Identify and Solve K_{sp} Problems Associated with Ionic Compounds

An ionic compound consists of a metal and a nonmetal, or a metal and a polyatomic ion.

A metal is either found in Group I, or Group II of the Periodic Table and will have a positive charge of +1 or +2. Metals outside of the group can have multiple valences (transition elements) and their charges are identified by the Roman numerals. The only exceptions are Aluminum (Al) = +3; Zinc (Zn) = +2; Silver (Ag) = +1. With a salt, the <u>net</u> charge of the molecule will be equal to zero (0). The negative charge can be determined once you realize that Group VII ions (Br, I, Cl, F) will be -1 and in the polyatomics associated with:

SO_4 = –2	PO_4 = -3	OH = -1

Calcium Sulfate	$CaSO_4$	Ca^{+2} $SO_4{}^{2-}$
Lead (II) Chloride	PbCl2	$Pb^{+2} + 2Cl^-$
Iron (III) Hydroxide	$Fe(OH)_3$	$Fe^{+3} + 3OH^-$

To determine the chemical formula of the above compounds, we need to determine the charges of the individual elements.

Examples:

1. **Calcium Sulfate**
   Calcium is in Group II and will have a positive (+2) charge, while sulfate (based on memorization of values of polyatomics), will equal (-2). Since the sum total of charges must equal), we have the following:

   $$Ca^{+2} + SO_4{}^{2-} = CaSO_4$$

2. **Lead (II) Chloride**
   Roman numeral (II) means lead has a (+2) charge – (Pb^{+2}). Chloride is found in the Group VII of the Periodic Table and its charge is equal to (– 1).

   Therefore, $Pb^{+2} + 2Cl^- = 0 = PbCl_2$

3. **Iron (III) Hydroxide**
   Iron has a (+3) charge – (Fe^{+3}). Based on polyatomic table values, the charge for OH is (–1). For the compound to be <u>neutral</u>, we need 3 (OH)'s, which would give a value of –3.

   $$Fe^{+3} + 3OH^- \leftrightarrow Fe\ (OH)_3$$

Solving K_{sp} Problems

Steps to follow:

1.) Dissociate salt into individual ions
2.) Write up ICE Table
3.) Solve for appropriate value

Examples:

1. Calculate the molar solubility of Lead (II) Iodide from its K_{sp} ($9.8x10^{-9}$)
   *The first step requires us to write the chemical formula of this compound. (See how to identify ionic compounds) and then break into a positive and negative ion:

   PbI_2-------→Pb^{+2} + $2I^-$ **NOTE: Roman numeral (II) means charge = +2

   ↘-----------------↗

   $Al_2(SO_4)_3$-----------→ $2Al^{+3}$ + $3SO_4^-$

   Remember, these salts will always dissociate into 2 separate ions, a positive and a negative ion.

   PbI_2 (K_{sp})= $9.8x10^{-9}$ (from table in book)

2. Next, set up an ICE Table, remembering that solids have <u>NO</u> impact on the K_{sp} ICE Table

PbI_2 (s) ⟶	Pb+2	+2I-
I	0	0
C	x	2x
E	x	2x

$$K_{sp} = \frac{[\text{products}]}{[\text{reactants}]} = \frac{[x]\,[2x]^2}{[PbI_2](s) = 1} = [x]\cdot[4x^2]$$

$9.8x10^{-9}$ = [x] [$4x^2$]

$9.8x10^{-9}$ = $4x^3$

$2.45x10^{-9}$ = x^3

$1.35x10^{-3}$ = x

MOLAR SOLUBILITY = x = **$1.35X10^{-3}$ moles/Liter = concentration of Pb in PBI_2)**

If the question asks for molar solubility of Iodide ion, the answer will be 2x, or $2.7x10^{-3}$ moles/Liter