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 $Pb(NO_3)_2$ (a) The actual species are Na^+, Cl^-, Pb^{2+}, and ${NO_3}^-$ (b) $PbCl_2$ will form (because it is insoluble in water) (c) The net ionic equation is $Pb^{2+}\ (aq) + 2\,Cl^-\ (aq) \longrightarrow PbCl_2\ (s)$

a) Mixing 0.1 M $MgCl_2$ and 0.1 M Na_3PO_4
b) Mixing 0.1 M HNO_3 and 0.1 M NaOH
c) Mixing 0.1 M $Fe(NO_3)_3$ and 0.1 M KOH
d) Mixing 0.1 M $ZnBr_2$ and 0.1 M $CuSO_4$
e) Mixing 0.1 M HCl and 0.1 M $NaHCO_3$
f) Mixing 0.1 M $AgNO_3$ and 0.1 M K_2CO_3
g) Mixing 0.1 M $Ba(OH)_2$ and 0.1 M Na_2SO_4
h) Mixing 0.1 M $HC_2H_3O_2$ and 0.1 M $Ba(OH)_2$
i) Mixing 0.1 M HC_6H_5O and 0.1 M NaOH
j) Mixing 0.1 M $H_2C_4H_4O_4$ (succinic acid) and excess 0.1 M NaOH. (Hint: You should write two equations for this.)

1.1 Solution

$\boxed{B.13}$ a/ $MgCl_2 + Na_3PO_4$

1) The actual species are Mg^{2+}, Cl^-, Na^+, and PO_4^{3-}
2) $Mg_3(PO_4)_2$ would form b/c it is insoluble in water
3) The net ionic equation:

$$3Mg^{2+}(aq) + 2\,PO_4^{3-}(aq) \rightarrow Mg_3(PO_4)_2(s)$$

b/ HNO_3 + NaOH

1) The actual species are H^+, NO_3^-, Na^+, OH^-

H^+ $\qquad$ Na^+ (always soluble)

NO_3^- $\qquad$ OH^-

2) H_2O would form b/c it is water.
3) The net ionic equation:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

c/ $Fe(NO_3)_3$ + $NaOH$

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

Fe^{3+} → OH^- ; Na^+ (always soluble)(a.s.)

NO_3^- (a.s.)

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

3) The net ionic equation:

$$Fe^{3+}(aq) + 3\,OH^-(aq) \rightarrow Fe(OH)_3(s)$$

d/ $ZnBr_2$ + $CuSO_4$

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

Zn^{2+} ; Cu^{2+}

Br^- ; SO_4^{2-}

2) No reaction

e/ HCl + $NaHCO_3$

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

H^+ → HCO_3^- ; Na^+ (always soluble)

Cl^-

2) H_2CO_3 forms, which degrades into H_2O & CO_2

3) Net ionic equation:

$$H^+(aq) + HCO_3^-(aq) \rightarrow H_2O(l) + CO_2(g)$$

f/ $AgNO_3$ + K_2CO_3

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

Ag^+ → CO_3^{2-} ; K^+ (always soluble)

NO_3^- (a.s.)

2) Ag_2CO_3 forms as a precipitate

3) Net ionic equation:

$$2Ag^+(aq) + CO_3^{2-}(aq) \rightarrow Ag_2CO_3(s)$$

g/ $Ba(OH)_2$ + Na_2SO_4

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

Ba^{2+} — Na^+ (always soluble)

OH^- — SO_4^{2-}

2) $BaSO_4$ forms as a precipitate

3) Net ionic equation:

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

h/ $HC_2H_3O_2$ + $Ba(OH)_2$

1) The actual species are H^+, $C_2H_3O_2^-$, Ba^{2+}, OH^-, $HC_2H_3O_2$

H^+ — Ba^{2+}

$C_2H_3O_2^-$ (a.s.) — OH^-

2) H_2O will form because it is water

3) The net ionic equation:

$$HC_2H_3O_2(aq) + OH^-(aq) \rightarrow H_2O(l) + C_2H_3O_2^-(aq)$$

i/ HC_6H_5O + $NaOH$

1) The actual species are HC_6H_5O, H^+, $C_6H_5O^-$, Na^+, OH^-

HC_6H_5O

H^+ — Na^+

C_6H_5O — OH^-

2) H_2O will form because it is water

3) The net ionic equation

$$HC_6H_5O(aq) + OH^-(aq) \rightarrow H_2O(l) + C_6H_5O^-(aq)$$

j/ $H_2C_4H_4O_4$ + $NaOH$

1) The actual species are $H_2C_4H_4O_4$, H^+, $C_4H_4O_4$, Na^+, OH^-, $HC_4H_4O_4^-$

$H_2C_4H_4O_4$ — Na^+ (always soluble)

H^+ — OH^-

$C_4H_4O_4^{2-}$

2) H_2O will form because it is water

3) Net ionic equations

$$H_2C_4H_4O_4(aq) + OH^-(aq) \rightarrow H_2O(l) + HC_4H_4O_4^-(aq)$$

$$HC_4H_4O_4^-(aq) + OH^-(aq) \rightarrow C_4H_4O_4^{2-}(aq) + H_2O(l)$$

2 Topic B Problem 14

Write balanced net ionic equations that explain the following observations.

a) When solutions of $BaCl_2$ and K_2CrO_4 are mixed, a bright yellow precipitate forms.

b) When solutions of $NaC_{12}H_{22}O_2$ and $Ca(NO_3)_2$ are mixed, a white precipitate forms.

2.1 Solution

B.14 a/ $BaCl_2 + K_2CrO_4$

1) Identify actual ~~reacta~~ species

Ba^{2+} $\longrightarrow$ CrO_4^{2-}

Cl^-

K^+ (always soluble)

2) Identify Potential Products

$BaCrO_4(s)$ is the only potential product

3) Write net ionic eq'n

$\boxed{Ba^{2+}(aq) + CrO_4^{2-}(aq) \rightarrow BaCrO_4(s)}$

b/ $NaC_{12}H_{22}O_2 + Ca(NO_3)_2$

1) Identify actual species

Na^+ (a.s.)

$C_{12}H_{22}O_2^-$ $\longrightarrow$ Ca^{2+}

NO_3^- (always soluble)

2) Identify potential products

$Ca(C_{12}H_{22}O_2)_2$ is the only potential product

3) Write a net ionic eq'n

$\boxed{Ca^{2+}(aq) + 2C_{12}H_{22}O_2^-(aq) \longrightarrow Ca(C_{12}H_{22}O_2)_2(s)}$

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) Cr_2O_3

3.1 Solution (a)

$$Mg(OH)_2\,(aq) + 2\,H^+\,(aq) \longrightarrow 2\,H_2O\,(l) + Mg^{2+}\,(aq)$$

3.2 Solution (b)

$$CuO\,(aq) + 2\,H^+\,(aq) \longrightarrow H_2O\,(l) + Cu^+\,(aq)$$

3.3 Solution (c)

$$Al(OH)_3\,(aq) + 3\,H^+\,(aq) \longrightarrow 3\,H_2O\,(l) + Mg^{3+}\,(aq)$$

3.4 Solution (d)

$$Cr_2O_3\,(aq) + 6\,H^+\,(aq) \longrightarrow 3\,H_2O\,(l) + 2\,Cr^{3+}\,(aq)$$

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.

a) Write a net ionic equation that shows why the $CaCO_3$ dissolves.

b) Write a net ionic equation that shows why the mixture bubbles.

4.1 Solution

$\boxed{B.16}$: $CaCO_3(s)$ + $HCl(aq)$

1) Identify actual species

Ca^{2+} H^+

CO_3^{2-} Cl^-

2) Identify potential products

H_2CO_3 could be produced, which decomposes into H_2O & CO_2

3) Net ionic eq'n

a/ $CaCO_3(s) + H^+(aq) \longrightarrow Ca^{2+}(aq) + HCO_3^-(aq)$

b/ $HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g)$

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

Note (b): The reason that the above equation shows why it produces bubbles is because it contains CO_2, which 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 H_2SO_4, the solid dissolves completely. When solid PbO is added to 3 M H_2SO_4, the solid changes color slightly, but does not dissolve. Explain this difference.

5.1 Solution

The MgO and the PbO would react with the ${SO_4}^{2-}$. The O would in both cases react to form H_2O, while the other cations would be attracted to the ${SO_4}^{2-}$. ${SO_4}^{2-}$ is solube with Mg^{2+}, while it would be insoluble with Pb^{2+}. This is what causes the solid of PbO to change color: it is turning into $PbSO_4$. Meanwhile, the MgO would be turning into fully soluble $MgSO_4$.

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

$\boxed{B.18}$ 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^-

7 Topic B Problem 19

Complete the following ICE table:

mol	$3\,Ca^{2+}$	$+\,3\,PO_4{}^{3-}$	$\rightarrow Ca_3(PO_4)_2$
I	0.0685	0.0505	0
C			
E			

7.1 Solution

B.19

mol	$3\,Ca^{2+}$	$+\ 2\,PO_4^{3-}$	$\rightarrow\ Ca_3(PO_4)_2$
I	0.0685	0.0505	0
C	-0.0685	-0.0457	0.0228
E	0	0.0048	0.0228

✓

Change{

$$\frac{n(PO_4^{3-})}{n(Ca^{2+})} = \frac{0.0505}{0.0685} > \frac{2}{3}$$ so Ca^{2+} is the LR

Ca^{2+} loses everything

$$-0.0685 \times \frac{2\,PO_4^{3-}}{3\,Ca^{2+}} = -0.0456 \approx -0.0457$$

$$0.0685 \times \frac{1\,Ca_3(PO_4)_2}{3\,Ca^{2+}} = 0.0228\overline{3}$$ }

End{

$0.0685 - 0.0685 = 0$

$0.0505 - 0.0457 = 0.0048$

$0 + 0.0228 = 0.0228$ }

8 Topic B Problem 20

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

mol	$3\,Ca^{2+}$	$+\,3\,PO_4{}^{3-}$	$\rightarrow Ca_3(PO_4)_2$
I	$\mathbf{x}$	$\mathbf{y}$	0
C			
E			

8.1 Solution

B.20 LR is Ca^{2+}

mol	$3\,Ca^{2+}$ +	$2\,PO_4^{3-}$	$\longrightarrow Ca_3(PO_4)_2$
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	$3Ca^{2+}$ +	$2PO_4^{3-}$ $\longrightarrow$	$Ca_3(PO_4)_2$
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.

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

10.1 Solution

B.22 0.0200 mol $CuCl_2$ + 0.0300 mol KOH

1) Identify actual species

Cu^{2+} K^+ (always soluble)

Cl^- OH^-

2) Identify potential products

$Cu(OH)_2$ is insoluble

3) Net ionic equation

a/ $\boxed{Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)}$

b/ Cl^- and K^+ are spectator ions. OH^- is the limiting reactant, so some Cu^{2+} would also be spectator ions

c/ $\frac{0.0300 \text{ mol } OH^-}{0.0200 \text{ mol } C^{2+}} < \frac{2OH^-}{1\ C^{2+}}$ so $\boxed{OH^- \text{ is the LR}}$

B.22 d/

mol	$Cu^{2+}(aq)$	$+\ 2OH^-(aq)$	$\rightarrow Cu(OH)_2(s)$
I	0.0200	0.0300	0
C	−0.0150	−0.0300	0.0150
E	0.0050	0	0.0150

Change{

$0.03 \text{ mol } OH^- \times \frac{1 Cu^{2+}}{2OH^-} = 0.015 \text{ mol } Cu^{2+}$

" $\times \frac{1 Cu(OH)_2}{2OH^-} = 0.015 \text{ mol } Cu(OH)_2$ }

End{

$0.020 - 0.015 = 0.005 \text{ mol } Cu^{2+}$ }

11 Topic B Problem 23

A chemist mixes 5.00 mL of 0.240 M KI with 4.00 mL of 0.200 M $Pb(NO_3)_2$.

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

11.1 Solution

$\boxed{\text{B.23}}$ KI + $Pb(NO_3)_2$

1) Identify actual species

K^+ (a.s.) $\quad Pb^{2+}$

I^- $\quad NO_3^-$ (always soluble)

2) Potential products

PbI_2 is insoluble

3) Net ionic eq'n

a/ $\boxed{Pb^{2+}(aq) + 2I^-(aq) \longrightarrow PbI_2(s)}$

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B.23 b/

mol	$Pb^{2+}(aq)$ +	$2I^-(aq)$ $\longrightarrow$	$PbI_2(s)$
I	0.800E-3	1.20E-3	0
C	-0.600E-3	-1.20E-3	0.600E-3
E	0.200E-3	0	0.600E-3

Initial{

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

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

LR{

$\frac{n(I^-)}{n(Pb^{2+})} = \frac{1.20E{-3}}{0.800E{-3}} = \frac{3}{2} < \frac{2}{1}$ so I^- is the LR}}

Change{

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

$1.20E{-3}\ mol\ I^- \times \frac{1\ PbI_2}{2I^-} = 0.600\ mol\ PbI_2$}

End{

$0.800E{-3} - 0.600E{-3} = 0.200E{-3}$

$0 + 0.600E{-3} = 0.600E{-3}$}

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

$n(PbI_2) \times MM(PbI_2) = 0.600E{-3}\ mol\ PbI_2 \times 461\ g/mol$

$= \underline{276.6}E{-3}\ g\ PbI_2 = \boxed{277 \times 10^{-3}\ g\ PbI_2}$

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

$= \boxed{0.0222\ M\ Pb^{2+}}$

e/ $n(NO_3^-) = 0.800E{-3}\ mol\ Pb(NO_3)_2 \times \frac{2\ NO_3^-}{1\ Pb(NO_3)_2} = 1.600E{-3}\ mol\ NO_3^-$

$C = \frac{n}{V} = \frac{1.60E{-3}\ mol}{9.00E{-3}\ L} = 0.\underline{177}7\ M\ NO_3^-$

$= \boxed{0.178\ M\ NO_3^-}$

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:

$$Ag_2O\,(s) + 2\,H^+(aq) + 2\,Br^-(aq) \longrightarrow 2\,AgBr\,(s) + H_2O\,(l)$$

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	$Ag_2O(s)$ +	$2H^+(aq)$ +	$2Br^-(aq)$ $\longrightarrow$	$2AgBr(s)$	+ $H_2O(\ell)$
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{

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

$n(Ag_2O) = \dfrac{1.35\text{ g } Ag_2O}{231.8\text{ g/mol}} = 0.00582\text{ mol}$

$\dfrac{n(H^+)}{n(Ag_2O)} = \dfrac{0.05}{0.00582} = 8.59 > \dfrac{2\,H^+}{1\,Ag_2O}$ so Ag_2O is the LR}

Change{

$5.82\text{ mmol } Ag_2O \times \dfrac{2\ H^+/Br^-/AgBr}{1\ Ag_2O} = 11.6\text{ mmol } H^+/Br^-/AgBr$}

End{ E = I + C in every case}

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

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

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

13 Topic B Problem 25

You have 50.0 mL of a 0.138 M $Ba(NO_3)_2$ 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

$\boxed{B.25}$ First find net ionic eq'n for this.

1) Actual species

$\underline{Ba(NO_3)_2}$ — Ba^{2+}, NO_3^- (a.s.)

$\underline{Na_3PO_4}$ — Na^+ (always soluble), PO_4^{3-}

2) Potential Products

$Ba_3(PO_4)_2$ is an insoluble compound

3) Net ionic equation

$$3Ba^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ba_3(PO_4)_2(s)$$

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

$$50.0\ mL \times 0.138\ M\ Ba(NO_3)_2 = 6.90\ mmol\ Ba(NO_3)_2$$

$$6.90\ mmol\ Ba(NO_3)_2 \times \frac{1\ Ba^{2+}}{1\ Ba(NO_3)_2} = 6.90\ mmol\ Ba^{2+}$$

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

$$6.90\ mmol\ Ba^{2+} \times \frac{2\ PO_4^{3-}}{3\ Ba^{2+}} = 4.60\ mmol\ PO_4^{3-}$$

$$4.60\ mmol\ PO_4^{3-} \times \frac{1\ Na_3PO_4}{1\ PO_4^{3-}} = 4.60\ mmol\ Na_3PO_4$$

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

$$V = \frac{n}{C} = \frac{4.60\ mmol\ Na_3PO_4}{0.131\ M\ Na_3PO_4} = 35.11\ mL \approx \boxed{35.1\ mL}$$

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 $Ba(NO_3)_2$, 0.877 g of $BaSO_4$ is formed. Calculate the molarity of sulfate ions in the original solution.

14.1 Solution

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

$$MM(BaSO_4) = 137.3 + 32.06 + 16.00 \times 4 = 233.36 \text{ g/mol}$$

$$n = \frac{m}{MM} = \frac{0.877 \text{ g}}{233.36 \text{ g/mol}} = 3.758 \text{ mmol } BaSO_4 = n(BaSO_4)$$

$$n(SO_4^{2-}) = n(BaSO_4) \times \frac{1\ SO_4^{2-}}{1\ BaSO_4} = 3.758 \text{ mmol } SO_4^{2-}$$

Since there is excess $Ba(NO_3)_2$, 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.

$$C = \frac{n}{V} = \frac{3.758 \text{ mmol } SO_4^{2-}}{20 \text{ mL}} = \boxed{0.188 \text{ M } SO_4^{2-}}$$

15 Topic B Problem 27

A solution contains an unknown concentration of citric acid, $H_3C_6H_5O_7$. 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:

$$3\,OH^-(aq) + H_3C_6H_5O_7(aq) \longrightarrow 3\,H_2O(l) + {C_6H_5O_7}^{3-}(aq)$$

15.1 Solution

$\boxed{\text{B.27}}$ This is a titration problem.

First find the moles of OH^- used.

$$n(NaOH) = V \cdot M = 23.44\ \text{mL} \times 0.321\ \text{M NaOH}$$

$$= 7.52424\ \text{mmol NaOH}$$

$$n(OH^-) = n(NaOH) \times \frac{1\ OH^-}{1\ NaOH} = 7.52424\ \text{mmol}\ OH^-$$

From that find the number of moles of $H_3C_6H_5O_7$.

$$n(H_3C_6H_5O_7) = n(OH^-) \times \frac{1\ H_3C_6H_5O_7}{3\ OH^-} = 2.50808\ \text{mmol}\ H_3C_6H_5O_7$$

This lets us find the molarity of the citric acid.

$$C = \frac{n}{V} = \frac{2.50808\ \text{mmol}\ H_3C_6H_5O_7}{15.73\ \text{mL}} = 0.159446\ \text{M}\ H_3C_6H_5O_7 = \boxed{0.159\ \text{M}\ H_3C_6H_5O_7}$$

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