1.5. Percentage yield and Atom economy

Percentage yield and atom economy are two numbers which help us gauge how efficient a reaction is for making a specific chemical. The atom economy tells us in theory how many atoms must be wasted in a reaction. The percentage yield tells us about the efficiency of the process.

1. Oxygen can be produced by a number of processes. Two possible processes are shown below;
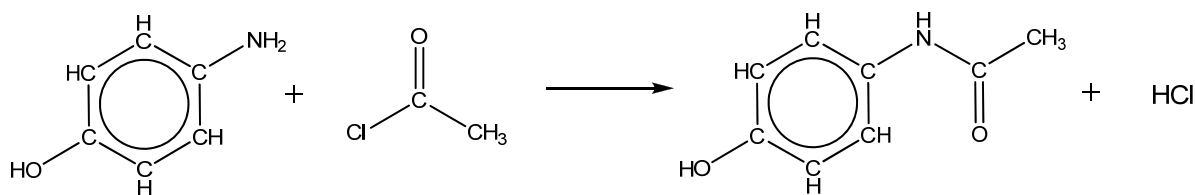
    Electrolysis of water; $2 H_2O \rightarrow 2 H_2 + O_2$
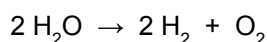
    Catalytic decomposition of water; $2 H_2O_2 \rightarrow 2 H_2O + O_2$
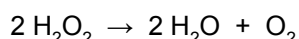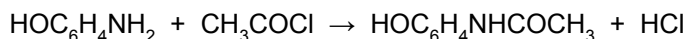
    By calculating the percentage atom economy of each process, decide which process is better for producing oxygen.   (3 marks)

2. Two students complete the synthesis of paracetamol from 4-aminophenol as shown by the equation below;

    4-aminophenol + ethanoyl chloride → paracetamol + hydrogen chloride

    $HOC_6H_4NH_2 + CH_3COCl \rightarrow HOC_6H_4NHCOCH_3 + HCl$

    Both students react 2 moles of 4-aminophenol with excess ethanoyl chloride.
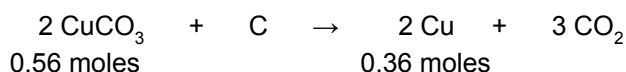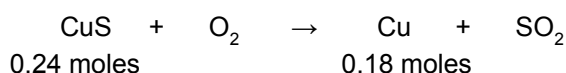
    Student 1 makes 1.5 moles of paracetamol.

    Student 2 makes 220 g of paracetamol.

    Which student has the better percentage yield?   (4 marks)

3. Copper can be made by either roasting copper sulphide or by the reduction of copper carbonate with carbon. The equations for the two processes are shown below.

    $$CuS \ + \ O_2 \ \rightarrow \ Cu \ + \ SO_2$$
    0.24 moles   0.18 moles

    $$2 CuCO_3 \ + \ C \ \rightarrow \ 2 Cu \ + \ 3 CO_2$$
    0.56 moles   0.36 moles

    By comparing the percentage atom economy and the percentage yields of the processes as shown, evaluate which is the better method from an industrial viewpoint.

                                                                          (3 marks)

1.5 Atom economy

1. Electrolysis of water; $2 H_2O \rightarrow 2 H_2 + O_2$ Atom economy = 32 / 36 × 100% = 88.9%

Catalytic decomposition of water; $2 H_2O_2 \rightarrow 2 H_2O + O_2$ Atom economy = 32 / 68 × 100% = 47.1%

∴ producing oxygen by the electrolysis of water has the better atom economy

2. Student 1's percentage yield = 1.5 moles / 2 moles × 100% = 75%   (1 mark)

Student 2's percentage yield;

Molar mass of paracetamol = 151.0 g mol^{-1}

∴ no. of moles paracetamol made by student 2 = 220 g / 151.0 g mol^{-1} = 1.46 moles   (1 mark)

∴ student 2's percentage yield = 1.46 moles / 2 moles × 100% = 73%   (1 mark)

∴ student 1 has the better percentage yield   (1 mark)

3. Roasting CuS: Atom economy = 49.8%   Percentage yield = 75%

Reduction of $CuCO_3$:   Atom economy = 49.0%   Percentage yield = 64%

∴ obtaining copper from CuS is the better method based on the atom economy of the process and the percentage yields given.

(1 mark for both atom economy's correct; 1 mark for both percentage yields correct; 1 mark for the evaluation)

1.6 Titration calculations

Concentration of vinegar taken from **John Smith's dinner**;

     Average titre = 18.475 cm^3

     No. of moles of NaOH = 1.85 × 10^{-3} moles

     ∴ Concentration of vinegar = **0.0739 mol dm^{-3}**

Concentration of vinegar taken from "**The Codfather**";

     Average titre = 10.075 cm^3

     No. of moles of NaOH = 1.51 × 10^{-3} moles

     ∴ Concentration of vinegar = **0.0756 mol dm^{-3}**

Concentration of vinegar taken from "**The Plaice**";

     Average titre = 14.775 cm^3

     No. of moles of NaOH = 1.85 × 10^{-3} moles

     ∴ Concentration of vinegar = **0.0739 mol dm^{-3}**