Leavening without yeast

Model 1. For more than three millennia, the method of preparing bread by means of yeast fermentation did not change substantially; that is, until the 1830s when bakers began adding baking soda (sodium bicarbonate) and *sour milk* to their dough[1]. The mixture allowed the dough to rise without the use of yeast!! Soured milk is sour because of *lactic acid* made by bacteria in the milk. The reaction of lactic acid with sodium bicarbonate is below.

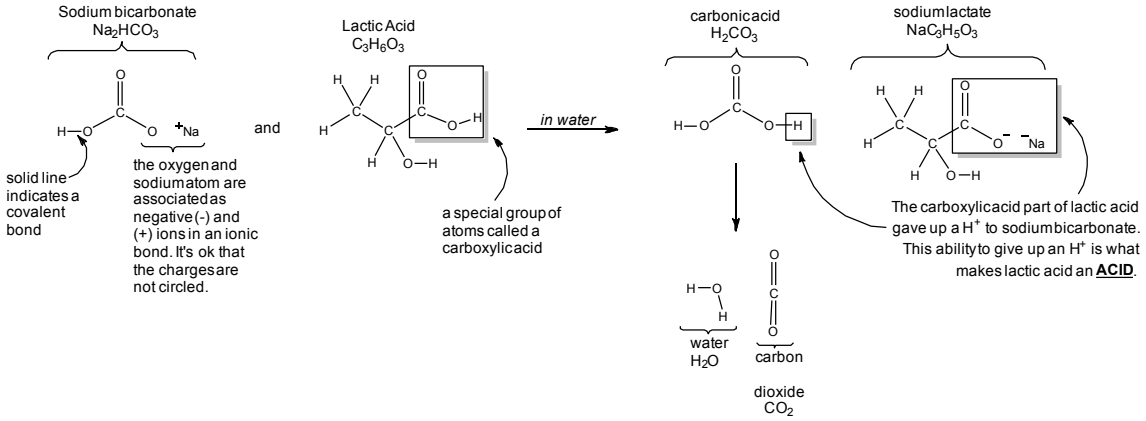


Figure 28.1. Sodium bicarbonate (the *base*) reacting with Lactic Acid to product carbonic acid and sodium lactate[2].

Table 28.1 Ingredients for biscuits
• 2 cups all-purpose flour
• 4 teaspoons baking powder
• 3 teaspoons sugar
• ½ teaspoon salt
• ½ cup shortening
• 1 egg
• ⅔ cup milk

Modern recipes for baked goods don't typically use *soured milk* in place of yeast! For example, here is a recipe for biscuits that "bake up tall, light and tender."[3]

A basic baking powder is a mixture of sodium bicarbonate (Na_2HCO_3) and cream of tartar (a.k.a. tartaric acid, $C_4H_6O_6$). The

[1] ChemMatters, June 2006
[2] For a lesson on acids and bases see Activity 8.
[3] Shirley Corriher's Cookwise, Touch of Grace Biscuits.

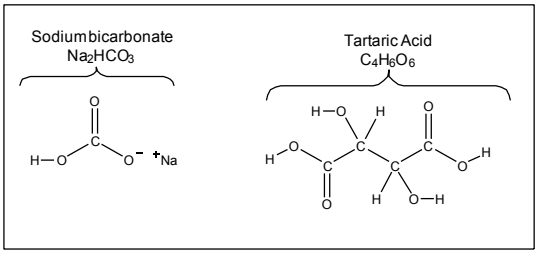


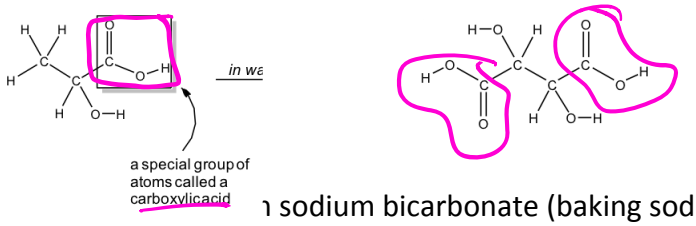
Figure 28.2 Sodium bicarbonate and tartaric acid (i.e. cream of tartar)

molecules of sodium bicarbonate and tartaric acid are shown in Figure 28.2.

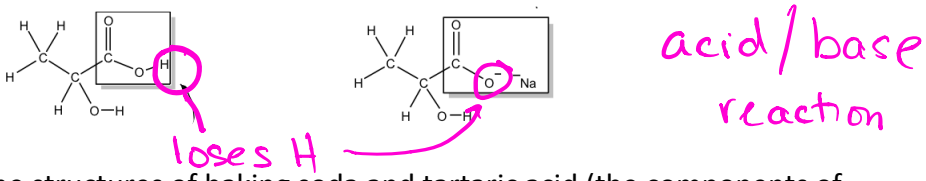
Modern, commercially available baking powders mix sodium bicarbonate (baking soda) with sodium acid pyrophosphate or monocalcium phosphate – both *acids.*

Questions:

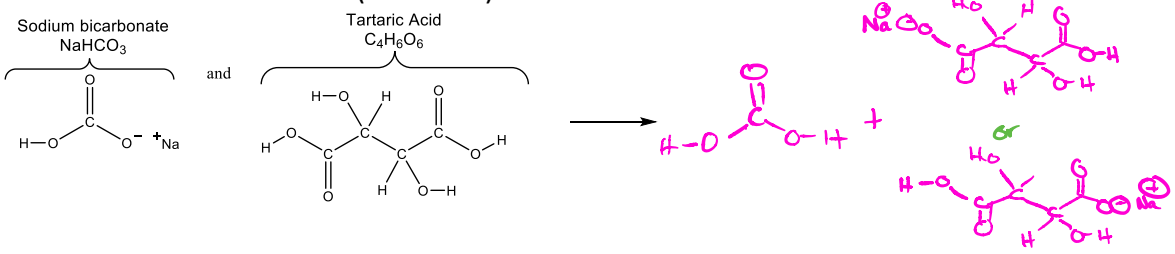
1. Lactic Acid and Tartaric Acid are both *acids*. What structural feature do these molecules have in common that makes them *acidic*? Draw the structures below and circle/box the signature structural feature that confers *acidity*.



2. When l ı sodium bicarbonate (baking soda), it becomes sodium lactate. Compare the structures of lactic acid and sodium lactate – what has changed? Why does this change qualify as a chemical *reaction*?



3. Looking at the structures of baking soda and tartaric acid (the components of baking powder), draw a chemical reaction that explains how the reaction of sodium bicarbonate and tartaric acid can accomplish the same effects as sodium bicarbonate and lactic acid (sour milk).

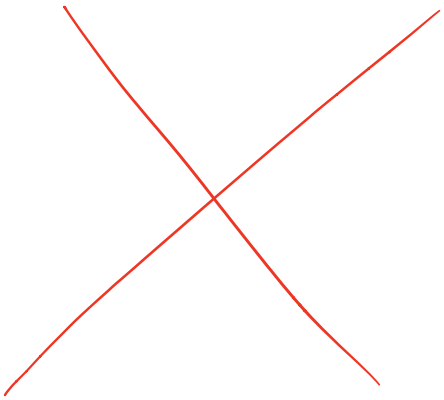


Model 2. When you are ready, see the instructor for the materials in Table 28.2

Table 28.2 Materials and procedure for chemical leavening experiment

Materials	Set up glass cylinders as follows: 1. Baking soda (¼ tsp) + cream of tartar (¼ tsp) - *solids only* 2. Baking soda (¼ tsp) + cream of tartar (¼ tsp) + 1 Tbsp. water 3. Baking powder (¼ tsp) + 1 Tbsp. water 4. Baking soda (¼ tsp) + 1 Tbsp. water + lemon juice (¼ tsp) *Cover each glass cylinder loosely with plastic wrap and secure with a rubber band. Wait 5 minutes.*
Baking soda	
Cream of Tartar	
Baking powder	
Very Warm water	
Plastic wrap	
Rubber bands	
Glass cylinders	
Lemon juice – a source of citric *acid*	

Observations:



4. Compare conditions (1) and (2) from the experiment in Table 28.2. What can you conclude about the reaction of cream of tartar (the *acid,* tartaric acid) with sodium bicarbonate.

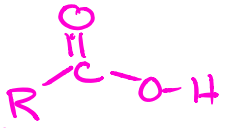
Only (2) has liquid. This is needed for acid-base reaction.

5. Compare conditions (1) and (4) from the experiment in Table 28.2.
   a. What can you conclude about lemon juice and cream of tartar?

both acids

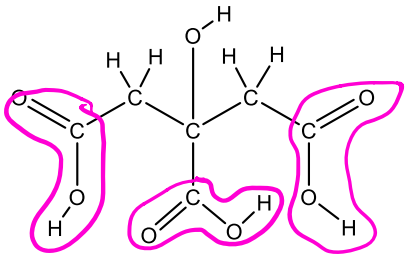
   b. What structural feature *would you predict* they both share? Draw an example of that structural feature below.

carboxylic acid



makes it general

   c. Now, consider the structure of citric acid shown below. Were you right in part (b)?



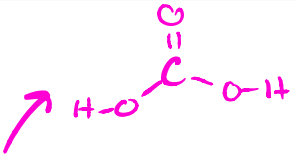
Citric Acid (found in all citrus fruits)

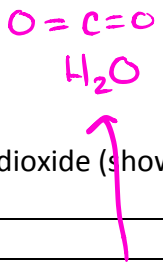
Yes, 3 carboxylic acid circled on structure

6. Condition (3) is a standard recommendation for checking the "effectiveness" of baking powder when its age or storage conditions are unknown. If the baking powder absorbs moisture (a.k.a. *water*) from the air – it can "lose its effectiveness". Why is it that old, "wet" baking powder is not effective when you add it to your recipe?

SKIP

Putting it all together:





7. Please explain how the reaction of carbonic acid to water and carbon dioxide (shown in Figure 28.1) abides by the *law of conservation of mass*.

	Quantity (#) of the atom	
	Carbonic acid	Water and carbon dioxide
Carbon	1	1
Hydrogen	2	2
Oxygen	3	3

8. Let us suppose that you are making the biscuit recipe in Table 28.1, but you do not have baking powder on hand. Can you substitute baking soda? Why or why not?

No → no acid present.

9. How is it that the reaction of baking soda (sodium bicarbonate) and lactic acid (sour milk!) is able to "replace" yeast?

Both produce CO_2 as a product of their reactions

10. If a recipe contains *acidic* ingredients such as buttermilk (lactic acid), lemon juice (citric acid), yogurt (lactic acid), honey (gluconic acid) etc, often some of the baking powder will be replaced with baking soda. This is recommended because *unconsumed* (a.k.a. *unreacted*) baking powder tastes unpleasant. What is the chemical reasoning behind this change to the recipe?

Do not want extra cream of tartar, which will be leftover if you add another form of acid.