Building a Lime Calcination Kiln for Class 7 Chemistry

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Recently, in August 2010, we built a lime kiln for the first chemistry lessons of Class 7 at Raphael House Rudolf Steiner School, Wellington NZ. The following is to facilitate class teachers repeating this sometimes elusive process.

We begin with a brief description of a way of teaching introductory chemistry to children at the end of their primary schooling in a way that both develops and extends their intellectual muscle while at the same time building a context for the experiences and concepts that can engage the young person in a deeper way with the everyday life around them. Our approach will look at 'substance' as the outcome of 'processes' - life processes at that. So substance not as the prime mover but rather the end of life processes whose qualities are then found metamorphosed in the qualities of the substances that emerge. The opposing approach will be the teaching of chemistry as if the world is primarily built on matter (the common paradigm). In that approach, children are taught about the aggregate states of matter from an atomistic point of view "as if atoms were little particles" that somehow form the basis of life, soul and spirit.

Fire is the starting point. It is not a thing that you can pick up and put in your pocket easily. It has more the characteristics of a process with movement and activity than "thing-like" properties. It dances and moves as light and warmth consuming form and substance as it does so. The whole environment becomes involved in the process. The surroundings are lit up and warmed; movement is created as air moves in and rises above. The bigger the fire, the greater the wind created - the more it involves its surroundings.

To stir their imagination, children could be told about fire – its role in human life. Perhaps the role of fire in the taming and domestication of wild animals such as the Asian elephant.

The following story is from my own childhood.

I remember the privilege of being allowed to spend some time in an elephant camp of a friend of my father, Lalji we called him, the Raja of Gauripur, Assam.

The elephant camp was in, what is now, the Garo Hills. Only men lived there, leaving their wives and children back in their villages. The life in the camps was intense and focussed on the catching and taming of these magnificent animals of the Asian jungles. Only on the Asian continent have these animals been tamed and brought under control of human hands. Fire is the element that plays a major role in this domestication of the elephant.

Deep in the jungle a sturdy stockade is built out of logs. A wild herd is then located and driven with much noise by the people on their tamed elephants into the stockade. Once inside the gates are closed and as night falls men climb onto the walls of the stockade with burning torches which terrifies the wild herd inside. When the herd is in this terrified state, the gates are opened and a number of domestic tuskers with disguised mounts enter. For disguise the mahouts cover themselves with elephant dung and hang beneath the necks of their charges. The tuskers then move amongst the herd isolating the young elephants from their mothers. When isolated the mahouts slip to the ground and place ropes around the young elephants. When a number have been bound in this way, there is a rising of the noise again and the gates are opened. The panic stricken herd, including the mothers, surge through the gates and into the night filled jungle leaving their offspring bound in the stockade between overbearing tuskers. Between these tuskers they are then walked back to the camp, fighting and straining against their captors.

In the camp the young elephants are bound by their back ankles to a tree behind and by their neck to a tree in front. Their front legs were free and they had limited lateral movement. One person was assigned to visit them daily with food and water.

After some time in this situation, say a week, most of the mahouts in the camp would visit the elephant at night. Usually a quantity of rice beer had been drunk by the men who carried burning torches and were singing in unison. They surrounded the elephant, waving the torches before him while singing and swaying. Fire and the human voice were combined in this way as something which the

elephant gradually had to become accustomed to. This was repeated on many nights and then enhanced by the singing, fire waving men rubbing the elephant with great wads of grass. The element of touch was then added to the sound of the human voice and the warmth of fire, the element that so terrified the wild creatures. A further enhancement is the climbing of the men beneath the belly of the elephant and finally climbing onto the elephant. After some nights of this ritual, the mahout assigned to that elephant gets onto its neck and between two tuskers is escorted to the river for its first 'domestic bath'. Eventually the mahout is able to take the elephant alone to the river for its daily bath.

Such a story gives a picture of how fire is so closely linked to humanity in its separateness from the natural order.

Another story that deals with this in a different way is the story from Greek mythology of Prometheus who stole the fire from the Gods to give the possibility of freedom to humankind - a deed he was severely punished for. Throughout these introductory lessons on chemistry, further stories can be introduced that develops this imagination of the connection between humanity and fire.

The first lessons then can be built around the building of fires from plant material and observing this primeval process. These experiments can be extended to look at different types of fires -

- glowing charcoal whose glow can be effected by the chimney created above it (an earthy fire);
- a flowing fire waterfall made of an ignited mixture of Methylated spirits and water in a proportion of 80% methylated spirits:20% water (a watery fire);
- the fire made by expelling propane gas, from a brown paper bag, over a candle (an airy fire);
- the fire made by careful controlled burning of petrol (a fiery fire, which could be described at another time, and needs careful preparation to be done safely).

A next step could be to collect the substances emerging from fire. The smoke from the flickering pole of the fire can be collected and passed through diluted juice[1] of a red cabbage (a sensitive indicator) which will become tinged to pink from its original violet colour. The ash, from the base of the fire, will colour the cabbage juice green (in neutral rain water the juice is violet). The juice of the cabbage is an indicator for acids when it is red and for alkalis when it is green. You can get a whole spectrum of colours with it using soap, vinegar, lemon juice, bicarbonate of soda and other things.

Other experiments could explore other substances from the children's lives — lemon juice, vinegar, soap, bicarbonate of soda, tartaric acid, window cleaner, etc. using taste in connection with the red cabbage juice. There is not space here to describe in detail the many experiments, questions and activities that can accompany the lessons. Suffice to say that from the fire can emerge the polarities of acid and base (alkali) - fundamental polarities of chemistry but also of life in a much broader sense, and also the idea of neutralization.

A further step in this introductory chemistry block is to take fire deeper - take it into the mineral world, into the limestone, the rock that comes out of animal life. Here we come upon another ancient process - Calcination, where limestone is heated to between 1000 degrees C and 1100 degrees C in a kiln. This process forms the basis of the making of lime mortar used for building houses and the lime milk for fresco painting. The process is very impressive but often is missed because of the perceived difficulties in achieving the high temperatures in the classroom during the time of a main lesson. The following description with picture provides a simple, safe and very efficient way of calcining limestone during a main lesson, while at the same time allowing the collection of the acidic gas (carbonic acid) coming off the process as "smoke" and the alkaline "ash" remaining behind as the "enlivened limestone" - the quick lime or "thirsty lime". When you heat the marble to 1000 degrees centigrade, the deadening gas, carbon dioxide is driven out of the marble, and bubbles through the red cabbage juice. Carbon dioxide is heavier than air and if the hose that comes out of the flask containing the red cabbage juice is put into a jug with a cloth over the top then the jug will fill up with the invisible liquid air. If you lower a little lighted candle into the jug, it will be extinguished. You can pour the invisible air into a cup and drink it. It will have a slightly sour taste. The red cabbage juice will go a slightly pink as the carbon dioxide dissolves in the water and forms carbonic acid.

1 During winter and spring, it is easy to find a red cabbage at the produce market or greengrocer. It is a cabbage which has a red-violet colour. Buy one of them and cut it in little slices. Put them in a pot and pour enough water to cover them. Boil for half an hour, then turn off the heat and let the temperature come down. Pour the blue-violet liquid you have obtained into a container.

If you peep into the kiln during the heating process you may see the brilliant white "limelight" emitted by the hot marble block. When the marble has cooled it will have lost its shine and become chalky. It has really come to life and responds to water by becoming very hot. It is very thirsty. It moves and steams and is very lively. Eventually its thirst is quenched and it becomes lime milk which can be used to make fresco paintings. This hydrated (slaked) lime then sucks back in carbon dioxide from the air and becomes limestone again. So the fresco is a painting that has become stone. (Ajanta Caves).

A further step in the main lesson would involve the burning of Sulphur which leaves no ash but only a very acid smoke.

Then would follow the burning of metal (copper) which leaves an ash but no smoke. This ash is the ore we find in the earth from which the pure metals are them smelted - another primeval process which makes up this introduction to chemistry.

The main lesson then spans fire in the plant world to fire in that part of the mineral world that comes from the animals to the fire in the fiery non-metal (sulphur) to the fire around the production of metals out of their ashes (ores) deep in the earth.

Construction of the kiln

The classroom kiln is built from loose concrete and/or clay bricks and lining made from sheets of ceramic fibre wool obtainable from a fireplace or kiln shop. The fire source is a propane gas Teclu Burner, or something similar, which produces a noisy very hot blue flame about 4cms long and 2cm thick. The pieces of limestone or marble to be calcined are fitted into the end of a length of steel piping (2.5cm diameter) that reaches into the kiln. The steel tube must be welded airtight closed at one end. The tube end rests on a larger piece of marble.

Figure 1: *The kiln being built to show the space needed.*
Figure 2: *Beginning the kiln*
Figure 3: *The back of the kiln where the burner will be inserted. Notice the little apron of ceramic fibre wool which forms the base of the fire box and extends out beneath where the burner will be to prevent the heat getting down to the bench.*

Figure 4: *The ceramic fibre lining of the sides of the fire box, which must be just big enough to fit the steel calcination tube with only small gaps around it.*

Figure 5: *The addition of the ceramic fibre top to the fire box.*

Figure 6: *The addition of the roof bricks on to the ceramic fibre top.*

Figure 7: *The calcination tube inserted into the front of the kiln.*

Figure 8: *The building up the chimney at the front of the kiln.*

Figure 9: *The back of the kiln with the steel calcination tube resting on piece of marble. Note the spacing.*

Figure 10: *The flap at the back of the kiln with the hole in the ceramic fibre wool. This arrangement protects the burner from the heat of the fire box. The burner in this case is a Teclu Burner, but can be replaced by something equivalent.*

Figure 11: *Looking back into the fire box from the chimney end.*

Figure 12: *The working kiln with the burner going and a glass tube extending from the calcination tube taking the vented gases through the conical flask containing dilute red cabbage juice.*

Figure 13: *The inlet to the flask containing red cabbage juice goes to the bottom of the vessel ensuring the gas bubbles up through the juice. The outlet has a rubber tube on it, which takes the gas into a jug, to be poured into glasses and tasted. The gas can also be shown to extinguish candle flames i.e. it is a 'dead' gas.*

Figure 14: *The calcination tube being emptied after 45 minutes. The shiny marble has become chalky white.*

Figure 15: *Slaking the thirst of the enlivened quick lime. After the expulsion of the 'dead' gas it has become very lively, giving of great heat, making sounds and moving.*

The story of Limestone begins with moist little creatures creating hard coverings (houses) for themselves (think of the bird's egg). These rain down out of the ocean creating vast deposits of lime sludge in the ocean, upto 1.5km deep, the precursors of future limestone rock and mountain formations. Limestome then gets eroded by acid rain creating the "airy" karst[2] landscapes with caves that form the homes for bats, bears and human beings. This limestone is then cut from the karst landscapes and calcined to make mortar for the making of houses again - a theme in the chemistry of limestone.

Summary:

The process is an archetypal chemical process which underlies the making of mortar for buildings, the beginnings of cement making and the painting of frescoes. It belongs in the sequence of combustion processes which make up the first chemistry of the Waldorf Steiner Schools - The burning of plant material and all that goes with that, then the calcination of limestone - a rock that derives from the animal kingdom, then the burning of Sulphur which has no ash only acid smoke, and finally the burning of metal which has no smoke but only an ash which is the ore of the metal which then leads to the smelting of cassiterite (tin oxide).

The kiln worked extremely well. ◆

2 The term karst referred originally to the limestone landscape of the Karst area, near Trieste around the Italy-Slovenia border. Large rivers disappear underground, and there are many caves, enclosed depressions, fluted rock outcrops, periodic lakes, subterranean rivers, and large springs.

References:

Manfred v. Mackensen, 1981. *Feuer-Kalk-Metalle. Einführende Unterrichtsgebiete aus phänomenologischem Ansatz für die Chemieepoche der 7. Klasse.* Als Manuskript vervielfältigt zum internen gebrauch von der Pädagogischen Forschungstelle beim Bund der Freien Waldorfschulen. Erhältlich von der Lehrmittelabteilung des berufsbildenden Gemeinschaftswerkes, 3500 Kassel-Wihelmshöhe, Brabanterstrasse 43. This excellent reference work for the introductory chemistry is not yet translated althought a summarised translation is available from the Pedagogical Section in Australia. pglasby@adam.com.au

Rudolf Steiner, 1923. *The Four Seasons and the Archangels.* The lecture from Oct. 7th 1923 on the Easter Imagination gives some interesting esoteric insights about limestone and its enlivening in the Spring (for the teacher's background).