Alternate Methods of Calculation
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An Analytical Chemistry Puzzle Question

A sample of a mixture of sodium bicarbonate and sodium carbonate of total mass **1932 mg** was analyzed and found to contain **578 mg** of sodium. Determine the amount of each of the two compounds in the sample.

Is it possible to solve this puzzle question without any knowledge of effervescent antacids or the decomposition reaction of sodium bicarbonate? Yes, it is possible, using percentage composition calculations and arithmetic. Alternate methods of solution of this question are described below.

This is an example of a problem type often posed in the end-of-chapter questions of post-secondary Analytical Chemistry texts. If you are planning to enter a post-secondary chemistry, chemical engineering, chemical technology, or related program, you may see such a problem in your course work. This information may then prove useful.

The analytical chemistry puzzle problem always concerns a mixture of two substances having a common component. For the $NaHCO_3$ / Na_2CO_3 mixture, the common component is the sodium. The problem must give the sample mass and the common component mass in order that calculations may be performed.

The first step towards a solution is to recognize that this is a percentage composition problem, and to assemble the necessary correct formulas and the percentage composition information. It can be helpful to calculate the boundary values also. The table below contains the required information for the problem. The sodium bicarbonate – sodium carbonate mixture problem stated above will be solved below by several methods as an example. The methods are all variations on a similar theme. There are two additional problems for practice at the end of this section.

The boundary values of minimum sodium (sample is 100 % sodium bicarbonate) and maximum sodium (sample is 100 % sodium carbonate) are shown.

Formula	Percent Sodium by Mass	Minimum or Maximum Sodium (mg)
$NaHCO_3$	27.366 % or 0.27366	(1932 mg) × (0.27366) = 528.7 mg
Na_2CO_3	43.381 % or 0.43381	(1932 mg) × (0.43381) = 838.1 mg

1. Guessing – Also Known as Trial and Error

Example: Suppose the sample contains a 50 / 50 mixture of $NaHCO_3$ and Na_2CO_3.
Then the mass of each component is (1932 mg)/2 = **966 mg**

Then the total mass of sodium is calculated as follows:
mass sodium (mg) = (966 mg) × (0.27366) + (966 mg) × (0.43381)
= 264.36 mg + 419.06 mg
= **683.42 mg** of sodium

This guess composition contains too much sodium and thus too high an amount of sodium carbonate. But this result eliminates more than half the possible answers. A wise strategy for searching can rapidly zero in on the correct result.

2. Algebra

The algebra method switches known and unknown in the trial-and-error calculation.

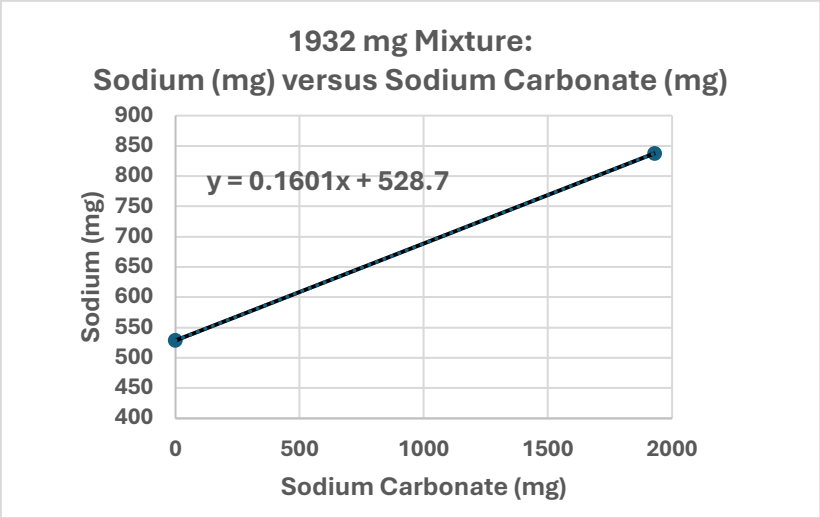
Let the mass of sodium carbonate in the sample be x mg;
Then the mass of the sodium bicarbonate is (1932 – x) mg;
Then the total mass of sodium present is:
(1932 - x) × (0.27366) mg + (x) × (0.43381) mg = 578 mg
528.7 mg – 0.27366 (x) mg + 0.43381(x) mg = 578 mg
528.7 mg + 0.16015 (x) mg = 578 mg
(x) mg = **307.1 mg** (= mass sodium carbonate)

The algebra equation above shows that the amount of sodium is a linear function of the amount of sodium carbonate. The remaining methods below all make use of this linearity either implicitly or explicitly.

3. Graphical Solution – Use of an x-y Plot

This is a straight-line function that can be plotted as an x-y scatter plot and used to solve the problem. The line is defined by the values of sodium content where sodium carbonate content is 0.0 mg (528.7 mg) and where it is 1932 mg (838.1 mg). An Excel plot is shown.

The coordinates of the two points defining the line are (**0;528.7**) and (**1932;838.1**).



The plot may be used directly to estimate a match for the given sodium content (578 mg). Or the equation of the straight line may be substituted into and solved for x mg.

4. Straight-line Geometry – Equation of a Straight Line

The straight-line equation generated by the Excel plot is identical to the second last line of the algebra solution of method 2 above.

528.7 mg + 0.16015 (x) mg = 578 mg
(x) mg = **307.1 mg** (= mass sodium carbonate)

Conclusion:
mass of sodium carbonate = <u>307.1</u> mg
mass of sodium bicarbonate = (1932 – 307.1) mg = <u>1625</u> mg

Practice Questions

1. A solid mixture contains only sodium chloride and potassium chloride.
   The chemical analysis of a **1.831 g** sample of the mixture found that the amount of chloride contained was **0.979 g**. Determine the mass of each component and the percent by mass of each component of the mixture.

2. A solid mixture contains only magnesium carbonate ($MgCO_3$) and calcium carbonate ($CaCO_3$). The chemical analysis of a **1.572 g** sample of the mixture found that the amount of carbonate (CO_3) contained was **0.964 g**. Determine the mass of each component and the percent by mass of each component of the mixture.