

Hydride Reduction & SDS Exploration – Beyond Labz Virtual ChemLab Activity

Purpose: In this virtual experiment, you will be investigating the reduction of a molecule, methyl acetylacetate, that contains two carbonyl groups - a ketone and an ester. You will be using sodium borohydride as the reducing agent, and collecting spectral data (IR and ^{13}C NMR) to determine the product of the reaction. From the identity of your product, you can draw conclusions about the selectivity of sodium borohydride as a reducing agent. You will also be exploring the Safety Data Sheet for sodium borohydride.

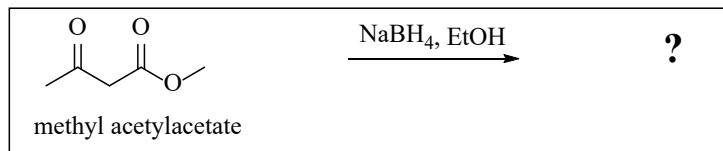


Figure 1. The reduction of methyl acetylacetate using sodium borohydride.

Introduction: Carbonyl carbons are electrophilic and if they are reacted with a nucleophilic hydride reagent (such as NaBH_4 or LiAlH_4), the result is a reduction of the carbonyl to form an alcohol. The extremely polar B–H and Al–H bonds are sometimes represented as ionic to simplify mechanisms. Examples of mechanisms using both conventions are shown in Figure 2. These are generally accepted methods to represent the nucleophilic addition of a hydride reagent to a carbonyl. Protonation of the resulting alkoxide intermediate affords an alcohol product. With sodium borohydride, the proton source is the solvent (a protic solvent, such as methanol or ethanol, is typically used with NaBH_4), and with lithium aluminum hydride the protonation occurs upon aqueous workup.

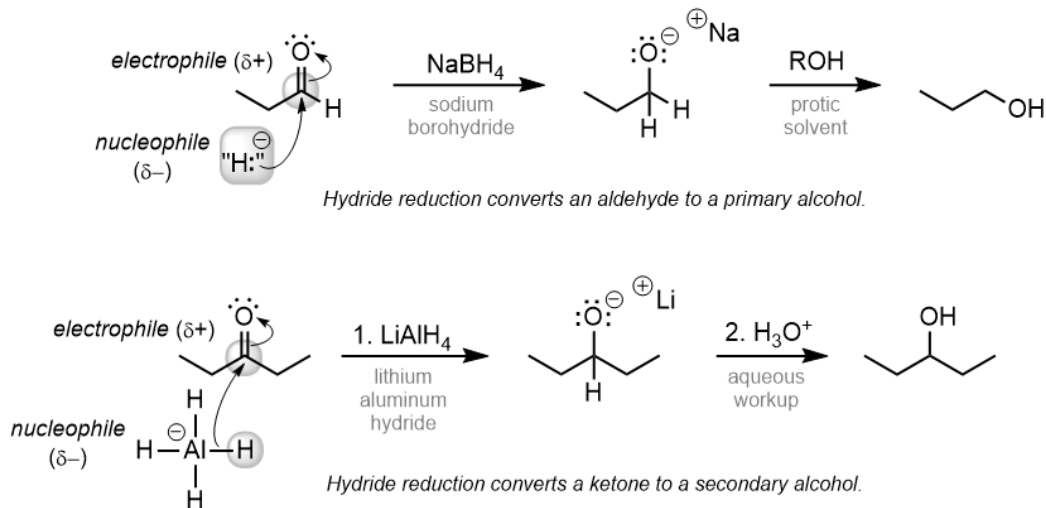


Figure 2. Examples of carbonyl reduction reactions by hydride reagents.

In this exercise, we will be reducing methyl acetylacetate. This substrate contains two carbonyl-containing functional groups, a ketone and an ester, that could potentially be reduced. During this virtual experiment, you will carry out the reduction of methyl acetylacetate using NaBH_4 and identify the product by IR spectroscopy and NMR spectroscopy (^1H and ^{13}C). The structures of the three possible products are shown in Figure 3.

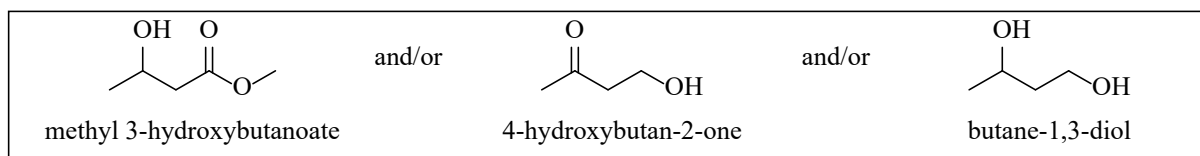


Figure 3. The possible products of the reduction of methyl acetylacetate.

Virtual Lab Instructions Help is available by clicking on the bell on the stockroom counter. *Note: The IR spectra for both the starting material and the product are provided in the Experimental Results section.*

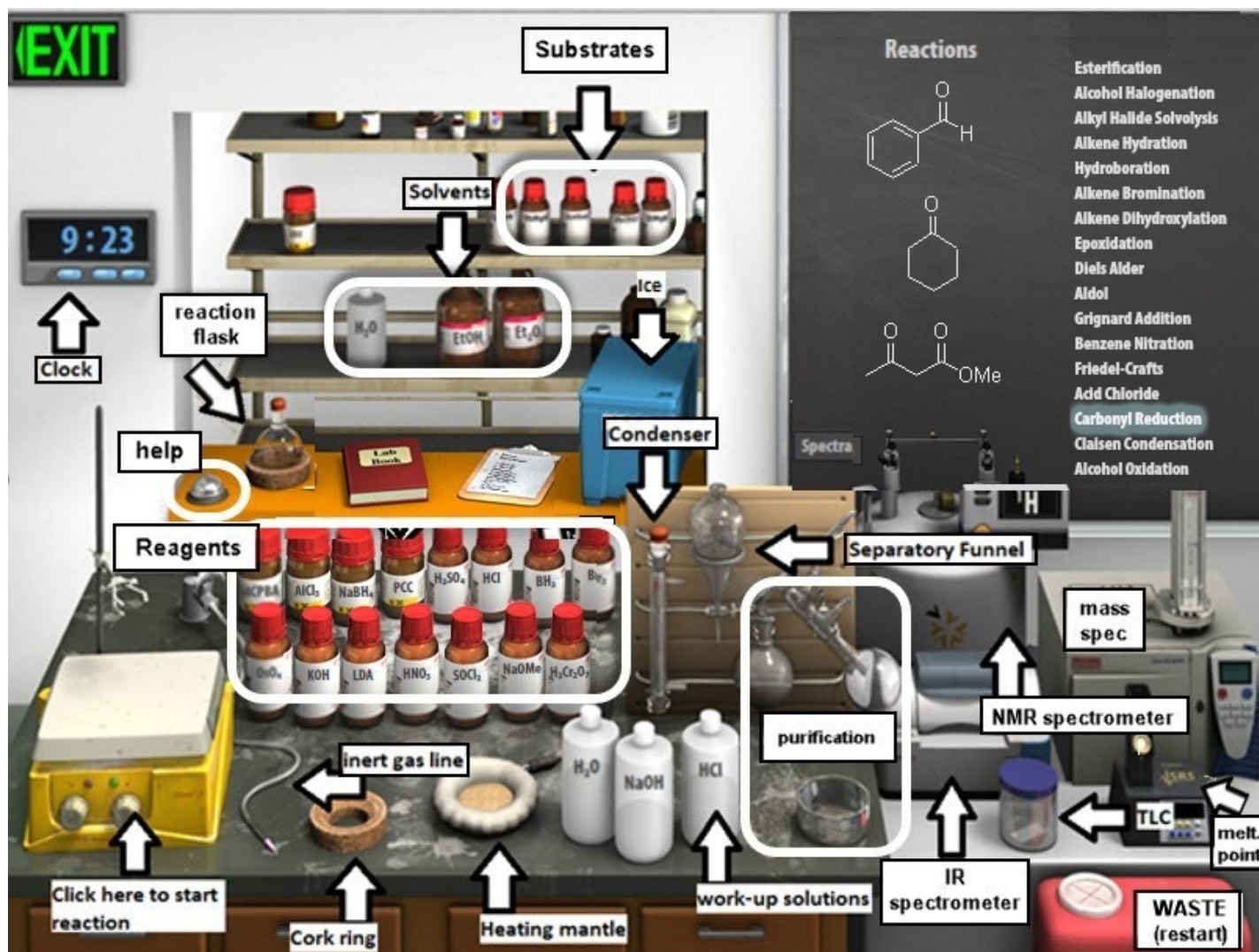


Figure 4. Beyond Labz SYNTHESIS virtual lab.

Part 1: Collect spectra of the starting material – N/A methyl acetylacetate spectra available in Spectra tab

Part 2: Methyl acetylacetate reduction.

1. From the Stockroom list, click on “**Carbonyl Reduction**,” and you will see the available substrates. You will notice that there are 3 different carbonyl containing compounds available from the “stockroom,” so be sure to select the correct starting material for the reaction.
2. *Clicking and dragging (or in some cases by double-clicking) adds materials into the round-bottom flask, via syringe through the rubber septum that is fitted on the flask opening.*
3. **Add solvent.** Scroll to the top of the Stockroom list to see the available Solvents. Click on the EtOH bottle and ethanol will be added to the flask. Assume that a volume of ~10 mL was added.
4. **Add ketoester substrate.** Click on the methyl acetylacetate and it will be added to the flask.

5. Check to see that the reagent and the solvent have been added to the flask by hovering your mouse over the flask. The contents of the flask will display on the chalkboard.
6. **Secure reaction flask to ring stand.** Double click on the flask to move it to the clamp above the stirring hot plate.
7. **Add hydride reagent.** You still need to add the sodium borohydride (NaBH_4). Find it on the bench top and click and drag to the flask. Assume that you have added an excess of sodium borohydride
8. Check the **Live Data** tab to verify that your flask contains methyl acetylacetate, ethanol, and sodium borohydride.
9. **Vent the system.** This reaction will be conducted at room temperature, so no heating mantle is needed. However, we want to avoid the buildup of any formed gases or solvent vapors if the reaction generates heat (is exothermic). The top of the flask is sealed with a rubber septum, so double-click on the nitrogen line to add it the top of the flask.
10. **Start the reaction** by clicking the right knob on the stirring hotplate.
11. Allow the reaction to proceed for 1 hour and 10 minutes (Advance the clock 1 hour and 10 minutes). The reaction should now be complete. In the lab, we would typically follow the progress of the reaction by TLC. Here, we can note that the starting material is no longer listed on the chalk board.
12. **Reaction Workup.** Stop the reaction by double-clicking on the separatory funnel to move it to the flask. The Live Data will display what is in the flask, which includes ethanol and your product. *Note: there would also be some salts formed as by-products which are not showing on the chalkboard but can be removed from the product by the liquid-liquid extraction in the workup procedure.*
13. Add water to the separatory funnel by clicking and dragging (or double-clicking). To extract an organic product, an organic solvent is required. After you have added the water to your aqueous reaction solution, you will see two layers of liquid in the funnel. *There is clearly an assumption that diethyl ether has been added as the organic solvent to extract the product, because ethanol is miscible with water!* Recall that the less dense ether layer (“organic layer”) will float on top of the aqueous layer. If you hover your mouse over the layers, it will display if the layer is organic or aqueous and the Live Data tab will display the chemicals contained within each layer.
14. Remove the lower aqueous/ethanol layer and discard it into the waste container by clicking and dragging it first into the cork ring support, and then into the red waste container. Make sure it only contains water before throwing it away! *Note: the lower aqueous layer should contain the ethanol solvent and any by-product salts formed in the reaction, unfortunately the virtual lab only shows that it contains water.*
15. Click and drag the ether layer to the cork ring support. You will notice when you do this that the ether disappears from the flask. This step assumes that you evaporated the solvent using a rotatory evaporator leaving you with just the product in the flask.
16. **Record the IR spectrum** of the product by clicking on the IR spectrometer and dragging the salt plate icon to the crystallization dish. This will display the IR spectrum on the screen. Click Save to save it to your lab notebook. Click X to close the spectrum window.
17. **Record the ^{13}C NMR.** By default, the NMR is set to record ^1H . Change it to ^{13}C by clicking the window displaying “ ^1H ” on the NMR spectrometer. Record the ^{13}C NMR spectrum of the product by clicking on the NMR spectrometer and dragging the NMR tube to the flask. This will display the ^{13}C NMR spectrum on the screen. Click Save to save the current view of the spectrum to your lab notebook. Click X to close the spectrum.
18. Reset the synthesis lab by clicking on the waste container to “Clear Lab” and discard all materials.
19. Your virtual experiment is now complete!

Prelab Assignment: SDS Activity

Name: _____

What is an SDS? When planning an experiment, there is nothing more important than ensuring the health and safety of everyone who is working in and around the laboratory. Many materials that we work with in the lab are hazardous to your health and/or dangerous to work with, but if we plan accordingly and take proper precautions, we can minimize risk of accidents and harm. To learn about the hazards associated with a given chemical, we turn to the chemical's Safety Data Sheet (SDS). Safety Data Sheets used to be named Material Safety Data Sheets (MSDS), so they may be found under both names. You can easily search for the safety information of a given chemical by using search terms such as "sodium borohydride sds" or "nabh4 msds." Good links to follow in the search results include those from universities or chemical manufacturers. Shown below is a catalog listing from the Sigma-Aldrich catalog, and you can see that a link to the SDS for that chemical is provided:

480886 Sigma-Aldrich

Sodium borohydride

granular, 99.99% trace metals basis
Synonym: Sodium tetrahydridoborate

CAS Number 16940-66-2 | Linear Formula NaBH₄ | Molecular Weight 37.83 | EC Number 241-004-4 | MDL number MFCD00003518 | PubChem Substance ID 248717243 | IACRES NA.22

[SDS](#) [RAMAN FTIR \(PDF\)](#) [Similar Products](#)

SKU-Pack Size	Availability	Pack Size	Price (USD)	Quantity
480886-25G	Available to ship on 09/04/20 - FROM	25 g	82.80	0
480886-100G	Available to ship on 09/04/20 - FROM	100 g	278.00	0

[Bulk orders?](#) [ADD TO CART](#)

SDS Activity Search online and explore *at least four* Safety Data Sheets for Sodium Borohydride, to see how they may vary slightly depending on the source. Use these resources to complete the following activity.

1. What are the major Hazards that all of the SDS sources have in common? (provide as a bulleted list)
2. Refer to the table of GHS Pictograms on the following page, and mark which symbols appear on the SDS (if the data sheets you have looked at so far don't have any pictograms, continue searching!).
3. What do the following acronyms stand for?
GHS
OSHA
4. Is this material toxic? (What does it mean to be toxic?)
5. Is this material a carcinogen? (What does it mean to be carcinogenic?)

6. Are there any other adverse health effects to be aware of?

7. What First Aid measures are to be taken in case of exposure to this material?

Eye Contact:

Skin contact:










Inhalation:

Ingestion:

8. What is the physical appearance of this material?

9. If you were a lab supervisor or lab instructor, consider the instructions you would give to someone who would be working with this material. In your own words, please describe the precautions you should take when handling this reagent, including appropriate PPE.

HCS Pictograms and Hazards

<p>Health Hazard</p>  <ul style="list-style-type: none">• Carcinogen• Mutagenicity• Reproductive Toxicity• Respiratory Sensitizer• Target Organ Toxicity• Aspiration Toxicity	<p>Flame</p>  <ul style="list-style-type: none">• Flammables• Pyrophorics• Self-Heating• Emits Flammable Gas• Self-Reactives• Organic Peroxides	<p>Exclamation Mark</p>  <ul style="list-style-type: none">• Irritant (skin and eye)• Skin Sensitizer• Acute Toxicity (harmful)• Narcotic Effects• Respiratory Tract Irritant• Hazardous to Ozone Layer (Non-Mandatory)
<p>Gas Cylinder</p>  <ul style="list-style-type: none">• Gases Under Pressure	<p>Corrosion</p>  <ul style="list-style-type: none">• Skin Corrosion/ Burns• Eye Damage• Corrosive to Metals	<p>Exploding Bomb</p>  <ul style="list-style-type: none">• Explosives• Self-Reactives• Organic Peroxides
<p>Flame Over Circle</p>  <ul style="list-style-type: none">• Oxidizers	<p>Environment (Non-Mandatory)</p>  <ul style="list-style-type: none">• Aquatic Toxicity	<p>Skull and Crossbones</p>  <ul style="list-style-type: none">• Acute Toxicity (fatal or toxic)

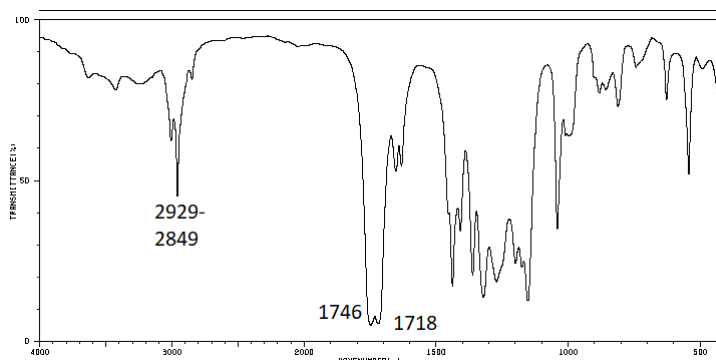
<https://www.osha.gov/Publications/OSHA3491QuickCardPictogram.pdf>

Experimental Results

Analysis of Starting Material Complete the following tables and answer any questions regarding the spectra of the starting material, methyl acetylacetate.

Infrared Spectrum Analysis

Absorbance peak (cm^{-1})	Bond(s)
2929-2849	
1746	
1718	



^{13}C NMR Spectrum Analysis. In the table below, draw the structure of methyl acetylacetate. Complete the table below to give the chemical shift of each peak, and number each carbon atom on your drawing to match the corresponding peak in the spectrum. Consider carefully your assignment of the carbonyl peaks (note that one is an ester carbonyl and the other is a ketone).

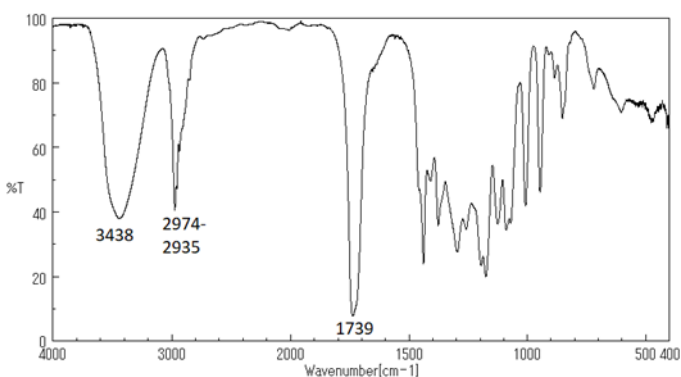
^{13}C NMR	Peak	Chemical Shift (δ , ppm)
	1	
	2	
	3	
	4	
	5	

Methyl acetylacetate (draw structure & label C atoms)

Analysis of Product Complete the following tables and answer questions regarding the spectra of the product.

Infrared Spectrum Analysis

Absorbance peak (cm^{-1})	Bond(s)
3438	
2974-2935	
1739	



¹³C NMR Spectrum Analysis. In the table below, draw the structure and give the name of the major product of the reduction of methyl acetylacetate with sodium borohydride. Complete the table below to give the chemical shift of each peak, and number each carbon atom on your drawing to match the corresponding peak in the spectrum.

¹³ C NMR Name of product: _____ Reduction Product (draw structure & label C atoms)	Peak	Chemical Shift (δ, ppm)
	1	
	2	
	3	
	4	
	5	

Postlab Questions

1. Consider the three possible reduction products shown in Figure 3. How did you use the IR spectrum to determine the correct structure of the product (and eliminate the other choices)? Explain fully.

2. Consider the three possible reduction products shown in Figure 3. How did you use the ¹³C NMR spectrum to determine the correct structure of the product (and eliminate the other choices)? Explain fully.

3. Consider the structure of the product formed. What conclusion can you draw about the reactivity of sodium borohydride towards ketones and esters?