1996 VCE CHEMISTRY CAT 3

DETAILED SUGGESTED SOLUTIONS

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

A copy of the 1996 Chemistry Cat 3 Examination paper for which these solutions are provided may be obtained from The Victorian Board of Studies. Click here.

http://www.bos.vic.edu.au/

Question 1 (12 marks, 15 minutes)

a. **i.** Of the elements, Na, Mg, Al, Si, P, S and Cl, the element with the smallest atomic radius is chlorine (Cl, Cl_2 both acceptable)

(1 mark)

ii. The trend in atomic radius across the third period of the periodic table can be explained by the core charge increase across the period. The greater the core charge, the more strongly the outer electron clouds are attracted. Hence, the atomic radius decreases.

(2 marks)

b. **i.** The non-metals are silicon (metalloid), phosphorus, sulfur and chlorine.

(1 mark)

ii In the third period, it is silicon (Si) which best exhibits a mixture of metallic and non-metallic properties.

(1 mark)

c. **i** In the third period, the strongest oxidant is chlorine (Cl, Cl_2 both acceptable) and the strongest reductant is sodium (Na is acceptable)

(2 marks)

ii The balanced equation for the reaction between sodium and chlorine is
$2Na(s) + Cl_2(g) = 2NaCl(s)$

(1 mark)

d. **i** The possible oxide formulae and equations are:

$SiO_2(s) + H_2O(l) = H_2SiO_3(aq)$ (or $+ 2H_2O = H_4SiO_4$)

$P_2O_3(s) + 3H_2O(l) = 2H_3PO_3(s)$ or (aq)

$P_2O_5(s) + 3H_2O(l) = 2H_3PO_4(l)$ or (aq)

$SO_2(g) + H_2O(l) = H_2SO_3(aq)$

$SO_3(l) + H_2O(l) = H_2SO_4(l)$

$Cl_2O(g) + H_2O(l) = 2HOCl(aq)$

$Cl_2O_7(l) + H_2O(l) = HClO_4(aq)$

(The acid can also be shown in dissociated form, e.g. $= H^+(aq) + ClO_4^-(aq)$)

(2 marks)

ii The possible oxide formulae and equations are:

$Na_2O(s) + H_2O(l) = 2NaOH(aq)$

$Na_2O_2(s) + 2H_2O(l) = NaOH(aq) + H_2O_2(aq)$

$MgO(s) + H_2O(l) = Mg(OH)_2(aq)$

(The base can also be shown in dissociated form, e.g. $= Mg^{2+}(aq) + 2OH^-(aq)$)

(2 marks)

Question 2 (5 marks, 7 minutes)

a. The experiment with α-particles enabled Rutherford to develop a new way of describing the structure of an atom because

(1) the result shows that atoms are mostly 'free space'

(2) the result shows that there must be a small concentrated mass of positive charge causing the occasional α-particle to bounce back

(3) free space must contain the electrons (possibly orbiting the nucleus)

(4) these observations were contrary to the then current 'plum pudding' model of the atom

(3 marks)

b. Additional features of the structure of the atom that have been discovered since Rutherford's time include:

(1) protons & neutrons in nucleus

(2) electrons are in constant motion around nucleus

(3) electrons arranged in shells around nucleus

(4) electrons arranged in shells and subshells

(5) electron spin

(2 marks)

Question 3 (7 marks, 10 minutes)

a. When proteins are used to produce energy in the human body, the end products formed are carbon dioxide, water and urea.
(B , C , J)

When carbohydrates are used to produce energy in the human body, the end products formed are carbon dioxide and water.
(B , C)

When fats are used to produce energy in the human body, the end products formed are carbon dioxide and water.
(B , C)

(3 marks)

b. The source of carbon that **can be directly absorbed by green plants** and used as ‘building blocks’ for their proteins, carbohydrates and fats is carbon dioxide.
(B)

The sources of hydrogen that **can be directly absorbed by green plants** and used as ‘building blocks’ for their proteins, carbohydrates and fats are water and the ammonium ion.
(C and G)

The sources of oxygen that **can be directly absorbed by green plants** and used as ‘building blocks’ for their proteins, carbohydrates and fats are carbon dioxide, water and the nitrate ion.
(B , C and H)

The sources of nitrogen that **can be directly absorbed by green plants** and used as ‘building blocks’ for their proteins, carbohydrates and fats are the ammonium ion and the nitrate ion.
(G and H)

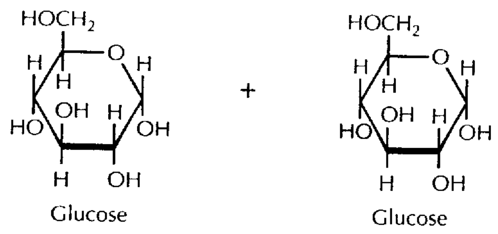
(4 marks)

Question 4 (6 marks, 8 minutes)

a. **i** This compound is a carbohydrate as shown by the formula $C_{12}H_{22}O_{11}$. This is the molecular formula for the disaccharide, sucrose.
This structure is the structure of sucrose.

(1 mark)

ii When glucose is hydrolysed by digestion, a water molecule is added and the -O- is converted to -OH and HO- as shown in the structures below.



(2 marks)

b. **i** Emulsifiers are added to some foods to stabilise a food (e.g butter) in a colloidal form that allows water and oil components to mix.

(1 mark)

ii The lecithin molecule has both hydrophilic $-O^-$, $-N(CH_3)_3^+$ parts for the water and hydrophobic ($-CH_2)_{16}CH_3$) parts for the oil.

(2 marks)

Question 5 (10 marks, 14 minutes)

a. The calibration factor = $\frac{\text{electrical energy deposited}}{\text{temperature rise}}$

$= \frac{VIt}{\Delta T} = \frac{7.50 \text{x} 1.35 \text{x} 5.00 \text{x} 60}{25.90 - 24.63} = \frac{3037.5}{1.27}$

= 2392 JK^{-1} **ANS**

(3 marks)

b. Energy content of biscuit $= \frac{\text{energy released}}{2.63} = \frac{(24.63 - 23.76) x 2.392}{2.63}$

$= \frac{0.87 x 2.392}{2.63} =$

= 0.791 kJ g^{-1} **ANS**

(2 marks)

c. Less energy per gram would be provided in practice in the human body by one of these biscuits because of incomplete digestion.

(1 mark)

d. It is not possible to define number of mole of biscuit because it is a mixture of many substances.

(1 mark)

e. Temperature rise = $\frac{\text{energy released}}{\text{calibration factor}} = \frac{n(CH_4) x 890000}{3550} = \frac{0.055 x 890000}{16 x 3550}$ = 0.862 K **ANS**

(3 marks)

Question 6 (6 marks, 8 minutes)

a. Number of mole of electrons passed = Q/F = (Ix t)/F = (3.00 x 2200)/96500

Number of mole of copper deposited = 4.40/63.5

The charge on copper ion = (mole of electrons passed)/(mole of copper deposited)

= (3.00 x 2200 x 63.5)/(96500 x 4.40) = 0.068/0.069 = 1.0

Hence, the copper ion in solution is Cu^{+}.

It would also be possible to assume a value for the charge on the copper ion, calculate a value of the Faraday constant and compare the calculated value to the actual value. The **actual charge** on the copper ion could then be deduced.

(3 marks)

b. From the graph, for the same number of coulomb, **C** is 4.2 mole, **D** is 2.1 mole and **E** is 1.4 mole. Hence, the number of mole of **E** is one third the number of mole of **C** and the number of mole of **D** is one half the number of mole of **C**. Hence,

The Ag deposition is **C** $Ag^{+}(aq) + e^{-} = Ag(s)$

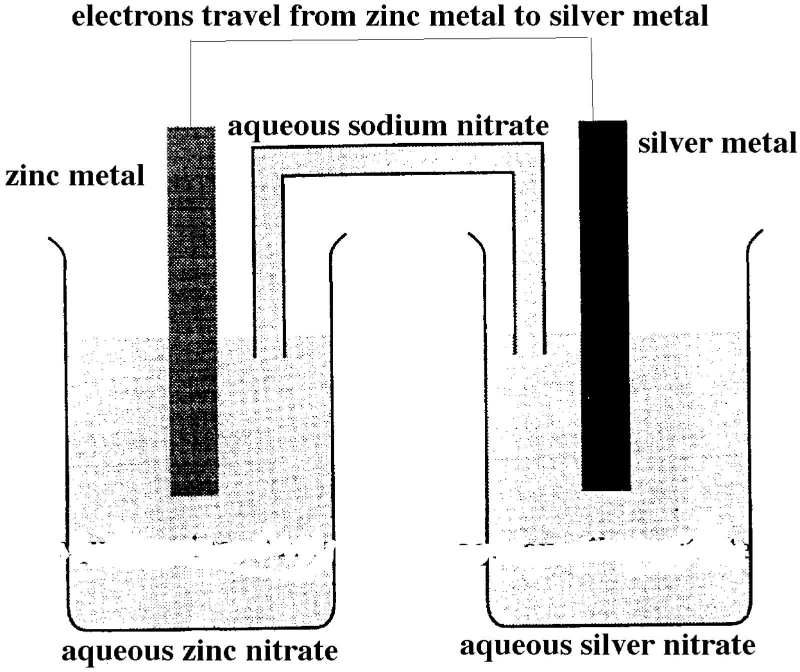
The Pb deposition is **D** $Cu^{2+}(aq) + 2e^{-} = Cu(s)$

The Cr deposition is **E** $Cr^{3+}(aq) + 3e^{-} = Cr(s)$

(3 marks)

Question 7 (7 marks, 9 minutes)

a.



Note that any strong electrolyte not containing a halide or hydroxide ion could be used in the salt bridge

(3 marks)

b.

The oxidation half-reaction is Zn(s) = Zn^{2+} (aq) + $2e^-$. This is the anode since it is oxidation.

The reduction half-reaction is Ag^+(aq) + e^- = Ag(s). This is the cathode since it is reduction.

Note that there is one mark only for the anode-cathode pair.
Both must be correct to gain the mark.

(3 marks)

c. The net reaction is: $2Ag^+$(aq) + Zn(s) = 2Ag(s) + Zn^{2+} (aq)

(1 mark)

Question 8 (6 marks, 9 minutes)

a. **i** When oxygen gas is bubbled through the solution, oxidation takes place since $O_2(g)$ has a higher E^0 value (+0.40V) than $Cr^{3+}(aq)$ (-0.41V). The balanced equation is:

$4Cr^{2+}(aq) + O_2(g) + 4H^+(aq) = 4Cr^{3+}(aq) + 2H_2O(l)$

(2 marks)

ii The balanced equation for the formation of the green precipitate is

$Cr^{3+}(aq) + 3OH^-(aq) = Cr(OH)_3(s)$

(1 mark)

iii. Oxidation also takes place here since $E^0(H^+) = 0.00V$and $E^0(Cr^{3+}) = -0.41V$.

The gas evolved is hydrogen. The balanced equation is:

$2Cr^{2+}(aq) + 2H^+(aq) = 2Cr^{3+}(aq) + H_2(g)$

An alternate equation would be $2Cr^{2+}(aq) + 2H_2O(l) = 2Cr^{3+}(aq) + H_2(g) + 2OH^-(aq)$

(1 mark)

iv. Ligand substitution has taken place. When the thiocyanate ion bonds with the chromium (ion-dipole bonding) a colour change occurs.

(1 mark)

b. The electronic configuration of the chromium atom is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$
(Note that the study structure does not require this detail for electronic structures. This question slipped through the net!)

(1 mark)

Question 9 (7 marks, 10 minutes)

a. A hydrogen atom with a single electron has an emission spectrum with many lines because

(1) Excitation involves an electron going to a higher energy level.

(2) Emission spectra result from the electron dropping from a high to a low energy state.

(3) Many different energy levels are available to the electron in the H atom.

(4) Each line in a complex spectrum corresponds with the difference between two energy levels.

(5) Energy difference is related to wavelength of emitted radiation (e.g. E = hf)

(3 marks)

b. The source of the energy released is Nuclear binding energy OR nuclear fusion OR conversion of mass into energy.

(1 mark)

c. The balanced equation is: $4\ {}^{1}H_{1} = {}^{4}He2 + 2e^{+}$

(1 mark)

d. The origin of the iron in the core of planet Earth can be explained as follows:

(1) Iron synthesised deep inside large stars by nuclear fusion.

(2) Large stars explode distributing the heavy elements widely.

(3) Planets like Earth condense from material containing some of the residue of an exploded star.

(2 marks)

END OF SUGGESTED SOLUTIONS

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