

# ACID RAIN

Rain is naturally acidic as it contains dissolved carbon dioxide, which reacts with water to give carbonic acid ( $\text{H}_2\text{CO}_3$ ).

In recent times rain has become much more acidic due to:

- Higher levels of  $\text{CO}_2$  in the atmosphere.
- Emissions of sulphur dioxide, sulphur trioxide, and various oxides of nitrogen into the atmosphere.

The affect of acid rain are most noticeable downwind from industrial centres.

Acid rain is responsible outbreaks of severe respiratory ailments, destruction of forests, pollution of lakes, erosion of marble and limestone and concrete corrosion and threatens delicate ecosystems.

The low pH in heavily industrialised and populated areas is caused by the acidic oxides sulphur dioxide,  $\text{SO}_2$ , and the nitrogen oxides  $\text{NO}$  and  $\text{NO}_2$ .

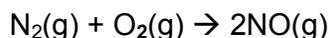
Rain unaffected by human activity contains mostly weak acids and has a pH of 5.7. The primary acid present is carbonic acid,  $\text{H}_2\text{CO}_3$ , which results from the dissolving of atmospheric carbon dioxide, an acidic oxide, in water.



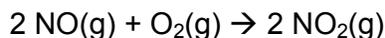
$$K = \frac{\text{H}_2\text{CO}_3}{\text{CO}_2(\text{gas})} = 10^{-1.5}$$

Not much  $\text{CO}_2$  dissolves but insufficient to shift the pH to about 5.7 for natural rain water.

The serious pollutants in acid rain are strong acids. Atmospheric nitrogen and oxygen can react to form  $\text{NO}$  at high temperatures of automobile internal combustion engines and electrical power stations:



Nitric oxide,  $\text{NO}$ , is not very soluble in water, but it can be oxidised further in air to form nitrogen dioxide:



The  $\text{NO}_2$  reacts with water, forming nitric acid and nitric oxide:

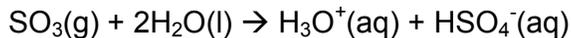
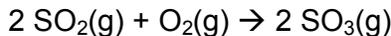


Catalytic converters in automobiles reduce the nitrogen in  $\text{NO}$  to  $\text{N}_2$  and are required in the United States for all new cars and trucks.

Sulphur dioxide is produced as a by product of burning of fossil fuels. It may combine with water directly to form sulphurous acid, a weak acid:



Alternatively, in the presence of particulate matter and aerosols, sulfur dioxide may react with atmospheric oxygen to form sulphur trioxide, which forms sulfuric acid in water:



Sulfuric acid is a strong acid that is especially damaging to soil because it causes the leaching of calcium ions. Most soil contains clay particles, which are surrounded by layers of ions, including  $\text{Ca}^{2+}$ . However, calcium ions on the clay particles can be replaced by hydrogen ions from sulphuric acid. Because calcium sulphate is insoluble in water, it can no longer circulate through the soil or be taken up by plants. If the calcium leached from soil is not replaced, plants suffer and entire forests can be affected.

Research on the impact of air pollution on forests is difficult. Forests cover such vast areas and the interplay of ionic air pollutants is so subtle that it may take many years to clarify the role of environmental stresses. However, control of acidic oxide emissions can be improved to maintain our quality of life without losing our precious natural heritage.

One process used to clean  $\text{SO}_2$  from the emissions of coal-fired furnaces is to pass the stack gases through a wet calcium carbonate slurry, where the following reaction occurs:



The problem remains as to what to do with the gypsum.

In the United States of America a program of emissions trading with sulphur dioxide ( $\text{SO}_2$ ) has commenced under the auspices of the Environmental Protection Agency.

*“The Acid Rain Program is working to significantly reduce electric utilities emissions of sulphur dioxide and nitrogen oxides, the pollutants responsible for acid deposition. The program’s system of tradeable  $\text{SO}_2$  emissions allowances is a landmark use of market incentives in environmental protection.”<sup>1</sup>*

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<sup>1</sup> United States Environmental Protection Agency Acid Rain Program at <http://www.epa.gov/docs/acidrain/ardhome.html>