Solutions

UNIT4: SOLUTIONS

All important vocabulary is in Italics and bold.

- Describe and give examples of various types of ***solutions***.
  Include: ***suspension, emulsion, colloid, alloy, solute, solvent, soluble, insoluble, miscible, and immiscible***

- Describe the structure of water in terms of ***electronegativity*** and the ***polarity*** of its chemical bonds. *Include: polar and non-polar covalent compounds*

- Explain the solution process of simple ionic and covalent compounds, using visual, particulate representations and chemical equations.
  Include: ***crystal structure, dissociation, hydration, heat of solution***

- Differentiate among ***saturated***, ***unsaturated***, and ***supersaturated*** solutions.

- Explain which factors can affect solubility of solids, liquids and gases. *Include: pressure and temperature*

- Use a graph of solubility data to solve problems.

- Explain freezing-point depression and boiling-point elevation at the molecular level.

- Differentiate among, and give examples of, the use of various representations of ***concentration***. *Include: grams per litre (g/L), % weight-weight (% w/w), % weight-volume (% w/v), % volume/volume (% v/v), parts per million (ppm), parts per billion (ppb), moles per litre (mol/L) (molarity)*

- Solve problems involving calculation for concentration, moles, mass, and volume.

- Solve problems involving the ***dilution*** of solutions.
  Include: dilution of stock solutions, mixing common solutions with different volumes and concentrations

- Explain examples of solubility and ***precipitation*** at both the particle and symbolic levels.

- Use a table of ***solubility rules*** to predict the formation of a precipitate.

Additional KEY Terms

Pure Mixture Homogeneous Heterogeneous
Electrolyte Non-electrolyte
Colligative Properties

Answer the following questions on dissociation and the dissolving process:

1. Explain why water is a polar molecule.

2. Describe how the dissolving of sugar and sodium chloride is different.

3. Write the equation for the dissolving of each of the following in water

   a. $PbSO_4(s)$

   b. $Al_2(SO_4)_3(s)$

   c. $C_{11}H_{22}O_{11}(s)$

   d. $Ba(OH)_2(s)$

   e. $CH_3OH(l)$

   f. calcium chloride(*s*)

   g. $Na_2CO_3(s)$

   h. silver dichromate(*s*)

   i. KBr(*s*)

   j. iron (III) sulfate(*s*)

   k. potassium permanganate(*s*)

   l. magnesium sulfide(*s*)

Polar Versus Non-Polar

To practice identifying different kinds of solutions and solids.

In general, "like dissolves like," so that polar solvents dissolve ionic solids and polar molecules, and non-polar solvents dissolve non-polar molecules. Alcohols, which have properties of both, tend to dissolve in both types of solvents to a degree. Indicate which solutes the following solvents will dissolve by checking the appropriate columns.

	SOLUTES	SOLVENTS		
		WATER	CCl_4	Methanol (CH_3OH)
a	NaI			
b	Br_2			
c	Ethanol (C_2H_5OH)			
d	Benzene (C_6H_6)			
e	$KClO_3$			
f	$KMnO_4$			
g	$C_6H_{12}O_6$			
h	C_3H_8			

Electrolyte vs. Non-Electrolytes

Classify the following compounds as either an electrolyte or a non-electrolyte by checking the appropriate column.

	Compound	**Electrolyte**	**Nonelectrolyte**
i	KF		
j	$C_{12}H_{22}O_{11}$		
k	NaOH		
l	CH_3OH		
m	$MgCl_2$		
n	H_2CO_3		
o	C_6H_{12}		

ANSWER THE FOLLOWING QUESTIONS ON SOLUBILITY AND SOLUBIILITY CURVES:

Part A

1. Explain why and how temperature affects the solubility of a solid in a liquid.

Part B

Use the solubility curves given to answer the following questions.

Assume the density of water is 1.00 g/mL

1. Calculate the solubility of each of the following in g of solute/100 g of water.

   a. 0.62 g dissolves in 15.0 mL of water.
   b. 75.0 g dissolves in 350.0 mL of water.
   c. 0.250 kg dissolves in 1.20 L.
   d. 24.0 g dissolves in 280.0 g of water.

2. Determine the solubility of the following in g solute/L water.

   a. 260.0 g of a solid dissolves in 1500.0 mL of water.
   b. 0.160 kg of a solid dissolves in 225.0 g of water.

3. At what temperature is the solubility of the substance specified? (All in water)

   a. NH_4Cl 60.0 g/100 g
   b. KNO_3 120.0 g/100 g
   c. $NaNO_3$ 1200.0 g/L
   d. $KClO_3$ 100.0 g/500.0 g

4. What is the solubility, in g/ 100g water, of the following at the specified temperature?

   a. $NaNO_3$ at 40°C
   b. $Ce_2(SO_4)_3$ at 25°C
   c. NH_3 at 30°C
   d. NH_4Cl at 5°C

5. How much more NH_4Cl can you dissolve in 100 g water at 60°C than at 20°C?

6. If you prepared a saturated solution of $NaNO_3$ at 80°C then cooled it to 30°C, what would happen? Be specific.

7. At which temperature do $NaNO_3$ and KNO_3 have the same solubility? NaCl and NH_3?

8. How much water is needed to dissolve 65.0 g of $NaNO_3$ at 35°C?

9. A saturated solution of KNO_3 in 200.0 g of water at 50°C is cooled to 20°C. How much KNO_3 settles out?

10. What temperature is necessary to dissolve twice as much KNO_3 as can be dissolved at 30°C?

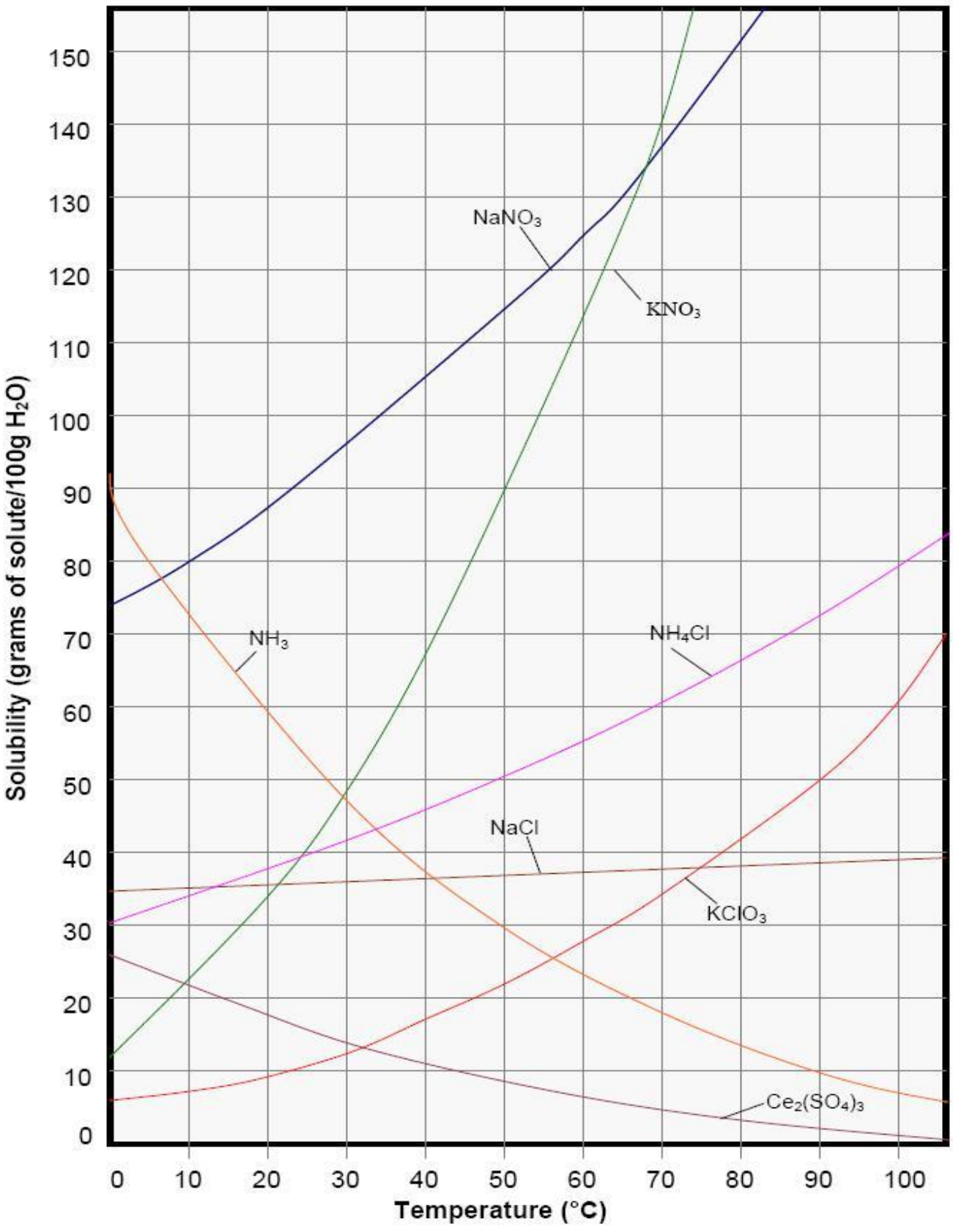
11. If the solubility of a solid in water is 118.0 g/L, how much water would you need to dissolve a piece of the same solid with a mass of 45.0 g?

12. If 18.0 g of KNO_3 are dissolved in 15.0 mL of water at 100°C, at what temperature will the solid begin to settle out?

13. If 40.0 g of KNO_3 is added to 50.0 mL of water at 40°C will it all dissolve? If not, how much would be left over?
    If you raised the temperature to 45°C, will it all dissolve? Give evidence.

14. What temperature is necessary to just dissolve 150 g of $KClO_3$ in 200.0 mL of water?

15. If 142 g of NH_4Cl are dissolved in 350.0 mL of water at 55°C, is the solution saturated?


Solubility vs. Temperature for Several Substances
Solubility (grams of solute/100g H_2O)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Temperature (°C)
$NaNO_3$
KNO_3
NH_3
NH_4Cl
NaCl
$KClO_3$
$Ce_2(SO_4)_3$

Answer the following questions using moles and concentration:

1. Calculate the concentration of a 200.0 mL solution that contains 0.250 moles of solute.

2. Find the concentration of a solution that contains 1.45 moles dissolved in 2.30 L of solution.

3. How many moles of NaOH would be needed to make 50.0 mL of a 0.750 mol/L solution?

4. What mass of $AgNO_3$ would be needed to make 250.0 mL of a 1.50 mol/L solution? **(63.7 g)**

5. What mass of $CaCO_3$ would be needed to make 20.0 mL of a 0.400 mol/L solution? **(0.801 g)**

6. How much solution is needed to dissolve 50.0 g of K_2SO_4 to make a 0.500 mol/L solution? **(0.574 L)**

7. What volume of solution is required to dissolve 18.04 g of aluminum sulphide to make a 0.160 mol/L solution? **(0.750 L)**

8. What mass of sodium sulphate would be needed to make 50.0 mL of 0.150 mol/L solution? **(1.07 g)**

9. What is the chloride ion concentration in a 0.250 mol/L solution of iron (III) chloride? **(0.75 mol/L)**

10. What is the concentration of sodium ions if 50.0 g of sodium sulphate is dissolved in 750.0 mL of solution? **(0.938 mol/L)**

11. What mass of cobalt (III) nitrate is needed to make 1.25 L of a solution with a nitrate ion concentration of 0.150 mol/L? **(15.3 g)**

Dilutions Worksheet

1) If I have 340 mL of a 0.5 M NaBr solution, what will the concentration be if I add 560 mL more water to it? **0.19 M**

2) If I dilute 250 mL of 0.10 M lithium acetate solution to a volume of 750 mL, what will the concentration of this solution be? **0.033 M**

3) If I leave 750 mL of 0.50 M sodium chloride solution uncovered on a windowsill and 150 mL of the solvent evaporates, what will the new concentration of the sodium chloride solution be? **0.63 M**

4) To what volume would I need to add water to the evaporated solution in problem 3 to get a solution with a concentration of 0.25 M? **1500 mL**

ANSWER THE FOLLOWING QUESTIONS ON STOCK DILUTIONS:

1. Find the final volume of a solution in which a 300.0 mL solution is diluted from 4.0 M to 3.0 M. **0.40 L**
2. Find the final concentration when 600.0 mL of 6.00 mol/L solution has 200.0 mL of water added to it? **4.50 mol/L**
3. A 0.500 mol/L solution is with a volume of 8.00 L. The original concentration was 2.50 M. What was the original volume? **1.60 L**
4. Assume we have a solution that is 0.800 M and 70.0 mL. We need a 0.300 M solution. What is the new volume of the solution? **0.187 L**
5. After dilution, a 1.70 mol/L solution has a volume 50.0 mL. If the original concentration of the solution was 2.00 mol/L, what was the solution's original volume? **0.0425 L**
6. We have 500.0 mL of 3.00 M sodium chloride solution. The solution is diluted to 580.0 mL. What is the new concentration? **2.59 mol/L**
7. 8.00 L of a 0.300 mol/L acid must be diluted to 0.0100 mol/L before it can safely be put into the sewage system. What is the final volume and how much water must be added? **232 L**
8. 60.0 mL of 6.00 mol/L Sulfuric acid is diluted to 5.00 L. What is the new concentration? **0.0720 mol/L**
9. Find the final volume when 60.0 mL of 2.50 M is diluted to 1.0×10^{-3} M. **150 L**
10. What is the new concentration when a 1.0 L of 0.10 mol/L solution is mixed with 1.0 L of 1.0 mol/L of the same solution? **0.55 mol/L**
11. What is the new concentration when 400.0 mL of 0.050 mol/L HCl is mixed with 600.0 mL of 0.020 mol/L HCl? **0.032 mol/L**
12. 450.0 mL of 2.40 M H_2SO_4 is mixed with 375 mL of 8.20 M H_2SO_4. What is the new concentration? **5.04 mol/L**
13. Describe how to make 250.0 mL of a 0.10 M solution of hydrochloric acid (HCl) from a solution which is 11.8 M. **0.00212 L**
14. What volume of 0.200 mol/L copper (II) nitrate is needed to prepare 250.0 mL of a solution with a nitrate ion concentration of 0.0100 mol/L. **6.25 mL**

Using the Ion Solubility Chart, identify each of the following compounds as soluble or insoluble (low solubility).

1. tin (III) sulphate
2. lithium carbonate
3. silver iodide
4. ammonium bromide
5. copper (II) chloride
6. nickel (II) iodide
7. barium phosphate
8. lead (II) chloride
9. copper (I) bromide
10. calcium sulfide

1. Identify if the following compounds are soluble or not.

a. barium hydroxide
b. aluminum nitrate
c. magnesium phosphate
d. copper (I) iodide
e. strontium carbonate
f. copper (II) chloride
g. barium sulfide
h. iron (III) sulfate

2.Write balanced precipitation, complete ionic and net ionic equations for the mixing of the following solutions. If no reaction occurs, write “no reaction”. Show states.

a. ammonium sulfate and rubidium carbonate
b. sodium hydroxide and nickel (II) chloride
c. strontium hydroxide and calcium iodide
d. ammonium phosphate and barium chloride
e. aluminum nitrate and magnesium sulfate
f. copper (II) chloride and sodium sulfide
g. magnesium bromide and potassium carbonate
h. barium hydroxide and iron (III) nitrate

Solubility Chart

Negative ions	Positive Ions	Solubility
essentially all	alkali ions (Li^+, Na^+, K^+, Rb^+, Cs^+)	soluble
essentially all	hydrogen ion $H^+_{(aq)}$	soluble
essentially all	ammonium ion (NH_4^+)	soluble
nitrate, NO_3^-	essentially all	soluble
acetate, CH_3COO^-	essentially all (EXCEPT Ag^+)	soluble
chloride, Cl^- bromide, Br^- iodide, I^-	Ag^+, Pb^{2+}, Hg_2^{2+}, Cu^+, Tl^+	low solubility
	all others	soluble
sulfate, SO_4^{2-}	Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}, Ra^{2+}	low solubility
	all others	soluble
sulfide, S^{2-}	alkali ions, $H^+_{(aq)}$, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}	soluble
	all others	low solubility
hydroxide, OH^-	alkali ions, $H^+_{(aq)}$, NH_4^+, Sr^{2+}, Ba^{2+}, Ra^{2+}, Tl^+	soluble
	all others	low solubility
phosphate, PO_4^{3-} carbonate, CO_3^{2-} sulfite, SO_3^{2-}	alkali ions, $H^+_{(aq)}$, NH_4^+	soluble
	all others	low solubility
chromate, CrO_4^{2-}	Ba^{2+}, Sr^{2+}, Pb^{2+}, Ag^+	low solubility
	all others	soluble

Answer the following questions on precipitate reactions:

1. Write balanced precipitation and net ionic equations for the mixing of the following solutions. If no reaction occurs, write “no reaction”. Show states.

   a. ammonium sulfate and rubidium carbonate

   b. sodium hydroxide and nickel (II) chloride

   c. strontium hydroxide and calcium iodide

   d. ammonium phosphate and barium chloride

   e. aluminum nitrate and magnesium sulfate

   f. copper (II) chloride and sodium sulfide

   g. magnesium bromide and potassium carbonate

   h. barium hydroxide and iron (III) nitrate

The labels have fallen off the bottles of six solutions. Each solution must be identified using precipitate reactions.

The solutions in the bottles which must be identified are:

- copper (II) sulphate
- sodium carbonate
- copper (II) nitrate
- ammonium sulphate
- barium chloride
- zinc sulphate

The bottles were assigned a letter from A to F. Each solution was observed and **mixed** to determine if the mixture **results in a precipitate**.

The results were recorded in the tables below:

	A	**B**	**C**	**D**	**E**	**F**
A	X	yes	yes	yes	no	yes
B		X	no	yes	no	no
C			X	yes	no	no
D				X	yes	no
E					X	no
F						X

Yes = precipitate
No = no precipitate

Use the ion solubility chart BELOW as the major tool for solving this mystery. It is known that solutions containing copper ions are blue. ***Bottles "C" and "E" are blue.***

Ion	Solubility	Exceptions
NO_3^-	soluble	none
ClO_4^-	soluble	none
Cl^-	soluble	except Ag^+, Hg_2^{2+}, *Pb^{2+}
I^-	soluble	except Ag^+, Hg_2^{2+}, Pb^{2+}
SO_4^{2-}	soluble	except Ca^{2+}, Ba^{2+}, Sr^{2+}, Hg^{2+}, Pb^{2+}, Ag^+
CO_3^{2-}	insoluble	except Group IA and NH_4^+
PO_4^{3-}	insoluble	except Group IA and NH_4^+
-OH	insoluble	except Group IA, *Ca^{2+}, Ba^{2+}, Sr^{2+}
S^{2-}	insoluble	except Group IA, IIA and NH_4^+

*slightly soluble

Identity of the solution in each bottle:

ANSWER THE FOLLOWING SOLUTIONS REVIEW QUESTIONS:

Including these questions, know ALL your definitions and theory.

1. What mass of solute is in 1.0 L of a 2.5 M solution of NaCl? **(145 g)**

2. Explain the steps needed to make 535.0 ml of 3.0 M NaOH solution. **(64.2 g - steps)**

3. Find the concentration if 75.0 g of KCl is dissolved in 855.0 ml of solution. **(1.19 M)**

4. There is only 75.0 g of KOH left in the lab. You need to make a 2.50 M solution; how much Are you able to make? **(535 mL)**

5. What is the molarity of a 725.0 mL solution containing 45.3 grams of dissolved sodium sulfate? **(0.437 M)**

6. What mass of aluminum phosphate is needed to prepare 1.25 L of a 0.350 M solution? **(55.4 g)**

7. What volume of 0.575 M ammonium chloride will contain 0.27 moles of ammonium chloride? **(470 mL)**

8. Explain three factors that affect solubility.

9. Write a complete, balanced equation for each of the following double displacement reactions. Using the solubility rules provided, label each product as *insoluble* or *soluble*.

    1. sodium sulfate reacts with barium chloride
    2. potassium phosphate reacts with strontium nitrate
    3. silver nitrate reacts with sodium sulfide

Basis Solubility Rules

1. All ionic compounds containing Group 1A elements, H^+ and ammonium ion are *soluble*.
2. All ionic compounds with Group VII A elements (other than F) and metals are *soluble*, except those of Ag^+, Hg^{+1}, and Pb^{+2}.
3. All acetates and nitrates are *soluble*.
4. All sulfates are *soluble* except those of Ba^+, Sr^{+2}, Pb^{+2}, Ca^{+2}, Ag^+, Hg^{+1}.
5. Except when bonded with those in rule 1; carbonates, hydroxides, oxides, sulfides, phosphates, chromates and dichromates are *insoluble*.

Possible long answer questions:

Write a dissociation equation?
What electronegativity means and how it works?
What “like dissolves like” means?
How to prepare a solution or dilution?
What the solubility rules mean and how to use them? (I will give you them on a test)