VCE CHEMISTRY
CAT 3 1993

“ANALYSIS AND EVALUATION”

DETAILED SUGGESTED SOLUTIONS

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.

Assuming that the colour intensity is directly proportional to the concentration of starch in the solution, a colour intensity of 1.2 is the original concentration and a colour intensity of 0.6 shows half of the original concentration.

From the graph, this reduction takes 5 minutes. **ANS**

b.

Fresh human saliva contains an enzyme which converts starch into simple sugars. This enzyme (a protein) is **less effective** at 55^{o}C which is considerably above normal body temperature.

c.

This is an hydrolysis reaction (reaction with water) as shown by the chemical equation:

$$(C_6H_{10}O_5)_n + nH_2O \xrightarrow{\text{enzyme}} nC_6H_{12}O_6$$

d.

One possible product of the reaction is the simple sugar (monosaccharide) glucose with the molecular formula $C_6H_{12}O_6$.

e.

Not all forms of carbohydrate are hydrolysed easily to produce simple sugars. There is a lot of cellulose in carrots which is not digested and therefore, does not contribute to the kilojoule count. On the other hand, cake contains a lot of simple sugars which are used directly by the cells in the body.

In summary then, $(C_6H_{10}O_5)_n$ (cellulose) is not hydrolysed and excreted from the body.

$C_6H_{12}O_6$ (monosaccharide) → energy → fat (if energy is not used in some other way).

Question 2

a.

Change in temperature during the addition of electrical energy to the calorimeter

$= \Delta T = 31.003 - 29.350 = 1.653$.

Hence, the calibration factor of the calorimeter plus contents

$= K = \frac{\text{energy}}{\Delta T} = \frac{12500}{1.653} = 7562 \text{ J } ^{o}C^{-1} = 7.562 \text{ kJ } ^{o}C^{-1}$. **ANS**

b.

Heat released during the combustion of the dried bread

$=K$ x change in temperature during combustion

$= \frac{12500}{1.653} \times (29.350 - 24.775) = 34596.19$ J.

Hence, the heat of combustion in kJ per gram

$= \frac{12500}{1.653} \times (29.350 - 24.775) \times \frac{1}{1000 \times 3.30}$

$= 10.48$

$= 10.5 \text{ kJ g}^{-1}$ **ANS**

Question 2 (continued)

c.

A simple way of finding out if a given sample of bread is completely dry:
(1) Dry the bread in the oven for an additional ten minutes.
(2) Find the mass of the bread.
(3) Dry the bread in the oven for another ten minutes.
(4) Find the mass of the bread.
(5) Repeat (3) and (4) until the mass of the bread is constant.

d.

Some energy would be needed to evaporate the water according to the equation $H_2O(l) \rightarrow H_2O(g)$. Further information would be required about the heat of evaporation of water (in kJ g^{-1}) to determine whether the measured heat of combustion would be greater or smaller than the actual value. If the heat of evaporation of water is greater than the heat of combustion of dried bread, then the measured heat of combustion would be greater than the actual value.

Question 3

a.

The ground electronic configuration of the carbon atom is $1s^2\ 2s^2\ 2p^2$.

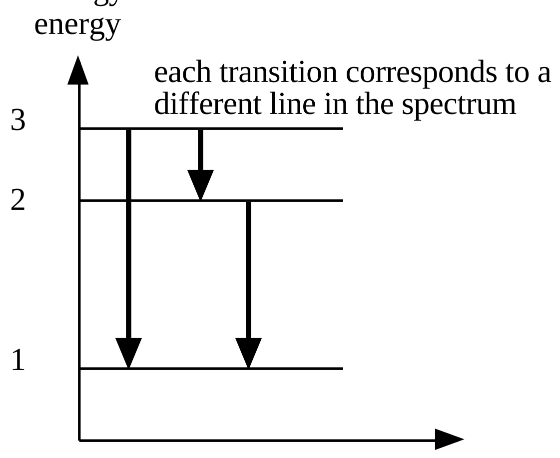
b.

One of the many possible electronic configurations for a carbon atom in an excited state is

$1s^2\ 2s^2\ 2p^1\ 3s^1$.

c.

When a gas such as hydrogen is heated, the electrons in the hydrogen atoms (only one in each atom) can move to move energetic orbitals. When the electrons drop back to lower energy orbitals as shown by the arrows in the diagram below, $3 \rightarrow 1$, $3 \rightarrow 2$, $2 \rightarrow 1$, energy is released equal to the difference in energy between these levels.



The frequency of the light emitted is proportional to this energy according to the relationship $E_3 - E_2 = hf$, where E_3 is the energy of level 3, E_2 is the energy of level 2, h is Planck's constant and f is the frequency of the light emitted. The different frequencies of light emitted make up the lines in the emission spectrum of hydrogen. Every kind of atom has its own distinctive emission spectrum - *fingerprints for atomic detectives!*

Question 3 (continued)
d.
An atomic emission spectrum is characteristic of the electronic configuration of the atom and the number of protons in the nucleus. ^{12}C and ^{13}C differ only in the number of neutrons in the nucleus. Hence, it is expected that ^{12}C and ^{13}C will have identical atomic emission spectra.

Question 4
The relevant half reactions and E^0 values from the Data Sheet are:

$O_2(g) + 4H+(aq) + 4e^- \rightarrow 2H_2O(l)$ $E^0 = +1.23$ V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $E^0 = +0.34$ V
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ $E^0 = -0.23$ V
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ $E^0 = -0.83$ V
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$ $E^0 = -2.34$ V

a.
During electrolysis, the most easily reduced species (the best electron acceptor) will be deposited first at the negative electrode. This is often the molecule or ion with the most positive E^0 value.However, it should be noted that the concentration of the species must also be considered when attempting to make this prediction. Notice that the concentrations of $Cu^{2+}(aq)$, $Ni^{2+}(aq)$ and $Mg^{2+}(aq)$ are each 0.05M. In this case, copper metal will be deposited on the negative electrode according to the half reaction: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$.

b.
During electrolysis, the most easily oxidised species (the best electron donor) will be deposited first at the positive electrode. No information is provided about the nitrate ion, $NO_3^-(aq)$, in the Data Sheet. The nitrate ion is not oxidised in aqueous solution. Water itself is oxidised according to the half reaction $2H_2O(l) \rightarrow O_2(g) + 4H+(aq) + 4e^-$.

c. i.
From the E^0 values, it can be seen that after the copper and nickel have been deposited on the negative electrode, hydrogen gas will be produced according to the half reaction
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$.

c. ii.
Only the copper and nickel have been deposited before the hyrogen gas is evolved. Magnesium metal will not be deposited in the presence of water. Magnesium has too negative an E^0 value. Hence, the negative electrode will be coated with copper as the first layer and nickel as the second layer.

Question 5

a.

The filter paper soaked in KCl solution contains K^{+}(aq) and Cl^{-}(aq) ions. These ions complete the circuit by allowing the passage of positive and negative ions between the half cells.

b.

The relevant half reactions and E^0 values from the Data Sheet are:

$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ $E^0 = +0.77$ V

$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ $E^0 = -0.76$ V

Fe^{3+}(aq) has a more positive E^0 value than Zn^{2+}(aq). Hence, Fe^{3+}(aq) is a stronger oxidant (electron acceptor) than Zn^{2+}(aq). Therefore, electrons will flow from **A** to **B** in the external circuit. Hence, **A** is the negative electrode and **B** is the positive electrode.

c.

At the positive electrode, reduction occurs (cathode) and the half reaction is

$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$.

At the negative electrode, oxidation occurs (anode) and the half reaction is

$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$.

d.

The balanced equation for the chemical reaction that occurs when the cell is discharging (producing current spontaneously) can be obtained by **adding** the half reactions from **c.** after balancing the number of electrons.

This gives $2Fe^{3+}(aq) + Zn(s) \rightarrow 2Fe^{2+}(aq) + Zn^{2+}(aq)$.

Question 6

a.

Atmospheric nitrogen is the element nitrogen, N_2. The oxidation state of any atom in the elemental state is zero.

b.

Nitrogen-fixing bacteria convert N_2(g) into NO_2^-(aq), nitrite ions and NO_3^-(aq), nitrate ions. To calculate the oxidation state of nitrogen in NO_2^- : N + (2 x -2) = -1 N = +3.

To calculate the oxidation state of nitrogen in NO_3^- : N + (3 x -2) = -1 N = +5.

Question 6 (continued)

c.

One **possible** flow chart is

N_2 IN ATMOSPHERE

nitrogen-fixing bacteria

NO_2^-(aq) AND NO_3^-(aq) IN SOIL

take up by plant

PLANT AMINO ACID

consumption

HUMAN AMINO ACID

condensation reaction (formation of peptide link)

HUMAN PROTEIN

Question 7

a.

An acidic functional group is a group of atoms which can lose an H^+ ion easily. The carboxyl group, -COOH, has the structure **-C = O**

```
-C = O
 |
 O-H
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In aqueous solution, the reaction that occurs is:

-COOH(aq) + H_2O(l) = $-COO^-$(aq) + H_3O^+(aq).

b.

A dipeptide structure is a molecule containing one peptide link (CO.NH) formed when two amino acids react with each other. Two different dipeptide structures can be formed in this case because the COOH group on serine can react with the NH_2 group on glycine OR the COOH group on glycine can react with the NH_2 group on serine. In each reaction, a peptide link (CO.NH) is formed with the elimination of a water molecule. This is known as a condensation reaction. The two dipeptide structures are shown below.

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(1) HO.CH2.CH.CO.NH.CH2.COOH        (2) HO.CH2.CH.COOH
           |                                  |
           NH2                                NH.CO.CH2.NH2
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Question 8

a.

A lipid (fat) molecule is produced when a fatty acid reacts with the trihydric alcohol called **glycerol** (also known as glycerine). A lipid is a triester of the fatty acid and glycerol Glycerol has the structure

$$\begin{array}{l} CH_2OH \\ \ | \\ CHOH \\ \ | \\ CH_2OH \end{array}$$

b.

The two lipid molecules that are produced in the reaction of the fatty acid with glycerol have the structure shown below. These are both examples of simple glycerides since the **R** grouping is the same throughout the molecule.

$$\begin{array}{l} CH_2OOC\mathbf{R} \\ \ | \\ CHOOC\mathbf{R} \\ \ | \\ CH_2OOC\mathbf{R} \end{array}$$

(1) Palmitic glyceride has the structure given above with

R = $CH_3(CH_2)_{14}$

(2) Linoleic glyceride has the structure given above with

R = $CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7$

Question 9

a.

A balanced equation for the reaction of butane with oxygen is

$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$

b.

One mole of butane has a mass of (4 x 12.0) + (10 x 1.0) = 58.0.

Therefore, the energy released per gram of butane burnt = $\frac{2886}{58.0}$ = 49.8 kJ g^{-1}. **ANS**

c.

The normal boiling temperature of water is $100^{o}C$. Hence, the change in the temperature of the water = 100 - 15 = $85^{o}C$. Therefore, the energy required = 4.2 x 850 x 85 = 303450 J = 303.45 kJ. Hence, the mass of butane required = $\frac{303.45}{49.8}$ = 6.1 g. **ANS**

Question 9 (continued)
d.
A camp stove should not be used inside a small space like a tent because

(1) the carbon dioxide concentration would increase rapidly.
(2) the air space could be contaminated with butane gas.
(3) risk of fire.

Question 10
a.i.
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$ is the element zinc, the last member of the first transition series. **ANS = C.**

a.ii.
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^4$ is the element selenium in group VI of the periodic table. This forms the ion Se^{2-}. **ANS = D**

a.iii.
$1s^2\ 2s^2\ 2p^6\ 3s^2$ is the element magnesium which is the second element in period 3.
ANS = B

a.iv.
$1s^2\ 2s^2\ 2p^6\ 3s^2$ is the element magnesium which is in group II of the priodic table.
ANS = B

b.
Here are a number of people who made major contributions to our understanding of the periodic table. Any one of these could have been chosen as an answer to this question.
This list is not exhaustive.

In 1863, **Newlands** placed the known elements in order of increasing atomic weight. He observed that, in many cases, certain properties periodically recurred and that the properties of every eighth element were similar. For example, he observed this with the elements lithium, sodium and potassium.

In 1869, **Meyer** in Germany and **Mendeleev** in Russia made listings similar to **Newlands** but their versions were somewhat improved. **Meyer** produced tables based on physical properties while **Mendeleev's** work was mainly with chemical characteristics.

Mendeleev arranged a table on the basis of the known properties of the elements using atomic weights merely as a guide. He concentrated on making vertical family groupings.When the order of atomic weights did not agree with his arrangement, he changed the order (he did this with the elements tellurium and iodine) or left a space. He even predicted with a high degree of accuracy the properties of three unknown elements, later known as gallium, scandium and germanium.

Question 11
The elements of period 3 are sodium, magnesium, aluminium, silicon, phosphorus, sulfur, chlorine and argon.
a.i.
Solid magnesium metal, Mg(s), has metallic bonding which is a three dimensional lattice of positive ions in a 'sea' of negative electrons. Metallic bonding can be classified broadly as strong bonding. Dispersion forces, caused by the instantaneous dipoles resulting from the movement of electrons in atoms, ions and molecules, are also present between the magnesium ions. Dispersion forces can be classified broadly as weak bonding.
Solid chlorine, Cl_2(s), has strong covalent bonding (a shared electron pair) between the chlorine atoms. There are dispersion forces between the chlorine molecules.

a.ii.
Solid chlorine has a much lower melting temperature than solid magnesium because to melt the magnesium requires the disruption of the strong three dimensional metallic bonding, whereas, to melt the chlorine requires disruption only of the the weak dispersion forces between the chlorine molecules. The covalent bonding between the chlorine molecules remains when the chloine is melted.

b.
A magnesium atom has 12 protons in its nucleus and three shells (major energy levels) of electrons around the nucleus. A chlorine atom has 17 protons in its nucleus and three shells (major energy levels) of electrons around the nucleus. It is the distance of the outershell electrons from the nucleus that determines the size of the atom. The larger positive charge in the chlorine nucleus pulls these electrons closer and so makes the chlorine atom smaller than the magnesium atom.
c.
Phosphorus, sulfur and chlorine form oxides which react with water to produce strongly acidic solutions. The balanced equations are
(1) $P_4O_{10}(g) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$
(2) $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$
(3) $Cl_2O_7(l) + H_2O(l) \rightarrow 2HClO_4(aq)$

These acids are ionised in aqueous solution according to the equations
(1) $H_3PO_4(aq) + 3H_2O(l) \rightarrow 3H_3O^+(aq) + PO_4^{3-}(aq)$
(2) $H_2SO_4(aq) + 2H_2O(l) \rightarrow 2H_3O^+(aq) + SO_4^{2-}(aq)$
(3) $HClO_4(aq) + H_2O(l) \rightarrow H_3O^+(aq) + ClO_4^-(aq)$

d.
The hydrides of the sulfur and chlorine form acidic solutions when they react with water.
(1) $H_2S(g) + H_2O(l) \rightarrow H_3O^+(aq) + HS^-(aq)$
(2) $HCl(g) + H_2O(l) \rightarrow H3O^{+(}aq) + Cl^-(aq)$

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TEL:(03) 9817 5374 FAX: (03) 9817 4334