Name: key
Blk: ____ Date: ____

Chemistry 11
STOICHIOMETRY Calculations Involving MOLAR CONCENTRATION

Recall that MOLARITY = $\frac{mol}{L}$

$M = \frac{mol}{L}$

$mol = M \times L$

$L = mol / M$

IMPT: the only time that you can use the value 22.4 L is when the question states specifically that you have a **gas @ STP**!!!

Example 1. Tums® is an antacid tablet that is made up primarily of $CaCO_3$ (s). It works to neutralize stomach acid (HCl (aq)) to produce solid calcium chloride , carbon dioxide gas and liquid water.

a. If a single tablet has a mass of 0.750 g, what *volume* of stomach acid, having a [HCl] = 0.0010 M, is neutralized by a single tablet?

Step 1. Write out the balanced equation:

$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(s) + CO_2(g) + H_2O(\ell)$

Step 2. Use last lesson's diagram + your knowledge of MOLARITY to identify the unknown, the initial and the conversion factors and solve:

$1\ Ca = 40.1$
$1\ C = 12.0$
$3\ O = 48.0$
$100.1\ g$

$$0.750\ g\ CaCO_3 \times \frac{1\ mol\ CaCO_3}{100.1\ g\ CaCO_3} \times \frac{2\ mol\ HCl}{1\ mol\ CaCO_3} = 1.50 \times 10^{-2}\ mol\ HCl$$

$$L = \frac{mol}{M} \therefore \frac{1.50 \times 10^{-2}\ mol\ HCl}{0.0010\ M} = \boxed{15\ L\ HCl}$$

b. What *volume of CO_2 (g) at STP* is produced if 1.25 L OF 0.0055 M HCl reacts with an excess of $CaCO_3$?

Step 1. Write out the balanced equation:

$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(s) + CO_2(g) + H_2O(\ell)$

Step 2. Use last lesson's diagram + your knowledge of MOLARITY to identify the unknown, the initial and the conversion factors and solve:

$$mol = M \times L \rightarrow 1.25\ L \times \frac{0.0055\ mol\ HCl}{1\ L} = 6.88 \times 10^{-3}\ mol\ HCl$$

$$6.88 \times 10^{-3}\ mol\ HCl \times \frac{1\ mol\ CO_2}{2\ mol\ HCl} \times \frac{22.4\ L}{1\ mol\ CO_2} = \boxed{7.70 \times 10^{-2}\ L\ CO_2}$$

TITRATIONS !!!!!

A TITRATION is a process in which a measured amount of a solution is reacted with a known volume of a known concentration of another solution until a desired equivalence pt is reached

The EQUIVALENCE POINT is (aka stoichiometric point or end point) is where the ratio of moles of each species equals the mole ratio in the balanced eqtn ... usually indicated by a COLOUR Δ !!

IN CHEMISTRY 11 we will only deal with titrations of NEUTRALIZATION REACTIONS!!!

Example 2. When a 25.0 mL sample of unknown concentration of Sodium hydroxide is titrated with 23.5 mL of 0.100 M Sulfuric Acid, the equivalence point is reached. What is the *concentration of NaOH*?

Step 1. Write out the balanced equation:

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$$

Step 2. Use the known concentration + volume to solve for moles

mol = L × M

$$0.0235\ \cancel{L} \times \frac{0.100\ mol\ H_2SO_4}{1\ \cancel{L}} = 0.00235\ mol\ H_2SO_4$$

Step 3. Use the MOLE BRIDGE to calculate the moles of the unknown

$$0.00235\ mol\ H_2SO_4 \times \frac{2\ mol\ NaOH}{1\ mol\ H_2SO_4} = 0.00470\ mol\ NaOH$$

Step 4. Divide the moles of unknown by volume of unknown to solve for concentration

$M = \frac{mol}{L}$

$$\frac{0.00470\ mol\ NaOH}{0.0250\ L} = \boxed{0.188\ M\ NaOH}$$

Example 3. What *volume of 0.200 M KOH* is required to react with 125 mL of 0.250 M H_3PO_4 in order to produce K_2HPO_4 according to this balanced equation: H_3PO_4 (aq) + 2 KOH (aq) → K_2HPO_4 (aq) + 2 H_2O (l)

Step 1. Identify the balanced equation:

$$H_3PO_4 + 2\ KOH \longrightarrow K_2HPO_4 + 2\ H_2O$$

Step 2. Use the known concentration + volume to solve for moles

$$0.125\ \cancel{L} \times \frac{0.250\ mol\ H_3PO_4}{1\ \cancel{L}} = 0.0313\ mol\ H_3PO_4$$

Step 3. Use the MOLE BRIDGE to calculate the moles of the unknown

$$0.0313\ mol\ H_3PO_4 \times \frac{2\ mol\ KOH}{1\ mol\ H_3PO_4} = 0.0625\ mol\ KOH$$

Step 4. Divide the moles of unknown by molarity of unknown to solve for volume

$L = \frac{mol}{M}$ ∴

$$\frac{0.0625\ mol\ KOH}{0.200\ M\ KOH} = \boxed{0.313\ L\ KOH}$$ or 313 mL

Name: key
Blk:_____ Date:_____

Chemistry 11
STOICHIOMETRY Calculations Involving MOLAR CONCENTRATION Exercises:

17. 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 sodium hydroxide solution according to the reaction

$$2\,Al(s) + 2\,NaOH(aq) + 2\,H_2O(l) \longrightarrow 2\,NaAlO_2(aq) + 3\,H_2(g).$$

What volume of NaOH solution is required? 0.496 L of NaOH

18. What volume of 0.250 M HCl is required to completely neutralize 25.0 mL of 0.318 M NaOH? [Hint: what is the balanced equation for the reaction between HCl and NaOH?] 0.0318 L of HCl

19. 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

$$Hg^{2+} + 2\,Cl^- \longrightarrow HgCl_2(s).$$

A 25.0 mL sample of water containing mercury reacts with 15.4 mL of 0.0148 M Cl^- (as NaCl).

a) What is the molar concentration of the mercury in the water sample? 4.56×10^{-3} M Hg^{2+}

b) What mass of $HgCl_2$ is formed in the reaction? 0.0310 g $HgCl_2$

20. A 10.0 mL sample of a saturated solution of $Ca(OH)_2$ is titrated with 23.5 mL of 0.0156 M HCl.

a) What is the molarity of the $Ca(OH)_2$ in the saturated solution? 0.0183 M $Ca(OH)_2$

b) What mass of $Ca(OH)_2$ is dissolved in 250.0 mL of saturated $Ca(OH)_2$? 0.340 g $Ca(OH)_2$

21. A student titrates a 2.00 mL sample of hydrogen peroxide solution, $H_2O_2(aq)$, according to the reaction

$$2\,MnO_4^-(aq) + 5\,H_2O_2(aq) + 6\,H^+(aq) \longrightarrow 2\,Mn^{2+}(aq) + 5\,O_2(g) + 8\,H_2O(l).$$

The supply bottle of H_2O_2 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? 0.0200 L of MnO_4^-

b) What volume of $O_2(g)$ at STP is produced during the reaction? 0.0556 L of $O_2(g)$

22. 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

$$2\,NaOH + H_3PO_4 \longrightarrow Na_2HPO_4 + 2\,H_2O.$$

a) What is the molar concentration of pure H_3PO_4? 18.7 M H_3PO_4

b) Calculate the density of pure H_3PO_4. 1.83×10^3 g/L H_3PO_4

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

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

If 17.6 mL of 0.125 M dichromate ion is required to titrate a 25.0 mL sample of Fe^{2+} solution,

a) what is the molarity of the Fe^{2+}? b) what mass of iron is present in the 25.0 mL sample?

24. 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

$$NH_4NO_3(aq) + NaOH(aq) \longrightarrow NH_3(g) + H_2O(l) + NaNO_3(aq)$$

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 she should use?

b) what volume of $NH_3(g)$ at STP would be produced?