

MYSTERY SOLUTIONS

©2004, 2001 by David A. Katz. All rights reserved.
Permission for academic use, provided the original copyright is included.

This was one of the early problems developed for testing. It is a form of the three solutions problem. There are no major hazards in this activity, but safety glasses and gloves are required,

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 material was sent to outside evaluators, in the field, to criticize and modify. The comments and modifications were reviewed, corrections were made, and the modified material 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.

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.

MYSTERY SOLUTIONS

(Student instructions)

Materials:

- 3 Beral pipettes labeled A, B, and C
 - one contains a calcium chloride solution
 - one contains a sodium carbonate solution
 - one contains dilute hydrochloric acid solution
- Well plate
- Scissors
- Safety glasses
- Gloves

NOTE: Read all instructions before you begin. All students must wear safety glasses and gloves during experimentation.

Task:

Using the materials provided, you team has 20 minutes to design and perform a chemistry experiment to:

Identify the contents of each pipette.

Provide the equations for the chemical reactions that identify the solutions.

Note: The pipette tips have been heat sealed. Use the scissors to cut off the sealed pipette tips.

After 20 minutes, you will give a 5-minute presentation for the evaluators explaining your observations and conclusions. Because you will be judged on your depth of knowledge, be sure to include appropriate scientific terminology.

All members of your team must participate in the presentation.

MYSTERY SOLUTIONS

ANSWER KEY & EXPLANATION

Materials

3 Beral pipettes labeled A, B, and C
 one contains a calcium chloride solution, CaCl_2
 one contains a sodium carbonate solution, Na_2CO_3
 one contains dilute hydrochloric acid solution, HCl
Well plate (24 or 48 wells)
Scissors
Safety glasses
Gloves

Task

Given the names of the compounds, identify the contents of each pipette.

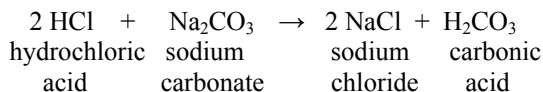
Note: The pipette tips have been heat sealed. Use the scissors to cut off the sealed pipette tips.

Reactions

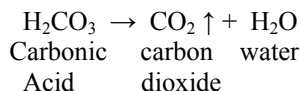
By mixing the three solutions in pairs, the students should be able to identify the three solutions.

Hydrochloric acid reacts with sodium carbonate to produce carbon dioxide gas (bubbles)

The chemical reactions that occur are:

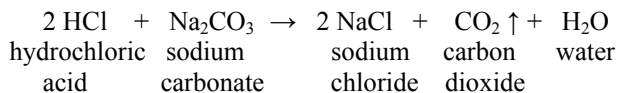


and the carbonic acid is unstable and decomposes:

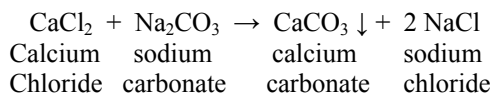


Note: The arrow \uparrow indicates that CO_2 is a gas

These two reactions can be combined and written as:

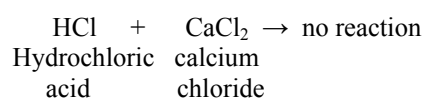


Calcium chloride reacts with sodium carbonate to produce calcium carbonate, a white precipitate, which is observed as a cloudy mixture.



Note: The arrow \downarrow indicates formation of a precipitate

There is no reaction when the hydrochloric acid and the calcium chloride are mixed



Mystery Solutions MASTER SCORESHEET

TOTAL of 500 points

Demonstration (160 points)

Students should demonstrate that:

- A. One combination of 2 solutions produces gas (bubbles) _____ 40 pts
- B. One combinations of 2 solutions produces a precipitate _____ 40 pts
- C. One combinations of 2 solutions produces no reaction _____ 40 pts

Students should identify all 3 solutions correctly. _____ 40 pts

calcium chloride, CaCl₂ is in pipette A

sodium carbonate, Na₂CO₃ is in pipette C

hydrochloric acid, HCl is in pipette B

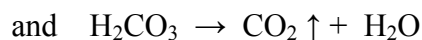
(Note) No points are awarded for combining 3 solutions, since that doesn't aid in the identification of the 3 solutions.

SUBTOTAL POINTS (160 Max.) _____

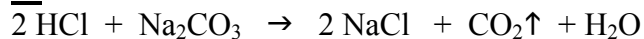
Explanation/Presentation (300 points)

A. ***hydrochloric acid + sodium carbonate → sodium chloride + carbonic acid***

1) For writing a correct chemical equation:



or



2) If they indicate that CO₂ is a gas, using the notation CO₂ (g) **or** CO₂↑ _____ 5 pts

3) If they that carbonic acid, H₂CO₃, is unstable and breaks down to form CO₂ _____ 10 pts

- 4) If the equation is properly balanced _____ 10 pts
- 5) Add five points for each formula that is correct up to a maximum of (25) twenty-five points _____ 25 pts
- 6) For a correct oral explanation of the reaction _____ 50 pts

B. *calcium chloride + sodium carbonate* → *calcium carbonate + sodium chloride*

- 1) For writing a correct chemical equation:
 $\text{CaCl}_2 + \text{Na}_2\text{CO}_3 \rightarrow \text{CaCO}_3 \downarrow + 2 \text{NaCl}$ _____ 25 pts
- 2) If the equation is properly balanced _____ 10 pts
- 2) Add (5) five points for each formula that is correct up to a maximum of (20) twenty points _____ 20 pts
- 3) Add (5) points if they indicate the CaCO_3 is a precipitate using the notation $\text{CaCO}_3(\text{s})$ or \downarrow _____ 5 pts
- 4) For a correct oral explanation of the reaction _____ 50 pts

C. *hydrochloric acid + calcium chloride* → *no reaction*

- 1) For writing the correct chemical equation:
 $\text{HCl} + \text{CaCl}_2 \rightarrow \text{no reaction (or N.R.)}$ _____ 20 pts
- 2) Add (5) five points for any formula that is correct up to a maximum of (10) ten points _____ 10 pts
- 3) For a correct oral explanation of the reaction _____ 30 pts

SUBTOTAL POINTS (300 Max.) _____

Presentation (40 points)

For all team members actively participating in the presentation.

(20 pts Max.) _____

Use of general public speaking skills such as voice projection,
eye contact, proper grammar, etc.

(20 pts Max.) _____

SUBTOTAL POINTS (40 Max.) _____

TOTAL POINTS (500 Max.) _____