KEY

Stoichiometry & Molar Concentrations

Name - _______________

1.) A student wants to put $50.0\ L$ of hydrogen gas at STP into a plastic bag by reacting excess aluminum metal with $3.00\ M$ of sodium hydroxide solution according to the reaction below. What volume of NaOH solution is required?

$$\_2\_\ Al_{(s)} + \_2\_\ NaOH_{(aq)} + \_2\_\ H_2O_{(l)} \rightarrow \_2\_\ NaAlO_{2\,(aq)} + \_3\_\ H_{2\,(g)}$$

Answer - $50.0\ L\ H_2 \times \frac{1\ mol\ H_2}{22.41\ L\ H_2} \times \frac{2\ mol\ NaOH}{3\ mol\ H_2} \times \frac{1\ L\ NaOH}{3.00\ mol\ NaOH} = 0.496\ L\ NaOH$

2.) What volume of $0.250\ M$ HCl is required to completely neutralize $25.0\ mL$ of $0.318\ M$ NaOH? (Hint - balanced equation?) $HCl + NaOH \rightarrow NaCl + H_2O$

Answer - $0.025\ L\ NaOH \times \frac{0.318\ mol\ NaOH}{1.00\ L\ NaOH} \times \frac{1\ mol\ HCl}{1\ mol\ NaOH} \times \frac{1\ L\ HCl}{0.250\ mol\ HCl} = 0.0318\ L\ HCl$

3.) A technician analyzes a sample of water from the "tailings" pond of a mine for the presence of mercury. After treating and concentrating the water sample, the technician carries out the titration reaction found below. A $25.0\ mL$ sample of the water containing mercury reacts with $15.4\ mL$ of $0.0148\ M$ Cl^-. $Hg^{+2}_{(aq)} + 2\ Cl^-_{(aq)} \rightarrow HgCl_{2\,(s)}$

a.) What is the molar concentration of the mercury in the water sample?

Answer - $0.0154\ L\ Cl^- \times \frac{0.0148\ mol\ Cl^-}{1.00\ L\ Cl^-} \times \frac{1\ mol\ Hg^{+2}}{2\ mol\ Cl^-} \times \frac{1}{0.025\ L} = 0.00456\ M\ Hg^{+2}$

b.) What mass of $HgCl_2$ is formed in the reaction?

Answer - $0.025\ L \times \frac{0.00456\ mol\ Hg^{+2}}{1.00\ L} \times \frac{1\ mol\ HgCl_2}{1\ mol\ Hg^{+2}} \times \frac{271.496\ g\ HgCl_2}{1.00\ mol\ HgCl_2} = 0.0310\ g\ HgCl_2$

KEY

4.) A $0.10\ mL$ sample of saturated solution of $Ca(OH)_2$ is reacted with $23.5\ mL$ of $0.0156\ M$ HCl.

a.) What is the molarity of the $Ca(OH)_2$ in the saturated solution?

Answer - $2\ HCl_{(aq)} + Ca(OH)_{2\,(aq)} \rightarrow CaCl_{2\,(aq)} + 2\ H_2O_{(l)}$

$$0.0235\ L\ HCl \times \frac{0.0156\ mol\ HCl}{1\ L} \times \frac{1\ mol\ Ca(OH)_2}{2\ mol\ HCl} \times \frac{1}{0.00010\ L} = 1.833\ M \qquad 1.8\ Ca(OH)_2$$

b.) What mass of $Ca(OH)_2$ is dissolved in $250.0\ mL$ of saturated $Ca(OH)_2$ solution?

Answer - $$0.2500\ L\ \ Ca(OH)_2 \times \frac{1.833\ mol\ \ Ca(OH)_2}{1\ L} \times \frac{74.10\ g\ Ca(OH)_2}{1\ mol\ \ Ca(OH)_2} = 33.956\ M \qquad 34\ g\ Ca(OH)_2$$

5.) A student titrates a $2.00\ mL$ sample of hydrogen peroxide solution, $H_2O_{2\,(aq)}$, according to the reaction

$$2\ MnO_4^-{}_{(aq)} + 5\ H_2O_{2\,(aq)} + 6\ H^+{}_{(aq)} \rightarrow 2\ Mn^{+2}{}_{(aq)} + 5\ O_{2\,(g)} + 8\ H_2O_{(l)}$$

The supply bottle of hydrogen peroxide is labelled as "3.00% by volume" ($3.00\ mL$ of H_2O_2 per $100\ mL$ of solution), which the student calculates to have $[H_2O_2] = 1.24\ M$.

a.) What volume of $0.0496\ M$ MnO_4^- is required for the titration?

Answer - $$0.002\ L\ H_2O_2 \times \frac{1.24\ mol\ H_2O_2}{1\ L} \times \frac{2\ mol\ MnO_4^-}{5\ mol\ H_2O_2} \times \frac{1\ L}{0.0496\ mol\ MnO_4^-} = 0.0200\ L\ MnO_4^-$$

b.) What volume of $O_{2\,(g)}$ at STP is produced during the reaction?

Answer - $$0.0200\ L\ \ MnO_4^- \times \frac{0.0496\ mol\ \ MnO_4^-}{1\ L} \times \frac{5\ mol\ O_2}{2\ mol\ \ MnO_4^-} \times \frac{22.41\ L\ O_2}{1\ mol\ O_2} = 0.0556\ L\ O_2$$

6.) A $1.00\ mL$ sample of pure phosphoric acid, H_3PO_4, is titrated with $43.8\ mL$ of $0.853\ M$ NaOH according to the reaction _2_ NaOH + ___ H_3PO_4 → ___ Na_2HPO_4 + _2_ H_2O

a.) What is the molar concentration of pure H_3PO_4?

Answer - $$0.0438\ L\ NaOH \times \frac{0.853\ mol\ NaOH}{1\ L\ NaOH} \times \frac{1\ mol\ H_3PO_4}{2\ mol\ NaOH} \times \frac{1}{0.00100\ L} = 18.68\ M\ H_3PO_4 \qquad 18.7\ M\ H_3PO_4$$

b.) Calculate the density of pure H_3PO_4.

Answer - $$\frac{18.68\ mol\ H_3PO_4}{1\ L\ H_3PO_4} \times \frac{98.00\ g\ H_3PO_4}{1\ mol\ H_3PO_4} = \frac{1830.64\ g}{1\ L}\ H_3PO_4 \qquad \frac{1831\ g}{1\ L}\ H_3PO_4$$

7.) The iron present in a sample of iron ore is converted to Fe^{+2} and titrated with the dichromate ion

$$Cr_2O_7^{-2} + 6\ Fe^{+2} + 14\ H^{+} \rightarrow 2\ Cr^{+3} + 6\ Fe^{+3} + 7\ H_2O$$

When $17.6\ mL$ of $0.125\ M$ dichromate ion is required to react a $25.0\ mL$ sample of Fe^{+2} solution,

a.) What is the molarity of the Fe^{+2}?

Answer - $0.0176\ L\ Cr_2O_7^{2-} \times \frac{0.125\ mol\ Cr_2O_7^{2-}}{1\ L\ Cr_2O_7^{2-}} \times \frac{6\ mol\ Fe^{2+}}{1\ mol\ Cr_2O_7^{2-}} \times \frac{1}{0.0250\ L} = 0.528\ M\ Fe^{2+}$

b.) What mass of iron is present in the $25.0\ mL$ sample?

Answer - $0.0250\ L\ \ Fe^{2+} \times \frac{0.528\ mol\ \ Fe^{2+}}{1\ L} \times \frac{55.845\ g\ Fe^{2+}}{1\ mol\ \ Fe^{2+}} = 0.737\ g\ Fe^{2+}$

8.) Prior to analyzing a fertilizer sample containing NH_4NO_3, a chemist makes a test solution by dissolving $15.5\ g$ of pure NH_4NO_3 and diluting it to $500.0\ mL$. If the chemist wishes to carry out the titration reaction ___ NH_4NO_3 (aq) + ___ NaOH (aq) → ___ NH_3 (g) + ___ H_2O (l) + ___ $NaNO_3$ (aq)

such that the reaction requires $25.0\ mL$ of NaOH when $10.0\ mL$ of the NH_4NO_3 solution is titrated,

a.) What is the molarity of the NaOH they should use?

Answer - $0.010\ L\ NH_4NO_3 \times \frac{15.5\ g\ NH_4NO_3}{0.500\ L\ NH_4NO_3} \times \frac{1\ mol\ NH_4NO_3}{80.0426\ g\ NH_4NO_3} \times \frac{1\ mol\ NaOH}{1\ mol\ NH_4NO_3} \times \frac{1}{0.025\ L\ NaOH} = 0.155\ M\ NaOH$

b.) What volume of NH_3 (g) at STP would be produced?

Answer - $0.010\ L\ NH_4NO_3 \times \frac{15.5\ g\ NH_4NO_3}{0.500\ L\ NH_4NO_3} \times \frac{1\ mol\ NH_4NO_3}{80.0426\ g\ NH_4NO_3} \times \frac{1\ mol\ NH_3}{1\ mol\ NH_4NO_3} \times \frac{22.41\ L\ NH_3}{1\ mol\ NH_3} = 0.0868\ L\ NH_3$

9.) The CO_2 content of a $10.0\ L$ sample of air at STP is determined as follows. The air pumped through a flask containing $25.0\ mL$ of $0.0538\ M$ $Ba(OH)_2$, precipitating the CO_2 present as $BaCO_3$

___ $Ba(OH)_2$ (aq) + ___ CO_2 (g) → ___ $BaCO_3$ (s) + ___ H_2O (l)

a.) How many moles of $Ba(OH)_2$ are present in the original $Ba(OH)_2$ solution?

Answer - $0.0250\ L\ \ Ba(OH)_2 \times \frac{0.0538\ mol\ \ Ba(OH)_2}{1\ L} = 0.001345\ g$

$0.00135\ g\ Ba(OH)_2$

b.) Only a small amount of the $Ba(OH)_2$ present reacts with the added CO_2. The remaining unreacted $Ba(OH)_2$ is titrated with hydrochloric acid according to the equation

$Ba(OH)_2 + 2\,HCl \rightarrow BaCl_2 + 2\,H_2O$ If the titration requires $23.0\ mL$ of $0.104\ M$ HCl, how many moles of $Ba(OH)_2$ solution after reacting with the CO_2 in the air?

Answer - $0.0230\ L\ HCl \times \frac{0.104\ mol\ HCl}{1\ L} \times \frac{1\ mol\ Ba(OH)_2}{2\ mol\ HCl} = 0.001196\ mol\ Ba(OH)_2$

$0.00120\ mol\ Ba(OH)_2$

c.) How many moles of $Ba(OH)_2$ are reacted by the CO_2?

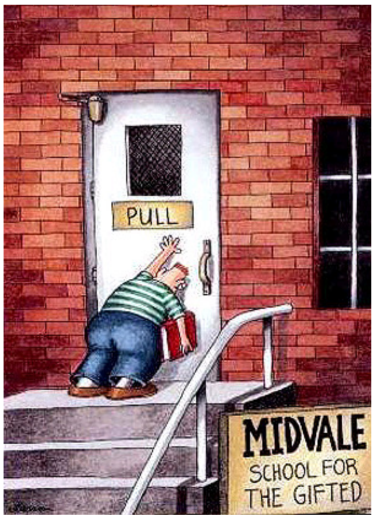
Answer - $0.001345 - 0.001196 = 0.000149\ mol\ Ba(OH)_2$

d.) How many moles of CO_2 are in the sample of air?

Answer - 1 to 1 ratio so . . . . . $0.000149\ mol\ CO_2$

e.) How many litres of CO_2 at STP are contained in the $10.0\ L$ sample of air? What percentage of the air sample's volume is CO_2?

Answer - $0.000154\ mol\ CO_2 \times \frac{22.4\ L}{1\ mol\ CO_2} = 0.00345\ L\ CO_2$



Answers – 1.) $2\,Al_{(s)} + 2\,NaOH_{(aq)} + 2\,H_2O_{(l)} \rightarrow 2\,NaAlO_{2\,(aq)} + 3\,H_{2\,(g)}$ $0.496\ L$

2.) $HCl + NaOH \rightarrow NaCl + H_2O$ $0.0318\ L$ 3a.) $0.00456\ M$ b.) $0.0310\ g$

4.) $Ca(OH)_2 + 2\,HCl \rightarrow CaCl_2 + 2\,H_2O$ a.) $1.83\ M$ b.) $33.9\ g$ 5a.) $0.0200\ L$ b.) $0.0556\ L$

6.) $2\,NaOH + H_3PO_4 \rightarrow Na_2HPO_4 + 2H_2O$ a.) $18.7\ M$ b.) $1831\,\frac{g}{L}$ 7a.) $0.528\ M$ b.) $0.737\ g$ 8a.) $0.155\ M$ b.) $0.0868\ L$

9a.) $0.00135\ mol$ b.) $0.00120\ mol$ c.) $0.000149\ mol$ d.) $0.000149\ mol$ e.) $0.00345\ L$