

A CHEMICAL REACTIONS PROBLEM

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The following problem is a variation of an unlabeled bottles experiment. This has been modified to use household materials, to be run in microscale, and to minimize safety hazards.

This problem was used in an academic competition where teams of students worked to solve the problem and then presented their results to a team of evaluators.

The factors that the evaluators looked for were first outlined by this author. That list of factors was sent to outside evaluators, in the field, to criticize and modify. The comments and modifications were reviewed, corrections were made, and the modified list was again sent out for review and further modification. It should be noted, that the process of evaluating active assessment-type questions is a process that takes time and the input of several people. The goal is to try to develop a more objective evaluation that identifies the knowledge of the students working on the problem. The final answer is only a small part of this type of problem solving.

Most practical exams, administered in a small department setting, are evaluated in a somewhat subjective manner and the same criteria are not uniformly applied to all the students or teams working on the problem. This is not necessarily a result of favoritism toward certain students, although it may play a role, but rather a result of limited time for evaluation, different evaluators, or just a cursory scan of results where the evaluator concentrated mainly on the answer.

One may consider the extensive list of items to consider to be overkill for the problem, but it is important to develop a fair evaluation process. Another consideration is that all points are **positive points**, that is, students or teams get points added for each correct part of the solution to the problem. The author believes this produces more of a positive feedback to the student/team.

CHEMICAL REACTIONS PROBLEM

Materials

Powders in vials labeled 1 thru 5:

- Alka seltzer
- calcium carbonate
- citric acid
- sodium bicarbonate
- sodium chloride

Liquids in vials or bottles labeled with names of the substances:

- 1 M hydrochloric acid
- Phenolphthalein solution (1% in alcohol)
- Water

3 Droppers

5 Popsicle stick spatulas

Well plate (24 wells)

Rubber gloves

Goggles

Aluminum foil drip pan

Task

Given the names of the compounds, identify the white powders.

Explain your experiments and reasoning in identifying the powders.

Write balanced chemical equations for all visible reactions that occur.

(Note 1: Solubility in water is not considered as a chemical reaction.)

(Note 2: If you do not know the formula for citric acid and/or alka seltzer, use words to describe any reaction that may occur)

CHEMICAL REACTIONS - Solution to the Problem

Reactions/Observations

285 points total - 15 points each reaction/observation

NOTE to the evaluators: Alka-Seltzer is a mixture of aspirin, citric acid, and sodium bicarbonate. Most students will not know this, but many are aware that Alka-Seltzer tablets will produce bubbles of gas when mixed with water.

- _____ Alka-seltzer reacts with water to produce bubbles.
- _____ Alka-seltzer reacts with hydrochloric acid to produce bubbles.
- _____ Alka seltzer will not cause any color change with phenolphthalein.

- _____ Calcium carbonate will not dissolve in water
- _____ Calcium carbonate will react with hydrochloric acid to produce bubbles.
- _____ Calcium carbonate will not cause any color change with phenolphthalein.

- _____ Citric acid is soluble in water provided a large excess of solid is not used.
- _____ Citric acid does not react with hydrochloric acid.
- _____ Citric acid will not cause any color change with phenolphthalein

- _____ Sodium bicarbonate will dissolve in water provided a large excess of solid is not used.
- _____ Sodium bicarbonate soda will react with hydrochloric acid to produce bubbles.
- _____ The solution of sodium bicarbonate in water will turn phenolphthalein pale pink with time.

- _____ Sodium chloride will dissolve in water provided a large excess of solid is not used.
- _____ Sodium chloride does not react with hydrochloric acid.
- _____ Sodium chloride will not cause any color change with phenolphthalein.

- The following can be used to differentiate between the sodium chloride and the citric acid:
 - _____ Citric acid mixed with calcium carbonate and water will produce bubbles.
 - _____ Citric acid mixed with sodium bicarbonate and water will produce bubbles.
 - _____ Sodium chloride mixed with calcium carbonate and water will not produce any visible reaction.
 - _____ Sodium chloride mixed with sodium bicarbonate and water will not produce any visible reaction.

Chemical Formulas:

25 points total – 5 points for each correct formula

- _____ Alka seltzer (no formula) Alka seltzer is a mixture of aspirin, citric acid and sodium bicarbonate. (Note: students should receive credit if they state Alka Seltzer contains an acid and sodium bicarbonate.)
- _____ Citric acid, $\text{HOC}(\text{CH}_2\text{COOH})_2\text{COOH}$
- _____ Calcium carbonate, CaCO_3
- _____ Sodium bicarbonate, NaHCO_3
- _____ Sodium chloride, NaCl

Identities of compounds:

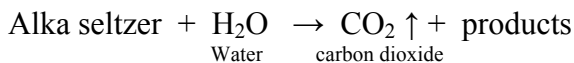
40 points total

1. Chalk (calcium carbonate)
2. Alka seltzer
3. Salt (sodium chloride)
4. Sour salt (citric acid)
5. Baking soda (sodium bicarbonate)

Chemical Equations:

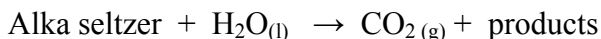
150 points total - 25 points for each equation

Alka-Seltzer and water



(Note: the actual product is sodium citrate, however, very few students, if any, would know this. Should a student report sodium citrate as a product, they should be given 5 points extra credit.)

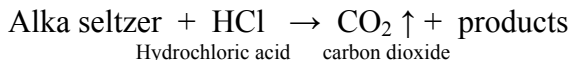
This equation could also be written as:



(Note: the letter subscripts represent the state of the material:

(s) = solid (l) = liquid (aq) = aqueous or solution (g) = gas

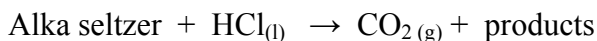
Alka-Seltzer and hydrochloric acid



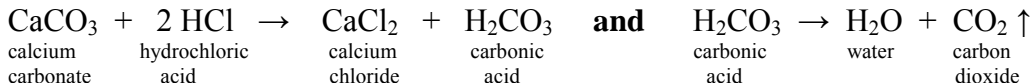
The arrow \uparrow indicates the compound is a gas.

(Note: the actual product is sodium chloride – there will be no reaction between the citric acid and the hydrochloric acid)

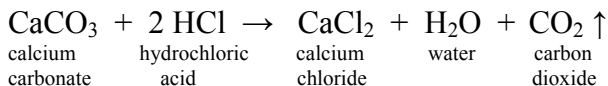
This equation could also be written as:



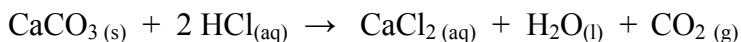
The reaction between calcium carbonate and hydrochloric acid can be written two ways:



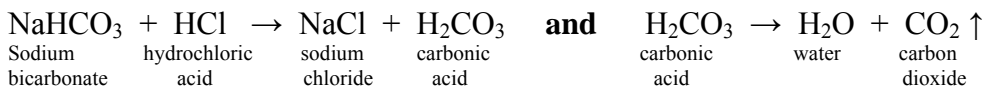
OR



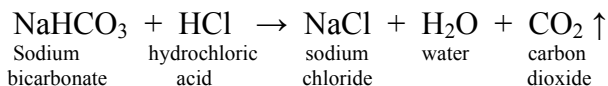
This equation could also be written as:



The reaction between sodium bicarbonate and hydrochloric acid can be written two ways:



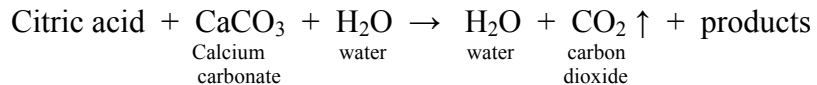
OR



This equation could also be written as:

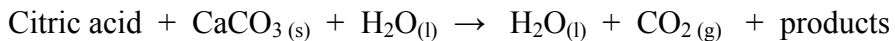


The reaction between citric acid and calcium carbonate is

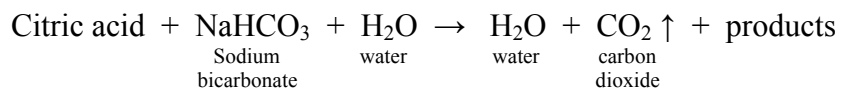


(Note: the actual product is calcium citrate)

This equation could also be written as:



The reaction between citric acid and sodium bicarbonate is



(Note: the actual product is sodium citrate)

This equation could also be written as:

