


Arrhenius Acid Definition



- An **acid** is a substance that generates hydronium ions, H_3O^+ (often described as H^+), when added to water.
- An **acidic solution** is a solution with a significant concentration of H_3O^+ ions.

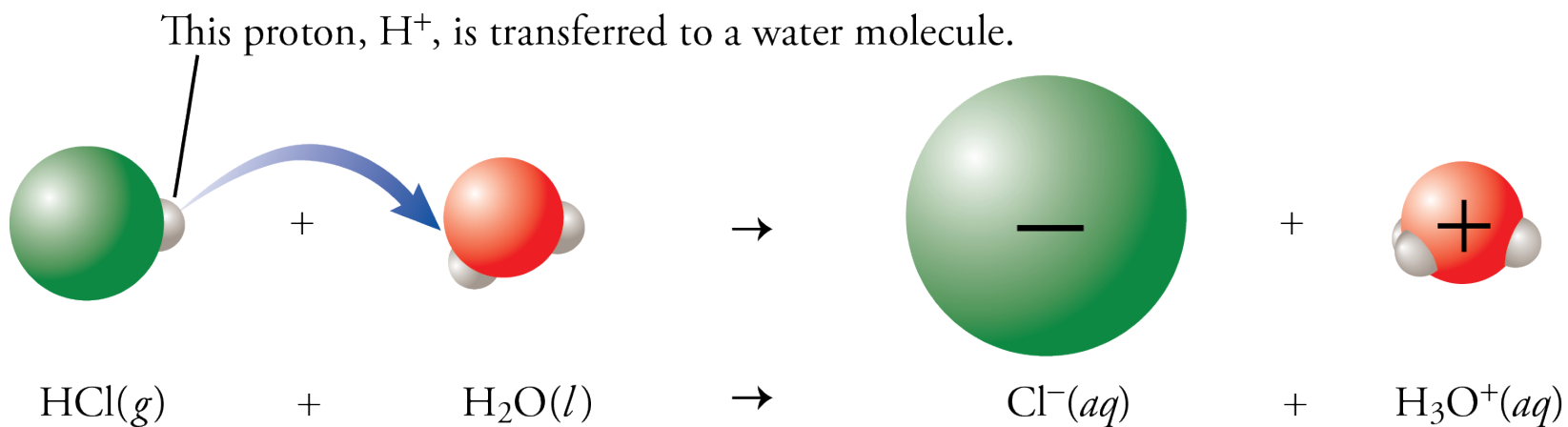
Characteristics of Acids



- Acids have a sour taste.
- Acids turn litmus from blue to red.
- Acids react with bases.

Strong Acid and Water

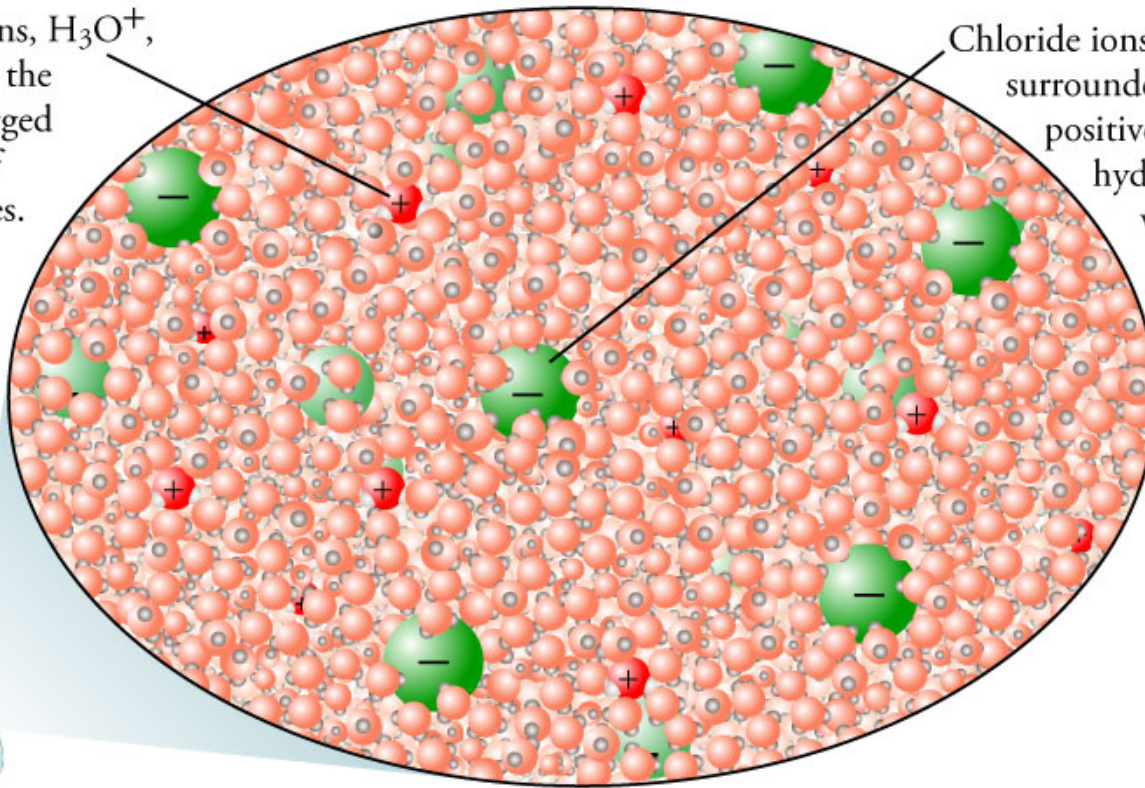
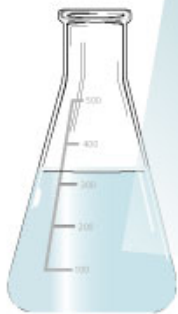
When HCl dissolves in water, hydronium ions, H_3O^+ , and chloride ions, Cl^- , ions form.



Solution of a Strong Acid

Hydronium ions, H_3O^+ , surrounded by the negatively charged oxygen ends of water molecules.

Chloride ions, Cl^- , surrounded by the positively charged hydrogen ends of water molecules.

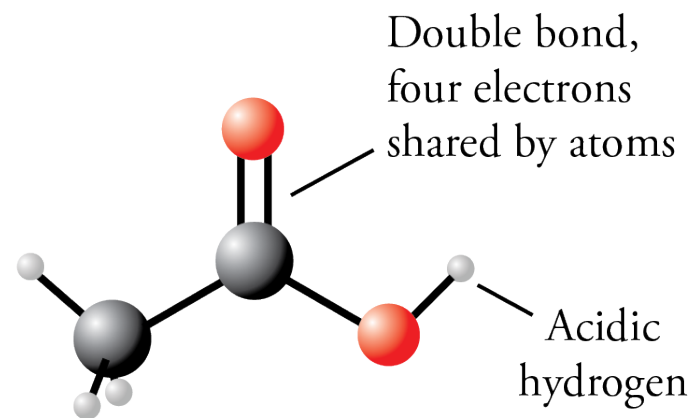
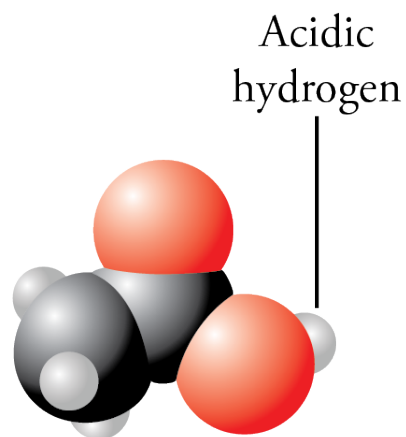
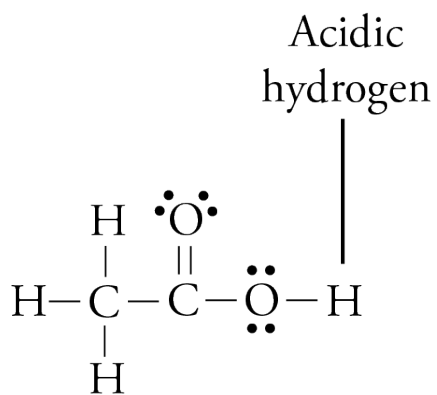


Types of Acids



- Binary acids have the general formula of $HX(aq)$
 - $HF(aq)$ and $HCl(aq)$
- Oxyacids have the general formula $H_aX_bO_c$.
 - HNO_3 and H_2SO_4
- Organic acids, which are also called carbon-based acids or carboxylic acids
 - $HC_2H_3O_2$

Acetic Acid



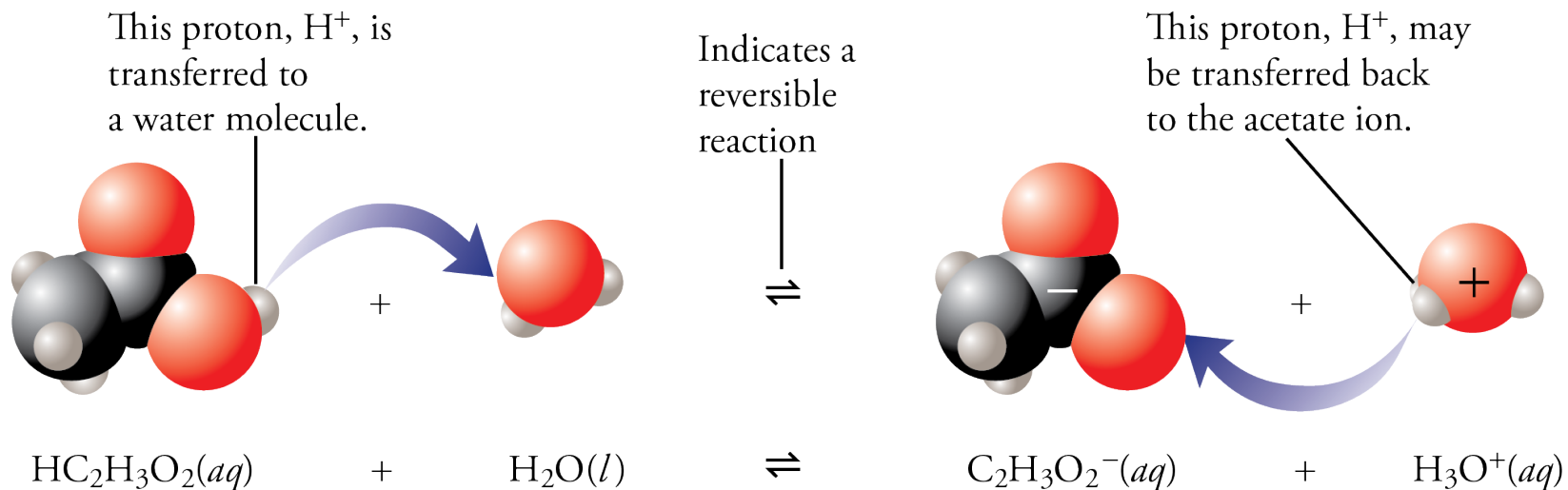
Monoprotic and Polyprotic Acids



- If each molecule of an acid can donate one hydrogen ion, the acid is called a **monoprotic acid**.
- If each molecule can donate two or more hydrogen ions, the acid is a **polyprotic acid**.
- A **diprotic acid**, such as sulfuric acid, H_2SO_4 , has two acidic hydrogen atoms.
- Some acids, such as phosphoric acid, H_3PO_4 , are **triprotic acids**.

Weak Acid and Water

Acetic acid reacts with water in a reversible reaction, which forms hydronium and acetate ions.

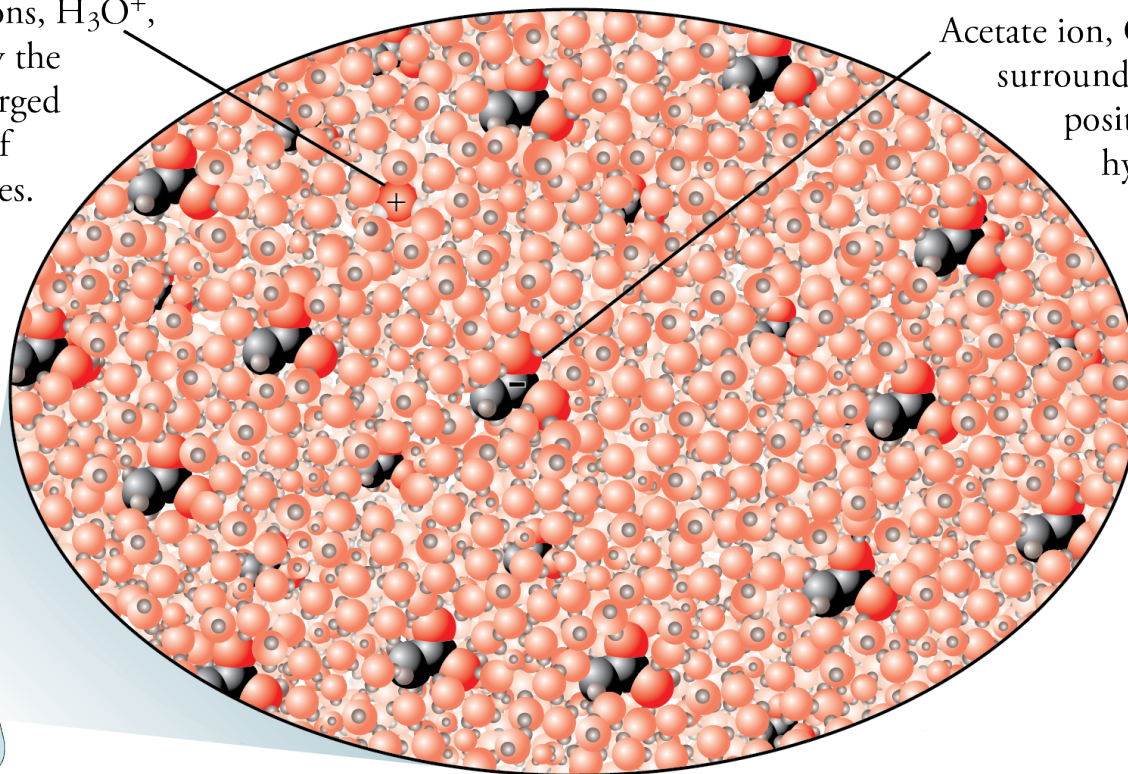
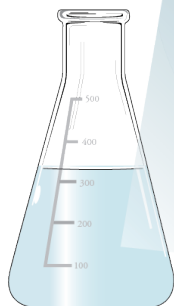


Solution of Weak Acid

In a typical acetic acid solution, there are about 250 times as many uncharged acetic acid molecules, $\text{HC}_2\text{H}_3\text{O}_2$, as acetate ions, $\text{C}_2\text{H}_3\text{O}_2^-$.

Hydronium ions, H_3O^+ , surrounded by the negatively charged oxygen ends of water molecules.

Acetate ion, $\text{C}_2\text{H}_3\text{O}_2^-$, surrounded by the positively charged hydrogen ends of water molecules.



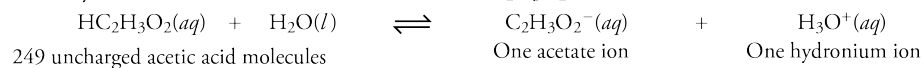
Strong and Weak Acids



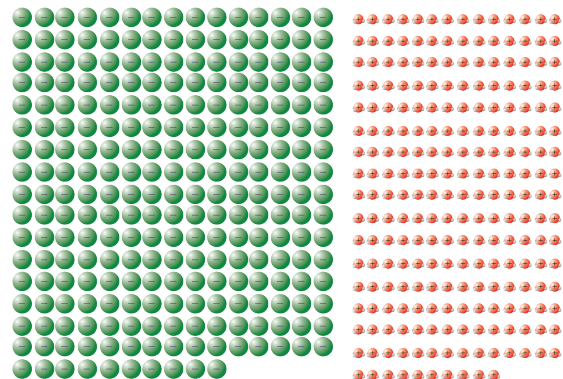
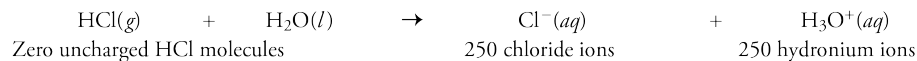
- **Weak Acid** = due to a reversible reaction with water, generates significantly less than one H_3O^+ for each molecule of acid added to water.
- **Strong Acid** = due to a completion reaction with water, generates close to one H_3O^+ for each acid molecule added to water.

Strong and Weak Acids

For every 250 molecules of the weak acid acetic acid, $\text{HC}_2\text{H}_3\text{O}_2$, added to water, there are about



For every 250 molecules of the strong acid hydrochloric acid, HCl , added to water, there are about



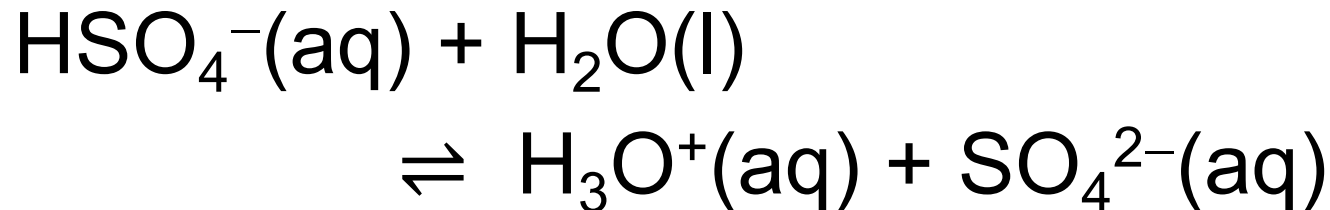
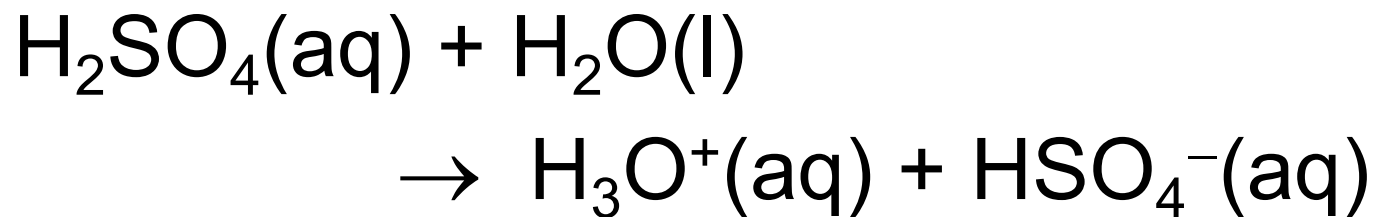
Acid Animation and Tutorial



- There is an animation on the textbook's website that will give you a better understanding of weak and strong acids.

https://preparatorychemistry.com/acids_Canvas.html

Sulfuric Acid

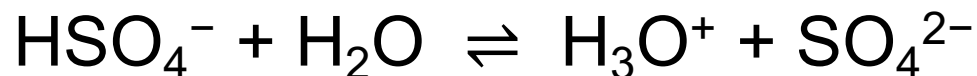
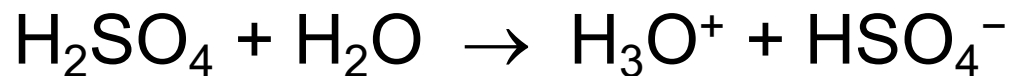


Acid Summary

	Strong	Weak
Binary acid	hydrochloric acid, HCl(aq)	Hydrofluoric acid
Oxyacid	nitric acid, HNO ₃ sulfuric acid, H ₂ SO ₄	other acids with H _a X _b O _c
Organic acid	none	acetic acid, HC ₂ H ₃ O ₂

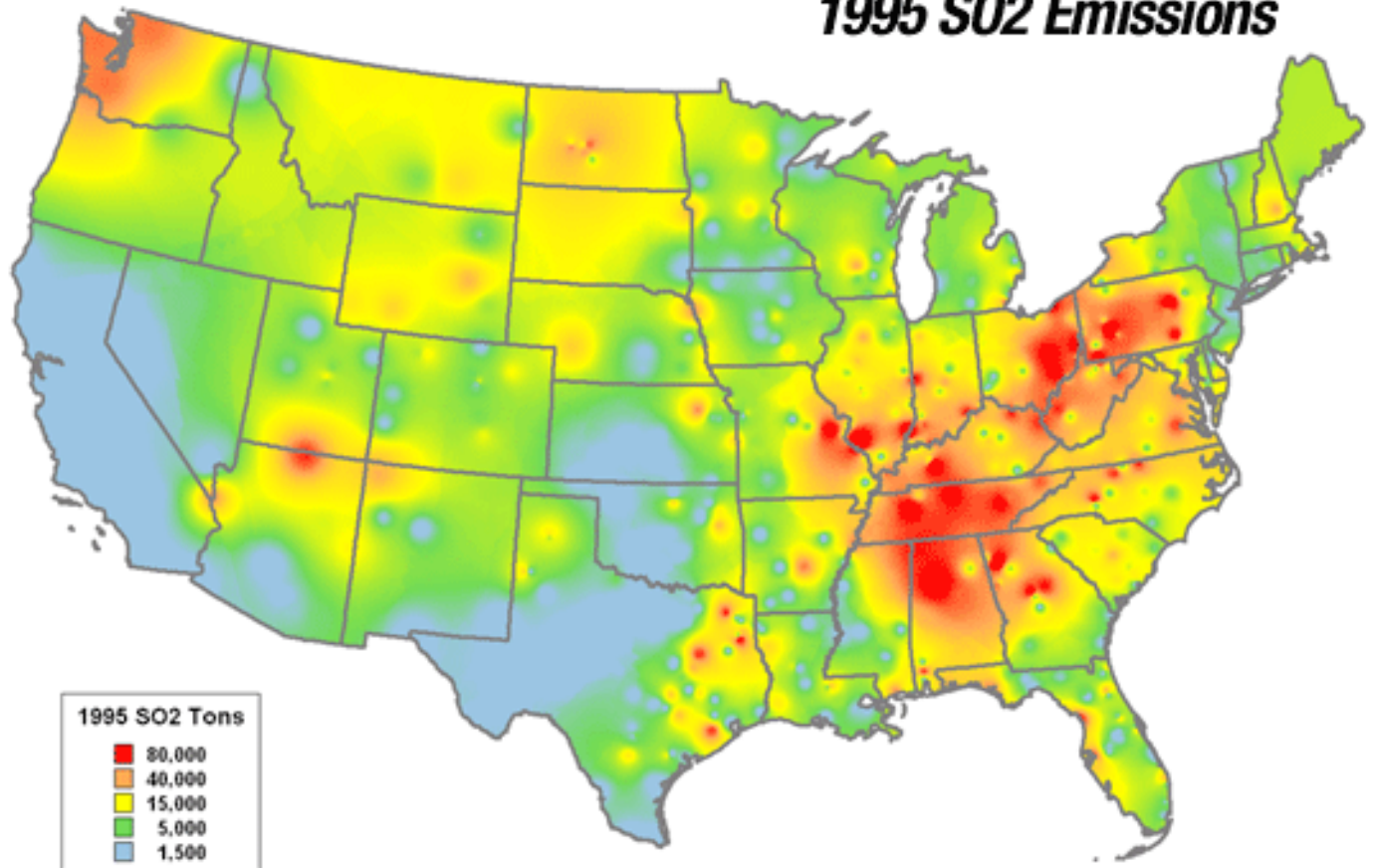
Acid Rain

- Large quantities of sulfur dioxide, SO_2 , are formed and released into the air from burning sulfur-containing substances in coal in power plants and in metal ores in smelting, which involves heating of metal ores to extract metals.
- SO_2 forms sulfuric acid, H_2SO_4 , in the atmosphere, which can dissolve in the clouds and form acid rain.
- Sulfuric acid forms hydronium ions.



1995 SO₂ Emissions

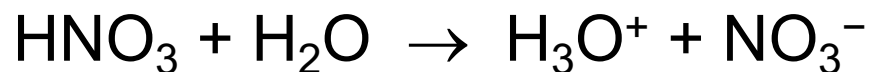
1995 SO₂ Emissions



NO_x and Nitric Acid



- The combination of air at high temperature, perhaps with a metal to act as a catalyst, leads to the formation of nitrogen monoxide, NO, and nitrogen dioxide, NO₂, often summarized as “NO_x”.
- Transportation and industry are major sources of nitrogen oxides.
- The NO₂ forms nitric acid in the atmosphere, which is a strong acid.



Acids and Acid Precursors

- Sulfur dioxide (SO_2) \rightarrow sulfuric acid (H_2SO_4)
 - primarily from coal burning and smelting
- Nitrogen oxides (NO , NO_2) \rightarrow nitric acid (HNO_3)
 - primarily from high-temperature combustion
- Formic and acetic acids (HCO_2H , $\text{CH}_3\text{CO}_2\text{H}$)
 - primarily from biomass burning, mostly in Africa and South America
- Carbonic acid ($\text{CO}_2 \rightarrow \text{H}_2\text{CO}_3$)
 - from CO_2 in atmosphere, responsible for acidity of pristine precipitation

strong acids

weak acids



pH

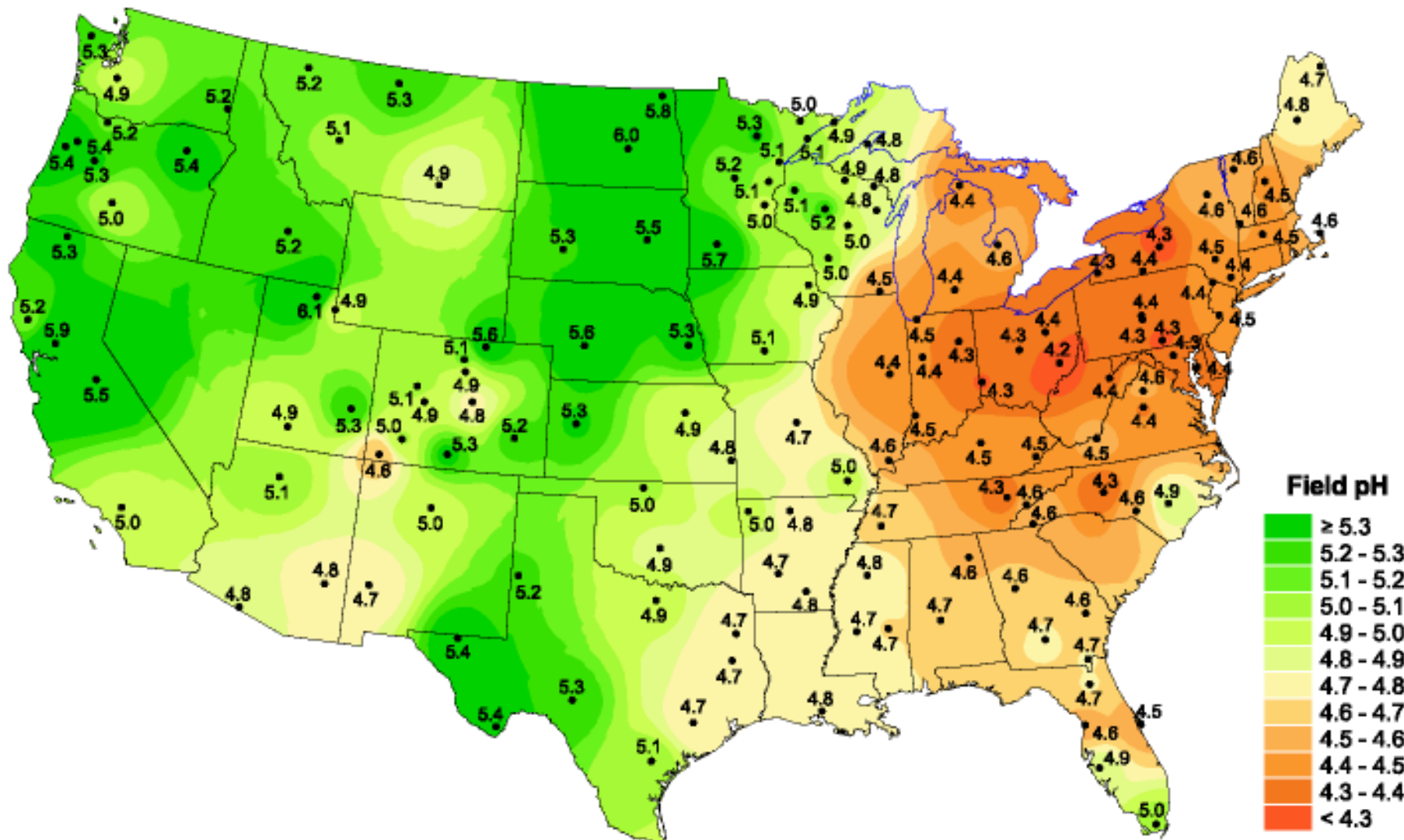
- The pH scale can be used to describe the acidity and basicity of dilute solutions of acid and base.
- Acidic solutions have pHs from 0 to 7.
- The lower the pH, the more acidic the solution, and a decrease in one pH unit is associated with an increase of 10-times the hydronium ion concentration.
- Therefore, small changes in pH reflect significant changes in H_3O^+ concentration.

Pristine Rain and Acid Rain



- Due to acids dissolved in natural rain, such as the carbonic acid that forms when CO_2 dissolves in water, pristine or unpolluted rain has a pH of about 5.6.
- Acid rain can have a pH close to 4.

Rain pH 1999



National Atmospheric Deposition Program/National Trends Network
<http://nadp.sws.uiuc.edu>

Impacts

- Lowering pH can damage freshwater ecosystems, forests, agriculture, human health, buildings, and other property.



Damage to Human Health

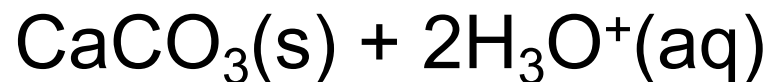


- More acidic rain dissolves more toxic metals in the soil, which increases the level of these metals in water systems, leading to consumption of fish with elevated concentrations of toxic metals (Al, Pb, Cd, Hg, Cu, Zn).
- Corrosion of pipes results in excess levels of Cu, Zn, Pb in drinking water.

Damage to Buildings and Property



- Acids etch glass, damage roofing and other building materials, and damage plastics and paint (especially automotive paint).
- Carbonate stones (marble, limestone, etc.), cement, mortar are dissolved by acids:



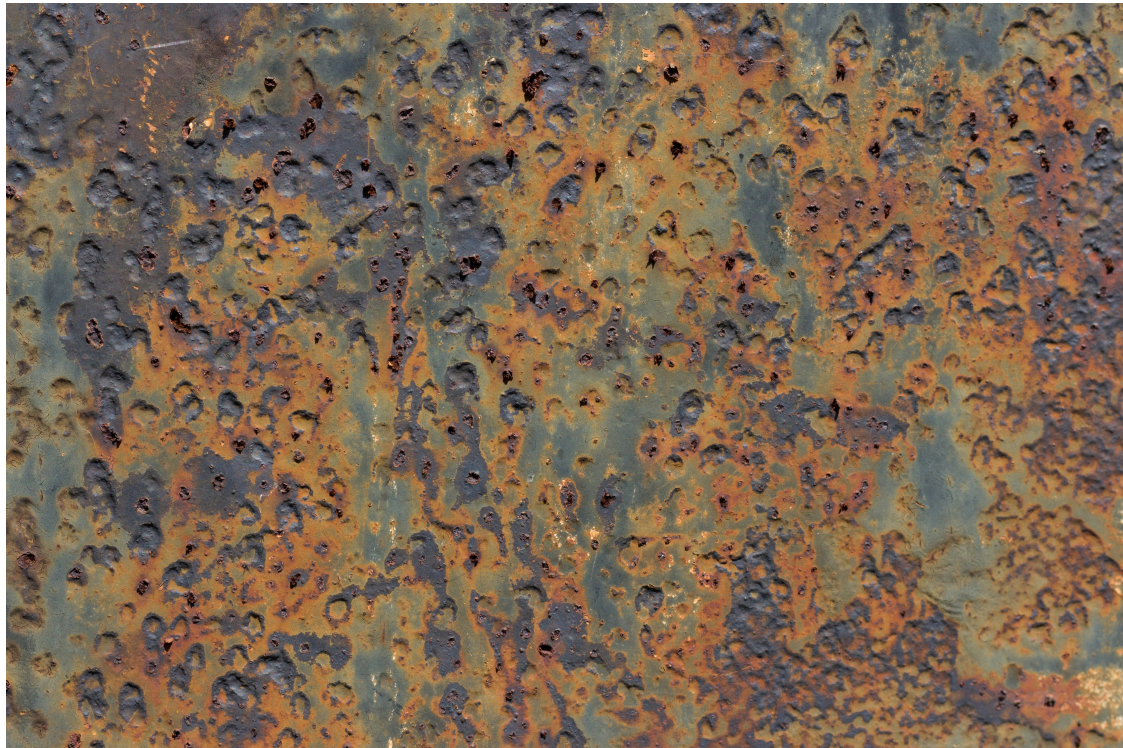
Damage to Art

The statues on the left were transported by William Randolph Hearst to his home in San Simeon, California. Because it so rarely rains there, and because San Simeon is far from any major sources of pollution, these statues are in much better condition than the similar statues found elsewhere, such as the one on the right, that have been damaged by acid rain.



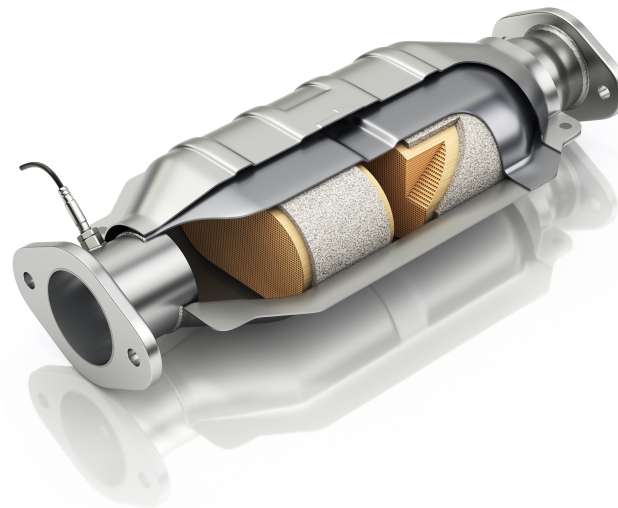
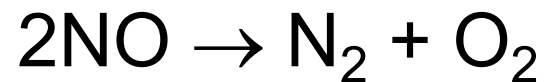
Effects on Metals

- Acid rain speeds the corrosion of metals.



Automobile Catalytic Converters

- Catalytic converters can convert up to 95% of the NO and NO₂ back to nitrogen and oxygen.



Mitigation - Sulfur



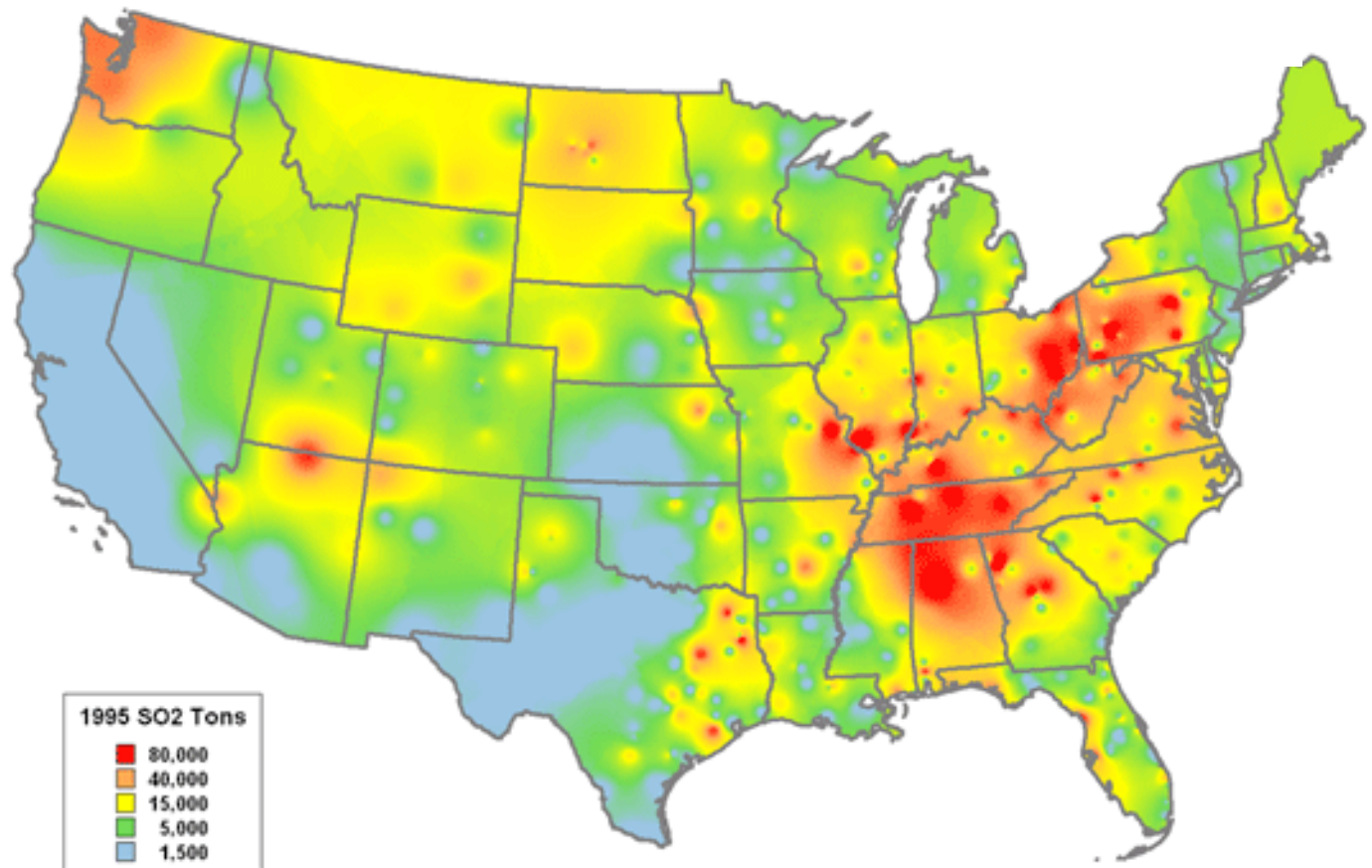
- Switch from coal to natural gas (0.001% S)
- Switch to low-sulfur coal
- Power plant scrubbers can use CaO (lime), CaCO₃ (limestone), or Ca(OH)₂ (lime) to remove SO₂ from the stack gases.

SO₂ Emissions Reduction

- Due largely to the US EPA's Acid Rain Program, the U.S. had a 33% decrease in SO₂ emissions between 1983 and 2002.



1995 SO₂ Emissions



2004 SO₂ Emissions

