Chemistry I – CH-1211

Extra Practice

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Contents

Exam 2 Review: Mole and Percent Composition

1. Which one of the samples contains the most particles?

   A. 1 mol $CO_2(g)$
   B. 1 mol $UF_6(g)$
   C. 1 mol $CH_3COCH_3(l)$
   D. 1 mol He(g)
   E. all contain the same number of particles

   E. Since there is 1 mole of each sample, each sample contains 6.022×10^{23} particles.

   sec02-q0033-01.tex
   Keyword:number of entities; moles

2. Which one of the samples has the largest mass?

   A. 1 mol $CO_2(g)$
   B. 1 mol $UF_6(g)$
   C. 1 mol $CH_3COCH_3(l)$
   D. 1 mol He(g)
   E. all have the same mass

   B. Since each sample contains the same number of particles, identify the particle with the largest mass. UF_6 has the largest mass and therefore, the 1 mole sample has the largest mass.

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   Keyword:number of entities; moles

3. What is the molar mass (in g mol^{-1} to four significant figures) of $Al_2(SO_4)_3 \cdot 18\ H_2O$?

   A: 666.5 g mol^{-1}

$$\begin{aligned} M[Al_2(SO_4)_3 \cdot 18\ H_2O] &= [2\ A_r^\circ(Al) + 3\ A_r^\circ(S) + 30\ A_r^\circ(O) + 36\ A_r^\circ(H)]\ M_u \\ &= [2\,(26.98) + 3\,(32.06) + 30\,(16.00) + 36\,(1.01)]\left(\frac{g}{mol}\right) \\ &= 666.\bar{4}6\ g\ mol^{-1} = 666.5\ g\ mol^{-1} \end{aligned}$$

   sec02-q0028-01.tex
   Keyword:molar mass

4. What is the molar mass (in $\mathrm{g\ mmol^{-1}}$ to three significant figures) of $(NH_4)_2HPO_4$?

A: 0.132 $\mathbf{g\ mmol^{-1}}$

$$M[(\mathrm{NH_4})_2\mathrm{HPO_4}] = [2\ A_r^\circ(\mathrm{N}) + 9\ A_r^\circ(\mathrm{H}) + A_r^\circ(\mathrm{P}) + 4\ A_r^\circ(\mathrm{O})]\ M_u$$
$$= [2\,(14.01) + 9\,(1.01) + (30.97) + 4\,(16.00)]\left(\frac{\mathrm{g}}{\mathrm{mol}}\right)\left(\frac{\mathrm{mol}}{10^3\ \mathrm{mmol}}\right)$$
$$= 0.13\bar{2}08\ \mathrm{g\ mmol^{-1}} = 0.132\ \mathrm{g\ mmol^{-1}}$$

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sec02-q0029-01.tex
Keyword:molar mass
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5. How many atoms are present in a 0.268 mol sample of CH_3OH?

A: 9.68×10^{23}

$$N(X) = n(\mathrm{CH_3OH})\ r(\mathrm{X}, \mathrm{CH_3OH})\ N_A$$
$$= 0.268\ \mathrm{mol\ CH_3OH}\left(\frac{6\ \mathrm{mol}\ X}{\mathrm{mol\ CH_3OH}}\right)\left(\frac{6.022\times10^{23}\ X}{\mathrm{mol}\ X}\right)$$
$$= 9.6\bar{8}33\times10^{23} = 9.68\times10^{23}$$

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sec02-q0030-01.tex
Keyword:number of entities; moles
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6. How many aluminum atoms are there in a 3.50 g sample of Al_2O_3?

A: 4.13×10^{22}

$$N(\mathrm{Al}) = m(\mathrm{Al_2O_3})\ M(\mathrm{Al_2O_3})^{-1}\ r(\mathrm{Al}, \mathrm{Al_2O_3})\ N_A$$
$$= 3.50\ \mathrm{g\ Al_2O_3}\left(\frac{\mathrm{mol\ Al_2O_3}}{101.96\ \mathrm{g}}\right)\left(\frac{2\ \mathrm{mol\ Al}}{\mathrm{mol\ Al_2O_3}}\right)\left(\frac{6.022\times10^{23}\ \mathrm{Al}}{\mathrm{mol\ Al}}\right)$$
$$= 4.1\bar{3}43\times10^{22} = 4.13\times10^{22}$$

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sec02-q0031-01.tex
Keyword:number of entities; moles
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7. Which one of the samples contains the most atoms?

   A. 1 mol $CO_2(g)$
   B. 1 mol $UF_6(g)$
   C. 1 mol $CH_3COCH_3(l)$
   D. 1 mol He(g)
   E. all contain the same number of atoms

C

$$\begin{aligned}\textbf{A}: N(X) &= n(\mathrm{CO_2})\ r(X,\mathrm{CO_2})\ N_\mathrm{A} \\ &= 1\ \mathrm{mol\ CO_2}\left(\frac{3\ \mathrm{mol}\ X}{\mathrm{mol\ CO_2}}\right)\left(\frac{N_0}{\mathrm{mol}}\right) \\ &= 4\,N_0\end{aligned}$$

$$\begin{aligned}\textbf{B}: N(X) &= n(\mathrm{UF_6})\ r(X,\mathrm{UF_6})\ N_\mathrm{A} \\ &= 1\ \mathrm{mol\ UF_6}\left(\frac{7\ \mathrm{mol}\ X}{\mathrm{mol\ UF_6}}\right)\left(\frac{N_0}{\mathrm{mol}}\right) \\ &= 7\,N_0\end{aligned}$$

$$\begin{aligned}\textbf{C}: N(X) &= n(\mathrm{CH_3COCH_3})\ r(X,\mathrm{CH_3COCH_3})\ N_\mathrm{A} \\ &= 1\ \mathrm{mol\ CH_3COCH_3}\left(\frac{10\ \mathrm{mol}\ X}{\mathrm{mol\ CH_3COCH_3}}\right)\left(\frac{N_0}{\mathrm{mol}}\right) \\ &= 10\,N_0\end{aligned}$$

$$\begin{aligned}\textbf{D}: N(X) &= n(\mathrm{He})\ N_\mathrm{A} \\ &= 1\ \mathrm{mol}\ X\left(\frac{N_0}{\mathrm{mol}}\right) \\ &= N_0\end{aligned}$$

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`Keyword:number of entities; moles`

8. Guanidine, $HNC(NH_2)_2$, is a fertilizer. What is the percent by mass (to one decimal place) of nitrogen in the fertilizer?

A: 71.1%

$$\begin{aligned} w(\mathrm{N})\% &= w(\mathrm{N}) \times 100\ \% \\ &= \left\{ \frac{3\,m(\mathrm{N})}{m(\mathrm{HNC(NH_2)_2})} \right\} \times 100\ \% \\ &= \left\{ \frac{3\,A_\mathrm{r}^\circ(\mathrm{N})}{[5\,A_\mathrm{r}^\circ(\mathrm{H})] + [3\,A_\mathrm{r}^\circ(\mathrm{N})] + A_\mathrm{r}^\circ(\mathrm{C})} \right\} \times 100\ \% \\ &= \left\{ \frac{3(14.01)}{(5 \times 1.01) + (3 \times 14.01) + 12.01} \right\} \times 100\ \% \\ &= \left(\frac{42.03}{59.09} \right) \times 100\ \% \\ &= 71.\bar{1}28\ \% = 71.1\ \% \end{aligned}$$

sec02-q0035-01.tex
Keyword:percent by mass

9. Determine the percent by mass (to one decimal place) of Mg in chlorophyll ($C_{55}H_{72}MgN_4O_5$), the green pigment in plant cells.

A: 2.7 %

$$\begin{aligned} w(\mathrm{Mg})\% &= w(\mathrm{Mg}) \times 100\ \% \\ &= \left\{ \frac{m(\mathrm{Mg})}{m(\mathrm{chlorophyll})} \right\} \times 100\ \% \\ &= \left\{ \frac{A_\mathrm{r}^\circ(\mathrm{Mg})}{[55 \times A_\mathrm{r}^\circ(\mathrm{C})] + [72 \times A_\mathrm{r}^\circ(\mathrm{H})] + A_\mathrm{r}^\circ(\mathrm{Mg}) + [4 \times A_\mathrm{r}^\circ(\mathrm{N})] + [5 \times A_\mathrm{r}^\circ(\mathrm{O})]} \right\} \times 100\ \% \\ &= \left\{ \frac{24.31}{(55 \times 12.01) + (72 \times 1.01) + 24.31 + (4 \times 14.01) + (5 \times 16.00)} \right\} \times 100\ \% \\ &= \left\{ \frac{24.31}{893.62} \right\} \times 100\ \% \\ &= 2.\bar{7}20\ \% = 2.7\ \% \end{aligned}$$

sec02-q0047-01.tex
Keyword:percent composition by mass

10. The mineral spodumene has the formula $LiAlSi_2O_6$. What is the mass (in g to two decimal places) of lithium in a 438 g sample?

A: 16.3 g

$$\begin{aligned} m(\text{Li}) &= w(\text{Li})\ m(\text{sample}) \\ &= \left(\frac{m(\text{Li})}{m(\text{LiAlSi}_2\text{O}_6)}\right) m(\text{sample}) \\ &= \left(\frac{A_\text{r}^\circ(\text{Li})}{A_\text{r}^\circ(\text{Li}) + A_\text{r}^\circ(\text{Al}) + [2\,A_\text{r}^\circ(\text{Si})] + [6\,A_\text{r}^\circ(\text{O})]}\right) m(\text{sample}) \\ &= \left(\frac{6.94}{186.1}\right) 438\ \text{g} \\ &= 16.\bar{3}33\ \text{g} = 16.3\ \text{g} \end{aligned}$$

sec02-q0048-01.tex

Keyword:mass fraction

Exam 2 Review: Mole and Percent Composition

11. Analysis of a sample of a covalent compound showed that it contained 14.4 % hydrogen and 85.6 % carbon by mass. What is the empirical formula for the compound?

A: CH_2

Here I choose the mass of the sample to be exactly 100 g.

$$
\begin{aligned}
w(\mathrm{H})\% &= w(\mathrm{H}) \times 100~\% \\
&= m(\mathrm{H})\; m(\mathrm{sample})^{-1} \times 100~\% \\
&= n(\mathrm{H})\; M(\mathrm{H})\; m(\mathrm{sample})^{-1} \times 100~\% \longrightarrow \\
n(\mathrm{H}) &= \left(\frac{w(\mathrm{H})~\%}{100~\%}\right) m(\mathrm{sample})\; M(\mathrm{H})^{-1} \\
&= \left(\frac{14.4~\%}{100~\%}\right)\left(\frac{100~\mathrm{g}}{}\right)\left(\frac{\mathrm{mol}}{1.01~\mathrm{g}}\right) \\
&= 14.\bar{2}57~\mathrm{mol~H}
\end{aligned}
$$

$$
\begin{aligned}
w(\mathrm{C})\% &= w(\mathrm{C}) \times 100~\% \\
&= m(\mathrm{C})\; m(\mathrm{sample})^{-1} \times 100~\% \\
&= n(\mathrm{C})\; M(\mathrm{C})\; m(\mathrm{sample})^{-1} \times 100~\% \longrightarrow \\
n(\mathrm{C}) &= w(\mathrm{C})\; m(\mathrm{sample})\; M(\mathrm{C})^{-1} \\
&= \left(\frac{w(\mathrm{C})~\%}{100~\%}\right) m(\mathrm{sample})\; M(\mathrm{C})^{-1} \\
&= \left(\frac{85.6~\%}{100~\%}\right)\left(\frac{100~\mathrm{g}}{}\right)\left(\frac{\mathrm{mol}}{12.01~\mathrm{g}}\right) \\
&= 7.1\bar{2}7~\mathrm{mol~C}
\end{aligned}
$$

$$
\begin{aligned}
r(\mathrm{H,C}) &= n(\mathrm{H})\; n(\mathrm{C})^{-1} \\
&= \frac{14.\bar{2}57~\mathrm{mol~H}}{7.1\bar{2}7~\mathrm{mol~C}} \\
&= \frac{2.00~\mathrm{mol~H}}{1~\mathrm{mol~C}}
\end{aligned}
$$

CH_2

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sec02-q0036-01.tex
Keyword:percent composition by mass; empirical formula
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12. How many moles (in normalized scientific notation) of Cs are contained in 595 kg of Cs?

A: 4.48 × 10^3 mol

$$\begin{aligned} n(\mathrm{Cs}) &= m(\mathrm{Cs})\ M(\mathrm{Cs})^{-1} \\ &= 595\ \mathrm{kg} \left(\frac{10^3\ \mathrm{g}}{\mathrm{kg}}\right) \left(\frac{\mathrm{mol}}{132.91\ \mathrm{g}}\right) \\ &= 44\bar{7}6.7\ \mathrm{mol} \\ &= 4.48 \times 10^3\ \mathrm{mol} \end{aligned}$$

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sec02-q0040-01.tex
Keyword:moles
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13. What is the mass (in g) of 2.6 × 10^{22} chlorine atoms?

A: 1.5 g

$$\begin{aligned} m(\mathrm{Cl}) &= n(\mathrm{Cl})\ M(\mathrm{Cl}) \\ &= N(\mathrm{Cl})\ N_{\mathrm{A}}^{-1}\ M(\mathrm{Cl}) \\ &= 2.6 \times 10^{22}\ \mathrm{Cl} \left(\frac{\mathrm{mol}}{6.022 \times 10^{23}\ \mathrm{Cl}}\right) \left(\frac{35.45\ \mathrm{g}}{\mathrm{mol}}\right) \\ &= 1.\bar{5}30\ \mathrm{g} \\ &= 1.5\ \mathrm{g} \end{aligned}$$

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sec02-q0042-01.tex
Keyword:moles
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14. How many iron atoms are contained in 354 g of iron?

A: 3.82 × 10^{24} atoms

$$\begin{aligned} N(\mathrm{Fe}) &= n(\mathrm{Fe})\ M(\mathrm{Fe}) \\ &= m(\mathrm{Fe})\ M(\mathrm{Fe})^{-1}\ N_{\mathrm{A}} \\ &= 354\ \mathrm{g} \left(\frac{\mathrm{mol}}{55.85\ \mathrm{g}}\right) \left(\frac{6.022 \times 10^{23}\ \mathrm{Fe}}{\mathrm{mol}}\right) \\ &= 3.8\bar{1}69 \times 10^{24}\ \mathrm{Fe} \\ &= 3.82 \times 10^{24}\ \mathrm{Fe} \end{aligned}$$

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sec02-q0043-01.tex
Keyword:moles; number of entities
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15. What is the mass (in ng) of 2.33×10^{20} oxygen atoms?

A: 6.19×10^{6} ng

$$\begin{aligned} m(\mathrm{O}) &= n(\mathrm{O})\ M(\mathrm{O}) \\ &= N(\mathrm{O})\ N_{\mathrm{A}}^{-1}\ M(\mathrm{O}) \\ &= 2.33 \times 10^{20}\ \mathrm{O} \left(\frac{\mathrm{mol}}{6.022 \times 10^{23}\ \mathrm{O}} \right) \left(\frac{16.00\ \mathrm{g}}{\mathrm{mol}} \right) \left(\frac{10^{9}\ \mathrm{ng}}{\mathrm{g}} \right) \\ &= 6.1\bar{9}06 \times 10^{6}\ \mathrm{ng} \\ &= 6.19 \times 10^{6}\ \mathrm{ng} \end{aligned}$$

`sec02-q0044-01.tex`
`Keyword:moles; number of entities`

16. What is the mass (in g) of 2.0×10^{24} Hg atoms?

A: 6.7×10^{2} g

$$\begin{aligned} m(\mathrm{Hg}) &= n(\mathrm{Hg})\ M(\mathrm{Hg}) \\ &= N(\mathrm{Hg})\ N_{\mathrm{A}}^{-1}\ M(\mathrm{Hg}) \\ &= 2.0 \times 10^{24}\ \mathrm{Hg} \left(\frac{\mathrm{mol}}{6.022 \times 10^{23}\ \mathrm{Hg}} \right) \left(\frac{200.59\ \mathrm{g}}{\mathrm{mol}} \right) \\ &= 6.\bar{6}61 \times 10^{2}\ \mathrm{g} \\ &= 6.7 \times 10^{2}\ \mathrm{g} \end{aligned}$$

`sec02-q0045-01.tex`
`Keyword:moles; number of entities`

17. A sample of a compound containing only carbon and oxygen decomposes and produces 24.5 g of carbon and 32.59 g of oxygen. Determine the sample by considering percent composition by mass.

A. CO
B. CO_2
C. CO_3
D. C_3O_2
E. C_2O

A

Total mass of sample:

$$m(\text{sample}) = 24.5\text{ g} + 32.59\text{ g} = 57.09\text{ g}$$

Mass percent of C and O in sample:

$$\begin{aligned} w(\text{C})\% &= w(\text{C}) \times 100\ \% \\ &= \frac{m(\text{C})}{m(\text{sample})} \times 100\ \% \\ &= \frac{24.5\text{ g}}{57.09\text{ g}} \times 100\ \% \\ &= 42.\bar{9}14\ \% \end{aligned}$$

$$\begin{aligned} w(\text{O})\% &= w(\text{O}) \times 100\ \% \\ &= \frac{m(\text{O})}{m(\text{sample})} \times 100\ \% \\ &= \frac{32.59\text{ g}}{57.09\text{ g}} \times 100\ \% \\ &= 57.0\bar{8}53\ \% \end{aligned}$$

Mass percent of C and O in CO:

$$\begin{aligned} w(\text{C})\% &= w(\text{C}) \times 100\ \% \\ &= \frac{A_r^\circ(\text{C})}{A_r^\circ(\text{CO})} \times 100\ \% \\ &= \frac{12.01}{28.01} \times 100\ \% \\ &= 42.8\bar{7}75\ \% \end{aligned}$$

$$\begin{aligned} w(\text{O})\% &= w(\text{O}) \times 100\ \% \\ &= \frac{A_r^\circ(\text{O})}{A_r^\circ(\text{CO})} \times 100\ \% \\ &= \frac{16.00}{28.01} \times 100\ \% \\ &= 57.1\bar{2}24\ \% \end{aligned}$$

The mass percent of C and O in the sample closely match the mass percent of C and O in CO. The other options give significantly different mass percent compositions.

`sec02-q0004-01.tex`
`Keyword:percent composition by mass`

18. The mineral spodumene has the formula $LiAlSi_2O_6$. How many lithium atoms are present in a 105 g sample?

A: 3.40×10^{23}

$$
\begin{aligned}
N(\mathrm{Li}) &= n(\mathrm{Li})\ N_\mathrm{A} \\
&= m(\mathrm{Li})\ M(\mathrm{Li})^{-1}\ N_\mathrm{A} \\
&= w(\mathrm{Li})\ m(\mathrm{sample})\ M(\mathrm{Li})^{-1}\ N_\mathrm{A} \\
&= \left(\frac{m(\mathrm{Li})}{m(\mathrm{LiAlSi_2O_6})}\right) m(\mathrm{sample})\ M(\mathrm{Li})^{-1}\ N_\mathrm{A} \\
&= \left(\frac{A_\mathrm{r}^\circ(\mathrm{Li})}{A_\mathrm{r}^\circ(\mathrm{Li}) + A_\mathrm{r}^\circ(\mathrm{Al}) + [2\,A_\mathrm{r}^\circ(\mathrm{Si})] + [6\,A_\mathrm{r}^\circ(\mathrm{O})]}\right) m(\mathrm{sample})\ M(\mathrm{Li})^{-1}\ N_\mathrm{A} \\
&= \left(\frac{6.94}{6.94 + 26.98 + [2 \times 28.09] + [6 \times 16.00]}\right) \left(\frac{105\ \mathrm{g}}{}\right) \left(\frac{\mathrm{mol}}{6.94\ \mathrm{g}}\right) \left(\frac{6.022 \times 10^{23}}{\mathrm{mol}}\right) \\
&= \left(\frac{6.94}{186.10}\right) \left(\frac{105\ \mathrm{g}}{}\right) \left(\frac{\mathrm{mol}}{6.94\ \mathrm{g}}\right) \left(\frac{6.022 \times 10^{23}}{\mathrm{mol}}\right) \\
&= 3.3\bar{9}76 \times 10^{23} \\
&= 3.40 \times 10^{23}
\end{aligned}
$$

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sec02-q0054-01.tex
Keyword:number of particles
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19. Which of the following statements are correct for sorbic acid, $C_6H_8O_2$, an inhibitor of mold and yeast?

I. It has a C:H:O mass ratio of 3:4:1
II. It has the same mass percent composition as C_3H_4O
III. It has the same empirical formula as $C_{12}H_{16}O_4$
IV. The highest percentage, by mass, is that of H
V. It is an alcohol

A. III and IV
B. II and III
C. I, II, III, IV, and V
D. II, III, and V
E. II, III, IV, and V

B

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sec02-q0055-01.tex
Keyword:percent by mass; empirical formula
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20. Find the mass (in g) of 500 atoms of iron.

A: 5×10^{-20}

$$\begin{aligned} m(\text{Fe}) &= n(\text{Fe})\ M(\text{Fe}) \\ &= N(\text{Fe})\ N_\text{A}^{-1}\ M(\text{Fe}) \\ &= 500\ \text{Fe} \left(\frac{\text{mol}}{6.022 \times 10^{23}\ \text{Fe}}\right)\left(\frac{55.85\ \text{g}}{\text{mol}}\right) \\ &= \bar{4}.63 \times 10^{-20}\ \text{g} \\ &= 5 \times 10^{-20}\ \text{g} \end{aligned}$$

`sec02-q0060-01.tex`
`Keyword:moles; number of particles`

21. How much Fe (in mol and number of atoms) are in 125.0 g of Fe?

A: 2.238 mol; 1.347×10^{24} atoms

$$\begin{aligned} n(\text{Fe}) &= m(\text{Fe})\ M(\text{Fe})^{-1} \\ &= 125.0\ \text{g} \left(\frac{\text{mol}}{55.85\ \text{g}}\right) \\ &= 2.23\bar{8}13\ \text{mol} \\ &= 2.238\ \text{mol} \end{aligned}$$

$$\begin{aligned} N(\text{Fe}) &= n(\text{Fe})\ N_\text{A} \\ &= 2.23\bar{8}13\ \text{mol} \left(\frac{6.022 \times 10^{23}\ \text{Fe}}{\text{mol}}\right) \\ &= 1.34\bar{7}80 \times 10^{24} \\ &= 1.347 \times 10^{24} \end{aligned}$$

`sec02-q0061-01.tex`
`Keyword:moles; number of particles`

22. Freon-12 (CCl_2F_2) is used as a refrigerant in air conditioners and as a propellant in aerosol cans. What is the number of freon-12 molecules and what is the mass (in mg) of Cl in a 5.56 mg sample of freon-12?

A: 2.77 × 10^19 molecules; 3.26 mg

$$\begin{aligned}
N(\mathrm{CCl_2F_2}) &= n(\mathrm{CCl_2F_2})\ N_\mathrm{A} \\
&= m(\mathrm{CCl_2F_2})\ M(\mathrm{CCl_2F_2})^{-1}\ N_\mathrm{A} \\
&= 5.56\ \mathrm{mg}\left(\frac{\mathrm{g}}{10^3\ \mathrm{mg}}\right)\left(\frac{\mathrm{mol}}{120.91\ \mathrm{g}}\right)\left(\frac{6.022\times10^{23}}{\mathrm{mol}}\right) \\
&= 2.7\bar{6}91\times10^{19}\ \mathrm{CCl_2F_2} \\
&= 2.77\times10^{19}\ \mathrm{CCl_2F_2}
\end{aligned}$$

$$\begin{aligned}
m(\mathrm{Cl}) &= n(\mathrm{Cl})\ M(\mathrm{Cl}) \\
&= N(\mathrm{CCl_2F_2})\ r(\mathrm{Cl},\mathrm{CCl_2F_2})\ N_\mathrm{A}^{-1}\ M(\mathrm{Cl}) \\
&= 2.7\bar{6}91\times10^{19}\ \mathrm{CCl_2F_2}\left(\frac{2\ \mathrm{Cl}}{1\ \mathrm{CCl_2F_2}}\right)\left(\frac{\mathrm{mol}}{6.022\times10^{23}\ \mathrm{Cl}}\right)\left(\frac{35.45\ \mathrm{g}}{\mathrm{mol}}\right)\left(\frac{10^3\ \mathrm{mg}}{\mathrm{g}}\right) \\
&= 3.2\bar{6}01\ \mathrm{mg} \\
&= 3.26\ \mathrm{mg}
\end{aligned}$$

`sec02-q0062-01.tex`

`Keyword:moles; number of particles`

23. *Prevacid* ($C_{16}H_{14}F_3N_3O_2S$) is used to treat gastroesophageal reflux disease (GERD). Determine each of the following:

A. the molar mass (in g mol^{-1}) of *Prevacid*
B. the mass (in g) of fluorine in a 0.75 mol sample of *Prevacid*
C. the number of C atoms in a 0.75 mol sample of *Prevacid*
D. the mass (in g) of 4.25×10^{21} molecules of *Prevacid*

A: 369.36 g mol^{-1}; 43 g; 7.2 × 10^{24}; 2.61 g

Let *Prevacid* be "PA".

A:

$$\begin{aligned} M(\text{PA}) &= \left\{[16\,A_r^\circ(\text{C})] + [14\,A_r^\circ(\text{H})] + [3\,A_r^\circ(\text{F})] + [3\,A_r^\circ(\text{N})] + [2\,A_r^\circ(\text{O})] + A_r^\circ(\text{S})\right\} M_u \\ &= \left\{[16 \times 12.01] + [14 \times 1.01] + [3 \times 19.00] + [3 \times 14.01] + [2 \times 16.00] + 32.06\right\}\left(\frac{\text{g}}{\text{mol}}\right) \\ &= 369.39 \text{ g mol}^{-1} \end{aligned}$$

B:

$$\begin{aligned} m(\text{F}) &= n(\text{F})\ M(\text{F}) \\ &= n(\text{PA})\ r(\text{F,PA})\ M(\text{F}) \\ &= 0.75 \text{ mol PA}\left(\frac{3 \text{ mol F}}{\text{mol PA}}\right)\left(\frac{19.00 \text{ g}}{\text{mol F}}\right) \\ &= 4\bar{2}.75 \text{ g} = 43 \text{ g} \end{aligned}$$

C:

$$\begin{aligned} N(\text{C}) &= n(\text{C})\ N_A \\ &= n(\text{PA})\ r(\text{C,PA})\ N_A \\ &= 0.75 \text{ mol PA}\left(\frac{16 \text{ mol C}}{\text{mol PA}}\right)\left(\frac{6.022 \times 10^{23} \text{ C}}{\text{mol}}\right) \\ &= 7.\bar{2}26 \times 10^{24} = 7.2 \times 10^{24} \end{aligned}$$

D:

$$\begin{aligned} m(\text{PA}) &= n(\text{PA})\ M(\text{PA}) \\ &= N(\text{PA})\ N_A^{-1}\ M(\text{PA}) \\ &= 4.25 \times 10^{21} \text{ PA}\left(\frac{\text{mol}}{6.022 \times 10^{23} \text{ PA}}\right)\left(\frac{369.39 \text{ g}}{\text{mol}}\right) \\ &= 2.6\bar{0}69 \text{ g} = 2.61 \text{ g} \end{aligned}$$

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sec02-q0063-01.tex
Keyword:moles; number of particles
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24. Find the percent composition by mass (to one decimal place) of each element in $YBa_2Cu_3O_7$.

A: Y: 13.3 %; Ba: 41.2 %; Cu: 28.6 %; O: 16.8 %

$$M(YBa_2Cu_3O_7) = \left\{ A_r^\circ(Y) + [2\ A_r^\circ(Ba)] + [3\ A_r^\circ(Cu)] + [7\ A_r^\circ(O)] \right\} M_u$$
$$= \left\{ 88.91 + [2 \times 137.33] + [3 \times 63.55] + [7 \times 16.00] \right\} \left(\frac{g}{mol}\right)$$
$$= 666.22\ g\ mol^{-1}$$

$$w(Y)\% = w(Y) \times 100\ \%$$
$$= \left(\frac{A_r^\circ(Y)}{A_r^\circ(YBa_2Cu_3O_7)}\right) \times 100\ \%$$
$$= \left(\frac{88.91}{666.22}\right) \times 100\ \%$$
$$= 13.\bar{3}45\ \%$$
$$= 13.3\ \%$$

$$w(Ba)\% = w(Ba) \times 100\ \%$$
$$= \left(\frac{2\ A_r^\circ(Ba)}{A_r^\circ(YBa_2Cu_3O_7)}\right) \times 100\ \%$$
$$= \left(\frac{2 \times 137.33}{666.22}\right) \times 100\ \%$$
$$= 41.\bar{2}26\ \%$$
$$= 41.2\ \%$$

$$w(Cu)\% = w(Cu) \times 100\ \%$$
$$= \left(\frac{3\ A_r^\circ(Cu)}{A_r^\circ(YBa_2Cu_3O_7)}\right) \times 100\ \%$$
$$= \left(\frac{3 \times 63.55}{666.22}\right) \times 100\ \%$$
$$= 28.\bar{6}16\ \%$$
$$= 28.6\ \%$$

$$w(O)\% = w(O) \times 100\ \%$$
$$= \left(\frac{7\ A_r^\circ(O)}{A_r^\circ(YBa_2Cu_3O_7)}\right) \times 100\ \%$$
$$= \left(\frac{7 \times 16.00}{666.22}\right) \times 100\ \%$$
$$= 16.\bar{8}11\ \%$$
$$= 16.8\ \%$$

sec02-q0064-01.tex
Keyword:percent composition by mass

25. Hemoglobin is a protein that transports oxygen in mammals. Hemoglobin is 0.347 % Fe (by mass). Each hemoglobin molecule contains 4 Fe atoms. What is the molar mass (in g mol^{-1} in standard notation) of hemoglobin?

A: 64,400 g mol^{-1}

$$
\begin{aligned}
w(\mathrm{Fe})\% &= w(\mathrm{Fe}) \times 100\ \% \\
&= \left(\frac{m(\mathrm{Fe})}{m(\mathrm{hemoglobin})}\right) \times 100\ \% \\
&= \frac{4\ A_\mathrm{r}^\circ(\mathrm{Fe})\ M_\mathrm{u}}{M(\mathrm{hemoglobin})} \times 100\ \% \longrightarrow \\
M(\mathrm{hemoglobin}) &= \frac{4\ A_\mathrm{r}^\circ(\mathrm{Fe})\ M_\mathrm{u}}{\left(\frac{w(\mathrm{Fe})\%}{100\ \%}\right)} \\
&= \frac{4\ (55.85)\ \left(\frac{\mathrm{g}}{\mathrm{mol}}\right)}{\left(\frac{0.347\ \%}{100\ \%}\right)} \\
&= 64\ \bar{3}80.4\ \mathrm{g\ mol^{-1}} = 64\ 400\ \mathrm{g\ mol^{-1}}
\end{aligned}
$$

sec02-q0065-01.tex

Keyword:percent composition by mass

Exam 2 Review: Mole and Percent Composition

26. A compound that only contains carbon, hydrogen, and oxygen is 48.64 % C and 8.16 % H (by mass). What is the empirical formula of this substance?

A: $C_3H_6O_2$

Assume an exact 100 g sample.
Find the moles of C, H, and O in an exact 100 g sample.

$$\begin{aligned} n(\mathrm{C}) &= w(\mathrm{C})\ m(\text{sample})\ M(\mathrm{C})^{-1} \\ &= \left(\frac{w(\mathrm{C})\%}{100\ \%}\right)\ m(\text{sample})\ M(\mathrm{C})^{-1} \\ &= \left(\frac{48.64\%\ \mathrm{C}}{100\ \%}\right)\left(\frac{100\ \mathrm{g}}{}\right)\left(\frac{\mathrm{mol}}{12.01\ \mathrm{g}}\right) \\ &= 4.04\bar{9}95 \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{H}) &= w(\mathrm{H})\ m(\text{sample})\ M(\mathrm{H})^{-1} \\ &= \left(\frac{w(\mathrm{H})\%}{100\ \%}\right)\ m(\text{sample})\ M(\mathrm{H})^{-1} \\ &= \left(\frac{8.16\%\ \mathrm{H}}{100\ \%}\right)\left(\frac{100\ \mathrm{g}}{}\right)\left(\frac{\mathrm{mol}}{1.01\ \mathrm{g}}\right) \\ &= 8.07\bar{9}20\ \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{O}) &= w(\mathrm{O})\ m(\text{sample})\ M(\mathrm{O})^{-1} \\ &= \left(\frac{w(\mathrm{O})\%}{100\ \%}\right)\ m(\text{sample})\ M(\mathrm{O})^{-1} \\ &= \left(\frac{[100-(48.64+8.16)]\ \ \%\ \mathrm{O}}{100\ \%}\right)\left(\frac{100\ \mathrm{g}}{}\right)\left(\frac{\mathrm{mol}}{16.00\ \mathrm{g}}\right) \\ &= 2.70\bar{0}00\ \mathrm{mol} \end{aligned}$$

Find the mole ratio of C, H, and O to a smallest whole number ratio by dividing by the smallest mole number and multiplying by an integer (here the integer is 2).

$$C_{4.04\bar{9}95}H_{8.07\bar{9}20}O_{2.70\bar{0}00}$$

$$C_{\frac{4.04\bar{9}9}{2.70\bar{0}00}}H_{\frac{8.07\bar{9}2}{2.70\bar{0}00}}O_{\frac{2.70\bar{0}00}{2.70\bar{0}00}}$$

$$C_{1.5}H_3O$$

$$C_{1.5\times2}H_{3\times2}O_{1\times2}$$

$$C_3H_6O_2$$

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sec02-q0066-01.tex
Keyword:percent composition by mass; empirical formula
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27. Consider four individual samples of phosphine (PH_3), water, hydrogen sulfide, and hydrogen fluoride, each with a mass of 121 g. Rank the compounds from the least to the greatest number of hydrogen atoms contained in each sample.

A: HF < H_2S < PH_3 < H_2O

PH_3

$$\begin{aligned} N(\mathrm{H}) &= n(\mathrm{H})\ N_\mathrm{A} \\ &= m(\mathrm{PH_3})\ M(\mathrm{PH_3})^{-1}\ r(\mathrm{H,PH_3})\ N_\mathrm{A} \\ &= 121\ \mathrm{g\ PH_3} \left(\frac{\mathrm{mol\ PH_3}}{34.00\ \mathrm{g}}\right) \left(\frac{3\ \mathrm{mol\ H}}{\mathrm{mol\ PH_3}}\right) \left(\frac{6.022 \times 10^{23}\ \mathrm{H}}{\mathrm{mol\ H}}\right) \\ &= 6.4\bar{2}93 \times 10^{24}\ \mathrm{H} = 6.43 \times 10^{24}\ \mathrm{H} \end{aligned}$$

H_2O

$$\begin{aligned} N(\mathrm{H}) &= n(\mathrm{H})\ N_\mathrm{A} \\ &= m(\mathrm{H_2O})\ M(\mathrm{H_2O})^{-1}\ r(\mathrm{H,H_2O})\ N_\mathrm{A} \\ &= 121\ \mathrm{g\ H_2O} \left(\frac{\mathrm{mol\ H_2O}}{18.02\ \mathrm{g}}\right) \left(\frac{2\ \mathrm{mol\ H}}{\mathrm{mol\ H_2O}}\right) \left(\frac{6.022 \times 10^{23}\ \mathrm{H}}{\mathrm{mol\ H}}\right) \\ &= 8.0\bar{8}72 \times 10^{24}\ \mathrm{H} = 8.09 \times 10^{24}\ \mathrm{H} \end{aligned}$$

H_2S

$$\begin{aligned} N(\mathrm{H}) &= n(\mathrm{H})\ N_\mathrm{A} \\ &= m(\mathrm{H_2S})\ M(\mathrm{H_2S})^{-1}\ r(\mathrm{H,H_2S})\ N_\mathrm{A} \\ &= 121\ \mathrm{g\ H_2S} \left(\frac{\mathrm{mol\ H_2S}}{34.08\ \mathrm{g}}\right) \left(\frac{2\ \mathrm{mol\ H}}{\mathrm{mol\ H_2S}}\right) \left(\frac{6.022 \times 10^{23}\ \mathrm{H}}{\mathrm{mol\ H}}\right) \\ &= 4.2\bar{7}61 \times 10^{24}\ \mathrm{H} = 4.28 \times 10^{24}\ \mathrm{H} \end{aligned}$$

HF

$$\begin{aligned} N(\mathrm{H}) &= n(\mathrm{H})\ N_\mathrm{A} \\ &= m(\mathrm{HF})\ M(\mathrm{HF})^{-1}\ r(\mathrm{H,HF})\ N_\mathrm{A} \\ &= 121\ \mathrm{g\ HF} \left(\frac{\mathrm{mol\ HF}}{20.01\ \mathrm{g}}\right) \left(\frac{1\ \mathrm{mol\ H}}{\mathrm{mol\ HF}}\right) \left(\frac{6.022 \times 10^{23}\ \mathrm{H}}{\mathrm{mol\ H}}\right) \\ &= 3.6\bar{4}14 \times 10^{24}\ \mathrm{H} = 3.64 \times 10^{24}\ \mathrm{H} \end{aligned}$$

HF < H_2S < PH_3 < H_2O

`sec02-q0067-01.tex`

`Keyword:moles; number of particles`

Exam 2 Review: Balancing Equations and Solubility

1. Write a balanced equation for the following reaction by placing appropriate stoichiometric coefficients.

$$\_\_\_\_ \; CH_3OH + \_\_\_\_ \; O_2 \longrightarrow \_\_\_\_ \; CO_2 + \_\_\_\_ \; H_2O$$

$$2\,CH_3OH + 3\,O_2 \longrightarrow 2\,CO_2 + 4\,H_2O$$

sec03-q0001-01.tex
Keyword:balancing equations

2. Write a balanced equation for the following reaction by placing appropriate stoichiometric coefficients.

$$\_\_\_\_ \; CH_3NHNH_2 + \_\_\_\_ \; O_2 \longrightarrow \_\_\_\_ \; CO_2 + \_\_\_\_ \; H_2O + \_\_\_\_ \; N_2$$

$$2\,CH_3OH + 5\,O_2 \longrightarrow 2\,CO_2 + 6\,H_2O + 2\,N_2$$

sec03-q0002-01.tex
Keyword:balancing equations

3. What values for m and n are required to balance the equation with the given stoichiometric coefficients?

$$B_mH_n + 3\,O_2 \longrightarrow B_2O_3 + 3\,H_2O$$

$m = 2$, $n = 6$

$$B_2H_6 + 3\,O_2 \longrightarrow B_2O_3 + 3\,H_2O$$

sec03-q0003-01.tex
Keyword:balancing equations

4. What values for m and n are required to balance the equation with the given stoichiometric coefficients?

$$H_mIO_n \longrightarrow H^+ + IO_4^- + 2\,H_2O$$

$m = 5$, $n = 6$

$$H_5IO_6 \longrightarrow H^+ + IO_4^- + 2\,H_2O$$

sec03-q0004-01.tex
Keyword:balancing equations

5. Write a balanced equation for the following reaction by placing appropriate stoichiometric coefficients. Include a coefficeint of "1" where appropriate for the purpose of this exercise.

$$\_\_\_\_ \ CH_4 + \_\_\_\_ \ H_2O \longrightarrow \_\_\_\_ \ CO + \_\_\_\_ \ H_2$$

$$1\ CH_4 + 1\ H_2O \longrightarrow 1\ CO + 3\ H_2$$

sec03-q0005-01.tex
Keyword:balancing equations

6. Solid silver oxide decomposes at high temperatures to yield metallic silver and oxygen gas. Balance the following reaction. Include a coefficeint of "1" where appropriate for the purpose of this exercise.

$$\_\_\_\_ \ Ag_2O(s) \longrightarrow \_\_\_\_ \ Ag(s) + \_\_\_\_ \ O_2$$

$$2\ Ag_2O(s) \longrightarrow 4\ Ag(s) + 1\ O_2$$

sec03-q0006-01.tex
Keyword:balancing equations

7. Chemical equations must be balanced because the resulting coefficients allow us to predict (select all that apply).

   A. the amount of product that can form from a given amount of reactant.
   B. whether the reaction requires a catalyst or not
   C. how much of one reactant is required to react with a given amount of another
   D. how much reactants are required to form a given amount of products
   E. whether the given reaction is possible or not

A, C, D

sec03-q0007-01.tex
Keyword:balancing equations

8. Select the appropriately balanced equation for the following reaction.

   aqueous silver sulfate + aqueous barium iodide $\longrightarrow$ solid barium sulfate + solid silver iodide

   A. $Ag_2SO_4 + BaI_2 \longrightarrow BaSO_4 + AgI$
   B. $Ag_2SO_4(l) + BaI_2(l) \longrightarrow BaSO_4(s) + 2\ AgI(s)$
   C. $Ag_2SO_4(aq) + BaI_2(aq) \longrightarrow BaSO_4(s) + 2\ AgI(s)$
   D. $AgSO_4(aq) + BaI(aq) \longrightarrow BaSO_4(s) + 2\ AgI(s)$
   E. $AgSO_4(l) + 2\ BaI(l) \longrightarrow Ba_2SO_4(s) + 2\ AgI_2(s)$

C

sec03-q0008-01.tex
Keyword:nomenclature; balancing equations

9. Write a balanced equation for the following reaction by placing appropriate stoichiometric coefficients. Include a coefficeint of "1" where appropriate for the purpose of this exercise.

$$\_\_\_\_ \text{ Se} + \_\_\_\_ \text{ BrF}_5 \longrightarrow \_\_\_\_ \text{ SeF}_6 + \_\_\_\_ \text{ BrF}_3$$

$$1 \text{ Se} + 3 \text{ BrF}_5 \longrightarrow 1 \text{ SeF}_6 + 3 \text{ BrF}_3$$

`sec03-q0009-01.tex`
`Keyword:balancing equations`

10. Classify each of the following (all that apply) as a

I. strong electrolyte
II. weak electrolyte
III. nonelectrolyte
IV. strong acid
V. strong base
VI. weak acid
VII. weak base
VIII. ionic compound
IX. organic compound

A. HBr
B. ammonium carbonate
C. $NaClO_4$
D. ethanol
E. acetic acid
F. NH_3

A. I, IV
B. I, VIII
C. I, VIII
D. III, IX
E. II, VI
F. II, VII

`sec03-q0010-01.tex`
`Keyword:electrolytes`

11. Which of the following compounds are insoluble in water? Select all that apply.

A. $CoCO_3$
B. $Cu_3(PO_4)_2$
C. $AgNO_3$
D. Na_2S
E. AgI

A, B, E

`sec03-q0012-01.tex`
`Keyword:solubility rules`

12. Which of the following combinations will form a precipitate? Select all that apply.

   A. $SrCl_2(aq) + Na_2S(aq)$
   B. $KCl(aq) + CaS(aq)$
   C. $Hg(NO_3)_2(aq) + Na_3PO_4(aq)$
   D. $Ba(NO_3)_2(aq) + KOH(aq)$
   E. $NaOH(aq) + FeCl_3(aq)$

   A, C, E

   A. $SrCl_2(aq) + Na_2S(aq) \longrightarrow SrS(s) + 2\ NaCl(aq)$
   B. $2\ KCl(aq) + CaS(aq) \longrightarrow K_2S(aq) + CaCl_2(aq)$
   C. $Hg(NO_3)_2(aq) + 2\ Na_3PO_4(aq) \longrightarrow Hg_3(PO_4)_2(s) + 6\ NaNO_3(aq)$
   D. $Ba(NO_3)_2(aq) + KOH(aq) \longrightarrow Ba(OH)_2(aq) + 2\ KNO_3(aq)$
   E. $NaOH(aq) + FeCl_3(aq) \longrightarrow Fe(OH)_3(s) + 3\ NaCl(aq)$

   `sec03-q0013-01.tex`
   `Keyword:solubility rules; precipitation`

13. Lead(II) nitrate reacts with sodium chloride. Choose the net ionic equation for the reaction.

   A. $Pb^{2+}(aq) + Cl^-(aq) \longrightarrow PbCl(s)$
   B. $Pb^{2+}(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \longrightarrow PbCl(s) + NaNO_3(aq)$
   C. $PbNO_3(aq) + NaCl(aq) \longrightarrow PbCl(s) + NaNO_3(aq)$
   D. $Pb^{2+}(aq) + 2\ Cl^-(aq) \longrightarrow PbCl_2(s)$

   D

   Molecular equation

$$Pb(NO_3)_2(aq) + 2\ NaCl(aq) \longrightarrow PbCl_2(s) + 2\ NaNO_3(aq)$$

   Complete ionic equation

$$Pb^{2+}(aq) + 2\ NO_3^-(aq) + 2\ Na^+(aq) + 2\ Cl^-(aq) \longrightarrow PbCl_2(s) + 2\ Na^+(aq) + 2\ NO_3^-(aq)$$

   Net ionic equation

$$Pb^{2+}(aq) + 2\ Cl^-(aq) \longrightarrow PbCl_2(s)$$

   `sec03-q0014-01.tex`
   `Keyword:solubility rules; precipitation; net ionic equation`

14. Aqueous solutions of sodium sulfate and barium chloride react. What is the sum of the coefficients from the balanced net ionic equation?

3

Molecular equation

$$Na_2SO_4(aq) + BaCl_2(aq) \longrightarrow 2\ NaCl(aq) + BaSO_4(s)$$

Complete ionic equation

$$2\ Na^{2+}(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + 2\ Cl^{-}(aq) \longrightarrow 2\ Na^{+}(aq) + 2\ Cl^{-}(aq) + BaSO_4(s)$$

Net ionic equation

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

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sec03-q0015-01.tex
Keyword:solubility rules; precipitation; net ionic equation; balancing equations
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15. Answer the questions for the following reaction.

$$2\ HI(aq) + Ca(OH)_2(aq) \longrightarrow 2\ H_2O(l) + CaI_2(aq)$$

A. Is the acid strong or weak?
B. Is the base strong or weak?
C. What is the net ionic equation for the reaction?

A. strong
B. strong
C. $H^{+}(aq) + OH^{-}(aq) \longrightarrow H_2O(l)$

Molecular equation

$$2\ HI(aq) + Ca(OH)_2(aq) \longrightarrow 2\ H_2O(l) + CaI_2(aq)$$

Complete ionic equation

$$2\ H^{+}(aq) + 2\ I^{-}(aq) + Ca^{2+}(aq) + 2\ OH^{-}(aq) \longrightarrow 2\ H_2O(l) + Ca^{2+}(aq) + 2\ I^{-}(aq)$$

Net ionic equation

$$H^{+}(aq) + OH^{-}(aq) \longrightarrow H_2O(l)$$

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sec03-q0016-01.tex
Keyword:acid-base reaction; net ionic equation; balancing equations
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16. A reaction between hydrobromic acid and potassium hydroxide occurs. What is the sum of the coefficients from the balanced net ionic equation?

3

Molecular equation

$$HBr(aq) + KOH(aq) \longrightarrow KBr(aq) + H_2O(l)$$

Complete ionic equation

$$H^+(aq) + Br^-(aq) + K^+(aq) + OH^-(aq) \longrightarrow K^+(aq) + Br^-(aq) + H_2O(l)$$

Net ionic equation

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

sec03-q0017-01.tex

Keyword:acid-base reaction; net ionic equation; balancing equations

17. Which is the spectator ion in the reaction between potassium carbonate and calcium iodide? Select all that apply.

A. $K^+(aq)$
B. $CO_3^{2-}(aq)$
C. $Ca^{2+}(aq)$
D. $I^-(aq)$

A, D

Molecular equation

$$K_2CO_3(aq) + CaI_2(aq) \longrightarrow 2\,KI(aq) + CaCO_3(s)$$

Complete ionic equation

$$2\,K^+(aq) + CO_3^{2-}(aq) + Ca^{2+}(aq) + 2\,I^-(aq) \longrightarrow 2\,K^+(aq) + 2\,I^-(aq) + +CaCO_3(s)$$

Net ionic equation

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CaCO_3(s)$$

sec03-q0018-01.tex

Keyword:solubility rules; precipitation; net ionic equation; balancing equations

18. What is the sum of the coefficients of the net ionic equation for aqueous sodium hydroxide neutralized by aqueous acetic acid?

4

Molecular equation

$$CH_3COOH(aq) + NaOH(aq) \longrightarrow NaCH_3COO(aq) + H_2O(l)$$

Complete ionic equation

$$CH_3COOH(aq) + Na^+(aq) + OH^-(aq) \longrightarrow Na^+(aq) + CH_3COO^-(aq) + H_2O(l)$$

Net ionic equation

$$CH_3COOH(aq) + OH^-(aq) \longrightarrow CH_3COO^-(aq) + H_2O(l)$$

sec03-q0019-01.tex

Keyword:acid-base reaction; net ionic equation; balancing equations

19. Balance each reaction complete with phase labels.

A. $FeSO_4(aq) + KCl(aq)$

B. $Al(NO_3)_3(aq) + Ba(OH)_2(aq)$

C. $CaCl_2(aq) + Na_2SO_4(aq)$

D. $K_2S(aq) + Ni(NO_3)_2(aq)$

E. $Hg_2(NO_3)_2(aq) + CuSO_4(aq)$

F. $Ni(NO_3)_2(aq) + CaCl_2(aq)$

G. $K_2CO_3(aq) + MgI_2(aq)$

H. $Na_2CrO_4(aq) + AlBr_3(aq)$

A. $FeSO_4(aq) + 2\ KCl(aq) \longrightarrow FeCl_2(aq) + K_2SO_4(aq)$ – no precipitate
B. $2\ Al(NO_3)_3(aq) + 3\ Ba(OH)_2(aq) \longrightarrow 2\ Al(OH)_3(s) + 3\ Ba(NO_3)_2(aq)$
C. $CaCl_2(aq) + Na_2SO_4(aq) \longrightarrow CaSO_4(s) + 2\ NaCl(aq)$
D. $K_2S(aq) + Ni(NO_3)_2(aq) \longrightarrow 2\ KNO_3(aq) + NiS(s)$
E. $Hg_2(NO_3)_2(aq) + CuSO_4(aq) \longrightarrow Hg_2SO_4(s) + Cu(NO_3)_2(aq)$
F. $Ni(NO_3)_2(aq) + CaCl_2(aq) \longrightarrow NiCl_2(aq) + Ca(NO_3)_2(aq)$ – no precipitate
G. $K_2CO_3(aq) + MgI_2(aq) \longrightarrow 2\ KI(aq) + MgCO_3(s)$
H. $6\ Na_2CrO_4(aq) + 2\ AlBr_3(aq) \longrightarrow 2\ NaBr(aq) + Al_2(CrO_4)_3(s)$

sec03-q0020-01.tex

Keyword:solubility rules; double-displacement reaction; balancing equations

20. Which of the following substances are soluble in water? Select all that apply.

    A. aluminum nitrate
    B. magnesium chloride
    C. rubidium sulfate
    D. nickel(II) hydroxide
    E. lead(II) sulfide
    F. barium hydroxide
    G. iron(III) phosphate

    A, B, C, F

    `sec03-q0021-01.tex`
    `Keyword:solubility rules`

21. Write the net ionic equations for the following reactions:

    A. ammonium sulfate and barium nitrate
    B. lead(II) nitrate and sodium chloride
    C. sodium phosphate and potassium nitrate
    D. sodium bromide and rubidium chloride
    E. copper(II) chloride and sodium hydroxide

    A. $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$
    B. $Pb^{2+}(aq) + 2\,Cl^{-}(aq) \longrightarrow PbCl_2(s)$
    C. none (all ions are spectators)
    D. none (all ions are spectators)
    E. $Cu^{2+}(aq) + 2\,NaOH(aq) \longrightarrow Cu(OH)_2(s)$

    `sec03-q0022-01.tex`
    `Keyword:net ionic equation; balancing equations; solubility rules`

22. Write the balanced molecular equation, complete ionic equation, and net ionic equation for the following acid-base reactions.

A. $HClO_4(aq) + Mg(OH)_2(s)$
B. $HCN(aq) + NaOH(aq)$
C. $HCl(aq) + NaOH(aq)$

A:

Molecular equation

$$2\,HClO_4(aq) + Mg(OH)_2(s) \longrightarrow 2\,H_2O(l) + Mg(ClO_4)_2(aq)$$

Complete ionic equation

$$2\,H^+(aq) + 2\,ClO_4^-(aq) + Mg(OH)_2(s) \longrightarrow 2\,H_2O(l) + Mg^{2+}(aq) + 2\,ClO_4^-(aq)$$

Net ionic equation

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

B:

Molecular equation

$$HCN(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaCN(aq)$$

Complete ionic equation

$$H^+(aq) + CN^-(aq) + Na^+(aq) + OH^-(aq) \longrightarrow H_2O(l) + Na^+(aq) + CN^-(aq)$$

Net ionic equation

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

C:

Molecular equation

$$HCl(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaCl(aq)$$

Complete ionic equation

$$H^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \longrightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)$$

Net ionic equation

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

`sec03-q0023-01.tex`
`Keyword:acid-base reaction; net ionic equation`

23. Write a balanced chemical equation between an acid and a base that would have the following salt appear as a product.

    A. potassium perchlorate
    B. cesium nitrate
    C. calcium iodide

A:

$$HClO_4(aq) + KOH(aq) \longrightarrow H_2O(l) + KClO_4(aq)$$

B:

$$HNO_3(aq) + CsOH(aq) \longrightarrow H_2O(l) + CsNO_3(aq)$$

C:

$$2\ HI(aq) + Ca(OH)_2(aq) \longrightarrow 2\ H_2O(l) + CaI_2(aq)$$

`sec03-q0024-01.tex`

`Keyword:acid-base reaction; salts`

Exam 2 Review: Oxidation-Reduction

1. Assign oxidation states for all atoms in each of the following compounds.

   A. $KMnO_4$
   B. NiO_2
   C. $Na_4Fe(OH)_6$
   D. $(NH_4)_2HPO_4$
   E. P_4O_6

A:

K	Mn	O_4
+1	+7	−2
+1	+7	−8

B:

Ni	O_2
+4	−2
+4	−4

C:

Na_4	Fe	(O	H $)_6$
+1	+2	−2	+1
+4	+2	−12	+6

D:

(N	H_4 $)_2$	H	P	O_4
−3	+1	+1	+5	−2
−3	+4	+1	+5	−8

E:

P_4	O_6
+3	−2
+12	−12

sec03-q0025-01.tex
Keyword:oxidation state

2. Assign oxidation states for all atoms in each of the following compounds.

   A. Fe_3O_4
   B. $XeOF_4$
   C. SF_4
   D. CO
   E. $C_6H_{12}O_6$

A:

Fe_3	O_4
+2/+3	−2
+8	−8

B:

Xe	O	F_4
+6	−2	−1
+6	−2	−4

C:

S	F_4
+4	−1
+4	−4

D:

C	O
+2	−2
+2	−2

E:

C_6	H_{12}	O_6
0	+1	−2
0	+12	−12

sec03-q0026-01.tex
Keyword:oxidation state

3. Specify which reactions are redox reactions and identify the oxidizing agent, reducing agent, the substance being oxidized, and the substance being reduced.

   A. $Cu(s) + 2\,Ag^{+}(aq) \longrightarrow 2\,Ag(s) + Cu^{2+}(aq)$
   B. $HCl(g) + NH_3(g) \longrightarrow NH_4Cl(s)$
   C. $SiCl_4(l) + 2\,H_2O(l) \longrightarrow 4\,HCl(aq) + SiO_2(s)$
   D. $SiCl_4(l) + 2\,Mg(s) \longrightarrow 2\,MgCl_2(s) + Si(s)$
   E. $Al(OH)_4^{-}(aq) \longrightarrow AlO_2^{-}(aq) + 2\,H_2O(l)$

A:

$$\underset{\substack{0\\0}}{\mathrm{Cu}}\,(s) + 2\,\underset{\substack{+1\\+1}}{\mathrm{Ag}^{+}}\,(aq) \longrightarrow 2\,\underset{\substack{0\\0}}{\mathrm{Ag}}\,(s) + \underset{\substack{+2\\+2}}{\mathrm{Cu}^{2+}}\,(aq)$$

Oxidizing agent: Ag^{+}(aq); Reducing agent: Cu(s)
Substance oxidized: Cu(s); Substance reduced: Ag^{+}(aq)

B:

$$\underset{\substack{+1\\+1}}{\mathrm{H}}\;\underset{\substack{-1\\-1}}{\mathrm{Cl}}\,(g) + \underset{\substack{-3\\-3}}{\mathrm{N}}\;\underset{\substack{+1\\+3}}{\mathrm{H_3}}\,(g) \longrightarrow \underset{\substack{-3\\-3}}{\mathrm{N}}\;\underset{\substack{+1\\+4}}{\mathrm{H_4}}\;\underset{\substack{-1\\-1}}{\mathrm{Cl}}\,(s)$$

Not a redox reaction.

C:

$$\underset{\substack{+4\\+4}}{\mathrm{Si}}\;\underset{\substack{-1\\-4}}{\mathrm{Cl_4}}\,(l) + 2\,\underset{\substack{+1\\+2}}{\mathrm{H_2}}\;\underset{\substack{-2\\-2}}{\mathrm{O}}\,(l) \longrightarrow 4\,\underset{\substack{+1\\+1}}{\mathrm{H}}\;\underset{\substack{-1\\-1}}{\mathrm{Cl}}\,(aq) + \underset{\substack{+4\\+4}}{\mathrm{Si}}\;\underset{\substack{-2\\-4}}{\mathrm{O_2}}\,(s)$$

Not a redox reaction.

D:

$$\underset{\substack{+4\\+4}}{\mathrm{Si}}\;\underset{\substack{-1\\-4}}{\mathrm{Cl_4}}\,(l) + 2\,\underset{\substack{0\\0}}{\mathrm{Mg}}\,(s) \longrightarrow 2\,\underset{\substack{+2\\+2}}{\mathrm{Mg}}\;\underset{\substack{-1\\-2}}{\mathrm{Cl_2}}\,(s) + \underset{\substack{0\\0}}{\mathrm{Si}}\,(s)$$

Oxidizing agent: $SiCl_4$(l); Reducing agent: Mg(s)
Substance oxidized: Mg(s); Substance reduced: $SiCl_4$(l)

E:

$$\underset{\substack{+3\\+3}}{\mathrm{Al}}\,(\underset{\substack{-2\\-8}}{\mathrm{O}}\;\underset{\substack{+1\\+4}}{\mathrm{H}})_4^{-}\,(aq) \longrightarrow 2\,\underset{\substack{+3\\+3}}{\mathrm{Al}}\;\underset{\substack{-2\\-4}}{\mathrm{O_2}}{}^{-}\,(aq) + 2\,\underset{\substack{+1\\+2}}{\mathrm{H_2}}\;\underset{\substack{-2\\-2}}{\mathrm{O}}\,(l)$$

Not a redox reaction.

`sec03-q0027-01.tex`
`Keyword:oxidation state`

4. Determine the half-reactions, the amount (in mol) of electrons transferred, and the overall balanced reaction (with phase labels) for the following redox reaction.

$$Fe(s) + Br_2(l) \longrightarrow FeBr_3(s)$$

$$\underset{\substack{0\\0}}{Fe}\ (s)\ +\ \underset{\substack{0\\0}}{Br_2}\ (l) \longrightarrow \underset{\substack{+3\\+3}}{Fe}\ \underset{\substack{-1\\-3}}{Br_3}\ (s)$$

Fe undergoes oxidation and Br_2 undergoes reduction.

Ox. half-reaction $\quad Fe \longrightarrow Fe^{3+} + 3\,e^-$

Red. half-reaction $\quad Br_2 + 2\,e^- \longrightarrow 3\,Br^-$

balance e^- $\quad 2\,(Fe \longrightarrow Fe^{3+} + 3\,e^-)$

$3\,(Br_2 + 2\,e^- \longrightarrow 3\,Br^-)$

6 mol e^- $\quad 2\,Fe \longrightarrow 2\,Fe^{3+} + 6\,e^-$

$3\,Br_2 + 6\,e^- \longrightarrow 6\,Br^-$

combine $\quad 2\,Fe + 3\,Br_2 \longrightarrow 2\,Fe^{3+} + 6\,Br^-$

Balanced reaction $\quad 2\,Fe(s) + 3\,Br_2(l) \longrightarrow 2\,FeBr_3(s)$

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sec03-q0028-01.tex
Keyword:oxidation state; oxidation-reduction reaction; balancing equations
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5. Determine the half-reactions, the amount (in mol) of electrons transferred, and the overall balanced reaction (with phase labels) for the following redox reaction.

$$Mn(s) + F_2(g) \longrightarrow MnF_4(s)$$

$$\underset{\substack{0\\0}}{Mn}\ (s)\ +\ \underset{\substack{0\\0}}{F_2}\ (g) \longrightarrow \underset{\substack{+4\\+4}}{Mn}\ \underset{\substack{-1\\-1}}{F_4}\ (s)$$

Mn undergoes oxidation and F_2 undergoes reduction.

Ox. half-reaction $\quad Mn \longrightarrow Mn^{4+} + 4\,e^-$

Red. half-reaction $\quad F_2 + 2\,e^- \longrightarrow 2\,F^-$

balance e^- $\quad Mn \longrightarrow Mn^{4+} + 4\,e^-$

$2\,(F_2 + 2\,e^- \longrightarrow 2\,F^-)$

4 mol e^- $\quad Mn \longrightarrow Mn^{4+} + 4\,e^-$

$2\,F_2 + 4\,e^- \longrightarrow 4\,F^-$

combine $\quad Mn + 2\,F_2 \longrightarrow Mn^{4+} + 4\,F^-$

Balanced reaction $\quad Mn(s) + 2\,F_2(g) \longrightarrow MnF_4(s)$

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sec03-q0029-01.tex
Keyword:oxidation state; oxidation-reduction reaction; balancing equations
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6. Determine the half-reactions, the amount (in mol) of electrons transferred, and the overall balanced reaction (with phase labels) for the following redox reaction.

$$Na(s) + I_2(g) \longrightarrow NaI(s)$$

$$\underset{\underset{0}{0}}{Na}\ (s) + \underset{\underset{0}{0}}{I_2}\ (g) \longrightarrow \underset{\underset{+4}{+4}}{Na}\ \underset{\underset{-1}{-1}}{I_2}\ (s)$$

Na undergoes oxidation and I_2 undergoes reduction.

$$\begin{aligned}
\text{Ox. half-reaction} \quad & Na \longrightarrow Na^{+} + e^{-} \\
\text{Red. half-reaction} \quad & I_2 + 2\,e^{-} \longrightarrow 2\,I^{-} \\
\textit{balance } e^{-} \quad & 2\,(Na \longrightarrow Na^{+} + e^{-}) \\
& I_2 + 2\,e^{-} \longrightarrow 2\,I^{-} \\
\textit{2 mol } e^{-} \quad & 2\,Na \longrightarrow 2\,Na^{+} + 2\,e^{-} \\
& I_2 + 2\,e^{-} \longrightarrow 2\,I^{-} \\
\textit{combine} \quad & 2\,Na + I_2 \longrightarrow 2\,Na^{+} + 2\,I^{-} \\
\text{Balanced reaction} \quad & 2\,Na(s) + I_2(g) \longrightarrow 2\,NaI(s)
\end{aligned}$$

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`Keyword:oxidation state; oxidation-reduction reaction; balancing equations`

7. Determine the half-reactions, the amount (in mol) of electrons transferred, and the overall balanced reaction (with phase labels) for the following redox reaction.

$$Mg(s) + Cl_2(g) \longrightarrow MgCl_2(s)$$

$$\underset{\underset{0}{0}}{Mg}\ (s) + \underset{\underset{0}{0}}{Cl_2}\ (g) \longrightarrow \underset{\underset{+2}{+2}}{Mg}\ \underset{\underset{-1}{-1}}{Cl_2}\ (s)$$

Mg undergoes oxidation and Cl_2 undergoes reduction.

$$\begin{aligned}
\text{Ox. half-reaction} \quad & Mg \longrightarrow Mg^{+} + 2\,e^{-} \\
\text{Red. half-reaction} \quad & Cl_2 + 2\,e^{-} \longrightarrow 2\,Cl^{-} \\
\textit{balance } e^{-} \quad & Mg \longrightarrow Mg^{+} + 2\,e^{-} \\
& Cl_2 + 2\,e^{-} \longrightarrow 2\,Cl^{-} \\
\textit{2 mol } e^{-} \quad & Mg \longrightarrow Mg^{+} + 2\,e^{-} \\
& Cl_2 + 2\,e^{-} \longrightarrow 2\,Cl^{-} \\
\textit{combine} \quad & Mg + Cl_2 \longrightarrow Mg^{+} + 2\,Cl^{-} \\
\text{Balanced reaction} \quad & Mg(s) + Cl_2(g) \longrightarrow MgCl_2(s)
\end{aligned}$$

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`Keyword:oxidation state; oxidation-reduction reaction; balancing equations`

8. Determine the half-reactions, the amount (in mol) of electrons transferred, and the overall balanced reaction (with phase labels) for the following redox reaction.

$$Fe(s) + O_2(g) \longrightarrow Fe_2O_3(s)$$

$$\underset{\substack{0\\0}}{Fe}\ (s) + \underset{\substack{0\\0}}{O_2}\ (g) \longrightarrow \underset{\substack{+3\\+6}}{Fe_2}\ \underset{\substack{-2\\-6}}{O_3}\ (s)$$

Fe undergoes oxidation and O_2 undergoes reduction.

Ox. half-reaction	$2\ Fe \longrightarrow 2\ Fe^{3+} + 6\ e^-$
Red. half-reaction	$O_2 + 4\ e^- \longrightarrow 2\ O^{2-}$
balance e^-	$2(2\ Fe \longrightarrow 2\ Fe^{3+} + 6\ e^-)$
	$3(O_2 + 4\ e^- \longrightarrow 2\ O^{2-})$
12 mol e^-	$4\ Fe \longrightarrow 4\ Fe^{3+} + 12\ e^-$
	$3\ O_2 + 12\ e^- \longrightarrow 6\ O^{2-}$
combine	$4\ Fe + 3\ O_2 \longrightarrow 4\ Fe^{3+} + 6\ O^{2-}$
Balanced reaction	$4\ Fe(s) + 3\ O_2(g) \longrightarrow 2\ Fe_2O_3(s)$

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`Keyword:oxidation state; oxidation-reduction reaction; balancing equations`

9. Determine the half-reactions, the amount (in mol) of electrons transferred, and the overall balanced reaction (with phase labels) for the following redox reaction.

$$Cr^{3+}(aq) + Mn^{2+}(aq) \longrightarrow Mn^{6+}(aq) + Cr(s)$$

$$\underset{+3}{\underset{+3}{Cr^{3+}}}\ (aq)\ +\ \underset{+2}{\underset{+2}{Mn^{2+}}}\ (aq) \longrightarrow \underset{+6}{\underset{+6}{Mn^{6+}}}\ (aq)\ \underset{0}{\underset{0}{Cr}}\ (s)$$

Mn^{2+} undergoes oxidation and Cr^{3+} undergoes reduction.

Ox. half-reaction $\quad Mn^{2+} \longrightarrow Mn^{6+} + 4\,e^-$

Red. half-reaction $\quad Cr^{3+} + 3\,e^- \longrightarrow Cr$

balance e⁻ $\quad 3(Mn^{2+} \longrightarrow Mn^{6+} + 4\,e^-)$

$4(Cr^{3+} + 3\,e^- \longrightarrow Cr)$

12 mol e⁻ $\quad 3\,Mn^{2+} \longrightarrow 3\,Mn^{6+} + 12\,e^-$

$4\,Cr^{3+} + 12\,e^- \longrightarrow 4\,Cr$

combine $\quad 4\,Cr^{3+} + 3\,Mn^{2+} \longrightarrow 3\,Mn^{6+} + 4\,Cr$

Balanced reaction $\quad 4\,Cr^{3+}(aq) + 3\,Mn^{2+}(aq) \longrightarrow 3\,Mn^{6+}(aq) + 4\,Cr(s)$

`sec03-q0033-01.tex`

`Keyword:oxidation state; oxidation-reduction reaction; balancing equations`

Exam 2 Review: Stoichiometry and Molarity

1. Balance the following equation.

$$\_\_\_\_\ Ag_2O(s) \longrightarrow \_\_\_\_\ Ag(s) + \_\_\_\_\ O_2(g)$$

Additionally, consider a 4.260×10^3 mg sample of impure silver oxide that, when completely decomposes, yields 283 mg of $O_2(g)$. Assuming that the silver oxide is the only source of oxygen, what is the mass percent of silver oxide in the sample?

A: 96.2 %

$$2\ Ag_2O(s) \longrightarrow 4\ Ag(s) + O_2(g)$$

$$\begin{aligned}
w(Ag_2O)\% &= w(Ag_2O) \times 100\ \% \\
&= \left\{ m(Ag_2O)\ m(\text{sample})^{-1} \right\} \times 100\ \% \\
&= \left\{ n(Ag_2O)\ M(Ag_2O)\ m(\text{sample})^{-1} \right\} \times 100\ \% \\
&= \left\{ n(O_2)\ r(Ag_2O, O_2)\ M(Ag_2O)\ m(\text{sample})^{-1} \right\} \times 100\ \% \\
&= \left\{ m(O_2)\ M(O_2)^{-1}\ r(Ag_2O, O_2)\ M(Ag_2O)\ m(\text{sample})^{-1} \right\} \times 100\ \% \\
&= \left\{ 283\ \text{mg}\ O_2 \left(\frac{\text{g}}{10^3\ \text{mg}} \right) \left(\frac{\text{mol}\ O_2}{32.00\ \text{g}\ O_2} \right) \left(\frac{2\ \text{mol}\ Ag_2O}{\text{mol}\ O_2} \right) \left(\frac{231.74\ \text{g}}{\text{mol}\ Ag_2O} \right) \right. \\
&\qquad \left. \left[4.260 \times 10^3\ \text{mg sample} \left(\frac{\text{g}}{10^3\ \text{mg}} \right) \right]^{-1} \right\} \times 100\ \% \\
&= \left(\frac{4.0\bar{9}89\ \text{g}\ Ag_2O}{4.260\ \text{g sample}} \right) \times 100\ \% \\
&= 96.\bar{2}18\ \% = 96.2\ \%
\end{aligned}$$

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Keyword:balancing equations; stoichiometry; percent composition by mass

2. Balance the following equation.

$$\_\_\_\_\ NH_3 + \_\_\_\_\ Cl_2 \longrightarrow \_\_\_\_\ NCl_3 + \_\_\_\_\ HCl$$

Additionally, what mass (in g) of HCl is produced if 1.27 g of NH_3 reacts with 4.53 g of Cl_2?

A: 2.33 g

$$NH_3 + 3\ Cl_2 \longrightarrow NCl_3 + 3\ HCl$$

$$\begin{aligned} m(\mathrm{HCl}) &= n(\mathrm{HCl})\ M(\mathrm{HCl}) \\ &= m(\mathrm{NH_3})\ M(\mathrm{NH_3})^{-1}\ r(\mathrm{HCl}, \mathrm{NH_3})\ M(\mathrm{HCl}) \\ &= 1.27\ \mathrm{g\ NH_3} \left(\frac{\mathrm{mol\ NH_3}}{17.04\ \mathrm{g}}\right) \left(\frac{3\ \mathrm{mol\ HCl}}{\mathrm{mol\ NH_3}}\right) \left(\frac{36.46\ \mathrm{g}}{\mathrm{mol\ HCl}}\right) \\ &= 8.1\bar{5}21\ \mathrm{g} = 8.15\ \mathrm{g} \end{aligned}$$

$$\begin{aligned} m(\mathrm{HCl}) &= n(\mathrm{HCl})\ M(\mathrm{HCl}) \\ &= m(\mathrm{Cl_2})\ M(\mathrm{Cl_2})^{-1}\ r(\mathrm{HCl}, \mathrm{Cl_2})\ M(\mathrm{HCl}) \\ &= 4.53\ \mathrm{g\ Cl_2} \left(\frac{\mathrm{mol\ Cl_2}}{70.90\ \mathrm{g}}\right) \left(\frac{3\ \mathrm{mol\ HCl}}{3\ \mathrm{mol\ Cl_2}}\right) \left(\frac{36.46\ \mathrm{g}}{\mathrm{mol\ HCl}}\right) \\ &= 2.3\bar{2}95\ \mathrm{g} = 2.33\ \mathrm{g} \end{aligned}$$

Cl_2 is the limiting reactant. 2.33 g of HCl is produced.

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Keyword:balancing equations; stoichiometry; limiting reactant
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3. Balance the following equation.

$$\_\_\_\_ \; C_3H_6 + \_\_\_\_ \; NH_3 + \_\_\_\_ \; O_2 \longrightarrow \_\_\_\_ \; C_3NH_3 + \_\_\_\_ \; H_2O$$

Additionally, determine the following:

A. What is the limiting reactant if 4.25 g of C_3H_6 reacts with 3.14 g of NH_3 and 6.12 g of O_2?
B. What mass (in g) of C_3NH_3 can theoretically be produced given the information in A?
C. What mass (in g) of C_3NH_3, NH_3, and O_2 would theoretically be leftover given the information in A?
D. If 1.94 g of C_3NH_3 was produced in an experiment, what is the percent yield?

A: C_3H_6; 5.36 g; 0 g, 1.42 g, and 1.27 g; 36.2 %

$$2\,C_3H_6 + 2\,NH_3 + 3\,O_2 \longrightarrow 2\,C_3NH_3 + 6\,H_2O$$

A. C_3H_6 is limiting.

$$\begin{aligned} n(C_3NH_3) &= n(C_3H_6)\; r(C_3NH_3, C_3H_6) \\ &= m(C_3H_6)\; M(C_3H_6)^{-1}\; r(C_3NH_3, C_3H_6) \\ &= 4.25 \text{ g } C_3H_6 \left(\frac{\text{mol } C_3H_6}{42.09 \text{ g}}\right)\left(\frac{2 \text{ mol } C_3NH_3}{2 \text{ mol } C_3H_6}\right) \\ &= 0.10\bar{0}97 \text{ mol} \longrightarrow m(C_3NH_3) = 0.10\bar{0}97 \text{ mol}\left(\frac{53.06 \text{ g}}{\text{mol } C_3NH_3}\right) = 5.3\bar{5}76 \text{ g} = 5.36 \text{ g} \end{aligned}$$

$$\begin{aligned} n(C_3NH_3) &= n(NH_3)\; r(C_3NH_3, NH_3) \\ &= m(NH_3)\; M(NH_3)^{-1}\; r(C_3NH_3, NH_3) \\ &= 3.14 \text{ g } NH_3 \left(\frac{\text{mol } NH_3}{17.04 \text{ g}}\right)\left(\frac{2 \text{ mol } C_3NH_3}{2 \text{ mol } NH_3}\right) \\ &= 0.18\bar{4}27 \text{ mol} \end{aligned}$$

$$\begin{aligned} n(C_3NH_3) &= m(O_2)\; r(C_3NH_3, O_2) \\ &= m(O_2)\; M(O_2)^{-1}\; r(C_3NH_3, O_2) \\ &= 6.12 \text{ g } O_2 \left(\frac{\text{mol } O_2}{32.00 \text{ g}}\right)\left(\frac{2 \text{ mol } C_3NH_3}{3 \text{ mol } O_2}\right) \\ &= 0.12\bar{7}50 \text{ mol} \end{aligned}$$

B. 5.36 g of C_3NH_3 can be produced (see work in **A**).

C.

$$\begin{aligned} m(C_3H_6)_{\text{leftover}} &= m(C_3H_6)_{\text{initial}} - m(C_3H_6)_{\text{reacted}} \\ &= m(C_3H_6)_{\text{initial}} - [n(C_3NH_3)\; r(C_3H_6, C_3NH_3)\; M(C_3H_6)] \\ &= 4.25 \text{ g } C_3H_6 - \left[0.10\bar{0}97 \text{ mol } C_3NH_3 \left(\frac{2 \text{ mol } NH_3}{2 \text{ mol } C_3NH_3}\right)\left(\frac{42.09 \text{ g}}{\text{mol } C_3H_6}\right)\right] \\ &= 4.25 \text{ g} - 4.2\bar{4}98 \text{ g} = 0 \text{ g} \end{aligned}$$

$$\begin{aligned} m(NH_3)_{\text{leftover}} &= m(NH_3)_{\text{initial}} - m(NH_3)_{\text{reacted}} \\ &= m(NH_3)_{\text{initial}} - [n(C_3NH_3)\; r(NH_3, C_3NH_3)\; M(NH_3)] \\ &= 3.14 \text{ g } NH_3 - \left[0.10\bar{0}97 \text{ mol } C_3NH_3 \left(\frac{2 \text{ mol } NH_3}{2 \text{ mol } C_3NH_3}\right)\left(\frac{17.04 \text{ g}}{\text{mol } NH_3}\right)\right] \\ &= 3.14 \text{ g} - 1.7\bar{2}05 \text{ g} = 1.4\bar{1}94 \text{ g} = 1.42 \text{ g} \end{aligned}$$

$$\begin{aligned} m(O_2)_{\text{leftover}} &= m(O_2)_{\text{initial}} - m(O_2)_{\text{reacted}} \\ &= m(O_2)_{\text{initial}} - [n(C_3NH_3)\; r(O_2, C_3NH_3)\; M(O_2)] \\ &= 6.12 \text{ g } O_2 - \left[0.10\bar{0}97 \text{ mol } C_3NH_3 \left(\frac{3 \text{ mol } O_2}{2 \text{ mol } C_3NH_3}\right)\left(\frac{32.00 \text{ g}}{\text{mol } O_2}\right)\right] \\ &= 6.12 \text{ g} - 4.8\bar{4}65 \text{ g} = 1.2\bar{7}34 \text{ g} = 1.27 \text{ g} \end{aligned}$$

D.

$$\% \text{ yield} = \left(\frac{m(\text{actual})}{m(\text{theoretical})}\right) 100\ \% = \left(\frac{1.94 \text{ g}}{5.3\bar{5}86 \text{ g}}\right) 100\ \% = 36.\bar{2}03\ \% = 36.2\ \%$$

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`Keyword:balancing equations; limiting reactant; percent yield; stoichiometry`

4. Balance the following reaction.

$$\_\_\_\_\ C_6H_5NO_2 + \_\_\_\_\ C_6H_{14}O_4 \xrightarrow[KOH]{Zn} \_\_\_\_\ (C_6H_5N)_2 + \_\_\_\_\ C_6H_{12}O_4 + \_\_\_\_\ H_2O$$

Additionally, determine the following:

A. What volume (in mL) of $C_6H_5NO_2$ ($\rho = 1.20\ \text{g mL}^{-1}$) must be allowed to react with an excess of $C_6H_{14}O_4$ to produce 6.21 g of $(C_6H_5N)_2$ if the percent yield is 83.7 %?

B. If 0.17 L of $C_6H_5NO_2$ ($\rho = 1.20\ \text{g mL}^{-1}$) and 0.52 L $C_6H_{14}O_4$ ($\rho = 1.12\ \text{g mL}^{-1}$) react to yield 64.4 g of $(C_6H_5N)_2$, what is the limiting reactant and what is the percent yield of the reaction?

A: 8.35 mL; $C_6H_5NO_2$; 43 %

$$2\ C_6H_5NO_2 + 4\ C_6H_{14}O_4 \xrightarrow[KOH]{Zn} (C_6H_5N)_2 + 4\ C_6H_{12}O_4 + 4\ H_2O$$

A.

$$\begin{aligned}
V(C_6H_5NO_2) &= m(C_6H_5NO_2)\ \rho(C_6H_5NO_2)^{-1} \\
&= m[(C_6H_5N)_2]\ M[(C_6H_5N)_2]^{-1}\ r[C_6H_5NO_2, (C_6H_5N)_2]\ M(C_6H_5NO_2)\ \rho(C_6H_5NO_2)^{-1} \\
&= 7.42\ \text{g}\ (C_6H_5N)_2 \left(\frac{\text{mol}\ (C_6H_5N)_2}{182.24\ \text{g}}\right)\left(\frac{2\ \text{mol}\ C_6H_5NO_2}{\text{mol}\ (C_6H_5N)_2}\right)\left(\frac{123.12\ \text{g}}{\text{mol}\ C_6H_5NO_2}\right) \\
&\quad \left(\frac{\text{mL}}{1.20\ \text{g}\ C_6H_5NO_2}\right) \\
&= 8.3\bar{5}48\ \text{mL} \\
&= 8.35\ \text{mL}
\end{aligned}$$

B.

$$\begin{aligned}
m[(C_6H_5N)_2] &= n[(C_6H_5N)_2]\ M[(C_6H_5N)_2] \\
&= V(C_6H_5NO_2)\ \rho(C_6H_5NO_2)\ M(C_6H_5NO_2)^{-1}\ r[(C_6H_5N)_2, C_6H_5NO)_2]\ M[(C_6H_5N)_2] \\
&= 0.17\ \text{L}\ C_6H_5NO_2 \left(\frac{10^3\ \text{mL}}{\text{L}}\right)\left(\frac{1.20\ \text{g}\ C_6H_5NO_2}{\text{mL}}\right)\left(\frac{\text{mol}\ C_6H_5NO_2}{123.12\ \text{g}}\right) \\
&\quad \left(\frac{\text{mol}\ (C_6H_5N)_2}{2\ \text{mol}\ C_6H_5NO_2}\right)\left(\frac{182.24\ \text{g}}{\text{mol}\ (C_6H_5N)_2}\right) \\
&= 1\bar{5}0.9\ \text{g} = 150\ \text{g}
\end{aligned}$$

$$\begin{aligned}
m[(C_6H_5N)_2] &= n[(C_6H_5N)_2]\ M[(C_6H_5N)_2] \\
&= V(C_6H_{14}O_4)\ \rho(C_6H_{14}O_4)\ M(C_6H_{14}O_4)^{-1}\ r[(C_6H_5N)_2, C_6H_{14}O_4]\ M[(C_6H_5N)_2] \\
&= 0.52\ \text{L}\ C_6H_{14}O_4 \left(\frac{10^3\ \text{mL}}{\text{L}}\right)\left(\frac{1.12\ \text{g}\ C_6H_{14}O_4}{\text{mL}}\right)\left(\frac{\text{mol}\ C_6H_{14}O_4}{150.20\ \text{g}}\right) \\
&\quad \left(\frac{\text{mol}\ (C_6H_5N)_2}{4\ \text{mol}\ C_6H_{14}O_4}\right)\left(\frac{182.24\ \text{g}}{\text{mol}\ (C_6H_5N)_2}\right) \\
&= 1\bar{7}6.6\ \text{g} = 180\ \text{g}
\end{aligned}$$

$C_6H_5NO_2$ is the limiting reactant.

$$\%\ \text{yield} = \left(\frac{m[(C_6H_5N)_2]_{\text{actual}}}{m[(C_6H_5N)_2]_{\text{theoretical}}}\right) 100\ \% = \left(\frac{64.4\ \text{g}}{1\bar{5}0.9\ \text{g}}\right) 100\ \% = 4\bar{2}.67\ \% = 43\ \%$$

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Keyword:balancing equations; limiting reactant; percent yield; stoichiometry

5. Balance the following reaction.

$$\_\_\_\_ \text{ Fe} + \_\_\_\_ \text{ Br}_2 + \_\_\_\_ \text{ Na}_2\text{CO}_3 \longrightarrow \_\_\_\_ \text{ NaBr} + \_\_\_\_ \text{ CO}_2 + \_\_\_\_ \text{ Fe}_3\text{O}_4$$

Additionally, an alloy contains 84.2 % Fe and 15.8 % Ni (by mass). A 6.41 g sample of the alloy reacts with 8.30 g Na_2CO_3 with excess Br_2.

A. What mass (in g) of Fe_3O_4 can be produced?
B. What mass (in g) of Fe_3O_4 is produced if the percent yield of the reaction is 94.3 %?

A: 4.53 g; 4.27 g

$$3\text{ Fe} + 4\text{ Br}_2 + 4\text{ Na}_2\text{CO}_3 \longrightarrow 8\text{ NaBr} + 4\text{ CO}_2 + \text{Fe}_3\text{O}_4$$

A.

$$\begin{aligned}
m(\text{Fe}_3\text{O}_4) &= n(\text{Fe}_3\text{O}_4)\ M(\text{Fe}_3\text{O}_4) \\
&= n(\text{Fe})\ r(\text{Fe}_3\text{O}_4, \text{Fe})\ M(\text{Fe}_3\text{O}_4) \\
&= m(\text{sample})\ w(\text{sample})\ M(\text{Fe})^{-1}\ r(\text{Fe}_3\text{O}_4, \text{Fe})\ M(\text{Fe}_3\text{O}_4) \\
&= 6.41\text{ g sample}\left(\frac{84.2\text{ \% Fe}}{100\text{ \% sample}}\right)\left(\frac{\text{mol Fe}}{55.85\text{ g}}\right)\left(\frac{\text{mol Fe}_3\text{O}_4}{3\text{ mol Fe}}\right)\left(\frac{231.55\text{ g}}{\text{mol Fe}_3\text{O}_4}\right) \\
&= 7.4\bar{5}88\text{ g} = 7.46\text{ g}
\end{aligned}$$

$$\begin{aligned}
m(\text{Fe}_3\text{O}_4) &= n(\text{Fe}_3\text{O}_4)\ M(\text{Fe}_3\text{O}_4) \\
&= n(\text{Na}_2\text{CO}_3)\ r(\text{Fe}_3\text{O}_4, \text{Na}_2\text{CO}_3)\ M(\text{Fe}_3\text{O}_4) \\
&= m(\text{Na}_2\text{CO}_3)\ M(\text{Na}_2\text{CO}_3)^{-1}\ r(\text{Fe}_3\text{O}_4, \text{Na}_2\text{CO}_3)\ M(\text{Fe}_3\text{O}_4) \\
&= 8.30\text{ g Na}_2\text{CO}_3\left(\frac{\text{mol Na}_2\text{CO}_3}{105.99\text{ g}}\right)\left(\frac{\text{mol Fe}_3\text{O}_4}{4\text{ mol Fe}}\right)\left(\frac{231.55\text{ g}}{\text{mol Fe}_3\text{O}_4}\right) \\
&= 4.5\bar{3}31\text{ g} = 4.53\text{ g}
\end{aligned}$$

Na_2CO_3 is the limiting reactant. 4.53 g of Fe_3O_4 can be produced.

B.

$$\begin{aligned}
\text{\% yield} &= \left(\frac{m(\text{Fe}_3\text{O}_4)_{\text{actual}}}{m(\text{Fe}_3\text{O}_4)_{\text{theoretical}}}\right) 100\text{ \%} \longrightarrow \\
m(\text{Fe}_3\text{O}_4)_{\text{actual}} &= \left(\frac{\text{\% yield}}{100\text{ \%}}\right) m(\text{Fe}_3\text{O}_4)_{\text{theoretical}} \\
&= \left(\frac{94.3\text{ \%}}{100\text{ \%}}\right) 4.5\bar{3}31\text{ g} \\
&= 4.2\bar{7}47\text{ g} = 4.27\text{ g}
\end{aligned}$$

sec04-q0005-01.tex

Keyword:balancing equations; limiting reactant; percent yield; stoichiometry

6. A mixture contained no fluorine compound except methyl fluoroacetate, FCH_2COOCH_3 ($M(FCH_2COOCH_3)$ = 92.08 g mol^{-1}). When chemically treated, all the fluorine was converted to CaF_2 ($M(CaF_2)$ = 78.08 g mol^{-1}). The mass of CaF_2 obtained was 20.1 g. Find the mass (in g) of methyl fluoroacetate in the original mixture.

A: 47.4 g

$$\begin{aligned} m(\mathrm{FCH_2COOCH_3}) &= n(\mathrm{FCH_2COOCH_3})\ M(\mathrm{FCH_2COOCH_3}) \\ &= m(\mathrm{CaF_2})\ M(\mathrm{CaF_2})^{-1}\ r(\mathrm{F^-}, \mathrm{CaF_2})\ r(\mathrm{FCH_2COOCH_3}, \mathrm{F^-})\ M(\mathrm{FCH_2COOCH_3}) \\ &= 20.1\ \mathrm{g\ CaF_2} \left(\frac{\mathrm{mol\ CaF_2}}{78.08\ \mathrm{g}}\right) \left(\frac{2\ \mathrm{mol\ F^-}}{\mathrm{mol\ CaF_2}}\right) \left(\frac{\mathrm{mol\ FCH_2COOCH_3}}{\mathrm{mol\ F^-}}\right) \\ &\quad \left(\frac{92.08\ \mathrm{g}}{\mathrm{mol\ FCH_2COOCH_3}}\right) \\ &= 47.\bar{4}07\ \mathrm{g} = 47.4\ \mathrm{g} \end{aligned}$$

sec04-q0013-01.tex
Keyword:stoichiometry

7. A 1.62 g sample of a metal chloride, MCl_2, is dissolved in water and treated with excess aqueous silver nitrate. The silver chloride that formed weighed 3.46 g. Calculate the molar mass (in g mol^{-1}) of the metal, M, and identify the metal.

A: 63.3 g mol^{-1}; Cu

$$\mathrm{MCl_2(aq) + 2\ AgNO_3(aq) \longrightarrow 2\ AgCl(s) + M(NO_3)_2(aq)}$$

$$\begin{aligned} M(\mathrm{M}) &= m(\mathrm{M})\ n(\mathrm{M})^{-1} \\ &= \left\{ m(\mathrm{MCl_2})\ n(\mathrm{MCl_2})^{-1} \right\} - 2\ M(\mathrm{Cl}) \\ &= \left\{ m(\mathrm{MCl_2}) \left[n(\mathrm{AgCl})\ r(\mathrm{Cl^-}, \mathrm{AgCl})\ r(\mathrm{MCl_2}, \mathrm{Cl^-}) \right]^{-1} \right\} - 2\ M(\mathrm{Cl}) \\ &= \left\{ m(\mathrm{MCl_2}) \left[m(\mathrm{AgCl})\ M(\mathrm{AgCl})^{-1}\ r(\mathrm{Cl^-}, \mathrm{AgCl})\ r(\mathrm{MCl_2}, \mathrm{Cl^-}) \right]^{-1} \right\} - 2\ M(\mathrm{Cl}) \\ &= \left\{ 1.62\ \mathrm{g\ MCl_2} \left[3.46\ \mathrm{g\ AgCl} \left(\frac{\mathrm{mol\ AgCl}}{143.32\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ Cl^-}}{\mathrm{mol\ AgCl}}\right) \left(\frac{\mathrm{mol\ MCl_2}}{2\ \mathrm{mol\ Cl^-}}\right) \right]^{-1} \right\} - \left[2 \left(\frac{35.45\ \mathrm{g}}{\mathrm{mol\ Cl}}\right) \right] \\ &= \left\{ \frac{1.62\ \mathrm{g\ MCl_2}}{0.012\bar{0}70\ \mathrm{mol\ MCl_2}} \right\} - \left[2 \left(\frac{35.45\ \mathrm{g}}{\mathrm{mol\ Cl}}\right) \right] \\ &= 63.\bar{3}07\ \mathrm{g} = 63.3\ \mathrm{g} \end{aligned}$$

sec04-q0014-01.tex
Keyword:stoichiometry

8. Which solution has the greatest molar concentration of SO_4^{2-}?

A. 0.060 M H_2SO_4
B. 0.27 M $MgSO_4$
C. 0.17 M Na_2SO_4
D. 0.098 M $Al_2(SO_4)_3$
E. 0.22 M $CuSO_4$

D

A. 0.06 M
B. 0.27 M
C. 0.17 M
D. 0.29 M
E. 0.22 M

`sec04-q0006-01.tex`

`Keyword:electrolytes; molarity`

9. A solution is prepared by dissolving 4.25 g NaCl, 0.175 g KCl, and 0.183 g $CaCl_2$ in water. The volume of the solution is 500.0 mL. What is the molar concentration (in mol L^{-1}) of Cl^- in the solution?

A: 0.157 *M*

All ionic compounds are soluble.

NaCl

$$\begin{aligned} n(\mathrm{Cl^-}) &= n(\mathrm{NaCl})\ r(\mathrm{Cl^-},\mathrm{NaCl}) \\ &= m(\mathrm{NaCl})\ M(\mathrm{NaCl})^{-1}\ r(\mathrm{Cl^-},\mathrm{NaCl}) \\ &= 4.25\ \mathrm{g}\left(\frac{\mathrm{mol\ NaCl}}{58.44\ \mathrm{g}}\right)\left(\frac{\mathrm{mol\ Cl^-}}{\mathrm{mol\ NaCl}}\right) \\ &= 0.072\bar{7}24\ \mathrm{mol} \end{aligned}$$

KCl

$$\begin{aligned} n(\mathrm{Cl^-}) &= n(\mathrm{KCl})\ r(\mathrm{Cl^-},\mathrm{KCl}) \\ &= m(\mathrm{KCl})\ M(\mathrm{KCl})^{-1}\ r(\mathrm{Cl^-},\mathrm{KCl}) \\ &= 0.175\ \mathrm{g}\left(\frac{\mathrm{mol\ KCl}}{74.55\ \mathrm{g}}\right)\left(\frac{\mathrm{mol\ Cl^-}}{\mathrm{mol\ KCl}}\right) \\ &= 0.0023\bar{4}74\ \mathrm{mol} \end{aligned}$$

$CaCl_2$

$$\begin{aligned} n(\mathrm{Cl^-}) &= n(\mathrm{CaCl_2})\ r(\mathrm{Cl^-},\mathrm{CaCl_2}) \\ &= m(\mathrm{CaCl_2})\ M(\mathrm{CaCl_2})^{-1}\ r(\mathrm{Cl^-},\mathrm{CaCl_2}) \\ &= 0.183\ \mathrm{g}\left(\frac{\mathrm{mol\ CaCl_2}}{110.98\ \mathrm{g}}\right)\left(\frac{2\ \mathrm{mol\ Cl^-}}{\mathrm{mol\ CaCl_2}}\right) \\ &= 0.0032\bar{9}78\ \mathrm{mol} \end{aligned}$$

Cl^- molar concentration

$$\begin{aligned} c(\mathrm{Cl^-}) &= n(\mathrm{Cl^-})\ V(\mathrm{solution})^{-1} \\ &= \left[(0.072\bar{7}24 + 0.0023\bar{4}74 + 0.0032\bar{9}78)\ \mathrm{mol}\right]\left[500.0\ \mathrm{mL}\left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right)\right]^{-1} \\ &= 0.15\bar{6}73\ \mathrm{mol\ L^{-1}} = 0.157\ \mathrm{mol\ L^{-1}} \end{aligned}$$

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sec04-q0007-01.tex
Keyword:electrolytes; molarity
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10. In the following reaction, 55.2 mL of potassium sulfate solution was added to excess lead acetate. What is the concentration of K^+ in the potassium sulfate solution if 1.23 g of $PbSO_4$ was produced?

$$K_2SO_4(aq) + Pb(C_2H_3O_2)_2(aq) \longrightarrow 2\ KC_2H_3O_2(aq) + PbSO_4(s)$$

A: 0.147 *M*

$$\begin{aligned} c(K^+) &= n(K^+)\ V(\text{solution})^{-1} \\ &= n(K_2SO_4)\ r(K^+, K_2SO_4)\ V(\text{solution})^{-1} \\ &= n(PbSO_4)\ r(K_2SO_4, PbSO_4)\ r(K^+, K_2SO_4)\ V(\text{solution})^{-1} \\ &= m(PbSO_4)\ M(PbSO_4)^{-1}\ r(K_2SO_4, PbSO_4)\ r(K^+, K_2SO_4)\ V(\text{solution})^{-1} \\ &= 1.23\ \text{g PbSO}_4 \left(\frac{\text{mol PbSO}_4}{303.26\ \text{g}}\right)\left(\frac{\text{mol K}_2\text{SO}_4}{\text{mol PbSO}_4}\right)\left(\frac{2\ \text{mol K}^+}{\text{mol K}_2\text{SO}_4}\right)\left(\frac{1}{52.2\ \text{mL}}\right)\left(\frac{10^3\ \text{mL}}{\text{L}}\right) \\ &= 0.15\bar{5}39\ \text{mol L}^{-1} = 0.155\ \text{mol L}^{-1} \end{aligned}$$

sec04-q0008-01.tex
Keyword:electrolytes; molarity; stoichiometry

11. You mix 285.0 mL of 1.20 *M* aqueous lead(II) nitrate with 300.0 mL of 1.55 *M* aqueous potassium iodide. Determine the following.

    A. the molecular equation for this reaction
    B. the limiting reactant
    C. the final molar concentration (in mol L^{-1}) of Pb^{2+}
    D. the mass (in g) of lead(II) iodide formed
    E. the final molar concentration (in mol L^{-1}) of K^{+}
    F. the final molar concentration (in mol L^{-1}) of NO_3^{-}

A.

$$\mathrm{Pb(NO_3)_2(aq) + 2\,KI(aq) \longrightarrow PbI_2(s) + 2\,KNO_3(aq)}$$

B. KI is limiting.

$$\begin{aligned}
c(\mathrm{PbI_2}) &= n(\mathrm{PbI_2})\ V(\mathrm{solution})^{-1} \\
&= V(\mathrm{Pb(NO_3)_2})\ c(\mathrm{Pb(NO_3)_2})\ r(\mathrm{PbI_2, Pb(NO_3)_2})\ V(\mathrm{solution})^{-1} \\
&= 285.0\ \mathrm{mL\ Pb(NO_3)_2} \left(\frac{1.20\ \mathrm{mol\ Pb(NO_3)_2}}{\mathrm{L}}\right)\left(\frac{\mathrm{mol\ PbI_2}}{\mathrm{mol\ Pb(NO_3)_2}}\right)\left(\frac{1}{(285.0+300.0)\ \mathrm{mL}}\right) \\
&= 0.58\bar{4}61\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

$$\begin{aligned}
c(\mathrm{PbI_2}) &= n(\mathrm{PbI_2})\ V(\mathrm{solution})^{-1} \\
&= V(\mathrm{KI})\ c(\mathrm{KI})\ r(\mathrm{PbI_2, KI})\ V(\mathrm{solution})^{-1} \\
&= 300.0\ \mathrm{mL\ KI}\left(\frac{1.55\ \mathrm{mol\ KI}}{\mathrm{L}}\right)\left(\frac{\mathrm{mol\ PbI_2}}{2\ \mathrm{mol\ KI}}\right)\left(\frac{1}{(285.0+300.0)\ \mathrm{mL}}\right) \\
&= 0.39\bar{7}43\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

C.

$$\begin{aligned}
c(\mathrm{Pb^{2+}})_{\mathrm{final}} &= n(\mathrm{Pb^{2+}})\ V(\mathrm{solution})^{-1} \\
&= \left\{ n(\mathrm{Pb(NO_3)_2})_{\mathrm{initial}} - n(\mathrm{Pb(NO_3)_2})_{\mathrm{reacted}} \right\} r(\mathrm{Pb^{2+}, Pb(NO_3)_2})\ V(\mathrm{solution})^{-1} \\
&= \left\{ \left[c(\mathrm{Pb(NO_3)_2})\ V(\mathrm{Pb(NO_3)_2}) \right] - \left[c(\mathrm{PbI_2}\ V(\mathrm{solution})\ r(\mathrm{PbI_2, Pb(NO_3)_2}) \right] \right\} \\
&\quad r(\mathrm{Pb^{2+}, Pb(NO_3)_2})\ V(\mathrm{solution})^{-1} \\
&= \left\{ \left[\left(\frac{1.20\ \mathrm{mol\ Pb(NO_3)_2}}{\mathrm{L}}\right)\left(\frac{285.0\ \mathrm{mL\ Pb(NO_3)_2}}{}\right)\left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \right] - \right. \\
&\quad \left. \left[\left(\frac{0.39\bar{7}43\ \mathrm{mol\ PbI_2}}{\mathrm{L}}\right)\left(\frac{(285.0\ \mathrm{mL} + 300.0)\ \mathrm{mL}}{}\right)\left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right)\left(\frac{\mathrm{mol\ Pb(NO_3)_2}}{\mathrm{mol\ PbI_2}}\right) \right] \right\} \\
&\quad \left(\frac{\mathrm{mol\ Pb^{2+}}}{\mathrm{mol\ Pb(NO_3)_2}}\right)\left(\frac{1}{(285.0+300.0)\ \mathrm{mL}}\right)\left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\
&= 0.18\bar{7}18\ \mathrm{mol\ L^{-1}} = 0.187\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

D.

$$\begin{aligned}
m(\mathrm{PbI_2}) &= c(\mathrm{PbI_2})\ V(\mathrm{solution})\ M(\mathrm{PbI_2}) \\
&= \frac{0.39\bar{7}43\ \mathrm{mol\ PbI_2}}{\mathrm{L}}\left(\frac{(285.0+300.0)\ \mathrm{mL}}{}\right)\left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right)\left(\frac{461\ \mathrm{g}}{\mathrm{mol\ PbI_2}}\right) \\
&= 10\bar{7}.18\ \mathrm{g} = 111\ \mathrm{g}
\end{aligned}$$

E.

$$\begin{aligned}
c(\mathrm{K^+}) &= n(\mathrm{K^+})\ V(\mathrm{solution})^{-1} \\
&= n(\mathrm{KI})\ r(\mathrm{K^+, KI})\ V(\mathrm{solution})^{-1} \\
&= c(\mathrm{KI})\ V(\mathrm{KI})\ r(\mathrm{K^+, KI})\ V(\mathrm{solution})^{-1} \\
&= \frac{1.55\ \mathrm{mol\ KI}}{\mathrm{L}}\left(\frac{300.0\ \mathrm{mL}}{}\right)\left(\frac{2\ \mathrm{mol\ K^+}}{2\ \mathrm{mol\ KNO_3}}\right)\left(\frac{1}{(285.0+300.0)\ \mathrm{mL}}\right) \\
&= 0.79\bar{4}87\ \mathrm{mol\ L^{-1}} = 0.795\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

F.

$$\begin{aligned}
c(\mathrm{NO_3^-}) &= n(\mathrm{NO_3^-})\ V(\mathrm{solution})^{-1} \\
&= c(\mathrm{Pb(NO_3)_2})\ V(\mathrm{Pb(NO_3)_2})\ r(\mathrm{NO_3^{2-}, Pb(NO_3)_2})\ V(\mathrm{solution})^{-1} \\
&= \frac{1.20\ \mathrm{mol\ Pb(NO_3)_2}}{\mathrm{L}}\left(\frac{285.0\ \mathrm{mL}}{}\right)\left(\frac{2\ \mathrm{mol\ NO_3^{2-}}}{\mathrm{mol\ Pb(NO_3)_2}}\right)\left(\frac{1}{(285.0+300.0)\ \mathrm{mL}}\right) \\
&= 1.1\bar{6}92\ \mathrm{mol\ L^{-1}} = 1.17\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

sec04-q0009-01.tex

Keyword:solubility rules; stoichiometry; molarity; limiting reactant

12. If all of the chloride in a 4.106 g sample of an unknown metal chloride is precipitated as AgCl with 70.90 mL of 0.2010 M $AgNO_3$, what is the percentage of chloride in the sample?

A: 12.30 %

$$
\begin{aligned}
w(\mathrm{Cl^-})\% &= w(\mathrm{Cl^-}) \times 100~\% \\
&= m(\mathrm{Cl^-})\ m(\mathrm{sample})^{-1} \times 100~\% \\
&= n(\mathrm{Cl^-})\ M(\mathrm{Cl^-})\ m(\mathrm{sample})^{-1} \times 100~\% \\
&= n(\mathrm{AgNO_3})\ r(\mathrm{Ag^+}, \mathrm{AgNO_3})\ r(\mathrm{AgCl}, \mathrm{Ag^+})\ r(\mathrm{Cl^-}, \mathrm{Ag^+})\ M(\mathrm{Cl^-})\ m(\mathrm{sample})^{-1} \times 100~\% \\
&= c(\mathrm{AgNO_3})\ V(\mathrm{AgNO_3})\ r(\mathrm{Ag^+}, \mathrm{AgNO_3})\ r(\mathrm{AgCl}, \mathrm{Ag^+})\ r(\mathrm{Cl^-}, \mathrm{Ag^+})\ M(\mathrm{Cl^-}) \\
&\quad m(\mathrm{sample})^{-1} \times 100~\% \\
&= \frac{0.2010\ \mathrm{mol\ AgNO_3}}{\mathrm{L}} \left(\frac{70.90\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{\mathrm{mol\ Ag^+}}{\mathrm{mol\ AgNO_3}}\right) \left(\frac{\mathrm{mol\ AgCl}}{\mathrm{mol\ Ag^+}}\right) \left(\frac{\mathrm{mol\ Cl^-}}{\mathrm{mol\ AgCl}}\right) \\
&\quad \left(\frac{35.45\ \mathrm{g}}{\mathrm{mol\ Cl^-}}\right) \left(\frac{1}{4.106\ \mathrm{g}}\right) \times 100~\% \\
&= 12.3\bar{0}38~\% = 12.30~\%
\end{aligned}
$$

sec04-q0010-01.tex
Keyword:stoichiometry; molarity; percent composition by mass

13. A mixture of $BaCl_2$ and NaCl is analyzed by precipitating all of the barium as $BaSO_4$. After the addition of excess Na_2SO_4 to a 3.988 g sample of the mixture, the mass of precipitate collected is 2.113 g. What is the mass percentage of barium chloride in the mixture?

A: 47.27 %

$$
\begin{aligned}
w(\mathrm{BaCl_2})\% &= w(\mathrm{BaCl_2}) \times 100~\% \\
&= m(\mathrm{BaCl_2})\ m(\mathrm{sample})^{-1} \times 100~\% \\
&= n(\mathrm{BaCl_2})\ M(\mathrm{BaCl_2})\ m(\mathrm{sample})^{-1} \times 100~\% \\
&= n(\mathrm{BaSO_4})\ r(\mathrm{BaCl_2}, \mathrm{BaSO_4})\ M(\mathrm{BaCl_2})\ m(\mathrm{sample})^{-1} \times 100~\% \\
&= m(\mathrm{BaSO_4})\ M(\mathrm{BaSO_4})^{-1}\ r(\mathrm{BaCl_2}, \mathrm{BaSO_4})\ M(\mathrm{BaCl_2})\ m(\mathrm{sample})^{-1} \times 100~\% \\
&= 2.113\ \mathrm{g\ BaSO_4} \left(\frac{\mathrm{mol\ BaSO_4}}{233.39\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ BaCl_2}}{\mathrm{mol\ BaSO_4}}\right) \left(\frac{208.23\ \mathrm{g}}{\mathrm{mol\ BaCl_2}}\right) \left(\frac{1}{3.988\ \mathrm{g}}\right) \times 100~\% \\
&= 47.2\bar{7}21~\% = 47.27~\%
\end{aligned}
$$

sec04-q0011-01.tex
Keyword:stoichiometry; molarity; percent composition by mass

14. A 3.00 g sample of an alloy containing only Pb and Sn was dissolved in nitric acid. Sulfuric acid was added to this solution, which precipitated 1.90 g of $PbSO_4$. Assuming that all of the lead was precipitated, what is the percentage of Sn in the sample? ($M(PbSO_4) = 303.26$ g mol^{-1})

A: 56.7 %

$$\text{alloy} + HNO_3(aq) + H_2SO_4(aq) \longrightarrow PbSO_4(s) + \text{other stuff}$$

$$\begin{aligned}
w(\text{Sn})\% &= w(\text{Sn}) \times 100\ \% \\
&= m(\text{Sn})\ m(\text{sample})^{-1} \times 100\ \% \\
&= \left\{ m(\text{sample}) - m(\text{Pb}^{2+}) \right\} m(\text{sample})^{-1} \times 100\ \% \\
&= \left\{ m(\text{sample}) - \left[n(\text{Pb}^{2+})\ M(\text{Pb}^{2+}) \right] \right\} m(\text{sample})^{-1} \times 100\ \% \\
&= \left\{ m(\text{sample}) - \left[n(\text{PbSO}_4)\ r(\text{Pb}^{2+}, \text{PbSO}_4)\ M(\text{Pb}^{2+}) \right] \right\} m(\text{sample})^{-1} \times 100\ \% \\
&= \left\{ m(\text{sample}) - \left[m(\text{PbSO}_4)\ M(\text{PbSO}_4)^{-1}\ r(\text{Pb}^{2+}, \text{PbSO}_4)\ M(\text{Pb}^{2+}) \right] \right\} \\
&\quad\ m(\text{sample})^{-1} \times 100\ \% \\
&= \left\{ 3.00\text{ g sample} - \left[1.90\text{ g PbSO}_4 \left(\frac{\text{mol PbSO}_4}{303.26\text{ g}} \right) \left(\frac{\text{mol Pb}^{2+}}{\text{mol PbSO}_4} \right) \left(\frac{207.2\text{ g}}{\text{mol Pb}^{2+}} \right) \right] \right\} \\
&\quad \left(\frac{1}{3.00\text{ g sample}} \right) \times 100\ \% \\
&= 56.\bar{7}28\ \% = 56.7\ \%
\end{aligned}$$

sec04-q0012-01.tex

Keyword:stoichiometry; molarity; percent composition by mass

15. You have 76.0 mL of a 2.50 *M* aqueous solution of Na_2CrO_4 and 125 mL of a 2.16 *M* aqueous solution of $AgNO_3$. Calculate the molar concentration (in mol L^{-1}) of CrO_4^{2-} after the two solutions are mixed together.

A: 0.274 *M*

$$Na_2CrO_4(aq) + 2\,AgNO_3(aq) \longrightarrow Ag_2CrO_4(s) + 2\,NaNO_3(aq)$$

Find the limiting reactant

$$\begin{aligned} n(Ag_2CrO_4) &= n(Na_2CrO_4)\; r(Ag_2CrO_4, Na_2CrO_4) \\ &= c(Na_2CrO_4)\; V(Na_2CrO_4)\; r(Ag_2CrO_4, Na_2CrO_4) \\ &= \frac{2.50 \text{ mol } Na_2CrO_4}{L} \left(\frac{76.0 \text{ mL } Na_2CrO_4}{}\right) \left(\frac{L}{10^3 \text{ mL}}\right) \left(\frac{\text{mol } Ag_2CrO_4}{\text{mol } Na_2CrO_4}\right) \\ &= 0.19\bar{0}00 \text{ mol} \end{aligned}$$

$$\begin{aligned} n(Ag_2CrO_4) &= n(AgNO_3)\; r(Ag_2CrO_4, AgNO_3) \\ &= c(AgNO_3)\; V(AgNO_3)\; r(Ag_2CrO_4, AgNO_3) \\ &= \frac{2.16 \text{ mol } AgNO_3}{L} \left(\frac{125 \text{ mL } AgNO_3}{}\right) \left(\frac{L}{10^3 \text{ mL}}\right) \left(\frac{\text{mol } Ag_2CrO_4}{2 \text{ mol } AgNO_3}\right) \\ &= 0.13\bar{5}00 \text{ mol} \end{aligned}$$

$AgNO_3$ is limiting

$$\begin{aligned} c(CrO_4^{2-}) &= n(CrO_4^{2-})\; V(\text{solution})^{-1} \\ &= n(Na_2CrO_4)_{\text{leftover}}\; r(CrO_4^{2-}, Na_2CrO_4)\; V(\text{solution})^{-1} \\ &= \left\{ n(Na_2CrO_4)_{\text{initial}} - n(Na_2CrO_4)_{\text{reacted}} \right\} r(CrO_4^{2-}, Na_2CrO_4)\; V(\text{solution})^{-1} \\ &= \left\{ \left[V(Na_2CrO_4)\; c(Na_2CrO_4) \right] - \left[n(Ag_2CrO_4)_{\text{formed}}\; r(Na_2CrO_4, Ag_2CrO_4) \right] \right\} \\ &\quad r(CrO_4^{2-}, AgNO_3)\; V(\text{solution})^{-1} \\ &= \left\{ \left[76.0 \text{ mL } Na_2CrO_4 \left(\frac{L}{10^3 \text{ mL}}\right) \left(\frac{2.50 \text{ mol } Na_2CrO_4}{L}\right) \right] - \right. \\ &\quad \left. \left[0.13\bar{5}00 \text{ mol } AgCrO_4 \left(\frac{\text{mol } Na_2CrO_4}{\text{mol } Ag_2CrO_4}\right) \right] \right\} \\ &\quad \left(\frac{\text{mol } CrO_4^{2-}}{\text{mol } Na_2CrO_4}\right) \left(\frac{1}{(76.0 + 125) \text{ mL}}\right) \left(\frac{10^3 \text{ mL}}{L}\right) \\ &= 0.27\bar{3}63 \text{ mol } L^{-1} \\ &= 0.274 \text{ mol } L^{-1} \end{aligned}$$

sec04-q0015-01.tex

Keyword:balancing equations; stoichiometry; molarity; solubility rules; limiting reactant

16. You have a 75.0 mL 2.50 M aqueous Na_2CrO_4 solution and 125 mL 2.29 M aqueous $AgNO_3$ solution. What is the molar concentration (in mol L^{-1}) of Ag^+ after the two solutions are mixed together?

A: 0 M

$$\mathrm{Na_2CrO_4(aq) + 2\ AgNO_3(aq) \longrightarrow Ag_2CrO_4(s) + 2\ NaNO_3(aq)}$$

Find the limiting reactant

$$\begin{aligned} n(\mathrm{Ag_2CrO_4}) &= n(\mathrm{Na_2CrO_4})\ r(\mathrm{Ag_2CrO_4}, \mathrm{Na_2CrO_4}) \\ &= V(\mathrm{Na_2CrO_4})\ c(\mathrm{Na_2CrO_4})\ r(\mathrm{Ag_2CrO_4}, \mathrm{Na_2CrO_4}) \\ &= 75.0\ \mathrm{mL\ Na_2CrO_4} \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{2.50\ \mathrm{mol\ Na_2CrO_4}}{\mathrm{L}}\right) \left(\frac{\mathrm{mol\ Ag_2CrO_4}}{\mathrm{mol\ Na_2CrO_4}}\right) \\ &= 0.18\bar{7}50\ \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{Ag_2CrO_4}) &= n(\mathrm{AgNO_3})\ r(\mathrm{Ag_2CrO_4}, \mathrm{AgNO_3}) \\ &= V(\mathrm{AgNO_3})\ c(\mathrm{AgNO_3})\ r(\mathrm{Ag_2CrO_4}, \mathrm{AgNO_3}) \\ &= 125\ \mathrm{mL\ AgNO_3} \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{2.29\ \mathrm{mol\ AgNO_3}}{\mathrm{L}}\right) \left(\frac{\mathrm{mol\ Ag_2CrO_4}}{2\ \mathrm{mol\ AgNO_3}}\right) \\ &= 0.14\bar{3}12\ \mathrm{mol} \end{aligned}$$

$AgNO_3$ is limiting; therefore, all Ag^+ is converted to Ag_2CrO_4(s).

$$c(\mathrm{Ag^+}) = 0\ \mathrm{mol\ L^{-1}}$$

`sec04-q0016-01.tex`

`Keyword:balancing equations; stoichiometry; molarity; solubility rules; limiting reactant`

17. You have 75.0 mL of a 2.50 *M* aqueous solution of Na_2CrO_4 and 125 mL of a 2.24 *M* aqueous solution of $AgNO_3$. Calculate the molar concentration (in mol L^{-1}) of NO_3^- after the two solutions are mixed together.

A: 1.40 *M*

$$\mathrm{Na_2CrO_4(aq) + 2\ AgNO_3(aq) \longrightarrow Ag_2CrO_4(s) + 2\ NaNO_3(aq)}$$

Find the limiting reactant

$$\begin{aligned}
n(\mathrm{Ag_2CrO_4}) &= n(\mathrm{Na_2CrO_4})\ r(\mathrm{Ag_2CrO_4}, \mathrm{Na_2CrO_4}) \\
&= V(\mathrm{Na_2CrO_4})\ c(\mathrm{Na_2CrO_4})\ r(\mathrm{Ag_2CrO_4}, \mathrm{Na_2CrO_4}) \\
&= 75.0\ \mathrm{mL\ Na_2CrO_4} \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{2.50\ \mathrm{mol\ Na_2CrO_4}}{\mathrm{L}}\right) \left(\frac{\mathrm{mol\ Ag_2CrO_4}}{\mathrm{mol\ Na_2CrO_4}}\right) \\
&= 0.18\bar{7}50\ \mathrm{mol}
\end{aligned}$$

$$\begin{aligned}
n(\mathrm{Ag_2CrO_4}) &= n(\mathrm{AgNO_3})\ r(\mathrm{Ag_2CrO_4}, \mathrm{AgNO_3}) \\
&= V(\mathrm{AgNO_3})\ c(\mathrm{AgNO_3})\ r(\mathrm{Ag_2CrO_4}, \mathrm{AgNO_3}) \\
&= 125\ \mathrm{mL\ AgNO_3} \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{2.24\ \mathrm{mol\ AgNO_3}}{\mathrm{L}}\right) \left(\frac{\mathrm{mol\ Ag_2CrO_4}}{2\ \mathrm{mol\ AgNO_3}}\right) \\
&= 0.14\bar{0}00\ \mathrm{mol}
\end{aligned}$$

$AgNO_3$ is limiting.

$$\begin{aligned}
c(\mathrm{NO_3^{2-}}) &= n(\mathrm{NO_3^{2-}})\ V(\mathrm{solution})^{-1} \\
&= n(\mathrm{AgNO_3})\ r(\mathrm{NO_3^{2-}}, \mathrm{AgNO_3})\ V(\mathrm{solution})^{-1} \\
&= n(\mathrm{Ag_2CrO_4})\ r(\mathrm{AgNO_3}, \mathrm{Ag_2CrO_4})\ r(\mathrm{NO_3^{2-}}, \mathrm{AgNO_3})\ V(\mathrm{solution})^{-1} \\
&= 0.14\bar{0}00\ \mathrm{mol} \left(\frac{2\ \mathrm{mol\ AgNO_3}}{\mathrm{mol\ Ag_2CrO_4}}\right) \left(\frac{\mathrm{mol\ NO_3^{2-}}}{\mathrm{mol\ AgNO_3}}\right) \left(\frac{1}{(75.0 + 125)\ \mathrm{mL}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\
&= 1.4\bar{0}00\ \mathrm{mol\ L^{-1}} = 1.40\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

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sec04-q0017-01.tex
Keyword:balancing equations; stoichiometry; molarity; solubility rules; limiting reactant
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18. Combine a 55 mL 1.00 M aqueous silver nitrate solution with a 25 mL 0.55 M silver chloride solution. What mass (in g) of silver chloride is produced?

A: 2.0 g

$$\mathrm{AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)}$$

Find the limiting reactant

$$\begin{aligned} n(\mathrm{AgCl}) &= n(\mathrm{AgNO_3})\ r(\mathrm{AgCl}, \mathrm{AgNO_3}) \\ &= V(\mathrm{AgNO_3})\ c(\mathrm{AgNO_3})\ r(\mathrm{AgCl}, \mathrm{AgNO_3}) \\ &= 55\ \mathrm{mL\ AgNO_3} \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{1.00\ \mathrm{mol\ AgNO_3}}{\mathrm{L}}\right) \left(\frac{\mathrm{mol\ AgCl}}{\mathrm{mol\ AgNO_3}}\right) \\ &= 0.05\bar{5}00\ \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{AgCl}) &= n(\mathrm{NaCl})\ r(\mathrm{AgCl}, \mathrm{NaCl}) \\ &= V(\mathrm{NaCl})\ c(\mathrm{NaCl})\ r(\mathrm{AgCl}, \mathrm{NaCl}) \\ &= 25\ \mathrm{mL\ NaCl} \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{0.55\ \mathrm{mol\ NaCl}}{\mathrm{L}}\right) \left(\frac{\mathrm{mol\ AgCl}}{\mathrm{mol\ NaCl}}\right) \\ &= 0.01\bar{3}75\ \mathrm{mol} \end{aligned}$$

NaCl is limiting

$$\begin{aligned} m(\mathrm{AgCl}) &= n(\mathrm{AgCl})\ M(\mathrm{AgCl})^{-1} \\ &= 0.01\bar{3}75\ \mathrm{mol} \left(\frac{143.32\ \mathrm{g}}{\mathrm{mol\ AgCl}}\right) \\ &= 1.\bar{9}70\ \mathrm{g} = 2.0\ \mathrm{g} \end{aligned}$$

`sec04-q0018-01.tex`

`Keyword:balancing equations; stoichiometry; molarity; solubility rules; precipitation; limiting reactant`

19. A 0.307 g sample of an unknown triprotic acid is completely neutralized using a 35.2 mL 0.106 *M* aqueous NaOH solution. What is the molar mass (in g mol^{-1}) of the acid?

A: 247 g mol^{-1}

$$H_3X(aq) + 3\ NaOH(aq) \longrightarrow 3\ H_2O(l) + Na_3X(aq)$$

$$\begin{aligned} M(H_3X) &= m(H_3X)\ n(H_3X)^{-1} \\ &= m(H_3X)\left[n(NaOH)\ r(H_3X, NaOH)\right]^{-1} \\ &= m(H_3X)\left[c(NaOH)\ V(solution)\ r(H_3X, NaOH)\right]^{-1} \\ &= 0.307\text{ g }H_3X\left[\left(\frac{0.106\text{ mol NaOH}}{L}\right)\left(\frac{35.2\text{ mL}}{}\right)\left(\frac{L}{10^3\text{ mL}}\right)\left(\frac{\text{mol }H_3X}{3\text{ mol NaOH}}\right)\right]^{-1} \\ &= 24\bar{6}.83\text{ g mol}^{-1} = 247\text{ g mol}^{-1} \end{aligned}$$

sec04-q0019-01.tex

Keyword:balancing equations; stoichiometry; molarity; acid-base reaction

20. A 0.685 g sample of an unknown diprotic acid requires a 42.57 mL 0.111 *M* aqueous NaOH solution to be completely neutralized. What is the molar mass (in g mol^{-1}) of the acid?

A: 290. g mol^{-1}

$$H_2X(aq) + 2\ NaOH(aq) \longrightarrow 2\ H_2O(l) + Na_2X(aq)$$

$$\begin{aligned} M(H_2X) &= m(H_2X)\ n(H_2X)^{-1} \\ &= m(H_2X)\left[n(NaOH)\ r(H_2X, NaOH)\right]^{-1} \\ &= m(H_2X)\left[c(NaOH)\ V(solution)\ r(H_2X, NaOH)\right]^{-1} \\ &= 0.685\text{ g }H_2X\left[\left(\frac{0.111\text{ mol NaOH}}{L}\right)\left(\frac{42.57\text{ mL}}{}\right)\left(\frac{L}{10^3\text{ mL}}\right)\left(\frac{\text{mol }H_2X}{2\text{ mol NaOH}}\right)\right]^{-1} \\ &= 28\bar{9}.93\text{ g mol}^{-1} = 290.\text{ g mol}^{-1} \end{aligned}$$

sec04-q0020-01.tex

Keyword:balancing equations; stoichiometry; molarity; acid-base reaction

21. What mass (in g) of NaOH is required to completely react with a 25.0 mL 2.2 *M* aqueous H_2SO_4 solution?

A: 4.4 g

$$H_2SO_4(aq) + 2\ NaOH(aq) \longrightarrow 2\ H_2O(l) + Na_2SO_4(aq)$$

$$\begin{aligned} m(\mathrm{NaOH}) &= n(\mathrm{NaOH})\ M(\mathrm{NaOH}) \\ &= n(\mathrm{H_2SO_4})\ r(\mathrm{NaOH}, \mathrm{H_2SO_4})\ M(\mathrm{NaOH}) \\ &= c(\mathrm{H_2SO_4})\ V(\mathrm{H_2SO_4})\ r(\mathrm{NaOH}, \mathrm{H_2SO_4})\ M(\mathrm{NaOH}) \\ &= \frac{2.2\ \mathrm{mol\ H_2SO_4}}{\mathrm{L}} \left(\frac{25.0\ \mathrm{mL\ H_2SO_4}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{2\ \mathrm{mol\ NaOH}}{\mathrm{mol\ H_2SO_4}}\right) \left(\frac{40.00\ \mathrm{g}}{\mathrm{mol\ NaOH}}\right) \\ &= 4.\bar{4}00\ \mathrm{g} = 4.4\ \mathrm{g} \end{aligned}$$

sec04-q0021-01.tex

Keyword:balancing equations; stoichiometry; molarity; acid-base reaction

22. What volume (in mL) of a 5.00 *M* hydrofluoric acid solution will completely react with 4.05 g of calcium hydroxide?

A: 21.9 mL

$$HF(aq) + Ca(OH)_2 \longrightarrow 2\ H_2O(l) + CaF_2(aq)$$

$$\begin{aligned} V(\mathrm{HF}) &= n(\mathrm{HF})\ c(\mathrm{HF})^{-1} \\ &= n(\mathrm{Ca(OH)_2})\ r(\mathrm{HF}, \mathrm{Ca(OH)_2})\ c(\mathrm{HF})^{-1} \\ &= m(\mathrm{Ca(OH)_2})\ M(\mathrm{Ca(OH)_2})^{-1}\ r(\mathrm{HF}, \mathrm{Ca(OH)_2})\ c(\mathrm{HF})^{-1} \\ &= 4.05\ \mathrm{g\ Ca(OH)_2} \left(\frac{\mathrm{mol\ Ca(OH)_2}}{74.10\ \mathrm{g}}\right) \left(\frac{2\ \mathrm{mol\ HF}}{\mathrm{mol\ Ca(OH)_2}}\right) \left(\frac{\mathrm{L}}{5.00\ \mathrm{mol\ HF}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\ &= 21.\bar{8}62\ \mathrm{mL} = 21.9\ \mathrm{mL} \end{aligned}$$

sec04-q0022-01.tex

Keyword:balancing equations; stoichiometry; molarity; acid-base reaction

23. Sulfamic acid (HSO_3NH_2) is a strong monoprotic acid that can be used to standardize a strong base. A 0.179 g sample of HSO_3NH_2 is required to completely neutralize a 19.4 mL aqueous KOH solution. What is the molar concentration (in mol L^{-1}) of the KOH solution?

A: 0.0950 *M*

$$\mathrm{HSO_3NH_3(aq) + KOH \longrightarrow H_2O(l) + KSO_3NH_2(aq)}$$

$$\begin{aligned}
c(\mathrm{KOH}) &= n(\mathrm{KOH})\ V(\mathrm{KOH})^{-1} \\
&= n(\mathrm{HSO_3NH_2})\ r(\mathrm{KOH, HSO_3NH_2})\ V(\mathrm{KOH})^{-1} \\
&= m(\mathrm{HSO_3NH_2})\ M(\mathrm{HSO_3NH_2})^{-1}\ r(\mathrm{KOH, HSO_3NH_2})\ V(\mathrm{KOH})^{-1} \\
&= 0.179\ \mathrm{g\ HSO_3NH_2} \left(\frac{\mathrm{mol\ HSO_3NH_2}}{97.10\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ KOH}}{\mathrm{mol\ HSO_3NH_2}}\right) \left(\frac{1}{19.4\ \mathrm{mL\ KOH}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\
&= 0.095\bar{0}23\ \mathrm{mol\ L^{-1}} = 0.0950\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

sec04-q0023-01.tex

Keyword:balancing equations; stoichiometry; molarity; acid-base reaction

24. A student weighs out 0.556 g of KHP (M(KHP) = 204.22 g mol^{-1}) and puts it into 36.78 mL of a stock NaOH solution. If that was enough to neutralize the NaOH, what is the concentration of the stock NaOH solution? KHP is a monoprotic acid.

A: 0.0740 *M*

$$\mathrm{HX(aq) + NaOH \longrightarrow H_2O(l) + KSO_3NH_2(aq)}$$

$$\begin{aligned}
c(\mathrm{NaOH}) &= n(\mathrm{NaOH})\ V(\mathrm{NaOH})^{-1} \\
&= n(\mathrm{HX})\ r(\mathrm{NaOH, HX})\ V(\mathrm{NaOH})^{-1} \\
&= m(\mathrm{HX})\ M(\mathrm{HX})^{-1}\ r(\mathrm{NaOH, HX})\ V(\mathrm{NaOH})^{-1} \\
&= 0.556\ \mathrm{g\ HX} \left(\frac{\mathrm{mol\ HX}}{204.22\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ NaOH}}{\mathrm{mol\ HX}}\right) \left(\frac{1}{36.78\ \mathrm{mL\ NaOH}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\
&= 0.074\bar{0}22\ \mathrm{mol\ L^{-1}} = 0.0740\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

sec04-q0024-01.tex

Keyword:balancing equations; stoichiometry; molarity; acid-base reaction

25. A 2.80 g sample of phosphoric acid is added to a 150.0 mL 1.00 M sodium hydroxide solution to give a 151.489 mL mixture and the acid is completely neutralized. Determine the following:

   A. $[\mathrm{Na^+}]$ (in mol $\mathrm{L^{-1}}$)
   B. $[\mathrm{PO_4^{3-}}]$ (in mol $\mathrm{L^{-1}}$)
   C. $[\mathrm{OH^-}]$ (in mol $\mathrm{L^{-1}}$)

A: 1.00 *M*; 0.189 *M*; 0.424 *M*

$$\mathrm{H_3PO_4(aq) + 3\ NaOH \longrightarrow 3\ H_2O(l) + Na_3PO_4(aq)}$$

Determine the limiting reagent.

$$\begin{aligned}
n(\mathrm{Na_3PO_4}) &= n(\mathrm{H_3PO_4})\ r(\mathrm{Na_3PO_4, H_3PO_4}) \\
&= m(\mathrm{H_3PO_4})\ M(\mathrm{H_3PO_4})^{-1}\ r(\mathrm{Na_3PO_4}) \\
&= 2.80\ \mathrm{g\ H_3PO_4} \left(\frac{\mathrm{mol\ H_3PO_4}}{98.00\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ Na_3PO_4}}{\mathrm{mol\ H_3PO_4}}\right) \\
&= 0.028\bar{5}71\ \mathrm{mol}
\end{aligned}$$

$$\begin{aligned}
n(\mathrm{Na_3PO_4}) &= n(\mathrm{NaOH})\ r(\mathrm{Na_3PO_4, NaOH}) \\
&= c(\mathrm{NaOH})\ V(\mathrm{NaOH})\ r(\mathrm{Na_3PO_4, NaOH}) \\
&= \frac{1.00\ \mathrm{mol\ NaOH}}{\mathrm{L}} \left(\frac{150.0\ \mathrm{mL\ NaOH}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{\mathrm{mol\ Na_3PO_4}}{3\ \mathrm{mol\ NaOH}}\right) \\
&= 0.050\bar{0}00\ \mathrm{mol}
\end{aligned}$$

$\mathrm{H_3PO_4}$ is limiting.

A. Since NaOH and $\mathrm{Na_3PO_3}$ are strong electrolytes, the $\mathrm{Na^+}$ concentration is equal to the initial NaOH(aq) concentration. $[\mathrm{Na^+}] = 1.00\ \mathrm{mol\ L^{-1}}$

B.

$$\begin{aligned}
c(\mathrm{PO_4^{3-}}) &= n(\mathrm{PO_4^{3-}})\ V(\mathrm{solution})^{-1} \\
&= n(\mathrm{Na_3PO_4})\ r(\mathrm{PO_4^{3-}, Na_3PO_4})\ V(\mathrm{solution}^{-1}) \\
&= 0.028\bar{5}71\ \mathrm{mol\ Na_3PO_4} \left(\frac{\mathrm{mol\ PO_4^{3-}}}{\mathrm{mol\ Na_3PO_4}}\right) \left(\frac{1}{151.489\ \mathrm{mL}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\
&= 0.18\bar{8}60\ \mathrm{mol\ L^{-1}} = 0.189\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

C.

$$\begin{aligned}
c(\mathrm{OH^-}) &= n(\mathrm{OH^-})\ V(\mathrm{solution})^{-1} \\
&= \left\{ n(\mathrm{NaOH})_{\mathrm{initial}} - n(\mathrm{NaOH})_{\mathrm{consumed}} \right\} r(\mathrm{OH^-, NaOH})\ V(\mathrm{solution})^{-1} \\
&= \left\{ \left[c(\mathrm{NaOH})\ V(\mathrm{NaOH}) \right] - \left[n(\mathrm{Na_3PO_4})\ r(\mathrm{NaOH, Na_3PO_4}) \right] \right\} r(\mathrm{OH^-, NaOH})\ V(\mathrm{solution})^{-1} \\
&= \left\{ \left[\frac{1.00\ \mathrm{mol\ NaOH}}{\mathrm{L}} \left(\frac{150.0\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \right] - \left[0.028\bar{5}71\ \mathrm{mol\ Na_3PO_4} \left(\frac{3\ \mathrm{mol\ NaOH}}{\mathrm{Na_3PO_4}}\right) \right] \right\} \\
&\quad \left(\frac{\mathrm{mol\ OH^-}}{\mathrm{mol\ NaOH}}\right) \left(\frac{1}{151.489\ \mathrm{mL}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\
&= 0.42\bar{4}36\ \mathrm{mol\ L^{-1}} = 0.424\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

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sec04-q0025-01.tex
Keyword:balancing equations; stoichiometry; molarity; acid-base reaction; limiting reactant
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26. A stock solution with a total volume of 1000.0 mL contains 37.1 g $Mg(NO_3)_2$. If you take a 20.0 mL aliquot and then dilute it with water to a total volume of 500.0 mL, what is the molar concentration (in mol L^{-1}) of Mg^{2+} and NO_3^{2-} in the final solution?

A: 0.0100 *M*; 0.0200 *M*

$$\begin{aligned} c(\mathrm{Mg^{2+}}) &= n(\mathrm{Mg^{2+}})_{\text{dilute aliquot}}\ V(\text{dilute aliquot})^{-1} \\ &= n(\mathrm{Mg^{2+}})_{\text{stock solution}}\ V(\text{stock solution})^{-1}\ V(\text{aliquot})\ V(\text{dilute aliquot})^{-1} \\ &= m(\mathrm{Mg(NO_3)_2})\ M(\mathrm{Mg(NO_3)_2})^{-1}\ r(\mathrm{Mg^{2+}}, \mathrm{Mg(NO_3)_2}) \\ &\quad V(\text{stock solution})^{-1}\ V(\text{aliquot})\ V(\text{dilute aliquot})^{-1} \\ &= 37.1\ \mathrm{g\ Mg(NO_3)_2} \left(\frac{\mathrm{mol\ Mg(NO_3)_2}}{148.33\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ Mg^{2+}}}{\mathrm{mol\ Mg(NO_3)_2}}\right) \\ &\quad \left(\frac{1}{1000.0\ \mathrm{mL}}\right) \left(\frac{20.0\ \mathrm{mL}}{}\right) \left(\frac{1}{500.0\ \mathrm{mL}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\ &= 0.010\bar{0}04\ \mathrm{mol\ L^{-1}} = 0.0100\ \mathrm{mol\ L^{-1}} \end{aligned}$$

$$\begin{aligned} c(\mathrm{NO_3^{2-}}) &= n(\mathrm{NO_3^{2-}})_{\text{dilute aliquot}}\ V(\text{stock solution})^{-1} \\ &= n(\mathrm{NO_3^{2-}})_{\text{stock solution}}\ V(\text{stock solution})^{-1}\ V(\text{aliquot})\ V(\text{dilute aliquot})^{-1} \\ &= m(\mathrm{Mg(NO_3)_2})\ M(\mathrm{Mg(NO_3)_2})^{-1}\ r(\mathrm{NO_3^{2-}}, \mathrm{Mg(NO_3)_2}) \\ &\quad V(\text{stock solution})^{-1}\ V(\text{aliquot})\ V(\text{dilute aliquot})^{-1} \\ &= 37.1\ \mathrm{g\ Mg(NO_3)_2} \left(\frac{\mathrm{mol\ Mg(NO_3)_2}}{148.33\ \mathrm{g}}\right) \left(\frac{2\ \mathrm{mol\ NO_3^{2-}}}{\mathrm{mol\ Mg(NO_3)_2}}\right) \\ &\quad \left(\frac{1}{1000.0\ \mathrm{mL}}\right) \left(\frac{20.0\ \mathrm{mL}}{}\right) \left(\frac{1}{500.0\ \mathrm{mL}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\ &= 0.020\bar{0}09\ \mathrm{mol\ L^{-1}} = 0.0200\ \mathrm{mol\ L^{-1}} \end{aligned}$$

Alternatively,

$$\begin{aligned} c(\mathrm{NO_3^{2-}}) &= c(\mathrm{Mg^{2+}})_{\text{dilute aliquot}}\ r(\mathrm{NO_3^{2-}}, \mathrm{Mg^{2+}}) \\ &= \frac{0.010\bar{0}04\ \mathrm{mol}}{\mathrm{L}} \left(\frac{2\ \mathrm{mol\ NO_3^{-}}}{\mathrm{mol\ Mg(NO_3)_2}}\right) \\ &= 0.020\bar{0}08\ \mathrm{mol\ L^{-1}} = 0.0200\ \mathrm{mol\ L^{-1}} \end{aligned}$$

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sec04-q0026-01.tex
Keyword:stoichiometry; molarity; dilution
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27. Determine the molar concentrations (in g mol^{-1}) the ions present in a solution created from mixing equal volumes of 1.0 *M* aqueous lead(II) nitrate and 1.0 *M* aqueous sodium chloride solutions? Assume that the volumes are precise to one decimal place in normalized scientific notation.

A: Pb^{2+}: 0.25 *M*; NO_3^{2-}: 1.0 *M*; Na^+: 0.50 *M*; Cl^-: 0 *M*

$$\mathrm{Pb(NO_3)_2(aq) + 2\,NaCl(aq) \longrightarrow PbCl_2(s) + 2\,NaNO_3(aq)}$$

This solution considers the mixing of two 1.0×10^0 L solutions to give a 2.0 L final solution. Determine the limiting reactant.

$$\begin{aligned} n(\mathrm{PbCl_2}) &= c(\mathrm{Pb(NO_3)_2})\ V(\mathrm{Pb(NO_3)_2})_{\text{initial}}\ r(\mathrm{PbCl_2}, \mathrm{Pb(NO_3)_2}) \\ &= \frac{1.0\ \text{mol Pb(NO}_3)_2}{\text{L}} \left(\frac{1.0\ \text{L}}{}\right) \left(\frac{\text{mol PbCl}_2}{\text{mol Pb(NO}_3)_2}\right) \\ &= 1.0\ \text{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{PbCl_2}) &= c(\mathrm{NaCl})\ V(\mathrm{NaCl})_{\text{initial}}\ r(\mathrm{PbCl_2}, \mathrm{NaCl}) \\ &= \frac{1.0\ \text{mol NaCl}}{\text{L}} \left(\frac{1.0\ \text{L}}{}\right) \left(\frac{\text{mol PbCl}_2}{2\ \text{mol NaCl}}\right) \\ &= 0.5\ \text{mol} \end{aligned}$$

NaCl is the limiting reactant.

$$\begin{aligned} c(\mathrm{Pb^{2+}}) &= n(\mathrm{Pb^{2+}})\ V(\text{solution})^{-1} \\ &= \left\{ n(\mathrm{Pb^{2+}})_{\text{initial}} - n(\mathrm{Pb^{2+}})_{\text{reacted}} \right\} r(\mathrm{Pb^{2+}}, \mathrm{Pb(NO_3)_2})\ V(\text{solution})^{-1} \\ &= \left\{ \left[c(\mathrm{Pb(NO_3)_2})\ V(\mathrm{Pb(NO_3)_2}) \right] - \left[n(\mathrm{PbCl_2})\ r(\mathrm{Pb(NO_3)_2}, \mathrm{PbCl_2}) \right] \right\} r(\mathrm{Pb^{2+}}, \mathrm{Pb(NO_3)_2})\ V(\text{solution})^{-1} \\ &= \left\{ \left[\left(\frac{1.0\ \text{mol Pb(NO}_3)_2}{\text{L}}\right) \left(\frac{1.0\ \text{L Pb(NO}_3)_2}{}\right) \right] - \left[0.5\ \text{mol PbCl}_2 \left(\frac{\text{mol Pb(NO}_3)_2}{\text{mol PbCl}_2}\right) \right] \right\} \left(\frac{\text{mol Pb}^{2+}}{\text{PbCl}_2}\right) \left(\frac{1}{2.0\ \text{L}}\right) \\ &= 0.25\ \text{mol L}^{-1} \end{aligned}$$

$$\begin{aligned} c(\mathrm{NO_3^{2-}}) &= n(\mathrm{NO_3^{2-}})\ V(\text{solution})^{-1} \\ &= c(\mathrm{Pb(NO_3)_2})\ V(\mathrm{Pb(NO_3)_2})_{\text{initial}}\ r(\mathrm{NO_3^{2-}}, \mathrm{Pb(NO_3)_2})\ V(\text{solution})^{-1} \\ &= \frac{1.0\ \text{mol Pb(NO}_3)_2}{\text{L}} \left(\frac{1.0\ \text{L}}{}\right) \left(\frac{2\ \text{mol NO}_3^{2-}}{\text{mol Pb(NO}_3)_2}\right) \left(\frac{1}{2.0\ \text{L}}\right) \\ &= 1.0\ \text{mol L}^{-1} \end{aligned}$$

$$\begin{aligned} c(\mathrm{Na^+}) &= n(\mathrm{Na^+})\ V(\text{solution})^{-1} \\ &= c(\mathrm{NaCl})\ V(\mathrm{NaCl})_{\text{initial}}\ r(\mathrm{Na^+}, \mathrm{NaCl})\ V(\text{solution})^{-1} \\ &= \frac{1.0\ \text{mol NaCl}}{\text{L}} \left(\frac{1.0\ \text{L}}{}\right) \left(\frac{\text{mol Na}^+}{\text{mol NaCl}}\right) \left(\frac{1}{2.0\ \text{L}}\right) \\ &= 0.5\ \text{mol L}^{-1} \end{aligned}$$

Because NaCl is the limiting reactant, all Cl^- ions are precipitated in $PbCl_2$.

$$c(\mathrm{Cl^-}) = 0.0\ \text{mol L}^{-1}$$

`sec04-q0027-01.tex`

`Keyword:stoichiometry; molarity; dilution; limiting reactant`

28. Determine the molar concentrations (in g mol^{-1}) the ions present in a solution created from mixing equal volumes of 1.0 *M* aqueous ammonium carbonate and 1.0 *M* aqueous potassium perchlorate. Assume that the volumes are precise to one decimal place in normalized scientific notation.

A: $NH_4{}^+$: 1.0 *M*; $CO_3{}^{2-}$: 0.50 *M*; K^+: 0.50 *M*; $ClO_4{}^-$: 0.50 *M*

$$(NH_4)_2CO_3(aq) + 2\ KClO_4(aq) \longrightarrow 2\ NH_4ClO_4(aq) + K_2CO_3(aq)$$

This solution considers the mixing of two 1.0 L solutions to give a 2.0 L final solution.

$$\begin{aligned}
c(\mathrm{NH_4^+}) &= n(\mathrm{NH_4^+})\ V(\text{solution})^{-1} \\
&= n(\mathrm{(NH_4)_2CO_3})\ r(\mathrm{NH_4^+}, \mathrm{(NH_4)_2CO_3})\ V(\text{solution})^{-1} \\
&= c(\mathrm{(NH_4)_2CO_3})\ V(\mathrm{(NH_4)_2CO_3})\ r(\mathrm{NH_4^+}, \mathrm{(NH_4)_2CO_3})\ V(\text{solution})^{-1} \\
&= \frac{1.0\ \mathrm{mol\ (NH_4)_2CO_3}}{\mathrm{L}} \left(\frac{1.0\ \mathrm{L}}{}\right) \left(\frac{2\ \mathrm{mol\ NH_4^+}}{\mathrm{mol\ (NH_4)_2CO_3}}\right) \left(\frac{1}{2.0\ \mathrm{L}}\right) \\
&= 1.0\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

$$\begin{aligned}
c(\mathrm{CO_3^{2-}}) &= n(\mathrm{CO_3^{2-}})\ V(\text{solution})^{-1} \\
&= n(\mathrm{(NH_4)_2CO_3})\ r(\mathrm{CO_3^{2-}}, \mathrm{(NH_4)_2CO_3})\ V(\text{solution})^{-1} \\
&= c(\mathrm{(NH_4)_2CO_3})\ V(\mathrm{(NH_4)_2CO_3})\ r(\mathrm{CO_3^{2-}}, \mathrm{(NH_4)_2CO_3})\ V(\text{solution})^{-1} \\
&= \frac{1.0\ \mathrm{mol\ (NH_4)_2CO_3}}{\mathrm{L}} \left(\frac{1.0\ \mathrm{L}}{}\right) \left(\frac{\mathrm{mol\ CO_3^{2-}}}{\mathrm{mol\ (NH_4)_2CO_3}}\right) \left(\frac{1}{2.0\ \mathrm{L}}\right) \\
&= 0.50\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

$$\begin{aligned}
c(\mathrm{K^+}) &= n(\mathrm{K^+})\ V(\text{solution})^{-1} \\
&= n(\mathrm{KClO_4})\ r(\mathrm{K^+}, \mathrm{KClO_4})\ V(\text{solution})^{-1} \\
&= c(\mathrm{KClO_4})\ V(\mathrm{KClO_4})\ r(\mathrm{K^+}, \mathrm{KClO_4})\ V(\text{solution})^{-1} \\
&= \frac{1.0\ \mathrm{mol\ KClO_4}}{\mathrm{L}} \left(\frac{1.0\ \mathrm{L}}{}\right) \left(\frac{\mathrm{mol\ K^+}}{\mathrm{mol\ KClO_4}}\right) \left(\frac{1}{2.0\ \mathrm{L}}\right) \\
&= 0.50\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

$$\begin{aligned}
c(\mathrm{ClO_4^-}) &= n(\mathrm{ClO_4^-})\ V(\text{solution})^{-1} \\
&= n(\mathrm{KClO_4})\ r(\mathrm{ClO_4^-}, \mathrm{KClO_4})\ V(\text{solution})^{-1} \\
&= c(\mathrm{KClO_4})\ V(\mathrm{KClO_4})\ r(\mathrm{ClO_4^-}, \mathrm{KClO_4})\ V(\text{solution})^{-1} \\
&= \frac{1.0\ \mathrm{mol\ KClO_4}}{\mathrm{L}} \left(\frac{1.0\ \mathrm{L}}{}\right) \left(\frac{\mathrm{mol\ ClO_4^-}}{\mathrm{mol\ KClO_4}}\right) \left(\frac{1}{2.0\ \mathrm{L}}\right) \\
&= 0.50\ \mathrm{mol\ L^{-1}}
\end{aligned}$$

`sec04-q0028-01.tex`

`Keyword:stoichiometry; molarity; dilution`

29. Determine the molar concentration (in g mol^{-1}) of the salt produced by a reaction between a 200. mL 0.100 M aqueous HCl solution with a 100. mL 0.50 M aqueous KOH solution.

A: 0.0667 M

$$HCl(aq) + KOH(aq) \longrightarrow H_2O(l) + KCl(aq)$$

Determine the limiting reactant.

$$\begin{aligned} n(\mathrm{KCl}) &= n(\mathrm{HCl})\ r(\mathrm{KCl},\mathrm{HCl}) \\ &= c(\mathrm{HCl})\ V(\mathrm{initial})\ r(\mathrm{KCl},\mathrm{HCl}) \\ &= \frac{0.100\ \mathrm{mol\ HCl}}{\mathrm{L}} \left(\frac{200.\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{\mathrm{mol\ KCl}}{\mathrm{mol\ HCl}}\right) \\ &= 0.0200\ \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{KCl}) &= n(\mathrm{KOH})\ r(\mathrm{KCl},\mathrm{KOH}) \\ &= c(\mathrm{KOH})\ V(\mathrm{initial})\ r(\mathrm{KCl},\mathrm{KOH}) \\ &= \frac{0.50\ \mathrm{mol\ KOH}}{\mathrm{L}} \left(\frac{100.\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{\mathrm{mol\ KCl}}{\mathrm{mol\ KOH}}\right) \\ &= 0.0500\ \mathrm{mol} \end{aligned}$$

KCl is the limiting reactant.

$$\begin{aligned} c(\mathrm{KCl}) &= n(\mathrm{KCl})\ V(\mathrm{final})^{-1} \\ &= 0.0200\ \mathrm{mol\ KCl} \left(\frac{1}{(200. + 100.)\ \mathrm{mL}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\ &= 0.0667\ \mathrm{mol\ L^{-1}} \end{aligned}$$

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sec04-q0029-01.tex
Keyword:stoichiometry; molarity; acid-base reaction; limiting reactant
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30. What volume (in mL) of a 0.100 M aqueous HNO_3 solution is required to neutralize a 50.0 mL 0.150 M aqueous $Ba(OH)_2$ solution?

A: 150. mL

$$2\ \mathrm{HNO_3(aq)} + \mathrm{Ba(OH)_2(aq)} \longrightarrow 2\ \mathrm{H_2O(l)} + \mathrm{Ba(NO_3)_2(aq)}$$

$$\begin{aligned} V(\mathrm{HNO_3}) &= n(\mathrm{HNO_3})\ c(\mathrm{HNO_3})^{-1} \\ &= n(\mathrm{Ba(OH)_2})\ r(\mathrm{HNO_3}, \mathrm{Ba(OH)_2})\ c(\mathrm{HNO_3})^{-1} \\ &= V(\mathrm{Ba(OH)_2})\ c(\mathrm{Ba(OH)_2})\ r(\mathrm{HNO_3}, \mathrm{Ba(OH)_2})\ c(\mathrm{HNO_3})^{-1} \\ &= 50.0\ \mathrm{mL\ Ba(OH)_2} \left(\frac{0.150\ \mathrm{mol\ Ba(OH)_2}}{\mathrm{L}}\right) \left(\frac{2\ \mathrm{mol\ HNO_3}}{\mathrm{mol\ Ba(OH)_2}}\right) \left(\frac{\mathrm{L}}{0.100\ \mathrm{mol}}\right) \\ &= 150.\ \mathrm{mL} \end{aligned}$$

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sec04-q0030-01.tex
Keyword:stoichiometry; molarity; acid-base reaction
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31. Hydrogen cyanide is produced industrally from a reaction between gaseous ammonia, oxygen, and methane.

$$2\,NH_3(g) + 3\,O_2(g) + 2\,CH_4(g) \longrightarrow 2\,HCN(g) + 6\,H_2O(l)$$

If 5.00×10^3 kg of each reactant react, what mass (in kg) of each product would be produced (assuming a 100 % yield)?

A: HCN: 2.82×10^3 kg; H_2O: 5.63×10^3 kg

Find the limiting reactant.

$$\begin{aligned} n(\mathrm{HCN}) &= n(\mathrm{NH_3})\ r(\mathrm{HCN,NH_3}) \\ &= m(\mathrm{NH_3})\ M(\mathrm{NH_3})^{-1}\ r(\mathrm{HCN,NH_3}) \\ &= 5.00 \times 10^3\ \mathrm{kg\ NH_3} \left(\frac{10^3\ \mathrm{g}}{\mathrm{kg}}\right) \left(\frac{\mathrm{mol\ NH_3}}{17.04\ \mathrm{g}}\right) \left(\frac{2\ \mathrm{mol\ HCN}}{2\ \mathrm{mol\ NH_3}}\right) \\ &= 2.9\bar{3}42 \times 10^5\ \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{HCN}) &= n(\mathrm{O_2})\ r(\mathrm{HCN,O_2}) \\ &= m(\mathrm{O_2})\ M(\mathrm{O_2})^{-1}\ r(\mathrm{HCN,O_2}) \\ &= 5.00 \times 10^3\ \mathrm{kg\ O_2} \left(\frac{10^3\ \mathrm{g}}{\mathrm{kg}}\right) \left(\frac{\mathrm{mol\ O_2}}{32.00\ \mathrm{g}}\right) \left(\frac{2\ \mathrm{mol\ HCN}}{3\ \mathrm{mol\ O_2}}\right) \\ &= 1.0\bar{4}16 \times 10^5\ \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{HCN}) &= n(\mathrm{CH_4})\ r(\mathrm{HCN,CH_4}) \\ &= m(\mathrm{CH_4})\ M(\mathrm{CH_4})^{-1}\ r(\mathrm{HCN,CH_4}) \\ &= 5.00 \times 10^3\ \mathrm{kg\ CH_4} \left(\frac{10^3\ \mathrm{g}}{\mathrm{kg}}\right) \left(\frac{\mathrm{mol\ CH_4}}{16.05\ \mathrm{g}}\right) \left(\frac{2\ \mathrm{mol\ HCN}}{2\ \mathrm{mol\ CH_4}}\right) \\ &= 3.1\bar{1}52 \times 10^5\ \mathrm{mol} \end{aligned}$$

O_2 is limiting.

$$\begin{aligned} m(\mathrm{HCN}) &= n(\mathrm{HCN})\ M(\mathrm{HCN}) \\ &= 1.0\bar{4}16 \times 10^5\ \mathrm{mol\ HCN} \left(\frac{27.03\ \mathrm{g}}{\mathrm{mol}}\right) \left(\frac{\mathrm{kg}}{10^3\ \mathrm{g}}\right) \\ &= 2.8\bar{1}54 \times 10^3\ \mathrm{kg} = 2.82 \times 10^3\ \mathrm{kg} \end{aligned}$$

$$\begin{aligned} m(\mathrm{H_2O}) &= n(\mathrm{H_2O})\ M(\mathrm{H_2O}) \\ &= n(\mathrm{HCN})\ r(\mathrm{H_2O,HCN})\ M(\mathrm{H_2O}) \\ &= 1.0\bar{4}16 \times 10^5\ \mathrm{mol\ HCN} \left(\frac{6\ \mathrm{mol\ H_2O}}{2\ \mathrm{mol\ HCN}}\right) \left(\frac{18.02\ \mathrm{g}}{\mathrm{mol}}\right) \left(\frac{\mathrm{kg}}{10^3\ \mathrm{g}}\right) \\ &= 5.6\bar{3}08 \times 10^3\ \mathrm{kg} = 5.63 \times 10^3\ \mathrm{kg} \end{aligned}$$

`sec04-q0031-01.tex`

`Keyword:stoichiometry; limiting reactant`

32. Acrylonitrile (C_3H_3N) is the starting material for many synthetic carpets and fabrics and is produced by the following reaction.

$$2\ C_3H_6(g) + 2\ NH_3(g) + 3\ O_2(g) \longrightarrow 2\ C_3H_3N(g) + 6\ H_2O(g)$$

If 15.0 g C_3H_6, 5.00 g NH_3, and 8.00 g O_2 react, what mass (in g) of acrylonitrile can be produced (assuming a 100 % yield)?

A: 11.1 g

Find the limiting reactant.

$$\begin{aligned}
n(C_3H_3N) &= n(C_3H_6)\ r(C_3H_3N, C_3H_6) \\
&= m(C_3H_6)\ M(C_3H_6)^{-1}\ r(C_3H_3N, C_3H_6) \\
&= 15.0\text{ g } C_3H_6 \left(\frac{\text{mol } C_3H_6}{53.07\text{ g}}\right)\left(\frac{2\text{ mol } C_3H_3N}{2\text{ mol } C_3H_6}\right) \\
&= 0.28\bar{2}64\text{ mol} \\
n(C_3H_3N) &= n(NH_3)\ r(C_3H_3N, NH_3) \\
&= m(NH_3)\ M(NH_3)^{-1}\ r(C_3H_3N, NH_3) \\
&= 5.00\text{ g } NH_3 \left(\frac{\text{mol } NH_3}{17.04\text{ g}}\right)\left(\frac{2\text{ mol } C_3H_3N}{2\text{ mol } NH_3}\right) \\
&= 0.29\bar{3}42\text{ mol} \\
n(C_3H_3N) &= n(O_2)\ r(C_3H_3N, O_2) \\
&= m(O_2)\ M(O_2)^{-1}\ r(C_3H_3N, O_2) \\
&= 8.00\text{ g } O_2 \left(\frac{\text{mol } O_2}{32.00\text{ g}}\right)\left(\frac{2\text{ mol } C_3H_3N}{3\text{ mol } O_2}\right) \\
&= 0.16\bar{6}66\text{ mol}
\end{aligned}$$

O_2 is limiting.

$$\begin{aligned}
m(C_3H_3N) &= n(C_3H_3N)\ M(C_3H_3N) \\
&= 0.16\bar{6}66\text{ mol mol } C_3H_3N \left(\frac{6\text{ mol } NH_3}{2\text{ mol } C_3H_3N}\right)\left(\frac{18.02\text{ g}}{\text{mol}}\right) \\
&= 8.8\bar{4}46\text{ g} = 8.84\text{ g}
\end{aligned}$$

`sec04-q0032-01.tex`

`Keyword:stoichiometry; limiting reactant`

33. Calcium chloride is a strong electrolyte and is used to "salt" streets in the winter to melt ice and snow. Write a net ionic reaction to show how this substance breaks apart when it dissolves in water.

$$\mathrm{CaCl_2(s) \longrightarrow Ca^{2+}(aq) + 2\ Cl^{-}(aq)}$$

`sec04-q0033-01.tex`
`Keyword:net ionic equation`

34. A solution of ethanol in water is prepared by dissolving 75.0 mL of ethanol (ρ = 0.79 g cm^{-3}) in enough water to make a 250.0 mL solution. What is the molar concentration (in mol L^{-1}) of the ethanol in this solution?

A: 5.14 *M*

$$\begin{aligned}
c(\mathrm{C_2H_6O}) &= n(\mathrm{C_2H_6O})\ V(\text{solution})^{-1} \\
&= m(\mathrm{C_2H_6O})\ M(\mathrm{C_2H_6O})^{-1}\ V(\text{solution})^{-1} \\
&= V(\mathrm{C_2H_6O})\ \rho(\mathrm{C_2H_6O})\ M(\mathrm{C_2H_6O})^{-1}\ V(\text{solution})^{-1} \\
&= 75.0\ \text{mL} \left(\frac{\text{cm}^3}{\text{mL}}\right) \left(\frac{0.79\ \text{g}}{\text{cm}^3}\right) \left(\frac{\text{mol C}_2\text{H}_6\text{O}}{46.08\ \text{g}}\right) \left(\frac{1}{250.0\ \text{mL}}\right) \left(\frac{10^3\ \text{mL}}{\text{L}}\right) \\
&= 5.1\bar{4}32\ \text{mol L}^{-1} = 5.14\ \text{mol L}^{-1}
\end{aligned}$$

`sec04-q0034-01.tex`
`Keyword:stoichiometry; molarity`

35. Which of the following aqueous solutions contains the largest number of ions?

A. 100.0 mL of 0.100 M NaOH
B. 50.0 mL of 0.200 M $BaCl_2$
C. 75.0 mL of 0.150 M Na_3PO_4

A: C

A: $\mathrm{NaOH(aq)} \longrightarrow \mathrm{Na^{+}(aq)} + \mathrm{OH^{-}(aq)}$

$$\begin{aligned} n(\mathrm{ions}) &= n(\mathrm{NaOH})\ r(\mathrm{ions, NaOH}) \\ &= c(\mathrm{NaOH})\ V(\mathrm{NaOH})\ r(\mathrm{ions, NaOH}) \\ &= \frac{0.100\ \mathrm{mol}}{\mathrm{L}} \left(\frac{100.0\ \mathrm{mL}}{1}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{2\ \mathrm{mol\ ions}}{\mathrm{mol\ NaOH}}\right) \\ &= 0.0200\ \mathrm{mol} \end{aligned}$$

B: $\mathrm{BaCl_2(aq)} \longrightarrow \mathrm{Ba^{2+}(aq)} + 2\ \mathrm{Cl^{-}(aq)}$

$$\begin{aligned} n(\mathrm{ions}) &= n(\mathrm{BaCl_2})\ r(\mathrm{ions, BaCl_2}) \\ &= c(\mathrm{BaCl_2})\ V(\mathrm{BaCl_2})\ r(\mathrm{ions, BaCl_2}) \\ &= \frac{0.200\ \mathrm{mol}}{\mathrm{L}} \left(\frac{50.0\ \mathrm{mL}}{1}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{3\ \mathrm{mol\ ions}}{\mathrm{mol\ BaCl_2}}\right) \\ &= 0.0300\ \mathrm{mol} \end{aligned}$$

C: $\mathrm{Na_3PO_4(aq)} \longrightarrow 3\ \mathrm{Na^{2}} + \mathrm{(aq)} + \mathrm{PO_4^{3-}(aq)}$

$$\begin{aligned} n(\mathrm{ions}) &= n(\mathrm{Na_3PO_4})\ r(\mathrm{ions, Na_3PO_4}) \\ &= c(\mathrm{Na_3PO_4})\ V(\mathrm{Na_3PO_4})\ r(\mathrm{ions, Na_3PO_4}) \\ &= \frac{0.150\ \mathrm{mol}}{\mathrm{L}} \left(\frac{75.0\ \mathrm{mL}}{1}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{4\ \mathrm{mol\ ions}}{\mathrm{mol\ Na_3PO_4}}\right) \\ &= 0.0450\ \mathrm{mol} \end{aligned}$$

C has the largest number of ions.

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sec04-q0035-01.tex
Keyword:stoichiometry; molarity; ions
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36. If 12.0 g of $AgNO_3$ is available, what volume (in L) of 0.25 M $AgNO_3$ can be prepared?

A: 0.28 L

$$\begin{aligned} V(\mathrm{AgNO_3}) &= n(\mathrm{AgNO_3})\ c(\mathrm{AgNO_3})^{-1} \\ &= m(\mathrm{AgNO_3})\ M(\mathrm{AgNO_3})^{-1}\ c(\mathrm{AgNO_3})^{-1} \\ &= 12.0\ \mathrm{g\ AgNO_3} \left(\frac{\mathrm{mol\ AgNO_3}}{169.88\ \mathrm{g}}\right) \left(\frac{\mathrm{L}}{0.25\ \mathrm{mol\ AgNO_3}}\right) \\ &= 0.2\bar{8}25\ \mathrm{L} = 0.28\ \mathrm{L} \end{aligned}$$

`sec04-q0036-01.tex`

`Keyword:stoichiometry; molarity`

37. A solution is prepared by dissolving 10.8 g ammonium sulfate in enough water to make 100.0 mL of stock solution. A 10.00 mL aliquot is taken and 50.00 mL of water is added. What is the molar concentration (in mol L^{-1}) of ammonium ions and sulfate ions in the final solution?

A: NH_4^+: 0.272 *M*; SO_4^{2-}: 0.136 *M*

$$\begin{aligned} c(\mathrm{NH_4^+}) &= n(\mathrm{NH_4^+})_{\text{dilute aliquot}}\ V(\text{dilute aliquot})^{-1} \\ &= n(\mathrm{NH_4^+})_{\text{stock solution}}\ V(\text{stock solution})^{-1}\ V(\text{aliquot})\ V(\text{dilute aliquot})^{-1} \\ &= m((\mathrm{NH_4})_2\mathrm{SO_4})\ M((\mathrm{NH_4})_2\mathrm{SO_4})^{-1}\ r(\mathrm{NH_4^+}, (\mathrm{NH_4})_2\mathrm{SO_4}) \\ &\quad V(\text{stock solution})^{-1}\ V(\text{aliquot})\ V(\text{dilute aliquot})^{-1} \\ &= 10.8\ \mathrm{g}\ (\mathrm{NH_4})_2\mathrm{SO_4} \left(\frac{\mathrm{mol}\ (\mathrm{NH_4})_2\mathrm{SO_4}}{132.16\ \mathrm{g}}\right) \left(\frac{2\ \mathrm{mol\ NH_4^+}}{\mathrm{mol}\ (\mathrm{NH_4})_2\mathrm{SO_4}}\right) \\ &\quad \left(\frac{1}{100.0\ \mathrm{mL}}\right) \left(\frac{10.0\ \mathrm{mL}}{}\right) \left(\frac{1}{60.0\ \mathrm{mL}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\ &= 0.27\bar{2}39\ \mathrm{mol\ L^{-1}} = 0.272\ \mathrm{mol\ L^{-1}} \end{aligned}$$

$$\begin{aligned} c(\mathrm{SO_4^{2-}}) &= n(\mathrm{SO_4^{2-}})_{\text{dilute aliquot}}\ V(\text{stock solution})^{-1} \\ &= n(\mathrm{SO_4^{2-}})_{\text{stock solution}}\ V(\text{stock solution})^{-1}\ V(\text{aliquot})\ V(\text{dilute aliquot})^{-1} \\ &= m((\mathrm{NH_4})_2\mathrm{SO_4})\ M((\mathrm{NH_4})_2\mathrm{SO_4})^{-1}\ r(\mathrm{SO_4^{2-}}, (\mathrm{NH_4})_2\mathrm{SO_4}) \\ &\quad V(\text{stock solution})^{-1}\ V(\text{aliquot})\ V(\text{dilute aliquot})^{-1} \\ &= 10.8\ \mathrm{g}\ (\mathrm{NH_4})_2\mathrm{SO_4} \left(\frac{\mathrm{mol}\ (\mathrm{NH_4})_2\mathrm{SO_4}}{132.16\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ SO_4^{2-}}}{\mathrm{mol}\ (\mathrm{NH_4})_2\mathrm{SO_4}}\right) \\ &\quad \left(\frac{1}{100.0\ \mathrm{mL}}\right) \left(\frac{10.0\ \mathrm{mL}}{}\right) \left(\frac{1}{60.0\ \mathrm{mL}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\ &= 0.13\bar{6}19\ \mathrm{mol\ L^{-1}} = 0.136\ \mathrm{mol\ L^{-1}} \end{aligned}$$

Alternatively,

$$\begin{aligned} c(\mathrm{SO_4^{2-}}) &= c(\mathrm{NH_4^+})_{\text{dilute aliquot}}\ r(\mathrm{SO_4^{2-}}, \mathrm{NH_4^+}) \\ &= \frac{0.27\bar{2}39\ \mathrm{mol}}{\mathrm{L}} \left(\frac{\mathrm{mol\ SO_4^{2-}}}{2\ \mathrm{mol\ NH_4^+}}\right) \\ &= 0.13\bar{6}19\ \mathrm{mol\ L^{-1}} = 0.136\ \mathrm{mol\ L^{-1}} \end{aligned}$$

`sec04-q0037-01.tex`

`Keyword:stoichiometry; molarity; dilution`

38. What mass (in g) of Na_2CrO_4 is required to precipitate all of the silver ions from a 75.0 mL 0.100 M aqueous solution of $AgNO_3$?

A: 0.607 g

$$\mathrm{Na_2CrO_4(aq) + 2\ AgNO_3(aq) \longrightarrow 2\ NaNO_3(aq) + Ag_2CrO_4(\mathit{s})}$$

$$\begin{aligned} m(\mathrm{Na_2CrO_4}) &= n(\mathrm{Na_2CrO_4})\ M(\mathrm{Na_2CrO_4}) \\ &= n(\mathrm{AgNO_3})\ r(\mathrm{Na_2CrO_4}, \mathrm{AgNO_3})\ M(\mathrm{Na_2CrO_4}) \\ &= c(\mathrm{AgNO_3})\ V(\mathrm{AgNO_3})\ r(\mathrm{Na_2CrO_4}, \mathrm{AgNO_3})\ M(\mathrm{Na_2CrO_4}) \\ &= \frac{0.100\ \mathrm{mol\ AgNO_3}}{\mathrm{L}} \left(\frac{75.0\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{\mathrm{mol\ Na_2CrO_4}}{2\ \mathrm{mol\ AgNO_3}}\right) \left(\frac{161.98\ \mathrm{g\ Na_2CrO_4}}{\mathrm{mol}}\right) \\ &= 0.60\bar{7}42\ \mathrm{g} = 0.607\ \mathrm{g} \end{aligned}$$

sec04-q0038-01.tex

Keyword:stoichiometry; molarity; precipitation

Exam 2 Review: Stoichiometry and Molarity

39. What mass (in g) of iron(III) hydroxide precipitate can be produced by reacting a 72.0 mL 0.105 *M* aqueous iron(III) nitrate solution with a 125 mL 0.150 *M* aqueous sodium hydroxide solution?

A: 0.668 g

$$\mathrm{Fe(NO_3)_3(aq) + 3\ NaOH(aq) \longrightarrow Fe(OH)_3(s) + 3\ NaNO_3(aq)}$$

Determine the limiting reactant.

$$\begin{aligned}
n(\mathrm{Fe(OH)_3}) &= n(\mathrm{Fe(NO_3)_3})\ r(\mathrm{Fe(OH)_3, Fe(NO_3)_3}) \\
&= c(\mathrm{Fe(NO_3)_3})\ V(\text{initial})\ r(\mathrm{Fe(OH)_3, Fe(NO_3)_3}) \\
&= \frac{0.105\ \text{mol Fe(NO}_3)_3}{\text{L}} \left(\frac{72.0\ \text{mL}}{}\right) \left(\frac{\text{L}}{10^3\ \text{mL}}\right) \left(\frac{\text{mol Fe(OH)}_3}{\text{mol Fe(NO}_3)_3}\right) \\
&= 7.5\bar{6}00 \times 10^{-3}\ \text{mol}
\end{aligned}$$

$$\begin{aligned}
n(\mathrm{Fe(OH)_3}) &= n(\mathrm{NaOH})\ r(\mathrm{Fe(OH)_3, NaOH}) \\
&= c(\mathrm{NaOH})\ V(\text{initial})\ r(\mathrm{Fe(OH)_3, NaOH}) \\
&= \frac{0.150\ \text{mol NaOH}}{\text{L}} \left(\frac{125\ \text{mL}}{}\right) \left(\frac{\text{L}}{10^3\ \text{mL}}\right) \left(\frac{\text{mol Fe(OH)}_3}{3\ \text{mol NaOH}}\right) \\
&= 6.2\bar{5}00 \times 10^{-3}\ \text{mol}
\end{aligned}$$

NaOH is limiting.

$$\begin{aligned}
m(\mathrm{Fe(OH)_3}) &= n(\mathrm{Fe(OH)_3})\ M(\mathrm{Fe(OH)_3}) \\
&= 6.2\bar{5}00 \times 10^{-3}\ \text{mol Fe(OH)}_3 \left(\frac{106.88\ \text{g Fe(OH)}_3}{\text{mol}}\right) \\
&= 0.66\bar{8}00\ \text{g} = 0.668\ \text{g}
\end{aligned}$$

sec04-q0039-01.tex

Keyword:stoichiometry; molarity; precipitation; limiting reactant

40. A 100.0 mL 0.200 *M* aqueous potassium hydroxide solution is mixed with a 100.0 mL 0.200 *M* aqueous magnesium nitrate solution.

A. Write a balanced chemical equation for the reaction that occurs.
B. Determine the precipitate that forms (if any).
C. Determine the mass (in g) of precipitate that forms (if any).
D. Determine the molar concentration (in g mol^{-1}) of each ion in solution after the reaction goes to 100 % completion. Assume the volume change of the solution is negligible.

A:

$$2\ \mathrm{KOH(aq)} + \mathrm{Mg(NO_3)_2(aq)} \longrightarrow 2\ \mathrm{KNO_3(aq)} + \mathrm{Mg(OH)_2(s)}$$

B: $Mg(OH)_2$
C: Determine the limiting reactant.

$$\begin{aligned} n(\mathrm{Mg(OH)_2}) &= c(\mathrm{KOH})\ V(\mathrm{initial})\ r(\mathrm{Mg(OH)_2}, \mathrm{KOH}) \\ &= \frac{0.200\ \mathrm{mol\ KOH}}{\mathrm{L}} \left(\frac{100.0\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{\mathrm{mol\ Mg(OH)_2}}{2\ \mathrm{mol\ KOH}}\right) \\ &= 0.0100\ \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{Mg(OH)_2}) &= c(\mathrm{Mg(NO_3)_2})\ V(\mathrm{initial})\ r(\mathrm{Mg(OH)_2}, \mathrm{Mg(NO_3)_2}) \\ &= \frac{0.200\ \mathrm{mol\ Mg(NO_3)_2}}{\mathrm{L}} \left(\frac{100.0\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{\mathrm{mol\ Mg(OH)_2}}{\mathrm{mol\ Mg(NO_3)_2}}\right) \\ &= 0.0200\ \mathrm{mol} \end{aligned}$$

KOH is limiting.

$$\begin{aligned} m(\mathrm{Mg(OH)_2}) &= n(\mathrm{Mg(OH)_2})\ M(\mathrm{Mg(OH)_2}) \\ &= 0.0100\ \mathrm{mol\ Mg(OH)_2} \left(\frac{58.33\ \mathrm{g\ Mg(OH)_2}}{\mathrm{mol}}\right) \\ &= 0.58\bar{3}30\ \mathrm{g} = 0.583\ \mathrm{g} \end{aligned}$$

D:

$$\begin{aligned} c(\mathrm{K^+}) &= n(\mathrm{K^+})\ V(\mathrm{solution})^{-1} \\ &= n(\mathrm{KOH})\ r(\mathrm{K^+}, \mathrm{KOH}) V(\mathrm{solution})^{-1} \\ &= c(\mathrm{KOH})\ V(\mathrm{KOH})\ r(\mathrm{K^+}, \mathrm{KOH}) V(\mathrm{solution})^{-1} \\ &= \frac{0.200\ \mathrm{mol\ KOH}}{\mathrm{L}} \left(\frac{100.0\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{mol\ K^+}}{\mathrm{mol\ KOH}}\right) \left(\frac{1}{(100.0 + 100.0)\ \mathrm{mL}}\right) \\ &= 0.100\ \mathrm{mol\ L^{-1}} \end{aligned}$$

$$c(\mathrm{OH^-}) = 0 \text{ since KOH is limiting and all hydroxide precipitates as } \mathrm{Mg(OH)_2}$$

$$\begin{aligned} c(\mathrm{Mg^{2+}})_{\mathrm{final}} &= n(\mathrm{Mg^{2+}})\ V(\mathrm{solution})^{-1} \\ &= \left\{ n(\mathrm{Mg(NO_3)_2})_{\mathrm{initial}} - n(\mathrm{Mg(NO_3)_2})_{\mathrm{reacted}} \right\} r(\mathrm{Mg^{2+}}, \mathrm{Mg(NO_3)_2})\ V(\mathrm{solution})^{-1} \\ &= \left\{ \left[c(\mathrm{Mg(NO_3)_2})\ V(\mathrm{Mg(NO_3)_2}) \right] - \left[n(\mathrm{Mg(OH)_2})_{\mathrm{formed}}\ r(\mathrm{Mg(NO_3)_2}, \mathrm{Mg(OH)_2}) \right] \right\} r(\mathrm{Mg^{2+}}, \mathrm{Mg(NO_3)_2})\ V(\mathrm{solution})^{-1} \\ &= \left\{ \left[\left(\frac{0.200\ \mathrm{mol\ Mg(NO_3)_2}}{\mathrm{L}}\right) \left(\frac{100.0\ \mathrm{mL\ Mg(NO_3)_2}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \right] - \left[\left(\frac{0.0100\ \mathrm{mol\ Mg(OH)_2}}{}\right) \left(\frac{\mathrm{mol\ Mg(NO_3)_2}}{\mathrm{mol\ Mg(OH)_2}}\right) \right] \right\} \\ &\quad \left(\frac{\mathrm{mol\ Mg^{2+}}}{\mathrm{mol\ Mg(NO_3)_2}}\right) \left(\frac{1}{(100.0 + 100.0)\ \mathrm{mL}}\right) \left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\ &= 0.0500\ \mathrm{mol\ L^{-1}} \end{aligned}$$

$$\begin{aligned} c(\mathrm{NO_3^-}) &= n(\mathrm{NO_3^-})\ V(\mathrm{solution})^{-1} \\ &= n(\mathrm{Mg(NO_3)_2})\ r(\mathrm{NO_3^-}, \mathrm{Mg(NO_3)_2}) V(\mathrm{solution})^{-1} \\ &= c(\mathrm{Mg(NO_3)_2})\ V(\mathrm{Mg(NO_3)_2})\ r(\mathrm{NO_3^-}, \mathrm{Mg(NO_3)_2}) V(\mathrm{solution})^{-1} \\ &= \frac{0.200\ \mathrm{mol\ Mg(NO_3)_2}}{\mathrm{L}} \left(\frac{100.0\ \mathrm{mL}}{}\right) \left(\frac{2\ \mathrm{mol\ NO_3^-}}{\mathrm{mol\ Mg(NO_3)_2}}\right) \left(\frac{1}{(100.0 + 100.0)\ \mathrm{mL}}\right) \\ &= 0.200\ \mathrm{mol\ L^{-1}} \end{aligned}$$

Keyword:balancing equations; stoichiometry; molarity; precipitation; limiting reactant

41. A 1.42 g sample of a pure, metal (M) containing compound (M_2SO_4) was dissolved in water and treated with an excess of aqueous calcium chloride. All the sulfate ions precipitated as calcium sulfate which was collected, dried, and found to be 1.36 g. What is the identity and standard atomic weight of the metal?

A: Na; 23.0

$$\mathrm{M_2SO_4(aq) + CaCl_2(aq) \longrightarrow CaSO_4(s) + 2\,MCl(aq)}$$

$$\begin{aligned}
M(\mathrm{M^+}) &= m(\mathrm{M^+})\, n(\mathrm{M^+})^{-1} \\
&= \left\{m(\mathrm{M_2SO_4}) - m(\mathrm{SO_4^{2-}})\right\} \left\{n(\mathrm{M_2SO_4})\, r(\mathrm{M_2SO_4, SO_4^{2-}})\, r(\mathrm{M^+, M_2SO_4})\right\}^{-1} M_\mathrm{u} \\
&= \left\{m(\mathrm{M_2SO_4}) - m(\mathrm{SO_4^{2-}})\right\} \left\{n(\mathrm{CaSO_4})\, r(\mathrm{SO_4^{2-}, CaSO_4})\, r(\mathrm{M_2SO_4, SO_4^{2-}})\, r(\mathrm{M^+, M_2SO_4})\right\}^{-1} M_\mathrm{u} \\
&= \left\{m(\mathrm{M_2SO_4}) - \left[m(\mathrm{CaSO_4})\, M(\mathrm{CaSO_4})^{-1}\, r(\mathrm{SO_4^{2-}, CaSO_4})\right]\right\} \\
&\quad \left\{m(\mathrm{CaSO_4})\, M(\mathrm{CaSO_4})^{-1}\, r(\mathrm{M_2SO_4, CaSO_4})\, r(\mathrm{M_2SO_4, SO_4^{2-}})\, r(\mathrm{M^+, M_2SO_4})\right\}^{-1} M_\mathrm{u} \\
&= \left\{1.42\ \mathrm{g\ M_2SO_4} - \left[1.36\ \mathrm{g\ CaSO_4} \left(\frac{\mathrm{mol\ CaSO_4}}{136.14\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ SO_4^{2-}}}{\mathrm{mol\ CaSO_4}}\right) \left(\frac{96.06\ \mathrm{g}}{\mathrm{mol\ SO_4^{2-}}}\right)\right]\right\} \\
&\quad \left\{1.36\ \mathrm{g\ CaSO_4} \left(\frac{\mathrm{mol\ CaSO_4}}{136.14\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ SO_4^{2-}}}{\mathrm{mol\ CaSO_4}}\right) \left(\frac{\mathrm{mol\ M_2SO_4}}{\mathrm{mol\ SO_4^{2-}}}\right) \left(\frac{2\ \mathrm{mol\ M^+}}{\mathrm{mol\ M_2SO_4}}\right)\right\}^{-1} \left(\frac{\mathrm{mol}}{\mathrm{g}}\right) \\
&= \frac{0.46\bar{0}38\ \mathrm{g}}{0.019\bar{9}79\ \mathrm{mol}} \left(\frac{\mathrm{mol}}{\mathrm{g}}\right) \\
&= 23.\bar{0}43 = 23.0
\end{aligned}$$

The metal is sodium (Na).

sec04-q0041-01.tex

Keyword:stoichiometry; molarity; precipitation; molar mass

42. What volume (in mL) of each of the following bases will will completely react with 25.0 mL of 0.200 *M* HCl?

   A. 0.100 *M* NaOH
   B. 0.0500 *M* $Sr(OH)_2$
   C. 0.250 *M* KOH

A: 50.0 mL; 50.0 mL; 20.0 mL

A: $HCl(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaCl(aq)$

$$\begin{aligned} V(\mathrm{NaOH}) &= n(\mathrm{NaOH})\ c(\mathrm{NaOH})^{-1} \\ &= n(\mathrm{HCl})\ r(\mathrm{NaOH}, \mathrm{HCl})\ c(\mathrm{NaOH})^{-1} \\ &= c(\mathrm{HCl})\ V(\mathrm{HCl})\ r(\mathrm{NaOH}, \mathrm{HCl})\ c(\mathrm{NaOH})^{-1} \\ &= \frac{0.200\ \mathrm{mol\ NaOH}}{\mathrm{L}} \left(\frac{25.0\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{mol\ NaOH}}{\mathrm{mol\ HCl}}\right) \left(\frac{\mathrm{L}}{0.100\ \mathrm{mol\ NaOH}}\right) \\ &= 50.0\ \mathrm{mL} \end{aligned}$$

B: $2\ HCl(aq) + Sr(OH)_2(aq) \longrightarrow 2\ H_2O(l) + SrCl_2(aq)$

$$\begin{aligned} V(\mathrm{Sr(OH)_2}) &= n(\mathrm{Sr(OH)_2})\ c(\mathrm{Sr(OH)_2})^{-1} \\ &= n(\mathrm{HCl})\ r(\mathrm{Sr(OH)_2}, \mathrm{HCl})\ c(\mathrm{Sr(OH)_2})^{-1} \\ &= c(\mathrm{HCl})\ V(\mathrm{HCl})\ r(\mathrm{Sr(OH)_2}, \mathrm{HCl})\ c(\mathrm{Sr(OH)_2})^{-1} \\ &= \frac{0.200\ \mathrm{mol\ NaOH}}{\mathrm{L}} \left(\frac{25.0\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{mol\ Sr(OH)_2}}{2\ \mathrm{mol\ HCl}}\right) \left(\frac{\mathrm{L}}{0.0500\ \mathrm{mol\ Sr(OH)_2}}\right) \\ &= 50.0\ \mathrm{mL} \end{aligned}$$

C: $HCl(aq) + KOH(aq) \longrightarrow H_2O(l) + KCl(aq)$

$$\begin{aligned} V(\mathrm{KOH}) &= n(\mathrm{KOH})\ c(\mathrm{KOH})^{-1} \\ &= n(\mathrm{HCl})\ r(\mathrm{KOH}, \mathrm{HCl})\ c(\mathrm{KOH})^{-1} \\ &= c(\mathrm{HCl})\ V(\mathrm{HCl})\ r(\mathrm{KOH}, \mathrm{HCl})\ c(\mathrm{KOH})^{-1} \\ &= \frac{0.200\ \mathrm{mol\ NaOH}}{\mathrm{L}} \left(\frac{25.0\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{mol\ KOH}}{\mathrm{mol\ HCl}}\right) \left(\frac{\mathrm{L}}{0.250\ \mathrm{mol\ KOH}}\right) \\ &= 20.0\ \mathrm{mL} \end{aligned}$$

`sec04-q0042-01.tex`
`Keyword:balancing equations; stoichiometry; molarity; acid-base reaction`

43. A 25.0 mL sample of HCl(aq) requires 24.16 mL of 0.106 *M* NaOH for complete neutralization. What is the molar concentration (in mol L^{-1}) of the original HCl(aq) solution?

A: 0.102 *M*

$$\mathrm{HCl(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaCl(aq)}$$

$$\begin{aligned} c(\mathrm{HCl}) &= n(\mathrm{HCl})\ V(\mathrm{HCl})^{-1} \\ &= n(\mathrm{NaOH})\ r(\mathrm{HCl, NaOH})\ V(\mathrm{HCl})^{-1} \\ &= c(\mathrm{NaOH})\ V(\mathrm{NaOH})\ r(\mathrm{HCl, NaOH})\ V(\mathrm{HCl})^{-1} \\ &= \frac{0.106\ \mathrm{mol\ NaOH}}{\mathrm{L}} \left(\frac{24.16\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{\mathrm{mol\ HCl}}{\mathrm{mol\ NaOH}}\right) \left(\frac{1}{25.0\ \mathrm{mL\ HCl}}\right) \\ &= 0.102\ \mathrm{mol\ L^{-1}} \end{aligned}$$

sec04-q0043-01.tex

Keyword:balancing equations; stoichiometry; molarity; acid-base reaction

44. 5.00 g of barium chloride was added to 225 mL of a 1.40 *M* solution of sodium sulfide.

A. Write the balanced molecular equation and include phase labels.
B. Write the full ionic equation and include phase labels.
C. Write the net ionic equation and include phase labels. If there is no net ionic equation, write "no net ionic equation."
D. Indicate the pricipitate (if any).
E. Determine the limiting reactant.

A: *Molecular equation:*

$$\mathrm{BaCl_2(aq) + Na_2S(aq) \longrightarrow BaS(aq) + 2\ NaCl(aq)}$$

B: *Complete ionic equation:*

$$\mathrm{Ba^{2+}(aq) + 2\ Cl^-(aq) + 2\ Na^+(aq) + S^{2-}(aq) \longrightarrow Ba^{2+}(aq) + S^{2-}(aq) + 2\ Na^+(aq) + 2\ Cl^-(aq)}$$

C: *Net ionic equation:*

no net ionic equation

D: There is no precipitate.

E:

$$\begin{aligned} n(\mathrm{BaS}) &= n(\mathrm{BaCl_2})\ r(\mathrm{BaS, BaCl_2}) \\ &= m(\mathrm{BaCl_2})\ M(\mathrm{BaCl_2})\ r(\mathrm{BaS, BaCl_2}) \\ &= 5.00\ \mathrm{g\ BaCl_2} \left(\frac{\mathrm{mol\ BaCl_2}}{208.23\ \mathrm{g}}\right) \left(\frac{\mathrm{mol\ BaS}}{\mathrm{mol\ BaCl_2}}\right) \\ &= 0.024\bar{0}11\ \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{BaS}) &= n(\mathrm{Na_2S})\ r(\mathrm{BaS, Na_2S}) \\ &= c(\mathrm{Na_2S})\ V(\mathrm{initial})\ r(\mathrm{BaS, Na_2S}) \\ &= \frac{1.40\ \mathrm{mol\ Na_2S}}{\mathrm{L}} \left(\frac{225\ \mathrm{mL}}{}\right) \left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right) \left(\frac{\mathrm{mol\ BaS}}{\mathrm{mol\ Na_2S}}\right) \\ &= 0.31\bar{5}00\ \mathrm{mol} \end{aligned}$$

$BaCl_2$ is limiting.

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sec04-q0044-01.tex
Keyword:balancing equations; stoichiometry; molarity; limiting reactant;
double-displacement reaction
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45. A precipitate forms when titanium(IV) chloride is added to water. Two water molecules react and form four HCl molecules. What is the identity of the precipitate?

A. What is the identity of the precipitate?
B. What is the molar concentration (in mol L^{-1}) of H^+ ions if 2.00 g of $TiCl_4$ was added to enough water to give a 100.0 mL solution?

A: $TiCl_4$; 0.422 *M*

A:

$$TiCl_4(s) + 2\,H_2O(l) \longrightarrow 4\,HCl(aq) + TiO_2(s)$$

$$TiO_2(s)$$

B:

$$\begin{aligned} c(H^+) &= n(H^+)\ V(\text{solution})^{-1} \\ &= n(HCl)\ r(H^+, HCl)\ V(\text{solution})^{-1} \\ &= n(TiCl_4)\ r(HCl, TiCl_4)\ r(H^+, HCl)\ V(\text{solution})^{-1} \\ &= m(TiCl_4)\ M(TiCl_4)^{-1}\ r(HCl, TiCl_4)\ r(H^+, HCl)\ V(\text{solution})^{-1} \\ &= 2.00\text{ g } TiCl_4 \left(\frac{\text{mol } TiCl_4}{189.67\text{ g}}\right)\left(\frac{4\text{ mol HCl}}{\text{mol } TiCl_4}\right)\left(\frac{\text{mol } H^+}{\text{mol HCl}}\right)\left[100.0\text{ mL}\left(\frac{\text{L}}{10^3\text{ mL}}\right)\right]^{-1} \\ &= 0.42\bar{1}78\text{ mol L}^{-1} = 0.422\text{ mol L}^{-1} \end{aligned}$$

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sec04-q0045-01.tex
Keyword:balancing equations; stoichiometry; molarity
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Exam 2 Review: Stoichiometry and Molarity

46. A 123 mL sample of 0.210 M aqueous magnesium chloride forms a precipitate when mixed with 324 mL 0.120 M aqueous sodium hydroxide.

A. How much (in g) precipitate is formed?
B. What is the molar concentration (in mol L^{-1}) of the magnesium(2+) ion?
C. What is the molar concentration (in mol L^{-1}) of the sodium(1+) ion?

A: 1.13 g; 0.0286 M; 0.0870 M

$$\mathrm{MgCl_2(aq) + 2\,NaOH(aq) \longrightarrow 2\,NaCl(aq) + Mg(OH)_2(s)}$$

A: Find the limiting reactant

$$\begin{aligned} n(\mathrm{Mg(OH)_2}) &= n(\mathrm{MgCl_2})\ r(\mathrm{Mg(OH)_2, MgCl_2}) \\ &= c(\mathrm{MgCl_2})\ V(\mathrm{MgCl_2})\ r(\mathrm{Mg(OH)_2, MgCl_2}) \\ &= \frac{0.210\ \mathrm{mol\ MgCl_2}}{\mathrm{L}}\left(\frac{123\ \mathrm{mL}}{}\right)\left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right)\left(\frac{\mathrm{mol\ Mg(OH)_2}}{\mathrm{mol\ MgCl_2}}\right) \\ &= 0.025\bar{8}3\ \mathrm{mol} \end{aligned}$$

$$\begin{aligned} n(\mathrm{Mg(OH)_2}) &= n(\mathrm{NaOH})\ r(\mathrm{Mg(OH)_2, NaOH}) \\ &= c(\mathrm{NaOH})\ V(\mathrm{NaOH})\ r(\mathrm{Mg(OH)_2, NaOH}) \\ &= \frac{0.120\ \mathrm{mol\ NaOH}}{\mathrm{L}}\left(\frac{324\ \mathrm{mL}}{}\right)\left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right)\left(\frac{\mathrm{mol\ Mg(OH)_2}}{2\ \mathrm{mol\ NaOH}}\right) \\ &= 0.019\bar{4}40\ \mathrm{mol} \end{aligned}$$

NaOH is limiting.

$$\begin{aligned} m(\mathrm{Mg(OH)_2}) &= n(\mathrm{Mg(OH)_2})\ M(\mathrm{Mg(OH)_2})^{-1} \\ &= 0.019\bar{4}40\ \mathrm{mol\ Mg(OH)_2}\left(\frac{58.33\ \mathrm{g\ Mg(OH)_2}}{\mathrm{mol}}\right) \\ &= 1.1\bar{3}39\ \mathrm{g} = 1.13\ \mathrm{g} \end{aligned}$$

B:

$$\begin{aligned} c(\mathrm{Mg^{2+}}) &= n(\mathrm{Mg^{2+}})\ V(\mathrm{solution})^{-1} \\ &= \left\{n(\mathrm{Mg^{2+}})_{\mathrm{initial}} - n(\mathrm{Mg^{2+}})_{\mathrm{reacted}}\right\} V(\mathrm{solution})^{-1} \\ &= \left\{\left[n(\mathrm{MgCl_2})_{\mathrm{initial}}\ r(\mathrm{Mg^{2+}, MgCl_2})\right] - \left[n(\mathrm{MgCl_2})_{\mathrm{final}}\ r(\mathrm{Mg^{2+}, MgCl_2})\right]\right\} V(\mathrm{solution})^{-1} \\ &= \left\{\left[n(\mathrm{Mg^{2+}})_{\mathrm{initial}}\ r(\mathrm{Cl^-, MgCl_2})\right] - \left[n(\mathrm{Mg(OH)_2})\ r(\mathrm{MgCl_2, Mg(OH)_2})\ r(\mathrm{Mg^{2+}, MgCl_2})\right]\right\} V(\mathrm{solution})^{-1} \\ &= \left\{\left[c(\mathrm{MgCl_2})_{\mathrm{initial}}\ V(\mathrm{MgCl_2})\ r(\mathrm{Mg^{2+}, MgCl_2})\right] - \left[n(\mathrm{Mg(OH)_2})\ r(\mathrm{MgCl_2, Mg(OH)_2})\ r(\mathrm{Mg^{2+}, MgCl_2})\right]\right\} \\ &\quad V(\mathrm{solution})^{-1} \\ &= \left\{\left[\frac{0.210\ \mathrm{mol\ MgCl_2}}{\mathrm{L}}\left(\frac{123\ \mathrm{mL}}{}\right)\left(\frac{\mathrm{L}}{10^3\ \mathrm{mL}}\right)\left(\frac{\mathrm{mol\ Mg^{2+}}}{\mathrm{mol\ MgCl_2}}\right)\right] - \right. \\ &\quad \left.\left[0.019\bar{4}40\ \mathrm{mol\ Mg(OH)_2}\left(\frac{\mathrm{mol\ MgCl_2}}{\mathrm{mol\ Mg(OH)_2}}\right)\left(\frac{\mathrm{mol\ Mg^{2+}}}{\mathrm{mol\ MgCl_2}}\right)\right]\right\}\left(\frac{1}{(123+324)\ \mathrm{mL}}\right)\left(\frac{10^3\ \mathrm{mL}}{\mathrm{L}}\right) \\ &= 0.014\bar{2}95\ \mathrm{mol\ L^{-1}} = 0.0143\ \mathrm{mol\ L^{-1}} \end{aligned}$$

C:

$$\begin{aligned} c(\mathrm{Na^+}) &= n(\mathrm{Na^+})\ V(\mathrm{solution})^{-1} \\ &= n(\mathrm{NaOH})_{\mathrm{initial}}\ r(\mathrm{Na^+, NaOH})\ V(\mathrm{solution})^{-1} \\ &= c(\mathrm{NaOH})_{\mathrm{initial}}\ V(\mathrm{NaOH})_{\mathrm{initial}}\ r(\mathrm{Na^+, NaOH})\ V(\mathrm{solution})^{-1} \\ &= \frac{0.120\ \mathrm{mol\ NaOH}}{\mathrm{L}}\left(\frac{324\ \mathrm{mL}}{}\right)\left(\frac{\mathrm{mol\ Na^+}}{\mathrm{mol\ NaOH}}\right)\left(\frac{1}{(123+324)\ \mathrm{mL}}\right) \\ &= 0.086\bar{9}79\ \mathrm{mol\ L^{-1}} = 0.0870\ \mathrm{mol\ L^{-1}} \end{aligned}$$

sec04-q0046-01.tex
Keyword:balancing equations; stoichiometry; molarity

47. If 275 mL of a 0.125 M aqueous NaCl solution and 375 mL of a 0.575 M aqueous Na_2SO_4 solution are mixed, determine the molar concentrations (in mol L^{-1}) of the following:

A. chloride ions
B. sulfate ions
C. sodium ions

A: 0.0481 *M*; 0.332 *M*; 0.712 *M*

$$NaCl(aq) + Na_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + NaCl(aq)$$

All compounds are soluble and there is no net ionic equation. Can determine ion molar concentrations without determining the limiting reactant.

A

$$\begin{aligned} c(Cl^-) &= n(Cl^-)\ V(\text{solution})^{-1} \\ &= c(NaCl)\ V(NaCl)\ r(Cl^-, NaCl)\ V(\text{solution})^{-1} \\ &= \frac{0.125 \text{ mol } MgCl_2}{L} \left(\frac{250.\text{ mL}}{}\right) \left(\frac{\text{mol } Cl^-}{\text{mol NaOH}}\right) \left(\frac{1}{(275+375)\text{ mL}}\right) \\ &= 0.048\bar{0}76 \text{ mol } L^{-1} = 0.0481 \text{ mol } L^{-1} \end{aligned}$$

B

$$\begin{aligned} c(SO_4^{2-}) &= n(SO_4^{2-})\ V(\text{solution})^{-1} \\ &= c(Na_2SO_4)\ V(Na_2SO_4)\ r(SO_4^{2-}, Na_2SO_4)\ V(\text{solution})^{-1} \\ &= \frac{0.575 \text{ mol } Na_2SO_4}{L} \left(\frac{375 \text{ mL}}{}\right) \left(\frac{\text{mol } SO_4^{2-}}{\text{mol } Na_2SO_4}\right) \left(\frac{1}{(275+375)\text{ mL}}\right) \\ &= 0.33\bar{1}73 \text{ mol } L^{-1} = 0.332 \text{ mol } L^{-1} \end{aligned}$$

C

$$\begin{aligned} c(Na^+) &= n(Na^+)\ V(\text{solution})^{-1} \\ &= \left\{ n(NaCl) + n(Na_2SO_4) \right\} V(\text{solution})^{-1} \\ &= \left\{ \left[c(NaCl)\ V(NaCl)\ r(Na^+, NaCl) \right] + \left[c(Na_2SO_4)\ V(Na_2SO_4)\ r(Na^+, Na_2SO_4) \right] \right\} V(\text{solution})^{-1} \\ &= \left\{ \left[\frac{0.125 \text{ mol NaCl}}{L} \left(\frac{250.\text{ mL}}{}\right) \left(\frac{\text{mol } Na^+}{\text{mol NaCl}}\right) \right] + \left[\frac{0.575 \text{ mol } Na_2SO_4}{L} \left(\frac{375 \text{ mL}}{}\right) \left(\frac{2 \text{ mol } Na^+}{\text{mol } Na_2SO_4}\right) \right] \right\} \\ &\quad \left(\frac{1}{(275+375)\text{ mL}}\right) \\ &= 0.71\bar{1}53 \text{ mol } L^{-1} = 0.712 \text{ mol } L^{-1} \end{aligned}$$

sec04-q0047-01.tex
Keyword:balancing equations; stoichiometry; molarity

Exam 2 Review: Thermochemistry Basics

1. Sugar is melted in a pot and its temperature is measured as it heats. In this scenario, what is the system?

   A. the pot and sugar
   B. the stove
   C. the entire kitchen
   D. the rest of the universe

   A

   `sec05-q0001-01.tex`
   `Keyword:thermochemistry basics`

2. Which of the following is not a type of potential energy (select all that apply)?

   A. Energy held in chemical bonds
   B. Energy resulting from intramolecular attractions
   C. Energy from the random motion of molecules
   D. Energy of a ball dropping from a height

   C, D

   `sec05-q0002-01.tex`
   `Keyword:thermochemistry basics`

3. Which of the following is true of heat (select all that apply)?

   A. Heat is a form of thermal energy.
   B. Heat is the transfer of thermal energy.
   C. Heat is the action of forces through a distance.
   D. A negative heat in the system means the surroundings loses energy.
   E. A negative heat in the system means the system loses energy.

   B, E

   `sec05-q0003-01.tex`
   `Keyword:thermochemistry basics`

4. Which of the following are false (select all that apply)?

   A. Energy can be converted from one type to another.
   B. Energy is the capacity to do work.
   C. Kinetic energy is energy resulting from condition, position, or composition.
   D. Potential energy is energy transferred between a system and its surroundings as a result of a temperature difference.

   C, D

   `sec05-q0004-01.tex`
   `Keyword:thermochemistry basics`

5. A block of ice absorbs heat and melts. The value q for the system is:

   A. Positive
   B. Negative
   C. Zero
   D. There is not enough information to determine.

   A

   `sec05-q0005-01.tex`
   `Keyword:thermochemistry basics`

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