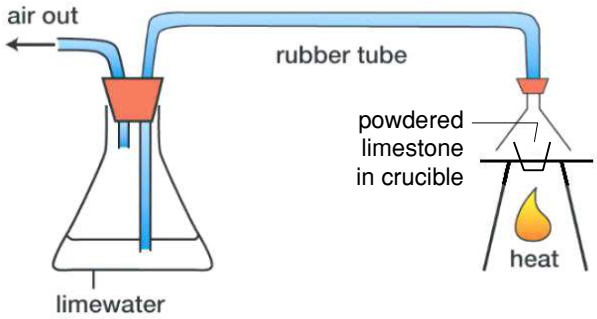
Make a mini lime kiln and discover limelight
Investigating the results of heating limestone

Show the pupils some examples of limestone, including chalk, and marble, if possible. Remind them that marble is metamorphosed limestone.
Ask the following questions:-

- what is the chemical composition of the limestone and marble? *(Calcium carbonate)*
- are they pure calcium carbonate? *(No - refer to the Earthlearningidea 'I'm pure calcium carbonate' - the calcium carbonate question. See Useful links)*
- what do you think will happen when we heat them? Let's find out.

Set up the apparatus as shown in the diagram (do not let the funnel touch the tripod - it can shatter)
The equipment needed is listed in Resources on page 2.



Reproduced with permission from ESEU

- record the following:
  - M1 (mass of the crucible)
  - M2 (mass of the crucible + crushed limestone)
  - M3 (mass of crushed limestone = M2-M1)
- heat the crushed limestone as strongly as possible for 10 minutes. (Wear eye protection)
- when the limestone is very hot, if practical, remove the Bunsen burner and direct its flame directly at the limestone for about 10 seconds. Move the Bunsen burner away and you may be able to see **'limelight'** *(refer to note at end)*
- remove the heat and allow the crucible and contents to cool (about 5 minutes)
- record the following:
  - M4 (mass of crucible+heated (calcined) limestone
  - M5 (mass of calcined limestone = M4-M1
- how much calcium carbonate has reacted?

limestone ($CaCO_3$) $\xrightarrow{\text{heat}}$ quicklime + carbon dioxide ($CaO + CO_2$)

100gm of calcium carbonate should leave 56g of calcium oxide, CaO (quicklime) after heating. Carbon dioxide gas is released in the process.

The molecular mass equation is:-

$Ca\ C\ O_3 \longrightarrow Ca\ O + C\ O_2$
$40+12+48=100 \qquad 40+16=56 \quad 12+32=44$

Pupils' mass of calcium carbonate (M3) should leave M2 x 56/100g. Pupils should compare this value with what they actually obtained (M5). M5 is the mass of quicklime.

- what happened to the lime water in the flask. Why? *The gas released when heating the powdered limestone dissolved in the limewater making it cloudy and creating a white solid in suspension (calcium hydroxycarbonate precipitate). The gas released is carbon dioxide. If more CO_2 is passed into the limewater, the suspension will re-dissolve as calcium hydrogen carbonate in solution.*

Now that pupils know that heating limestone will produce quicklime and release carbon dioxide, **ask them to do the following:**

- mix sandy soil (acid) with water in a boiling tube
- when the soil has settled, add Universal indicator
- record its colour
- add some of the quicklime produced by heating the limestone (wear eye protection). Slaked lime is produced when just sufficient water is added to fully react with the quicklime. When there is excess water, the product is known as hydrated lime, (both are calcium hydroxide)

calcium oxide + water ($CaO + H_2O$) $\longrightarrow$ calcium hydroxide $Ca(OH)_2$

- record how the colour of the indicator changes
- record what this tells them about adding lime to soil
  Adding lime adds alkali to acidic soils, increasing their productivity and improving soil structure.

Lastly ask the pupils to look at a photo of an old **lime kiln,** *(page 2).* Tell them that limestone was added at the top and quicklime was raked out at the bottom. Discuss how it worked.
Layers of limestone and wood or coal were put into the kiln and the fuel was burned until a temperature of 900 - 1000^{0}C was reached. The quicklime would be raked out at the bottom when the kiln had cooled - a very dangerous job.

……

The back up:

Title: Make a mini lime kiln and discover limelight.

Subtitle: Investigating the results of heating limestone.

Topic: A pupil activity to decompose limestone by heat and to discuss the uses of the resulting quicklime. A good activity for science, geography or environmental science classes.

An old lime kiln *(Peter Kennett)*

Age range of pupils: 11 - 16 years

Time needed to complete activity: 20 - 30 minutes

Pupil learning outcomes: Pupils can:
- explain that heat will cause the chemical breakdown of calcium carbonate;
- realise that when limestone is heated, calcium oxide, quicklime, is produced and carbon dioxide is released;
- weigh and measure accurately;
- explain how limelight is formed;
- use Universal indicator effectively to indicate the pH of liquids;
- explain that water added to lime creates hydrated lime or slaked lime depending on the quantity added;
- explain how quicklime reacts with soil and water to decrease the soil's acidity and increase its pH;
- complete word equations for the decomposition process;
- explain the use of lime kilns and how they worked.

Context: It is often not appreciated that calcium carbonate rocks (such as limestones) can be decomposed by heat, releasing a gas. Soil liming is an important agricultural process now and in the past. In the kiln, limestone would be heated (using wood in early times, and later coal) The quicklime (calcium oxide) formed usually had water added to it (hydrated lime or slaked lime) before it was spread on the soil. Ancient lime kilns can be found in many parts of the world. Today, the same process is used at lime-manufacturing plants near limestone quarries, and the lime is sold in bags for use by farmers and gardeners.
However, the main usage of limestone today is in crushed limestone aggregate and cement manufacture for the construction industry.

Limelight was used in the first theatrical spotlights. The Scottish engineer Thomas Drummond invented the limelight in 1816. He used a core of limestone that was heated to incandescence by a burning mixture of oxygen and hydrogen. The incandescent quicklime formed on the outer layer of the heated limestone provided very brilliant light that could be directed and focused. The limelight was first employed in the theatre in 1855 and became widely used by the 1860s. Its intensity made it useful for spotlighting and for the realistic simulation of effects such as sunlight and moonlight. It could also be used for general stage illumination. The limelight required constant attention of an individual operator, who had to keep adjusting the block of limestone as it burned and to tend to the gas that fuelled it.

Following up the activity:
More uses for quicklime and slaked lime could be investigated. Quicklime was spread directly on the ground to reduce the acidity of soils, and, in the eighteenth century its use was often a requirement set down in farm leases. It was also used for the disposal of hanged bodies in gaols.
Slaked lime forms a slurry or paste which can be used for building and lime-washing walls. Until cement was widely available, bricklayers used a mixture of sand and slaked lime as mortar. Over a long period of time, the mortar became hardened by absorbing carbon dioxide from the atmosphere. Lime mortar is still used in conservation work on old buildings.

Underlying principles:
- Heat causes the chemical breakdown of calcium carbonate.
- When limestone is heated, calcium oxide is produced and carbon dioxide is released.
- Limelight is created by heating limestone to incandescence by a burning mixture of oxygen and hydrogen.
- When quicklime or slaked lime are added to acid soil, they increase the pH and improve the soil's productivity and structure.

Thinking skill development:
Discussion about the results involves metacognition. Relating the activities to lime kilns and lime manufacturing plants is a bridging skill.

Resource list:
- Bunsen burner
- tripod, heatproof mat, matches
- electronic balance
- crucible (a tin lid could be used)
- limewater
- funnel
- tube
- conical flask and bung

- delivery tube
- water vacuum pump to draw air through the apparatus (optional)
- eye protection
- powdered limestone (50/50 mix, $MgCO_3$ + $CaCO_3$, the magnesium carbonate decomposes more readily. Magnesium is found in dolomitic limestone so this is a justifiable 'fix'!)
- sandy soil (eg. a 250 ml beaker full)
- Universal indicator
- boiling tube

Useful links:
http://www.earthlearningidea.com/248_Calcium_carbonate.pdf
https://en.wikipedia.org/wiki/Lime_kiln

Source: Adapted by Elizabeth and Martin Devon from the ESEU 'Science under the limelight: teaching KS3 chemistry' workshop booklet. and from CLEAPPSS Supporting Practical Science, D&T and Art, 'Heating marble chips: a quantitative approach'.