Solution Dilution

Write molarity as $M=\frac{n}{V}$, where M is molarity, n = moles of solute, and V = volume of solution.

Then n = moles of solute in solution = MV (or =VM).

In a dilution problem, water is added to a solution to change its concentration (molarity).

If before water is added the solution (solution 1) has M_1 and V_1 , then after the water is added it will have M_2 and V_2. Since only water is added the moles of solute before water is added (n_1) must equal the moles of solute after the water is added (n_2). That is, $n_1 = n_2$ and $n_1 = M_1V_1 = M_2V_2 = n_2$.

Thus the dilution equation is **$M_1V_1 = M_2V_2$**

Problem 1: Water is added to 200.0 mL of 3.00 M HCl(aq) until the volume is 450.0 mL. What is the new molarity?

Solution: The new molarity = $M_2 = \frac{M_1V_1}{V_2} = \frac{3.00\ M \times 200.0\ mL}{450.0\ mL}$ = 1.33 M HCl

2. 500.0 mL of water is added to 200.0 mL 2.22 M NaCl(aq). Determine the new molarity.

3. How much water must be added to 100.0 mL 1.80 M H_2O_2(aq) to make a 0.800 M H_2O_2(aq)?

4. 200.0 mL of 0.500 M $CaCl_2$(aq) is mixed with 600.0 mL of 0.200 M K_2SO_4(aq). No reaction takes place. Calculate the concentration of **each ion** in the resulting mixture.

5. Determine [NH_3] when 2.00 L of 3.00 M NH_3(aq) is mixed with 0.500 L of 5.00 M NH_3(aq).

6. 100.0 mL of 0.200 M $Al(NO_3)_3$ (aq) is mixed with 250.0 mL of 1.00 M $NaNO_3$(aq). Determine the molarity of the nitrate ion in the resulting mixture. molarity = total moles NO_3^- / total liters solution

7. How many milliters of 12.0 M HCl(aq) are required to make 2.000 L of 0.600 M HCl(aq)

Answers:

2. 0.634 M NaCl 3. 125.0 mL water (added to 100.0 mL soln gives 225.0 mL 0.800 M soln)

4. [Ca^{2+}] = 0.125 M [Cl^-] = 0.250 M [SO_4^{2-}] = 0.150 M [K^+] = 0.300 M

5. [NH_3] = 3.4 M

6. [NO_3^-] = 0.886 M NO_3^- also [Al^{3+}] = 0.0571 M [Na^+] = 0.714 M

7. 100.0 mL of 12.0 M HCl(aq)

Solutions to Problems

2. $M_2 = \frac{M_1V_1}{V_2} = \frac{2.22\ M\ NaCl \times 200.0\ mL}{700.0\ mL\ (total)} = 0.634\ M\ NaCl$ 700. mL from 200 mL + 500 mL

3. $V_2 = \frac{M_1V_1}{M_2} = \frac{1.80\ M\ H_2O_2 \times 100.0\ mL}{0.800\ M\ H_2O_2} = 225.0\ mL$ = new volume

so add (225.0 mL – 100.0 mL =) **125.0 mL** water to 100.0 mL of solution

4. $M_2 = \frac{M_1V_1}{V_2} = \frac{0.500\ M\ CaCl_2 \cdot 200.0\ mL}{800.0\ mL\ (total)} = \frac{0.125\ mol\ CaCl_2}{1\ L\ soln} \times \frac{1\ mol\ Ca^{2+}}{1\ mol\ CaCl_2} = 0.125\ M\ Ca^{2+}$

$M_2 = \frac{M_1V_1}{V_2} = \frac{0.500\ M\ CaCl_2 \cdot 200.0\ mL}{800.0\ mL\ (total)} = \frac{0.125\ mol\ CaCl_2}{1\ L\ soln} \times \frac{2\ mol\ Cl^-}{1\ mol\ CaCl_2} = 0.250\ M\ Cl^-$

$M_2 = \frac{M_1V_1}{V_2} = \frac{0.200\ M\ K_2SO_4 \times 600.0\ mL}{800.0\ mL\ (total)} = \frac{0.150\ mol\ K_2SO_4}{1\ L\ soln} \times \frac{1\ mol\ SO_4^{2-}}{1\ mol\ K_2SO_4} = 0.150\ M\ SO_4^{2-}$

$M_2 = \frac{M_1V_1}{V_2} = \frac{0.200\ M\ K_2SO_4 \times 600.0\ mL}{800.0\ mL\ (total)} = \frac{0.150\ mol\ K_2SO_4}{1\ L\ soln} \times \frac{2\ mol\ K^+}{1\ mol\ K_2SO_4} = 0.300\ M\ K^+$

5. $[NH_3] = \frac{total\ moles\ NH_3}{total\ volume} = \frac{M_1V_1 + M_2V_2}{V_1 + V_2} = \frac{3.00M \times 2.00\ L + 5.00\ M \times 0.50\ L}{2.00\ L + 0.500\ L} = 3.400\ M\ NH_3$

6. for NO_3^- $n_3 = n_1 + n_2$ so $M_3V_3 = M_1V_1 + M_2V_2$ and $V_3 = V_1 + V_2$ = 100.0 mL + 250.0 mL = 350.0 mL

so $M_3 = \frac{M_1V_1 + M_2V_2}{V_3} = \frac{0.200\ M\ Al(NO_3)_3 \cdot \frac{3\ mol\ NO_3^-}{1\ mol\ Al(NO_3)_3} \cdot 100.0\ mL + 1.00\ M\ NO_3^- \cdot 250.0\ mL}{350.0\ mL}$

$= 0.886\ M\ NO_3^-$ for Al^{3+} $M_2 = \frac{M_1V_1}{V_2} = \frac{0.200\ M\ Al(NO_3)_3 \cdot 100.0\ mL}{350.0\ mL} = 0.057\ M\ Al^{3+}$

for Na^+ $M_2 = \frac{M_1V_1}{V_2} = \frac{1.0\ M\ NaNO_3 \cdot 250.0\ mL}{350.0\ mL} = 0.714\ M\ Na^+$

7. $V_1 = \frac{M_2V_2}{M_1} = \frac{0.600\ M\ HCl \times 2.000\ L}{12.0\ M\ HCl} = 0.100\ L\ (12\ M)\ HCl$ (= 100. mL)