

### Hydrated Formula Practice

6. The crystalline mineral carnallite has the general formula  $(\text{MgCl}_2)_x(\text{KCl})_y \cdot z\text{H}_2\text{O}$ .

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  $2.105 \text{ mol L}^{-1}$  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:

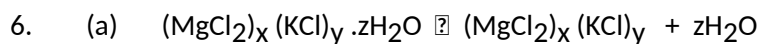


36.50 g of the pure hydrated compound is treated with excess sodium carbonate solution and it is found that 10.38 g of highly insoluble chromium (III) carbonate is precipitated.

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.

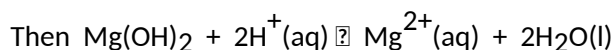
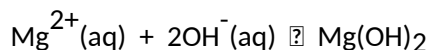
[Hint: Use percentages].

## ANSWERS



$$5.830\text{g} \rightarrow 3.561\text{g} + 2.269\text{g}$$

$$\%[\text{H}_2\text{O}] \text{ in carnallite} = 2.269\text{g}/5.830\text{g} \times 100 = 38.92\%$$



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

$$n(\text{MgCl}_2) = 0.03894 \text{ mol. (in 10.270g of carnallite)}$$

$$m(\text{MgCl}_2) = n.M = (0.03694 \text{ mol})(95.2 \text{ g mol}^{-1}) = 3.5171\text{g.}$$

$$\%\text{MgCl}_2 = 3.5171\text{g}/10.270 \text{ g} \times 100 = 34.25\%$$

$$\%(\text{H}_2\text{O}) = 38.92\%, \quad \%\text{(MgCl}_2) = 34.25\%, \quad \%\text{(KCl)} = 26.83\%$$

$$\text{Hence, in 100g carnallite, } m(\text{H}_2\text{O}) = 38.92 \text{ g ; } n(\text{H}_2\text{O}) = 2.16 \text{ mol.}$$

$$m(\text{MgCl}_2) = 34.25 \text{ g ; } n(\text{MgCl}_2) = 0.3597 \text{ mol.}$$

$$m(\text{KCl}) = 26.83 \text{ g ; } n(\text{KCl}) = 0.3599 \text{ mol.}$$

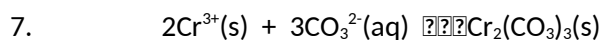
By dividing the three mole amounts by 0.3597 to obtain the simplest ratio,

Ans (a): The EF of carnallite is  $\text{MgCl}_2 \cdot \text{KCl} \cdot 6\text{H}_2\text{O}$  (ie  $x=1$ ;  $y=1$ ;  $z=6$ ).

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

$$\text{Since from the formula, } n(\text{ions}) = 5n(\text{carnallite}) = 5(0.0209828\text{mol}).$$

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



$$m(\text{Cr}_2(\text{CO}_3)_3) = 10.38\text{g}$$

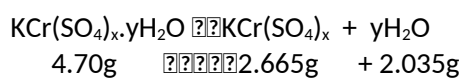
$$n(\text{Cr}_2(\text{CO}_3)_3) = m/M = 10.38\text{g}/284.03\text{ g mol}^{-1} = 0.03655\text{ mol.}$$

$$n(\text{Cr}) = 2n(\text{Cr}_2(\text{CO}_3)_3) = 0.07309\text{ mol.}$$

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

$$n(\text{K}) = n(\text{Cr}) = 0.07309\text{ mol.}$$

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



$$\%K = [m(\text{K}) / m(\text{compound})] \times 100 = [(2.858\text{ g}) / (36.50\text{ g})] \times 100 = 7.83\%$$

$$\%Cr = [m(\text{Cr}) / m(\text{compound})] \times 100 = [3.801\text{ g}) / (36.50\text{ g})] \times 100 = 10.4\%$$

$$\%\text{H}_2\text{O} = [(m(\text{H}_2\text{O}) / (m(\text{sample})) \times 100 = (2.035\text{g})/(4.70\text{g}) \times 100 = 43.3\%$$

$$\% \text{SO}_4^{2-} = [100 - (\%\text{H}_2\text{O} + \%K + \%Cr)] = 38.5\%$$

Consider 100g of the compound:

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

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

$$m(\text{SO}_4^{2-}) = 38.5\text{g} \quad n(\text{SO}_4^{2-}) = m/M = 38.5\text{g}/96.06\text{ g mol}^{-1} = 0.400\text{ mol.} = 2$$

$$m(\text{H}_2\text{O}) = 43.3\text{g} \quad n(\text{H}_2\text{O}) = m/M = 43.3\text{g}/18.016\text{ g mol}^{-1} = 2.40\text{ mol} = 12$$

Ans: EF =  $\text{K}_1\text{Cr}_1(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ .