Connexions module: m17123

DILUTION*

Sunil Kumar Singh

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Dilution means adding solvent (A) to a solution (S). The amount of solute (B) remains constant, but the amount of solution increases. Dilution of solution is needed as solutions are purchased and stored in concentrated form; whereas we use solution of different concentration in accordance with the requirement of the application.

Concentration of solution is expressed in different concentration format as mass percent, mole fraction, molarity, normality or any other format. The underlying principle, here, is that quantity of solute remains the same before and after dilution.

Dilution of a solution of a given chemical entity can also be realized by mixing solution of higher concentration with solution of lower concentration. This mixing is equivalent to increasing amount of solvent. This aspect has already been dealt in the module titled "Gram equivalent concept".

1 Mass percentage and dilution

Mass percentage is equal to percentage of mass of solute with respect to solution and is given by:

$$y = \frac{\text{Mass of solute(B)}}{\text{Mass of solution(S)}} = \frac{W_B}{W_S} X 100 = \frac{g_B}{g_S} X 100$$

Let 1 and 2 subscripts denote before and after states, then mass of solute before and after dilution is same :

$$W_{B_1} = W_{B_2}$$

$$y_1 W_{S_1} = y_2 W_{S_2}$$

Similarly,

$$y_1 g_{S_1} = y_2 g_{S_2}$$

Example 1

Problem : How much water would you need to prepare 600 grams of a 4% (w/w) Hydrogen Peroxide (H_2O_2) solution using a solution of 20% (w/w)?

Solution: Here,

$$g_{S_1} = 600 \ gm$$

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$$y_1 = 4$$

$$y_2 = 20$$

$$y_1 g_{S_1} = y_2 g_{S_2}$$

$$\Rightarrow 4X600 = 20Xg_{S_2}$$

$$\Rightarrow g_{S_2} = \frac{4X600}{20} = 120 \quad gm$$

Total mass of 4% = mass of 20% solution + mass of water added

mass of water added =
$$600 - 120 = 480$$
 qm

2 Molarity and dilution

Molarity is equal to ratio of moles of solute and volume of solution and is given by:

$$M = \frac{\text{moles of solute}}{V_L} == \frac{\text{mill-moles of solute}}{V_{CC}}$$

Let 1 and 2 subscripts denote before and after dilution, then:

moles before dilution = moles after dilution

$$M_1V_{L_1} = M_2V_{L_2}$$

Similarly,

$$M_1 V_{CC_1} = M_2 V_{CC_2}$$

Example 2

Problem: What volume of water should be added to 100 ml nitric acid having specific gravity 1.4 and 70% strength to give 1 M solution?

Solution: We first need to convert the given strength of concentration to molarity. Molarity is given by:

$$M = \frac{10yd}{M_O}$$

The specific gravity is 1.4 (density compared to water). Hence, density of solution is 1.4 gm/ml.

$$\Rightarrow M = \frac{10X70X1.4}{(1+14+3X16)} = 15.55M$$

Applying dilution equation,

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$$M_1V_{CC_1} = M_2V_{CC_2}$$

$$\Rightarrow 15.55X100 = 1XV_2$$

$$\Rightarrow V_2 = 1555 \quad ml$$

The volume of water to be added = 1555 - 100 = 1455 ml

Example 3

Problem : In an experiment, 300 ml of 6.0 M nitric acid is required. Only 50 ml of pure nitric acid is available. Pure anhydrous nitric acid (100%) is a colorless liquid with a density of 1522 kg/m^3 . Would it be possible to carry out the experiment?

Solution: Here.

$$M_1 = 6M; \quad M_2 = ?; \quad V_{CC_1} = 300 \quad ml; \quad V_{CC_2} = ?$$

In order to apply dilution equation, we need to know the molarity of concentrated nitric acid. Now 1 litre pure concentrate weighs 1000 X 1.522 = 1522 gm. The number of moles in 1 litre of nitric acid is:

$$\Rightarrow n_B = \frac{1522}{(1+14+3X16)} = 24.16$$

Hence, molarity of the nitric acid concentrate is 24.16 M. Applying dilution equation,

$$M_1 V_{CC_1} = M_2 V_{CC_2}$$

$$M_1 V_{CC} = 6X300$$

$$\Rightarrow V_{CC_2} = \frac{M_1 V_{CC_1}}{M_2} = \frac{6X300}{24.16} = 74.5 \quad ml$$

It means requirement of concentrate (74.5 ml) is more than what is available (50 ml). As such, experiment can not be completed.

Example 4

Problem: A 100 ml, 0.5 M calcium nitrate solution is mixed with 200 ml of 1.25M calcium nitrate solution. Calculate the concentration of the final solution. Assume volumes to be additive.

Solution: We first calculate milli-moles for each solution. Then, add them up to get the total moles present in the solution. Finally, we divide that total moles by the total volume.

Milli-moles in the first solution =
$$M_1V_{CC_1} = 100X0.5 = 50$$

Milli-moles in the second solution =
$$M_2V_{CC_2} = 200X1.25 = 250$$

Milli-moles in the final solution = 50 + 250 = 300

Total volume of the solution = 100 + 200 = 300 ml

Hence, molarity of the final solution is:

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$$M = \frac{\text{Milli-moles of solute}}{V_{CC}} = \frac{300}{300} = 1M$$

Alternative method

Molarity of the first solution when diluted to final volume of 300 ml is obtained as:

$$M_1 V_{CC_1} = M_2 V_{CC_2}$$

$$\Rightarrow 0.5X100 = M_2X300$$

$$\Rightarrow M_2 = \frac{50}{300} = \frac{1}{6}$$

Molarity of the second solution when diluted to final volume of 300 ml is obtained as:

$$M_1V_{CC_1} = M_2V_{CC_2}$$

$$\Rightarrow 1.25X200 = M_2X300$$

$$\Rightarrow M_2 = \frac{250}{300} = \frac{5}{6}$$

Hence, molarity of the final combined solution is:

$$M = \frac{1}{6} + \frac{5}{6} = 1$$

3 Normality and dilution

As there is no change in the amount of solute due to dilution, the amount expressed as gram equivalents should also remain same before and after dilution. Like in the case of molarity, we state the condition of dilution in terms of normality as:

Gram equivalents in the solution = $N_1V_1 = N_2V_2$

Example 5

Problem: What volume of water should be added to 100 ml sulphuric acid having specific gravity 1.1 and 80% strength to give 1 N solution?

Solution: We first need to convert the given strength of concentration to Normality. For that we first calculate molarity and then use the formula::

$$N = xM$$

Now, molarity is given by

$$M = \frac{10yd}{M_O}$$

The specific gravity is 1.4 (density compared to water). Hence, density of solution is 1.4 gm/ml.

$$\Rightarrow M = \frac{10X80X1.1}{(2X1 + 32 + 4X16)} = 8.98M$$

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The valence factor of H_2SO_4 is 2. Hence,

$$\Rightarrow N = xM = 2X8.98 = 17.96N$$

Applying dilution equation,

$$N_1 V_{CC_1} = N_2 V_{CC_2}$$

$$\Rightarrow 17.96 X 100 = 1 X V_2$$

$$\Rightarrow V_2 = 1796 \quad ml$$

The volume of water to be added = 1796 - 100 = 1696 ml