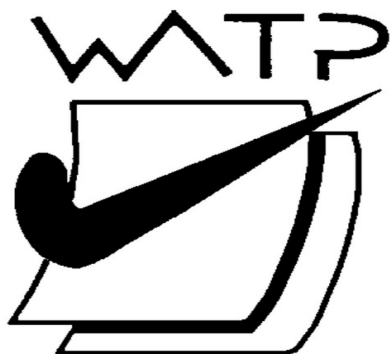


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Year 12

Chemistry

2009

SOLUTIONS

Part 1:

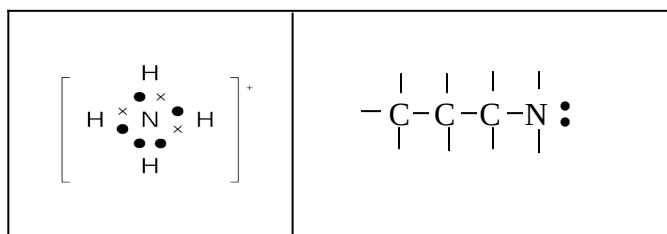
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|--------|---------|---------|---------------------|
| 1. (c) | 9. (b) | 17. (b) | 25. (b) |
| 2. (b) | 10. (a) | 18. (b) | 26. (c) |
| 3. (c) | 11. (d) | 19. (b) | 27. (b) |
| 4. (a) | 12. (b) | 20. (a) | 28. (c) |
| 5. (d) | 13. (a) | 21. (d) | 29. (d) |
| 6. (a) | 14. (b) | 22. (a) | 30. (a) |
| 7. (c) | 15. (d) | 23. (a) | |
| 8. (b) | 16. (c) | 24. (c) | (30 x 2 = 60 marks) |

Part 2:

- 1(a) $\text{CH}_3(\text{CH}_2)_2\text{CHCH}_2(\text{l}) + \text{Br}_2(\text{aq}) \rightarrow \text{CH}_3(\text{CH}_2)_2\text{CHBrCH}_2\text{Br}(\text{l})$ (2)
Red colour of liquid fades to colourless; two layers form. (1)
- 1(b) $\text{Cu}(\text{OH})_2(\text{s}) + 4\text{NH}_3(\text{aq}) \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq})$ (2)
Blue solid dissolves to form a deep blue solution. (1)
- 1(c) No visible reaction. (2)
No visible changes occur. (1)
- 1(d) $\text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{NH}_3(\text{g}) + \text{H}_2\text{O}(\text{l})$ (2)
Characteristic pungent smell is observed. (1)
2. phenolphthalein (1)
nitrogen dioxide gas (1)
potassium dichromate (1)
nickel carbonate or chromium(III) carbonate or copper(II) carbonate (1)
- 3(a) butanoic acid, methanol and sulfuric acid (catalyst) (3)
3(b) $\text{CH}_3(\text{CH}_2)_2\text{COOCH}_3$ (2)
3(c) butyl methanoate / ethyl propanoate / propyl ethanoate etc (any two) (2)

- 4(a) $\text{CH}_3\text{CH}_2\text{CHCH}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow \text{CH}_3\text{CH}_2\text{CHClCH}_2\text{Cl}(\text{g})$ (2)
Also accept subsequent substitution reactions.
- 4(b) $2\text{HCCH} + 5\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$ (2)
- 5(a) Mercury(II) ions (1)
- 5(b) \leftarrow (Arrow must point to the left). (1)
- 5(c) $\text{Cl}^-(\text{aq})$ or $\text{NO}_3^-(\text{aq})$ (1)
- 5(d) Anode: $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$ (2)
Cathode: $2\text{Hg}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Hg}_2^{2+}(\text{aq})$ (2)
- 5(e) 0.57 V (2)

6.



(6)

- 7(a). Ionisation Energy is the energy required to remove a mole of electrons from a mole of atoms or ions in the gas phase. (1)
Electronegativity is the electron attracting ability of an atom in a covalent bond (1)
- 7(b) Sodium has a low ionisation energy because it is the first element of the third period. It has the smallest nuclear charge for this row, so the atom's attraction for its outermost electron is the lowest of any third period element. (2)
- 7(c) The first ionisation energy of Group VII elements decreases as you go down the group. This is because although nuclear charge increases down the group, $[\text{F} \rightarrow \text{Cl} \rightarrow \text{Br} \rightarrow \text{I}]$ the attraction for the outermost electrons decreases at a greater rate due to increasing distance of the valence electrons from the nucleus, making the overall attraction for the outermost electrons lowest in the case of iodine. (2)
- 8(a) $\text{CH}_3\text{CH}_2\text{CHBrCHCFCH}_3$ (2)
- 8(b) $\text{Cl}_2\text{CHCH}_2\text{CH}(\text{CH}_3)\text{CCH}$ (2)
- 8(c) 2-bromobutanoic acid (1)
- 8(d) 2-heptanone (1)
- 9(a) $n(\text{OH}^-) = c.V = (1.00 \text{ mol L}^{-1})(0.020 \text{ L}) = 0.020 \text{ mol}.$
 $n(\text{H}^+) = c.V = (1.00 \text{ mol L}^{-1})(0.0199 \text{ L}) = 0.0199 \text{ mol}.$
 Excess $n(\text{OH}^-) = 0.0001 \text{ mol}$
 $c(\text{OH}^-) = n / V_T = (0.0001 \text{ mol}) / (0.0399 \text{ L}) = 0.00251 \text{ mol L}^{-1}$
 $c(\text{H}^+) = (10^{-14}) / (0.00251) = 3.98 \times 10^{-12}$
 Hence, $\text{pH} = 11.4$ (2)
- 9(b) $n(\text{OH}^-) = 0.020 \text{ mol}$
 $n(\text{H}^+) = 0.0201 \text{ mol}$
 excess $n(\text{H}^+) = 0.0001 \text{ mol}.$
 $c(\text{H}^+) = (0.0001 \text{ mol}) / (0.0401 \text{ L}) = 0.00249 \text{ mol L}^{-1}$
 Hence, $\text{pH} = 2.6$ (2)
- 9(c) In the last 0.2 mL, the pH has dropped from 11.4 to 2.6 ie by 8.8 points.
 Methyl Orange and Phenolphthalein are suitable indicators for this titration because

they both undergo colour changes (pink to clear and yellow to orange-red) in this range (2)

10

| | |
|---|---|
| $\begin{array}{c} & & & \\ -C & -C & -C & -C-OH \\ & & & \end{array}$ | $\begin{array}{c} & & & & \\ & & -C & & \\ & & & & \\ & & & & \\ -C & -C & -C & -C- \\ & & & \\ & & OH & & \end{array}$ |
| Name: 1-butanol | 2-methyl-2-butanol |

Primary alcohol

Tertiary alcohol (6)

11. If each alcohol is shaken separately with acidified dichromate solution, only the primary alcohol will cause a colour change from orange to green. The primary alcohol is oxidised to an aldehyde, and the orange dichromate ions are reduced to green chromium(III) ions. The tertiary alcohol cannot be oxidised, so the orange colour of the solution will remain. The reaction is:
- $$3\text{CH}_3(\text{CH}_2)_3\text{OH} + \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 8\text{H}^+(\text{aq}) \rightarrow 3\text{CH}_3(\text{CH}_2)_2\text{CHO}(\text{l}) + 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}).$$
- (Also accept acidified permanganate solution as the oxidising agent.) (4)

Part 3:

- 1(a). $\text{C}_x\text{F}_y\text{Cl}_z \rightarrow x\text{CO}_2(\text{g}) + z\text{HCl}(\text{aq})$
 2.130 g 0.9198 g
- $$n(\text{CO}_2) = m / M = (0.9198 \text{ g}) / (44.01 \text{ g mol}^{-1}) = 0.02090 \text{ mol CO}_2$$
- $$n(\text{C}) = n(\text{CO}_2) = 0.02090 \text{ mol C}$$
- $$m(\text{C}) = n.M = (0.02090 \text{ mol})(12.01 \text{ g mol}^{-1}) = \underline{0.2510 \text{ g C}}$$
- $$n(\text{Cl}) = n(\text{HCl}) = n(\text{NaOH}) = c.V = (1.020 \text{ mol L}^{-1})(0.0410 \text{ L}) = 0.0418 \text{ mol Cl}$$
- $$m(\text{Cl}) = n.M = (0.0418 \text{ mol})(35.45 \text{ g mol}^{-1}) = \underline{1.482 \text{ g Cl}}$$
- $$m(\text{F}) = m(\text{sample}) - [m(\text{C}) + m(\text{Cl})] = 2.130 \text{ g} - 1.733 \text{ g} = \underline{0.397 \text{ g F}}$$
- $$n(\text{C}) = 0.0209 \text{ mol} \equiv 1$$
- $$n(\text{F}) = m / M = (0.397 \text{ g}) / (19.00 \text{ g mol}^{-1}) = 0.0209 \text{ mol} \equiv 1$$
- $$n(\text{Cl}) = 0.0418 \text{ mol} \equiv 2$$
- Ans (a): The empirical formula of the compound is CFCl_2 (8)

- 1(b) 1.27 g of compound \rightarrow 0.1396 L gas at STP
- Hence, 1.270 g represents $(0.1396 \text{ L}) / (22.41 \text{ L mol}^{-1}) = 6.23 \times 10^{-3} \text{ mol}$
- $$M(\text{compound}) = m/n = (1.270 \text{ g}) / (6.23 \times 10^{-3} \text{ mol}) = 203.8 \text{ g mol}^{-1}$$
- Now, EFM = 12.01 + 19.00 + 70.90 = 101.9
- Ans (b): Clearly, TFM = 2(EFM) Hence, the true formula is $\text{C}_2\text{F}_2\text{Cl}_4$ (2)

- 1(c) A possible structure for the compound is: $\text{CCl}_3\text{CF}_2\text{Cl}$ (1)
- The name of this compound is : 1,1,1,2- tetrachloro-2,2-difluoroethane (1)

- 2(a) $m(\text{K}_2\text{S})$ (per litre) = 14.85 g.

Hence, $n(\text{K}_2\text{S}) (\text{L}^{-1}) = m / M = (14.85 \text{ g}) / (110.26 \text{ g mol}^{-1}) = 0.13468 \text{ mol (L}^{-1})$

In sample taken, $n(\text{K}_2\text{S}) = c.V = (0.13468 \text{ mol L}^{-1})(0.120 \text{ L}) = 0.01616 \text{ mol}$.

$n(\text{K}^+) = 2n(\text{K}_2\text{S}) = 0.3232 \text{ mol}$. and $n(\text{S}^{2-}) = n(\text{K}_2\text{S}) = 0.01616 \text{ mol}$.

$n(\text{Cd}(\text{NO}_3)_2) = c.V = (0.2060 \text{ mol L}^{-1})(0.250 \text{ L}) = 0.0515 \text{ mol}$.

$n(\text{Cd}^{2+}) = n(\text{Cd}(\text{NO}_3)_2) = 0.0515 \text{ mol}$ and $n(\text{NO}_3^-) = 2n(\text{Cd}(\text{NO}_3)_2) = 0.103 \text{ mol}$.

Clearly, equal moles of Cd^{2+} and S^{2-} are required for a stoichiometric reaction,

Ans(a): The limiting reagent is K_2S (or S^{2-}) (3)

2(b) The reaction is: $0.01616 \text{ mol Cd}^{2+} + 0.01616 \text{ mol S}^{2-} \rightarrow 0.01616 \text{ mol CdS(s)}$

$m(\text{CdS}) = n.M = (0.01616 \text{ mol})(144.46 \text{ g mol}^{-1}) = 2.33 \text{ g CdS(s)}$

Ans(b): The mass of precipitate is 2.33 g. (2)

2(c) Ions remaining in solution are $\text{K}^+(\text{aq})$, $\text{NO}_3^-(\text{aq})$ and excess $\text{Cd}^{2+}(\text{aq})$

$c(\text{K}^+(\text{aq})) = n / V = (0.3232 \text{ mol}) / (0.370 \text{ L}) = \underline{0.874 \text{ mol L}^{-1}}$ (1)

$c(\text{NO}_3^-(\text{aq})) = n / V = (0.103 \text{ mol}) / (0.370 \text{ L}) = \underline{0.278 \text{ mol L}^{-1}}$ (1)

excess $n(\text{Cd}^{2+}(\text{aq})) = n(\text{Cd}^{2+})_{\text{original}} - n(\text{Cd}^{2+})_{\text{consumed}} = 0.0353 \text{ mol}$

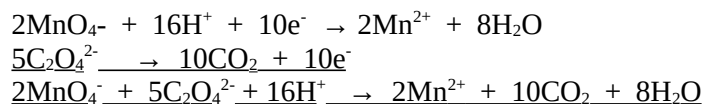
$c(\text{Cd}^{2+}(\text{aq})) = (0.0353 \text{ mol}) / (0.370 \text{ L}) = \underline{0.0955 \text{ mol L}^{-1}}$ (1)

3. The reaction is:

$$\begin{array}{l} \text{Mn}^{4+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Mn}^{2+}(\text{aq}) \\ \text{C}_2\text{O}_4^{2-}(\text{aq}) \rightarrow 2\text{CO}_2(\text{g}) + 2\text{e}^- \\ \hline \text{Mn}^{4+}(\text{aq}) + \text{C}_2\text{O}_4^{2-}(\text{aq}) \rightarrow \text{Mn}^{2+}(\text{aq}) + 2\text{CO}_2(\text{g}) \end{array}$$

$n(\text{C}_2\text{O}_4^{2-})_{\text{total}} = c.V. = (0.0965 \text{ mol L}^{-1})(0.150 \text{ L}) = 0.014475 \text{ mol}$.

The **excess** moles of oxalate were reacted with standardised permanganate solution:



$n(\text{C}_2\text{O}_4^{2-})_{\text{excess}} = 5/2 n(\text{MnO}_4^-) = 5/2(c.V) = 5/2(0.0125 \text{ mol L}^{-1})(0.02157 \text{ L})$
 $= 6.741 \times 10^{-4} \text{ mol}$.

Hence, the moles of oxalate which reacted with the Mn^{4+} as in the first equation above:

$= (\text{total moles} - \text{excess moles}) = (0.014475 \text{ mol} - 0.0006741 \text{ mol}) = 0.01380 \text{ mol}$.

Hence, $n(\text{MnO}_2) = 0.01380 \text{ mol}$

$m(\text{MnO}_2) = n.M = (0.01380 \text{ mol})(86.94 \text{ g mol}^{-1}) = 1.1998 \text{ g}$.

Hence, % purity $= (m(\text{MnO}_2)) / (m(\text{sample})) \times 100 =$

$$[(1.1998 \text{ g}) / (1.325 \text{ g})] \times 100 = 90.55\%$$

Answer: The sample is 90.6% by mass manganese(IV) oxide. (10)

4. The first reaction is : $\text{H}^+_{\text{total}} + \text{OH}^- \rightarrow \text{H}_2\text{O(l)}$

$n(\text{H}^+)_{\text{total}} = n(\text{OH}^-) = n(\text{NaOH}) = c.V = (0.504 \text{ mol L}^{-1})(0.0298 \text{ L}) = 0.01502 \text{ mol}$.

The second reaction produces barium sulfate solid:

$m(\text{BaSO}_4) = 0.712 \text{ g}$

$n(\text{BaSO}_4) = m/M = (0.712 \text{ g}) / (233.36 \text{ g mol}^{-1}) = 3.051 \times 10^{-3} \text{ mol}$.

$$n(\text{H}_2\text{SO}_4) = n(\text{BaSO}_4) = 0.003051 \text{ mol.}$$

$$c(\text{H}_2\text{SO}_4) = n/V = (0.003051 \text{ mol}) / (0.025 \text{ L}) = 0.122 \text{ mol L}^{-1}$$

$$n(\text{H}^+)_{\text{sulfuric}} = 2n(\text{H}_2\text{SO}_4) = 0.006102 \text{ mol.}$$

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

$$= 0.01502 \text{ mol} - 0.006102 \text{ mol} = 0.008918 \text{ mol.}$$

$$n(\text{tartaric acid}) = \frac{1}{2} n(\text{H}^+)_{\text{tartaric}} = 4.459 \times 10^{-3} \text{ mol}$$

$$\text{Hence, } c(\text{tartaric acid}) = n / V = (4.459 \times 10^{-3} \text{ mol}) / (0.25 \text{ L}) = 0.178 \text{ mol L}^{-1}$$

Answer: The concentration of sulfuric acid is 0.122 mol L⁻¹ (5)

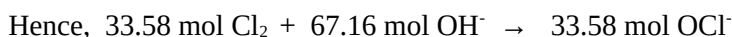
and The concentration of tartaric acid is 0.178 mol L⁻¹ (5)

5. Coulombs = amps x seconds = 300 A x 21600 s = 6.48 x 10⁶ C

$$n(e^-) = (6.48 \times 10^6 \text{ C}) / (96490 \text{ C mol}^{-1}) = 67.16 \text{ mol } e^-$$

$$\text{At the cathode, } n(\text{OH}^-) = n(e^-) = 67.16 \text{ mol.}$$

$$\text{At the anode, } n(\text{Cl}_2) = \frac{1}{2} n(e^-) = 33.58 \text{ mol.}$$



$$n(\text{NaOCl}) = n(\text{OCl}^-) = 33.58 \text{ mol.}$$

Ans(a): 33.6 moles of NaOCl will be formed (6)

5(b). Original $n(\text{Cl}^-) = n(\text{NaCl}) = c.V = (6.50 \text{ mol})(2000\text{L}) = 13\,000 \text{ mol.}$

$$n(\text{Cl}^-)_{\text{consumed}} = n(\text{Cl}_2) = 33.58 \text{ mol. [since chloride ion is also generated in third reaction]}$$

$$n(\text{Cl}^-)_{\text{remaining}} = 13\,000 \text{ mol} - 33.58 \text{ mol} = 12\,970 \text{ mol.}$$

$$[\text{Cl}^-]_{\text{final}} = n / V = 12970 \text{ mol} / 2000 \text{ L} = 6.48 \text{ mol L}^{-1}$$

Ans(b): The final concentration of chloride ions is 6.48 mol L⁻¹ (4)

Part 4: The following is not a prescriptive answer. It suggests the minimum amount of information. Students may gain extra marks for including relevant labelled diagrams in their answers

- To increase the rate of the reaction, the liquid sulfur is sprayed as a fine mist into the air. This greatly increases the surface area of the reactant, and allows more collisions per second between the sulfur atoms and oxygen molecules, and hence a faster rate of production of sulfur dioxide. If the pressure of the air is increased, the higher concentration of oxygen molecules ensures more collisions per second with the sulfur, leading to a faster reaction rate. Increasing the temperature will increase the average velocity, and hence the kinetic energy, of the reactant molecules, ensuring a greater chance of favourable collisions occurring. (6)
- In Stage 2, a moderate temperature is chosen for the following reasons::
If the temperature is too low, there will be insufficient energy in the collisions to overcome the activation energy barrier for the reaction, so few collisions will result in a slow reaction rate. The forward reaction is exothermic. If too high a temperature is used, LCP predicts that the system will favour the reaction which lowers the temperature ie the reverse reaction. This would reduce the yield of sulfur trioxide gas. (6)
- The reactions involving the vanadium are:

$$\text{V}_2\text{O}_5(\text{s}) + \text{SO}_2(\text{g}) \rightarrow 2\text{VO}_2(\text{s}) + \text{SO}_3(\text{g})$$
and
$$4\text{VO}_2(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{V}_2\text{O}_5(\text{s})$$
 (4)

4. In pure sulfur , $[S] = 0$
In SO_2 , $[S] = +4$
In SO_3 , $[S] = +6$
In H_2SO_4 , $[S] = +6$.

Hence, from sulfur to sulfur trioxide,

there is a progressive increase in oxidation number from $0 \rightarrow +4 \rightarrow +6$.

There is no increase in oxidation number between sulfur trioxide and sulfuric acid.

(4)

END OF SOLUTIONS