ARC

HSC CHEMISTRY 2003
SUGGESTED MARKING GUIDELINES

Multiple Choice

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

Extended Answers

16. a. $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

b. Yeast

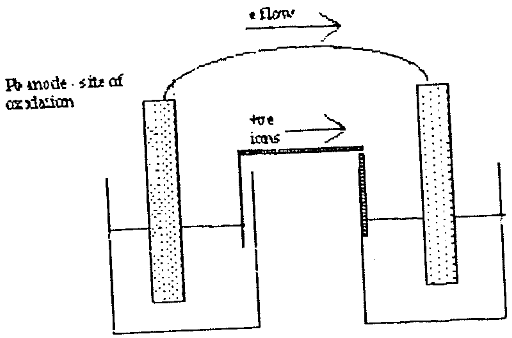
c. Heat the mixture with a water cooled condenser. The water cooled condenser prevents the escape of volatile reactants or products.

17. a i. Zn > Pb > Cu > Ag

ii. Zn reacts with all of the three ions losing its electrons (oxidation) to the ions which attract the electrons (reduction). The Zn is, therefore, the strongest reducing agent, the ions are more powerful oxidising agents attracting electrons. Similarly, the Pb reacts with the copper and silver ions losing its electrons and being oxidised. It is therefore, a stronger reducing agent than either of the two ions. The Cu reacts only with the silver ions and thus is the stronger reducing agent of this couple. From these reactions the order of strength of reducing agent can be deduced.

iii. $Cu + 2Ag^+ \longrightarrow Cu^{2+} + 2Ag$
$Zn + Cu^{2+} \longrightarrow Cu + Zn^{2+}$

18. a i.



18. a. ii. $Pb - 2e \longrightarrow Pb^{2+}$
$Cu^{2+} + 2e \longrightarrow Cu$
Overall : $Pb + Cu^{2+} \longrightarrow Pb^{2+} + Cu$

b. i. +2, +3, +3

ii. Oxidation, as the oxidation state is increased from −3 to +4.
Reduction, as the oxidation state is decreased from −4 to −2

19. a. Formation of a polymer from two different monomers each with two identical functional groups. Reaction takes place between functional groups with the release of a small molecule (e.g. water).

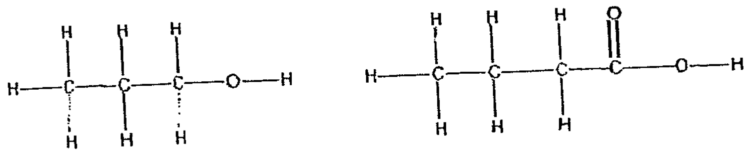
b. For example, PET – polyethene terephthalate (Terylene or Dacron).

c. Formed by the condensation polymerisation of β-glucose monomers. The –OH in the 1 position of one glucose monomer reacts with the –OH in the 4 position of the other monomer

d. Cellulose contains basic carbon chain structures that are needed to build compounds that are presently obtained from petrochemicals. It is a major component of biomass. The chemical potential energy can be released from this biomass by eating plant material or by burning wood.

20. a. propylbutanoate

b.



1-propanol butanoic acid

c. Heat under reflux with a few drops of concentrated sulfuric acid.

d. For example, solvents or fragrances

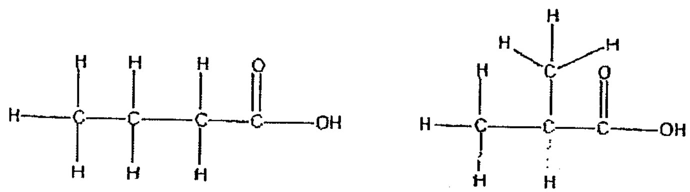
21. a. The stronger the acid, the greater the extent of the dissociation into ions. Hence the strongest acid will produce the greater hydrogen ion concentration, i.e. it gives the lowest pH. The order of increasing H^+ is pH 6.1, 4.2, 2.7, 2.0. Thus the order of increasing acid strength is B, A, D and C.

21. b. If a 0.10M acid solution was completely dissociated $[H^+]$ would be 0.10M
$pH = -\log[H^+] = -\log 0.10 = 2.0$
thus acid C is completely dissociated.

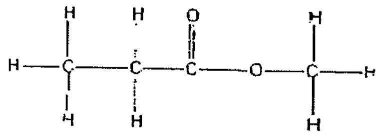
22. Molar mass of Na_2CO_3 is 106 g per mol
Thus, no of moles = 5.404/106 = 0.05098 mol in 0.5L
Concentration of Na_2CO_3 is thus 0.102 mol/L

23. a $C_4H_8O_2$

b.



c.



methylpropanoate

d. Lower boiling point than X. Alkanoic acid has hydrogen bonding between their molecules (-OH group) which raises the boiling point.

24 a. Can be produced from a renewable resource. e.g. corn, a source of ethanol, can be grown in quantities required

b. For example,
large areas of agricultural land needed to grow suitable crops for production of ethanol OR
Higher engine compression ratio is required to utilise ethanol's higher octane rating (measure of efficiency of burning of fuel). This leads to greater wear in car engine and shorter engine life

25 a. Polymer membranes composed of materials such as cellulose acetate.

b. Particles larger than 2nm, such as bacteria or large organic molecules.

c. Contaminating cations cannot be removed by membrane filters. They can be removed by special materials that coat the membrane and bind metal ions.

26. a. $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

b. i. High pressures shifts the equilibrium reaction to the right (product) to compensate for the increased pressure (4 moles gives 2 moles)

ii. Equilibrium is exothermic. If the temperature is too high the yield is reduced as the equilibrium shifts to the left. If too low, the rate of reaction is too low.

iii. The use of a catalyst allows the reaction to proceed at a fast rate. A catalyst lowers the activation energy for the reaction.

SECTION II – OPTIONS

INDUSTRIAL CHEMISTRY

27. a i. Three stages:
Burning of sulfur to make sulfur dioxide
Combination of sulfur dioxide with oxygen to form sulfur trioxide gas
Solution of sulfur trioxide gas in sulfuric acid to give highly concentrated sulfuric acid, called oleum.

ii. The SO_2 is highly water soluble and so the air must be dried to ensure only SO_2 forms

iii. The reaction is exothermic and so an increase in temperature will lead to a reversal of the equilibrium leading to a lower yield of SO_3. Thus a catalyst is preferred.

iv 98.5 g per 100 g H_2SO_4 i.e. 985 g per 1000 g
or 985 g per 555.6 mL (since in 1 mL there is 1.8 g)
or 1772.9 g per litre i.e. 1772.9/98 moles per litre
18.1 $molL^{-1}$

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27. a. v. Reactions for the formation of sulfuric acid in the Contact process involve equilibrium processes that are exothermic. According to Le Chateliers principle, such reactions are favoured by low temperatures and high pressures. Low temperatures slow the rate of reaction so intermediate temperatures of about 500°C are chosen. Increased pressures are used but because the catalyst used in the Contact process, V_2O_5, is very effective, pressures of only about 2 atmospheres are used.

vi. Sulfuric acid , although very corrosive, is easily handled and transported. Together with the fact of its acid strength and low cost of production make it the most important industrial chemical. It is used in very large quantities in the manufacture of fertilisers, in the petroleum industry, in the production of steel, in the manufacture of organic dyes, plastics and many other products.

b. Chlorine and sodium hydroxide are manufactured by either :

Mercury Cell process. Salt water is continuously passed into a electrolysis cell that has graphite anodes and a flowing liquid layer of mercury as cathode. Sodium reacts with the mercury cathode forming an amalgam. The amalgam reacts with water outside the cell to produce sodium hydroxide.

$$Na^+ + e^- \longrightarrow Na; \; Na + Hg \longrightarrow NaHg$$

$$2NaHg + 2H_2O \longrightarrow 2Na^+ + 2OH^- + 2Hg + H_2$$

The chlorine gas is produced by the oxidation of Cl^- at the anode

$$2Cl^- \longrightarrow Cl_2 + 2e^-$$

Diaphragm Cell process. A titanium anode and a steel cathode are in two compartments separated by a diaphragm made of asbestos. At the anode chlorine is given off by the oxidation of Cl^-

$$2Cl^- \longrightarrow Cl_2 + 2e^-$$

At the cathode, water is reduced to hydrogen gas and hydroxide ions are formed which combine with Na^+ ions to form sodium hydroxide.

$$2H^+ + 2e^- \longrightarrow H_2; \; 2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$$

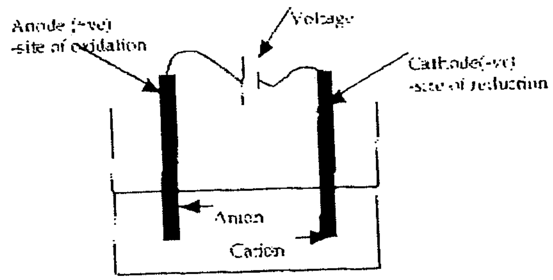
c. i. Saponification is the process in which a fat or oil is hydrolysed in alkali to produce a soap and glycerol.

ii. Olive oil or other suitable oil and a 20% NaOH solution and salt.

iii. Place the oil and alkali in a large beaker and heat for up to 60 mins. Add salt to precipitate the salt. Filter and wash the soap product.

SHIPWRECKS, CORROSION and CONSERVATION

28. a. i.



ii. $Na^+ + e^- \longrightarrow Na$

$$2Cl^- \longrightarrow Cl_2 + 2e^-$$

iii. The electrolyte is sodium chloride and it is in a molten state.

b. i. $Ni(s) + I_2(aq) \rightleftharpoons Ni^{2+}(aq) + 2I^-(aq)$

ii. $Mn(s) + I_2(aq) \rightleftharpoons Mn^{2+}(aq) + 2I^-(aq)$; +1.73 volts

iii. Voltage will increase if the concentration of the reactant I_2 is increased. Increase in concentration will result in the adjustment of the equilibrium so as to minimise the change, i.e the reaction will shift to the product side.

c. i. Iron and steel rust in the presence of oxygen and moisture. The rust that forms is a hydrated form of iron(III) oxide. It is a galvanic process where iron(II) ions are formed by oxidation of iron, and hydroxide ions are formed by the reduction of oxygen in the presence of water. The products of the redox process result in the formation of iron(II) hydroxide; the iron(III) oxide (rust) is then formed from the oxidation of the hydroxide.

ii. Galvanising means the covering of the iron surface with a thin layer of a more reactive metal such as zinc. Instead of the iron(II) ions combining with hydroxide ions to start the formation of rust, zinc ions (formed by a galvanic reaction with iron(II) ions) preferentially react with the hydroxide ions to form zinc hydroxide (some of which is converted to zinc carbonate). These zinc compounds form an impervious layer over any exposed iron.

iii. Temperature, concentration of oxygen and sulfate-reducing and/or acid producing bacteria.

30. a. iii. When atoms of various elements in the sun
radiation from the sun, the electrons change from the
allowed excited states. Atoms absorb the wavelength
these allowed energy changes. All other wavelengths
the atmosphere unchanged. The dark lines are the wa
allowed energy changes in atoms of the solar atmospl
is all other wavelengths of solar radiation.

b. i. The loss of one electron makes it more difficul
As the number of electrons in the outermost shell is r
the electron-electron repulsion is reduced and the ele
positive protons in the nucleus and the remaining ele

ii. This large increase in value means that all the ele
the outermost shell, and the electron being removed i
below – there is now a much higher effective nuclear

iii. A - 3– B - 1+ C - 2+

c. i. Ligand = an ion or neutral molecule having a lo
used to form a bond to a metal ion
Complex ion – a charged species consisting of
ligands

ii. s, p, d, f

iii. d = 5, f = 7, p = 3, s = 1

iv. $1s^22s^22p^63s^23p^63d^5$

v. For example, Cu (+1 and +2)

vi. $[Fe(H_2O)_6]^{3+}$

vii. Sc^{3+} does not have a partially filled d sub-level.
electron transitions between the d orbitals which are

viii. Chromium, $[Ar]4s^13d^5$, has six valence shell ele
be involved in bonding, leading to multiple stable oxi
aluminium $[Ne]3s^23p^1$, has only three valence electro
during bonding, producing the +3 state exclusively.

28. c. iv. Temperature affects the rate at which chemical reactions occur: low temperatures slow reaction rates.

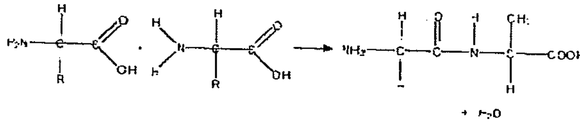
Oxygen is reduced in the galvanic process of rusting and is essential to the process.

The presence of acid producing bacteria accelerates the corrosion process as the galvanic process, involving oxygen, occurs more rapidly in slightly acidic solution. Anaerobic sulfate-reducing bacteria also influence the process of corrosion as hydroxide ions are a product in the process of bacterial reduction of sulfate to sulfide, these hydroxide ions combine with oxidised iron to initiate the formation of rust.

v. In deep oceans the conditions are quite different from the conditions at shallow ocean sites on the continental shelves. The rate of corrosion in shallow water is generally faster because the temperature and concentration of oxygen is higher. Also large amounts of organic matter are usually present at shallow sites which permits the growth of acid producing bacteria. In contrast, temperatures and oxygen concentrations are lower in deep oceans: the bacteria present are of the anaerobic sulfate-reducing type.

THE BIOCHEMISTRY OF MOVEMENT

29. a. i.



ii. Secondary structure refers to the manner in which proteins fold or form repeated patterns – features such as alpha-helix, pleated sheets which are maintained through H-bonding.

Tertiary structure refers to the three dimensional shape formed by interaction between amino acid side chains – the interactions can include hydrophobic and hydrophilic interactions, salt linkages, H-bonds, disulfide linkages, dispersion forces.

iii. As biological catalysts (enzymes), structural molecules; hormones.

iv. Denaturation refers to the loss of the three dimensional structure of protein. This structure is essential to their normal activity.

b. i. The storage polysaccharide in animals is glycogen. It is a complex carbohydrate consisting of numerous 1-4 glycosidic linked alpha-glucose monomer units. When the body has a high glucose concentration, the pancreas releases insulin which converts glucose into glycogen and stores it in the liver. When the glucose concentration is low, this glycogen is converted by the hormone glucagon back into glucose. Glucose and oxygen are the ingredients necessary for cellular respiration and the release of energy for the body to do work.

29. b. ii. Fats are a special type of ester. Esters are made up of an organic molecule and an alcohol. In fats, the alcohol is always glycerol (1,2,3-propantriol). Since glycerol has three –OH bonds, a single molecule of glycerol can have three (different) acid molecules attached to it through ester bonds. Compounds with three acids attached to the glycerol are known as triglycerides and the attached acids are fatty acid side chains. Examples of acids are stearic, a saturated acid, or oleic, an unsaturated (contains C=C bonds) acid. The acids in fats are almost always straight chain carboxylic acids.

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 much better biological source of fuel.

c. When a compound such as glucose is broken down in living systems, some of the energy released is caught and packaged in adenosine triphosphate, ATP, molecules. These molecules are present in all living cells and participate in virtually every series of biochemical reaction.

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. 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. Associated with the myosin protein are enzymes that split ATP to ADP and the release of energy associated with this ATP split is required for the contraction of muscle to occur. It appears that the stimulation of the muscle membrane by a nerve impulse release calcium ions which also facilitate the splitting of ATP to ADP and the subsequent interaction between actin and myosin.

THE CHEMISTRY OF ART

30. a. i. Quantization means that energy can only be absorbed or emitted by atoms in specific amounts or multiples of these amounts. This minimum amount of energy is equal to a constant times the frequency of the radiation absorbed or emitted.

ii. When applied to atoms, the idea of quantized energies means that only certain values of energy transitions between energy levels in the atom are allowed. These discrete energy transitions are seen as the lines in the emission spectra of excited atoms.

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30. a iii. When atoms of various elements in the sun's atmosphere are exposed to radiation from the sun, the electrons change from the ground state to one of several allowed excited states. Atoms absorb the wavelengths of light which correspond to these allowed energy changes. All other wavelengths of solar radiation pass through the atmosphere unchanged. The dark lines are the wavelengths that correspond to allowed energy changes in atoms of the solar atmosphere. The continuous background is all other wavelengths of solar radiation.

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. A - 3+ B - 1- C - 2+

c. i. Ligand – an ion or neutral molecule having a lone pair of electrons that can be used to form a bond to a metal ion

Complex ion – a charged species consisting of a metal ion with its attached ligands

ii. s, p, d, f

iii. d = 5, f = 7, p = 3, s = 1

iv. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$

v. For example, Cu (+1 and +2)

vi. $[Fe(H_2O)_6]^{3+}$

vii. Sc^{3+} does not have a partially filled d sub-level. The colour of Fe^{3+} is due to electron transitions between the d orbitals which are split by the ligands.

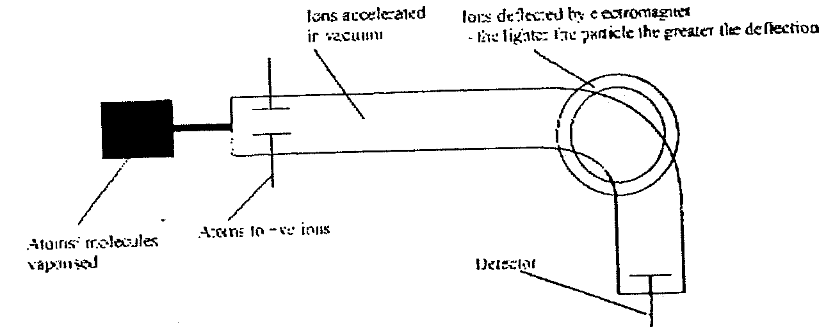
vii. Chromium, $[Ar]4s^2 3d^5$, has six valence shell electrons, some or all of which can be involved in bonding, leading to multiple stable oxidation states. By contrast, aluminium $[Ne]3s^2 3p^1$, has only three valence electrons which are all lost or shared during bonding, producing the +3 state exclusively.

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. In DNA there are four possible nitrogenous bases that may be part of a nucleotide, split into two groups, the purines and the pyrimidines. Purines are double ringed structures and consist of the bases adenine and guanine, the pyrimidines have a single ringed structure and consist of cytosine and thymine. The sugar part of the nucleotide in DNA is deoxyribose.

A nucleic acid polymer consists of a chain of nucleotides formed by condensation reactions. A backbone of alternating sugar and phosphate groups is formed with the nitrogen bases emerging from this backbone. The sequence of the nitrogen bases is the basis of storage of genetic information. DNA in genetic material consists of two strands of nucleic acid that interact through hydrogen bonds between opposing bases to form a double helical structure. In the structure adenine and thymine are present in the helix opposite each other as are cytosine and guanine.

b. i.



ii. Mass spectrometry analyses substances on the basis of the masses of their positive ions. Mass spectra for compounds are unique and can be used as 'fingerprints' for identifying the compounds. Thus, mass spectra are useful for forensic chemistry for their ability to help in the identification of unknown samples, e.g. prohibited performance-enhancing drugs in the urine of athletes can be detected by these means.

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31 c. i. All chromatography techniques involve two phases, a stationary phase and a mobile phase. In paper chromatography the mobile phase moves through the stationary phase and the components of a mixture are then separated according to how much time each component spends in the different phases.

In paper chromatography a spot of mixture is applied to absorbent paper. The end of the paper is then dipped in a suitable solvent. The solvent soaks through the paper by capillary action, moving past the spot where the mixture was applied. The chromatography is continued until the solvent front is near the end of the adsorbent paper. The components that bond strongly to the solvent will be carried along in the direction that the solvent is moving, where as those that do not bond to it or only partially bond to it will remain nearer the mixture spot. The separated components of the mixture are visualised by appropriate techniques (such as staining). The components are then identified (compared to known compounds) by the ratio of the distance travelled by the component to the distance travelled by the solvent front.

ii. Paper chromatography separates amino acids on the basis of their different solubilities in polar and non-polar solvents. Electrophoresis separates them on the basis of charge and size.

Electrophoresis provides more flexibility in separation – variation of the conditions of separation can give more effective separation.

Electrophoresis is a more complex and expensive technique than paper chromatography.

d. i. In the ring structure of glucose, the α isomer has the hydroxyl group on the opposite side of the ring structure from the CH_2OH group, while with the β isomer it is on the same side.

ii. Both are made from glucose monomer units, but the monomers are joined together in slightly different ways. Cellulose consists of long chains of β glucose monomers joined together. Starch consists of α glucose molecules joined together. Cellulose is an insoluble fibrous substance. Starch is a globular substance which exists in two forms – a soluble unbranched form called amylose and an insoluble branched form called amylopectin.

iii. Reducing sugars contain the $-CHO$ and $-CO\text{-}CH_2OH$ groups in their open chain form.

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