## 1.9.3: Henry's Law

Having a soft drink in outer space poses some special problems. Under microgravity, the carbonation can quickly dissipate if not kept under pressure. You can't open the can, or you will lose carbonation. So, a special pressurized container has been developed to get around the problem of gas loss at low gravity.

### Henry's Law

Pressure has very little effect on the solubility of solids or liquids, but has a significant effect on the solubility of gases. Gas solubility increases as the partial pressure of a gas above the liquid increases. Suppose a certain volume of water is in a closed container with the space above it occupied by carbon dioxide gas at standard pressure. Some of the $\mathrm{CO_2}$ molecules come into contact with the surface of the water and dissolve into the liquid. Now suppose that more $\mathrm{CO_2}$ is added to the space above the container, causing a pressure increase. In this case, more $\mathrm{CO_2}$ molecules are in contact with the water and so more of them dissolve. Thus, the solubility increases as the pressure increases. As with a solid, the $\mathrm{CO_2}$ that is undissolved reaches an equilibrium with the dissolved $\mathrm{CO_2}$, represented by the equation:

$$\mathrm{CO_2}\,(g) \rightleftharpoons \mathrm{CO_2}\,(aq)$$

At equilibrium, the rate of gaseous $\mathrm{CO_2}$ dissolution is equal to the rate of dissolved $\mathrm{CO_2}$ coming out of the solution.

When carbonated beverages are packaged, they are done so under high $\mathrm{CO_2}$ pressure so that a large amount of carbon dioxide dissolves in the liquid. When the bottle is open, the equilibrium is disrupted because the $\mathrm{CO_2}$ pressure above the liquid decreases. Immediately, bubbles of $\mathrm{CO_2}$ rapidly exit the solution and escape out of the top of the open bottle. The amount of dissolved $\mathrm{CO_2}$ decreases. If the bottle is left open for an extended period of time, the beverage becomes "flat" as more and more $\mathrm{CO_2}$ comes out of the liquid.

The relationship of gas solubility to pressure is described by Henry's law, named after English chemist William Henry (1774-1836). **Henry's Law** states that the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid. Henry's law can be written as follows:

$$\frac{S_1}{P_1} = \frac{S_2}{P_2}$$

$S_1$ and $P_1$ are the solubility and the pressure at an initial set of conditions; $S_2$ and $P_2$ are the solubility and pressure at another changed set of conditions. The solubility of a gas is typically reported in $\mathrm{g/L}$.

#### Example 1.9.3.1

The solubility of a certain gas in water is $0.745\ \mathrm{g/L}$ at standard pressure. What is its solubility when the pressure above the solution is raised to $4.50\ \mathrm{atm}$? The temperature is constant at $20^\mathrm{o}\mathrm{C}$.

**Solution**

***Step 1: List the known quantities and plan the problem.***

**Known**

- $S_1 = 0.745\ \mathrm{g/L}$
- $P_1 = 1.00\ \mathrm{atm}$
- $P_2 = 4.50\ \mathrm{atm}$

**Unknown**

Substitute into Henry's law and solve for $S_2$.

***Step 2: Solve.***

$$S_2 = \frac{S_1 \times P_2}{P_1} = \frac{0.745\ \mathrm{g/L} \times 4.50\ \mathrm{atm}}{1.00\ \mathrm{atm}} = 3.35\ \mathrm{g/L}$$

***Step 3: Think about your result.***

The solubility is increased to 4.5 times its original value, according to the direct relationship.

## Summary