UNIT TEST 3 – SOLUBILITY EQUILIBRIA

1. What is the concentration of the ions in 3.0 L of 0.50 M $Al_2(SO_4)_3$?

	$[Al^{3+}]$	$[SO_4^{2-}]$
A.	0.33 M	0.50 M
B.	1.0 M	1.5 M
C.	1.5 M	1.5 M
D.	3.0 M	4.5 M

2. Consider the following equilibrium:

$$MgCO_{3(s)} \rightleftarrows Mg^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$$

Adding which of the following would cause the solid to dissolve?

A. HCl

B. K_2CO_3

C. $MgCO_3$

D. $Mg(NO_3)_2$

3. Which of the following compounds could be used to prepare a solution with a $[S^{2-}]$ greater than 0.1 M?

A. ZnS

B. PbS

C. Ag_2S

D. Rb_2S

4. Which of the following will not form a precipitate when mixed with an equal volume of 0.2 M $AgNO_3$?

A. 0.2 M NaBr

B. 0.2 M $NaIO_3$

C. 0.2 M $NaNO_3$

D. 0.2 M $NaBrO_3$

5. A solution is prepared containing both 0.2 M OH^- and 0.2 M PO_4^{3-} ions. An equal volume of a second solution is added in order to precipitate only one of these two anions. The second solution must contain which of the following?

A. 0.2 M Cs^+

B. 0.2 M Zn^{2+}

C. 0.2 M Pb^{2+}

D. 0.2 M Sr^{2+}

6. Consider the following equilibrium:

$$CaS_{(s)} \rightleftarrows Ca^{2+}_{(aq)} + S^{2-}_{(aq)}$$

When $Ca(NO_3)_{2(aq)}$ is added to this solution, the equilibrium shifts to the

A. left and $[S^{2-}]$ increases

B. left and $[S^{2-}]$ decreases

C. right and $[S^{2-}]$ increases

D. right and $[S^{2-}]$ decreases

7. How many moles of Pb^{2+} are there in 500.0 mL of a saturated solution of $PbSO_4$?

A. 3.2×10^{-16}

B. 9.0×10^{-9}

C. 6.7×10^{-5}

D. 1.3×10^{-4}

8. Which of the following compounds is least soluble in water?

A. CuI

B. BeS

C. CsOH

D. $AgBrO_3$

9. The following data was collected to determine the solubility of a substance:

Mass of solute dissolved	5.00 g
Volume of solvent	250.0 mL
Molar mass of solute	100.0 g/mol
Molar mass of solvent	20.0 g/mol

Which of the following best describes its solubility?

A. 2.00×10^{-2} g/mL

B. 5.00×10^{-2} mol

C. 0.250 mol

D. 1.00 mol/L

10. Which value best represents the total ion concentration when 0.10 moles of K_3PO_4 is present in 0.5L of solution?

A. 0.1M

B. 0.2M

C. 0.4M

D. 0.8M

11. What will happen when equal volumes of 0.20 M $(NH_4)_2S$ and 0.20 M $Sr(OH)_2$ are mixed?

A. SrS precipitates.

B. NH_4OH precipitates.

C. Both NH_4OH and SrS precipitate.

D. No precipitate forms.

12. Which anion would be most effective in removing the cations responsible for hard water?

A. S^{2-}

B. Cl^-

C. PO_4^{3-}

D. SO_4^{2-}

13. Which of the following is the K_{sp} expression for barium phosphate?

A. $K_{sp} = [Ba^{2+}][PO_4^{3-}]$

B. $K_{sp} = [Ba^{2+}]^3[PO_4^{3-}]^2$

C. $K_{sp} = [3Ba^{2+}][2PO_4^{3-}]$

D. $K_{sp} = [3Ba^{2+}]^3[2PO_4^{3-}]^2$

14. The solubility of $Mg(OH)_2$ is found to be 1.2×10^{-4} M. What is its K_{sp}?

A. 6.9×10^{-12}

B. 1.7×10^{-12}

C. 1.4×10^{-8}

D. 1.2×10^{-4}

15. Which of the following is true for the salt SrF_2 at 25°C?

A. It has a high solubility.

B. It will not dissolve at all.

C. Its solubility is 1.6×10^{-3} M.

D. Its solubility is 1.0×10^{-3} M.

16. Which of the following ions could be used in the lowest concentration to remove Ag^+ ions from a polluted water sample?

A. I^-

B. Br^-

C. BrO_3^-

D. CO_3^{2-}

17. Which of the following best describes an acidic solution?

	Litmus Colour	Reaction with Zn
A.	red	reaction
B.	red	no reaction
C.	blue	no reaction
D.	blue	reaction

Written Response

1. a) Write the net ionic equation for the reaction between $Pb(NO_3)_{2(aq)}$ and $NaCl_{(aq)}$. **(2 marks)**

b) Determine, with calculations, whether a precipitate will form when 15.0 mL of 0.500 M $Pb(NO_3)_2$ is added to 35.0 mL of 0.085 M NaCl. **(4 marks)**

2. After a 50.0 mL sample of a saturated solution of Ag_2SO_4 was heated to dryness, 7.2×10^{-4} g of solid Ag_2SO_4 remained. What is the value of K_{sp} for Ag_2SO_4? **(5 marks)**

3. a) How would a saturated solution be prepared at room temperature? **(1 mark)**

b) Write a chemical equation to illustrate the equilibrium that exists in a saturated solution of $Be_3(PO_4)_2$. **(2 marks)**

ANSWERS AND SOLUTIONS
UNIT TEST 3 – SOLUBILITY EQUILIBRIA

1. B	6. B	11. D	16. A
2. A	7. C	12. C	17. A
3. D	8. A	13. B	WR1–3. See Solution
4. C	9. A	14. A	
5. D	10. D	15. D	

1. B

$Al_2(SO_4)_3 \rightarrow 2Al^{3+} + 3SO_4^{2-}$ in aqueous solution. Therefore,

$[Al^{3+}] = 2/1 \times [Al_2(SO_4)_3] =$
$2/1 \times 0.50\ M = 1.0\ M$

$[SO_4^{2-}] = 3/1 \times [Al_2(SO_4)_3] =$
$3/1 \times 0.50\ M$
$= 1.5\ M$

2. A

If HCl was added to the system: $MgCO_{3(s)} \rightleftarrows Mg^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$, the following reaction would occur: $H_3O^+_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow H_2CO_{3(aq)} + H_2O_{(l)}$. Since $H_2CO_{3(aq)}$ is a weak acid, it would only be slightly ionized. Therefore $[CO_3^{2-}]$ in the system would decrease, and Le Châtelier's Principle would predict that the equilibrium would shift right, causing more $MgCO_3$ to dissolve.

3. D

According to the solubility chart on page A4 of the *Data Booklet*, alkali ions including Rb^+, have solubility greater than 0.1 M with S^{2-}.

4. C

Ag^+ ions will form a precipitate with most anions at very low concentrations. NO_3^-, contained in $NaNO_3$, is the one exception on the solubility chart on page A4 of the *Data Booklet*.

5. D

According to the solubility chart on page 4 of the *Data Booklet*, Sr^{2+} will form a precipitate with PO_4^{3-}, but not with OH^- at this concentration.

6. B

As the concentration of $Ca^{2+}_{(aq)}$ increases due to the addition of $Ca(NO_3)_{2(aq)}$, the equilibrium will shift to the left, consuming $S^{2-}_{(aq)}$.

7. C

$PbSO_4 \rightarrow Pb^{2+} + SO_4^{2-}$

$K_{sp} = 1.8\times10^{-8}$ (Data Booklet, p.5)

$= [Pb^{2+}] \bullet [SO_4^{2-}]$

Since, according to the equation, $[Pb^{2+}] = [SO_4^{2-}]$,

$[Pb^{2+}]^2 = 1.8\times10^{-8}$

$[Pb^{2+}] = \sqrt{1.8\times10^{-8}} = 1.3\times10^{-4}\ M$

$1.3\times10^{-4}\ M \times 0.5000\ L = 6.7\times10^{-5}\ mol$

8. A

CsOH and BeS both have solubilities greater than 0.1 M according to the chart on page 4 of the *Data Booklet*. CuI and $AgBrO_3$ have lower solubilities, but since they are both 1:1 formulas, the one with the lower K_{sp} will have the lower solubility. CuI has a lower K_{sp} according to the chart on page A5 of the *Data Booklet*.

9. A

Solubilities must have concentration units of some sort, therefore only choices A and D are possible. Calculation shows A to be correct:

$$\frac{5.00\,\text{g}}{250.0\,\text{mL}} = 0.0200\,\text{g/mL}$$

10. D

$K_3PO_{4(aq)} \rightarrow 3\,K^+_{(aq)} + PO_4^{3-}{}_{(aq)}$

0.10 mol in 0.5 L

c = 0.10 mol / 0.5L

= 0.2 M $\qquad$ 3 × 0.2 M $\quad$ 1 × 0.2 M

0.6 M $\qquad$ 0.2 M

Total ion concentration

0.6 M + 0.2 M = 0.8 M

11. D

$(NH_4)_2S_{(aq)} + Sr(OH)_{2(aq)} \rightarrow$

$2NH_4OH_{(aq)} + SrS_{(aq)}$. Both NH_4OH and SrS have high solubilities, and therefore neither will precipitate.

12. C

Hard water is caused primarily by the presence of $Ca^{2+}{}_{(aq)}$ and $Mg^{2+}{}_{(aq)}$. Any anion that will cause these ions to precipitate out will be useful. Even if you'd forgotten this, $PO_4^{3-}{}_{(aq)}$ has low solubility with more cations than any of the other choices and therefore would likely be the correct answer.

13. B

$Ba_3(PO_4)_{2(s)} \rightarrow 3\,Ba^{2+}{}_{(aq)} + 2PO_4^{3-}{}_{(aq)}$

$K_{sp} = \left[Ba^{2+}\right]^3\left[PO_4^{3-}\right]^2$

14. A

The concentration of each of the ions must first be determined at maximum concentration.

$Mg(OH)_{2(aq)} \rightarrow Mg^{2+}{}_{(aq)} + 2\,OH^-{}_{(aq)}$

1.2×10^{-4} M $\quad 1.2 \times 10^{-4}$ M $\quad 2 \times 1.2 \times 10^{-4}$ M

2.4 x 10-4 M

$K_{sp}\left[Mg^{2+}{}_{(aq)}\right]\left[OH^-{}_{(aq)}\right]^2 =$

$(1.2\times10^{-4}\text{M})(2.4\times10^{-4}\text{M})^2 = 6.9\times10^{-12}$

15. D

Basically the reverse of question 24; this time use K_{sp} to determine solubility.

$SrF_{2(aq)} \rightarrow Sr^{2+}{}_{(aq)} + 2\,F^-{}_{(aq)}$

$x \quad x \qquad 2x$

$K_{sp} = 4.3\times10^{-9} = \left[Sr^{2+}{}_{(aq)}\right]\left[F^-{}_{(aq)}\right]^2$

$4.3\times10^{-9} = (x)(2x)^2 = 4x^3$

x = solubility = 1.0×10^{-3} M

16. A

The K_{sp} of AgI is more than 6 000 times smaller than the nearest one so it is unnecessary to do a calculation. I^- ions will precipitate Ag^+ at a **very** low concentration.

17. A

Acids will turn litmus paper red. Active metals like Zn will react to some degree with all acids.

Written Response

1. **a)** *Write the net ionic equation for the reaction between* $Pb(NO_3)_{2(aq)}$ *and* $NaCl_{(aq)}$. **(2 marks)**

Solution:

$Pb^{2+}_{(aq)} + 2Cl^-_{(aq)} \rightarrow PbCl_{2(s)}$ **(2 marks)**

b) *Determine, with calculations, whether a precipitate will form when 15.0 mL of 0.050 M* $Pb(NO_3)_2$ *is added to 35.0 mL of 0.085 M NaCl.* **(4 marks)**

Solution:

$$[Pb^{2+}] = 0.050\,M \times \frac{15.0\,mL}{50.0\,mL} = 0.015\,M$$ ← **1 mark**

$$[Cl^-] = 0.085\,M \times \frac{35.0\,mL}{50.0\,mL} = 0.0595\,M$$ ← **1 mark**

$$\text{Trial } K_{sp} = [Pb^{2+}][Cl^-]^2 = (0.015)(0.0595)^2 = 5.3\times10^{-5}$$ ← **1 mark**

K_{sp} for $PbCl_2 = 1.2\times10^{-5}$
Since Trial $K_{sp} > K_{sp}$, a precipitate does form. ← **1 mark**

2. *After a 50.0 mL sample of a saturated solution of* Ag_2SO_4 *was heated to dryness,* 7.2×10^{-4} *g of solid* Ag_2SO_4 *remained. What is the value of* K_{sp} *for* Ag_2SO_4*?* **(5 marks)**

Solution:

Example:

$Ag_2SO_{4(s)} \rightleftarrows 2Ag^+_{(aq)} + SO_4^{2-}{}_{(aq)}$ ← **1 mark**

← **1 mark**

$$[Ag_2SO_4] = \frac{7.2\times10^{-4}\,g}{0.0500\,L} \times \frac{1\,mole}{311.9\,g} = 4.62\times10^{-5}\,M$$ ← **1 mark**

$$[Ag^+] = 2\times4.62\times10^{-5}\,M = 9.23\times10^{-5}\,M$$
$$[SO_4^{2-}] = 4.62\times10^{-5}\,M$$ ← **1 mark**

$$K_{sp} = [Ag^+]^2[SO_4^{2-}] = (9.23\times10^{-5})^2(4.62\times10^{-5}) = 3.9\times10^{-13}$$ ← **1 mark**

(Deduct $\frac{1}{2}$ mark for incorrect significant figures.)

3. **a)** *How would a saturated solution be prepared at room temperature?* **(1 mark)**

For Example:

Add solute to solvent until no more solute dissolves.

b) *Write a chemical equation to illustrate the equilibrium that exists in a saturated solution of* $Be_3(PO_4)_2$. **(2 marks)**

For Example:

$Be_3(PO_4)_{2(s)} \rightleftarrows 3Be^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)}$