

Problem Set #3
CHEM101A: General College Chemistry

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September 5, 2025

1 Topic B Problem 13

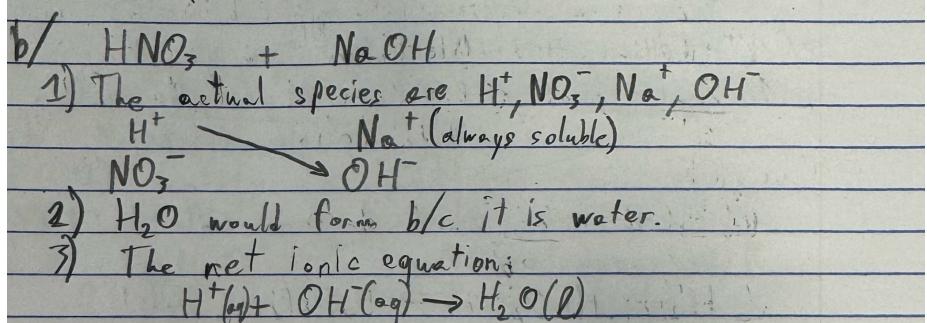
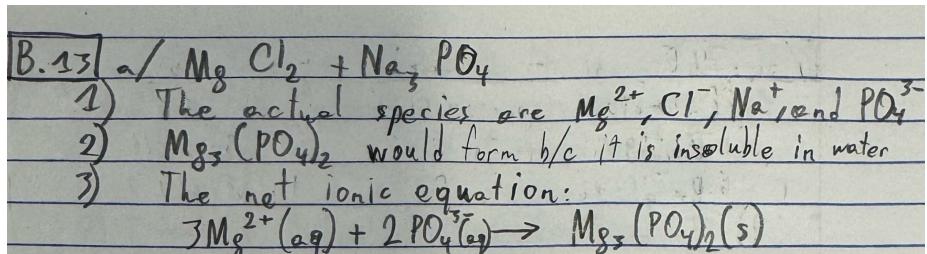
For each of the mixtures below, do the following:

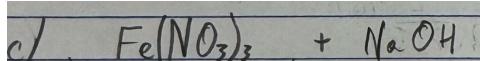
- 1) Identify the actual species that are present in the mixture (before any reaction occurs).
- 2) Write the formula of any product that forms. If no product will form, write "no reaction" and skip Step 3.
- 3) Write the net ionic equation for the reaction that occurs, including the state of each substance (s, l, g, or aq).

Example: Mixing 0.1 M NaCl and 0.1 M Pb(NO₃)₂ (a) The actual species are Na⁺, Cl⁻, Pb²⁺, and NO₃⁻ (b) PbCl₂ will form (because it is insoluble in water) (c) The net ionic equation is Pb²⁺(aq) + 2Cl⁻(aq) → PbCl₂(s)

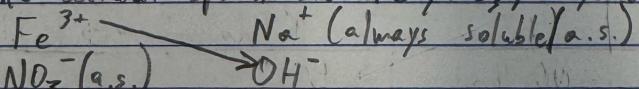
- a) Mixing 0.1 M MgCl₂ and 0.1 M Na₃PO₄
- b) Mixing 0.1 M HNO₃ and 0.1 M NaOH
- c) Mixing 0.1 M Fe(NO₃)₃ and 0.1 M KOH
- d) Mixing 0.1 M ZnBr₂ and 0.1 M CuSO₄
- e) Mixing 0.1 M HCl and 0.1 M NaHCO₃
- f) Mixing 0.1 M AgNO₃ and 0.1 M K₂CO₃
- g) Mixing 0.1 M Ba(OH)₂ and 0.1 M Na₂SO₄
- h) Mixing 0.1 M HC₂H₃O₂ and 0.1 M Ba(OH)₂
- i) Mixing 0.1 M HC₆H₅O and 0.1 M NaOH
- j) Mixing 0.1 M H₂C₄H₄O₄ (succinic acid) and excess 0.1 M NaOH. (Hint: You should write two equations for this.)

1.1 Solution



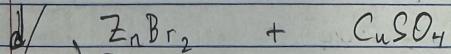
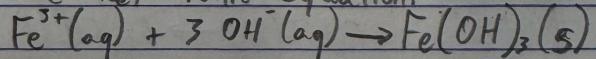


1) The actual species are Fe^{3+} , NO_3^- , Na^+ , and OH^-

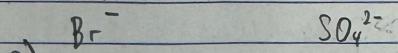
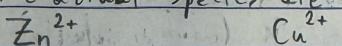


2) $\text{Fe}(\text{OH})_3$ would form b/c it is insoluble in water.

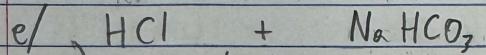
3) The net ionic equation:



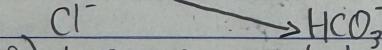
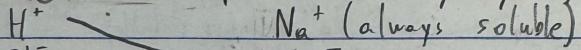
1) The actual species are Zn^{2+} , Br^- , Cu^{2+} , SO_4^{2-}



2) No reaction

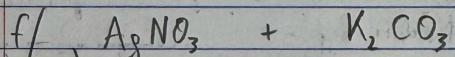
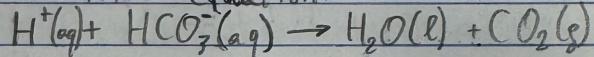


1) The actual species are H^+ , Cl^- , Na^+ , HCO_3^- .



2) H_2CO_3 forms, which degrades into H_2O & CO_2

3) Net ionic equation:

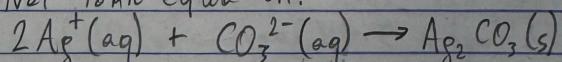


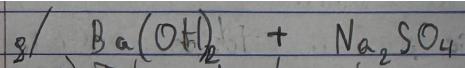
1) The actual species are Ag^+ , NO_3^- , K^+ , CO_3^{2-}



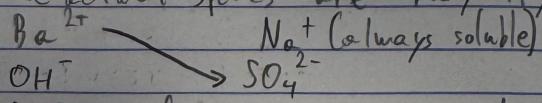
2) Ag_2CO_3 forms as a precipitate

3) Net ionic equation:



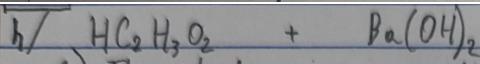
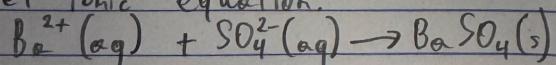


1) The actual species are Ba^{2+} , OH^- , Na^+ , and SO_4^{2-}

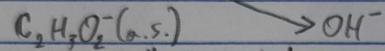


2) BaSO_4 forms as a precipitate

3) Net ionic equation:

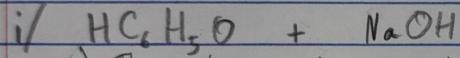
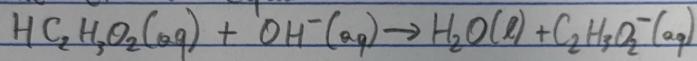


1) The actual species are H^+ , $\text{C}_2\text{H}_3\text{O}_2^-$, Ba^{2+} , OH^- , $\text{HC}_2\text{H}_3\text{O}_2$

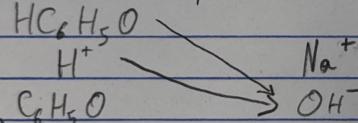


2) H_2O will form because it is water

3) The net ionic equation:

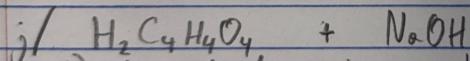
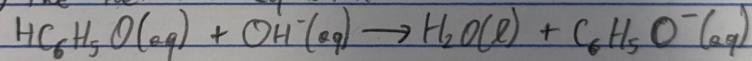


1) The actual species are $\text{HC}_6\text{H}_5\text{O}$, H^+ , $\text{C}_6\text{H}_5\text{O}^-$, Na^+ , OH^-

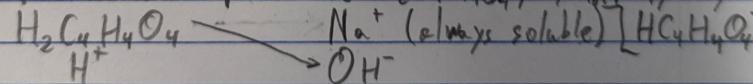


2) H_2O will form because it is water

3) The net ionic equation:

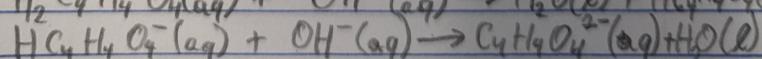
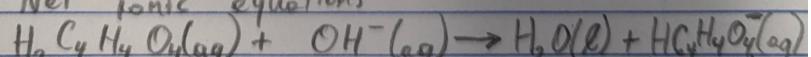


1) The actual species are $\text{H}_2\text{C}_4\text{H}_4\text{O}_4$, H^+ , $\text{C}_4\text{H}_4\text{O}_4^{2-}$, Na^+ , OH^-



2) H_2O will form because it is water

3) Net ionic equations:

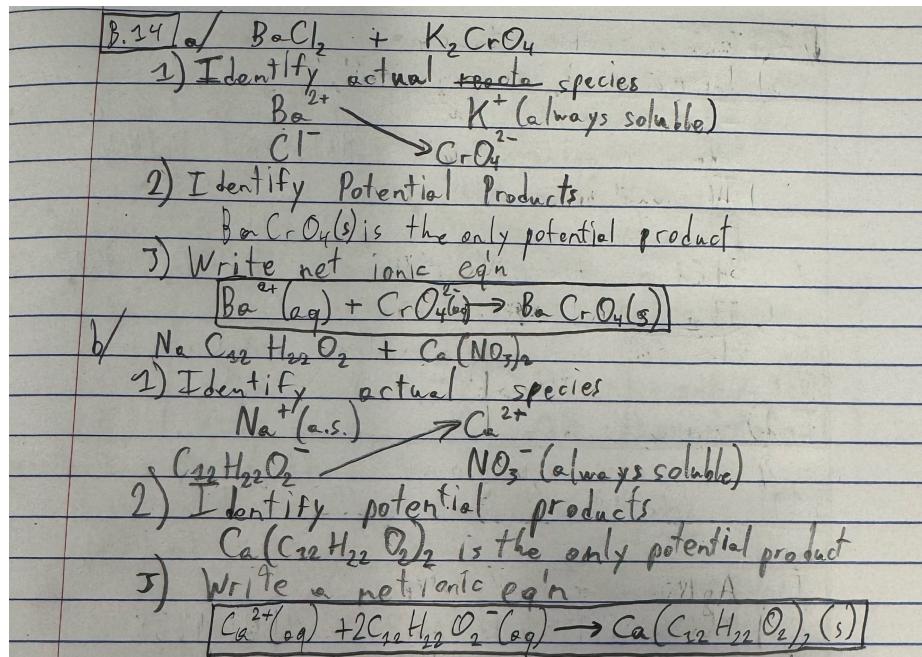


2 Topic B Problem 14

Write balanced net ionic equations that explain the following observations.

- When solutions of BaCl_2 and K_2CrO_4 are mixed, a bright yellow precipitate forms.
- When solutions of $\text{NaC}_{12}\text{H}_{22}\text{O}_2$ and $\text{Ca}(\text{NO}_3)_2$ are mixed, a white precipitate forms.

2.1 Solution

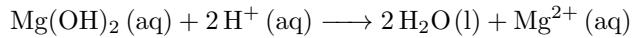


3 Topic B Problem 15

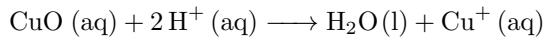
Write the net ionic equation for the reaction that occurs when each of the following insoluble compounds is mixed with excess 6 M HCl. Be sure to include the state of each substance.

- a) Mg(OH)₂ b) CuO c) Al(OH)₃ d) Cr₂O₃

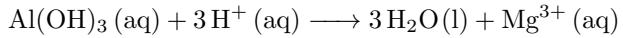
3.1 Solution (a)



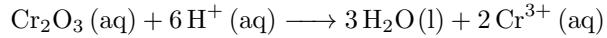
3.2 Solution (b)



3.3 Solution (c)



3.4 Solution (d)

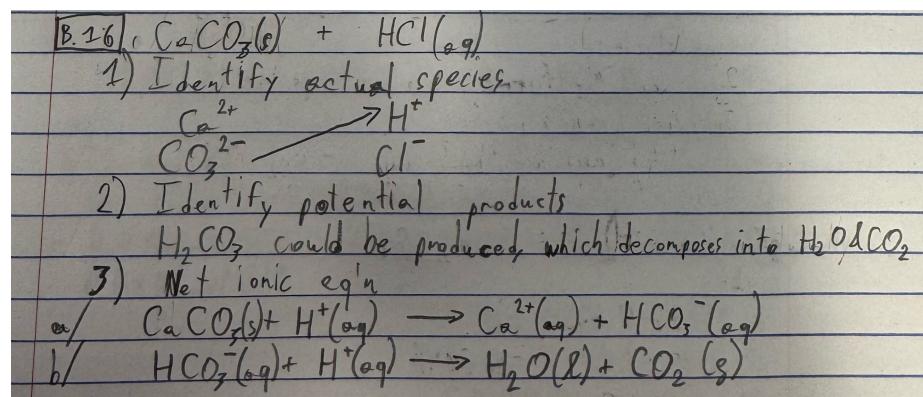


4 Topic B Problem 16

If you put some solid CaCO_3 into a beaker of water and slowly add HCl solution, stirring vigorously the whole time, the CaCO_3 gradually dissolves. As the last of the CaCO_3 dissolves, bubbles begin to form, and if you continue to add HCl, you observe steady bubble formation.

- Write a net ionic equation that shows why the CaCO_3 dissolves.
- Write a net ionic equation that shows why the mixture bubbles.

4.1 Solution



Note (a): The reason that the above equation shows that CaCO_3 dissolves is because the two results are both aqueous.

Note (b): The reason that the above equation shows why it produces bubbles is because it contains CO_2 , which is a gas that would create bubbles.

5 Topic B Problem 17

Both MgO and PbO are insoluble in water. When solid MgO is added to 3 M H₂SO₄, the solid dissolves completely. When solid PbO is added to 3 M H₂SO₄, the solid changes color slightly, but does not dissolve. Explain this difference.

5.1 Solution

The MgO and the PbO would react with the SO₄²⁻. The O would in both cases react to form H₂O, while the other cations would be attracted to the SO₄²⁻. SO₄²⁻ is soluble with Mg²⁺, while it would be insoluble with Pb²⁺. This is what causes the solid of PbO to change color: it is turning into PbSO₄. Meanwhile, the MgO would be turning into fully soluble MgSO₄.

6 Topic B Problem 18

A solution contains one or more of the following anions: I^- , PO_4^{3-} , and NO_3^- . A chemist carries out the following experiments on this solution:

- Experiment 1: The chemist adds 0.1 M $Ba(NO_3)_2$ to a small portion of this solution, and no precipitate forms.
- Experiment 2: The chemist adds 0.1 M $AgNO_3$ to the solution from Experiment 1, and a precipitate forms.

Based on these results, tell which anions are definitely present in the original solution, which anions are definitely absent from the original solution, and which anions cannot be determined from the information given here. Explain your answer.

6.1 Solution

[B.18] NO_3^- is soluble with everything, so we can't determine if any is present.
 I^- is soluble with Ba^{2+} but not Ag^+ , so it would form a precipitate with $AgNO_3$ but not $Ba(NO_3)_2$.
 I^- could be in the solution.
 PO_4^{3-} forms a precipitate with both Ba^{2+} and Ag^+ . Since no precipitate forms from $Ba(NO_3)_2$, PO_4^{3-} is not in the solution.

In the sol'n: I^-
Not in the sol'n: PO_4^{3-}
Indeterminate: NO_3^-

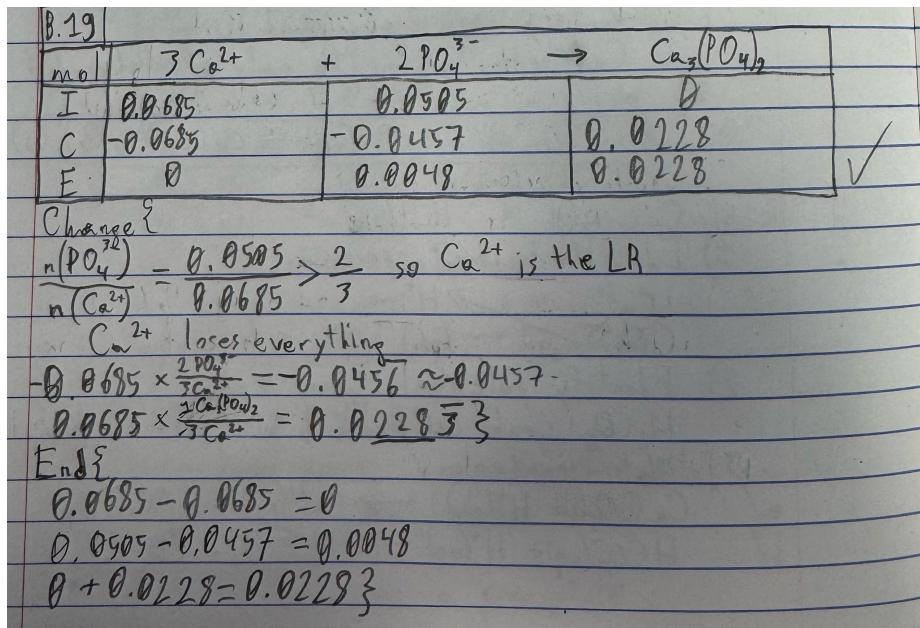
12-12-2014 v. 0.0 alternate B.1

7 Topic B Problem 19

Complete the following ICE table:

mol	$3\text{Ca}^{2+} + 3\text{PO}_4^{3-} \rightarrow \text{Ca}_3(\text{PO}_4)_2$	
I	0.0685	0.0505
C		
E		0

7.1 Solution



8 Topic B Problem 20

Complete the following ICE table, assuming Ca^{2+} is the limiting reactant:

mol	$3\text{Ca}^{2+} + 3\text{PO}_4^{3-} \rightarrow \text{Ca}_3(\text{PO}_4)_2$		
I	x	y	0
C			
E			

8.1 Solution

B.20 LR is Ca^{2+}

mol	3Ca^{2+}	$+ 2\text{PO}_4^{3-}$	$\rightarrow \text{Ca}_3(\text{PO}_4)_2$
I	x	y	0
C	-x	$\frac{2}{3}x$	$\frac{1}{3}x$
E	0	$y - \frac{2}{3}x$	$\frac{1}{3}x$

9 Topic B Problem 21

Repeat Problem 20, but now assume that PO_4^{3-} is the limiting reactant.

9.1 Solution

B. 21		LR is PO_4^{3-}		
mol	3Ca^{2+}	$+ 2\text{PO}_4^{3-}$	$\rightarrow \text{Ca}_3(\text{PO}_4)_2$	
I	x	y	0	
C	$-\frac{3}{2}y$	$-y$	$\frac{1}{2}y$	
E	$x - \frac{3}{2}y$	0	$\frac{1}{2}y$	

10 Topic B Problem 22

A chemist prepares a mixture that contains 0.0200 mol of CuCl_2 and 0.0300 mol of KOH dissolved in water.

- Write the balanced net ionic equation for the reaction that occurs.
- What are the spectator ions in this reaction?
- What is the limiting reactant in this reaction? (Hint: it's an ion.)
- Construct an ICE table for this reaction, using the net ionic equation.

10.1 Solution

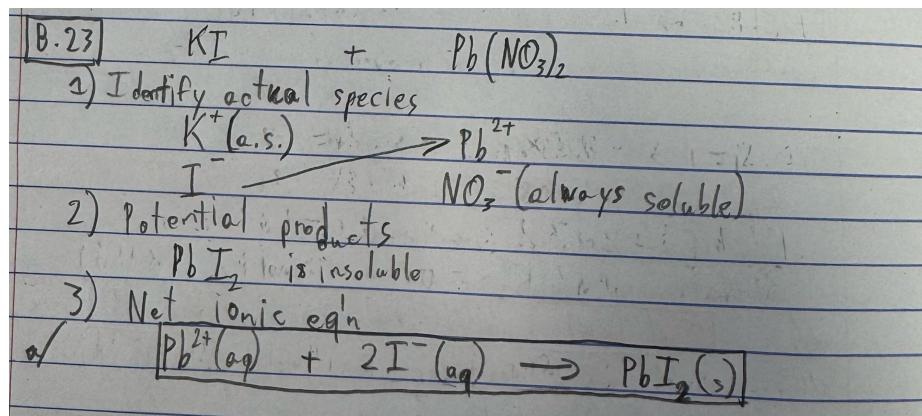
B. 22	$0.0200 \text{ mol CuCl}_2 + 0.0300 \text{ mol KOH}$																
1)	Identify actual species $\text{Cu}^{2+} \longrightarrow \text{K}^+$ (always soluble) $\text{Cl}^- \longrightarrow \text{OH}^-$																
2)	Identify potential products $\text{Cu}(\text{OH})_2$ is insoluble																
3)	Net ionic equation $\boxed{\text{Cu}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Cu}(\text{OH})_2(\text{s})}$																
b/	Cl^- and K^+ are spectator ions OH^- is the limiting reactant, so some Cu^{2+} would also be spectator ions																
c/	$\frac{0.0300 \text{ mol OH}^-}{0.0200 \text{ mol Cu}^{2+}} < \frac{2\text{OH}^-}{1\text{Cu}^{2+}}$ so $\boxed{\text{OH}^- \text{ is the LR}}$																
B. 22 d/	<table border="1"> <thead> <tr> <th>mol</th> <th>$\text{Cu}^{2+}(\text{aq})$</th> <th>$+ 2\text{OH}^-(\text{aq})$</th> <th>$\rightarrow \text{Cu}(\text{OH})_2(\text{s})$</th> </tr> </thead> <tbody> <tr> <td>I</td> <td>0.0200</td> <td>0.0300</td> <td>0</td> </tr> <tr> <td>C</td> <td>-0.0150</td> <td>-0.0300</td> <td>0.0150</td> </tr> <tr> <td>E</td> <td>0.0050</td> <td>0</td> <td>0.0150</td> </tr> </tbody> </table> <p>Change { $0.03 \text{ mol OH}^- \times \frac{1\text{Cu}^{2+}}{2\text{OH}^-} = 0.015 \text{ mol Cu}^{2+}$ $\times \frac{1\text{Cu}(\text{OH})_2}{2\text{OH}^-} = 0.015 \text{ mol Cu}(\text{OH})_2 \}$</p> <p>End { $0.020 - 0.015 = 0.005 \text{ mol Cu}^{2+} \}$</p>	mol	$\text{Cu}^{2+}(\text{aq})$	$+ 2\text{OH}^-(\text{aq})$	$\rightarrow \text{Cu}(\text{OH})_2(\text{s})$	I	0.0200	0.0300	0	C	-0.0150	-0.0300	0.0150	E	0.0050	0	0.0150
mol	$\text{Cu}^{2+}(\text{aq})$	$+ 2\text{OH}^-(\text{aq})$	$\rightarrow \text{Cu}(\text{OH})_2(\text{s})$														
I	0.0200	0.0300	0														
C	-0.0150	-0.0300	0.0150														
E	0.0050	0	0.0150														

11 Topic B Problem 23

A chemist mixes 5.00 mL of 0.240 M KI with 4.00 mL of 0.200 M Pb(NO₃)₂.

- Write the balanced net ionic equation for the reaction that occurs.
- Construct an ICE table for this reaction, using the net ionic equation.
- What mass of solid product is formed?
- What is the concentration of the excess reactant in the final mixture?
- What is the concentration of nitrate ions in the final mixture?

11.1 Solution



Continued on next page

B.23	b/		
mol	$Pb^{2+}(aq)$	$2I^-(aq) \longrightarrow PbI_2(s)$	
I	0.800×10^{-3}	1.20×10^{-3}	0
C	-0.600×10^{-3}	-1.20×10^{-3}	0.600×10^{-3}
E	0.200×10^{-3}	0	0.600×10^{-3}

Initial

$$5 \text{ mL} \times 0.240 \text{ M KI} = 1.20 \times 10^{-3} \text{ mol} \quad KI \times \frac{1I^-}{1KI} = 1.20 \times 10^{-3} \text{ mol } I^-$$

$$4 \text{ mL} \times 0.200 \text{ M } Pb(NO_3)_2 = 0.800 \times 10^{-3} \text{ mol } Pb(NO_3)_2 \times \frac{1Pb^{2+}}{2Pb(NO_3)_2} = 0.400 \times 10^{-3} \text{ mol } Pb^{2+}$$

L.R.S

$$\frac{n(I^-)}{n(Pb^{2+})} = \frac{1.20 \times 10^{-3}}{0.800 \times 10^{-3}} = \frac{3}{2} < \frac{2}{1} \text{ so } I^- \text{ is the L.R.}$$

Change

$$1.20 \times 10^{-3} \text{ mol } I^- \times \frac{1Pb^{2+}}{2I^-} = 0.600 \text{ mol } Pb^{2+}$$

$$1.20 \times 10^{-3} \text{ mol } I^- \times \frac{2PbI_2}{2I^-} = 0.600 \text{ mol } PbI_2$$

End

$$0.800 \times 10^{-3} - 0.600 \times 10^{-3} = 0.200 \times 10^{-3}$$

$$0 + 0.600 \times 10^{-3} = 0.600 \times 10^{-3}$$

$$c/MM(PbI_2) = 207.2 + 2 \times 126.9 = 461 \text{ g/mol}$$

$$n(PbI_2) \times MM(PbI_2) = 0.600 \times 10^{-3} \text{ mol } PbI_2 \times 461 \text{ g/mol} \\ = 276.6 \times 10^{-3} \text{ g } PbI_2 = [277 \times 10^{-3} \text{ g } PbI_2]$$

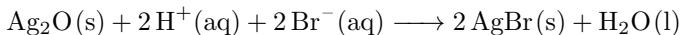
$$d/C = \frac{n}{V} = \frac{0.200 \times 10^{-3} \text{ mol}}{5 \text{ mL} + 4 \text{ mL}} = \frac{0.200}{9.00} \text{ M} = 22.2 \times 10^{-3} \text{ M } Pb^{2+}$$

$$e/n(NO_3^-) = 0.800 \times 10^{-3} \text{ mol } Pb(NO_3)_2 \times \frac{2NO_3^-}{2Pb(NO_3)_2} = 1.600 \times 10^{-3} \text{ mol } NO_3^-$$

$$C = \frac{n}{V} = \frac{1.60 \times 10^{-3} \text{ mol}}{9.00 \times 10^{-3} \text{ L}} = \boxed{0.1777 \text{ M } NO_3^-} \\ = \boxed{0.178 \text{ M } NO_3^-}$$

12 Topic B Problem 24

A chemist adds 1.35 g of solid Ag_2O to 25.0 mL of 2.00 M HBr, causing this reaction:



- a) What mass of solid AgBr is formed?
- b) What is the concentration of H^+ ions in the final mixture? (You may assume that the final solution volume is 25.0 mL.)

12.1 Solution

B.24 a/					
mol	$\text{Ag}_2\text{O}(s)$	$2\text{H}^+(aq)$	$2\text{Br}^-(aq)$	$2\text{AgBr}(s)$	$\text{H}_2\text{O}(l)$
I	0.00582	0.0500	0.0500	0	0
C	-0.00582	-0.0116	-0.0116	0.0116	0.00582
E	0	0.0384	0.0384	0.0116	0.00582

Initial {

$$n(\text{H}^+) = n(\text{Br}^-) = 25.0 \text{ mL} \times 2.00 \text{ M HBr} = 0.0500 \text{ mol}$$

$$n(\text{Ag}_2\text{O}) = \frac{1.35 \text{ g Ag}_2\text{O}}{231.8 \text{ g/mol}} = 0.00582 \text{ mol}$$

$$\frac{n(\text{H}^+)}{n(\text{Ag}_2\text{O})} = \frac{0.05}{0.00582} = 8.59 > 2 \frac{\text{H}^+}{\text{Ag}_2\text{O}}$$

so Ag_2O is the LR }

Change {

$$5.82 \text{ mol Ag}_2\text{O} \times \frac{2\text{H}^+/\text{Br}^-/\text{AgBr}}{1\text{Ag}_2\text{O}} = 11.6 \text{ mmol H}^+/\text{Br}^-/\text{AgBr}$$

End { E = I + C in every case }

$$\text{MM(AgBr)} = 107.9 + 79.90 = 187.8 \text{ g/mol}$$

$$m(\text{AgBr}) = n \times \text{MM} = 0.0116 \text{ mol} \times 187.8 \text{ g/mol} = 2.18 \text{ g}$$

b/C = $\frac{n}{V} = \frac{0.0384 \text{ mol}}{0.0250 \text{ L}} = 1.536 \text{ M H}^+ \approx 1.54 \text{ M H}^+$

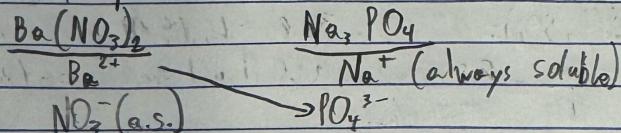
13 Topic B Problem 25

You have 50.0 mL of a 0.138 M $\text{Ba}(\text{NO}_3)_2$ solution. What is the minimum volume of 0.131 M Na_3PO_4 solution that you must add in order to remove all of the barium ions from the solution?

13.1 Solution

B.25 First find an ionic eq'n for this.

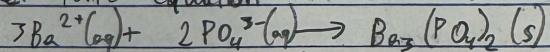
2) Actual species



2) Potential Products

$\text{Ba}_3(\text{PO}_4)_2$ is an insoluble compound

3) Net ionic equation



Find the number of Ba^{2+} ions.

$$50.0 \text{ mL} \times 0.138 \text{ M } \text{Ba}(\text{NO}_3)_2 = 6.90 \text{ mmol } \text{Ba}(\text{NO}_3)_2$$

$$6.90 \text{ mmol } \text{Ba}(\text{NO}_3)_2 \times \frac{3 \text{ Ba}^{2+}}{2 \text{ Ba}(\text{NO}_3)_2} = 6.90 \text{ mmol } \text{Ba}^{2+}$$

Use that to find the number of PO_4^{3-} ions necessary for full reaction, and from that the amount of Na_3PO_4 .

$$6.90 \text{ mmol } \text{Ba}^{2+} \times \frac{2 \text{ PO}_4^{3-}}{3 \text{ Ba}^{2+}} = 4.60 \text{ mmol } \text{PO}_4^{3-}$$

$$4.60 \text{ mmol } \text{PO}_4^{3-} \times \frac{1 \text{ Na}_3\text{PO}_4}{2 \text{ PO}_4^{3-}} = 2.30 \text{ mmol } \text{Na}_3\text{PO}_4$$

Use this and the molarity of the solution to find the necessary volume to be used.

$$V = \frac{n}{C} = \frac{4.60 \text{ mmol } \text{Na}_3\text{PO}_4}{0.131 \text{ M } \text{Na}_3\text{PO}_4} = 35.11 \text{ mL} \approx 35.2 \text{ mL}$$

14 Topic B Problem 26

A solution contains an unknown concentration of sulfate ions. When 20.00 mL of this solution is mixed with excess aqueous $\text{Ba}(\text{NO}_3)_2$, 0.877 g of BaSO_4 is formed. Calculate the molarity of sulfate ions in the original solution.

14.1 Solution

B.26 First find the number of moles of SO_4^{2-} through the number of moles of BaSO_4 .

$$\text{MM}(\text{BaSO}_4) = 137.3 + 32.06 + 16.00 \times 4 = 233.36 \text{ g/mol}$$
$$n = m / \text{MM} = 0.877 \text{ g} / 233.36 \text{ g/mol} = 3.758 \text{ mmol BaSO}_4 = n(\text{BaSO}_4)$$
$$n(\text{SO}_4^{2-}) = n(\text{BaSO}_4) \times \frac{1 \text{ SO}_4^{2-}}{1 \text{ BaSO}_4} = 3.758 \text{ mmol SO}_4^{2-}$$

Since there is excess $\text{Ba}(\text{NO}_3)_2$, there is excess Ba^{2+} , so all the sulfate would react. This means we can use the number of sulfate ions and the volume of solution added to find the molarity.

$$C = \frac{n}{V} = \frac{3.758 \text{ mmol SO}_4^{2-}}{20 \text{ mL}} = 0.188 \text{ M SO}_4^{2-}$$

15 Topic B Problem 27

A solution contains an unknown concentration of citric acid, $\text{H}_3\text{C}_6\text{H}_5\text{O}_7$. A 15.73 mL portion of this solution is placed in a flask and titrated with 0.321 M NaOH. The endpoint is reached when 23.44 mL of the NaOH solution has been added. Calculate the molarity of the original citric acid solution. The net ionic equation for the reaction that occurs is:



15.1 Solution

B.27 This is a titration problem.

First find the moles of OH^- used.

$$n(\text{NaOH}) = V \cdot M = 23.44 \text{ mL} \times 0.321 \text{ M NaOH}$$
$$= 7.52424 \text{ mmol NaOH}$$
$$n(\text{OH}^-) = n(\text{NaOH}) \times \frac{1 \text{ OH}^-}{1 \text{ NaOH}} = 7.52424 \text{ mmol OH}^-$$

From that find the number of moles of $\text{H}_3\text{C}_6\text{H}_5\text{O}_7$.

$$n(\text{H}_3\text{C}_6\text{H}_5\text{O}_7) = n(\text{OH}^-) \times \frac{1 \text{ H}_3\text{C}_6\text{H}_5\text{O}_7}{3 \text{ OH}^-} = 2.50808 \text{ mmol H}_3\text{C}_6\text{H}_5\text{O}_7$$

This lets us find the molarity of the citric acid.

$$C = \frac{n}{V} = \frac{2.50808 \text{ mmol H}_3\text{C}_6\text{H}_5\text{O}_7}{15.73 \text{ mL}} = 0.159446 \text{ M H}_3\text{C}_6\text{H}_5\text{O}_7$$
$$= 0.159 \text{ M H}_3\text{C}_6\text{H}_5\text{O}_7$$

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