

**YEAR 12**

**CHEMISTRY**

**2001**

**SOLUTIONS**

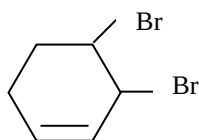
**Part 1:**

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

**Part 2:**

- 1a  $2\text{NH}_4^+(\text{aq}) + \text{Ca}(\text{OH})_2(\text{s}) \rightarrow \text{Ca}^{2+}(\text{aq}) + 2\text{NH}_3(\text{g}) + 2\text{H}_2\text{O}(\text{l})$ .  
Solid dissolves; Characteristic pungent smell is detected.
- 1b  $\text{CH}_3\text{CHOHCH}_3(\text{l}) + \text{Na}(\text{s}) \rightarrow \text{CH}_3\text{CHONaCH}_3(\text{l}) + \frac{1}{2} \text{H}_2(\text{g})$   
Metal dissolves; Bubbles of colourless gas evolved.
- 1c  $\text{Cr}^{3+}(\text{aq}) + 4\text{OH}^-(\text{aq}) \rightarrow \text{Cr}(\text{OH})_4^-(\text{aq})$ .  
A green ppt forms at first then dissolves to form a deep green solution.
- 1d No chemical reaction occurs. Hence, no equation. (tertiary alcohols do not oxidize).  
n.v.r.
- 2a (i) Anode :  $\text{Co}(\text{s})$   
(ii) Cathode :  $\text{Hg}(\text{l})$   
(iii) electron flow from left (anode) to right (cathode)  
(iv) chloride ions flow from right to left (towards anode)
- 2b (i)  $\text{Co}(\text{s}) \rightarrow \text{Co}^{2+}(\text{aq}) + 2\text{e}^-$ .  
(ii)  $2\text{Hg}_2^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Hg}_2^{2+}(\text{aq})$ .
- 2c Voltmeter should (theoretically) read 1.19 volts.
- 3 Test 1. Add  $\text{HNO}_3(\text{aq})$  to a small sample of each solid.  
A colourless gas is released in one case. Others do not react.  
The colourless gas indicates the zinc carbonate.
- Test 2. Add water to dissolve each solid, then add sodium sulfate solution to each.  
A white ppt. Is formed in one case. Others show no change.  
The white ppt indicates the barium nitrate.
- Test 3. Add water to dissolve samples of the remaining two solids, then add sodium carbonate solution to each solution.  
A white ppt forms in one case. The other remains colourless.  
The white ppt indicates the magnesium chloride.
- 4 Oxidation:  $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$ .....x 1  
Reduction:  $\text{NO}_3^-(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$ ... x 2  
Overall:  $\text{Cu}(\text{s}) + 2\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$

5a

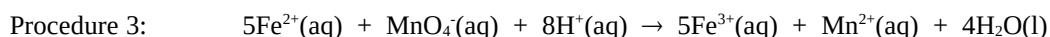
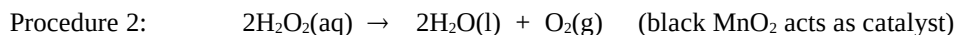
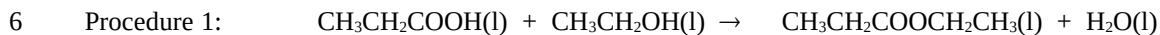


5b



5c

5-chloropentanoic acid



- 7 Change 1: (a) more.  
 (b) The reaction produces heat. LCP predicts if heat is increased, system will favour the reaction which consumes heat ie. the reverse reaction. Hence, more  $\text{HCl(g)}$  is formed.
- Change 2: (a) less.  
 (b) Pressure is increased. LCP predicts system will try to reduce pressure. It can do this by forming less molecules. Hence, forward reaction is favoured. Hence, less  $\text{HCl(g)}$ .
- Change 3: (a) unchanged.  
 (b) By LCP, the catalyst only changes the rate of attainment of equilibrium. It has no effect on the equilibrium mixture.

8 A sulfur dioxide molecule consists of a sulfur atom with a double covalent bond to one oxygen atom and a single covalent bond to the other oxygen atom. The central sulfur atom also has one lone pair of electrons making up its octet of electrons. The three regions of charge around the sulfur atom repel as far away as possible, hence the molecule has an  $\text{O}=\text{S}-\text{O}$  bond angle of about  $120^\circ$ , giving a bent (or planar triangular) molecule.

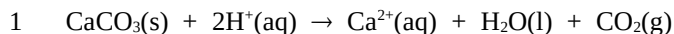
The sulfur dioxide molecule is slightly polar because the two oxygen atoms draw electrons away from the central sulfur atom, creating two bond dipoles. Since these are not opposite (because of the bent shape of the molecule), the dipoles add to give a molecular dipole directed from the sulfur end of the molecule towards the oxygen end of the molecule.

A carbon dioxide molecule differs from sulfur dioxide in that the central carbon atom has two double bonds to two oxygen atoms and no lone pairs. The two regions of charge around the central carbon atom repel as far away as possible so the  $\text{O}-\text{C}-\text{O}$  bond angle is  $180^\circ$ . Hence, the molecule is linear.

The carbon dioxide molecule is non-polar even though it has two bond dipoles directed from the central carbon atom towards the oxygen atoms. Due to the linear shape of the molecule, these bond dipoles are equal and opposite so they cancel, resulting in a non-polar molecule.

- 9 There are seven (7) isomers in total - 5 chain isomers and 2 cyclic isomers:

$\text{CH}_3\text{CHCl}_2$ ,	1,1-dichloropropene
$\text{CH}_3\text{CClCHCl}$ ,	1,2-dichloropropene
$\text{CH}_2\text{ClCHCHCl}$ ,	1,3-dichloropropene
$\text{CH}_2\text{ClCClCH}_2$	2,3-dichloropropene
$\text{CHCl}_2\text{CHCH}_2$	3,3-dichloropropene
1,1-dichlorocyclopropane and	
1,2-dichlorocyclopropane.	

**Part 3:**

$$n(\text{CaCO}_3) = \frac{1}{2} n(\text{H}^+) = \frac{1}{2} n(\text{HCl})_{\text{reacting}}$$

$$n(\text{H}^+)_{\text{total}} = n(\text{HCl}) = c.V = (0.0905 \text{ mol L}^{-1})(0.100 \text{ L}) = 9.05 \times 10^{-3} \text{ mol.}$$

$$n(\text{H}^+)_{\text{excess}} = n(\text{OH}^-) = c.V = (0.250 \text{ mol L}^{-1})(0.0170 \text{ L}) = 4.25 \times 10^{-3} \text{ mol.}$$

$$\text{Hence, } n(\text{H}^+)_{\text{reacting}} = n(\text{H}^+)_{\text{total}} - n(\text{H}^+)_{\text{excess}}$$

$$= 9.05 \times 10^{-3} \text{ mol} - 4.25 \times 10^{-3} \text{ mol} = 4.80 \times 10^{-3} \text{ mol.}$$

$$n(\text{CaCO}_3) = \frac{1}{2} n(\text{H}^+)_{\text{reacting}} = 2.40 \times 10^{-3} \text{ mol}$$

$$m(\text{CaCO}_3) = n.M = (2.40 \times 10^{-3} \text{ mol})(100.09 \text{ g mol}^{-1}) = 0.2402 \text{ g}$$

$$\text{Hence, percentage purity} = (m(\text{CaCO}_3))/(m(\text{sample})) \times 100 = (0.2402 \text{ g})/(0.2450 \text{ g}) \times 100 = 98.0\%$$

Answer: The sample is 98.0% calcium carbonate by mass.

$$2a \quad m(\text{NaOCl}) = 30.0 \text{ g}$$

$$n(\text{NaOCl}) = m/M = (30.0 \text{ g})/(74.44 \text{ g mol}^{-1}) = 0.403 \text{ mol L}^{-1}$$

Answer: The concentration of sodium hypochlorite in original solution = 0.403 mol L<sup>-1</sup>

$$2b \quad \text{From the balanced equation, } n(\text{OCl}^-) = \frac{1}{2} n(\text{S}_2\text{O}_3^{2-})$$

$$n(\text{S}_2\text{O}_3^{2-}) = c.V = (0.250 \text{ mol L}^{-1})(0.0475 \text{ L}) = 0.011875 \text{ mol}$$

$$n(\text{OCl}^-) \text{ (in 20.0 mL)} = 5.9375 \times 10^{-3} \text{ mol.}$$

$$c(\text{OCl}^-) = n/V = (5.9375 \times 10^{-3} \text{ mol})/(0.020 \text{ L}) = 0.297 \text{ mol L}^{-1}$$

Answer: The concentration of hypochlorite ions in final solution = 0.297 mol L<sup>-1</sup>

$$3a \quad \text{Coulombs supplied} = \text{amperes} \times \text{seconds} = (2.00 \text{ A})(35 \text{ h})(3600 \text{ s h}^{-1}) = 2.52 \times 10^5 \text{ C.}$$

$$n(\text{e}^-) \text{ transferred} = (2.52 \times 10^5 \text{ C})/(96490 \text{ C mol}^{-1}) = 2.612 \text{ mol.}$$

$$\text{From the anode reaction, } n(\text{Pb}) = \frac{1}{2} n(\text{e}^-) = \frac{1}{2} (2.612 \text{ mol}) = 1.3058 \text{ mol.}$$

$$m(\text{Pb}) = n.M = (1.3058 \text{ mol})(207.2 \text{ g mol}^{-1}) = 270.6 \text{ g.}$$

Answer: The minimum mass of pure lead per cell = 271 g (3SF)

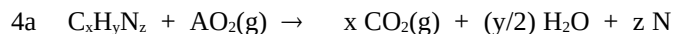
$$3b \quad \text{Combining anode and cathode reactions,}$$



$$n(\text{H}_2\text{SO}_4) = 2n(\text{Pb}) = 2.612 \text{ mol}$$

$$\text{Since } n = c.V, \quad V(\text{H}_2\text{SO}_4) = n/c = (2.612 \text{ mol})/(12.0 \text{ mol L}^{-1}) = 0.218 \text{ L}$$

Answer: Each cell of the battery needs 218 mL of 12.0 mol L<sup>-1</sup> sulfuric acid



$$m(CO_2) = 4.753 \text{ g} \quad \text{Hence, } n(CO_2) = m/M = (4.753 \text{ g})/(44.01 \text{ g mol}^{-1}) = 0.108 \text{ mol.}$$

$$n(C) = 0.108 \text{ mol} \quad \text{Hence, } m(C) = n.M = (0.108 \text{ mol})(12.01 \text{ g mol}^{-1}) = \underline{1.297 \text{ g C}}$$

$$m(H_2O) = 3.405 \text{ g} \quad \text{Hence, } n(H_2O) = m/M = (3.405 \text{ g})/(18.016 \text{ g mol}^{-1}) = 0.1890 \text{ mol}$$

$$n(H) = 2n(H_2O) = 0.3780 \text{ mol.} \quad \text{Hence, } m(H) = (0.3780 \text{ mol})(1.008 \text{ g mol}^{-1}) = \underline{0.381 \text{ g H}}$$

$$\text{Hence, } m(N) = m(\text{sample}) - [m(C) + m(H)] = 2.435 \text{ g} - 1.678 \text{ g} = 0.757 \text{ g}$$

$$\text{Hence, } n(C) = 0.108 \text{ mol; } n(H) = 0.378 \text{ mol; } n(N) = m/M = (0.757 \text{ g})/(14.01 \text{ g mol}^{-1}) = 0.054 \text{ mol}$$

$$\text{Simplest ratios:} \quad \begin{array}{ccc} 2 & 7 & 1 \end{array}$$

Answer: The empirical formula of the compound is  $C_2H_7N$

4b 2.435 g of compound occupies 1.321 L at 25 °C and 101.3 kPa

Convert to STP by applying the combined gas law equation:

$$V_1/T_1 = V_2/T_2 \quad \text{Hence, } V_2 = (V_1)(T_2)/(T_1) = 1.210 \text{ L at STP}$$

$$n(\text{vapour}) = (1.210 \text{ L})/(22.41 \text{ L mol}^{-1}) = 0.05402 \text{ mol.}$$

$$\text{Since } n = m/M, \quad M = m/n = (2.435 \text{ g})/(0.05402 \text{ mol}) = 45.08 \text{ g mol}^{-1}$$

$$\text{E.F.M.} = 2(C) + 7(H) + 1(N) = 45.08$$

Clearly, the true formula mass (molar mass) = E.F.M.

Answer: The true formula of the compound = E.F. =  $C_2H_7N$

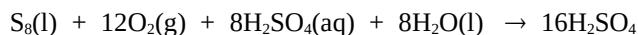
4c Since the compound is an amine, its formula is  $R.NH_2$ .

By subtraction of  $NH_2$  from the true formula,  $R = C_2H_5$

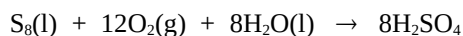
Answer: The structure of the compound is  $CH_3CH_2NH_2$ . The IUPAC name = ethanamine

5a To combine the equations, multiply the second equation by 4  
multiply the third equation by 8  
multiply the fourth equation by 8

Then cancel out the intermediate products. This leads to the combined equation:



Cancel the  $8H_2SO_4$  from both sides since this is provided – not produced - in the reaction:



$$\text{Clearly, } n(S_8) = 1/8 n(H_2SO_4) = 1/8 (10^6 \text{ g})/(98.076 \text{ g mol}^{-1}) = 1274.5 \text{ mol.}$$

$$m(S_8) = n.M = (1274.5 \text{ mol})(256.48 \text{ g mol}^{-1}) = 3.269 \times 10^5 \text{ g.}$$

$$m(S_8)_{\text{impure}} = (100)/(98) \cdot (3.269 \times 10^5 \text{ g}) = 3.34 \times 10^5 \text{ g}$$

Answer:  $3.34 \times 10^5 \text{ g}$  of the 98% pure liquid sulfur is needed.

5b From the balanced equation,  $n(\text{O}_2) = 12/8 n(\text{H}_2\text{SO}_4) = 12/8(10196 \text{ mol}) = 15294 \text{ mol}$ .

$$V(\text{O}_2) = (15294 \text{ mol})(22.41 \text{ L mol}^{-1}) = 342739 \text{ L at S.T.P.}$$

Now change from STP to non-STP using  $P_1V_1/T_1 = P_2V_2/T_2$  Hence,  $V_2 = (P_1)(V_1)(T_2)/(P_2)(T_1)$

$$V_2 = 8.08 \times 10^5 \text{ L}$$

Answer: The volume of oxygen gas required is  $8.08 \times 10^5 \text{ L}$

5c From the balanced equation,  $n(\text{H}_2\text{O(l)}) = n(\text{H}_2\text{SO}_4) = 10196 \text{ mol}$ .

$$m(\text{H}_2\text{O}) = n.M = (10196 \text{ mol})(18.016 \text{ g mol}^{-1}) = 1.84 \times 10^5 \text{ g or } 1.84 \times 10^2 \text{ kg.}$$

Answer: The mass of water required is  $1.84 \times 10^2 \text{ kg}$

**Part 4** These answers are given as a guide only and are not meant to be an exhaustive or prescriptive indication of acceptable answers.

**ESSAY 1:** Van der Waal's forces: their nature and significance.

VDW forces include all intermolecular forces of attraction. These may be discussed under the headings of hydrogen bonding, dipole-dipole interactions and dispersion forces. The first type - hydrogen bonds - occur between polar molecules in which a hydrogen atom in one molecule attached to a fluorine, oxygen or nitrogen atom is attracted electrostatically to the lone pair of a fluorine, oxygen or nitrogen atom in an adjacent molecule. The strength of the attraction depends on the strength of the particular bond dipoles involved in each molecule and how closely the atoms are able to approach each other. The most significant hydrogen bonds are the ones within liquid or solid water. The effect is to significantly increase the intermolecular forces, thus raising the melting and boiling point of water above the values shown by similarly sized non-polar molecules. In addition, hydrogen bonding in water allows this common liquid to interact strongly with, and dissolve, many other polar and ionic substances, resulting in water being described as the "universal solvent". Without hydrogen bonding between water molecules, life on earth would be vastly different – there would be no ice and little or no liquid water on the planet at its present temperatures - our planet would be a steamy world similar to Venus where clouds of gas obscure the surface of the planet.

Dipole-dipole forces occur between polar molecules, but are not strong enough to qualify as hydrogen bonding. Such interactions occur between polar gas molecules such as sulfur dioxide, carbon monoxide and nitrogen monoxide resulting in a higher boiling and melting point than occurs in the case of similarly sized non-polar molecules. These changes are less marked than the ones involving hydrogen bonding. Water is still able to interact quite significantly with such polar molecules. Hydrogen chloride gas, for example, is highly soluble (and highly ionized) in water due to dipole-dipole interactions.

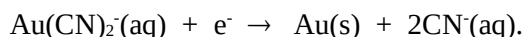
Dispersion forces occur between all adjacent molecules in the solid and liquid state, but are only of significance where hydrogen bonds and dipole-dipole interactions are absent. Dispersion forces are the only interactions between non-polar molecules. While much weaker than hydrogen bonds, they become stronger as the number of electrons in the adjacent molecules increases. All hydrocarbons, for example, are non-polar, but exhibit an increase in boiling points as their formula masses increase. Short chain hydrocarbons are all gases at room temperature, but heptane, with a seven carbon chain has almost the same boiling point as the much smaller water molecule. Longer chain hydrocarbons such as wax, become solids at room temperature when they exceed about 20 carbon atoms in length. The properties of many polymers are determined by the total dispersion forces between the very long chains of atoms. PVC, for example, is much stronger than polythene due to the presence of larger chlorine atoms greatly increasing the dispersion forces within the material.

ESSAY 2: Extraction, purification and uses of gold and iron.

The differences between the chemical extraction and purification processes required for gold and iron are due to the great difference in their chemical reactivities. Gold - one of the least active metals - is found largely in the uncombined state in quartz rocks, and its extraction requires the separation of the very small amounts of the precious metal from the large amount of rock material containing it. After crushing, the very tiny specks of gold are leached out of the mass by selective dissolving of the gold when it forms a soluble complex ion in a cyanide solution through which air is bubbled:



The dicyanoaurate(I) ions are then concentrated by adsorbing them onto the surface of activated charcoal in a process which is known as the carbon-in-pulp treatment. After washing the ions off the charcoal, the concentrated solution is then electrolysed using inert anodes and steel wool cathodes. The gold is then reduced to the pure metal on the surface of the steel wool:



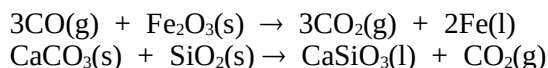
Thus, the changes in the oxidation numbers of the gold through the entire process are from 0 to +1 (dissolving) then from +1 back to 0 (reduction).

After treating with acid to dissolve the steel wool, the gold is about 98% pure. It undergoes further purification in mints to produce gold which is 99.9% pure.

Due to its lack of reaction in air and with other chemicals, gold is used in coinage, jewellery, dentistry and in plating more active metals such as in electronic contacts in computers which must resist the corrosive effects of sparks.

Iron is a comparatively active metal seldom found free in nature (except in meteorites) and exists in the [+3] oxidation state principally as hematite ( $\text{Fe}_2\text{O}_3$ ).

It must be reduced to the [0] oxidation state by reacting it with a suitable reducing agent (carbon monoxide is chosen) at high temperature in a blast furnace. It must also be separated from silica type impurity by adding limestone to the mixture, which converts it to calcium silicate:



The iron product (cast iron) is only about 96% pure. The main impurity is carbon which is then removed by oxidizing the carbon in a Bessemer Converter, resulting in wrought iron (99.5% pure iron).

It is not necessary to purify the iron any further because it is usually then alloyed with other metals to create desired properties (eg, with chromium to form stainless steel, or with tungsten and molybdenum to produce tool steel.)

Due to the high tensile strength of steel, it is used extensively in constructing buildings, bridges, motor vehicles, machinery and tools.

Unlike gold, iron does not resist corrosion because the layer of oxide which forms on its surface is porous to both oxygen and water. The iron surface must be painted or coated with zinc (galvanizing) or other impervious material. Iron structures may also be protected electrochemically or electrolytically. Without this protection, iron rapidly corrodes in moist air, resulting in the total breakdown of the metal to useless rust. Such corrosion requires the regular replacement of many iron objects such as exhaust pipes on motor vehicles.