Radical Reactions

Author(s): Paul Orbe

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Subject: Chemistry/Organic Chemistry

Grade Level: High School

Standards: Next Generation Science Standards (www.nextgenscience.org)

HS-PS1-3 Plan and conduct an investigation to examine the structure of particles and matter.

HS-PS1-7 Use mathematical representations to support the claim that atoms and mass are conserved during a reaction.

Schedule:

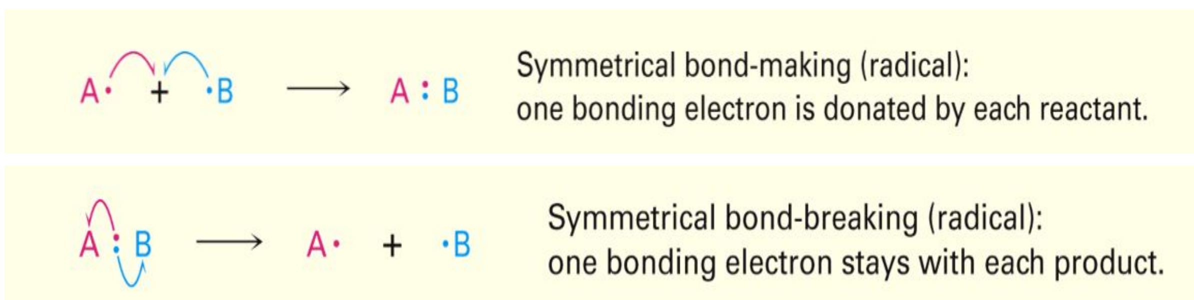
CCMR Lending Library Connected Activities:

Objectives:	**Vocabulary:**
1. To review the mechanism of a radical reaction 2. To build a polymer and determine its molecular weight 3. To compare and contrast polymerization at different conversion rates	Catalyst Heterolytic bond breakage Homolytic bond breakage Initiator Mechanism Octet Propagation step Radical Radical reaction Symmetrical Unsymmetrical
Students Will: - Activating Prior Knowledge - Draw the mechanism for a homolytic radical reaction. - Use curved arrows to indicate the formation and breakage of bonds. - Explain movement of electrons. - Simulate a polymerization reaction. - Build a polymer, determine the theoretical and experimental molecular weight of polymers. - Discuss the effect of the conversion rate on a reaction.	**Materials:** ● K'Nex rods and connectors (Micro or standard size) ● Die ● Scale
Safety	There are no safety concerns with this activity.

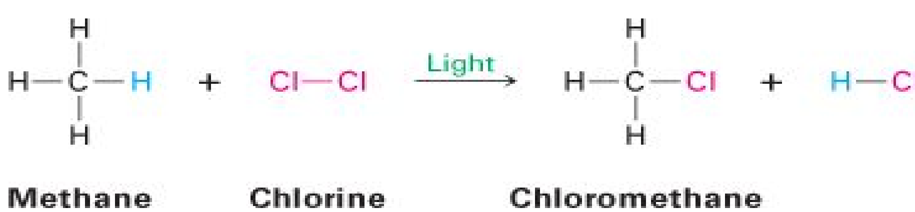
Science Content for the Teacher:

Radical Reactions

All chemical reactions, whether in the laboratory or in living organisms, follow certain order. To understand further, it's necessary to know *how* chemical reactions take place.
A mechanism describes what takes place at each stage of chemical transformation – which bonds are broken and which bonds are formed. Reaction mechanisms account for all reactants used and products formed. Radical reactions are symmetrical bond-breaking and bond-making processes. A radical is highly reactive because it contains an atom with an odd number of electrons in its valence shell, rather than a stable octet.



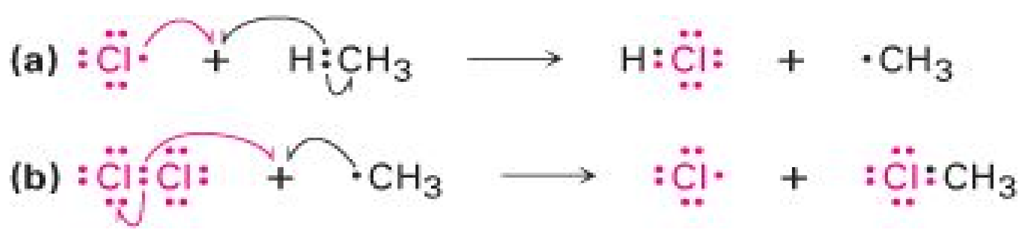
An example of an industrially useful radical reaction is the chlorination of methane to yield chloromethane. This reaction is the first step in the preparation of the solvents dichloromethane and chloroform.



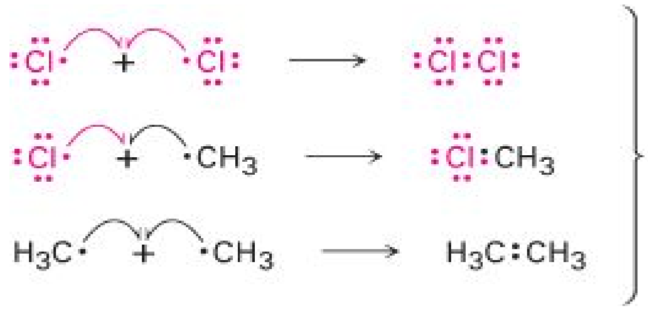
Like many radical reactions in the laboratory, methane chlorination requires three steps: *initiation, propagation*, and *termination*.

Initiation Irradiation with ultraviolet light begins the reaction by breaking the relatively weak bond of a small number of molecules to give a few reactive chlorine radicals.

Propagation A reactive chlorine radical collides with a methane molecule in a propagation step, removing a hydrogen atom to give HCl and a methyl radical. This methyl radical reacts further with Cl_2 in a second propagation step to give the product chloromethane plus a new chlorine radical. This chlorine radical cycles back and repeats the propagation step. Thus, once the sequence has been initiated, it becomes a self-sustaining cycle, making the overall process a *chain reaction*.



Termination Occasionally, two radicals might collide and combine to form a stable product. When that happens, the reaction cycle is broken and the chain is ended.



In this activity, students will look at the reaction mechanism of radical reactions and then, simulate a polymerization reaction by building polymers and determining their molecular weight. Moreover, students will discuss the impact of the conversion rate on radical reactions.

Classroom Procedure:

Prep work:

Bags with a given number of K'Nex connectors and rods will be prepared in advance. Each bag should contain 2 yellow connectors, 10 red connectors and 20 black rods at a minimum. Micro or regular size connectors and rods may be used.

Activity #1

Activating Prior Knowledge
Draw the mechanism for a homolytic free radical reaction. Use curved arrows to indicate breaking and forming of bonds. Explain movement of electrons.

1. What are the 2 types of bond formation or breakage?
2. What is the difference between full head arrowheads and half head arrowheads (fish-hook)?

Activity #2

Simulating a polymerization reaction.
Part A. Building a polymer.

1. Separate K'Nex connectors and rods in the bag.

2. Record color and mass of connectors and rod in table 1. There are only 3 distinct items and there is no need to obtain mass for all. Use a scale to determine the mass.

3. Roll the die and record the action indicated by the roll in table 2.

4. Roll the die again to propagate your polymer.

Each group is responsible for constructing several polymers. Polymers may be of same or different length.

Part B. Determining the molecular weight of polymers.

Procedure:

1. Complete table 3 and table 4.

2. Record the color, mass and quantity of each of the connectors and rods used to build your polymers. Calculate the theoretical molecular weight of your polymers by multiplying mass and quantity and then adding totals.

3. Weigh each built polymer using the scale and record its weight in table 5. This will constitute the experimental molecular weight.

Compare the theoretical molecular weight and the experimental molecular weight for your polymers.

Is there a difference? How can you explain the difference on the molecular weight?

Activity #3

Part C. Examining the conversion rate of reactions and the degree of polymerization.

Define converstion rate of reaction. Determine the molecular weight of your polymers when the conversion rate for the reaction is 50% and 25%. Use the experimental molecular weight for your calculations. Explain your findings.

Research about the number average molecular weight, Mn and the weight average molecular weight, Mw in polymers. Discuss their differences.

Assessment:

Assessment of learning objectives will include several methods. First, teacher will conduct direct observation by circulating the classroom and probing students. Students will be asked to verbalize and write explanations to phenomena from the activity. Similarly, students will be assessed in their ability to collect data and adequately interpret information derived from this data. Second, students will be required to use the Claim (C), Evidence (E) and Reasoning (R) model to demonstrate full understanding of the mechanism involved in a polymerization reaction. Students will work in groups and are responsible for selecting evidence supporting their claim in order to provide a thorough explanation. A CER template is provided for student use.

Conversely, students will be asked to either complete a metacognitive journal entry or an individual reflection. For the journal entry, students will need to respond to several prompts. These prompts are: *What did I learn?* and *How did I learn it?*

Resources:

McMurry, J. (2016). Organic Chemistry.
http://www.knex.com
http://pslc.ws/macrog/weight.htm
http://ngss.nsta.org/PracticesFull.aspx

Extra Activities:

Extension activities include the following:

1. Conduct online research on how K'Nex sets are produced. Students must provide the polymers used in the manufacturing of K'Nex sets. Additionally, students must provide the names and chemical formulas of these polymers.

2. Create a poster describing the impact of free radicals in the body. Students will conduct online research on the use of anti-oxidants to combat free radicals. Alternatively, students may create a presentation that will be shared with the class and included in their digital portfolio.

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