

### Big Idea 3: Chemical Reactions

Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.

*When all else fails*, remember that boys dance with girls. Many chemical reactions (not all) come down to the exchange of cations and anions. If you cannot figure out a reaction, try determine who the boys and girls are in the reaction and try to remember who likes to hook up. Think about forming water, precipitates, or production of a gas.

LO 3.1 Students can translate among macroscopic observations of change, chemical equations, and particle views.

Example:

A strong acid, HCl, is titrated with a strong base, NaOH. Write the net ionic equation for the reaction. Do not include spectator ions in the equation.



LO 3.2 The student can translate an observed chemical change into a balanced chemical equation and justify the choice of equation type (molecular, ionic, or net ionic) in terms of utility for the given circumstances.

Example:

A solution contains silver ions ( $Ag^+$ ). You have to get them out.

- a) Identify a chemical that would work to add to the solution to remove the silver ions. NaCl  
b) Write the appropriate equation for the reaction to remove the silver ions.



- c) Describe why it does not matter what the counter ions are for the reactions you listed above.

*The counter ions are spectators in the reaction and do not help remove the  $Ag^+$  from solution.*

LO 3.3 The student is able to use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results.

Example:

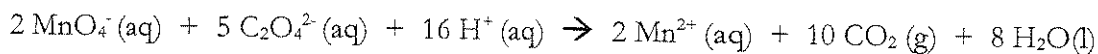
When a 2.50 g sample of an unknown hydrate of copper sulfate,  $CuSO_4 \cdot x H_2O (s)$ , is heated, water (molar mass 18) is driven off. The mass of the anhydrous  $CuSO_4(s)$  (molar mass 160 g) that remains is 1.60 g. The value of x in the hydrate is

- a) 0.90    b) 1.8    c) 5.0    d) 6.0

$$\begin{aligned} 2.50g - 1.60g &= 0.90g H_2O \\ \frac{0.90g}{18g/mol} &= 0.05 mol H_2O & \frac{0.05}{0.01} &= 5 \\ \frac{1.60g CuSO_4}{160g/mol} &= 0.01 mol CuSO_4 \end{aligned}$$

LO 3.4 The student is able to relate quantities (measured mass of substances, volumes of solutions, or volumes and pressures of gases) to identify stoichiometric relationships for a reaction, including situations involving limiting reactants and situations in which the reaction has not gone to completion.

Example:



Permanganate and oxalate ions react in an acidified solution according to the balanced equation above. How many moles  $\text{Mn}^{2+} (\text{g})$  are produced when 40. mL of acidified 0.20 M  $\text{KMnO}_4$  solution are added to 100. mL of 0.10 M  $\text{Na}_2\text{C}_2\text{O}_4$ ?

Handwritten calculations for LO 3.4 example:

$$104 \text{L MnO}_4^- \times \frac{0.20 \text{ mol MnO}_4^-}{\text{L}} \times \frac{2 \text{ Mn}^{2+}}{2 \text{ MnO}_4^-} = 0.008 \text{ mol Mn}^{2+}$$

$$100 \text{L C}_2\text{O}_4^{2-} \times \frac{0.10 \text{ mol C}_2\text{O}_4^{2-}}{\text{L}} \times \frac{2 \text{ Mn}^{2+}}{5 \text{ C}_2\text{O}_4^{2-}} = 0.004 \text{ mol Mn}^{2+}$$

Options: a) 0.0020 mol    **b) 0.0040 mol**    c) 0.010 mol    d) 0.020 mol

LO 3.5 The student is able to design a plan in order to collect data on the synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions.

Example:

A sample of iron is heated in oxygen to produce a product. Design an experiment to quantitatively determine whether the product is iron(II) oxide or iron(III) oxide.

Handwritten notes for LO 3.5 example:

Measure mass of iron and mass of product, difference is mass of oxygen.

$$\frac{\text{g Fe}}{55.85 \text{ g/mol}} = \text{moles Fe} \quad \frac{\text{g O}}{16 \text{ g/mol}} = \text{moles O}$$

Compare ratio of moles to get formula

LO 3.6 The student is able to use data from synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions.

Example:

A compound consists of the following elements by weight percent:

carbon - 40.0%      oxygen - 53.3%      hydrogen - 6.7%

The ratio of carbon : oxygen : hydrogen in the empirical formula is

Options: a) 1:2:1    **c) 1:1:2**    b) 1:1:1    d) 2:1:2

Handwritten calculations for LO 3.6 example:

$$\frac{40.0 \text{ g C}}{12.01 \text{ g/mol}} = 3.33 \text{ mol C}$$

$$\frac{53.3 \text{ g O}}{16.00 \text{ g/mol}} = 3.33$$

$$\frac{6.7 \text{ g H}}{1.01} = 6.6 \text{ mol H}$$

Water is added to 4.267 grams of  $\text{UF}_6$ . The only products are 3.730 grams of a solid containing only uranium, oxygen and fluorine and 0.970 gram of a gas. The gas is 95.0% fluorine, and the remainder is hydrogen.

(a) From these data, determine the empirical formula of the gas.

Handwritten calculations for LO 3.6 (a):

$$0.970 \text{ g} \times 0.95 \text{ F} = 0.9215 \text{ g F} = \frac{0.9215 \text{ g}}{19.00 \text{ g/mol}} = 0.0485 \text{ mol F}_2$$

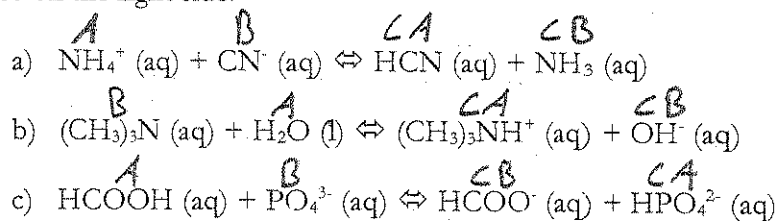
$$0.970 \text{ g} \times 0.05 \text{ H} = 0.0485 \text{ g H} = \frac{0.0485 \text{ g}}{1.01 \text{ g/mol}} = 0.0480 \text{ mol H} = 1$$

Empirical formula: **H-F**

**LO 3.7** The student is able to identify compounds as Bronsted-Lowry acids, bases, and/or conjugate acid-base pairs, using proton-transfer reactions to justify the identification.

Example:

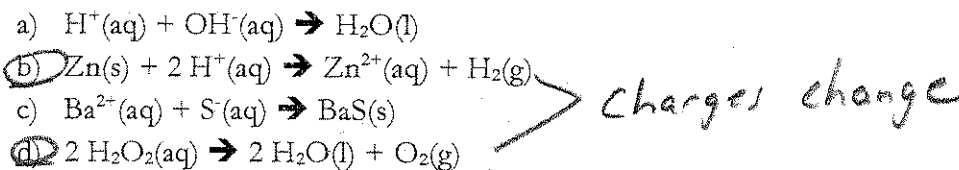
Designate the Bronsted-Lowry acid and base on the left side of each equation and the conjugate acid and base on the right side:



**LO 3.8** The student is able to identify redox reactions and justify the identification in terms of electron transfer.

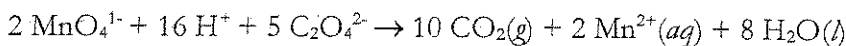
Example:

Given the following reactions, circle the reactions that are redox reactions:



**LO 3.9** The student is able to design and/or interpret the results of an experiment involving a redox titration.

Example:



In a titration experiment,  $\text{C}_2\text{O}_4^{2-}$  reacts  $\text{MnO}_4^-$  with as represented by the equation above. The dark purple  $\text{KMnO}_4$  solution is added from a buret to an acidified colorless solution in an Erlenmeyer flask.

At some point in the experiment, the rate of appearance of  $\text{Mn}^{2+}$  ions was  $1.0 \times 10^{-4} \text{M/s}$ . What was the rate of disappearance of  $\text{C}_2\text{O}_4^{2-}$ ?

- a)  $4.0 \times 10^{-4} \text{M/s}$     b)  $4.0 \times 10^{-5} \text{M/s}$      c)  $2.5 \times 10^{-4} \text{M/s}$     d)  $2.5 \times 10^{-5} \text{M/s}$

$$\text{Rate} = \frac{\Delta[\text{Mn}^{2+}]}{2t} = - \frac{\Delta[\text{C}_2\text{O}_4^{2-}]}{5t}$$

$$\Delta[\text{C}_2\text{O}_4^{2-}] = \frac{5}{2} \Delta[\text{Mn}^{2+}]$$

$$\frac{5}{2} (1.0 \times 10^{-4})$$

$$2.5 \times 10^{-4}$$

LO 3.10 The student is able to evaluate the classification of a process as a physical change, chemical change, or ambiguous change based on both macroscopic observations and the distinction between rearrangement of covalent interactions and noncovalent interactions.

Example:

Which of the following is a chemical change?

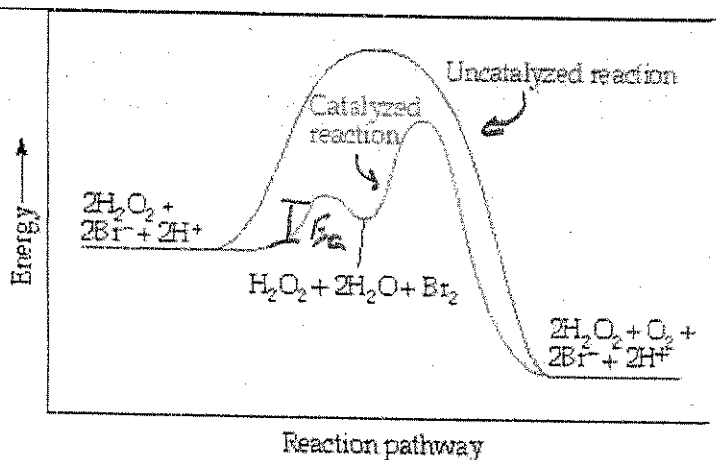
- a) Boiling water  $H_2O(l) \rightarrow H_2O(g)$
- b) Hydrogen peroxide decomposing into oxygen and water  $2H_2O_2 \rightarrow 2H_2O + O_2$
- c) Tearing paper  $paper \rightarrow 2(\frac{1}{2} paper)$
- d) Melting wax  $wax(s) \rightarrow wax(l)$

LO 3.11 The student is able to interpret observations regarding macroscopic energy changes associated with a reaction or process to generate a relevant symbolic and/or graphical representation of the energy changes.

Example:

The reaction profile on the right is for the decomposition of hydrogen peroxide. What is the reason that the catalyzed reaction (the blue line that follows the lower path) is faster than the uncatalyzed reaction (the red line that follows the upper path)?

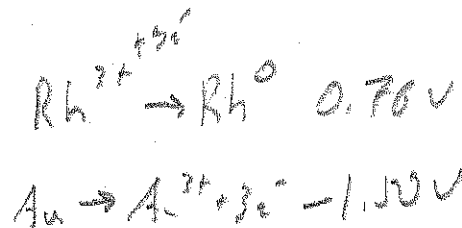
- a) The catalyzed reaction has more components to it, which makes it faster
- b) The catalyzed reaction has two peaks, which makes it faster
- c) The catalyzed reaction has a lower activation energy, which makes it faster
- d) The catalyzed reaction has a higher activation energy, which makes it faster



LO 3.12 The student can make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday's laws.

A student hypothesizes that placing a gold ring in a 1.0 M solution of  $\text{Rh}(\text{NO}_3)_3(\text{aq})$  will result in a reaction in which Rh metal is deposited on the white gold ring. Based on the information in the table below, calculate the  $E^\circ$  for the reactions that may occur between ions in solution and atoms in the ring, and indicate whether or not the student's hypothesis is correct.

Half-Reaction	$E^\circ$ (V)
$\text{Au}^{3+}(\text{aq}) + 3e^- \rightarrow \text{Au}(\text{s})$	1.50
$\text{Pd}^{2+}(\text{aq}) + 2e^- \rightarrow \text{Pd}(\text{s})$	0.92
$\text{Rh}^{3+}(\text{aq}) + 3e^- \rightarrow \text{Rh}(\text{s})$	0.76



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$$E^\circ = -0.74$$

Since  $E^\circ$  is negative, the reaction is nonspontaneous and Rh will NOT plate onto the gold ring spontaneously.

LO 3.13 The student can analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions.

Based off the  $E^\circ_{\text{red}}$  table from the previous question, which of those elements, Au, Pd, or Rh is most easily oxidized? Describe how you know.

Rh is most easily oxidized, since it has the lowest  $E^\circ_{\text{red}}$