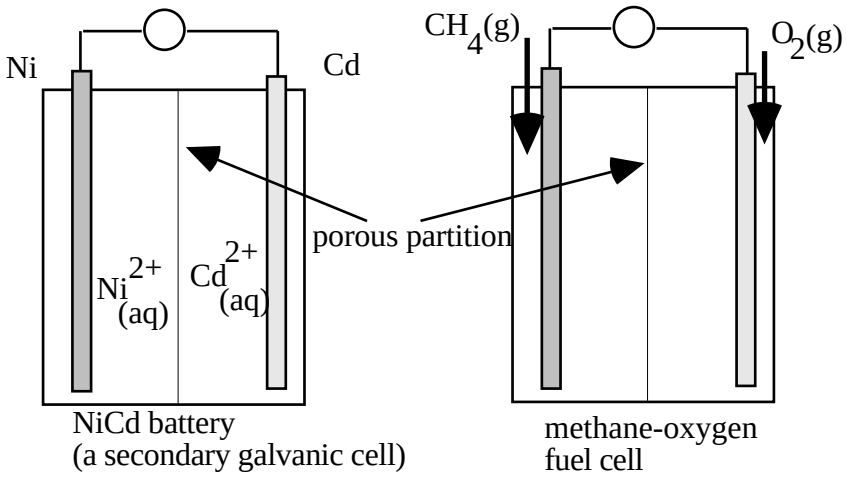
(ii) the activation energy for the catalysed reaction.

(iii) the ΔH value for the catalysed reaction.

(9 minutes, 1+2+3 = 6 marks)

QUESTION 2

Two sources of energy that are undergoing continuous improvement for our energy-hungry world are the secondary galvanic cell and the fuel cell.
Examples of each of these are shown in **simplified diagrams** below.



(a) Write a balanced chemical equation for the overall reaction occurring in the nickel-cadmium (NiCd) battery during use.

_____

(b) What is the maximum *emf* that could be expected from this battery?

_____

_____

_____

_____

_____

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

_____

QUESTION 2 (continued)

(d) If electricity can be produced directly from methane and oxygen in a fuel cell, give **two** reasons why fossil fuel power stations are still used in preference to fuel cells.

_____

_____

_____

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_____

(e) One of the advantages of the NiCd cell is that it can be recharged.

(i) Write the half-cell equation for the reaction occurring at the nickel electrode during recharging.

_____

(ii) Comment on the polarity and the potential that should be used during the recharging.

_____

_____

_____

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_____

(iii) Eventually, the NiCd cell loses its ability to be recharged. Give one reason for this.

_____

_____

_____

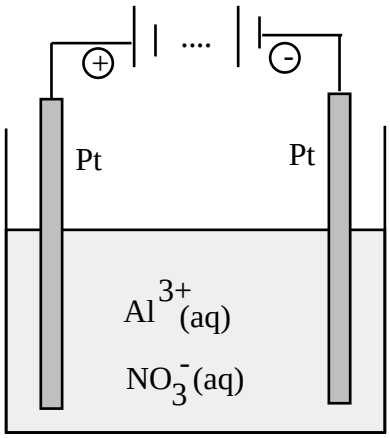
_____

_____

(10 minutes, 1+1+1+1+3 = 7 marks)

QUESTION 3

A student prepares a solution containing the aqueous aluminium ion, $Al^{3+}(aq)$, and the aqueous nitrate ion, $NO_3^-(aq)$ and connects it in a circuit as shown below.



(a) Write a half-equation for the reaction occurring at the positive electrode.

_____

(b) Write a half-equation for the reaction occurring at the negative electrode.

_____

(c) Calculate the volume of gas produced at STP at the positive electrode when a current of 2.3 A is passed through the solution for 1 hour.

_____

_____

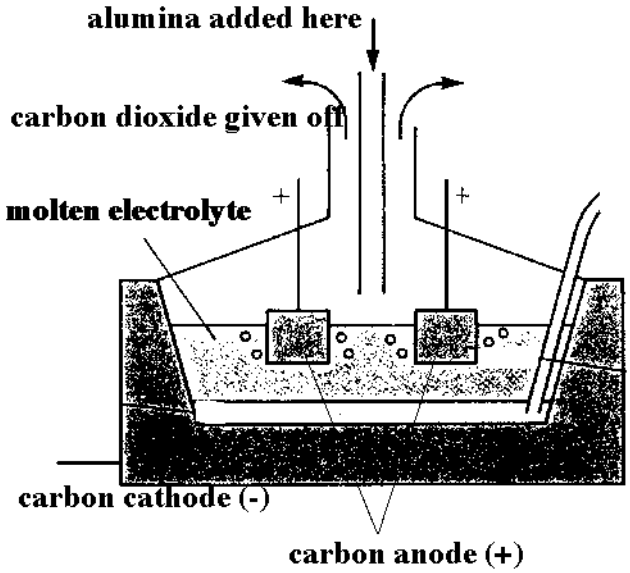
_____

_____

_____

QUESTION 3 (continued)

Aluminium metal is produced industrially by the electrolysis of aluminium oxide, Al_2O_3, dissolved in molten cryolite as shown in the simplified diagram below.



(d) Explain why a molten electrolyte is used in the commercial production of aluminium metal.

_____

_____

_____

_____

_____

(e) (i) Write the half-equation for the cathode reaction.

_____

(ii) Write the half-equation for the anode reaction.

_____

(iii) Explain how this anode reaction is a major cost in the production of aluminium metal.

_____

_____

_____

_____

_____

(11 minutes, 1+1+1+1+3 = 7 marks)

QUESTION 4

(a) Give the name and chemical formula of a complex carbohydrate that can be digested in the human body.

NAME _____FORMULA_____

(b) Give the name and chemical formula of a complex carbohydrate that **cannot** be digested in the human body.

NAME _____FORMULA_____

(c) Give a reason why the complex carbohydrate in (b) cannot be digested.

_____

_____

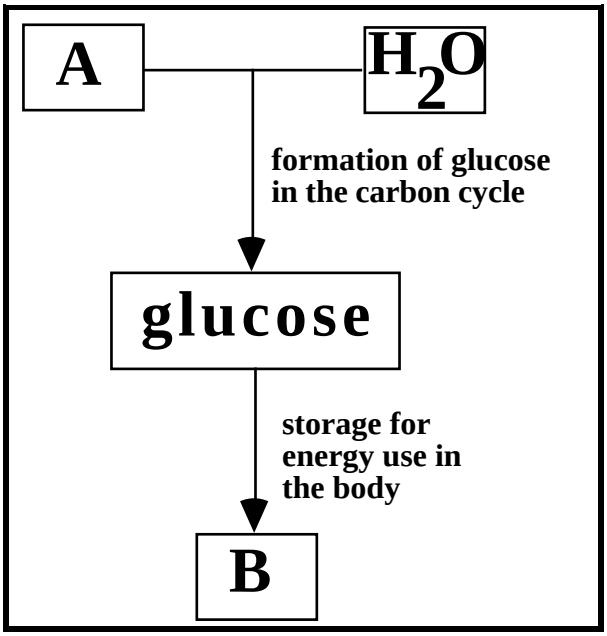
_____

_____

_____

QUESTION 4 (continued)

(d) The following flowchart shows two of the chemical reactions involving the production and use of glucose



Compound A is _____

Compound B is _____

QUESTION 4 (continued)

(e) Triglycerides can be used for energy production in the body by first being broken down to fatty acids and glycerol.

(i) What name is given to this reaction?

_____

(ii) Write a balanced chemical equation for the production of a fatty acid and glycerol from the triglyceride

$CH_2COO - R$
|
$CHCOO - R$
|
$CH_2COO - R$

where $R = C_nH_{2n+1}$

_____

_____

_____

(iii) If $R = C_{15}H_{31}$, write a balanced chemical equation for the complete oxidation of the fatty acid produced in (ii).

_____

_____

(10 minutes, 1+1+1+1+3 = 7 marks)

QUESTION 5

(a) A person is philosophically opposed to eating meat. Therefore, this person has a vegetarian diet. What advice could you give this person about proteins in the diet with respect to essential and non-essential amino acids?

_____

_____

_____

_____

(b) Two amino acids in the vegetarian diet have the formulae

where R and Z are groups of atoms.

(i) Draw the structure of the dipeptide produced when these amino acids combine.

(ii) What name is given to this type of reaction?

_____

(c) A molecule of the amino acid, alanine, $NH_2CH(CH_3)COOH$ is no longer required by the body. In one possible reaction, alanine reacts with oxygen to produce urea, carbon dioxide and water.

(i) Write a balanced chemical equation for this reaction.

_____

QUESTION 5 (continued)

(c) (ii) Draw the molecular structure of urea.

(d) Proteins act as important catalysts in biochemical reactions.

(i) What does a biochemical catalyst do?

(ii) By referring to the structure of proteins, explain what is meant by the **denaturation** of a protein and its subsequent loss of biochemical activity.

(iii) Name one factor that can cause the denaturation of a protein.

(12 minutes, 1+1+1+2+3 = 8 marks)

QUESTION 6

A packet of salted peanuts contains the following nutritional information on a 50 g net packet.

energy	**1194 kJ**
protein	**12.2 g**
carbohydrate	**4.3 g**
fat	**24.5 g**
fibre	**4.1 g**

A bomb calorimeter is used to determine the energy content of the peanuts. The calorimeter constant is 25 kJ / ^{o}C.

(a) Explain the meaning of this calorimeter constant.

_____

_____

_____

_____

_____

(b) All of the peanuts in the packet are crushed to a fine powder and reacted completely with oxygen gas in the calorimeter.

Why are the peanuts crushed before combustion?

_____

_____

_____

_____

_____

(c) The temperature in the calorimeter rises by 46 ^{o}C.
Calculate the energy content of the packet of peanuts.

_____

_____

_____

_____

_____

_____

QUESTION 6 (continued)

(d) Give one possible reason why the experimentally determined energy is different from the energy given on the packet.

_____
_____
_____
_____
_____

(e) Calculate the percentage of the energy given on the packet that comes from the fat in the peanuts, given that the heat of combustion of fat is 39 kJ g^{-1}.

_____
_____
_____
_____
_____

(8 minutes, 1+1+1+1+1 = 5 marks)

QUESTION 7

One hundred years ago, scientists held the view that atoms were the fundamental particles making up all matter. Nothing was known about the internal structure of the atom. Then radioactivity was discovered.

(a) Write a balanced equation for the radioactive decay of radon(222) (Rn) to polonium(218) (Po) with the emission of an alpha particle.

_____

(b) Briefly explain how the discovery of radioactive elements resulted in a new picture of the atom.

_____
_____
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(c) Briefly describe the contribution of one individual to our understanding of the internal structure of the atom

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(10 minutes, 1+3+3 = 7 marks)

QUESTION 8

(a) There are three ions listed in the table below.
Write the electronic configuration of each ion.

element	ion	electronic configuration
sodium	Na^{+}	
sulfur	S^{2-}	
iron	Fe^{3+}	

(b) Write the formula of one of the oxides formed by each of these elements and describe the acid/base properties of each oxide.

element	formula of oxide	acid/base properties of oxide
sodium		
sulfur		
aluminium		

(9 minutes, 1+1+1+1+1+1 = 6 marks)

QUESTION 9

				section I			*section II*		
A	**B**			**D**	**E**	**G**	**J**	**L**	**M**
Q	**R**	**T**	**Z**	**S**	**U**	**V**	**W**	**X**	**Y**
α									δ

break in periodic table

In the diagram above showing part of the Periodic Table, letters have been used to represent the elements. These letters are **not** chemical symbols.
Notice that there is a break between section I and section II of the part of the Periodic Table shown.
Element M is the noble gas argon (Ar).

(a) What kind of bonding would occur between elements **A** and **X**?

_____

(b) Give the formula of the compound formed between elements **Q** and **L**.

_____
_____
_____
_____
_____

(c) How does the first ionisation energy of the elements change while moving from **A** across the row to **M**? Give a reason for your answer.

_____
_____
_____
_____
_____

(d) Would you expect a low, intermediate or high melting temperature for the compound formed between elements **J** and **L**? Give a reason for your answer.

_____
_____
_____
_____
_____

QUESTION 9 (continued)

(e) Write the letter for an element with one or more electrons in the d subshell.

_____

(f) Write the letter for the element which is the strongest reductant in this part of the Periodic Table.

_____

(g) Which one of the elements **M**, **Y** and δ would have the highest boiling temperature? Give a reason for your answer.

_____
_____
_____
_____
_____

(11 minutes, 1+1+1+1+1+1+1 = 7 marks)

END OF QUESTION AND ANSWER BOOKLET

1995 CHEMISTRY TRIAL CAT 3

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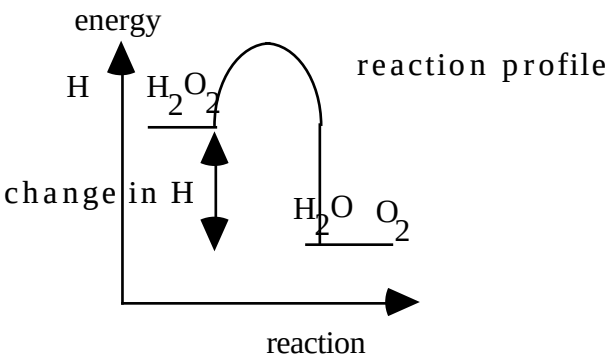
SUGGESTED SOLUTIONS

Question 1

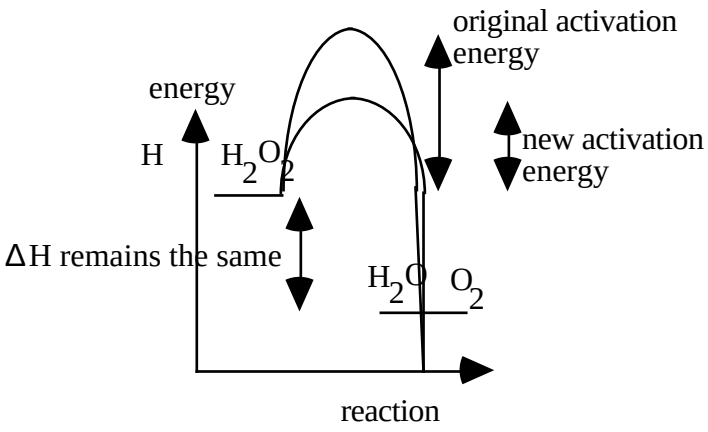
(a)

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

(b)



(c)



SUGGESTED SOLUTIONS

Question 2

(a) $Ni^{2+}(aq) + Cd(s) \rightarrow Ni(s) + Cd^{2+}(aq)$

(b) max emf = -0.23 - (-0.40) = 0.17 V **ANS**

(c) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

(d) The rate of reaction in fuel cells is too slow and the cost of the electrodes is too great.

(e) (i) During recharging: $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$

(ii) The potential needs to be greater than 0.17 V with the positive terminal connected to the nickel electrode.

(iii) The ability to be recharged is lost when the reaction products move away from the electrodes and the reactions cannot be reversed.

Question 3

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

(b) $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

(c) $n(O_2) = \frac{1}{4} \times n(e^-) = \frac{1}{4} \times \frac{2.3 \times 60 \times 60}{96\,500}$.

Hence, $V(O_2)$ at STP $= \frac{1}{4} \times \frac{2.3 \times 60 \times 60}{96\,500} \times 22.4$ L = 0.48 L **ANS**

(d) A molten electrolyte is used so that the ions can move freely in the electric field in the absence of water. Hydrogen gas is produced from water more easily than aluminium metal is produced from aqueous aluminium ions and so, water cannot be used in the electrolyte.

(e) (i) At the cathode: $Al_2O_3(l) + 6e^- \rightarrow 2Al(l) + 3O^{2-}(l)$

(ii) At the anode: $C(s) + O^{2-}(l) \rightarrow CO_2(g) + 2e^-$

(iii) The carbon anodes are consumed in the electrolysis as shown in the equation (ii) above. Hence, the carbon anodes must be replaced at regular intervals. This is a significant cost in the production of aluminium.

SUGGESTED SOLUTIONS

Question 4

(a) Starch $(C_6H_{10}O_5)_n$, can be digested in the human body.

(b) Cellulose $(C_6H_{10}O_5)_n$, cannot be digested in the human body.

(c) The structural formula for cellulose is different from the structural formula for starch. The human body has an enzyme that will catalyse the hydrolysis of starch but no enzyme to catalyse the hydrolysis of cellulose.

(d) **A** is carbon dioxide. **B** is glycogen (a polymer of glucose).

(e) (i) The breaking down of triglycerides into fatty acids and glycerol is called hydrolysis.

(ii) $CH_2COORCHCOORCH_2COOR + 3H_2O \rightarrow 3RCOOH + C_3H_5(OH)_3$

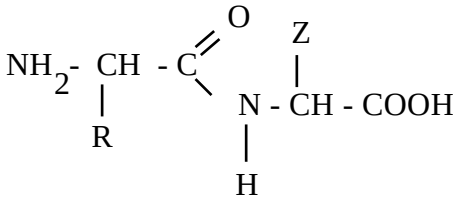
fatty acid **glycerol**

(iii) $C_{15}H_{31}COOH + 23O_2(g) \rightarrow 16CO_2(g) + 16H_2O(l)$

Question 5

(a) The person must have a wide variety of vegetarian food to ensure that all nine essential amino acids (amino acids that cannot be manufactured by the human body) are supplied by the food.

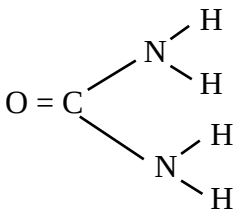
(b) (i)



(ii) This dipeptide is formed by a condensation reaction. (The other product is water).

(c) (i) $2NH_2CH(CH_3)COOH(aq) + 6O_2(g) \rightarrow CO(NH_2)_2(aq) + 5CO_2(g) + 5H_2O(l)$

(ii) The structure of urea is



Question 5 (continued)

(d) (i) A biochemical catalyst specifically speeds up one particular biological reaction at body temperature.

(ii) A protein is denatured when its tertiary structure is destroyed. The chemical bonds cross-linking and holding the protein in a specific three-dimensional shape are broken. As a result, specific sites for the catalysis of chemical reactions are no longer available.

(iii) The denaturation of a protein can be caused by excess heat or change in pH.

Question 6

(a) The calorimeter constant of 25 kJ/^{o}C means that it requires 25 kJ to raise the temperature of the calorimeter and its contents by 1^{o}C.

(b) The peanuts are crushed so that they will burn more rapidly and completely in the oxygen.

(c) Energy content = 25 x 46 = 1150 kJ **ANS**

(d) Both of these values are determined experimentally. They could be different because of experimental error. (The experiments could be repeated to check for random errors). Alternatively, the contents of the packets for both experiments could be different. Note that the total mass listed on the packet is only 45.1 g.

(e) Percentage of energy from fat = $\frac{24.5 \times 39}{1194} \times 100 = 80.0\%$ **ANS**

Question 7

(a) $^{222}Rn_{86} \rightarrow {}^{218}Po_{84} + {}^{4}He_{2}$

(b) The emission of charged particles such as positive alpha particles and negative beta particles from the atom indicated that there was an internal structure to the atom that consisted of positive and negative charges.

(c) (There are many possible correct answers to this question.) For example, Rutherford's experiment in which alpha particles were scattered through large angles when colliding with gold foil indicated that there was a small, massive positively charged core to the atom. Subsequently, this came to be known as the nucleus.

SUGGESTED SOLUTIONS

Question 8

(a)

element	ion	electronic configuration
sodium	Na^+	$1s^2 2s^2 2p^6$
sulfur	S^{2-}	$1s^2 2s^2 2p^6 3s^2 3p^6$
iron	Fe^{3+}	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$

(b)

element	formula of oxide	acid/base properties of oxide
sodium	Na_2O or NaO_2 or Na_2O_2	basic
sulfur	SO_2 or SO_3	acidic
aluminium	Al_2O_3	amphoteric (amphiprotic)

SUGGESTED SOLUTIONS

Question 9

(a) The bonding between metal **A** and non-metal **X** would be ionic.

(b) Since **Q** would form the ion $\mathbf{Q}^+$ and **L** would form the ion $\mathbf{L}^-$, the formula of the compound would be **QL**.

(c) As one moves from **A** to **M** across the row, the first ionisation energy increases because the positive charge in the nucleus increases while the electrons remain in the same shell. The core charge increases and so the first ionisation energy increases.

(d) Elements **J** and **L** are both non-metals. Hence, there will form a molecular covalent compound with weak intermolecular forces.
Therefore, the melting temperature will be low.

(e) Elements **T** and **Z** are transition metals with electrons in the d subshell.

(f) The strongest reductant in this section of the Periodic Table is the element which can lose its outershell electron most easily. This occurs at the bottom left hand corner of the Periodic Table where the core charge is smallest. Element α.

(g) These elements are all noble gases. Boiling temperatures increase going down the Group because the weak intermolecular forces increase in strength as the number of electrons in the atoms increases. Element δ.

END OF SUGGESTED SOLUTIONS

1995 CHEMISTRY TRIAL CAT 3

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