Problem Based Practical Activities

Problem 1: Carbonate rocks!

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Problem 1:
Carbonate rocks!

Curriculum links;
mole calculations, reacting masses, thermal decomposition of metal carbonates

Practical skills;
top pan balance, observation skills

The chairman of a local geology society has contacted the students to ask them to help him identify four different rock samples (all essentially metal carbonates or hydrogen carbonates). The students need to heat the samples, measure the mass change and record visual observations. Using the visual observations, the students are asked to identify each sample and using the mass changes the students are asked to determine the purity of the samples.

Extension discussion points:

- Can the students explain the trend in the thermal stabilities of the 's' block metal carbonates and hydrogen carbonates?
- To what degree of accuracy should the final percentage purities of the rock samples C and D be given?

Problem 1: Carbonate rocks!

Pre-Lab questions

(Remember to give full references for any information beyond A-level that you find out)

1. Identify the principal mineral in each of the sedimentary rocks a - d below?

a) Nahcolite

b) Limestone

c) Rhodochrosite

d) Smithsonite

2. Sedimentary rocks often contain metal carbonates and hydrogen carbonates. Carry out some research to find information on the thermal stabilities of '*s*' block metal hydrogen carbonates, '*s*'-block metal carbonates and transition metal carbonates. Include in your answer a word equation for the thermal decomposition of a metal carbonate and a metal hydrogen carbonate.

3. Transition and other metal carbonates can often be identified by the colour changes associated with their thermal decomposition. For each of the samples below, identify the colour changes you would expect to observe on heating a sample of each compound;

a) zinc carbonate

b) manganese carbonate

c) copper carbonate

4. A student decides to investigate the thermal decomposition of lead carbonate. She heats an impure sample of the carbonate strongly for 5 min until there is no further decrease in mass and records the following results;

Mass of empty metal crucible	= 16.65 g
Mass of crucible + lead carbonate before heating	= 23.31 g
Mass of crucible + lead oxide after heating	= 22.33 g

a) Write a word and symbol equation for the thermal decomposition of lead carbonate, $PbCO_3$.

b) What mass of carbon dioxide and therefore how many moles of carbon dioxide are given off in the reaction?

c) Use your understanding of the stoichiometry of the reaction together with your answer to part b) to calculate;

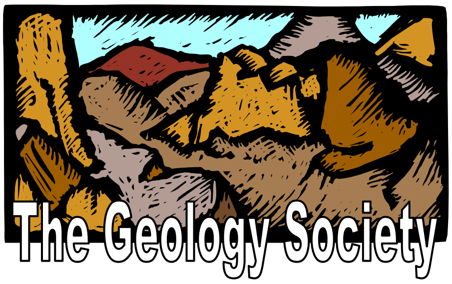
i. the number of moles of lead carbonate in the original sample

ii. the mass of lead carbonate in the original sample

d) Using your answer to c) ii., calculate the percentage purity of the lead carbonate sample (you may assume that any impurities in the sample are thermally stable).

Problem 1: Carbonate rocks!

Introduction



Dear analyst,

I am a member of the regional group of The Geology Society and have responsibility for maintaining and updating our collection of rocks, of which we are very proud. We have over a thousand rock samples collected from countries around the world. The rarest rock we hold is a small piece of Kimberlite originating from South Africa.

Sadly, an elderly and well respected member of our group recently passed away. He had a small collection of rocks which he very kindly donated to us in his will. However in packing and transportation, four of these rocks lost their labels. From the labels found loose in the bottom of the box, we know them to be samples of;

Nahcolite

Limestone

Rhodochrosite

Smithsonite

But we do not know which is which.

Please can you help us with the identification of each sample. We have taken the liberty of grinding a small sample of each rock into a powder and labelling them A-D for your analysis. Samples of Rhodochrosite and Smithsonite often contain impurities so in addition to the identification of these samples we would appreciate an analysis of their percentage purity.

We are a society of high standing in academic circles with an excellent reputation for exactness to uphold. We are therefore relying on you for your analyses to be accurate to the highest degree possible.

Please provide a full report detailing your methods and full calculations for our records.

Many thanks for your help,

B. Rubble

B. Rubble

Teacher and Technician Pack

Pre-Lab answers

(Remember to give full references for any information beyond A-level that you find out)

1. a) Nahcolite = sodium hydrogen carbonate
b) Limestone = calcium carbonate
c) Rhodochrosite = manganese carbonate
d) Smithsonite = zinc carbonate

2. metal carbonate $\rightarrow$ metal oxide + carbon dioxide

Group one metal carbonates; Lithium carbonate decomposes at Bunsen temperatures but other group one metal carbonates (e.g. sodium carbonate) are stable to heat.

Group two metal carbonates; The thermal stability of group two metal carbonates increases as you move down the group. Approximate decomposition temperatures are;

Carbonate	$BeCO_3$	$MgCO_3$	$CaCO_3$	$SrCO_3$	$BaCO_3$
Decomposition temperature	Unstable at room temp	400 °C	900 °C	1280 °C	1360 °C

Transition metal carbonates; Undergo thermal decomposition at Bunsen temperatures usually accompanied with a change in colour.

metal hydrogen carbonate $\rightarrow$ metal carbonate + carbon dioxide + water

Group one metal hydrogen carbonates; These are stable enough to exist as solids but do readily undergo thermal decomposition on heating

Group two hydrogen carbonates; These are so thermally unstable that they only exist in solution

3. a) White (zinc carbonate) to yellow when hot / white when cold (zinc oxide)
b) Black (manganese carbonate) to dark brown (manganese oxide)
c) Green (copper carbonate) to black (copper oxide)

4. a) lead carbonate $\rightarrow$ lead oxide + carbon dioxide
$PbCO_3 \rightarrow PbO + CO_2$

b) Mass of CO_2 produced = 23.31 g – 22.33 g = **0.98 g**
$\therefore$ Moles of CO_2 produced = 0.98 g ÷ 44.0 g mol^{-1} = **0.022 moles**

c) If 0.022 moles of CO_2 are produced then 0.022 moles of $PbCO_3$ must have reacted. Hence there must have been **0.022 moles** of $PbCO_3$ in the original sample.
mass = moles × molar mass $\therefore$ mass of $PbCO_3$ = 0.022 moles × 267.2 g mol^{-1} = **5.95 g**

d) Mass of sample heated = 23.31 g – 16.65 g = 6.66 g
Mass of $PbCO_3$ in sample = 5.95 g
$\therefore$ Percentage purity of sample = (5.95 g ÷ 6.66 g) × 100% = **89.3%**

WARNING! The **products** from the reactions are not Low hazard. A crucible with a loose fitting lid should be used to minimise the generation of dust.

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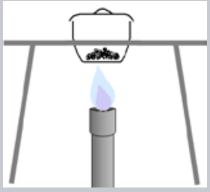
Proposed method

Planning stage

Using the pre-lab questions, students identify the rocks as either a metal carbonate or a metal hydrogen carbonate. Therefore, by heating a known mass of each rock sample and observing colour and mass changes, the identity of each rock can be determined.



Results

Sample A

Mass of crucible = 17.65 g
Mass of crucible + sample **[Low hazard]** = 26.04 g
Mass of crucible + product **[Corrosive]** = 26.02 g

Colour change = none

Sample A is Limestone (no mass change)

Sample B

Mass of crucible = 17.59 g
Mass of crucible + sample **[Low hazard]** = 22.50 g
Mass of crucible + product **[Irritant]** = 20.66 g

Colour change = none

Sample B is Nahcolite (no colour change)

Sample C [Low hazard]

Mass of crucible = 17.48 g
Mass of crucible + sample **[Low hazard]** = 19.67 g
Mass of crucible + product **[Harmful]** = 19.07 g

Colour change = white to pale yellow to white

Sample C is Smithsonite (from colour changes)

Sample D [Low hazard]

Mass of crucible = 16.65 g
Mass of crucible + sample **[Low hazard]** = 20.52 g
Mass of crucible + product **[Dangerous for the environment]** = 19.22 g

Colour change = black to dark brown

Sample D is Rhodochrosite (from colour changes)

Analysis of purity

Sample C

Mass of CO_2 produced = 0.60 g
∴ Moles of CO_2 produced = 0.014 moles
∴ Moles of $ZnCO_3$ in sample = 0.014 moles
∴ Mass of $ZnCO_3$ in sample = 1.71 g

∴ Purity of sample = 78.1%

Sample D

Mass of CO_2 produced = 1.30 g
∴ Moles of CO_2 produced = 0.030 moles
∴ Moles of $MnCO_3$ in sample = 0.030 moles
∴ Mass of $MnCO_3$ in sample = 3.39 g

∴ Purity of sample = 87.6%

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Equipment list

See the **Health and safety guidance** section in the **Introduction** for more general information on risk assessments and a key to the health and safety symbols used.

Students will need access to;

Samples of powdered rock labelled as below;

Calcium carbonate, $CaCO_3$ labelled *Rock Sample A* **[Low hazard]**

Sodium hydrogen carbonate, $NaHCO_3$ labelled *Rock Sample B* **[Low hazard]**

Zinc carbonate, $ZnCO_3$ labelled *Rock Sample C* **[Low hazard]**

Manganese carbonate, $MnCO_3$ labelled *Rock Sample D* **[Low hazard]**

An accurate balance (2 or 3 decimal point)

Each group will need;

2 × crucibles with loose fitting lids

2 × Bunsen burner, tripod, heatproof mat and pipe clay triangle

Spatulas

Tongs

Health and safety note

The **products** of the decomposition are not Low hazard. A crucible with a loose fitting lid is therefore required to minimise the generation of dust. The waste should be dealt with in an appropriate manner depending on amounts to be disposed of and in accordance with employer's requirements and any local rules.

Product	From the decomposition of	Hazard
Calcium oxide	Calcium carbonate	**Corrosive**
Sodium carbonate	Sodium hydrogen carbonate	**Irritant**
Manganese oxide	Manganese carbonate	**Harmful**
Zinc oxide	Zinc carbonate	**Dangerous for the environment**