More Mole Calculations Answers

1. The reaction equation is:
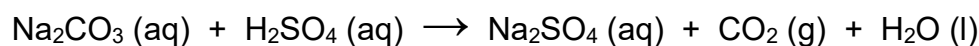
    Na_2CO_3 (aq) + H_2SO_4 (aq) $\longrightarrow$ Na_2SO_4 (aq) + CO_2 (g) + H_2O (l)
    So, 1 mole of H_2SO_4 neutralises 1 mole of Na_2CO_3

    Moles of H_2SO_4 = volume (dm^3) x concentration (mol dm^{-3})
    = (41.2 x 10^{-3}) x 0.05 = 2.05 x 10^{-3} mol
    So, moles of Na_2CO_3 = 2.05 x 10^{-3} mol

    Also, moles of Na_2CO_3 = volume (dm^3) x concentration (mol dm^{-3})
    = (25.0 x 10^{-3}) x concentration
    Therefore, 2.05 x 10^{-3} = (25.0 x 10^{-3}) x concentration
    Or, concentration of solution = 2.05 x 10^{-3} / 25.0 x 10^{-3} = 0.082 mol dm^{-3}

    Number of moles in the whole 250.0 cm^3 solution =
    volume (dm^3) x concentration (mol dm^{-3}) = (250.0 x 10^{-3}) x 0.082 = 0.0205 mol

    Mass of Na_2CO_3 = M_r (g mol^{-1}) x moles (mol) =106.0 x 0.0205 = 2.17 g
    (M_r of Na_2CO_3 = (23.0 x 2) + 12.0 + (3 x 16.0) = 106.0)

    % of Na_2CO_3 = mass of Na_2CO_3 (g) / mass of soda crystals (g) x 100
    = 2.17 / 5.45 x 100 = 39.8% or 40% (rounding up)

    The washing soda crystals are 40% sodium carbonate

2. The reaction equation is:

    Na_2CO_3 (aq) + 2HCl (aq) $\longrightarrow$ 2NaCl (aq) + CO_2 (g) + H_2O (l)
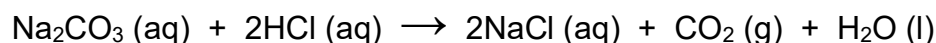
So, 2 moles of HCl neutralises 1 mole of Na_2CO_3

Moles of HCl = volume (dm^3) x concentration (mol dm^{-3})
= $(24.65 \times 10^{-3}) \times 0.100 = 2.465 \times 10^{-3}$ mol
So, moles of $Na_2CO_3 = 2.465 \times 10^{-3} / 2 = 1.233 \times 10^{-3}$ mol

Mass of $Na_2CO_3 = M_r$ (g mol^{-1}) x moles (mol) = $106.0 \times (1.233 \times 10^{-3}) = 0.131$ g
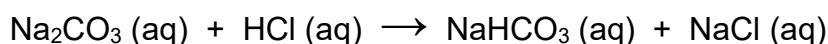(M_r of $Na_2CO_3 = (23.0 \times 2) + 12.0 + (3 \times 16.0) = 106.0$)

Mass of H_2O in the sample = $0.352 - 0.131 = 0.221$ g
Moles of $H_2O = 0.221 / 18 = 12.278 \times 10^{-3}$ mol

Mole ratio of $Na_2CO_3 : H_2O = 1.233 \times 10^{-3} : 12.278 \times 10^{-3} = 1 : 9.958$
= 10 (rounding up). So, x = 10, $Na_2CO_3.10H_2O$

3. Here are the reactions:

Na_2CO_3 (aq) + HCl (aq) $\longrightarrow$ $NaHCO_3$ (aq) + NaCl (aq)
$NaHCO_3$ (aq) + HCl (aq) $\longrightarrow$ NaCl (aq) + CO_2 (g) + H_2O (l)

Phenolphthalein changes from pink to colourless at the end of the first reaction, when the pH of the solution is 9, and so the reaction measured is:

CO_3^{2-} (aq) + H^+ (aq) $\longrightarrow$ HCO_3^- (aq)
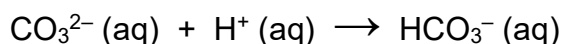
Methyl orange changes from yellow to orange at the end of the second reaction, when the pH of the solution is 7, and so the reaction measured is:

HCO_3^- (aq) + H^+ (aq) $\longrightarrow$ CO_2 (g) + H_2O (l)
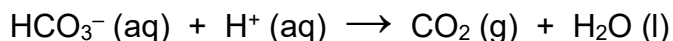
So, in the first stage, the CO_3^{2-} (aq) in the mixture is converted into HCO_3^- (aq).
Moles of HCl (aq) to convert CO_3^{2-} (aq) to HCO_3^- (aq) = volume x concentration
= $(28.3 \times 10^{-3}) \times 0.08 = 2.26 \times 10^{-3}$ mol
Moles of CO_3^{2-} (aq) = 2.26×10^{-3} mol
Concentration of CO_3^{2-} (aq) in the solution = moles / volume
= 2.26×10^{-3} mol / $25.0 \times 10^{-3} = 9.04 \times 10^{-2}$ mol dm^{-3}
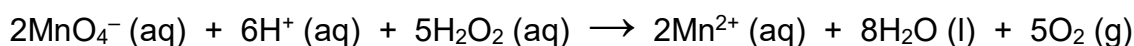
In the second stage, the volume of HCl (aq) needed to neutralise the total HCO_3^- (aq) is 31.3 cm^3. Of this, 28.3 cm^3 of HCl (aq) are required to neutralise the HCO_3^- (aq) formed from CO_3^{2-} (aq) in the first stage. The remaining 3.0 cm^3 neutralises the HCO_3^- (aq) that is present in the original solution.

Moles of HCl (aq) to convert needed to react with HCO_3^- (aq) =
volume x concentration = (3.0×10^{-3}) x 0.08 = 0.24×10^{-3} mol
Moles of HCO_3^- (aq) = 0.24×10^{-3} mol
Concentration of HCO_3^- (aq) in the solution = moles / volume
= 0.24×10^{-3} (mol) / 25.0×10^{-3} (dm^3) = 9.60×10^{-3} mol dm^{-3}

4. Balancing the electrons in the two half-equations, means that we need to multiple the MnO_4^- (aq) equation by 2, and the H_2O_2 (aq) equation by 5. Combining the two half-equations [16H$^+$ (left of the arrow) – 10H$^+$ (right) = 6H$^+$ (left)] gives:

$$2MnO_4^- \text{ (aq)} + 6H^+ \text{ (aq)} + 5H_2O_2 \text{ (aq)} \longrightarrow 2Mn^{2+} \text{ (aq)} + 8H_2O \text{ (l)} + 5O_2 \text{ (g)}$$

Moles of MnO_4^- (aq) = volume x concentration = (48.3×10^{-3}) x 0.0150
= 0.725×10^{-3} mol
Moles of H_2O_2 (aq) = (0.725×10^{-3}) x 5 / 2 = (0.725×10^{-3}) x 2.5
= 1.81×10^{-3} mol
Concentration of H_2O_2 (aq) = moles / volume =
(1.81×10^{-3}) / (25.0×10^{-3}) = 0.0724 mol dm^{-3}
Concentration of H_2O_2 (aq) in the original solution = 25.0 x 0.0724
= 1.81 mol dm^{-3}

5. Balancing the electrons in the two half-equations, means that we need to multiple the Fe^{2+} (aq) equation by 6. Combining the two half-equations gives:

$$Cr_2O_7^{2-} \text{ (aq)} + 14H^+ \text{ (aq)} + 6Fe^{2+} \longrightarrow 2Cr^{3+} \text{ (aq)} + 6Fe^{3+} + 7H_2O \text{ (l)}$$
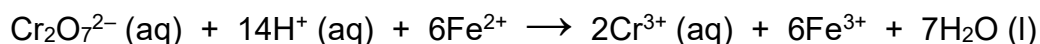
Moles of $Cr_2O_7^{2-}$ (aq) = volume x concentration = (29.3×10^{-3}) x 0.0193
= 0.565×10^{-3} mol
Moles of Fe^{2+} (aq) in 25.0 cm^3 = (0.565×10^{-3}) x 6 = 3.39×10^{-3} mol
Moles of Fe^{2+} (aq) in the whole 250.0 cm^3 solution =
(3.39×10^{-3}) x 10 = 3.39×10^{-2} mol
Mass of Fe in the whole 250.0 cm^3 solution = (3.39×10^{-2}) x 55.8 = 1.89 g

% of Fe in the wire = (1.89 / 2.45) x 100 = 77.1% = 77% (rounding up)

6. Balancing the electrons in the two half-equations means that we need to multiple the Fe^{2+} (aq) equation by 5. Combining the two half-equations gives:

$$MnO_4^- (aq) + 8H^+ (aq) + 5Fe^{2+} (aq) \longrightarrow Mn^{2+} (aq) + 4H_2O (l) + 5Fe^{3+} (aq)$$
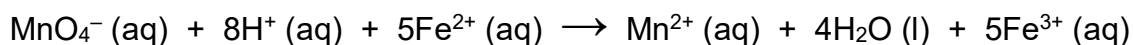
Moles of MnO_4^- (aq) = volume x concentration = (25.0×10^{-3}) x 0.0200
= 5.00×10^{-4} mol
Moles of Fe^{2+} (aq) = (5.00×10^{-4}) x 5 = 2.50×10^{-3} mol
Mass of Fe^{2+} = (2.50×10^{-3}) x 55.8 = 0.140 g
% of Fe^{2+} in the lawn sand = (0.140 / 3.00) x 100 = 4.67% = 5% (rounding up)

7. Moles of excess EDTA (aq) = volume x concentration =
(16.4×10^{-3}) x (1.115×10^{-2}) = 1.83×10^{-4} mol
Moles of total EDTA (aq) = volume x concentration =
(50.0×10^{-3}) x (1.00×10^{-2}) = 0.50×10^{-3} mol
Moles of EDTA that reacts with Al^{3+} = (0.50×10^{-3}) – (1.83×10^{-4}) =
3.17×10^{-4} mol
Moles of Al^{3+} in 25.0 cm³ portion (1 mol of Al^{3+} reacts with 1 mol of EDTA) =
3.17×10^{-4} mol
Moles of Al^{3+} in 250.0 cm³ portion = (3.17×10^{-4}) x 10 = 3.17×10^{-3} mol
M_r of aluminium sulfate hydrate = mass (g) / moles (mol) =
2.00 / (3.17×10^{-3}) = 630.9 g mol^{-1}
M_r of $Al_2(SO_4)_3$ = (2 x 27.0) + (3 x 32.1) + (12 x 16.0) = 342.3 g mol^{-1}
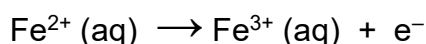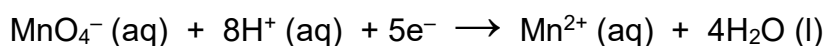M_r of nH_2O = 630.9 – 342.3 = 288.6 g mol^{-1}
n = 288.6 / 18.0 = 16.0 = 16 (rounding up)

8. Moles of total MnO_4^- (aq) = volume x concentration =
(25.9×10^{-3}) x 0.02 = 0.518×10^{-3} mol

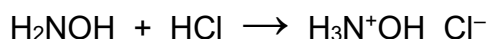Using the half equations:
$$MnO_4^- (aq) + 8H^+ (aq) + 5e^- \longrightarrow Mn^{2+} (aq) + 4H_2O (l)$$
$$Fe^{2+} (aq) \longrightarrow Fe^{3+} (aq) + e^-$$
We can deduce that the number of moles of Fe^{3+} =
5 x number of moles of MnO_4^- (aq) = 5 x (0.518×10^{-3}) = 2.59×10^{-3} mol

Hydroxylamine reacts with hydrochloric acid as follows:

$H_2NOH + HCl \longrightarrow H_3N^+OH \ Cl^-$

Concentration of the chloride salt in mol dm^{-3} =
Concentration (g dm^{-3}) / M_r (g mol^{-1}) =
3.60 / (4 x 1.01) + 14.0 + 16.0 + 35.5) = 3.60 / 69.5 = 0.0518 mol dm^{-3}
Moles of $H_3N^+OH \ Cl^-$ = volume x concentration =
(25.0 x 10^{-3}) x 0.0518 = 1.30 x 10^{-3} mol

Ratio of Fe^{3+} : $H_3N^+OH \ Cl^-$ = 2.59 x 10^{-3} / 1.30 x 10^{-3} = 1.99 = 2 (rounding up)

9.   The H^+ and HO^- ions are attracted to cathode and anode, respectively
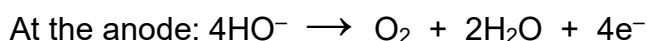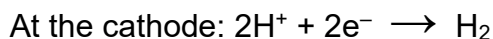
At the cathode: $2H^+ + 2e^- \longrightarrow H_2$
At the anode: $4HO^- \longrightarrow O_2 + 2H_2O + 4e^-$
The volume of hydrogen produced at the cathode is twice the volume of oxygen
produced at the anode (as $4H^+ + 4e^- \longrightarrow 2H_2$)

Coulombs (C) = Amperes (A) x Seconds (s) =
0.0250 x 6.50 x 60 x 60 = 585 C
(60 minutes in an hour, and 60 seconds in a minute)

One mole of electrons = 96 500 C
Moles of electrons = 585 / 96 500 = 6.06 x 10^{-3} mol

As two moles of electrons are required to produce H_2,
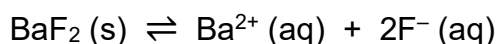Moles of H_2 = 6.06 x 10^{-3} / 2 = 3.06 x 10^{-3} mol

The molar volume of a gas at s.t.p. = 22.4 dm^3
Volume of H_2 = 22.4 x (3.06 x 10^{-3}) = 0.0679 dm^3 = 67.9 cm^3
Volume of O_2 = 67.9 / 2 = 34.0 cm^3

10.   The dissociation equation is:
BaF_2 (s) $\rightleftharpoons$ Ba^{2+} (aq) + $2F^-$ (aq)

So, K_{sp} = $[Ba^{2+}][F^-]^2$ = 1.00 x 10^{-6}
Assuming $[Ba^{2+}]$ is x, as we have two F^- ions for every Ba^{2+} ion, we can rewrite
the equation as:
1.00 x 10^{-6} = $(x)(2x)^2$ = $(x)(4x^2)$

$1.00 \times 10^{-6} = 4x^3$

$x^3 = 1.00 \times 10^{-6} / 4 = 2.50 \times 10^{-7}$

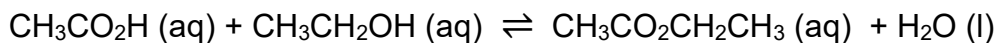$x = \sqrt[3]{2.50 \times 10^{-7}} = 6.30 \times 10^{-3}$

$[Ba^{2+}] = 6.30 \times 10^{-3}$ mol dm^{-3}

$[BaF_2] = 6.30 \times 10^{-3}$ mol dm^{-3}

Moles of BaF_2 = concentration x volume =

$(6.30 \times 10^{-3}) \times (50.0 \times 10^{-3}) = 3.15 \times 10^{-4}$ mol

Grams of BaF_2 = moles x M_r = $(3.15 \times 10^{-4}) \times 175 = 0.0551$ g

$[M_r$ of $BaF_2 = 137 + (19.0 \times 2) = 175]$

11. The reaction equation is:

CH_3CO_2H (aq) + CH_3CH_2OH (aq) $\rightleftharpoons$ $CH_3CO_2CH_2CH_3$ (aq) + H_2O (l)

The equilibrium constant, K_c, is equal to:

$K_c = [CH_3CO_2CH_2CH_3] / [CH_3CO_2H] [CH_3CH_2OH]$

As 0.50 mol of CH_3CO_2H (aq) was used initially, and 0.16 mol remains at equilibrium then:

Moles of CH_3CO_2H (aq) that reacted = 0.50 – 0.16 = 0.34 mol

So, moles of CH_3CH_2OH (aq) that reacted = 0.34 mol

So, moles of $CH_3CO_2CH_2CH_3$ (aq) that was produced = 0.34 mol

	Initial moles	Change in moles	Moles at eqm.
ethanol	2.50	–0.34	2.16
ethanoic acid	0.50	–0.34	0.16
ethyl ethanoate	0.00	+0.34	0.34

Concentration at equilibrium = moles / volume = moles / 1 dm^3
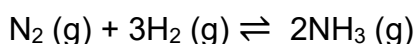
Concentration of ethanol = 2.16 mol dm^{-3}

Concentration of ethanoic acid = 0.16 mol dm^{-3}

Concentration of ethyl ethanoate = 0.34 mol dm^{-3}

$K_c = [CH_3CO_2CH_2CH_3] / [CH_3CO_2H] [CH_3CH_2OH] =$

0.34 / (0.16 x 2.16) = 0.34 / 0.35 = 0.97 dm^3 mol^{-1}

12. The reaction equation is:

N_2 (g) + $3H_2$ (g) $\rightleftharpoons$ $2NH_3$ (g)

Total moles of gas = 18 + 54 + 48 = 120 mol

The fraction of N_2 is: $x(N_2)$ = 18/120
So, the partial pressure of N_2 = $p(N_2)$ = 200 x (18/120) = 30 atm
The fraction of H_2 is: $x(H_2)$ = 54/120
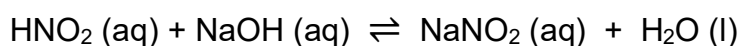So, the partial pressure of H_2 = $p(H_2)$ = 200 x (54/120) = 90 atm
The fraction of NH_3 is: $x(NH_3)$ = 48/120
So, the partial pressure of NH_3 = $p(H_2)$ = 200 x (48/120) = 80 atm

K_p = $p(NH_3)^2$ / $p(N_2)$ x $p(H_2)^3$ = 80^2 / (30×80^3) = 2.9 x 10^{-4} atm^{-2}

13. The reaction equation is:
HNO_2 (aq) + NaOH (aq) $\rightleftharpoons$ $NaNO_2$ (aq) + H_2O (l)

pK_a of HNO_2 = $-logK_a$ = $-log(4.5 \times 10^{-4})$ = 3.35

Moles of HNO_2 = (40.0×10^{-3}) x 1 = 40 x 10^{-3} mol
Moles of NaOH = (20.0×10^{-3}) x 1 = 20 x 10^{-3} mol
So, 50% of HNO_2 reacts to form the salt ($NaNO_2$) and 50% is left behind

pH = pK_a + log[salt]/[acid] = 3.35 + log [20 x 10^{-3}] / [20 x 10^{-3}]
= 3.35 + log 1 = 3.35 + 0 = 3.35

14. The mass of the solution is 500 g
Heat capacity of solution = mass of solution x specific heat capacity of solution
= 0.500 kg x 4200 J kg^{-1} K^{-1} = 2100 J K^{-1}
Heat capacity of copper calorimeter = mass of calorimeter x specific heat capacity of copper
= 0.500 kg x 400 J kg^{-1} K^{-1} = 200 J K^{-1}

Increase in temperature = 2.50 °C
Heat evolved = (heat capacity of solution + heat capacity of copper) x ΔT
= (2100 + 200) x 2.50 = 2300 x 2.50 = 5750 J

Moles of water formed = moles of NaOH = moles of HCl
Moles of water formed = (250×10^{-3}) x 0.400 = 0.100 mol
Heat evolved per mole of water = 5750 / 0.100 = 57 500 J mol^{-1}

Standard enthalpy of neutralisation = −57.5 kJ mol^{-1}

15. For compound A:
Moles of carbon = 71.1 / 12.0 = 5.93 mol of C
Moles of nitrogen = 10.4 / 14.0 = 0.743 mol of N
Moles of oxygen = 11.8 / 16.0 = 0.738 mol of O
Moles of hydrogen = 6.7 / 1.01 = 6.63 mol of H

Dividing the numbers by the lowest number (0.74) gives C_8H_9NO
Also, C_8H_9NO has an M_r = (12.0 x 8) + (1.01 x 9) + 14.0 +16 = 135.1 g mol^{-1}
Which is consistent with the given M_r

For compound B:
Moles of carbon = 77.1 / 12.0 = 6.43 mol of C
Moles of nitrogen = 15.1 / 14.0 = 1.08 mol of N
Moles of hydrogen = 7.5 / 1.01 = 7.43 mol of H

Dividing the numbers by the lowest number (1.08) gives C_6H_7N
Also, C_6H_7N has an M_r = (12.0 x 6) + (1.01 x 7) + 14.0 = 93.07 g mol^{-1}
Which is consistent with the given M_r

Bromine water is decolourised and forms a white precipitate on reaction with
aniline ($C_6H_5NH_2$) or phenol (PhOH). So, C_6H_7N is likely to be aniline, which,
being an aromatic amine is basic.

Hydrolysis of A (C_8H_9NO) gives $C_6H_5NH_2$. So, A must contain the $C_6H_5NH–$
fragment. This leaves a C_2H_3O group, likely to be $–COCH_3$, as the amide
$C_6H_5NHCOCH_3$ would be hydrolysed to $C_6H_5NH_2$ (B) and CH_3CO_2H.

A = $C_6H_5NHCOCH_3$
B = $C_6H_5NH_2$