**Water Hardness Determination – SCH 4U**

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| sample volume (mL) | |
| titrant (0.001 M EDTA) (mL) | |
| hardness determination using kit (p.p.m. $CaCO_3$) | |

**Calculations and Concluding Questions**

1. Write the structural formula (i.e. and organic molecule) for EDTA. Present this as the "disodium salt" form. What has happened to two of the carboxylic acid groups to make the disodium salt. Answers with specific reference to any and all charges involved.

2. How does EDTA interact with a metal ion? You may use $Ca^{2+}$ for an example. Include a diagram! Why is this titration called a "complexometric" titration.

3. What exactly is water hardness. How is it commonly expressed. (See lab sheet for answers)

4. Draw the structural formula for Eriochrome Black T. Suggest possible locations on this molecule that could from coordinate covalent bonds with $Ca^{2+}$ or $Mg^{2+}$ ions. Why is control of the pH necessary for the Eriochrome Black T to function correctly?

For the purposes of simpler stoichiometric calculations, make the simplification that all ions responsible for water hardness (i.e. $Ca^{2+}$, $Mg^{2+}$ plus minute quantities of other ions) will be treated as though they are $Ca^{2+}$ ions. This simplification is a common practice and the reason that hardness is expressed as a mg $CaCO_3$ per L (also known as p.p.m. $CaCO_3$). Use this to answers question #5 and #6.

5. What is the mole ration of EDTA to $Ca^{2+}$ ion. Using this information and multiple convertion factors, convert the volume of EDTA titrant you used in ml to the mass of calcium ion in your sample in mg. Use the following as a guide:

   volume EDTA (mL) ⇨ volume EDTA (L) ⇨ amount EDTA (mol) ⇨

   amount $Ca^{2+}$ (mol) ⇨ mass $Ca^{2+}$ (g) ⇨ mass $Ca^{2+}$ (mg)

   Show one long conversion rather than several short ones (as done in grade eleven chemistry). Include extended units for each conversion factor (as done in grade eleven chemistry).

6. Parts per million (p.p.m.) can be defined as the mass of a solute in mg found in 1 L of a dilute aqueous solution. Since 1 L of water has a mass of 1 million mg, this is in fact mg of solute per million mg of solution (hence the parts per million). The best formula for p.p.m. is:

$$\text{p.p.m.} = \frac{\text{mass of solute in mg}}{\text{volume of sample in L}}$$

Use this formula, your answer in question #5 and the 25 mL volume of your sample to determine the p.p.m. $Ca^{2+}$ in the tap water.

7. Compare your answer in #6 with the value for calcium determined by Schlenker using the Hardness kit. Determine the percent difference between these two values.

$$\text{percent difference} = \frac{|\text{measurement \#1} - \text{measurement \#2}|}{\frac{1}{2}(\text{measurement \#1} + \text{measurement \#2})} \times 100\%$$

8. What are the health advantages of drinking local tap water with its relatively high calcium and magnesium ion concentration?

9. The equilibrium reactions in this lab are:

$$\{\text{EDTA–}Ca^{2+}\text{ complex}\} \rightleftharpoons \text{EDTA} + Ca^{2+}$$

$$\underset{\text{(red)}}{\{\text{Erio–}Ca^{2+}\text{ complex}\}} \rightleftharpoons \underset{\text{(blue)}}{\text{Erio}} + Ca^{2+}$$

The second reaction includes the observed colour of the "complexed" Erio vs the "free" Erio. (Actually the red colour in attributed to the Erio-$Mg^{2+}$ complex which has an even lower Keq value than the Erio-$Ca^{2+}$ complex. In some applications for Eriochrome Black T it is necessary to introduce a small amount of $MgSO_4$ to produce the red colour that this indicator depends on. Given the relatively high concentration of $Mg^{2+}$ in our tap water, this in not a necessary step.) Both of these reactions have very small Keq values and hence lie far to the left. Now, using Le Chatelier's Principle, determine the effect of adding EDTA to the first equilibrium. What effect will this have on the second equilibrium (include a second L.C.P. Why does the colour of the indicator switch from red to blue when addequate EDTA has been added.

10. This titration is said to be stoichiometric. This is not entirely true because all reactions are equilibrium and as such are not 100% complete. Why than is it acceptable to think of this as a stoichiometric titration.

11. The above is known as a multiple equilibria system, where a change in one equilibrium will effect the position of other equilibrium reactions. For a good **bonus question**, research the multiple equilibria that is responsible for the formation of a ester from a carboxylic acid, alcohol and sulphuric acid catalyst. A search using the key words "esterification mechanism" will get you started.