

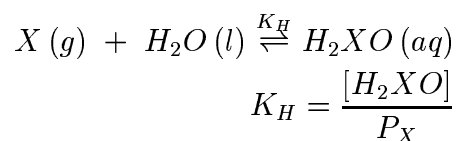
# Acid Rain

## Outline:

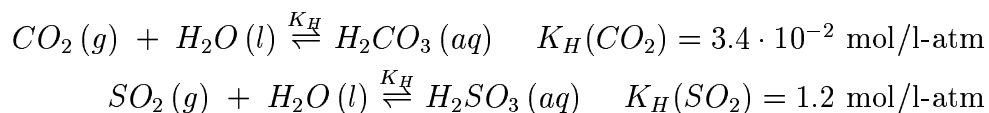
1. Constituents of rainwater
2. pH and pKa
3. Sources of acid rain
4. Adverse effects of acid rain
5. Controls

## 1: Constituents of rainwater

- Gases are soluble in water: Henry's law



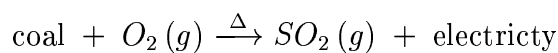
- Examples



- Important soluble gases:  $CO_2$ ,  $SO_2$  and  $NO_2$  (  $K_H(NO_2) = 6.4 \cdot 10^{-3} \text{ mol/l-atm}$  )
  - Direct absorption of  $NO_2(g)$  negligible:  $HNO_3$  produced by action of hydroxy radical
- Major sources of soluble gases (reminder)

- $SO_2$

1. Coal burning



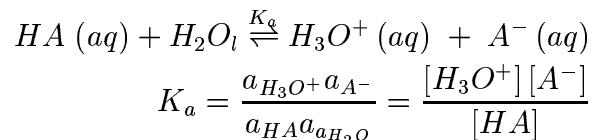
2. Volcanos

- $NO_2$

1. Natural: microbial decomposition in soil, lightning
2. Anthropogenic: transportation industry

# pH and pKa

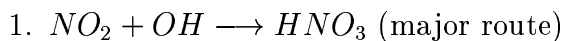
- $pH = -\log a_{H_3O^+} = -\log [H_3O^+]$ .
- Hydrogen bonding in water leads to important physical properties:
  1. Density of ice lower than liquid water in range  $T = 0-4$  C. Important in evolution of life
  2. Pressure dependence: applying pressure melts ice
  3. Hydrophobic and hydrophilic interactions: protein structure, membranes, micelles, ...
- $H_3O^+$  represents an excess proton in water.
  - Proton “solvated” by surrounding water molecules in cage-like structure
  - Rapid and complicated dynamics of proton motion in water
- $pKa = -\log K_a$ , where  $K_a$  is the dissociative equilibrium constant for the reaction



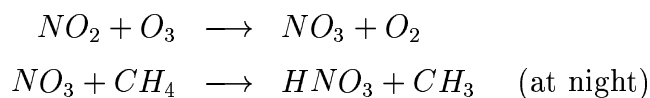
- Large  $K_a \implies$  lots of dissociation  $\implies$  strong acid.
- Key Point: solubility and strength of acid important for pH
  - Small amounts of  $SO_2$  greatly affect pH since
    1. Very soluble in  $H_2O$ : large  $K_H$
    2. Strong acids formed upon dissolving:  $H_2SO_4$  and  $H_2SO_3$ .

# Chemistry of Acid Rain

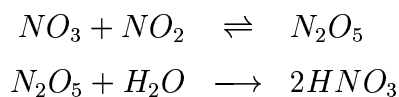
- $NO_2$  chemistry



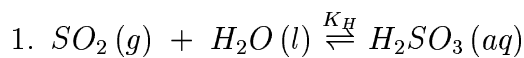
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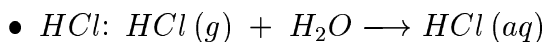
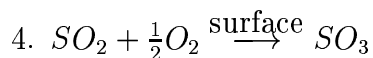
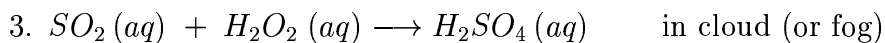
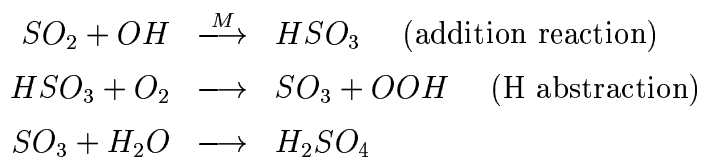
- 3.



- $SO_2$  chemistry



- 2.



**Primary cause of acid rain:**  $SO_2$  processes

- Occasionally  $HNO_3$  more important when very high levels of  $NO_x$ -Southern California