Year 12
Chemistry
2005

SOLUTIONS

Part 1:

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

(60)

Part 2:

1(a) $CH_3CHO(l) + H_2O(l) \rightarrow CH_3COOH(aq) + 2H^+(aq) + 2e^-$

$\underline{Br_2(aq) + 2e^- \rightarrow 2Br^-(aq).}$

$\underline{CH_3CHO(l) + Br_2(aq) + H_2O(l) \rightarrow CH_3COOH(aq) + 2Br^-(aq) + 2H^+(aq)}$
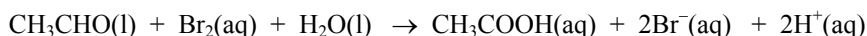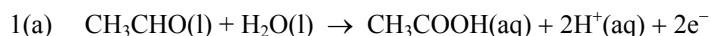
Red-brown colour of liquid fades to colourless.   (4)

1(b) $Zn(OH)_2 (s) + 4NH_3(aq) \rightarrow Zn(NH_3)_4^{2+}(aq) + 2OH^-(aq)$
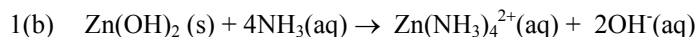
White solid dissolves; solution remains colourless .   (3)

1(c)   No reaction
No visible reaction.   (3)

1(d) $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(aq) + H_2O(l)$
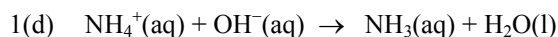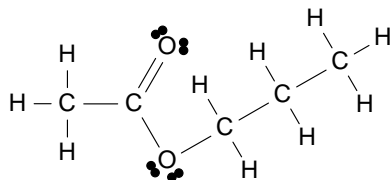
Characteristic pungent smell of gas is produced.   (3)

2.   (i) Phenolphthalein   (ii) Chlorine gas   (iii) Potassium dichromate   (iv) Calcium carbonate   (4)
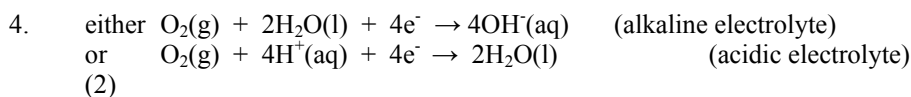
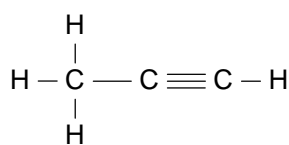3(a)   Ethanoic acid, propanol and sulfuric acid   (3)

3(b)

(2)

3(c)   ethyl propanoate or butyl methanoate or methyl butanoate (any two)   (2)

4.   either $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ (alkaline electrolyte)
     or $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ (acidic electrolyte)
     (2)

5(a) $Pd^{2+}(aq)$ (1)

5(b)   Arrow must point to the left   ←   (1)

5(c) Cl^- or $NO_3^-(aq)$ (2)

5(d)   Anode: $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
       Cathode: $Pd^{2+}(aq) + 2e^- \rightarrow Pd(s)$ (4)

5(e)   0.58 V   (2)
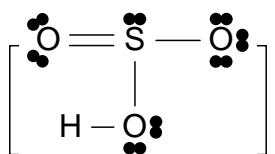
6.

            propyne   hydrogensulfite ion   (6)
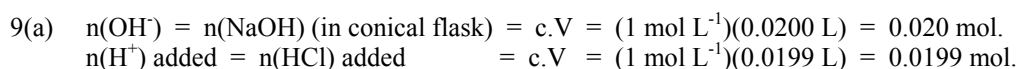
7.   Ionisation Energy is the energy needed to remove a mole of electrons from a mole of atoms or ions of an element in the gas phase. Electronegativity is the electron attracting ability of an atom in a covalent bond.
   Argon has a high first ionisation energy (E_1), but has no electronegativity because since it does not normally form covalent bonds with other elements , it is not possible to measure the relative the electron attracting ability of the argon atom. Argon has a full outer shell which is a stable arrangement so it has no need to attract electrons.
   For Group VII, E_1 decreases down the column from fluorine to astatine.   (6)

8   Iodine, $I_2(s)$ has large non-polar molecules which have strong dispersion forces between them.
   Kerosene ($C_{12}H_{26}$) also has fairly large non-polar molecules with strong dispersion forces between them.
   Water has small polar molecules with relatively strong hydrogen bonding between them.
   Thus, when iodine is placed in kerosene, the iodine-kerosene attraction is similar in magnitude to the iodine-iodine and kerosene-kerosene interaction. For this reason, iodine is soluble in kerosene.
   When iodine is placed in water, the iodine-water interaction is only weak dispersion force because of the relatively small size of the water molecules. Since the iodine-water interaction is much weaker than the iodine-iodine or water-water interactions, iodine is not very soluble in water.   (6)
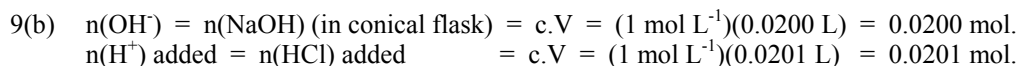
9(a) $n(OH^-) = n(NaOH)$ (in conical flask) $= c.V = (1$ mol $L^{-1})(0.0200$ L$) = 0.020$ mol.
       $n(H^+)$ added $= n(HCl)$ added $= c.V = (1$ mol $L^{-1})(0.0199$ L$) = 0.0199$ mol.
       Since the reaction between the two solutions is $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$,
       The excess $n(OH^-) = 0.0001$ mol.
       Hence, $[OH^-] = n/V = (0.0001$mol$) / (0.0399$ L$) = 2.51 \times 10^{-3}$ mol.
       Hence, $[H^+] = 10^{-14} / [OH^-] = 3.98 \times 10^{-12}$ mol L^{-1}.   Hence, pH = 11.4

9(b) $n(OH^-) = n(NaOH)$ (in conical flask) $= c.V = (1$ mol $L^{-1})(0.0200$ L$) = 0.0200$ mol.
       $n(H^+)$ added $= n(HCl)$ added $= c.V = (1$ mol $L^{-1})(0.0201$ L$) = 0.0201$ mol.
       Clearly, $n(H^+)$ excess $= 0.0001$ mol
       Hence, $[H^+] = n/V = (0.0001$ mol$) / (0.0401$ L$) = 2.49 \times 10^{-3}$ mol. Hence, pH = 2.6
       The initial statement is verified since the change in pH is 8.8 !   (6)

10.
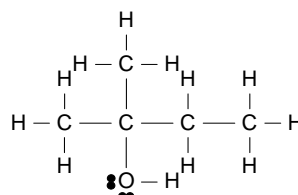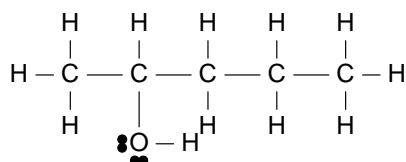
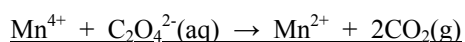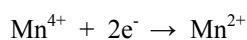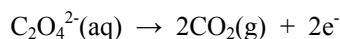2-pentanol   2-methyl-2-butanol   (6)

11.   Shake a little of each alcohol with some acidified permanganate solution. The one which decolorises the solution from purple to pale pink is the secondary alcohol. (The secondary alcohol has been oxidised to 2-pentanone and the permanganate ion has been reduced to Mn^{2+}(aq)).
       The tertiary alcohol does not produce a visible change since tertiary alcohols are not readily oxidised!)
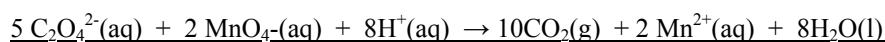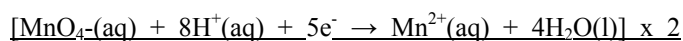   (4)

Part 3:

1.   There are two reactions in this problem:

      (i)   The reaction between the Mn^{4+} and $C_2O_4^{2-}$(aq):

             $$C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-$$
             $$\underline{Mn^{4+} + 2e^- \rightarrow Mn^{2+}}$$
             $$\underline{Mn^{4+} + C_2O_4^{2-}(aq) \rightarrow Mn^{2+} + 2CO_2(g)}$$

      (ii)   The reaction between the excess $C_2O_4^{2-}$ and MnO_4^-(aq):

             $$[C_2O_4^{2-}(aq) \rightarrow 2CO_2(g) + 2e^-] \ x \ 5$$
             $$\underline{[MnO_4\text{-}(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)] \ x \ 2}$$
             $$\underline{5 C_2O_4^{2-}(aq) + 2 MnO_4\text{-}(aq) + 8H^+(aq) \rightarrow 10CO_2(g) + 2 Mn^{2+}(aq) + 8H_2O(l)}$$

      $n(C_2O_4^{2-}(aq))_{total}$ = c.V = (0.0965 mol L^{-1})(0.050 L) = 4.825 x 10^{-3} mol

      $n(C_2O_4^{2-}(aq))_{excess}$ = 5/2 n(MnO_4^-) = 5/2 c.V = (5/2)(0.0332 mol L^{-1})(0.0125 L) = 1.0375 x 10^{-3} mol

      Hence, $n(C_2O_4^{2-}(aq))$ reacting with Mn^{4+} = (4.825 x 10^{-3} mol) - (1.0375 x 10^{-3} mol) = 3.7875 x 10^{-3} mol.

      Hence, $n(Mn^{4+})$ = $n(C_2O_4^{2-}(aq)$ = 3.7875 x 10^{-3} mol.

      $n(MnO_2)$ = $n(Mn^{4+})$ = 3.7875 x 10^{-3} mol

      $m((MnO_2)$ = n.M = (3.7875 x 10^{-3} mol)(86.94 g mol^{-1}) = 0.32929 g.

      % MnO_2 = [m(MnO_2) / (m(sample))] x 100 = [(0.32929 g) / (0.3350 g)] x 100 = 98.3%

      <u>Answer: The sample is 98.3% by mass manganese(IV) oxide.</u>   (10)

2(a). $C_xF_yCl_z$ + ...$O_2(g) \rightarrow$ x $CO_2(g)$ + y F + z Cl
       2.320 g   → 0.9267 g

       m(CO_2) = 0.9267 g Hence, n(CO_2) = m/M = (0.9267 g) / (44.01 g mol^{-1}) = 0.021057 mol.

       n(C) = n(CO_2) = 0.021057 mol. Hence, m(C) = n.M = (0.021057 mol)(12.01 g mol^{-1}) = 0.2529 g C

       Reaction: $H^+(aq)$ + $NH_3(aq) \rightarrow NH_4^+(aq)$

       n(Cl) = n(HCl) = n(H^+) = n(NH_3) = c.V = (3.062 mol L^{-1})(0.0172 L) = 0.052666 mol.

       m(Cl) = n.M = (0.052666 mol)(35.45 g mol^{-1}) = 1.867 g Cl.

       Hence, m(F) = m(sample) - [m(C) + m(Cl)] = 2.320 g - 2.1199 g = 0.2001 g.

       Hence,   n(C) = 0.02106 mol   = 2

                   n(Cl) = 0.05267 mol   = 5

                   n(F) = 0.0105 mol   = 1

       <u>Ans(a): The empirical formula of the compound is C_2FCl_5</u>
                                                                                    (5)

2(b).   1.503 g (compound) $\rightarrow$ 0.1528 L vapour at STP.

n(vapour) = (0.1528 L) / (22.41 L mol^{-1}) = 6.818 x 10^{-3} mol.

M(compound) = m/n = (1.503 g) / (6.818 x 10^{-3} mol) = 220.4 g mol^{-1}

EFM = 2(12.01) + 1(F) + 5(Cl) = 220.5 g mol^{-1}

Clearly, the empirical formula mass is equal to the true (molecular) formula mass.

Ans(b): The molecular formula of the chlorofluorocarbon is C_2FCl_5 (3)

2(c)
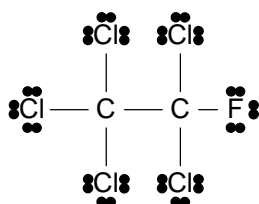
                                                                        (2)

3.   The three balanced equations are: $4FeS_2 + 11O_2(g) \rightarrow 2Fe_2O_3(s) + 8SO_2(g)$
                                              $[2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)] \times 4$

                                              $[SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)] \times 8$

Adding the three equations gives: $4FeS_2(s) + 15O_2(g) + 8H_2O(l) \rightarrow 2Fe_2O_3(s) + 8H_2SO_4(l)$

From the balanced final equation, $n(H_2SO_4) = 2n(FeS_2)$

$m(H_2SO_4)$ = 1.00 x 10^6 g

$n(H_2SO_4)$ = m/M = (1.00 x 10^6 g) / (98.076 g mol^{-1}) = 10196 mol.

$n(FeS_2)$ = ½ (10196 mol) = 5098 mol.

$m(FeS_2)$ = n.M = (5098 mol)(119.97 g mol^{-1}) = 611607 g.

Answer: The mass of $FeS_2(s)$ needed is 6.12 x 10^5 g or 0.612 tonnes.   (10)

4(a).   The reaction is: $H_2S(g) + Pb^{2+}(aq) \rightarrow PbS(s) + 2H^+(aq)$

From the balanced equation, the required mole ratio (RMR): $n(H_2S) / n(Pb^{2+})$ = 1/1 = 1.00

$n(H_2S)$ = m/M = 0.3753 g) / (34.076 g mol^{-1}) = 0.01101 mol

$n(Pb^{2+}(aq))$ = $n(Pb(NO_3)_2)$ = c.V = (0.2060 mol L^{-1})().150 L) = 0.0309 mol.

Hence, the actual mole ratio (AMR): $n(H_2S) / n(Pb^{2+})$ = (0.01101 mol) / (0.0309 mol) = 0.36

Clearly, the actual mole ratio is less than the required mole ratio, so the $H_2S(g)$ is the limiting reagent.

Ans(a): The $H_2S(g)$ is the limiting reagent   (3)

4(b).   All the $H_2S(g)$ is consumed in the reaction.

The reaction is 0.01101 mol. $H_2S(g)$ + 0.01101 mol $Pb^{2+}(aq) \rightarrow$ 0.01101 mol. PbS(s)

n(PbS) = 0.01101 mol.

m(PbS) = n.M = (0.01101 mol)(239.26 g mol^{-1}) = 2.64 g

Ans(b): The mass of the precipitate is 2.64 g.   (3)

4(c): $n(NO_3)^-(aq) = 2n(Pb(NO_3)_2) = 2(0.0309 \text{ mol}) = 0.0618 \text{ mol}$.

$[NO_3^-(aq)]$ $n/V = (0.0618 \text{ mol}) / (0.150 \text{ L}) = \underline{0.412 \text{ mol L}^{-1}}$ (1)

$n(H^+(aq)) = 2n(H_2S) = 2(0.01101 \text{ mol}) = 0.02202 \text{ mol}$

$[H^+(aq)] = n/V = (0.02202 \text{ mol}) / (0.150 \text{ L}) = \underline{0.147 \text{ mol L}^{-1}}$ (1)

Since $Pb^{2+}(aq)$ is the excess reagent,

excess $n(Pb^{2+}(aq)) = $ original $n(Pb^{2+}(aq))$ - consumed $n(Pb^{2+}(aq))$

$= 0.0309 \text{ mol} - 0.01101 \text{ mol} = 0.01989 \text{ mol}$.

Hence, $\underline{[Pb^{2+}(aq)]} = n_{excess} / V = (0.01989 \text{ mol}) / (0.150 \text{ L}) = \underline{0.133 \text{ mol L}^{-1}}$ (2)

5(a): Cathode reaction is: $Al^{3+}(l) + 3e^- \rightarrow Al(l)$

Per cell per day: coulombs = amperes x seconds = $(300\ 000)(24)(60)(60) = 2.592 \times 10^{10} \text{ C}$

$n(e^-) = (\text{coulombs}) / (96490 \text{ C mol}^{-1}) = (2.592 \times 10^{10} \text{ C}) / (96490 \text{ C mol}^{-1}) = 268629 \text{ mol}$.

$n(Al) = n(Al^{3+}) = 1/3 (268629 \text{ mol}) = 89543 \text{ mol}$.

$m(Al) = n.M = (89543 \text{ mol})(26.98 \text{ g mol}^{-1}) = 2.416 \times 10^6 \text{ g}$

For 408 cells, $m(Al) = (408)(2.416 \times 10^6 \text{ g}) = 9.857 \times 10^8 \text{ g}. = 985.7 \text{ tonnes} = 9.857 \times 10^5 \text{ kg}$.

hence, the number of 22.5 kg ingots = $(9.857 \times 10^5 \text{ kg}) / (22.5 \text{ kg ingot}^{-1}) = 4.38 \times 10^4$ ingots

Ans(a): The smelter is able to produce 4.38×10^4 ingots per day   (6)

5(b)   The anode reaction is: $C(s) + 2O^{2-}(l) \rightarrow CO_2(g) + 4e^-$

Clearly, $n(CO_2(g) = ¼ n(e^-) = ¼ (268629 \text{ mol}) = 6.716 \times 10^4$ mol.

Hence, $V(CO_2(g)) = (6.716 \times 10^4 \text{ mol})(22.41 \text{ L mol}^{-1}) = 1.50 \times 10^6 \text{ L}$ at 0°C and 101.3 kPa.

Hence, at 20°C (293 K), $V(CO_2(g)) = (1.50 \times 10^6 \text{ L}) \times (293) / (273) = 1.62 \times 10^6 \text{ L}$

For 408 cells, $V(CO_2(g)) = (408)(1.62 \times 10^6 \text{ L}) = 6.59 \times 10^8 \text{ L}$

Ans(b): The smelter produces $6.59 \times 10^8 \text{ L}$ of $CO_2(g)$ at 20°C and 101.3 kPa per day.   (4)

Part 4:   Please note the following answer is not meant to be prescriptive. It indicates only what the examiner believes is adequate.

1(a): In equation ...(3) as given, if $[H_3O^+]$ is increased, LCP predicts that $\leftarrow$ (reverse reaction) is favoured.

This will increase $[H_2CO_3(aq)]$.

In equation ....(2) as given, if $[H_2CO_3(aq)]$ is increased, LCP predicts that $\leftarrow$ will be favoured.

This will increase $[CO_2(aq)]$.

In equation ...(1) as given, if $[CO_2(aq)]$ is increased, LCP predicts that $\leftarrow$ will be favoured.

This will increase $[CO_2(g)]$ in the lungs.

1(b): In equation ...(3), since $H_2CO_3(aq)$ is a weak acid, the position of equilibrium will be to the left i.e. there will be a high concentration of dissolved molecules, but only a low concentration of ions in the solution.

1(c): The pH of the blood is 7.4. Hence, $[H_3O^+(aq)] = 4.0 \times 10^{-8} \text{ mol L}^{-1}$ (Slightly below $10^{-7} \text{ mol L}^{-1}$)

If $[H_3O^+(aq)]$ is increased, Le Chatelier's Principle predicts that this will consume $H_3O^+(aq)$, thus producing a higher concentration of neutral H_2CO_3 molecules. This will increase the pH back to around its original value.

If $[H_3O^+(aq)]$ is decreased, Le Chatelier's Principle predicts that the weak acid $H_2CO_3(aq)$ will ionise to produce more $HCO_3^-(aq)$ and $H_3O^+(aq)$. This will lower the pH back to around its original value.

1(d):   If 10 mL of 1.00 mol L^{-1} HCl is added to 1.0 L of water:

$n(H^+(aq)) = n(HCl) = c.V = (1.00 \text{ mol } L^{-1})(0.010 \text{ L}) = 0.010 \text{ mol}$

$[H^+(aq)] = n/V = (0.010 \text{ mol}) / (1.01 \text{ L}) = 9.90 \times 10^{-3} \text{ mol } L^{-1}$

Hence, $pH = -\log(9.90 \times 10^{-3}) = 2.00$

Clearly, if 10 mL of 1.00 mol L^{-1} HCl(aq) is added to 1.00 L of pure water, the pH drops from 7 to 2

(a drop of 5 units) whereas for a similar volume of blood, the pH drops by only 0.2 units!!

Thus, blood has an effective chemical means of minimizing changes to its pH!

<div align="right">(20)</div>

END OF SOLUTIONS