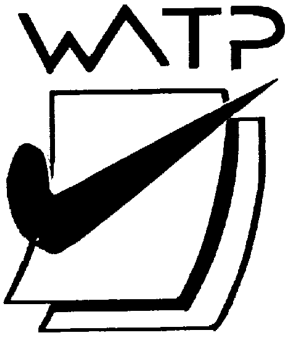


# Year 12
# Chemistry
## 2004

## SOLUTIONS

**Part 1:**

| | | | | | |
|---|---|---|---|---|---|
| 1 | (a) | 11 | (a) | 21 | (a) |
| 2 | (b) | 12 | (b) | 22 | (b) |
| 3 | (d) | 13 | (c) | 23 | (d) |
| 4 | (a) | 14 | (a) | 24 | (a) |
| 5 | (c) | 15 | (c) | 25 | (c) |
| 6 | (b) | 16 | (d) | 26 | (d) |
| 7 | (c) | 17 | (d) | 27 | (b) |
| 8 | (c) | 18 | (b) | 28 | (a) |
| 9 | (b) | 19 | (c) | 29 | (a) |
| 10 | (c) | 20 | (b) | 30 | (d) |

**Part 2:**

1(a) $(CH_3CH_2CHO(l) + H_2O(l) \rightarrow CH_3CH_2COOH(l) + 2H^+(aq) + 2e^-) \times 3$

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l).$

$3CH_3CH_2CHO(l) + Cr_2O_7^{2-}(aq) + 8H^+(aq) \rightarrow 3CH_3CH_2COOH(aq) + 2Cr^{3+}(aq) + 4H_2O(l)$

Orange colour of liquid changes to green. (4)

1(b) $Zn(OH)_2(s) + 4NH_3(aq) \rightarrow Zn(NH_3)_4^{2+}(aq) + 2OH^-(aq)$

White solid dissolves; solution remains colourless . (3)

1(c) No reaction

No visible reaction. (3)

1(d) $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(aq) + H_2O(l)$

Characteristic pungent smell of gas is produced. (3)

2.

| Substance | Raw material consumed |
|---|---|
| Aluminium | $Al_2O_3 .3H_2O$ or C or $Na_3AlF_6$ |
| Sulfuric acid | S or $S_8$ or $O_2$ or $H_2O$ |
| Hydrochloric acid | $H_2$ or $Cl_2$ |
| Iron | $CaCO_3$ or C or $Fe_2O_3$ |

(4)

3(a) polythene / polyvinylchloride or similar (1)

3(b) ethene $H_2C{=}CH_2$ / vinyl chloride $CH_2{=}CHCl$ or similar (1+ 2 = 3)

4. $PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$ (2)

5(a) $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ (2)

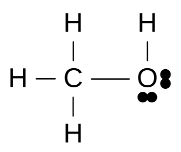
5(b) Arrow must point to the right: → (1)

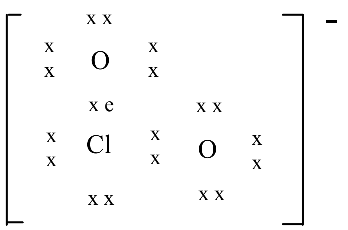
5(c) $NH_4^+(aq)$ or $Mg^{2+}(aq)$ (1)

5(d) 3.17 volts (2)

5(e) It could supply a greater current (but not a greater voltage!) for a longer time. (2)

6.





(6)

7.

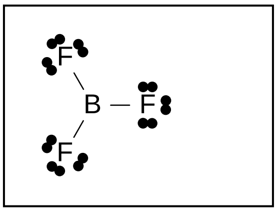
| IUPAC NAME | SEMI-STRUCTURAL FORMULA |
|---|---|
| (a) 2-iodo-3-methyl-2-pentanol | **$CH_3CH_2CH(CH_3)CIOHCH_3$** |
| (b) 2-pentyne | **$CH_3CH_2CCCH_3$** |
| (c) **Sodium butoxide** | $CH_3CH_2CH_2CH_2ONa$ |
| (d) **2-heptanone** | $CH_3COCH_2CH_2CH_2CH_2CH_3$ |
| (e) Methyl propanoate | **$CH_3CH_2COOCH_3$** |

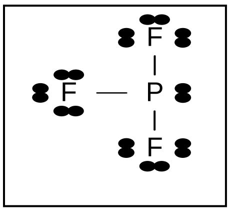
8(a) The solution turns darker red. (1)
Adding $SCN^-$(aq) increases [$SCN^-$(aq]. LCP predicts the system will react by trying to decrease the [$SCN^-$(aq)]. It can do this by favouring → which consumes $SCN^-$(aq) and produces more $FeSCN^{2+}$. (3)

8(b) No visible reaction. (1)
Neither $K^+$(aq) nor $NO_3^-$(aq) has any reaction with any of the species in the equation. Hence, no concentrations are changed, so there is no shift in equilibrium. (3)

9. "Amphoteric" applies to a substance which is able to act as an acid or a base.
eg $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^- (aq)$.
The above reaction shows $Al(OH)_3$ acting as an acid.
$Al(OH)_3(s) + 3H^+(aq) \rightarrow Al^{3+}(aq) + 3H_2O(l)$.
The above reaction shows $Al(OH)_3$ acting as a base.
OR
$2Al(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2(g)$ (Aluminium acting as a base)
$2Al(s) + 2OH^-(aq) + 6H_2O(l) \rightarrow 2[Al(OH)_4]^-(aq) + 3H_2(g)$ (as an acid). (6)

10.





In a $BF_3$ molecule, the central boron atom has only three pairs of electrons in its outer shell. These repel each other "as far away as possible" - which for three regions of charge, equates to angles of $120^o$ and forms a planar triangular molecule.

In a $PF_3$ molecule, the central phosphorus atom has four regions of charge - one lone pair of electrons and three bond pairs of electrons. These four regions of charge repel each other "as far away as possible" which produces bond angles of $107^o$, and forms a pyramidal shaped molecule.
The three bond dipoles in the $BF_3$ molecule are symmetrical and cancel each other to produce a non-polar molecule.
In the $PF_3$ molecule, the three bond dipoles do not cancel because they are all directed downwards from the phosphorus atom to the fluorine atoms which form the base of the pyramid. In this case, the molecule has an overall molecular dipole, and hence $PF_3$ is polar. (6)

11. Anode reaction: $2I^-(l) \rightarrow I_2(s) + 2e^-$
Cathode reaction: $K^+(l) + e^- \rightarrow K(l)$

Anode reaction: $2I^-(aq) \rightarrow I_2(s) + 2e^-$
Cathode reaction: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$. (4)

12. "Electronegativity" refers to the electron attracting ability of an atom in a covalent bond. It is measured on an arbitrary scale from 0 to 4.
"Ionisation Energy" is defined as the energy needed to remove a mole of electrons from a mole of atoms or ions of an element in the gas phase. It is measured in units of kJ $mol^{-1}$. (4)

**Part 3:**

1(a) $C_xF_yCl_z \rightarrow x\ CO_2 + z\ Cl$ ( as z HCl)

5.318 g → 2.201 g

$n(CO_2) = m/M = (1.703\ g) / (44.01\ g\ mol^{-1}) = 0.038696\ mol$

$n(C) = n(CO_2) = 0.038696\ mol$.

$m(C) = n.M = (0.038696\ mol)(12.01\ g\ mol^{-1}) = 0.4647\ g\ C$.

$n(Cl) = n(HCl) = n(NH_3) = c.V = (2.052\ mol\ L^{-1})(0.0566\ L) = 0.11614\ mol$.

$m(Cl) = n.M = (0.11614\ mol)(35.45\ g\ mol^{-1}) = 4.117\ g\ Cl$.

$m(F) = m(sample) - m[Cl + C] = 5.318\ g - 4.582\ g = 0.7360\ g\ F$.

$n(C) = 0.0387\ mol = 1$

$n(Cl) = 0.11614\ mol = 3$

$n(F) = 0.0387\ mol = 1$

Hence, the Empirical formula of the compound is $CFCl_3$. (8)

1(b) $V(STP) = 0.2516\ L$

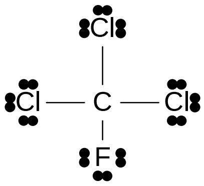
$n(compound) = (0.2516\ L) / (22.41\ L\ mol^{-1}) = 0.01123\ mol$.

$M(compound) = m/n = (1.542\ g) / (0.01123\ mol) = 137.3\ g\ mol^{-1}$.

$CFCl_3 = 12.01 + 19.00 + 3(35.45) = 137.36$

Hence, True formula = Empirical formula = $CFCl_3$ (2)

1(c) Possible structure:



Name: trichloro(mono)fluoromethane (2)

2(a) ($NiCO_3.xH_2O$ + impurities) → ($NiCO_3(s)$ + impurities) + $xH_2O(g)$

5.75 g → 4.164 g

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

$n(Ni) = n(Ni^{2+}) = m / M = (1.707 g) / (58.69 g mol^{-1}) = 0.02908$ mol.

$n(NiCO_3) = n(Ni) = 0.02908$ mol.

$m(NiCO_3) = n.M = (0.02908 mol)(118.72 g mol^{-1}) = 3.452 g NiCO_3$

Hence, 5.75 g of ore contains 3.452 g of $NiCO_3$

The mass of water driven off was 1.586 g.

$n(NiCO_3) = 0.02908$ mol = 1

$n(H_2O) = (1.586 g) / (18.016 g mol^{-1}) = 0.0880$ mol = 3

Ans(a): The formula is $NiCO_3.3H_2O$. (8)

2(b) The percentage of $NiCO_3.3H_2O$ in the ore is:

$[m(NiCO_3.3H_2O) / (m(ore))] \times 100 = [(5.038 g) / (5.750 g)] \times 100$

Ans (b): The ore is 87.6% $NiCO_3$ by mass. (2)

3(a). 10 mL $H_2O_2$(conc) → 250 mL $H_2O_2$ (dilute) then 20 mL sample reacts with $MnO_4^-(aq)$

$n(MnO_4^-)_{TOTAL} = c.V = (0.0740 mol L^{-1})(0.0500L) = 3.70 \times 10^{-3}$ mol.

$n(MnO_4^-)_{EXCESS} = (2/5) n(H_2C_2O_4) = (2/5) c.V = 2/5 (0.245 mol L^{-1})(0.01875 L) = 1.8375 \times 10^{-3}$ mol.

$n(MnO_4^-)_{\text{reacting with H2O2}} = 3.7 \times 10^{-3} mol - 1.8375 \times 10^{-3} mol = 1.8625 \times 10^{-3}$ mol.

Reaction is: $5H_2O_2(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_2O(l)$

Clearly, $n(H_2O_2) = (5/2) n(MnO_4^-) = 5/2 (1.8625 \times 10^{-3} mol) = 4.6563 \times 10^{-3}$ mol.

ie $n(H_2O_2)$ in 20.0 mL dilute soln = $4.6563 \times 10^{-3}$ mol.

Hence, $n(H_2O_2)$ in 250 mL dilute soln = $(250/20)\, 4.6563 \times 10^{-3}$ mol = 0.05820 mol.

This no. of moles was originally in 10 mL of the conc. $H_2O_2(aq)$

Hence, $[H_2O_2]_{CONC} = n / V = (0.05820 mol) / (0.010 L) = 5.82 mol L^{-1}$

Ans(a): The original $H_2O_2(aq)$ was 5.82 mol $L^{-1}$ (10)

3(b). From the decomposition reaction for $H_2O_2(aq)$, $n(O_2) = ½ n(H_2O_2)$

For 1.00 L of original solution, $n(H_2O_2) = 5.82$ mol

Hence, $n(O_2) = 2.910$ mol.

$V(O_2)$ at STP = $(2.910 mol)(22.41 L mol^{-1}) = 65.2$ L of $O_2(g)$.

Ans(b): The volume strength of the original solution is 65.2 L $O_2(g)$ per litre of solution. (2)

4(a) From the balanced equation, $n(Na_2CO_3) = 2n(Fe_2O_3.Cr_2O_3))$

$n(chromite) = m/M = (1.00 \times 10^6 g) / (311.7 g mol^{-1}) = 3208$ mol.

$n(Na_2CO_3) = 2(3208) = 6416$ mol.

$m(Na_2CO_3) = n.M = (6416 mol)(105.99 g mol^{-1}) = 6.80 \times 10^5$ g.

Ans(a): $6.80 \times 10^5$ g of $Na_2CO_3$ is required. (5)

4(b) From the balanced equation:

$n(O_2) = (3/2) n(chromite) = (3/2)(3208 mol) = 4812.3$ mol.

$V(O_2)$ (STP) = $(4812.3 mol)(22.41 L mol^{-1}) = 107844$ L

Since $(P_1V_1) / (T_1) = (P_2V_2) / (T_2)$, $V_2 = (P_1V_1T_2) / (P_2T_1)$

$V_2$ = (101.3)(107844)(303) / (98.0)(273) = $1.24 \times 10^5$ L

Ans(b): The volume of oxygen gas required is $1.24 \times 10^5$ L at 30°C and 98.0 kPa. (5)

5. Reaction is: $Hg_2^{2+}(aq) + 2Br^-(aq) \rightarrow Hg_2Br_2(s)$

Required mole ratio $n(Br^-) / n(Hg_2^{2+}) = 2/1 = 2$

Actual mole ratio:

$n(Hg_2^{2+}) = n(Hg_2(NO_3)_2) = c.V = (0.0502 \text{ mol L}^{-1})(0.150 \text{ L}) = 0.00753$ mol.

$n(Br^-) = n(KBr) = c.V = (0.0203 \text{ mol L}^{-1})(0.250 \text{ L}) = 0.005075$ mol.

Hence, $n(Br^-) / n(Hg_2^{2+}) = (0.005075 \text{ mol}) / (0.00753 \text{ mol}) = 0.674$

Clearly, $Br^-$ is the limiting reagent.

All the limiting reagent is consumed.

Reaction is: 0.005075 mol $Br^-$ + 0.0025375 mol $Hg_2^{2+}$ → 0.0025375 mol $Hg_2Br_2$

$n(Hg_2Br_2) = 0.0025375$ mol.

$m(Hg_2Br_2) = n.M = (0.0025375 \text{ mol})(561.0 \text{ g mol}^{-1}) = 1.42$ g $Hg_2Br_2$

Ans: The mass of mercury(I) bromide obtainable is 1.42 g (6)

**Part 4:**

The following sample answers are given as a guide only, and are not intended to be prescriptive or all-inclusive.

**Essay 1:** Aluminium and Gold.

(i) The first step in the extraction of each metal from its ore is a reaction in which the metal is dissolved to separate it from unwanted impurities:

Aluminium: $[Al(OH)_3(s) + \text{impurities}(s)] + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq) + [\text{impurities}]$

Gold: $4Au(s) + 8CN^-(aq) + O_2(g) + 2H_2O(l) \rightarrow 4[Au(CN)_2]^-(aq) + 4OH^-(aq)$.

The main difference between the two metals in this stage is that the aluminium exists in a [+3] oxidation stage whereas the gold exists in a [0] oxidation state. The aluminium remains in a [+3] oxidation state whereas the gold is oxidised by oxygen gas to a [+1] oxidation state.

(ii) The second stage in the recovery of the metals is a precipitation stage. The tetrahydroxoaluminate ions in solution are precipitated by cooling and seeding the hot solution:

$$[Al(OH)_4]^-(aq) \rightarrow Al(OH)_3(s) + OH^-(aq)$$

The dicyanoaurate(I) ions in solution are adsorbed onto the surface of activated charcoal in a number of tanks to produce "loaded" activated charcoal.

(iii) The aluminium hydroxide is then roasted to drive off the water and convert it to pure aluminium oxide ("alumina") :

$$2Al(OH)_3(s) \rightarrow Al_2O_3(s) + 3H_2O(g).$$

The adsorbed gold is then washed from the activated charcoal using alkaline sodium cyanide solution to produce a concentrated solution of dicyanoaurate(I) ions.

(iv) The final stage in the extraction of each metal is electrolysis. The aluminium oxide is mixed with cryolite and heated to 950°C. The molten mixture then undergoes oxidation and reduction:

Aluminium: Cathode reaction: $Al^{3+}(l) + 3e^- \rightarrow Al(l)$.

Gold: Cathode reaction: $[Au(CN)_2]^-(aq) + e^- \rightarrow Au(s) + 2CN^-(aq)$.

The liquid aluminium is then cooled into ingots.

The gold plated steel wool cathode is then dissolved in acid and the solid gold is further refined to a purity of 99.97% when it is called gold bullion.

(v) The main difference between the final stages of recovery of these two metals is related to the difference in chemical activity between the two metals. Aluminium ions must be in a **molten** phase (no water present) when it is reduced. This is because $Al^{3+}$ has less tendency to reduce than water (-1.66 V compared with -0.41 V). Gold ions have a higher tendency to reduce than water, so an aqueous solution can be used.

(20)

**Essay 2:** Comparison of covalent molecular and covalent network compounds

Covalent bonding occurs when two nonmetal atoms share one, two or three pairs of valence electrons to gain a full outer shell. The shared pair(s) of electrons is/are simultaneously attracted to both atoms. This attractive force between shared electrons and two atomic nuclei constitutes the strength of the covalent bond. Such bonding between nonmetal atoms produces either a molecule or a network solid.

**Covalent molecular substances** form discrete units called molecules in which a relatively small number of atoms are **covalently** bonded to each other. Such molecules may be polar or non-polar.

Intermolecular forces between polar molecules may be **hydrogen bonding** or slightly weaker **dipole-dipole interactions**. Intermolecular forces between non-polar molecules are even weaker and are known as **dispersion forces**.

Hydrogen bonding, although the strongest of the intermolecular forces, is much weaker than the covalent bonds which hold the atoms together **within** the molecules.

It is the intermolecular forces which determine the melting points and boiling points of these substances. Hence, non-polar molecules tend to have the lowest melting and boiling points because the forces holding them together are weakest.

Covalent molecular substances tend to be **relatively soft** due to the weak intermolecular forces. They do not conduct electricity when solid or molten because the molecules are neutral and there are no delocalised electrons. All atoms within the molecules have full outer shells.

**Covalent network substances** such as C(s)(diamond), C(s)(graphite) and $SiO_2$, all involve at least one Group IV element. They have **extended** covalent bonding throughout, so there is no particular basic unit for such substances. They form lattices or crystals which may involve many moles of atoms.

Since covalent bonds are much stronger than any intermolecular forces, network solids have much higher melting points and boiling points than the covalent molecular substances.

Network solids tend to be much harder than covalent molecular substances because extended covalent bonding is stronger than any intermolecular forces. For example, diamond, with extended carbon-carbon covalent bonding has a boiling point about 4800 K, while sulfur, which has discrete non-polar $S_8$ molecules held together by dispersion forces, boils at about 700 K.

Network solids tend not to conduct electricity because there are no ions or delocalised electrons - the atoms in forming covalent bonds gain full outer shells.

Thus, the main differences between covalent molecular and covalent network substances lies in the fact that the covalent bonding in the first is limited to a few atoms while in the latter, is unlimited.

Properties such a melting and boiling point and hardness will be relatively low for the former group and relatively high for the latter. Neither group tends to conduct electricity.

(20)

End of Solutions.