Chemistry 11

Copper Cycle Stoichiometry

Name: Key
Date:
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Show all steps and calculations in the space provided below.

1. Consider the reaction below, which is the first step in the process of recycling copper

$$\_\_\_ Cu_{(s)} + \underline{4}\ HNO_{3\,(aq)} \rightarrow \_\_\_ Cu(NO_3)_{2\,(aq)} + \underline{2}\ NO_{2\,(g)} + \underline{2}\ H_2O_{(l)}$$

a. If a student began the experiment with 0.020g of copper metal, what volume (in mL) of 15.8M HNO_3 would be required to complete the reaction?

$$0.020\,g_{Cu} \times \frac{1\,mol_{Cu}}{63.55\,g_{Cu}} \times \frac{4\,mol\,HNO_3}{1\,mol_{Cu}} \times \frac{1\,L_{HNO_3}}{15.8\,mol_{HNO_3}} \times \frac{1000\,mL_{HNO_3}}{1\,L_{HNO_3}} = \boxed{0.080\,mL_{HNO_3}}$$

b. How many mL of NO_2 gas would be produced in the reaction was carried out at STP?

$$0.020\,g_{Cu} \times \frac{1\,mol_{Cu}}{63.55\,g_{Cu}} \times \frac{2\,mol_{NO_2}}{1\,mol_{Cu}} \times \frac{22.4\,L_{NO_2}}{1\,mol_{NO_2}} \times \frac{1000\,mL_{NO_2}}{1\,L_{NO_2}} = \boxed{14\,mL_{NO_2}}$$

c. How much $Cu(NO_3)_2$ (in grams) would be produced?

$$0.020\,g_{Cu} \times \frac{1\,mol_{Cu}}{63.55\,g_{Cu}} \times \frac{1\,mol\,Cu(NO_3)_2}{1\,mol\,Cu} \times \frac{187.57\,g_{Cu(NO_3)_2}}{1\,mol_{Cu(NO_3)_2}} = \boxed{0.059\,g_{Cu(NO_3)_2}}$$

2. The next step in the process follows the reaction below:

$$\_\_\_ Cu(NO_3)_{2(aq)} + \underline{2}\ NaOH_{(aq)} \rightarrow \_\_\_ Cu(OH)_{2(s)} + \underline{2}\ NaNO_{3\,(aq)}$$

a. If all of the $Cu(NO_3)_2$ produced in question 1 was used, what would be the mass of the solid produced in the reaction above?

$$0.059\,g_{Cu(NO_3)_2} \times \frac{1\,mol_{Cu(NO_3)_2}}{187.57\,g_{Cu(NO_3)_2}} \times \frac{1\,mol_{Cu(OH)_2}}{1\,mol\,Cu(NO_3)_2} \times \frac{97.57\,g_{Cu(OH)_2}}{1\,mol\,Cu(OH)_2} = \boxed{0.031\,g_{Cu(OH)_2}}$$

b. How much base (mL of 0.10M NaOH) would be needed in order to have a complete reaction?

$$0.059\,g_{Cu(NO_3)_2} \times \frac{1\,mol_{Cu(NO_3)_2}}{187.57\,g_{Cu(NO_3)_2}} \times \frac{2\,mol_{NaOH}}{1\,mol\,Cu(NO_3)_2} \times \frac{1\,L_{NaOH}}{0.10\,mol_{NaOH}} \times \frac{1000\,mL_{NaOH}}{1\,L_{NaOH}} = \boxed{6.3\,mL_{NaOH}}$$

3. The solid copper (II) hydroxide decomposes in heat to form copper (II) oxide and steam according to the reaction below

$$\_\_\_ Cu(OH)_{2\,(g)} + heat \rightarrow \_\_\_ CuO_{(s)} + \_\_\_ H_2O_{(g)}$$

What mass of solid CuO would result if the reaction went to completion?

From 2.a.

$$0.031\,g_{Cu(OH)_2} \times \frac{1\,mol_{Cu(OH)_2}}{97.57\,g_{Cu(OH)_2}} \times \frac{1\,mol_{CuO}}{1\,mol_{Cu(OH)_2}} \times \frac{79.85\,g_{CuO}}{1\,mol_{CuO}} = \boxed{0.025\,g_{CuO}}$$

4. When reacted with sulphuric acid (H_2SO_4), the reaction follows the following equation:

$$\_\_\_ CuO_{(s)} + \_\_\_ H_2SO_{4\,(aq)} \rightarrow \_\_\_ CuSO_{4\,(aq)} + \_\_\_ H_2O_{(l)}$$

a. What volume in milliliters of 6.0 M sulphuric acid (H_2SO_4) would be needed to fully react with the CuO produced in question 3?

$$0.025\,g_{CuO} \times \frac{1\,mol_{CuO}}{79.85\,g_{CuO}} \times \frac{1\,mol\,H_2SO_4}{1\,mol\,CuO} \times \frac{1\,L\,H_2SO_4}{6.0\,mol\,H_2SO_4} \times \frac{1000\,mL}{1\,L} = \boxed{0.052\,mL\,H_2SO_4}$$

b. What mass of copper (II) sulphate ($CuSO_4$) would be in solution at the end of the reaction?

$$0.025\,g_{CuO} \times \frac{1\,mol_{CuO}}{79.85\,g_{CuO}} \times \frac{1\,mol\,CuSO_4}{1\,mol\,CuO} \times \frac{159.62\,g\,CuSO_4}{1\,mol\,CuSO_4} = \boxed{0.050\,g_{CuSO_4}}$$

5. In the final step of the process, solid copper metal is reformed using magnesium metal, according to the following reaction (complete the reaction):

$$\_\_\_ CuSO_{4\,(aq)} + \_\_\_ Mg_{(s)} \rightarrow Cu_{(s)} + MgSO_{4\,(aq)}$$

From 4.b.

a. What mass of $MgSO_4$ would be produced in this reaction?

$$0.050\,g_{CuSO_4} \times \frac{1\,mol\,CuSO_4}{159.62\,g\,CuSO_4} \times \frac{1\,mol\,MgSO_4}{1\,mol\,CuSO_4} \times \frac{120.38\,g\,MgSO_4}{1\,mol\,MgSO_4} = \boxed{0.038\,g\,MgSO_4}$$

b. What is the minimum mass of magnesium metal that could be used in this reaction?

$$0.050\,g_{CuSO_4} \times \frac{1\,mol\,CuSO_4}{159.62\,g\,CuSO_4} \times \frac{1\,mol\,Mg}{1\,mol\,CuSO_4} \times \frac{24.31\,g\,Mg}{1\,mol\,Mg} = \boxed{0.0076\,g\,Mg}$$

c. What should the final mass of copper metal be? How does this mass compare to the starting mass of copper metal in question 1?

$$0.050\,g_{CuSO_4} \times \frac{1\,mol\,CuSO_4}{159.62\,g\,CuSO_4} \times \frac{1\,mol\,Cu}{1\,mol\,CuSO_4} \times \frac{63.55\,g\,Cu}{1\,mol\,Cu} = \boxed{0.020\,g\,Cu}$$

It's the same as the starting mass!