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Worked exercise Topic 0

The acid HA (where A stands for an unknown group of atoms) has a molar mass of 231 g·mol^{-1}. HA reacts with the base XOH (molar mass 125 g·mol^{-1}) to produce H_2O and the salt XA. In one experiment 2.45 g of HA react with 1.5 g of XOH to form 2.91 g of XA. What is the percentage yield of the reaction?
Solution: 81.2%

How to solve it:

Some of you have cleverly thought that mass conserves so if we have (2.45+1.5)=3.95 g in the reactants side, and the amount of XA is 2.91, then the amount of formed water should be 3.95-2.91 = 1.04 g H_2O, which is equivalent to 1.04/18 = 0.0578 mol H_2O. But unfortunately, this is completely WRONG. The reason is that you are assuming that ALL HA reacts with ALL XOH and that is not necessarily true. We must check this before.

2.45 g HA <> 2.45/231 = 0.0106 mol HA (please note that a minimum of 3 significant digits –if not more– are usually needed in chemical calculations.
1.5 g XOH <> 1.5/125 = 0.012 mol XOH

Since the reaction proceeds with 1:1 molar stoichiometry, there is a defect of HA or an excess of XOH. That means that HA is the limiting reactant. So ALL HA will react but with a fraction of the initially present amount of XOH. The amount of reacted XOH will be exactly the same as the amount of reacted HA, that is to say, 0.0106 mol XOH. This means that there is an excess of 0.012 – 0.0106 =0.0014 mol of XOH, which is equivalent to 0.0014x125 =0.175 g XOH.

We are asked to find the Yield so we must firstly calculate the maximum possible amount of XA. Since the stoichiometry is 1:1, the maximum amount of XA will be 0.0106 moles, that is to say, we must assume that ALL HA reacts. But, how many mol of XA are effectively formed? Answer: 0.0106 x M(XA) where M(XA) is the molar mass of XA. How can we calculate the molar mass of XA?

If M(HA) = 231 g/mol, then 231 – M(H)= 230 g/mol will be the molar mass of A^-.
If M(XOH) =125 g/mol, then 125 – M(H) – M(O) = 125 – 1 – 16 = 108 g/mol will be the molar mass of X^+
So M(XA) = 230 + 108 = 338 g/mol

Therefore, the maximum possible amount of XA will be 0.0106 x 338 = 3.58 g XA

Yield is therefore Y(%) = 100 x (actual amount of XA)/(maximum possible amount of XA) = 100 x 2.91 /3.58 = 81.3% The difference with the solution given above (81.2) is due to the number of digits used for M(XA).