# Jar Test

When 1 mole of alum ($Al_2(SO_4)_3{\cdot}18H_2O$) is added into water that contains adequate alkalinity, 6 mole of $HCO_3^-$ (alkalinity) is consumed and produced 6 mole of $CO_2$ as shown in equation (1)

$$Al_2(SO_4)_3{\cdot}18H_2O + 6HCO_3^- == 2Al(OH)_3(s) + 3SO_4^{2-} + 18H_2O + 6CO_2 \qquad (1)$$

As we know that $CO_2$ in water is the same as $H_2CO_3$ (carbonic acid). Therefore, the reaction in equation (1) shifts the carbonate equilibrium and pH changes slightly because $H_2CO_3$ is a weak acid.

If water contains no alkalinity, the pH changes dramatically because sulfuric acid is produced instead of $CO_2$ as express in equation (2). Sulfuric acid is a strong acid that dissociate 100 % to proton, or $H^+$.

$$Al_2(SO_4)_3{\cdot}18H_2O + 6H_2O == 2Al(OH)_3(s) + 3H_2SO_4 + 18H_2O \qquad (2)$$

# Calculation for alkalinity change

**<u>MW</u>:** $Al_2(SO_4)_3{\cdot}18H_2O$ = 666 g/mol; $Al^{3+}$ = 2(27) = 54 g/mol

**In the lab, the concentration of alum solution was prepared in mg/L as $Al^{3+}$ (not as $Al_2(SO_4)_3{\cdot}18H_2O$), so we have to convert $Al^{3+}$ to alum ($Al_2(SO_4)_3{\cdot}18H_2O$):**

Assume: we get 10 mg/L (beaker # 2) of $Al^{3+}$ as the optimum dosage (the lowest turbidity).

Since 1 mol/L (or 666 g/L) of $Al_2(SO_4)_3{\cdot}18H_2O$ contains 2(27) = 54 g/L of $Al^{3+}$

Therefore, 54 g/L of $Al^{3+}$ comes from = 666 g/L of $Al_2(SO_4)_3{\cdot}18H_2O$

10 mg/L, or $10(10^{-3})$ g/L of $Al^{3+}$ comes from $= \left(\frac{666}{54}\right) \times 10(10^{-3})$ g/L of $Al_2(SO_4)_3{\cdot}18H_2O$

Change $\left(\frac{666}{54}\right) \times 10(10^{-3})$ g/L of $Al_2(SO_4)_3{\cdot}18H_2O$ to unit of mol/L

We get: $Al_2(SO_4)_3{\cdot}18H_2O = \left(\frac{666}{54}\right) \times 10(10^{-3})\ \text{g/L} \left(\frac{1\ \text{mol}}{666\ \text{g}}\right) = \frac{10}{54}(10^{-3})$ mol/L

Since 1 mol of $Al_2(SO_4)_3{\cdot}18H_2O$ is equal to 6 mol of $HCO_3^-$ from the above equation (1)

Therefore, $[HCO_3^-] = 6 \times \frac{10}{54}(10^{-3})$ mol/L

Then change the unit into mg/L as $CaCO_3$

$$[HCO_3^-] = 6 \times \frac{10}{54}(10^{-3})\ \text{mol/L} \times 61\text{g/mol} \times 10^3\ \text{mg/g} \times \left(\frac{50}{61}\right) = 55.55\ \text{mg/L as } CaCO_3$$

Theoretical alkalinity depleted = 55.55 mg/L as $CaCO_3$.

From the lab as shown in the below Table, the alkalinity was changed = 240 – 180 = 60 mg/L as $CaCO_3$. The results do not show much difference between the alkalinity change in theory and practice.

**Note:**

1) Adding alum into water decreases the pH, but
2) If water contains some alkalinity ($HCO_3^-$, the major specie at neutral pH), the pH does not be dramatically reduced (compared to the condition when the alkalinity is not present).

$CO_{2\,(g)}$ elaboration indicates formation of carbonic acid [$H^+ + HCO_3^- \leftrightarrow H_2CO_3^* \leftrightarrow H_2O + CO_{2(ag)} \leftrightarrow CO_{2(g)}$]

| Beaker # | RAW | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Dosage mg/L of Alum as $Al^{3+}$ | 0 | 5 | 10 | 20 | 30 | 40 | 50 |
| Turbidity NTU of all samples | 12 | 10 | 1.0 | 2.0 | 3.0 | 4.0 | 5.3 |
| pH of all samples | 8.29 | 8.16 | 7.30 | 6.90 | 6.46 | 6.09 | 5.06 |
| Alkalinity mg/L as $CaCO_3$ of RAW and one of beakers with lowest turbidity | 240 | | 180 | | | | |