ANSWER KEY

Unit 9 - Solutions & Equilibrium Cumulative Practice

INTRODUCTION:

Molarity is one way to measure the concentration of a solution. The molarity of a solution is the number of moles of solute per liter of solution. The symbol for molarity is M. Thus a 3.0 molar solution of nitric acid, abbreviated 3.0 M HNO_3, contains 3.0 moles of HNO_3 per 1 liter of solution.

$$\text{Molarity} = \frac{\text{Moles Solute}}{\text{Liters Solution}} \qquad \text{Symbols for molarity: } M = \text{“molar”} = \frac{mol}{L}$$

PRACTICE PROBLEMS:

Solve the following problems. In the space below each problem, show a labeled setup (questions ~~1-6~~ 1-4 require dimensional analysis method). Write the answers in the spaces at the right. Do not forget to include units!

1) What is the molarity of a solution that contains 210. grams of $Al_2(SO_4)_3$ in 2.75 liters of solution?

0.223 M $Al_2(SO_4)_3$

① $\frac{210.\ g\ Al_2(SO_4)_3}{1}\Big|\frac{1\ mol\ Al_2(SO_4)_3}{342.17\ g\ Al_2(SO_4)_3} = 0.614\ mol\ Al_2(SO_4)_3$

② $M = \frac{mol}{L} \rightarrow M = (0.614\ mol\ Al_2(SO_4)_3)\ /\ 2.75\ L\ soln = 0.223\ M\ Al_2(SO_4)_3$

2) How many grams of potassium dichromate are required to prepare a 250.-mL solution whose concentration is 2.16 M $K_2Cr_2O_7$?

159 g $K_2Cr_2O_7$

① $M = \frac{mol}{L} \rightarrow mol = (M)(L) \rightarrow mol = (2.16M)(0.250L) = 0.540\ mol\ K_2Cr_2O_7$

② $\frac{0.540\ mol\ K_2Cr_2O_7}{1}\Big|\frac{294.18\ g\ K_2Cr_2O_7}{1\ mol\ K_2Cr_2O_7} = 159\ g\ K_2Cr_2O_7$

3) What is the volume *(in mL)* of a solution required to provide 2.14 g of sodium chloride from a 0.270 M solution?

136 mL NaCl Soln

① $\frac{2.14\ g\ NaCl}{1}\Big|\frac{1\ mol\ NaCl}{58.44\ g\ NaCl} = 0.0366\ mol\ NaCl$

② $M = \frac{mol}{L} \rightarrow L = \frac{mol}{M} \rightarrow L = \frac{0.0366\ mol\ NaCl}{0.270M} \rightarrow 0.136\ L = 136\ mL$

4) What volume of 0.300 *M* solution can be prepared using 0.850 grams of acetic acid ($HC_2H_3O_2$)?

0.0472 L $HC_2H_3O_2$

① $\frac{0.850\ g\ HC_2H_3O_2}{1}\Big|\frac{1\ mol\ HC_2H_3O_2}{60.052\ g\ HC_2H_3O_2} = 0.0142\ mol\ HC_2H_3O_2$

② $M = \frac{mol}{L} \rightarrow L = \frac{mol}{M} \rightarrow L = \frac{0.0142\ mol\ HC_2H_3O_2}{0.300M} \rightarrow 0.0472\ L\ HC_2H_3O_2$

MIXING SOLUTIONS:

Calculate the molarities of the following solutions. In the space below each problem, show a labeled setup. Write the answers in the spaces at the right. Do not forget to include units!

Formula for a solution: $M = \frac{\text{Total Moles}}{\text{Total Volume}}$

5) Calculate the final molarity when 70.0 mL of 3.0 M sodium chloride solution is added to 30.0 mL of a 1.00 M solution of sodium chloride.

2.40 M NaCl

① $mol = (M)(L) \rightarrow mol = (3.0M)(0.0700\ L) = 0.210\ mol\ NaCl$

② $mol = (M)(L) \rightarrow mol = (1.00M)(0.0300L) = + 0.0300\ mol\ NaCl$

③ $(0.0700L) + (0.0300L) = 0.100\ L\ soln$

0.240 mol NaCl

$M = \frac{0.240\ mol\ NaCl}{0.100\ L\ soln} \rightarrow 2.40\ M\ NaCl$

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DILUTIONS:

Calculate the molarities of the following solutions. In the space below each problem, show a labeled setup. Write the answers in the spaces at the right. Do not forget to include units!

Formula for dilution of a solution: $M_1V_1 = M_2V_2$

6) A solution is prepared by dissolving 10.8 g ammonium sulfate, $(NH_4)_2SO_4$, in enough water to make 100.0 mL of stock solution. A 10.0 mL sample of this stock solution is added to 50.0 mL of water.

What is the molarity of the ***stock*** solution?

0.817 M $(NH_4)_2SO_4$

① $\frac{10.8\ g\ (NH_4)_2SO_4}{1}\Big|\frac{1\ mol\ (NH_4)_2SO_4}{132.154\ g\ (NH_4)_2SO_4} = 0.0817\ mol\ (NH_4)_2SO_4$; ② $M = \frac{0.0817\ mol}{0.100\ L}$

What is the final molarity of the ***dilution*** once water was added?

0.136 M $(NH_4)_2SO_4$

$M_1V_1 = M_2V_2 \rightarrow M_2 = \frac{M_1V_1}{V_2}$

$M_2 = \frac{(0.817M)(10.0mL)}{(60mL)} \rightarrow M_2 = 0.136M\ (NH_4)_2SO_4$

7) What volume of concentrated 12.0 M stock solution is necessary to make 1.00 L of 0.500 M solution?

0.0417 L

$M_1V_1 = M_2V_2 \rightarrow V_1 = \frac{M_2V_2}{M_1}$

$V_1 = \frac{(0.500M)(1.00L)}{(12.0M)} \rightarrow V_1 = 0.0417\ L$

8) To what volume should 25.0 mL of 15.0 M nitric acid (HNO_3) be diluted to prepare a 3.00 M solution?

125 mL HNO_3 Soln

$M_1V_1 = M_2V_2 \rightarrow V_2 \rightarrow \frac{M_1V_1}{M_2}$

$V_2 = \frac{(15.0M)(25.0mL)}{(3.00M)} \rightarrow V_2 = 125\ mL\ HNO_3\ soln$

PREPARING SOLUTIONS & DILUTIONS:

Explain how you would make (prepare) the following solutions.

* ***SOLUTIONS*** Example: 0.750 L of 0.250 *M* Na_2SO_4

“Dissolve 26.64 grams of Na_2SO_4 with solvent (water) in a beaker. Pour the solution into a graduated cylinder and then dilute up to 750 milliliters.”

9) 250. mL of 0.750 *M* lithium nitrite

① $mol = (M)(L) \rightarrow mol = (0.750M)(0.250L) = 0.188\ mol\ LiNO_2$

② $\frac{0.188\ mol\ LiNO_2}{1}\Big|\frac{52.951\ g\ LiNO_2}{1\ mol\ LiNO_2} = \boxed{9.96\ g\ LiNO_2}$

Dissolve 9.96g $LiNO_2$ with water in a beaker. Pour into grad cyl and then dilute up to 250 mL.

* ***DILUTIONS*** Example: 2.00 L of a 0.250 M NaOH solution from 1.00 M NaOH stock solution.

“Measure 500. mL of 1.00 M NaOH stock solution. Dilute with water until the solution reaches 2.00 L.”

10) $\overset{(500mL)}{5.00 \times 10^2}$ mL of 1.75 *M* H_2SO_4 solution, starting with an 8.61 *M* stock solution of H_2SO_4.

$M_1V_1 = M_2V_2 \rightarrow V_1 = \frac{M_2V_2}{M_1} \rightarrow V_1 = \frac{(1.75M)(500mL)}{(8.61M)} \rightarrow \boxed{V_1 = 102\ mL\ H_2SO_4}$

* Measure 102 mL of 8.61M H_2SO_4 stock solution. Dilute with water until the solution reaches 500 mL.

SOLUBILITY CURVES:

1. A solution is also known as a homogeneous mixture. How is a solution different from a heterogeneous mixture?

Solute dissolved in solvent at given temperature looks uniform throughout in a solution.

2) In an aqueous solution of sodium chloride, what is the solute? NaCl What is the solvent? H_2O

3) Why is water considered the universal solvent?

H_2O, a polar substance, is able to dissolve many polar & ionic substances

4) Does solubility of a solid solute increase of decrease as temperature increases?

↑T = ↑ solubility of solid solutes

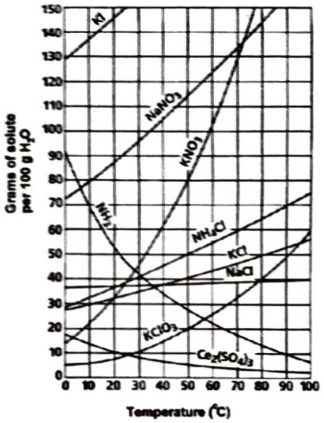
Here's an example of how to read the graph. Find the curve for $KClO_3$.

5) At 30°C approximately 10g of $KClO_3$ will dissolve in 100g of water. If the temperature is increased to 80°C, approximately 40g of the substance will dissolve in 100g (or 100mL) of water.

Directions: Use the graph to answer the following questions. REMEMBER UNITS!

6) What mass of solute will dissolve in 100mL of water at the following temperatures?

a. KNO_3 at 70°C = 130g
b. NaCl at 100°C= 40g
c. NH_4Cl at 90°C= 70g
d. Which of the above three substances is most soluble in water at 15°C. = NaCl



7) On a solubility curve, the lines indicate the concentration of a saturated solution - the maximum amount of solute that will dissolve at that specific temperature.

8) Values on the graph ([✓ below], along, above) a curve represent unsaturated solutions - more solute could be dissolved at that temperature.

Types of Solutions - Use the Solubility Curve

9) Label the following solutions as saturated or unsaturated. If unsaturated, write how much more solute can be dissolved in the solution.

Solution	Saturated or Unsaturated?	If unsaturated: How much more solute can dissolve in the solution?
(a) a solution that contains 70g of $NaNO_3$ at 30°C (in 100 mL H_2O)	Unsaturated	25g $NaNO_3$
(b) a solution that contains 50g of NH_4Cl at 50°C (in 100 mL H_2O)	Saturated	—
(c) a solution that contains 20g of $KClO_3$ at 50°C (in 100 mL H_2O)	Saturated	—
(d) a solution that contains 70g of KI at 0°C (in 100 mL H_2O)	Unsaturated	60 g KI

in 100g H_2O

10) What is the solubility of KCl at 5°C? ~29g c. What is the solubility of $Ce_2(SO_4)_3$ at 10°C? ~12g

11) What is the solubility of KCl at 25°C? ~33g d. What is the solubility of $Ce_2(SO_4)_3$ at 50°C? ~5g

12) At 90°C, you dissolved 10 g of KCl in 100. g of water. Is this solution saturated or unsaturated?

@90°C → $\frac{52g\ KCl}{100g\ H_2O}$; 10g KCl < 52g KCl ∴ $\boxed{\text{Unsaturated}}$

13) A mass of 100 g of $NaNO_3$ is dissolved in 100 g of water at 80°C.

a) Is the solution saturated or unsaturated? @80°C → $\frac{145g\ NaNO_3}{100g\ H_2O}$; 100g < 145g ∴ $\boxed{\text{Unsaturated}}$

b) As the solution is cooled, at what temperature should solid first appear in the solution? Explain.

$\boxed{\text{~40°C}}$ → Temp at which solution is supersaturated upon slow cooling from 80°C

** Use the solubility curve to answer questions 14-16:*

14) Which compound is most soluble at 20 °C? KI Which is the least soluble at 40 °C? $Ce_2(SO_4)_3$

15) Which substance on the graph is least soluble at 10°C? $KClO_3$

16) A mass of 80 g of KNO_3 is dissolved in 100 g of water at 50 °C. The solution is heated to 70°C. How many more grams of potassium nitrate must be added to make the solution saturated? Explain your reasoning. @50°C → $\frac{80g\ KNO_3}{100g\ H_2O}$; @70°C → $\frac{130g\ KNO_3}{100g\ H_2O}$; 130g − 80g = $\boxed{50g\ KNO_3}$

17) What are 3 ways to increase the solubility of a solid substance in a solid?

① Increase temperature of system (reaction)
② Agitate/stir the solution
③ Increase surface area of solute

18) How can the solubility of a gas in a liquid be increased?

① Decrease temperature
② Increase pressure

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CHEMICAL EQUILIBRIUM:

Write the equilibrium expression (K) for the following reactions:

1. $H_{2(g)} + I_{2(g)} \rightleftharpoons 2\,HI_{(g)}$ → $K=\frac{[HI]^2}{[H_2][I_2]}$

2. $NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$ → $K=[NH_3][HCl]$

3. $As_4O_{6(s)} + 6\,C_{(s)} \rightleftharpoons As_{4(g)} + 6\,CO_{(g)}$ → $K=[As_4][CO]^6$

4. $SnO_{2(s)} + 2\,CO_{(g)} \rightleftharpoons Sn_{(s)} + 2\,CO_{2(g)}$ → $K=\frac{[CO_2]^2}{[CO]^2}$

5. $Fe_2O_{3(s)} + 3\,H_{2(g)} \rightleftharpoons 2\,Fe_{(s)} + 3\,H_2O_{(g)}$ → $K=\frac{[H_2O]^3}{[H_2]^3}$

6. $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$ → $K=[CO_2]$

Balance each equation and then write the equilibrium expression (K) for each reaction:

1. 2 $C_2H_{6(g)}$ + 7 $O_{2(g)}$ ⇌ 4 $CO_{2(g)}$ + 6 $H_2O_{(g)}$ $K=\frac{[CO_2]^4[H_2O]^6}{[C_2H_6]^2[O_2]^7}$

2. 1 $FeO_{(s)}$ + 1 $CO_{(g)}$ ⇌ 1 $Fe_{(s)}$ + 1 $CO_{2(g)}$ → $K=\frac{[CO_2]}{[CO]}$

3. 1 $KCl_{(l)}$ + 1 $Na_{(l)}$ ⇌ 1 $NaCl_{(l)}$ + 1 $K_{(g)}$ → $K=[K]$

4. 1 $NaCl_{(s)}$ + 1 $H_2SO_{4(l)}$ ⇌ 1 $HCl_{(g)}$ + 1 $NaHSO_{4(s)}$ → $K=[HCl]$

5. 1 $P_{4(s)}$ + 6 $NO_{(g)}$ ⇌ 1 $P_4O_{6(s)}$ + 3 $N_{2(g)}$ → $K=\frac{[N_2]^3}{[NO]^6}$

6. 2 $NO_{(g)}$ + 2 $H_{2(g)}$ ⇌ 1 $N_{2(g)}$ + 2 $H_2O_{(l)}$ → $K=\frac{[N_2]}{[NO]^2[H_2]^2}$

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LeChatelier's Principle:

Part I: Complete the following table. Write *(left, right, or none)* for equilibrium shift, and *(decreases, increases, or remains same)*, for concentrations of reactants and products and for equilibrium constant (K):

52.7 kJ + 1 $H_{2(g)}$ + 1 $I_{2(g)}$ ⇌ 2 $HI_{(g)}$

Stress Type	Equilibrium Shift	$[H_2]$	$[I_2]$	$[HI]$	Equilibrium Constant (K)
Add H_2	Right	-----	↓	↑	Same
Add I_2	Right	↓	-----	↑	Same
Add HI	Left	↑	↑	-----	Same
Remove H_2	Left	-----	↑	↓	Same
Remove I_2	Left	↑	-----	↓	Same
Remove HI	Right	↓	↓	-----	Same
↑ Temperature	Right	↓	↓	↑	Increase
↓ Temperature	Left	↑	↑	↓	Decrease
↑ Pressure	NONE				Same
↓ Pressure	NONE				Same

Equal moles gas

Part II: Complete the following table. Write *(left, right, or none)* for equilibrium shift, and *(decreases, increases, or remains same)*, for concentrations of reactants and products and for equilibrium constant (K):

1 $NaOH_{(s)}$ ⇌ 1 $Na^+_{(aq)}$ + 1 $OH^-_{(aq)}$ + 44.3 kJ

(Remember that pure solids and liquids do not affect equilibrium values)

Stress Type	Equilibrium Shift	Amount of $NaOH_{(s)}$	$[Na^+]$	$[OH^-]$	Equilibrium Constant (K)
Add $NaOH_{(s)}$	Right	-----	↑	↑	Same
Add NaCl (Adds Na^+)	Left	↑	-----	↓	Same
Add KOH (Adds OH^-)	Left	↑	↓	-----	Same
Add H^+ (Removes OH^-)	Right	↓	↑	-----	Same
↑ Temperature	Left	↑	↓	↓	Decrease
↓ Temperature	Right	↓	↑	↑	Increase
↑ Pressure	NONE				Same
↓ Pressure	NONE				Same

No gas present