

# HSC CHEMISTRY 2004 – Sample Examination

## MARKING GUIDELINES

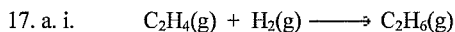
### Multiple Choice

1 D 2 A 3 C 4 D 5 D 6 D 7 A 8 C 9 A 10 D 11 B  
12 C 13 A 14 D 15 D

### Extended Answers

16. a. The S in  $\text{SO}_2$  has an oxidation number of +4, in  $\text{SO}_4^{2-}$  it is +6. The oxidation number has thus increased and the S has been oxidised.  
The Br in  $\text{BrO}_3^-$  has an oxidation number of +5, in  $\text{Br}^-$  it is -1. The oxidation number has thus decreased the Br is reduced.

b. The species oxidised is the reducing agent,  $\text{SO}_2$ , and the species reduced is the oxidising agent,  $\text{BrO}_3^-$ .

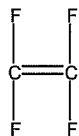


ii. Addition reaction

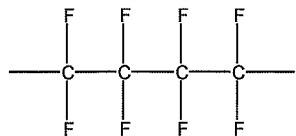
b. i. Polymerisation is the linking together into a long chain molecule (polymer) of repeating sub-unit molecules (monomers).



iii.

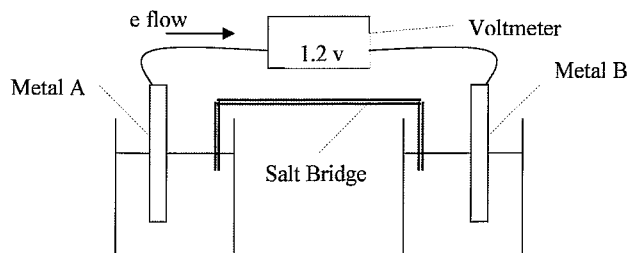


tetrafluoroethene monomer



polytetrafluoroethene (Teflon) polymer

18. a.

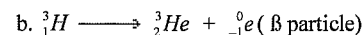


### Quest 18 (cont)

b. A. The B electrode is positive which means the reactions that occur in the cell are  $\text{A} \longrightarrow \text{A}^+ + \text{e}^-$  and  $\text{B}^+ + \text{e}^- \longrightarrow \text{B}$ .  
Hence the reaction  $\text{A} \longrightarrow \text{A}^+ + \text{e}^-$  has a greater tendency to occur than does  $\text{B} \longrightarrow \text{B}^+ + \text{e}^-$  and so A is the stronger reductant.

c.  $\text{A} > \text{C} > \text{B}$ . The values of the voltages show that A is a much stronger reductant than B and that C is only slightly stronger than B, so A must be a stronger reductant than C.

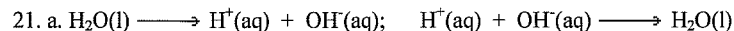
19. a. Radioactive tracers are radioactive isotopes that are used to follow the movement of atoms during a biological or chemical process.



c. At time 0, 100% of isotope which loses half its activity each 12 years;  
after 12 years, 50% remaining  
after 24 years, 25% remaining  
after 36 years, 12.5% remaining  
hence, after 36 years there is 87.5% decrease in activity.

20. a. The concentration of lead ions would remain the same. Solubility does not depend on the amount of solid in contact with the solution

b. Yes. Although solubility does not change, both solution and precipitation are occurring at equal rates as the solution is in dynamic equilibrium with the solid. Some of the radioactive sulfate ions goes into solution as an equal amount already in solution comes out.



b. As  $\text{OH}^-$  is removed from solution, more  $\text{H}_2\text{O}$  must dissociate to replace it, thus increasing the  $[\text{H}^+]$ .

c.  $\text{pK}_w = 13.76, \quad \text{K}_w = 10^{-13.76} = 1.738 \times 10^{-14}$   
 $[\text{H}^+] = [\text{OH}^-], \quad \text{K}_w = [\text{H}^+]^2, \text{ thus } 1.738 \times 10^{-14} = [\text{H}^+]^2, \text{ i.e. } [\text{H}^+] = 1.3 \times 10^{-7} \text{M}$

22. a. HX is weaker. The pH at the equivalence point is determined by the identity and concentration of the conjugate base,  $\text{X}^-$  or  $\text{Y}^-$ . The higher the pH at the equivalence point, the stronger the conjugate base ( $\text{X}^-$ ) and the weaker the conjugate acid (HX).

b.  $40.0 \text{ mL HNO}_3 \times (0.900 \text{ mol HNO}_3 / 1000 \text{ mL soln}) \times (1 \text{ mol NaOH} / 1 \text{ mol HNO}_3)$   
 $\times (1000 \text{ mL soln} / 0.0850 \text{ mol NaOH})$   
 $= 42.353 = 42.4 \text{ mL NaOH soln}$

23. a. 1- Butanol  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$  Ethanoic acid  $\text{CH}_3\text{COOH}$

b. The reaction rate is quite slow and so the system requires a long period of reflux to achieve equilibrium. The reaction does not proceed to completion.

c. The ester would be found in the organic layer. Butyl ethanoate is insoluble in water.

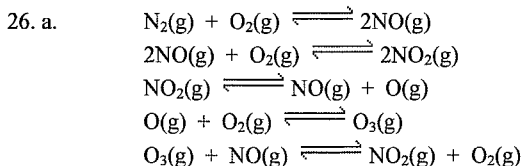
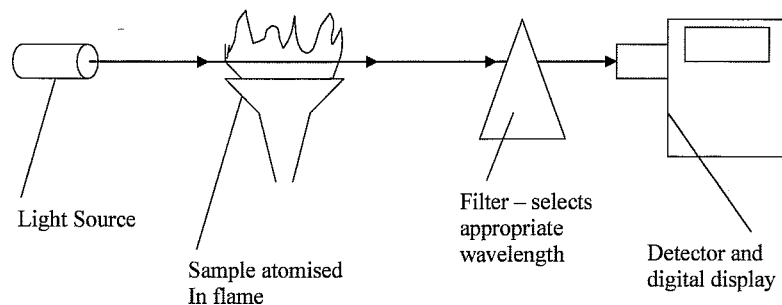
24. a. BOD (biological oxygen demand) provides a measure of the quantity of organic material in water that is potentially oxidisable by microorganisms.

b.  $[\text{O}_2]$  decreases as it is used up by microorganisms in the decomposition of the organic material in the water.

c. Secondary treatment in which oxidisable impurities are removed by bacteria in presence of oxygen supplied by aeration.

d. Nutrients in water can lead to excess growth of aquatic life. The process that causes pollution by such excessive growth is referred to as eutrophication. The excessive organic material in water due to such growth contributes to the BOD.

25.



b. In the middle of the day there is a high level of ultra violet radiation. This promotes the photodissociation of  $\text{NO}_2$  to form oxygen atoms which rapidly react with  $\text{O}_2$  to form  $\text{O}_3$ . Thus the ozone levels are high in the middle of the day in a polluted environment.

## SECTION II – OPTIONS

### INDUSTRIAL CHEMISTRY

27. a i.  $K = \frac{[\text{CS}_2][\text{H}_2]^4}{[\text{CH}_4][\text{H}_2\text{S}]^2}$

ii. The value of the equilibrium expression, applying the data in the question, is 1.49. This is not equal to the value of the equilibrium constant at 1000K of 2.1, so the reaction is not at equilibrium.

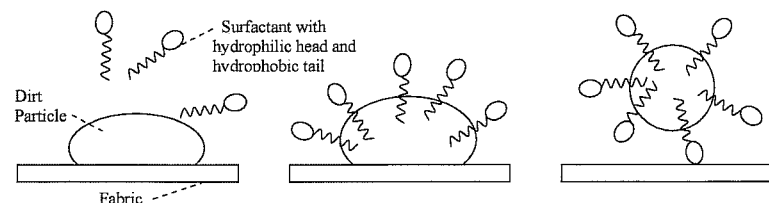
iii. The concentrations will decrease. The reaction occurs in the direction that makes the value of the equilibrium expression approach the value of the equilibrium constant, K. For this to happen the value of the denominator of the expression will decrease, i.e. the reaction will go from left to right when the concentrations of  $\text{CH}_4$  and  $\text{H}_2\text{S}$  will decrease.

iv. Increase. Le Chatelier's Principle indicates that the reaction will move in the direction to absorb the added heat, i.e. the endothermic direction to the right. The value of the equilibrium constant thus will become greater.

v. Value of equilibrium constant for the reaction as given will be  $1/K$ , i.e.  $1/2.1$  or  $0.48 \text{ (mol/L)}^{-2}$

b. i. A surfactant works to decrease the surface tension of water and so the water is more easily able to 'wet' dirt and grease particles and move them off the fabric. The water soluble anionic head of the surfactant is said to be hydrophilic (water loving) while the water repelling tail is described as hydrophobic (water hating). The hydrophobic tail attaches to the dirt/grease while the hydrophilic head is dissolved in water. A diagram is shown at the top of the next page.

Quest 27. b. i. (cont)



ii. Anionic surfactants have a long hydrophobic hydrocarbon tail and an negatively charged hydrophilic, water soluble, anionic head, whereas a cationic surfactant has a long hydrophobic hydrocarbon tail but the water soluble part is a positively charged N atom. Anionic surfactants are commonly used in laundry or dishwashing detergents while the cationic detergents are commonly used in hair conditioners or fabric softeners.

c. i. Advantage: produces very pure NaOH

Disadvantage: waste water may contain mercury residues

ii. Cathode:  $\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na(l)}$

Anode:  $2\text{Cl}^- \rightleftharpoons \text{Cl}_2(\text{g}) + 2\text{e}^-$

iii. The mercury cell is not as commonly used due to the contamination of local water systems by mercury residues

iv. Some salt still contaminates the NaOH. Diaphragm cells that use asbestos pose a health problem

v. The NaOH produced using ion-selective membranes is much purer than that produced by diaphragm cells. The cell is more energy efficient

d. Some escape of mercury from a mercury cell chlor-alkali plant inevitably occurs. Mercury reacts with many organic compounds and the organomercury compounds formed find their way into the food chain.

Intake of mercury compounds by humans causes a disease called Minamata disease. The organomercury compounds enter fish by the food chain and, when ingested by humans, the compounds can disrupt the function of proteins.

Mercury poisoning in humans can cause inflammation of gums, nausea, diarrhoea, kidney failure, blindness, and damage to the brain and nervous tissue.

## SHIPWRECKS, CORROSION and CONSERVATION

28. a. i. Concentrations of solutions:

For dilute solutions of NaCl, oxygen is evolved at the anode (positive electrode) as  $\text{OH}^-$  ions are discharged. However, with concentrated solutions of NaCl,  $\text{Cl}^-$  ions will give up electrons and chlorine will be evolved.

ii. Nature of the electrodes:

Usually the electrode is assumed to be inert but in certain cases it may react. For example,  $\text{CuSO}_4(\text{aq})$  with an inert electrode (Pt or graphite) will give oxygen at the anode as  $\text{OH}^-$  ions are discharged. However, with a copper anode the anode itself will react to give copper ions and electrons.

|                   |                    |   |
|-------------------|--------------------|---|
| b. i. NaCl:       | Positive electrode | $2\text{Cl}^- \longrightarrow \text{Cl}_2 + 2\text{e}^-$                      |
|                   | Negative electrode | $\text{Na}^+ + \text{e}^- \longrightarrow \text{Na}$                          |
| $\text{CuSO}_4$ : | Positive electrode | $4\text{OH}^- \longrightarrow 2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^-$ |
|                   | Negative electrode | $\text{Cu}^{2+} + 2\text{e}^- \longrightarrow \text{Cu}$                      |

ii. Total charge passed =  $0.5 \times 135 \times 60 = 4050\text{C} = 0.0420\text{F}$   
 Therefore, no of moles  $\text{Cl}_2$  formed =  $0.0420/2 = 0.0210$  moles  
 No of moles of  $\text{O}_2$  formed =  $0.0420/4 = 0.0105$  moles  
 Total no of moles of gas formed =  $0.0315$  moles  
 Total volume of gas evolved at STP =  $0.0315 \times 22.4 = 0.706 \text{ L}$

c. i. Rust is a hydrated form of iron(III) oxide,  $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ .

ii. At locations on the iron the reaction  $\text{Fe} \longrightarrow \text{Fe}^{2+} + 2\text{e}^-$  occurs. The electrons flow through the iron metal to another site where they reduce oxygen,  $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \longrightarrow 4\text{OH}^-$ . The  $\text{OH}^-$  and  $\text{Fe}^{2+}$  ions migrate through surface moisture on the iron and combine,  $\text{Fe}^{2+} + 2\text{OH}^- \longrightarrow \text{Fe}(\text{OH})_2(\text{s})$ . This is oxidised by oxygen to form rust,  $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ .

Oxygen is needed to form hydroxide; water is needed to provide a medium through which the ions can migrate to form  $\text{Fe}(\text{OH})_2$ . Migration of ions is faster through salt water because of its greater conductivity. Impurities provide the site on which oxygen is reduced to  $\text{OH}^-$ .

iii. When zinc plating is scratched, the zinc prevents the exposed iron from rusting and re-forms a protective layer. Any oxidation of iron is reversed:

$\text{Fe} \longrightarrow \text{Fe}^{2+} + 2\text{e}^-$  is followed by  $\text{Zn} + \text{Fe}^{2+} \longrightarrow \text{Zn}^{2+} + \text{Fe}$   
 and then zinc ions form zinc oxide and zinc carbonate which form an impervious layer over the iron.

iv. Initial corrosion of aluminium leads to an impervious layer of oxide,  $\text{Al}_2\text{O}_3$ , which prevents any further oxidation/corrosion. With iron the oxide layer is very porous and oxidation can continue.

d. A first step is to remove any encrustations which is usually done by sharp strikes to the iron causing the encrustations to break off. The chloride salts can then be removed from the iron by electrolysis. The iron object to be restored is made the cathode and a stainless steel anode is used with the electrolyte a sodium hydroxide solution. Free  $\text{Cl}^-$  migrates toward the anode.  $\text{OH}^-$  also migrates to the anode in this process which acts to convert various rust deposits back to iron.

## THE BIOCHEMISTRY OF MOVEMENT

29. a. i.  $\text{CH}_2\text{O}$

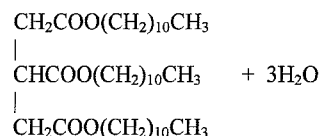
ii. Carbohydrates are the main energy source for our bodies.

iii. When monosaccharides, such as glucose, combine to form polysaccharides, such as glycogen, they do so through condensation reactions by eliminating a water molecule to form a C-O-C bond between rings; this is called a glycosidic linkage.

b. i. In fats, the alcohol is always glycerol, 1,2,3-propantriol,  
 $\text{CH}_2\text{OHCHOHCH}_2\text{OH}$ .

ii.  $\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$

iii.  $\text{CH}_2\text{OHCHOHCH}_2\text{OH} + 3\text{CH}_3(\text{CH}_2)_{10}\text{COOH} \longrightarrow$



iv. Fats are a very efficient way for the body to store energy. Hydrolysis of a fat produces glycerol and the corresponding fatty acid present in the fat. The fatty acids are oxidised to produce large amounts of energy. Much more energy is released from the oxidation of fats compared to carbohydrates and fats are thus a better biological source of fuel.

c. i. Amino acids are unique compounds which contain both a carboxyl group (-COOH) and an amino group (-NH<sub>2</sub>).  $\alpha$ -amino acids are so called because the amino group is attached to the  $\alpha$ -carbon atom, the one next to the carboxylic group.

c. ii. In forming a peptide, amino acids undergo a condensation reaction between the amino group of one amino acid and the carboxylic acid group of the reacting amino acid. The bond is called a peptide linkage and water is released during the formation of the bond.

iii. Hydrogen bonds between a NH group on the polypeptide chain and the unshared electron pair of a carbonyl group further along the chain are responsible for the  $\alpha$ -helical structure of the protein. The pitch and general shape (resembles a spiral staircase) of the helix are determined by the hydrogen bonding arrangement.

iv. Denaturation refers to the loss of the three dimensional structure of the protein. Denaturation affects the functioning of a protein since the exact three dimensional structure is the key to the function of the protein.

d. ATP is composed of three types of components – a nitrogen base (adenine), a five-carbon sugar and phosphate. As the name implies ATP contains three phosphates. The third phosphate group can be removed from ATP by hydrolysis, leaving ADP (adenosine diphosphate) and a phosphate. In the course of this reaction a large amount of chemical energy is released per mole of ATP. Removal of a second phosphate group to produce AMP (adenosine monophosphate) can release more energy. Living systems have evolved in such a way as to take advantage of the energy made available by hydrolysis of ATP and ADP.

e. Contraction of muscle is triggered by nerve impulses arriving at the muscle cell membrane. Contraction results when a muscle actin filament protein slides past the myosin filament protein. It appears that the stimulation of the muscle membrane by a nerve impulse release calcium ions which facilitates the splitting of ATP to ADP and the subsequent temporary bond formation that causes the interaction between actin and myosin.

## THE CHEMISTRY OF ART

30. a. i. A pigment is an insoluble colouring matter suspended in a liquid medium to make paint. Examples are red ochre and emerald green. A dye is a soluble colouring material in a solution, usually water. Often vegetable extracts, examples include indigo and alizarin.

ii. The pigment is precipitated from solution and then extracted, dried and mixed with a medium for use.

iii. A reflectance spectrum can be obtained from a painting by shining white light onto the surface of a chosen pigment and analysing the resulting light reflected from the pigment. The reflectance spectrum can be then compared to those of known pigments and identification made.

30. b. i. The loss of one electron makes it more difficult to remove a second electron. As the number of electrons in the outermost shell is reduced, within the energy level the electron-electron repulsion is reduced and the electrostatic attraction between the positive protons in the nucleus and the remaining electrons is increased.

ii. This large increase in value means that all the electrons have been removed from the outermost shell, and the electron being removed is from the complete inner shell below – there is now a much higher effective nuclear charge.

iii.  $\text{C} - 2e \longrightarrow \text{C}^{2+}$

c. i. The transition elements have electron configurations that include the d-block orbital which is being filled. The other elements in the main groups of the Periodic table have their d-block orbitals either completely empty or completely filled.

ii. Colour in transition elements relates to the movement of electrons in the d-orbitals.  $Ti^{4+}$  does not have a coloured compound because they have no electrons occupying d-orbitals which can be promoted to higher energy level d-orbitals. However,  $Ti^{3+}$  have partially filled d-orbitals with electrons that can be promoted into higher energy d-orbitals when they absorb energy.

iii. The  $[Cr(H_2O)_6]^{3+}$  ion is violet and the  $[Cr(CN)_6]^{3-}$  is yellow. The type of ligand present affects the colour; bound water molecules produce a violet colour whereas the cyanide ion produces a yellow colour.

iv. Titanium - +2, +3, +4 OR Chromium - +2, +3, +6

d. The hemoglobin molecule is complex containing four heme groups each of which has an iron(II) ion at its centre. Each heme group acts as a planar ligand that uses the lone pair of electrons on each of its four N atoms to bond to the iron(II) ion. A fifth N atom, which is part of the globin protein which wraps around the heme groups, also bonds to the central iron(II) ion. An oxygen molecule can bond to the iron in a position above the plane of the chelate ring to form oxyhemoglobin. In this way oxygen is transported through the blood to be released for cell metabolism.

## FORENSIC CHEMISTRY

31. a. The DNA (deoxyribonucleic acid) molecule is a polymeric chain of nucleotides. Nucleotides consists of three components, a phosphate group, a pentose sugar group and an nitrogenous base. The sequence of the nitrogen bases is the basis of storage of genetic information.

DNA is characteristic of a particular organism and is independent of organism age or tissue sample. This means it can be used to identify a species or an individual member of a species. Comparisons can be made between different types of biological samples

Quest 31. (cont)

because most cells in an individual contain identical DNA. DNA can remain intact for thousands of years making it possible to preserve evidence. DNA analyses have high analytical sensitivity with only tiny sample being required for an analysis.

31. b. Paper Chromatography: used to provide information about inks and pigments.

Gas Chromatography: used to measure blood alcohol levels.

Ion Exchange Chromatography: used in the separation of proteins.

Column Chromatography: used for the separation of aromatic phenols.

c. Forensic techniques should be developed that allow as much evidence as possible to be gathered from a crime scene when small samples often are only available as forensic evidence. Techniques are required that only require minute amounts of sample, e.g. a smear or drop of blood. Also as many tests as possible should be able to be carried out on the one sample and analytical methods should be used that do not destroy the sample (i.e. non-destructive methods) in the process of analysis

d. i. Reducing sugars, such as glucose, are oxidised by Benedict's solution forming a red precipitate. Sucrose cannot be oxidised by Benedict's solution.

ii. 2-hexene decolourises bromine solution - the red-brown colour of bromine changes to colourless. Hexane does not react with bromine solution.

iii. Flame test. Sodium chloride gives a bright yellow colour, characteristic of sodium, when a solution is sprayed into a bunsen flame. Potassium chloride give a lilac colour, characteristic of potassium.

e. i. Vibrations within the molecules, stretching and bending of chemical bonds.

ii. There are many vibrational modes within a molecule and each leads to absorption at a different wavelength.

iii. By comparing the spectra of the unknown compound with a database of spectra of known compounds to find a compound that has the same absorption bands.

f. Forensic scientists must be impartial. They should not be employed by either the prosecution or defence in a trial. Their role is equally concerned with identifying and examining evidence that might establish the innocence or guilt of a suspect. The accuracy and reliability of forensic results must be reported in an unbiased way, including a description of the uncertainty involved in a particular analysis.