Hydrated Formula Practice

6. The crystalline mineral carnallite has the general formula $(MgCl_2)_x(KCl)_y .zH_2O$.

When a sample of pure carnallite of mass 5.830 g is heated, all the water of crystallisation is driven off and the remaining anhydrous powder weighs 3.561g.

All the magnesium in a further 10.270 g sample of the mineral is converted into "insoluble" magnesium hydroxide which required 35.10 mL of 2.105 mol L^{-1} hydrochloric acid to dissolve it completely.

(a) Determine the empirical formula of carnallite from the above information, i.e. find the values of x, y and z.

(b) What total number of moles of ions are present in 1.00 L of solution which contains 5.830 g of dissolved carnallite?

7. A double sulfate of potassium and chromium (III) has the general formula:

$KCr(SO_4)_x .yH_2O$. where x and y are integers.

36.50 g of the pure hydrated compound is treated with excess sodium carbonate solution and it is found that 10.38 g of highly insoluble chromium (III) carbonate is precipitated.
A further 4.700 g sample of the compound is heated strongly to drive off all the water of crystallisation. A constant mass of 2.665 g of anhydrous powder remains after several heatings. From this information, calculate the empirical formula of the compound.
[Hint: Use percentages].

ANSWERS

6. (a) $(MgCl_2)_x(KCl)_y.zH_2O \rightarrow (MgCl_2)_x(KCl)_y + zH_2O$

5.830g → 3.561g + 2.269g

%[H_2O] in carnallite = 2.269g/5.830g x 100 = 38.92%

$Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2$

Then $Mg(OH)_2 + 2H^+(aq) \rightarrow Mg^{2+}(aq) + 2H_2O(l)$

$n(Mg^{2+}) = n(H^+) = n(HCl) = (c.V) = 0.03694$ mol.

$n(MgCl_2) = 0.03894$ mol. (in 10.270g of carnallite)

$m(MgCl_2) = n.M = (0.03694\ mol)(95.2\ g\ mol^{-1}) = 3.5171g.$

$\%MgCl_2 = 3.5171g/10.270\ g \times 100 = 34.25\%$

$\%(H_2O) = 38.92\%$, $\%(MgCl_2) = 34.25\%$, $\%(KCl) = 26.83\%$

Hence, in 100g carnallite, $m(H_2O) = 38.92$ g ; $n(H_2O) = 2.16$ mol.

$m(MgCl_2) = 34.25$ g ; $n(MgCl_2) = 0.3597$ mol.

$m(KCl) = 26.83$ g ; $n(KCl) = 0.3599$ mol.

By dividing the three mole amounts by 0.3597 to obtain the simplest ratio,

Ans (a): The EF of carnallite is $MgCl_2.KCl.6H_2O$ (ie x=1; y=1; z=6).

(b) $n(carnallite) = 5.830g/277.846g\ mol^{-1} = 0.0209828$ mol.

Since from the formula, n(ions) = 5n(carnallite) = 5(0.0209828mol).

Ans (b): The number of moles of ions is 0.105 mol.

7. $2Cr^{3+}(s) + 3CO_3^{2-}(aq) \rightarrow Cr_2(CO_3)_3(s)$

$m(Cr_2(CO_3)_3) = 10.38g$

$n(Cr_2(CO_3)_3) = m/M = 10.38g/284.03\ g\ mol^{-1} = 0.03655$ mol.

$n(Cr) = 2n(Cr_2(CO_3)_3) = 0.07309$ mol.

$m(Cr) = n.M = (0.07309\ mol)(52.00\ g\ mol^{-1}) = 3.801$ g.

$n(K) = n(Cr) = 0.07309$ mol.

$m(K) = n.M = (0.07309\ g)(39.10\ g\ mol^{-1}) = 2.858$ g.

$KCr(SO_4)_x.yH_2O \rightarrow KCr(SO_4)_x + yH_2O$
4.70g → 2.665g + 2.035g

%K = [m(K) / m(compound)] x 100 = [(2.858 g) / (36.50 g)] x 100 = 7.83%

%Cr = [m(Cr) / m(compound)] x 100 = [3.801 g) / (36.50 g)] x 100 = 10.4%

$\%H_2O = [(m(H_2O) / (m(sample)] \times 100 = (2.035g)/(4.70g) \times 100 = 43.3\%$

$\%\ SO_4^{2-} = [100 - (\%H_2O + \%K + \%Cr)] = 38.5\%$

Consider 100g of the compound:

$m(K) = 7.83g \quad n(K) = m/M = 7.83g/39.10\ g\ mol^{-1} = 0.200$ mol. = 1

$m(Cr) = 10.4g \quad n(Cr) = m/M = 10.4g/52.00\ g\ mol^{-1} = 0.200$ mol. = 1

$m(SO_4^{2-}) = 38.5g \quad n(SO_4^{2-}) = m/M = 38.5g/96.06\ g\ mol^{-1} = 0.400$ mol. = 2

$m(H_2O) = 43.3g \quad n(H_2O) = m/M = 43.3g/18.016\ g\ mol^{-1} = 2.40$ mol = 12

Ans: $\underline{EF = K_1Cr_1(SO_4)_2.12H_2O}$.