**Unit 3 Matter as Solutions, Acids, and Bases**
**Chapter 5 Solutions**
**Solutions to Practice Problems**

**1. a)**
**Problem**
Calculate the percent by mass of an aqueous solution with a mass of 82.0 g that contains 17.0 g of hydrogen sulfate, $H_2SO_4(l)$.

**What is Required?**
You must calculate the mass of hydrogen sulfate, $H_2SO_4(l)$, that is present in 100 g of solution. This is the percent by mass.

**What is Given ?**
The mass of solute (hydrogen sulfate) is 17.0 g and the mass of solution is 82.0 g.

**Plan Your Strategy**

$$\text{The percent by mass } (m/m) = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$$

**Act on Your Strategy**

$$\text{Percent by mass } (m/m) = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$$

$$= \frac{17.0\text{ g}}{82.0\text{ g}} \times 100\%$$

$$= 20.7\%$$

**Solution**
The concentration of the solution in mass/mass percent is 20.7% (*m/m*)

**Check Your Solution**
The answer has the correct units (percent *m/m*) and the correct number of significant digits (3).

**1. b)**
**Problem**
Calculate the percent by mass of an aqueous solution with a mass of 110.6 g that contains 18.37 g of sodium chloride, NaCl(s).

**What is Required?**
You must calculate the mass of sodium chloride, NaCl(s), that is present in 100 g of solution. This is the percent by mass.

**What is Given ?**
The mass of solute (sodium chloride) is 18.37 g and the mass of solution is 110.6 g.

**Plan Your Strategy**

The percent by mass (*m/m*) = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$

**Act on Your Strategy**

Percent by mass (*m/m*) = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$

$= \frac{18.37\ \text{g}}{110.6\ \text{g}} \times 100\%$

$= 16.61\%$

**Solution**

The concentration of the solution in mass/mass percent is 16.61% (*m/m*)

**Check Your Solution**

The answer has the correct units (percent *m/m*) and the correct number of significant digits (4).

**1. c)**

**Problem**

Calculate the percent by mass of a benzene solution with a mass of 85.4 g that contains 12.9 g of carbon tetrachloride, $CCl_4(l)$.

**What is Required?**

You must calculate the mass of carbon tetrachloride, $CCl_4(l)$, that is present in 100 g of solution. This is the percent by mass.

**What is Given ?**

The mass of solute ($CCl_4$) is 12.9 g and the mass of solution is 85.4 g.

**Plan Your Strategy**

The percent by mass (*m/m*) = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$

**Act on Your Strategy**

Percent by mass (*m/m*) = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$

$= \frac{12.9\ \text{g}}{85.4\ \text{g}} \times 100\%$

$= 15.1\%$

**Solution**

The concentration of the solution in mass/mass percent is 15.1% (*m/m*)

**Check Your Solution**
The answer has the correct units (percent *m/m*) and the correct number of significant digits (3).

**2.**
**Problem**
If 55.0 g of potassium hydroxide, KOH(s), is dissolved in 100.0 g of water, what is the concentration of the solution expressed as a percent by mass? (**Hint:** Remember to use the mass of the *solution*, not the mass of the *solvent* in your calculation.)

**What is Required?**
You must calculate the concentration of the potassium hydroxide solution as percent by mass.

**What is Given ?**
The mass of solute (potassium hydroxide) is 55.0 g and the mass of solvent (water) is 100 g.

**Plan Your Strategy**
Calculate the total mass of solution (solute + solvent). Substitute the given amounts into percent by mass (*m/m*) = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$

**Act on Your Strategy**
mass of solution = mass of solute + mass of solvent
= 55.0 g + 100.0 g
= 155.0 g

Percent by mass (*m/m*) = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$
$= \frac{55.0\text{ g}}{155.0\text{ g}} \times 100\%$
= 35.5%

**Solution**
The concentration of the solution in mass/mass percent is 35.5% (*m/m*)

**Check Your Solution**
The answer has the correct units (percent *m/m*) and the correct number of significant digits (3).

**3.**
**Problem**
Steel contains about 98.3 percent iron and about 1.7 percent 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 5.0 kg sample of steel?

**What is Required?**
You must calculate the mass of carbon required to make 5.0 kg of steel.

**What is Given?**
You know that the alloy is 1.7 percent carbon by mass. The total mass of the alloy is 5.0 kg.

**Plan Your Strategy**
Since percent by mass (*m/m*) = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$, therefore, mass of solute (carbon) =
mass percent × mass of solution
Convert the mass of carbon from kilograms to grams by multiplying by 1000 g/kg.

**Act on Your Strategy**
$$\text{mass of carbon} = \frac{1.7\,\text{g}}{100\,\text{g}} \times 5.0\ \text{kg}$$

$$= 0.085\ \text{kg}$$

$$0.085\ \text{kg} \times \frac{1000\,\text{g}}{1\,\text{kg}} = 85\ \text{g}$$

**Solution**
The mass of carbon in 5.0 kg of steel is 85 g.

**Check Your Solution**
This answer has the correct units (g) and the correct number of significant digits (2).

**4.**
**Problem**
Most cutlery is made of stainless steel, which is a variety of steel that resists corrosion. Stainless steel contains at least 10.5 percent chromium. What is the minimum mass of chromium needed to make a stainless steel fork with a mass of 60.5 g?

**What is Required?**
You must determine the minimum mass of chromium in a stainless steel fork that has a mass of 60.5 g.

**What is Given?**
The percent by mass of chromium in the steel is 10.5 percent and the fork has a mass of 60.5 g.

**Plan Your Strategy**
Since percent by mass (*m/m*) = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$, therefore, mass of solute (chromium) = mass percent × mass of solution (fork)

**Act on Your Strategy**
$$\text{mass of chromium} = \frac{10.5\,\text{g}}{100\,\text{g}} \times 60.5\,\text{g} = 6.35\ \text{g}$$

**Solution**
The minimum mass of chromium is 6.35 g.

**Check Your Solution**
This answer has the correct units (g) and the correct number of significant digits (3).

**5.**
**Problem**
Eighteen-carat white gold is an alloy. It contains 75 percent gold, 12.5 percent silver, and 12.5 percent copper. A piece of jewelry, made of 18-carat white gold, has a mass of 20 g. What mass of pure gold (in grams) does it contain?

**What is Required?**
You must determine the minimum mass of pure gold in a piece of jewelry that has a mass of 20 g.

**What is Given?**
The percent by mass of gold in the jewelry is 75 percent and the piece of jewelry (solution) has a mass of 20 g.

**Plan Your Strategy**

Since percent by mass (*m/m*) = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$,

therefore, mass of solute (gold) = mass percent × mass of solution

**Act on Your Strategy**

mass of pure gold = $\frac{75\,\text{g}}{100\,\text{g}} \times 20\,\text{g} = 15\ \text{g}$

**Solution**
The minimum mass of gold is 15 g.

**Check Your Solution**
This answer has the correct units (g) and the correct number of significant digits (2).

**6. a)**
**Problem**
Symptoms of mercury poisoning become apparent after a person has accumulated 20 mg of mercury in his or her body. Express this concentration as parts per million for a 60 kg person.

**What is Required?**
You must express the concentration of mercury in a 60 kg person as ppm.

**What is Given?**
The mass of the person (solution) is 60 kg and the mass of mercury (solute) is 20 mg.

**Plan Your Strategy**
Convert the mass of the person from kilograms to grams by multiplying 60 kg by 1000 g/kg and the mass of mercury from milligrams to grams by multiplying by 0.001 g/mg.

$$\text{concentration in ppm} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^6 \text{ ppm}$$

**Act on Your Strategy**

$$\text{mass of person} = 60 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 60\,000 \text{ g}$$

$$\text{mass of mercury} = 20 \text{ mg} \times \frac{0.001 \text{ g}}{1 \text{ mg}} = 0.020 \text{ g}$$

$$\text{concentration in ppm} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^6 \text{ ppm}$$

$$= \frac{0.020 \text{ g}}{60\,000 \text{ g}} \times 10^6 \text{ ppm}$$

$$= 0.33 \text{ ppm}$$

**Solution**
The concentration of mercury is 0.33 ppm.

**Check Your Solution**
The answer has the correct number of significant digits (2) and the correct units (ppm).

**6. b)**
**Problem**
Symptoms of mercury poisoning become apparent after a person has accumulated 20 mg of mercury in his or her body. Express this concentration as parts per billion for the same person.

**What is Required?**
You must express the concentration of mercury in a 60 kg person as ppb.

**What is Given?**
The mass of the person (solution) is 60 kg and the mass of mercury (solute) is 20 mg.

**Plan Your Strategy**
Convert the mass of the person from grams to kilograms by multiplying 60 kg by 1000 g/kg and the mass of mercury from milligrams to grams by multiplying by 0.001 g/mg concentration in

$$\text{ppb} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^9 \text{ ppb}$$

**Act on Your Strategy**

$$\text{mass of person} = 60\ \text{kg} \times \frac{1000\,\text{g}}{1\,\text{kg}} = 60\ 000\ \text{g}$$

$$\text{mass of mercury} = 20\ \text{mg} \times \frac{0.001\,\text{g}}{1\,\text{mg}} = 0.020\ \text{g}$$

$$\text{concentration in ppb} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^9\ \text{ppb}$$

$$= \frac{0.020\,\text{g}}{60\ 000\,\text{g}} \times 10^9\ \text{ppb}$$

$$= 3.3 \times 10^2\ \text{ppb}$$

**Solution**

The concentration of mercury is $3.3 \times 10^2$ ppb.

**Check Your Solution**

The answer has the correct number of significant digits (2) and the correct units (ppb).

**6. c)**

**Problem**

Symptoms of mercury poisoning become apparent after a person has accumulated 20 mg of mercury in his or her body. Express this amount as percent by mass for the same person.

**What is Required?**

You must express the concentration of mercury in a 60 kg person as percent by mass.

**What is Given?**

The mass of the person (solution) is 60 kg and the mass of mercury (solute) is 20 mg.

**Plan Your Strategy**

Convert the mass of the person from grams to kilograms by multiplying 60 kg by the conversion factor 1000 g/kg and the mass of mercury from milligrams to grams by multiplying by the conversion factor 1 g/1000 mg or 0.001 g/mg.

$$\text{percent by mass } (m/m) = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100\%$$

**Act on Your Strategy**

$$\text{mass of person} = 60\ \text{kg} \times \frac{1000\,\text{g}}{1\,\text{kg}} = 60\ 000\ \text{g}$$

$$\text{mass of mercury} = 20\ \text{mg} \times \frac{0.001\,\text{g}}{1\,\text{mg}} = 0.020\ \text{g}$$

$$\text{percent by mass} = \frac{0.20\,\text{g}}{60\ 000\,\text{g}} \times 100\% = 3.3 \times 10^{-5}\%\ (m/m)$$

**Solution**
The concentration is $3.3 \times 10^{-5}$% (*m/m*).

**Check Your Solution**
The answer has the correct number of significant digits (2) and the correct units (percent *m/m*).

**7.**
**Problem**
A concentration of 700 ppm hydrogen sulfide in air will cause a person to lose consciousness. Express this concentration as percent *m/m*.

**What is Required?**
You must convert concentration units of ppm to concentration units expressed as mass percent.

**What is Given?**
The concentration of the hydrogen sulfide in air is 700 ppm.

**Plan Your Strategy**

Since concentration in ppm = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^6$ ppm ,

therefore, $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} = \frac{\text{concentration in ppm}}{10^6 \text{ ppm}}$

and percent by mass = $\frac{\text{concentration in ppm}}{10^6 \text{ ppm}} \times 100\%$

**Act on Your Strategy**

percent by mass = $\frac{700 \text{ ppm}}{10^6 \text{ ppm}} \times 100\% = 0.0700\%$ (*m/m*)

**Solution**
The percent by mass is 0.0700% (*m/m*).

**Check Your Solution**
The answer has the correct number of significant digits (3) and the correct units percent (*m/m*).

**8.**
**Problem**
The use of the pesticide DDT has been banned in Canada since 1969 because of its damaging effect on wildlife. In 1967, 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 2.5 kg trout with a DDT concentration of 16 ppm?

**What is Required?**
You must calculate the mass of DDT in a fish having a mass of 2.5 kg.

**What is Given?**
The concentration of DDT (solute) is 16 ppm and the mass of the fish (solution) is 2.5 kg.

**Plan Your Strategy**
Convert the mass of the solution from kilograms to grams by multiplying 2.5 kg by the conversion factor 1000 g/kg.

Since concentration in ppm = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^6$ ppm

Therefore, mass of solute = $\frac{\text{concentration in ppm} \times \text{mass of solution}}{10^6 \text{ppm}} \times 100\%$

**Act on Your Strategy**

$2.5 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{kg}} = 2500 \text{ g}$

mass of DDT = $\frac{16 \text{ ppm} \times 2500 \text{ g}}{10^6 \text{ ppm}} = 0.040 \text{ g}$

**Solution**
The mass of DDT is 0.040 g.

**Check Your Solution**
The answer has the correct units (g) and the correct number of significant digits (2).

**9.**
**Problem**
The concentration of chlorine in a swimming pool is generally kept between 1.4 mg/L and 4.0 mg/L. What is the concentration range in ppm? (Assume 1.0 L of water has a mass of 1.0 kg)

(**Hint**: 1 ppm = $\frac{1 \text{g}}{1 \times 10^6 \text{ g}} = \frac{1000 \text{ mg}}{1000 \text{ kg}} = \frac{1 \text{mg}}{1 \text{ kg}} = \frac{1 \text{mg}}{\text{L}}$)

**What is Required?**
You must calculate the concentration range in units of ppm.

**What is Given?**
The concentration range is from 1.4 mg/L to 4.0 mg/L.

**Plan Your Strategy**
Since 1 g = 1000 mg, 1 L of water has a mass of 1 kg and 1 kg = 1000 g (for dilute solutions). Concentration units of ppm is equivalent to mg/L.

**Act on Your Strategy**
A range of 1.4 mg/L to 4.0 mg/L = a range of 1.4 ppm to 4.0 ppm

**Solution**
The range of concentration of chlorine is 1.4 ppm to 4.0 ppm.

**Check Your Solution**
The answer has the correct units (ppm) and the correct number of significant digits (2).

**10.**
**Problem**
The drinking water in Stratford, Ontario has a fluoride concentration of 1.6 ppm. A long-term study showed that Stratford residents experienced a much lower incidence of tooth decay than did their neighbours in Woodstock, whose tap water was non-fluoridated. If the average adult consumes 2.0 L of water daily, what mass of fluoride is consumed? (Assume 1.0 mL of tap water has a mass of 1.0 g.)

**What is Required?**
You must determine the mass of fluoride in 2.0 L of Stratford tap water.

**What is Given?**
The concentration of fluoride (solute) is 1.6 ppm and the volume of water (solution) consumed is 2.0 L.

**Plan Your Strategy**
Calculate the mass of tap water by multiplying the volume in litres by the conversion factor 1000 mL/L and using the relationship that the mass of 1.0 mL of this water is 1.0 g.

Since concentration in ppm = $\frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^6 \text{ ppm}$

Therefore, mass of solute = $\frac{\text{concentration in ppm} \times \text{mass of solution}}{10^6 \text{ppm}} \times 100\%$

**Act on Your Strategy**

mass of water = 2.0 L $\times$ 1 000 $\frac{\text{mL}}{\text{L}} \times 1 \frac{\text{g}}{\text{mL}}$ = 2 000 g

mass of solute (fluoride) = $\frac{1.6 \text{ ppm} \times 2\,000\, g}{10^6 \text{ ppm}}$ = 0.0032 g

**Solution**
The mass of fluoride in 2.0 L of Stratford tap water is 0.0032 g.

**Check Your Solution**
The answer has the correct number of significant digits (2) and the correct units (g).

**11. a)**
**Problem**
Calculate the molar concentration of the 0.50 mol of NaCl(s) dissolved in 0.30 L of solution.

**What is Required?**
You must calculate the molar concentration of a NaCl solution.

**What is Given?**
The number of moles of NaCl(s) (solute) is 0.50 and the volume of solution is 0.30 L.

**Plan Your Strategy**

Calculate the molar concentration of the solution using $C = \frac{n}{V}$.

**Act on Your Strategy**

molar concentration = $C = \frac{n}{V} = \frac{0.50\,\text{mol}}{0.30\ \text{L}} = 1.7$ mol/L

**Solution**
The molar concentration of the NaCl solution is 1.7 mol/L.

**Check Your Solution**
The answer has the correct units for concentration (mol/L) and the correct number of significant digits (2).

**11. b)**
**Problem**
Calculate the molar concentration of 0.289 mol of iron(III) chloride, $FeCl_3(s)$ dissolved in 120 mL of solution.

**What is Required?**
You must calculate the molar concentration of the iron(III) chloride solution.

**What is Given?**
The number of moles of iron(III) chloride (solute) is 0.289 and the volume of solution is 120 mL.

**Plan Your Strategy**
Change 120 mL to litres by multiplying by 0.001 L/mL. Calculate the molar concentration of the solution using $C = \frac{n}{V}$.

**Act on Your Strategy**

volume of solution = 125 mL $\times \frac{0.001\,\text{L}}{1\,\text{mL}} = 0.125$ L

molar concentration = $C = \frac{n}{V} = \frac{0.289\,\text{mol}}{0.120\,\text{L}} = 2.41$ mol/L

**Solution**
The molar concentration of the iron(III) chloride solution is 2.41 mol/L.

**Check Your Solution**
The answer has the correct units for concentration (mol/L) and the correct number of significant digits (3).

**12. a)**
**Problem**
Calculate the molar concentration of 4.63 g of sugar, $C_{12}H_{22}O_{11}(s)$, dissolved in 16.8 mL of solution.

**What is Required?**
You must calculate the molar concentration of a sucrose solution.

**What is Given?**
The mass of sucrose (solute) is 4.63 g and the volume of solution is 16.8 mL.

**Plan Your Strategy**
Change 16.8 mL to litres by multiplying by 0.001 L/mL. Calculate the molar mass of sucrose, $C_{12}H_{22}O_{11}$, and use this value to determine the number of moles of solute using the relationship $n = \frac{m}{M}$. Calculate the molar concentration of the solution using $C = \frac{n}{V}$.

**Act on Your Strategy**

$$\text{volume of solution} = 16.8\ \text{mL} \times \frac{0.001\,\text{L}}{1\,\text{mL}} = 0.0168\ \text{L}$$

molar mass of $C_{12}H_{22}O_{11}$ = 342.34 g/mol

$$\text{moles of } C_{12}H_{22}O_{11} = \frac{4.63\,\text{g}}{342.34\ \text{g/mol}} = 1.352 \times 10^{-2}\ \text{mol}$$

$$\text{molar concentration} = C = \frac{n}{V} = \frac{1.35 \times 10^{-2}\ \text{mol}}{0.0168\,\text{L}} = 8.05 \times 10^{-1}\ \text{mol/L}$$

**Solution**
The molar concentration of the sucrose solution is $8.05 \times 10^{-1}$ mol/L.

**Check Your Solution**
The answer has the correct units for concentration (mol/L) and the correct number of significant digits (3).

**12. b)**
**Problem**
Calculate the molar concentration of 1.2 g of sodium nitrate, $NaNO_3(s)$, dissolved in 80 mL of solution.

**What is Required?**
You must calculate the molar concentration of sodium nitrate solution.

**What is Given?**
The mass of sodium nitrate (solute) is 1.2 g and the volume of solution is 80 mL.

**Plan Your Strategy**
Change 80 mL to litres by multiplying by 0.001 L/mL. Write the chemical formula for sodium nitrate and calculate the molar mass of this compound. Use this value to determine the number of moles of solute using the relationship $n = \frac{m}{M}$. Calculate the molar concentration of the solution using $C = \frac{n}{V}$.

**Act on Your Strategy**

volume of solution = 80 mL $\times \frac{0.001\,\text{L}}{1\,\text{mL}}$ = 0.080 L

sodium nitrate = $NaNO_3$
molar mass of $NaNO_3$ = 85.0 g/mol

moles of $NaNO_3 = \frac{1.2\,\text{g}}{85.0\,\text{g/mol}} = 1.41 \times 10^{-2}$ mol

molar concentration = $C = \frac{n}{V} = \frac{1.41 \times 10^{-2}\ \text{mol}}{0.80\,\text{L}} = 1.8 \times 10^{-1}$ mol/L

**Solution**
The molar concentration of the sodium nitrate solution is $1.8 \times 10^{-1}$ mol/L.

**Check Your Solution**
The answer has the correct units for concentration (mol/L) and the correct number of significant digits (2).

**13.**
**Problem**
If $1.37 \times 10^{-2}$ g of ammonium phosphate is dissolved in enough water to make 125 mL of solution, what is the molar concentration of the solution?

**What is Required?**
You must calculate the molar concentration of the ammonium phosphate solution.

**What is Given?**
The mass of ammonium phosphate (solute) is $1.37 \times 10^{-2}$ g and the volume of solution is 125 mL.

**Plan Your Strategy**
Change 125 mL to litres by multiplying by 0.001 L/mL. Calculate the molar mass of ammonium phosphate $(NH_4)_3PO_4$ and use this value to determine the number of moles of solute using the relationship $n = \frac{m}{M}$. Calculate the molar concentration of the solution using $C = \frac{n}{V}$.

**Act on Your Strategy**

volume of solution = 125 mL $\times \frac{0.001\text{L}}{1\,\text{mL}} = 0.125$ L

molar mass of $(NH_4)_3PO_4$ = 149.12 g/mol

moles of $(NH_4)_3PO_4 = \frac{1.37 \times 10^{-2}\ \text{g}}{149.12\ \text{g/mol}} = 9.187 \times 10^{-5}$ mol

molar concentration = $C = \frac{n}{V} = \frac{9.187 \times 10^{-5}\ \text{mol}}{0.125\ \text{L}} = 7.35 \times 10^{-4}$ mol/L

**Solution**
The molar concentration of the ammonium phosphate solution is $7.35 \times 10^{-4}$ mol/L.

**Check Your Solution**
The answer has the correct units for concentration (mol/L) and the correct number of significant digits (3).

**14.**
**Problem**
What is the molar concentration of a solution in which 2.1 mg of copper(II) sulfate pentahydrate is dissolved to make 1500 mL of solution?

**What is Required?**
You must calculate the molar concentration of a copper(II) sulfate pentahydrate solution.

**What is Given?**
The mass of copper(II) sulfate pentahydrate is 2.1 mg and the volume of solution is 1500 mL.

**Plan Your Strategy**
Write the chemical formula for copper(II) sulfate pentahydrate and determine the molar mass of this compound. Convert 2.1 mg to grams by multiplying by the conversion factor 0.001 g/mg and 1500 mL to litres by multiplying by the conversion factor 0.001 L/mL. Calculate the moles of copper(II) sulfate pentahydrate using the formula $n = \frac{m}{M}$. Calculate the molar concentration using the formula
$C = \frac{n}{V}$.

**Act on Your Strategy**
copper(II) sulfate pentahydrate = $CuSO_4 \bullet 5H_2O$ $M$ = 249.72 g/mol

2.1 mg × 0.001 g/mg = 0.0021 g; 1500 mL × $\frac{0.001\text{L}}{1\,\text{mL}}$ = 1.500 L

$n = \frac{m}{M} = \frac{0.0021\,\text{g}}{249.72\,\text{g/mol}} = 8.409 \times 10^{-6}$ mol

$C = \frac{n}{V} = \frac{8.409 \times 10^{-6}\ \text{mol}}{1.500\ \text{L}} = 5.6 \times 10^{-6}$ mol/L

**Solution**
The molar concentration is $5.7 \times 10^{-6}$ mol/L.

**Check Your Solu**tion
The answer has the correct number of significant digits (2) and the correct units for concentration (mol/L).

**15.**
**Problem**
What is the molar concentration of a solution with a concentration of 200 ppm fluoride ions? Remember that the mass of 1 mL of water is 1.0 g.

**What is Required?**
You must convert the concentration of fluoride ion from ppm to moles/L.

**What is Given?**
The concentration of fluoride ion is 200 ppm.

**Plan Your Strategy**
Express the concentration of ppm as mg/L. Convert milligrams to grams by multiplying by 0.001 g/mg. Calculate the number of moles of fluoride ion by dividing the mass of fluoride in grams by the molar mass of fluoride ion 19.00 g/mol, $n = \frac{m}{M}$. Calculate the molar concentration of fluoride ion using the formula $C = \frac{n}{V}$.

**Act on Your Strategy**
Since 1 g = 1 000 mg, 1 L of water has a mass of 1 kg and 1 kg = 1000 g (for dilute solutions), therefore

1 ppm = $\frac{1\text{g}}{1 \times 10^6\ \text{g}} = \frac{1000\,\text{mg}}{1000\,\text{kg}} = \frac{1\,\text{mg}}{1\,\text{kg}} = \frac{1\,\text{mg}}{\text{L}}$

200 ppm = 200 mg/L = 0.200g/L

moles of $F^-(aq) = n = \frac{m}{M} = \frac{0.200\,\text{g}}{19.00\,\text{g/mol}} = 1.05 \times 10^{-2}$ mol

$C = \frac{n}{V} = \frac{1.05 \times 10^{-2}\ \text{mol}}{1.00\,\text{L}} = 1.05 \times 10^{-2}$ mol/L

**Solution**
The molar concentration of the fluoride solution is $1.05 \times 10^{-2}$ mol/L.

**Check Your Solution**
The answer has the correct number of significant digits (3) and the correct units for concentration (mol/L).

**16.**
**Problem**
What is the molar concentration of a solution that is 10 percent (*m/m*) methanol?

**What is Required?**
You must convert a methanol solution concentration from percent by mass to moles/L.

**What is Given?**
The percent by mass concentration of $CH_3OH$ is 10 percent (*m/m*).

**Plan Your Strategy**
10% (*m/m*) means 10 g of $CH_3OH$ per 100 g of solution. Determine the molar mass of $CH_3OH$ and calculate the moles of this compound using $n = \frac{m}{M}$. Assume that 1 g of $CH_3OH$ solution has a volume of 1 mL. Express the concentration as mole per 1 00 g (therefore 100 mL). Convert this concentration to moles per litre using the conversion factor 1000 mL/L.

**Act on Your Strategy**
molar mass of $CH_3OH$ = 32.05 g/mol
moles of $CH_3OH = n = \frac{m}{M} = \frac{10\,\text{g}}{32.05\,\text{g/mol}} = 0.312$ mol

concentration of methanol solution = 0.312 mol/100 g = 0.312 mol/100 mL
0.312 mol/100mL × 1000 ml/L = 3.12 mol/L

**Solution**
The concentration of the methanol solution is 3.1 mol/L

**Check Your Solution**
The answer has the correct number of significant digits (2) and the correct units for concentration (mol/L).

**17.**
**Problem**
Calculate the molar concentration of sodium ions if 2.7 g of sodium carbonate, $Na_2CO_3(s)$, is dissolved in 175 mL of water.

**What is Required?**
You must calculate the concentration of $Na^+(aq)$ ions in a solution of $Na_2CO_3$.

**What is Given?**
The mass of $Na_2CO_3$ is 2.7 g and the volume of water is 175 mL.

**Plan Your Strategy**
Determine the molar mass of $Na_2CO_3$ and calculate the number of moles of this compound using $n = \frac{m}{M}$. Assume that the volume of solution is the same as the volume of water used (175 mL). Use the conversion factor 1 L/1000 mL to change this volume to litres. Calculate the molar concentration of the solution using $C = \frac{n}{V}$. Write the dissociation equation for $Na_2CO_3(s)$ and determine the mol ratio of $Na^+(aq)$to $Na_2CO_3$. Multiply the concentration of $Na_2CO_3\,(aq)$ by this ratio to obtain the concentration of $Na^+(aq)$.

**Act on Your Strategy**
molar mass of $Na_2CO_3$ = 105.99 g/mol

moles of $Na_2CO_3 = n = \frac{m}{M} = \frac{2.7\,\text{g}}{105.99\,\text{g/mol}} = 2.55 \times 10^{-2}$ mol

$$175\text{ ml} \times \frac{1\text{L}}{1000\,\text{mL}} = 0.175\text{ L}$$

concentration of $Na_2CO_3 = C = \frac{n}{V} = \frac{2.55\times10^{-2}\text{ mol}}{0.175\,\text{L}} = 1.46 \times 10^{-1}$ mol/L

$Na_2CO_3(s) \longrightarrow 2Na^+(aq) + CO_3^{2-}(aq)$

concentration of $Na^+(aq) = 1.46 \times 10^{-1}$ mol/L $\times \frac{2\,\text{mol Na}^+\text{(aq)}}{1\,\text{mol Na}_2\text{CO}_3} = 0.292$ mol/L

**Solution**
The concentration of $Na^+(aq)$ is 0.29 mol/L

**Check Your Solution**
The answer has the correct number of significant digits (2) and the correct units for concentration (mol/L).

**18.**
**Problem**
What is the concentration of calcium ions if $1.3 \times 10^{-4}$ g of calcium phosphate, $Ca_3(PO_4)_2(s)$, is dissolved to make 3.95 L of solution?

**What is Required?**
You must calculate the concentration of $Ca^{2+}(aq)$ ions in a solution of $Ca_3(PO_4)_2$.

**What is Given?**
The mass of $Ca_3(PO_4)_2$ is $1.3 \times 10^{-4}$ g and the volume of solution is 3.95 L.

**Plan Your Strategy**
Write the chemical formula for calcium phosphate and determine the molar mass of this compound. Calculate the number of moles of this compound using $n = \frac{m}{M}$. Calculate the molar concentration of the solution using $C = \frac{n}{V}$. Write the dissociation equation for $Ca_3(PO_4)_2$ and determine the mol ratio of $Ca^{2+}(aq)$ to $Ca_3(PO_4)_2$. Multiply the concentration of $Ca_3(PO_4)_2$ by this ratio to obtain the concentration of $Ca^{2+}(aq)$.

**Act on Your Strategy**
molar mass of $Ca_3(PO_4)_2$ = 310.18 g/mol

moles of $Ca_3(PO_4)_2 = n = \frac{m}{M} = \frac{1.3 \times 10^{-4}\ \text{g}}{310.18\ \text{g/mol}} = 4.19 \times 10^{-7}\ \text{mol}$

concentration of $Ca_3(PO_4)_2 = C = \frac{n}{V} = \frac{4.19 \times 10^{-7}\ \text{mol}}{3.95\ \text{L}} = 1.061 \times 10^{-7}\ \text{mol/L}$

$Ca_3(PO_4)_2(s) \longrightarrow 3Ca^{2+}(aq) + 2PO_4^{3-}(aq)$

concentration of $Ca^{2+}(aq) = 1.061 \times 10^{-7}\ \text{mol/L} \times \frac{3\,\text{mol}\,Ca^{2+}(aq)}{1\,\text{mol}\,Ca_3(PO_4)_2} = 3.2 \times 10^{-7}\ \text{mol/L}$

**Solution**
The concentration of $Ca^{2+}(aq)$ is $3.2 \times 10^{-7}$ mol/L

**Check Your Solution**
The answer has the correct number of significant digits (2) and the correct units for concentration (mol/L).

**19.**
**Problem**
Determine the molar concentration of the cation (positive ion) if 0.000 453 g of strontium nitrate is dissolved to make 1 L of solution.

**What is Required?**
You must calculate the concentration of $Sr^{2+}(aq)$ ions in a solution of strontium nitrate

**What is Given?**
The mass of strontium nitrate is $4.53 \times 10^{-4}$ g and the volume of solution is 1 L.

**Plan Your Strategy**
Write the chemical formula for strontium nitrate and determine the molar mass of this compound. Calculate the number of moles of this compound using $n = \frac{m}{M}$. Calculate the molar concentration of the solution using $C = \frac{n}{V}$. Write the dissociation equation for strontium nitrate and determine the mol ratio of $Sr^{2+}(aq)$ to strontium nitrate. Multiply the concentration of strontium nitrate by this ratio to obtain the concentration of $Sr^{2+}(aq)$.

**Act on Your Strategy**
strontium nitrate = $Sr(NO_3)_2$
molar mass of $Sr(NO_3)_2$ = 211.64 g/mol

moles of $Sr(NO_3)_2 = n = \frac{m}{M} = \frac{4.53\times10^{-4}\,\text{g}}{211.64\,\text{g/mol}} = 2.140 \times 10^{-6}$ mol

concentration of $Sr(NO_3)_2 = C = \frac{n}{V} = \frac{2.140\times10^{-6}\,\text{mol}}{1.00\,\text{L}} = 2.140 \times 10^{-6}$ mol/L

$Sr(NO_3)_2(s) \longrightarrow Sr^{2+}(aq) + 2NO_3^-(aq)$

concentration of $Sr^{2+}(aq) = 2.140 \times 10^{-6}$ mol/L $\times \frac{1\,\text{mol}\,Sr^{2+}(aq)}{1\,\text{mol}\,Sr(NO_3)_2} = 2.140 \times 10^{-6}$ mol/L

**Solution**
The concentration of $Sr^{2+}(aq)$ is $2 \times 10^{-6}$ mol/L

**Check Your Solution**
The answer has the correct number of significant digits (1) and the correct units for concentration (mol/L).

**20.**
**Problem**
Calculate the molar concentration of fluoride ions if 1.45 $\mu$g sodium fluoride, NaF(s), is contained in 100 mL of aqueous solution ($\mu$g means $10^{-6}$ g)

**What is Required?**
You must calculate the concentration of fluoride ion in a solution of NaF

**What is Given?**
The mass of NaF is 1.45 $\mu$g and the volume of water is 100 mL.

**Plan Your Strategy**
Determine the molar mass of NaF and calculate the number of moles of this compound using $n = \frac{m}{M}$. Assume that the volume of solution is the same as the volume of water used (100 mL).

Use the conversion factor 1 L /1000 mL to change this volume to litres. Change the mass of NaF from $\mu$g to grams using the conversion factor 1g/ $1.00 \times 10^6$ $\mu$g. Calculate the molar concentration of the solution using $C = \frac{n}{V}$. Write the dissociation equation for NaF and determine the mol ratio of $F^-$ to NaF. Multiply the concentration of NaF by this ratio to obtain the concentration of $F^-(aq)$.

**Act on Your Strategy**

molar mass of NaF = 41.99 g/mol

$$1.45\ \mu\text{g NaF} \times \frac{1.00\,\text{g}}{1\times10^6\ \mu\text{g}} = 1.45 \times 10^{-6}\ \text{g}$$

$$\text{moles of NaF} = n = \frac{m}{M} = \frac{1.45\times10^{-6}\,\text{g}}{41.99\,\text{g/mol}} = 3.45 \times 10^{-8}\ \text{mol}$$

$$100\ \text{ml} \times \frac{1\text{L}}{1000\,\text{mL}} = 0.100\ \text{L}$$

$$\text{concentration of NaF} = C = \frac{n}{V} = \frac{3.45\times10^{-8}\ \text{mol}}{0.100\ \text{L}} = 3.45 \times 10^{-7}\ \text{mol/L}$$

$$\text{NaF(s)} \longrightarrow \text{Na}^+\text{(aq)} + \text{F}^-\text{(aq)}$$

$$\text{concentration of F}^-\text{(aq)} = 3.45 \times 10^{-7}\ \text{mol/L} \times \frac{1\text{mol F}^-\text{(aq)}}{1\text{mol NaF}} = 3.45 \times 10^{-7}\ \text{mol/L}$$

**Solution**

The fluoride concentration is $3.45 \times 10^{-7}$ mol/L.

**Check Your Solution**

The answer has the correct number of significant digits (3) and the correct units for concentration (mol/L).

**21.**

**Problem**

What is the molar concentration of nitrate ions if 9.0 g of aluminium nitrate is dissolved to make 5.3 L of solution?

**What is Required?**

You must calculate the molar concentration of nitrate ions in a solution of aluminium nitrate.

**What is Given?**

The mass of aluminium nitrate is 9.0 g and the volume of solution is 5.3 L.

**Plan Your Strategy**

Write the chemical formula for aluminium nitrate and determine the molar mass of this compound. Calculate the number of moles of this compound using $n = \frac{m}{M}$. Calculate the molar

concentration of the solution using $C = \frac{n}{V}$. Write the dissociation equation for aluminium nitrate and determine the mol ratio of nitrate ion to aluminium nitrate. Multiply the concentration of aluminium nitrate by this ratio to obtain the concentration of nitrate ion.

**Act on Your Strategy**
aluminium nitrate = $Al(NO_3)_3$
molar mass of $Al(NO_3)_3$ = 213.01 g/mol

moles of $Al(NO_3)_3 = n = \frac{m}{M} = \frac{9.0\,g}{213.01 g/mol} = 4.23 \times 10^{-2}$ mol

concentration of $Al(NO_3)_3 = C = \frac{n}{V} = \frac{4.23 \times 10^{-2}\ mol}{5.3\ L} = 7.98 \times 10^{-3}$ mol/L

$Al(NO_3)_3(s) \longrightarrow Al^{3+}(aq) + 3NO_3^-(aq)$

concentration of $NO_3^-(aq) = 7.98 \times 10^{-3}$ mol/L $\times \frac{3\,mol\ NO_3^-(aq)}{1\,mol\ Al(NO_3)_3} = 2.39 \times 10^{-2}$ mol/L

**Solution**
The concentration of $NO_3^-(aq)$ is $2.4 \times 10^{-2}$ mol/L.

**Check Your Solution**
The answer has the correct number of significant digits (2) and the correct units for concentration (mol/L).

**22.**
**Problem**
Determine the molar concentration of the anion (negative ion) if 4.34 kg of lithium phosphate is dissolved in 3.75 kL of water.

**What is Required?**
You must calculate the concentration of phosphate ion in a solution of lithium phosphate.

**What is Given?**
The mass of lithium phosphate is 4.34 kg and the volume of water is 3.75 kL.

**Plan Your Strategy**
Use the conversion factors 1000 g/ kg and 1000 L/kL to change respectively the 4.34 kg to grams and the 3.75 kL to L. Write the chemical formula for lithium phosphate and determine the molar mass of this compound. Calculate the number of moles of this compound using $n = \frac{m}{M}$. Assume that the volume of solution is the same as the volume of water used (3.75 kL). Calculate the molar concentration of the solution using $C = \frac{n}{V}$. Write the dissociation equation for lithium phosphate and determine the mol ratio of phosphate ion to lithium phosphate. Multiply the concentration of lithium phosphate by this ratio to obtain the concentration of phosphate ion.

**Act on Your Strategy**
lithium phosphate = $Li_3PO_4$
molar mass of $Li_3PO_4$ = 115.79 g/mol

$4.34\ \text{kg} \times \frac{1000\,\text{g}}{\text{kg}} = 4.34 \times 10^3\ \text{g}$

moles of $Li_3PO_4 = n = \frac{m}{M} = \frac{4.34 \times 10^3\ \text{g}}{115.79\,\text{g/mol}} = 3.748 \times 10^1\ \text{mol}$

$3.75\ \text{kL} \times 1000\ \text{L/kL} = 3.75 \times 10^3\ \text{L}$

concentration of $Li_3PO_4 = C = \frac{n}{V} = \frac{3.748 \times 10^1\ \text{mol}}{3.75 \times 10^3\ \text{L}} = 9.995 \times 10^{-3}\ \text{mol/L}$

$Li_3PO_4(s) \longrightarrow 3Li^+(aq) + PO_4^{3-}(aq)$

concentration of $PO_4^{3-}(aq) = 9.995 \times 10^{-3}\ \text{mol/L} \times \frac{1\,\text{mol}\ PO_4^{3-}(aq)}{1\,\text{mol}\ Li_3PO_4} = 9.995 \times 10^{-3}\ \text{mol/L}$

**Solution**
The fluoride concentration is $1.00 \times 10^{-2}$ mol/L.

**Check Your Solution**
The answer has the correct number of significant digits (3) and the correct units for concentration (mol/L).

**23. a)**
**Problem**
Calculate the mass of solute that could be crystallized from 125 mL of 0.200 mol/L NaCl(aq).

**What is Required?**
You must calculate the mass of NaCl that will crystallize from an aqueous solution of NaCl.

**What is Given?**
The concentration of the solution is 0.200 mol/L and the volume of solution is 125 mL.

**Plan Your Strategy**
Convert 125 mL to litres using the conversion factor 1 L/1000 mL. Calculate the moles of solute (NaCl) using $n = C \times V$. Determine the molar mass of NaCl. Since $n = \frac{m}{M}$, therefore, mass of solute = $m = n \times M$.

**Act on Your Strategy**
molar mass = 58.44 g/mol

$125\ \text{mL} \times \frac{1\,\text{L}}{1000\,\text{mL}} = 0.125\ \text{L of solution}$

moles of solute = $n = C \times V = 0.200\ \text{mol/L} \times 0.125\ \text{L} = 0.0250\ \text{mol}$

mass of solute = $m = n \times M$ = 0.0250 mol × 58.44 g/mol = 1.46 g

**Solution**
The mass of NaCl in this solution is 1.46 g

**Check Your Solution**
The answer has the correct units (g) and the correct number of significant digits (3).

**23. b)**
**Problem**
Calculate the mass of solute that could be crystallized from 1.35 L of 1.25 mol/L $NH_4NO_3$(aq).

**What is Required?**
You must calculate the mass of $NH_4NO_3$(s) that will crystallize from an aqueous solution.

**What is Given?**
The concentration of the solution is 1.25 mol/L and the volume of solution is 1.35 L.

**Plan Your Strategy**
Calculate the moles of solute ($NH_4NO_3$) using $n = C \times V$. Determine the molar mass of $NH_4NO_3$.
Since $n = \frac{m}{M}$, therefore, mass of solute = $m = n \times M$.

**Act on Your Strategy**
molar mass = 80.06 g/mol
moles of solute = $n = C \times V$ = 1.25 mol/L × 1.35 L = 1.688 mol
mass of solute = $m = n \times M$ = 1.688 mol × 80.06 g/mol = 135.1 g

**Solution**
The mass of $NH_4NO_3$ in this solution is 135 g.

**Check Your Solution**
The answer has the correct units (g) and the correct number of significant digits (3).

**24. a)**
**Problem**
What mass of solute could be obtained by evaporation from 0.38 L of $4.25 \times 10^{-3}$ mol/L ammonium carbonate.

**What is Required?**
You must calculate the mass of ammonium carbonate, $(NH_4)_2CO_3$(s), that will crystallize from an aqueous solution.

**What is Given?**
The concentration of the solution is $4.25 \times 10^{-3}$ mol/L and the volume of solution is 0.38 L.

**Plan Your Strategy**
Write the chemical formula for ammonium carbonate and determine the molar mass of this compound. Calculate the moles of solute using $n = C \times V$. Since $n = \frac{m}{M}$, therefore, mass of solute = $m = n \times M$.

**Act on Your Strategy**
molar mass = 96.11g/mol
moles of solute = $n = C \times V = 4.25 \times 10^{-3}$ mol/L $\times$ 0.38 L = $1.62 \times 10^{-3}$ mol
mass of solute = $m = n \times M = 1.62 \times 10^{-3}$ mol $\times$ 96.11 g/mol = 0.155 g

**Solution**
The mass of $NH_4NO_3$ in this solution is 0.16 g.

**Check Your Solution**
The answer has the correct units (g) and the correct number of significant digits (2).

**24. b)**
**Problem**
What mass of solute could be obtained by evaporation from 2.0 L of 1.25 mol/L magnesium hydroxide.

**What is Required?**
You must calculate the mass of magnesium hydroxide that will crystallize from an aqueous solution.

**What is Given?**
The concentration of the solution is 1.25 mol/L and the volume of solution is 2.0 L.

**Plan Your Strategy**
Write the chemical formula for magnesium hydroxide and determine the molar mass of this compound. Calculate the moles of solute using $n = C \times V$. Since $n = \frac{m}{M}$, therefore, mass of solute = $m = n \times M$.

**Act on Your Strategy**
molar mass = 58.33 g/mol
moles of solute = $n = C \times V$ = 1.25 mol/L $\times$ 2.0 L = 2.5 mol
mass of solute = $m = n \times M$ = 2.5 mol $\times$ 58.33 g/mol = $1.5 \times 10^2$ g

**Solution**
The mass of $NH_4NO_3$ in this solution is $1.5 \times 10^2$ g.

**Check Your Solution**
The answer has the correct units (g) and the correct number of significant digits (2).

**25.**

**Problem**

A 100 mL bottle of skin lotion contains a number of solutes. One of these solutes is zinc oxide, ZnO(s). The concentration of zinc oxide in the skin lotion is 0.915 mol/L. What mass of zinc oxide is present in the bottle?

**What is Required?**

You must calculate the mass of zinc oxide that will crystallize from a solution of lotion.

**What is Given?**

The concentration of the solution is 0.915 mol/L and the volume of solution is 100 mL.

**Plan Your Strategy**

Convert 100 mL to litres using the conversion 1 L/1000 mL. Determine the molar mass of this compound. Calculate the moles of solute using $n = C \times V$. Since $n = \frac{m}{M}$, therefore, mass of solute = $m = n \times M$.

**Act on Your Strategy**

$$100 \text{ mL} \times \frac{1 \text{L}}{1000 \text{ mL}} = 0.100 \text{ L}$$

molar mass = 81.39 g/mol

moles of solute = $n = C \times V$ = 0.915 mol/L × 0.100 L = 0.0915 mol

mass of solute = $m = n \times M$ = 0.0915 mol × 81.39 g/mol = 7.45 g

**Solution**

The mass of ZnO in this solution is 7.45 g.

**Check Your Solution**

The answer has the correct units (g) and the correct number of significant digits (3).

**26.**

**Problem**

Formalin is an aqueous solution of formaldehyde, HCHO(aq), used to preserve biological specimens. What mass of formaldehyde is needed to prepare 1.5 L of formalin with a concentration of 10 mol/L?

**What is Required?**

You must calculate the mass of formaldehyde that will crystallize from an aqueous solution of formalin.

**What is Given?**

The concentration of the solution is 10 mol/L and the volume of the solution is 1.5 L.

**Plan Your Strategy**
Determine the molar mass of formaldehyde, HCHO. Calculate the moles of solute using $n = C \times V$. Since $n = \frac{m}{M}$, therefore, mass of solute = $m = n \times M$.

**Act on Your Strategy**
molar mass = 30.03 g/mol
moles of solute = $n = C \times V$ = 10 mol/L × 1.5 L = 15 mol
mass of solute = $m = n \times M$ =15 mol × 30.03 g/mol = $4.5 \times 10^2$ g

**Solution**
The mass of HCHO in this solution is $4.5 \times 10^2$ g.

**Check Your Solution**
The answer has the correct units (g) and the correct number of significant digits (2).

**27. a)**
**Problem**
Calculate the volume of solution that could be prepared from 1.65 mol/L solution beginning with 3.3 g of NaCl(s).

**What is Required?**
You must calculate the volume of solution that can be prepared from a given mass of solute.

**What is Given?**
The mass of solute (NaCl) is 3.3 g and the molar concentration of the solution 1.65 mol/L.

**Plan Your Strategy**
Determine the molar mass of NaCl and calculate the number of moles of this solute using $n = \frac{m}{M}$. Since $n = C \times V$, therefore $V = \frac{n}{C}$.

**Act on Your Strategy**
molar mass of NaCl = 58.44 g/mol

moles of NaCl = $n = \frac{m}{M} = \frac{3.3\,\text{g}}{58.44\,\text{g/mol}}$ = 0.0565 mol NaCl

volume of solution = $V = \frac{n}{C} = \frac{0.0565}{1.65\,\text{mol/L}}$ = 0.034 L

**Solution**
The volume of solution that can be prepared is 0.034 L.

**Check Your Solution**
The answer has the correct units of volume (L) and the correct number of significant digits (2).

**27. b)**

**Problem**

Calculate the volume of solution that could be prepared from 0.225 mol/L solution beginning with 2.0 g of $AgNO_3(s)$.

**What is Required?**

You must calculate the volume of solution that can be prepared from a given mass of solute.

**What is Given?**

The mass of solute ($AgNO_3$) is 2.0 g and the molar concentration of the solution is 0.225 mol/L.

**Plan Your Strategy**

Determine the molar mass of $AgNO_3$ and calculate the number of moles of this solute using $n = \frac{m}{M}$. Since $n = C \times V$, therefore $V = \frac{n}{C}$.

**Act on Your Strategy**

molar mass of $AgNO_3$ = 169.88 g/mol

moles of $AgNO_3 = n = \frac{m}{M} = \frac{2.0\,\text{g}}{169.88\,\text{g/mol}} = 0.01177$ mol $AgNO_3$

volume of solution $= V = \frac{n}{C} = \frac{0.01177\ \text{mol}}{0.225\ \text{mol/L}} = 0.052$ L

**Solution**

The volume of solution that can be prepared is 0.052 L

**Check Your Solution**

The answer has the correct units (L) and the correct number of significant digits (2).

**28. a)**

**Problem**

What volume of solution could be prepared from 0.398 mol/L solution beginning with 10.0 g of potassium dichromate, $K_2Cr_2O_7(s)$.

**What is Required?**

You must calculate the volume of solution that can be prepared from a given mass of solute.

**What is Given?**

The mass of solute (potassium dichromate) is 10.0 g and the molar concentration of the solution is 0.398 mol/L.

**Plan Your Strategy**
Write the chemical formula for potassium dichromate and determine the molar mass of this compound. Calculate the number of moles of this solute using $n = \frac{m}{M}$. Since $n = C \times V$, therefore $V = \frac{n}{C}$.

**Act on Your Strategy**
potassium dichromate = $K_2Cr_2O_7$
molar mass of $K_2Cr_2O_7$ = 294.20 g/mol
moles of $K_2Cr_2O_7 = n = \frac{m}{M} = \frac{10.0\,\text{g}}{294.20\,\text{g/mol}} = 0.03399$ mol $K_2Cr_2O_7$

volume of solution = $V = \frac{n}{C} = \frac{0.03399\text{ mol}}{0.398\text{ mol/L}} = 0.0854$ L

**Solution**
The volume of solution that can be prepared is 0.0854 L

**Check Your Solution**
The answer has the correct units and the correct number of significant digits (3).

**28. b)**
**Problem**
What volume of solution could be prepared from 4.25 mmol/L solution beginning with 4.5 g of sucrose, $C_{12}H_{22}O_{11}$(s).

**What is Required?**
You must calculate the volume of solution that can be prepared from a given mass of solute.

**What is Given?**
The mass of solute (sucrose) is 4.5 g and the molar concentration of the solution is 4.25 mmol/L.

**Plan Your Strategy**
Write the chemical formula for sucrose and determine the molar mass of this compound.
Calculate the number of moles of this solute using $n = \frac{m}{M}$.
Since $n = C \times V$, therefore $V = \frac{n}{C}$. Change the concentration from mmol/L to mol/L using the conversion factor $\frac{1\,\text{mol/L}}{1000\,\text{mmol/L}}$.

**Act on Your Strategy**
sucrose = $C_{12}H_{22}O_{11}$

molar mass of $C_{12}H_{22}O_{11}$ = 342.34 g/mol

moles of $C_{12}H_{22}O_{11} = n = \frac{m}{M} = \frac{4.5\,\text{g}}{342.34\,\text{g/mol}} = 0.0131$ mol $C_{12}H_{22}O_{11}$

$4.25\ \text{mmol/L} \times \frac{1\,\text{mol/L}}{1000\,\text{mmol/L}} = 0.00425$ mol/L

volume of solution $= V = \frac{n}{C} = \frac{0.0131\ \text{mol}}{0.00425\ \text{mol/L}} = 3.1$ L

**Solution**
The volume of sucrose solution that can be prepared is 3.1 L

**Check Your Solution**
The answer has the correct units (L) and the correct number of significant digits (2).

**29.**
**Problem**
Intravenous solutions are commonly 0.28 mol/L glucose. What volume of a standard intravenous solution, measured in litres, could be made from 2.5 kg of glucose, $C_6H_{12}O_6$(s)?

**What is Required?**
You must calculate the volume of solution that can be prepared from a given mass of solute.

**What is Given?**
The mass of solute (glucose) is 2.5 kg and the molar concentration of the solution is 0.28 mol/L.

**Plan Your Strategy**
Write the chemical formula for glucose and determine the molar mass of this compound. Change the mass of 2.5 kg to grams using the conversion factor 1000 g/kg. Calculate the number of moles of this solute using $n = \frac{m}{M}$. Since $n = C \times V$, therefore $V = \frac{n}{C}$.

**Act on Your Strategy**
glucose = $C_6H_{12}O_6$

mass of glucose $= 2.5\ \text{kg} \times \frac{1000\,\text{g}}{1\,\text{kg}} = 2.5 \times 10^3$ g

molar mass of $C_6H_{12}O_6$ = 180.18 g/mol

moles of $C_6H_{12}O_6 = n = \frac{m}{M} = \frac{2.5 \times 10^3\ \text{g}}{180.18\,\text{g/mol}} = 13.9$ mol $C_6H_{12}O_6$

volume of solution $= V = \frac{n}{C} = \frac{13.9\ \text{mol}}{0.28\ \text{mol/L}} = 50$ L

**Solution**
The volume of glucose solution that can be prepared is 50 L

**Check Your Solution**
The answer has the correct units (L) and the correct number of significant digits (2).

**30.**
**Problem**
Household vinegar is a 0.016 mol/L solution of acetic acid, $CH_3COOH(aq)$. How much acetic acid solution with a concentration of 0.016 mol/L could be made from 1.0 g of pure (glacial) acetic acid?

**What is Required?**
You must calculate the volume of acetic acid solution that can be prepared from a given mass of solute.

**What is Given?**
The mass of solute (acetic acid) is 1.0 g and the molar concentration of the solution is 0.016 mol/L.

**Plan Your Strategy**
Determine the molar mass of $CH_3COOH$. Calculate the number of moles of this solute using $n = \frac{m}{M}$. Since $n = C \times V$, therefore $V = \frac{n}{C}$.

**Act on Your Strategy**
molar mass of $CH_3COOH$ = 60.06 g/mol

moles of $CH_3COOH = n = \frac{m}{M} = \frac{1.0\,\text{g}}{60.06\,\text{g/mol}} = 0.01665$ mol $CH_3COOH$

volume of solution $= V = \frac{n}{C} = \frac{0.01665\,\text{mol}}{0.016\ \text{mol/L}} = 1.04$ L

**Solution**
The volume of acetic acid solution that can be prepared is 1.0 L

**Check Your Solution**
The answer has the correct units (L) and the correct number of significant digits (2).

**31. a)**
**Problem**
Suppose that you are given a 1.25 mol/L standard aqueous solution of sodium chloride, NaCl(aq). What volume of standard solution must you use to prepare 50 mL of 1.00 mol/L NaCl(aq).

**What is Required?**
You must determine the volume of a standard sodium chloride solution ($V_1$) that must be used to prepare a dilute solution sodium chloride solution.

**What is Given?**
The concentration of the standard solution ($c_1$) = 1.25 mol/L. The volume of dilute solution ($V_2$) is 50 mL and the concentration of the dilute solution ($c_2$) is 1.00 mol/L.

**Plan Your Strategy**
Change the volume of 50 mL to litres using the conversion factor 1 L/1000 mL. The number of moles of solute is the same in both the concentrated and in the diluted solution. Therefore, use the formula $c_1V_1 = c_2V_2$ and solve for $V_1$.

**Act on Your Strategy**

$$V_2 = 50 \text{ mL} = 50 \text{ mL} \times \frac{1\text{L}}{1000\ \text{mL}} = 0.050 \text{ L}$$

$$c_1V_1 = c_2V_2 \text{ therefore } V_1 = \frac{c_2V_2}{c_1} = \frac{1.00\,\text{mol/L} \times 0.050\,\text{L}}{1.25\,\text{mol/L}} = 0.040 \text{ L}$$

**Solution**
The volume of concentrated acetic acid required is 0.040 L.

**Check Your Solution**
The answer has the correct units (L) and the correct number of significant digits (2). The volume is smaller than the final volume of the dilute solution as expected.

**31. b)**
**Problem**
Suppose that you are given a 1.25 mol/L standard aqueous solution of sodium chloride, NaCl(aq). What volume of standard solution must you use to prepare 200 mL of 0.800 mol/L NaCl(aq).

**What is Required?**
You must determine the volume of a standard sodium chloride solution ($V_1$) that must be used to prepare a dilute solution sodium chloride solution.

**What is Given?**
The concentration of the standard solution ($c_1$) = 1.25 mol/L. The volume of dilute solution ($V_2$) is 200 mL and the concentration of the dilute solution ($c_2$) is 0.800 mol/L.

**Plan Your Strategy**
Change the volume of 50 mL to litres using the conversion factor 1 L/1 000 mL. The number of moles of solute is the same in both the concentrated and in the diluted solution. Therefore, use the formula $c_1V_1 = c_2V_2$ and solve for $V_1$.

**Act on Your Strategy**

$$V_2 = 200 \text{ mL} = 200 \text{ mL} \times \frac{1\text{L}}{1000\ \text{mL}} = 0.200 \text{ L}$$

$c_1V_1 = c_2\ V_2$ therefore $V_1 = \dfrac{c_2V_2}{c_1} = \dfrac{0.800\,\text{mol/L} \times 0.200\,\text{L}}{1.25\,\text{mol/L}} = 0.128\ \text{L}$

**Solution**
The volume of concentrated acetic acid required is 0.128 L.

**Check Your Solution**
The answer has the correct units (L) and the correct number of significant digits (3). The volume is smaller than the final volume of the dilute solution as expected.

**32. a)**
**Problem**
What concentration of solution is obtained by diluting 50.0 ml of 0.720 mol/L aqueous sodium nitrate, $NaNO_3(aq)$, to 120 mL.

**What is Required?**
You must determine the final concentration of a solution ($c_2$) prepared by diluting a given volume of a concentrated solution of sodium nitrate.

**What is Given?**
The initial concentration of the sodium nitrate solution ($c_1$) = 0.720 mol/L. The volume of sodium nitrate solution used ($V_1$) is 50.0 mL. The final volume of the diluted solution ($V_2$) is 120 mL.

**Plan Your Strategy**
Change the volumes of solution from milliliters to litres using the conversion factor 1 L/1000 mL. The number of moles of solute is the same in both the concentrated and in the diluted solution. Therefore, use the formula $c_1V_1 = c_2V_2$ and solve for $c_2$.

**Act on Your Strategy**

$V_1 = 50.0\ \text{mL} = 50.0\ \text{mL} \times \dfrac{1\,\text{L}}{1000\ \text{mL}} = 0.0500\ \text{L}$

$V_2 = 120\ \text{mL} = 200\ \text{mL} \times \dfrac{1\,\text{L}}{1000\,\text{mL}} = 0.120\ \text{L}$

$c_1V_1 = c_2V_2$ therefore $c_2 = \dfrac{0.720\,\text{mol/L} \times 0.0500\,\text{L}}{0.120\,\text{L}} = 0.300\ \text{mol/L}$

**Solution**
The concentration of the diluted solution is 0.300 mol/L.

**Check Your Solution**
The answer has the correct units (mol/L) and the correct number of significant digits (3). The concentration of the dilute solution is less than the concentration of the initial concentrated solution.

**32. b)**
**Problem**
What concentration of solution is obtained by diluting 50.0 ml of 0.720 mol/L aqueous sodium nitrate, $NaNO_3(aq)$, to 400 mL.

**What is Required?**
You must determine the final concentration of a solution ($c_2$) prepared by diluting a given volume of a concentrated solution of sodium nitrate.

**What is Given?**
The initial concentration of the sodium nitrate solution ($c_1$) = 0.720 mol/L. The volume of sodium nitrate solution used ($V_1$) is 50.0 mL. The final volume of the diluted solution ($V_2$) is 400 mL.

**Plan Your Strategy**
Change the volumes of solution from milliliters to litres using the conversion factor 1 L/1000 mL. The number of moles of solute is the same in both the concentrated and in the diluted solution. Therefore, use the formula $c_1V_1 = c_2V_2$ and solve for $c_2$.

**Act on Your Strategy**

$$V_1 = 50.0 \text{ mL} = 50.0 \text{ mL} \times \frac{1\text{L}}{1000\,\text{mL}} = 0.0500 \text{ L}$$

$$V_2 = 400 \text{ mL} = 400 \text{ mL} \times \frac{1\text{L}}{1000\,\text{mL}} = 0.400 \text{ L}$$

$$c_1V_1 = c_2V_2 \text{ therefore } c_2 = \frac{c_1V_1}{V_2} = \frac{0.720\,\text{mol/L} \times 0.0500\,\text{L}}{0.400\,\text{L}} = 0.0900 \text{ mol/L}$$

**Solution**
The concentration of the diluted solution is 0.0900 mol/L.

**Check Your Solution**
The answer has the correct units (mol/L) and the correct number of significant digits (3). The concentration of the dilute solution is less than the concentration of the initial concentrated solution.

**32. c)**
**Problem**
What concentration of solution is obtained by diluting 50.0 ml of 0.720 mol/L aqueous sodium nitrate, $NaNO_3(aq)$, to 5.00 L.

**What is Required?**
You must determine the final concentration of a solution ($c_2$) prepared by diluting a given volume of a concentrated solution of sodium nitrate.

**What is Given?**
The initial concentration of the sodium nitrate solution ($c_1$) = 0.720 mol/L. The volume of sodium nitrate solution used ($V_1$) is 50.0 mL. The final volume of the diluted solution ($V_2$) is 5.00 L.

**Plan Your Strategy**
Change the initial volume of solution from milliliters to litres using the conversion factor 1 L/1 000 mL. The number of moles of solute is the same in both the concentrated and in the diluted solution. Therefore, use the formula $c_1V_1 = c_2 V_2$ and solve for $c_2$.

**Act on Your Strategy**

$$V_1 = 50.0 \text{ mL} = 50.0 \text{ mL} \times \frac{1\text{L}}{1000\,\text{mL}} = 0.0500 \text{ L}$$

$$c_1V_1 = c_2V_2 \text{ therefore } c_2 = \frac{c_1V_1}{V_2} = \frac{0.720\,\text{mol/L} \times 0.050\,\text{L}}{5.00\,\text{L}} = 0.00720 \text{ mol/L}$$

**Solution**
The concentration of the diluted solution is 0.00720 mol/L.

**Check Your Solution**
The answer has the correct units (mol/L) and the correct number of significant digits (3). The concentration of the dilute solution is less than the concentration of the initial concentrated solution.

**33.**
**Problem**
A solution is prepared by *adding* 600 mL of distilled water to 100 mL of 0.15 mol/L ammonium nitrate. Calculate the molar concentration of the solution. Assume that the volume quantities can be added together.

**What is Required?**
You must determine the final concentration of a solution ($c_2$) prepared by diluting a given volume of a concentrated solution of ammonium nitrate.

**What is Given?**
The initial concentration of the ammonium nitrate solution ($c_1$) = 0.15 mol/L. The volume of ammonium nitrate solution used ($V_1$) is 100 mL. The final volume of the diluted solution ($V_2$) is 600 mL + 100 mL = 700 mL.

**Plan Your Strategy**
Change the initial volume of solution from milliliters to litres using the conversion factor 1 L/1000 mL. The number of moles of solute is the same in both the concentrated and in the diluted solution. Therefore, use the formula $c_1V_1 = c_2V_2$ and solve for $c_2$.

**Act on Your Strategy**

$V_1 = 50.0 \text{ mL} = 50.0 \text{ mL} \times \frac{1\text{L}}{1000\,\text{mL}} = 0.0500 \text{ L}$

$V_2 = 700 \text{ mL} = 700 \text{ mL} \times \frac{1\text{L}}{1000\,\text{mL}} = 0.700 \text{ L}$

$c_1V_1 = c_2V_2$ therefore $c_2 = \frac{c_1V_1}{V_2} = \frac{0.15\,\text{mol/L} \times 0.100\,\text{L}}{0.700\,\text{L}} = 0.021 \text{ mol/L}$

**Solution**

The concentration of the diluted solution is 0.021 mol/L.

**Check Your Solution**

The answer has the correct units (mol/L) and the correct number of significant digits (2). The concentration of the dilute solution is less than the concentration of the initial concentrated solution.