Expressing Concentration

- **Concentration** is defined as the amount/quantity of solute relative to the amount/quantity of solvent
- A solution is considered **dilute** when there are relatively small amounts of solute dissolved in a large amount of solvent
- A solution is considered **concentrated** when there is a large ratio of solute to solvent
- Concentrations can be expressed in a variety of ways and units
- **Percent by mass** is a concentration that compares the mass of a solute to the mass of solution, expressed as a percentage
  ↳ solvent + solute! NOT just solvent

* memorize!

$$\%\ \text{mass} = \frac{\text{mass solute}}{\text{mass solution}} \times 100\%$$

* units just need to be consistent!

  - Percent by mass is also referred to as *mass percent*

EXAMPLES:

1. Calcium chloride, $CaCl_{2(s)}$, can be used instead of road salt to melt ice on roads during the winter. To determine how much calcium chloride had been used on a nearby road, a student took a sample of slush to analyze. The sample had a mass of 23.47g. When the solvent was evaporated, the residue had a mass of 4.58g. What was the percent by mass of calcium chloride in the slush?

$m_{solution} = 23.47\text{g}$

$m_{solute} = 4.58\text{g}$

$\%\ \text{mass} = ?$

$$\%\ \text{mass} = \frac{4.58\text{g}}{23.47\text{g}} \times 100\%$$

$\%\ \text{mass} = 19.5142...\%$

$\%\ \text{mass} = 19.5\%$

2. Sterling silver is a metal alloy that contains copper and silver. If a sterling silver ring contains 11.1g of pure silver and 0.90 g of copper, what is the mass percent of silver in the ring?

$\%$ mass = ? → the solute!

$m_{solute} = 11.1\,g$

$m_{solution} = 11.1\,g + 0.90\,g$

$m_{solution} = 12.0\,g$

$$\%\ mass = \frac{m_{solute}}{m_{solution}} \times 100\%$$

$$\%\ mass = \frac{11.1\,g}{12.0\,g} \times 100\%$$

$$\%\ mass = 92.5\%$$

$$\boxed{\%\ mass = 93\%}$$

- For very small concentrations, the concentration **parts per million (ppm)** is commonly used

*memorize!

$$ppm = \frac{mass\ of\ solute}{mass\ of\ solution} \times 10^6$$

units just need to be consistent!

  - For example, air that contains 30 ppm carbon monoxide contains 30g of carbon monoxide per 1 000 000g (1 million grams) of air

- To use parts per million as a concentration for aqueous solutions, keep in mind that 1 mL of water has a mass of approximately 1g
  - 1 mL = 1 g for aqueous solutions

EXAMPLES:

1. Dissolved oxygen in natural waters is an important measure of the health of the ecosystem. In a chemical analysis of 250mL of water at SATP, 2.2mg of oxygen was measured. What is the concentration of oxygen in parts per million?

$m_{oxygen} = 2.2\text{mg} \times \left(\frac{10^{-3}}{1\text{m}}\right)$

$m_{oxygen} = 0.0022\text{g}$

$V_{solution} = 250\text{mL}$

$m_{solution} = 250\text{g}$

$ppm = ?$

$$ppm = \frac{m_{solute}}{m_{solution}} \times 10^6$$

$$ppm = \frac{0.0022\text{g}}{250\text{g}} \times 10^6$$

$$\boxed{ppm = 8.8\ ppm}$$

2. "Hard" water contains a relatively large quantity of dissolved minerals, one of which is calcium carbonate. Hard water in Alberta may contain up to 300 ppm of calcium carbonate. Older models of toilets use up to 20L per flush. How much calcium carbonate could be crystalized from the water in one flush of an older model of toilet?

$ppm = 300\ ppm$

$V_{solution} = 20\text{L} \times \left(\frac{1\text{m}}{10^{-3}}\right)$

$V_{solution} = 2.0 \times 10^4\text{mL}$

$m_{solution} = 2.0 \times 10^4\text{g}$

$m_{solute} = ?$

$$ppm = \frac{m_{solute}}{m_{solution}} \times 10^6$$

$$\frac{(ppm)(m_{solution})}{10^6} = m_{solute}$$

$$\frac{(300\text{ppm})(2.0 \times 10^4\text{g})}{10^6} = m_{solute}$$

$$\boxed{6.0\text{g} = m_{solute}}$$

*****Now try Practice Problems*****

Practice Problems

1. An aqueous solution with a mass of 82.0g contains 17.0g of sulphuric acid, $H_2SO_{4(aq)}$. Calculate the percent mass of the sulphuric acid. **[20.7 %]**
2. If 55.0g of potassium hydroxide, $KOH_{(s)}$, is dissolved in 100.0g of water, what is the concentration of the solution expressed as a percent by mass? **[35.5 %]**
3. Steel contains about 98.3% iron and about 1.7% carbon. It also contains very small amounts of other materials, such as manganese and phosphorus. What mass of carbon, in grams, is needed to make a 5.0kg sample of steel? **[85 g]**
4. Most cutlery is made of stainless steel, which is a variety of steel that resists corrosion. Stainless steel contains at least 10.5% chromium. What is the minimum mass of chromium needed to make a stainless steel fork with a mass of 60.5g? **[6.35 g]**
5. Symptoms of mercury poisoning become apparent after a person has accumulated 20mg of mercury in his or her body. Express this concentration as parts per million for a 60kg person. **[0.33 ppm]**
6. A concentration of 700 ppm hydrogen sulphide in air will cause a person to lose consciousness. Express this concentration as a percent by mass. **[0.07000%]**
7. The use of the pesticide DDT has need banned in Canada since 1969 because of its damaging effect on wildlife. In 1969, the concentration of DDT in an average lake trout, taken from Lake Simcoe in Ontario, was 16 ppm. Today it is less than 1 ppm. What mass of DDT would have been present in a 2.5kg trout with a DDT concentration of 16 ppm? **[0.040g]**
8. The sample of drinking water has a fluoride concentration of 1.6 ppm. If the average adult consumes 2.0L of water daily, what mass of fluoride is consumed daily? **[0.0032g]**