

Dilution Problems

- 1) You have a bottle of 85% isopropyl alcohol. How much alcohol and water need to be mixed to prepare 100 mL of 68% alcohol?
- 2) If you have a stock solution of 3.0 M NaI, how would you prepare 200. mL of a working solution of 5.0 μ M NaI? A stock solution is the concentrated solution which is being diluted and a working solution is the resulting diluted solution.
- 3) Starting with 10. mL of 5.0 M HNO₃, how would you prepare 20. mL of 1.0 x 10⁻⁶ M HNO₃?
- 4) The concentration of a stock solution of a dye is 0.25 mol/dm³. In order to use this dye as a stain, the concentration in the dilute solution must fall in the range of 1.0 x 10⁻⁴ mol/dm³ – 4.0 x 10⁻⁴ mol/dm³. How would you prepare 5.0 cm³ of this dye using a serial dilution?

Solutions

- 1) You have a bottle of 85% isopropyl alcohol. How much alcohol and water need to be mixed to prepare 100 mL of 68% alcohol?

$$\begin{array}{ll} [\text{C}_3\text{H}_8\text{O}]_c = 0.85 & [\text{C}_3\text{H}_8\text{O}]_d = 0.68 \\ V_c = ? & V_d = 100 \text{ mL} \end{array}$$

$$\text{DF} = [\text{C}_3\text{H}_8\text{O}]_d / [\text{C}_3\text{H}_8\text{O}]_c = 0.68 \text{ M} / 0.85 \text{ M} = 0.80$$

$$\text{DF} = V_c / V_d$$

$$V_c = 0.80 \times 100. \text{ mL} = 80. \text{ mL} \times 1.0 \mu\text{L} / 10^{-3} \text{ mL} = 8.0 \times 10^4 \mu\text{L}$$

Now the question becomes, a simple or serial dilution? You can not accurately measure volumes smaller than 1.0 μL (10^{-3} mL, 10^{-6} L), so when the need arises you must use a serial dilution.

$V_c = 8.0 \times 10^4 \mu\text{L}$ which rules out a serial dilution.

After measuring out 80. mL $\text{C}_3\text{H}_8\text{O}$, you would add 20. mL of distilled water and stir thoroughly. You would need distilled water to ensure a two-component system.

2) If you have a stock solution of 3.0 M NaI, how would you prepare 200. mL of a working solution of 5.0 μ M NaI?

$$[\text{NaI}]_c = 3.0 \text{ M}$$
$$V_c = ?$$

$$[\text{NaI}]_d = 5.0 \text{ } \mu\text{M}$$
$$V_d = 200. \text{ mL}$$

$$\text{DF} = [\text{NaI}]_d / [\text{NaI}]_c = (5.0 \times 10^{-6} \text{ M}) / 3.0 \text{ M} = 1.7 \times 10^{-6}$$

$$\text{DF} = V_c / V_d$$

$$V_c = 1.7 \times 10^{-6} \text{ mL} * 200. \text{ mL} * 10^3 \text{ } \mu\text{L} / 1 \text{ mL} = 0.34 \text{ } \mu\text{L}$$

A simple dilution is ruled out.

When doing serial dilution problems, it is always best to keep simple what is simple. Do not be afraid of making paper and pencil mistakes. For example, what is a reasonable approach to dilute a solution by a factor of 1.7×10^{-6} ?

Rewrite 1.7×10^{-6} as:

$$1.7/10^6 = 1.7/10^1 \times 1/10^3 \times 1/10^2$$

Does the order of terms matter? Algebraically no, but this order would be very convenient to carry out the dilution.

Step 1 of the titration would be to thoroughly mix 1.7 mL of NaI with 8.3 mL of distilled water. The total dilution so far is 1.7/10 (D1).

Step 2 of the titration would be to thoroughly mix 1.0 mL of D1 with 999.0 mL of distilled water. The total dilution so far is 0.17/1000 (D2).

Step 3 of the titration would be to thoroughly mix 2.0 mL of D2 with 198.0 mL of distilled water. The final dilution is $1.7 \times 10^{-4} / 100 = 1.7 \times 10^{-6}$ (D3).

$$\text{DF} = \text{D1} \times \text{D2} \times \text{D3} = 1.7/10 \times 0.17/1000 \times 1.7 \times 10^{-4}/100 = 1.7 \times 10^{-6}$$

When calculating for a serial dilution it always best to start with the coefficient when it is not equal to 1. Because the problem stated that a final volume of 200. mL was required, it is most convenient to have that be the final step of the dilution.

3) Starting with 10. mL of 5.0 M HNO₃, how would you prepare 20. mL of 1.0 x 10⁻⁶ M HNO₃?

$$[\text{HNO}_3]_c = 5.0 \text{ M}$$
$$V_c = 10. \text{ mL}$$

$$[\text{HNO}_3]_d = 1.0 \times 10^{-6} \text{ M}$$
$$V_d = 20. \text{ mL}$$

$$\text{DF} = [\text{HNO}_3]_d / [\text{HNO}_3]_c = (1.0 \times 10^{-6} \text{ M}) / 5.0 \text{ M} = 2.0 \times 10^{-7}$$

$$\text{DF} = V_c / V_d$$

$$V_c = 2.0 \times 10^{-7} * 20. \text{ mL} * 10^3 \mu\text{L} / 1 \text{ mL} = 4.0 \times 10^{-3} \mu\text{L}$$

A simple dilution is ruled out.

Step 1 of the titration would be to thoroughly mix 2.0 mL of HNO₃ with 8.0 mL of distilled water. The total dilution so far is 2.0/10 (D1).

Step 2 of the titration would be to thoroughly mix 1.0 mL of D1 with 99999 mL of distilled water. The total dilution so far is 2.0/10 * 1/10⁵ (D2).

Step 3 of the titration would be to thoroughly mix 2.0 mL of D2 with 18.0 mL of distilled water. The final dilution is 2.0/10 * 1/10⁵ * 2/20 (D3).

$$\text{DF} = \text{D1} \times \text{D2} \times \text{D3} = 2.0/10 * 1/10^5 * 2/20 = 2.0 \times 10^{-7}$$

- 4) The concentration of a stock solution of a dye is 0.25 mol/dm^3 . In order to use this dye as a stain, the concentration in the dilute solution must fall in the range of $1.0 \times 10^{-4} \text{ mol/dm}^3 - 4.0 \times 10^{-4} \text{ mol/dm}^3$. How would you prepare 5.0 cm^3 of this dye using a serial dilution?

$$\begin{aligned} []_c &= 0.25 \text{ M} \\ V_c &= \end{aligned}$$

$$\begin{aligned} []_d &= 1.0 \times 10^{-4} \text{ mol/dm}^3 - 4.0 \times 10^{-4} \text{ mol/dm}^3 \\ V_d &= 5.0 \text{ cm}^3 \end{aligned}$$

$$DF = []_d / []_c = (2.5 \times 10^{-4} \text{ mol/dm}^3) / 0.25 \text{ mol/dm}^3 = 1.0 \times 10^{-3}$$

$$DF = V_c / V_d$$

$$V_c = 1.0 \times 10^{-3} * 5.0 \text{ mL} * 10^3 \text{ } \mu\text{L} / 1 \text{ mL} = 5.0 \text{ } \mu\text{L}$$

A serial dilution could have been ruled out but the problem specifically asked for a serial dilution.

Step 1 of the titration would be to thoroughly mix 0.50 mL of dye with 4.5 mL of distilled water. The total dilution so far is $0.50/5.0$ (D1).

Step 2 of the titration would be to thoroughly mix 0.50 mL of D1 with 4.5 mL of distilled water. The total dilution so far is $0.50/5.0 \times 0.50/5.0$ (D2).

Step 3 of the titration would be to thoroughly mix 0.50 mL of D2 with 4.5 mL of distilled water. The final dilution is $0.50/5.0 \times 0.50/5.0 \times 0.50/5.0$ (D3).

$$DF = D1 \times D2 \times D3 = 0.50/5.0 \times 0.50/5.0 \times 0.50/5.0 = 1.0 \times 10^{-3}$$

The reason for choosing 5.0 mL for the total volume for each dilution is that question specified 5.0 mL. In most cases, if you had prepared 10. mL which would leave 5.0 mL in excess, it would be, who cares? But if the stock solution for the dye was very expensive, you would also want to be economical.