ACS Chemistry for Life®

GROUP ACTIVITY

CHEMISTRY ROCKS!
Exploring the Chemistry of Rocks and Minerals

This activity helps students explore how nature creates calcium carbonate, a compound needed to manufacture cement, at ambient temperatures and using abundant, readily available raw materials. It has been modified from: "Concrete without Quarries" and is used with permission from the Biomimicry Institute, https://biomimicry.org

BALANCED CHEMICAL EQUATIONS

The following series of 4 balanced chemical equations describe the reactions required to produce calcium carbonate from carbon dioxide:

1) Bubbling carbon dioxide through water causes the formation of carbonic acid: $CO_2 + H_2O \rightarrow H_2CO_3$

2) The addition of the base causes the formation of sodium hydrogen carbonate and water: $H_2CO_3 + NaOH \rightarrow NaHCO_3 + H_2O$

3) The addition of even more base results in the formation of sodium carbonate and water: $NaHCO_3 + NaOH \rightarrow Na_2CO_3 + H_2O$

4) Finally the sodium carbonate reacts with the aqueous calcium chloride (seawater) to form the calcium carbonate that will be used in the production of cement for concrete (plus sodium chloride, or salt): $Na_2CO_3 + CaCl_2 \rightarrow CaCO_3 + 2NaCl$

QUESTIONS

Use the reaction series above to answer the following questions:

1) **Classify each of the above reactions either as a synthesis, decomposition, single replacement, or double replacement reaction. Explain your reasoning.**

2) **Assuming all the carbon dioxide reacts in the first step, if one mole of carbon dioxide is bubbled through excess water, how many moles of calcium carbonate could be produced?**

3) **If you started with one metric ton (1000 kg) carbon dioxide, how many kilograms of calcium carbonate could be produced assuming all the carbon dioxide reacts?**

4) **If 1138 kg of calcium carbonate are produced when one metric ton of carbon dioxide is reacted, what percent yield does this represent?**

5) **How many kilograms of calcium chloride would be required if one metric ton of carbon dioxide were reacted?**

ACTIVITY ANSWER KEY

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4) Finally the sodium carbonate reacts with the aqueous calcium chloride (seawater) to form the calcium carbonate that will be used in the production of cement for concrete (plus sodium chloride, or salt): $Na_2CO_3 + CaCl_2 \rightarrow CaCO_3 + 2NaCl$

QUESTIONS

Use the reaction series above to answer the following questions:

1) **Classify each of the above reactions either as a synthesis, decomposition, single replacement, or double replacement reaction. Explain your reasoning.** ***Reaction 1 is a synthesis reaction because two materials are combining to form a new material. Reactions 2, 3, and 4 are all double replacement reactions because in all three there are two exchanges of positive ions and negative ions.***

2) **Assuming all the carbon dioxide reacts in the first step, if one mole of carbon dioxide is bubbled through excess water, how many moles of calcium carbonate could be produced?** ***One mole of CO_2 produces one mole of H_2CO_3 and / One mole of H_2CO_3 produces one mole of $NaHCO_3$ and / One mole of $NaHCO_3$ produces one mole of Na_2CO_3 and finally / One mole of Na_2CO_3 produces one mole of $CaCO_3$. So overall one mole of CO_2 produces one mole of $CaCO_3$.***

3) **If you started with one metric ton (1000 kg) carbon dioxide, how many kilograms of calcium carbonate could be produced assuming all the carbon dioxide reacts?**

$$\frac{1000\ \text{kg } CO_2}{1} \times \frac{1000\text{g}}{1\ \text{kg}} \times \frac{1\ \text{mol } CO_2}{44.00\ \text{g } CO_2} \times \frac{1\ \text{mol } CaCO_3}{1\ \text{mol } CO_2} \times \frac{100.09\ \text{g } CaCO_3}{1\ \text{mol } CaCO_3} \times \frac{1\ \text{kg}}{1000\ \text{g}} \quad 2275\ \text{kg}$$

So about 2.25 metric tons of calcium carbonate can be produced from 1 metric ton of carbon dioxide!

4) **If 1138 kg of calcium carbonate are produced when one metric ton of carbon dioxide is reacted, what percent yield does this represent?**
% yield = 1138 kg/ 2275 kg = .5002 = 50.02 %

5) **How many kilograms of calcium chloride would be required if one metric ton of carbon dioxide were reacted?**

$$\frac{1000\ \text{kg } CO_2}{1} \times \frac{1000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{mol } CO_2}{44.00\ \text{g } CO_2} \times \frac{1\ \text{mol } CaCl_2}{1\ \text{mol } CO_2} \times \frac{110.98\ \text{g } CaCl_2}{1\ \text{mol } CaCl_2} \times \frac{1\ \text{kg}}{1000\ \text{g}} \quad 2522\ \text{kg}$$

So about 2.5 metric tons of calcium chloride are required to react completely with 1 metric ton of carbon dioxide.