

## pH Calculations

All aqueous solutions (water) contain some  $H^+$  ions and some  $OH^-$  ions.

- *Neutral* solutions contain equal concentrations of each
- *Acidic* solutions contain more  $H^+$  ions
- *Basic* solutions contain more  $OH^-$  ions

$pH = -\log[H^+]$  where  $[H^+]$  is the hydrogen ion concentration in  $\text{mol L}^{-1}$

$pOH = -\log[OH^-]$  where  $[OH^-]$  is the hydroxide ion concentration in  $\text{mol L}^{-1}$

$pH + pOH = 14$

$$[H^+] = 10^{-pH}$$

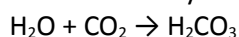
$$[OH^-] = 10^{-pOH}$$

$$[H^+] \times [OH^-] = 10^{-14} \text{ at } 25^\circ\text{C}$$

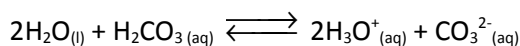
When hydrogen ions ( $H^+$ ) are in aqueous solution they 'attach' themselves to the unbonded electron pair and hence are also known as hydronium ions ( $H_3O^+$ ).

## Acid Rain

Rain is naturally acidic (a pH between 6.5 and 5.6) because  $CO_2$  dissolves in it to make carbonic acid:

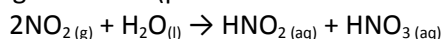


The acid then partially ionises to produce acidic solution:

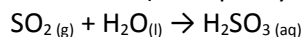


Rain becomes "acid rain" when its pH drops below 5.6. It usually occurs when oxides of nitrogen and sulfur dissolve in water in the atmosphere.

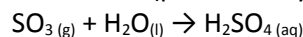
Nitrogen dioxide (produced when nitric oxide  $NO$  reacts with  $O_2$  in the atmosphere):



Sulphur dioxide (an impurity in carbon-based fuels):



Sulphur trioxide (produced by some of the released  $SO_2$  reacting with  $O_2$  in the atmosphere):



Nitric acid ( $HNO_3$ ) and sulfuric acid ( $H_2SO_4$ ) are strong acids, so are the major contributors to acid rain.

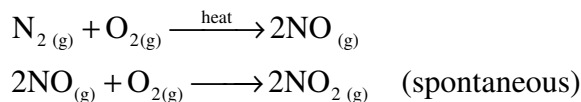
Acid rain has harmful environmental effects:

- Corrodes metals and carbonates. Example equations:
  - $Fe(s) + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2(g)$
  - $CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$
- Causes mobilisation in the soil (leaching) of toxic cations such as aluminium, lead and cadmium
  - Example:  $Al^{3+}_{(soil)} + H^+(aq) \rightarrow Al^{3+}_{(aq)} + H^+(soil)$
  - Free aluminium ions disrupt defense mechanisms in plants and damage necessary bacteria
  - Free aluminium ions adhere to gills of fish and restrict oxygen supply leading to suffocation
  - Toxic cations (lead, cadmium, etc) can enter human drinking water and cause disease or death
- Reduces the pH in lakes and rivers, reducing fish populations
  - Eggs and fry (recently-hatched fish) are sensitive to low pH
  - Low pH leads to excessive loss of sodium from the gills
- Damages the foliage of plants

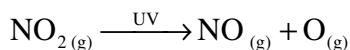
## Photochemical Smog

Photochemical smog is a form of lower atmosphere pollution which is visible as a yellow-brown haze, and is made up of many primary and secondary pollutants.

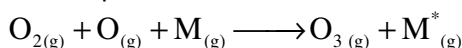
High temperature engines and furnaces can allow  $N_2$  to react with  $O_2$ , producing NO, which spontaneously reacts with  $O_2$  to produce  $NO_2$ :



Nitrogen oxides lead to the formation of ozone in the lower atmosphere (troposphere). Nitrogen dioxide absorbs UV and breaks into nitric oxide (NO) and atomic oxygen (O).



The atomic oxygen is then able to react with  $O_2$  present and form  $O_3$ . This reaction releases excess energy which must be absorbed by a 'stabilising' molecule (commonly  $N_2$  or  $O_2$  but represented as M in the equation below). The \* represents that the molecule is absorbing the excess energy.



'Primary pollutants' are released directly into the atmosphere. They commonly come from sources such as combustion engines and furnaces, and include NO, CO,  $CO_2$ ,  $SO_2$  and unburnt hydrocarbons.

'Secondary pollutants' are formed when primary pollutants react with air, water or sunlight. Examples are  $O_3$ ,  $NO_2$ ,  $SO_3$ ,  $HNO_3$ , and  $H_2SO_4$ .

**Note:** Ozone is a pollutant in the troposphere but not in the stratosphere (where the ozone layer is).

Harmful effects of ozone:

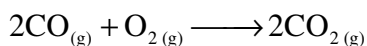
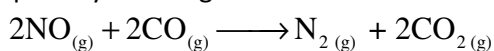
- Health problems in animals (adverse effects on respiratory system)
- Reduction of photosynthesis in plants (yellowing of leaves)
- Break chains in long molecules (e.g. rubber, polymers) causing cracking and perishing

Harmful effects of oxides of nitrogen:

- Similar effects on plants and animals as ozone
- Forms acid rain

## Catalytic Converters

A catalytic converter contains platinum or a similar element which acts as a catalyst for reactions which reduce the quantity of nitrogen oxides and carbon monoxide emitted.

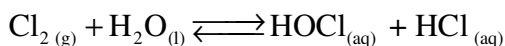


## Water Treatment

*Flocculation* is a process by which suspended particles in water can be removed. Salts containing highly charged cations (such as  $Al^{3+}$ ) are added to the water. Clay particles in water are negatively charged so the cations will attract them and join them together in larger clumps which are too large to stay suspended and will settle. The clay can then be removed as a sediment or filtered out.

For water to be potable (suitable for drinking) the bacteria in it must be killed. One way of achieving this is to treat the water with an oxidising agent such as  $Cl_2$  (chlorine gas) or  $OCl^-$  (hypochlorite ions).

One equilibrium that occurs in pool water is shown below.



This equilibrium depends on the pH and the temperature.

Chlorine, hypochlorous acid and hypochlorite ions are all oxidising agents. They oxidise bacteria (killing it) and are in the process reduced to chloride ions.