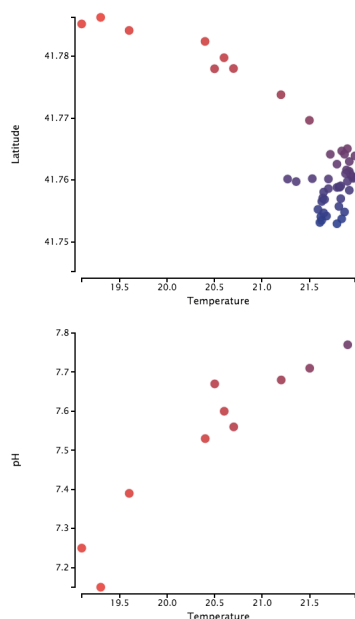


## Field trip

a)



b)  $pH = 7$

c) The alkalinity of pure water is 0

d) Samples taken from the Pawtuxet River boat launch had  $pH < 7.0$  (acidic). However, it is still possible for these waters to have a alkalinity due to the presence of bicarbonate. Alkalinity as a buffer is only depleted past pH 4.73.

e) Alkalinity has not changed because dissolution and exsolution of  $CO_2$  does not affect alkalinity. However, the pH does change because the carbon dioxide lost decreases the concentration of carbonic acid.

f) It is not possible to measure alkalinity of the water because the concentration of carbonate and bicarbonate have changed.

## Rainwater ions

a) Coastal rain may have concentrations of chloride because the main source of chloride in rainwater is sea salt. Sodium is also typically predominately from sea salt. Entry into rainwater from sea spray is important, so these are usually limited to coastal areas. Other ions such as calcium, magnesium, potassium, aluminium, and iron are more associated with terrestrial processes and are more likely to be found in continental rainwater.

ion	$Cl^-$ ratio in seawater	observed concentration	observed $Cl^-$ ratio	abundance
$Cl^-$	1	3.43	1	0
$Na^+$	0.56	2.00	0.583	+0.079
$SO_4^{2-}$	0.14	1.39	0.405	+0.910
$Mg^{2+}$	0.07	0.37	0.108	+0.130
$Ca^{2+}$	0.02	0.79	0.230	+0.721
$K^+$	0.02	0.25	0.084	+0.181

All concentrations  $mg/L$ ,  $excess = [a]_{measured} - ratio * [Cl^-]_{measured}$

c) The sodium ion concentration correlates with chloride very well; excess sodium could be from the presence of other sodium salts in seawater. Excess of magnesium and potassium are most likely of terrestrial origin. Calcium and sulfate are in great excess, and may be indicative of terrestrial biomass burning or industrial pollution. A comprehensive list can be found in the class notes.

## Alkalinity

a) Overall, the oxidation of sulfure dioxide can be expressed  $2H_2O + SO_2 \rightarrow H_2SO_4 + 2H^+$  Oxidation of  $NO_2$  is a similar reaction. It is the redox reaction which generates the proton, causing the acidity. Because protons contribute Bronsted acidity, the aprotic  $SO_4^{2-}$  anion does not contribute to acidity. It is the conjugate base of the strong acid sulfuric acid, making it a weak base, so it also does not contribute to pH changes.

b) Natural waters in some regions are less affected by acid rain than those of other regions because of alkalinity. Waters with higher alkalinity will have the ability to buffer greater addition of acids than waters with less alkalinity. The carbonate system makes up the majority of total alkalinity.  $H_2CO_3 \rightleftharpoons HCO_3^- \rightleftharpoons CO_3^{2-}$

c) Simply, alkalinity is  $[HCO_3^-] + 2[CO_3^{2-}]$ . Alkalinity is the amount of conjugate base of a weak acid available to accept a proton. If sulfuric acid is added to a water with high alkalinity, the sulfuric acid will dissociate completely, and the protons will be taken up by the carbonate and bicarbonate anions to form the weak acid carbonic acid, which has a higher pKa than sulfuric acid. The concentration of the weak acid and the salt will change, but the change in the log of their ratio is smaller, buffering the change in pH.

## Historic rainwater pH

$$\begin{aligned}[H_2CO_3] &= 3.38 * 10^{-2} \frac{mol}{atmL} * 400ppm * 7 \\ [H^+]^2 &= 10^{-6.4} * 10^{-4.02} = 10^{-10.42} \\ [H^+] &= 10^{-5.21} \\ pH &= 5.21\end{aligned}$$

## Rainwater acidity

$$\begin{aligned}[SO_4^{2-}] &= 0.19 \frac{mg}{L} = 1.9779 * 10^{-6} M \\ [NO_3^-] &= 0.25 \frac{mg}{L} = 4.0319 * 10^{-6} M \\ [H^+] &= 10^{-5.097}\end{aligned}$$

$pH = 5.097$ , this calculation only accounts for sulfuric and nitric acids; there could be other acids such as carbonic acid also.

## Goldich's stability series

Minerals which are formed in conditions which are farther away from ambient conditions on the surface of the Earth are generally less stable than those formed in conditions which are closer to those found on the surface of the Earth. Therefore, the minerals which are first to crystallize are also the ones which are first to weather. The sediments which contain mostly quartz and clays have been weathered more than those which also contain feldspars and micas because feldspars and micas are more easily weathered.

## Soil horizons

See notes

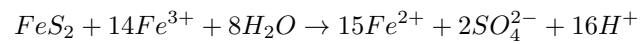
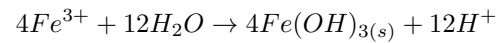
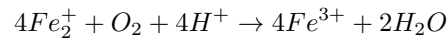
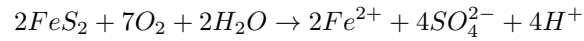
## Weathering products

Kaolinite, bauxite, and smectite are clay minerals made of sheets with different properties. Kaolinite is a clay mineral which has equal amounts of Si and Al. The mineral has alternating sheets of tetrahedral silicates and octohedral alumina; Si and Al are in a 1:1 ratio. Bauxite is an ore which contains the further weathering products of kaolinite where Si is lost as silicic acid. This occurs in hot and wet environments which are capable of leeching out even silica. Smectite minerals are hydrated and have alternating sandwiches of tetrahedral, octahedral, tetrahedral with other cations substituted into both the silicate and alumina layers. Water molecules are found in between the sandwiches. Smectite minerals make a poor material for foundations and

can cause structural damage because the soil can expand or contract due to the presence of water, causing destabilization.

## Acid mine drainage

a) Acid mine drainage:



Oxidation of  $Fe(II)$  (black) to  $Fe(III)$ , which has a orange color.

The increased acidity of the water helps to solubilize otherwise immobile  $Cd$  species.

b) The decrease the occurrence of acid mine drainage, which can often be difficult. Limestone drainage channels, anaerobic swamps, etc. Decrease flow of water through the mine.