1. The solubility of the salt, $M_3X$, is $7.50 \times 10^{-4} \text{ g/L}$. Calculate the solubility product constant, $K_{sp}$, for this salt. The molar mass of the salt is 177.2 g/mol. [5 pts] **Homework Problem**

\[
\frac{7.50 \times 10^{-4} \text{ g}}{1 \text{ L}} \times \frac{1 \text{ mol}}{177.2 \text{ g}} = 4.23 \times 10^{-6} \text{ mol/L} = x
\]

\[
M_3X (s) \rightleftharpoons 3M^+ (aq) + X_3^- (aq)
\]

Initial ($M$): ? 0 0
Change ($M$): $-x$ +3x +x
Equilibrium ($M$): 3x x

\[
K_{sp} = [M^+]^3[X_3^-]
\]

\[
K_{sp} = (3x)^3(x) = 27x^4
\]

\[
K_{sp} = 27(4.23 \times 10^{-6})^4 = 8.64 \times 10^{-21}
\]

2. Calculate the solubility (in moles/liter) of the salt $MX_2$ in the presence of the common ion $X^-$ (concentration $8.00 \times 10^{-4} \text{ M}$) if the value of the solubility product constant, $K_{sp}$, for the salt is $3.90 \times 10^{-25}$. [4 pts] **Homework Problem**

\[\begin{array}{c}
\text{[a]} \ 3.90 \times 10^{-25} \text{ M} \\
\text{[b]} \ 6.09 \times 10^{-19} \text{ M} \\
\text{[c]} \ 4.88 \times 10^{-22} \text{ M} \\
\text{[d]} \ 4.60 \times 10^{-9} \text{ M} \\
\text{[e]} \ 5.80 \times 10^{-9} \text{ M}
\end{array}\]

\[
MX_2 (s) \rightleftharpoons M^{2+} (aq) + 2 X^- (aq)
\]

Initial ($M$): ? 0 $8.00 \times 10^{-4}$
Change ($M$): $-x$ +x +2x
Equilibrium ($M$): $x$ $8.00 \times 10^{-4} + 2x$

\[
K_{sp} = [M^{2+}][X^-]^2
\]

\[
3.90 \times 10^{-25} = (x)(8.00 \times 10^{-4} + 2x)^2 \approx (x)(8.00 \times 10^{-4})^2
\]

\[
x = 6.09 \times 10^{-19} \text{ M}
\]

3. True or False. [2 pts each]

a) Phenolphthalein ($K_a \approx 1 \times 10^{-9}$) would be a poor choice as an indicator for a weak base/strong acid titration.

**TRUE.** Phenolphthalein will change color approximately over the range $pK_a \pm 1$ (pH = 8–10). The pH at the equivalence point of a weak base/strong acid titration is less than 7 (typically about pH $\approx$ 5). Starting with weak base in the flask and strong acid in the buret, phenolphthalein would change color before the equivalence point, and thus would be a poor choice as an indicator.
b) When a *common ion* is added to a saturated solution of an “insoluble” salt, the solubility of the salt will *decrease*.

**TRUE**

4. Identify which compound is soluble or insoluble? [4 pts] **Homework Problem**

<table>
<thead>
<tr>
<th>Solubility</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>insoluble</td>
<td>CaCO₃</td>
</tr>
<tr>
<td>insoluble</td>
<td>CaSO₄</td>
</tr>
<tr>
<td>soluble</td>
<td>AgNO₃</td>
</tr>
<tr>
<td>soluble</td>
<td>NaCl</td>
</tr>
</tbody>
</table>

5. Consider the titration of 46.0 mL of 0.92 M KOH with 0.59 M HNO₃. **Homework Problem**

a) Calculate the **pH** of the mixture after 38.10 mL of 0.59 M HNO₃ have been added. [4 pts]

\[
\begin{align*}
\text{KOH (aq) } + & \text{ HNO}_3 (aq) \rightarrow \text{KNO}_3 (aq) + \text{H}_2\text{O (l)} \\
\text{Initial (mol):} & \quad 0.04232 \quad 0.02248 \\
\text{Change (mol):} & \quad -0.02248 \quad -0.02248 \\
\text{Final (mol):} & \quad 0.01984 \quad 0 \\
\end{align*}
\]

\[
[\text{KOH}] = [\text{OH}^-] = \frac{0.01984 \text{ mol}}{0.0841 \text{ L}} = 0.236 \text{ M} \\
p\text{OH} = -\log(0.236) = 0.63 \\
p\text{H} = 13.37
\]

b) What is the **pH** at the equivalence point at 25°C? [2 pts]

**pH = 7**

c) Calculate the **pH** of the mixture after 91.94 mL of 0.59 M HNO₃ have been added. [4 pts]

\[
\begin{align*}
\text{KOH (aq) } + & \text{ HNO}_3 (aq) \rightarrow \text{KNO}_3 (aq) + \text{H}_2\text{O (l)} \\
\text{Initial (mol):} & \quad 0.04232 \quad 0.05424 \\
\text{Change (mol):} & \quad -0.04232 \quad -0.04232 \\
\text{Final (mol):} & \quad 0 \quad 0.01192 \\
\end{align*}
\]

\[
[H\text{NO}_3] = [H_3\text{O}^+] = \frac{0.01192 \text{ mol}}{0.13794 \text{ L}} = 0.0864 \text{ M} \\
p\text{H} = -\log(0.0.0864) = 1.06
\]

6. 5.35 g of a mixture containing an unknown monoprotic weak acid (HA) is titrated with 0.21 M NaOH. It takes 20.58 mL of NaOH to reach the equivalence point. Calculate the **mass %** of the unknown weak acid in the mixture. The molar mass of the unknown acid is 208 g. Assume that the other component of the mixture does not react with NaOH. [5 pts] **Homework Problem**

\[
\text{HA (aq) } + \text{ NaOH (aq) } \rightarrow \text{NaA (aq) } + \text{H}_2\text{O(l)}
\]

\[
\text{mass % acid} = \frac{\text{g acid}}{\text{g mixture}} \times 100\%
\]
Mass of mixture is given. We need to first calculate the mass of acid in the mixture.

\[
\frac{0.21 \text{ mol NaOH}}{1 \text{ L}} \times 0.02058 \text{ L} = 4.322 \times 10^{-3} \text{ mol NaOH} \times \frac{1 \text{ mol HA}}{1 \text{ mol NaOH}} = 4.322 \times 10^{-3} \text{ mol HA}
\]

\[
4.322 \times 10^{-3} \text{ mol HA} \times \frac{208 \text{ g HA}}{1 \text{ mol HA}} = 0.899 \text{ g HA}
\]

\[
\text{mass } \% \text{ acid} = \frac{\text{g acid}}{\text{g mixture}} \times 100\% = \frac{0.899 \text{ g}}{5.35 \text{ g}} \times 100 = 16.8\%
\]