UNIT 4 CHEMISTRY 2005
TRIAL EXAMINATION SOLUTIONS

SECTION A – MULTIPLE CHOICE QUESTIONS

QUESTION 1 **C**

Note: When transition metal ions develop high oxidation numbers, they form species that act as strong oxidants (strong electron acceptors). The higher the oxidation state the stronger the oxidant formed.

QUESTION 2 **D**

QUESTION 3 **A**

Higher oxidation states are formed in covalent compounds.

QUESTION 4 **D**

Note: The concept of core charge does not apply to ions!

QUESTION 5 **C**

Note: NH_4^+ cannot act as a ligand as it does not possess a lone pair of electrons.

QUESTION 6 **C**

QUESTION 7 **B**

Under standard conditions (1 M) the following reactions will occur:

$$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$$

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$$

Therefore, the pH at the cathode increases and the pH at the anode decreases.

At very high concentrations (10 M), the following reactions occur:

$$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(aq)}$$

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$$

Therefore, the pH at the cathode increases and the pH at the anode stays relatively constant.

At intermediate concentrations (2.5 M NaCl), both possible anode reactions occur.

$$Cl_{2(g)} + 2e^- \rightarrow 2Cl^-_{(aq)}$$

$$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$$

$$2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$$

Therefore, the pH at the cathode increases and the pH at the anode decreases, but to a smaller extent than that observed with $1M\ \ NaCl$.

QUESTION 8 D

Note: Samples are atomised before entering the atomic absorption spectrometer and hence the sample being analysed only consists of atoms.

QUESTION 9 A

Saturated fatty acids = $C_nH_{2n}O_2$
For every $C = C$, two hydrogen atoms are lost.

QUESTION 10 B

QUESTION 11 B

$$\text{RAM} = \frac{(17 \times 121) + (13 \times 123)}{30} = \frac{3656}{30} = 121.87$$

QUESTION 12 C

QUESTION 13 D

QUESTION 14 D

$$n(methanol) = \frac{m}{M} = \frac{1.50}{32} = 0.046875\, mol$$

$$1mol \rightarrow -727\, kJ$$
$$0.046875\, mol \rightarrow x\, kJ$$
$$x = 34.078\, kJ$$

$$CF = \frac{E(J)}{\Delta T} \qquad \Delta T = \frac{34078}{5410} = 6.30^0 C$$

Final temperature is $20.50 + 6.30 = 26.80^o C$

QUESTION 15 D

Note: $2CH_3OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 4H_2O_{(g)} \quad \Delta H = -1454\ kJ/mol$

The value in the ΔH must be doubled. $\Delta H = -1454\ kJ/mol$

QUESTION 16 A

To evaporate water, energy is required. To evaporate 6 mol of water liquid, $6 \times 44\,kJ$ of energy will be used up. Therefore, the amount of heat released will decrease by $6 \times 44\,kJ$.

QUESTION 17 D

QUESTION 18 C

QUESTION 19 B

QUESTION 20 C

Alkaline Fuel Cell Reactions:

Anode: $H_{2(g)} + 2OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + 2e^-$

Cathode: $O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$

Overall: $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$

Acid Fuel Cell Reactions:

Anode: $H_{2(g)} \rightarrow 2H^+_{(aq)} + 2e^-$

Cathode: $O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$

Overall: $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$

SECTION B – SHORT ANSWER QUESTIONS

QUESTION 1

a. (i) The temperatures required for energy releasing fusion reactions are difficult to generate (an atomic bomb is required), and there are significant problems in relation to confining the reactions: there are no materials available that can withstand the high temperatures required.

(ii) Answer is B.

A Fission (endothermic)
B Fusion (exothermic)
C Fusion (endothermic)
D Fission (exothermic)

(iii) Fusion reactions involving elements with a greater atomic number than iron are endothermic. The energy required for this process is generated when a star explodes.

b. (i) ${}^{263}_{106}Sg \rightarrow {}^{259}_{104}Rf + {}^{4}_{2}He$

(ii) ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$

(iii) ${}^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{1}e$

QUESTION 2

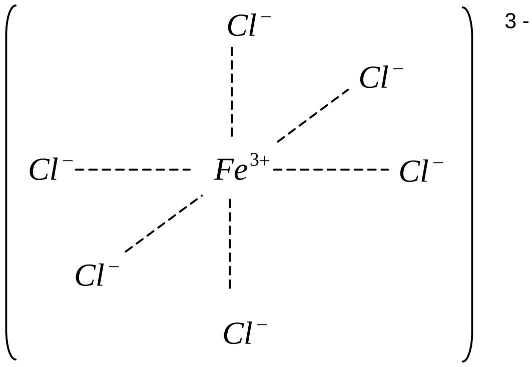
a. When one moves across a period in the main body of the table, the outer electron configuration continually changes. As chemical properties are related to outer electron configurations, there is a marked change in properties across a period.

The outer electron configuration across each series of transition metals generally remains identical (for example: across Series 1, the outer electron configuration is $4s^2$ with the exception of copper and chromium $= 4s^1$). As outer electron configurations are essentially identical, there is great similarity in properties across a transition metal series.

b. (i) Coloured compounds involving transition metal ions may occur if the metal ion displays an incompletely filled d subshell. When zinc ions are formed, the outer electron configuration is $3d^{10}$ i.e. the d subshell is full. Hence zinc ions cannot form coloured compounds.

(ii) Zinc forms the Zn^{2+} ion by losing the two electrons from the $4s$ subshell. The $3d$ electrons cannot be readily removed as they experience a strong electrostatic attraction to the nucleus.

c.



Bonding: Ion - ion bonding

d. $Fe^{3+} + 3C_2O_4^{2-} \rightarrow Fe(C_2O_4)_3^{3-}$

Note: $C_2O_4^{2-}$ is a bidentate ligand. Each ligand will form 2 attachments to the central metal ion and hence, only 3 molecules of $C_2O_4^{2-}$ are required to produce a complex with a coordination number of 6.

e. $Al_4[Fe(CN)_6]_3$

Note: Complex ions will partner with ions of opposite charge in such a manner so as to attain electrical neutrality.

QUESTION 3

a. The bottom left hand side of the table i.e. the elements with the largest radii.

b. (i) As each electron is removed, the remaining electrons experience greater attraction to the nucleus (nuclear charge remains constant but the effects are distributed across fewer numbers of electrons). This has the effect of drawing the valence electrons closer to the nucleus.

Therefore, the energy requirement for electron removal increases with each successive electron.

(ii) Students are required to discuss how the patterns in ionisation energies in the given graph/table can be used to explain the existence of shells and subshells.

The electron configuration of sodium is $1s^2\ 2s^2\ 2p^6\ 3s^1$
i.e. Sodium involves the filling of 3 shells.

The three distinctly different sets of electrons, each set indicated by the different steps in the graph requires **marked** differences in ionisation energy requirements. These differences are associated with the fact that these electrons occupy different shells in the sodium atom.

Electrons 2 through to 9 correspond to the removal of electrons from the second shell. These electrons require similar amounts of energies for their removal, suggesting that the energies within a shell do not vary significantly. There is however a small difference in energy requirements for the removal of the first 6 electrons $(2p^6)$ as opposed to the electrons in $2s^2$, suggesting that these clusters of electrons exist in sub energy levels or sub shells.

c. A – Number of valence electrons is 7 and is therefore located in Group VII of the Periodic Table.

B – Number of valence electrons is 6 and is therefore located in Group VI of the Periodic Table.

Both elements are non metals and will form compounds via covalent bonding. To obtain a full outer shell, one B will bond with two A atoms. Formula is:

BA_2

QUESTION 4

a. An EMF of $1.2\,V$ is obtained when the following half cell reactions are used:

$$Ag^{+}_{(aq)} + e^{-} \rightarrow Ag_{(s)} \qquad +0.80$$
$$Cd^{2+}_{(aq)} + 2e^{-} \rightarrow Cd_{(s)} \qquad -0.403$$

EMF $= E^{o}_{cathode} - E^{o}_{anode} = 0.80 - -0.403 = 1.2\,V$

(i) X must represent the anode as it is wasting away i.e Cd.

(ii) Y must represent the cathode as a deposit is forming on its surface i.e. Ag.

Comment:

The predominant reaction will occur between the strongest oxidant and reductant i.e. the oxidant with the most positive E^{o} value and the reductant with the most negative E^{o} value.

Many students have fallen into the habit of selecting the oxidant that is highest on the left hand side of the series and the reductant which is located on the bottom right hand side of the series. This technique only applies when equations are presented in order of their E^{o} values (from most positive to most negative).

b. (i) Chemical potential energy $\rightarrow$ Electrical energy.
Reaction is exothermic (as all galvanic processes are).

(ii) Electrons move in a path of least resistance. If the reactants were all contained in one cell, electrons would move directly from one reactant to the other, and no electricity would be harnessed. Chemical potential energy would be converted directly into heat energy.

c. (i) $Q = It$
$8640 + I \times 2 \times 60 \times 60$
$I = 1.20\,A$

(ii) $n(e-) = \frac{Q}{F} = \frac{8640}{96500} = 0.08953\,mol$

$n(Cd) = 0.5 \times n(e-) = 0.044767\,mol$

$m(Cd) = n \times M = 0.044767 \times 112.4 = 5.03\,g$

(iii) % Efficiency = $\frac{actual\ mass\ loss}{theoretical\ mass\ loss} \times 100 = \frac{4.25}{5.03} \times 100 = 84.5\%$

Comment: Students should note that Faraday's Laws can be applied not only to electrolytic applications but to galvanic cells as well.

QUESTION 5

a. Under the given voltage, $1.6V$, the only metals that could be deposited are Cu, Sn and Co.

b. First layer will not be pure. Predominant reaction occurring will be the reduction of $Cu^{2+}_{(aq)}$, however, small amounts of Sn and Co will also be deposited, as sufficient voltage is passing through the cell to enable these reactions to occur.

c. $Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

$Sn^{2+}_{(aq)} + 2e^- \rightarrow Sn_{(s)}$

$Co^{2+}_{(aq)} + 2e^- \rightarrow Co_{(s)}$

Assuming that all the metals ions were consumed (cathode mass stopped changing) then

$0.500\ mol$ of Cu had been produced. This required $1.000\,mol$ of electrons.
$0.500\ mol$ of Sn had been produced. This required $1.000\,mol$ of electrons.
$0.500\ mol$ of Co had been produced. This required $1.000\,mol$ of electrons.

Total number of mole of electrons required $= 3.000\,mol$

Number of coulomb $= 3 \times 96{,}500 = 289{,}500\,C = 2.90 \times 10^5\ C$

QUESTION 6

a. (i) $Al_2O_{3(s)} + 2OH^-_{(aq)} + 3H_2O_{(l)} \rightarrow 2Al(OH)^-_{4(aq)}$

Acidic oxides produce more acidic solutions i.e. pH decreases.

(ii) $Al_2O_{3(s)} + 6H^+_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3H_2O_{(l)}$

Basic oxides produce more basic solutions i.e. pH increases.

(iii) $Al^{3+}_{(aq)}$ is a weaker oxidant than water. Water will preferentially react at the cathode, and no $Al_{(s)}$ will be produced.

(iv) $2Al_2O_{3(l)} + 3C_{(s)} \rightarrow 4Al_{(l)} + 3CO_{2(g)}$

b. (i) Sodium chloride melts at about 800^0C. The addition of $CaCl_2$ lowers the melting temperature of the mixture to about 600^0C. Less energy will therefore be expended in keeping the mixture in its molten state.

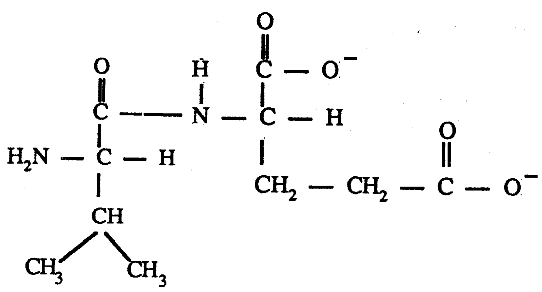
(ii) Ca^{2+} is a weaker oxidant than Na^+ and will not interfere will the cell reactions.

(iii) This screen ensures that the sodium and chlorine produced do not mix once they have been produced at the electrodes.

QUESTION 7

a. (i) Alkaline pH (pH > 7).

(ii) One possible dipeptide (when valine is joined to glutamic acid in that order) is



b. (i) Covalent bonding (peptide linkage)
(ii) Hydrogen bonding.
(iii) Bonding at A.
(iv) Bonding at C.

c. The protein chain in an enzyme molecule is folded so that it has a particular shape, and it is this shape that determines whether the enzyme can interact with the appropriate substrate.

d. (i) The rate of a chemical reaction usually increases as the temperature increases. This is because a larger proportion of the reactants have enough energy to overcome the activation energy barrier. The kinetic energy of the system increases and there is a greater number of effective collisions. Reaction rates increase.

(ii) Although the temperature is still increasing, the reaction rate decreases. This is due to the tertiary structure of the protein undergoing changes (denaturation) as the temperature rises over $40^{o}C$. The enzyme functions less well as a catalyst, and loses all activity once denaturation becomes complete.

(iii) The amount of enzyme and maltose.

QUESTION 8

a. In the presence of light and oxygen, highly reactive chemical species known as free radicals may be formed (particles that have one or more unpaired electrons). These free radicals attack the $C=C$ bonds, cleaving the double bond between carbon atoms. The oil/fat is broken down into smaller units, creating an unpleasant taste and smell.

Antioxidants are added to fatty foods to protect the $C=C$ bonds from oxygen i.e. antioxidants reduce atmospheric oxygen before it can oxidise the susceptible double bonds between carbon atoms.

Circle CHCH in one of the top two fatty acid chains in the given molecule.

b. (i)

$$
\begin{array}{ll}
\quad\quad\quad\quad O & \\
\quad\quad\quad\quad // & \\
CH_2-O-C-(CH_2)_7CHCH(CH_2)_7CH_3 & \\
| \quad\quad\quad\quad O & \\
| \quad\quad\quad\quad // & +3H_2O_{(l)} \\
CH-O-C-(CH_2)_7CHCH(CH_2)_7CH_3 & \\
| \quad\quad\quad\quad O & \\
| \quad\quad\quad\quad // & \\
CH_2-O-C-(CH_2)_{14}CH_3 &
\end{array}
$$

$$\downarrow$$

$$C_3H_8O_3+2COOH(CH_2)_7CHCH(CH_2)_7CH_3 \ +COOH(CH_2)_{14}CH_3$$

(ii) Enzymatic hydrolysis.

c. (i) Reagent A is $H_{2(g)}$.
Substance B is a catalyst.

(ii) Addition reaction or hydrogenation reaction.

(iii) Molecule becomes more saturated.

(iv) Answer is C.

QUESTION 9

a. $O_{2(g)} + 4H^{+}_{(aq)} + 4e^{-} \rightarrow 2H_2O_{(l)}$

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

Overall: $O_{2(g)} + 4H^{+}_{(aq)} + 4Fe^{2+}_{(aq)} \rightarrow 2H_2O_{(l)} + 4Fe^{3+}_{(aq)}$

b. (i) Fixation describes the conversion of atmospheric nitrogen into soluble nitrogen compounds that <u>can</u> be absorbed by plants.

(ii) Atmospheric nitrogen does not naturally combine with other substances in the soil and air and therefore, needs to be fixed in order to be absorbed.

(iii) $N_{2(g)} \rightarrow NH_{3(aq)} \rightarrow NH^{+}_{4(aq)}$

$N_{2(g)} \rightarrow NO_{(g)} \rightarrow NO_{2(g)} \rightarrow NO^{-}_{3(aq)}$

Note: The latter stages in these reactions require nitrogen fixing bacteria.