

Sodium carbonate – a versatile material

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Introduction

This booklet presents learning material based on the manufacture and uses of sodium carbonate made by the Solvay (ammonia-soda) process. It is the result of a Learning Material Workshop organised by The Royal Society of Chemistry in conjunction with The Institute of Materials and The Worshipful Company of Armourers and Brasiers. The workshop was held at the Brunner Mond Company, Northwich, Cheshire.

A group of chemistry teachers spent a day at Brunner Mond and was given a presentation by the company on various aspects of the Solvay (ammonia-soda) process for the manufacture of sodium carbonate and sodium hydrogencarbonate. This was followed by a tour of the plant. The following day was spent brainstorming and drafting the material which is presented here in edited form.

The teachers involved were:

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Keith Huggins, Aylesbury High School; and

Barry McFarland.

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The material

The booklet includes teacher's notes and material to photocopy as follows:

Part 1. Manufacturing sodium carbonate – an overview for teachers

An overview for teachers of sodium carbonate and sodium hydrogencarbonate manufacture (especially by the Solvay process) and of the uses of these products. It includes some unusual details of the process and anecdotes which could be used by teachers to enhance their own teaching.

Part 2. Making sodium carbonate

A worksheet for 11–13 year old students. It includes some simple practical work as well as an account of the Solvay process and questions on the process and raw materials.

Part 3. Manufacturing sodium carbonate

A worksheet for 14–16 year old students with an account of the Solvay process and questions on the process and raw materials.

Part 4. Manufacturing sodium carbonate by the Solvay process

An account of the Solvay process based on 1 above but with some of the detail, that which is intended specifically for teachers, removed. It is aimed at post-16 students but would also be accessible to more able pre-16 students.

Part 5. The thermodynamics and equilibria involved in the Solvay process for the production of sodium carbonate

A worksheet for post-16 students with questions on the thermodynamics and acid-base aspects of the Solvay process and the uses of the products. It could be used independently but would ideally be used after students have read part 4.

Using the material

None of the material assumes any prior knowledge of the Solvay process. Parts 3 and 5 are entirely self-contained and require no teacher input. They are therefore suitable as homework exercises or as work to be tackled in the event of teacher absence.

The Solvay process is not a core part of current syllabuses and specifications but the aim of the worksheets is to get students to apply chemical principles in an unfamiliar context, not for them to learn details of this process.

Part 2

Making sodium carbonate

Material for 11–13 year old students

Making sodium carbonate

Sodium carbonate is a very useful material. About one million tonnes of it is made each year in the UK – all by the Brunner Mond company in Cheshire. Although it is a white powder, most of it is used in making glass. This involves mixing it with sand and other substances and heating it. To make sodium carbonate, Brunner Mond uses two raw materials:

- ▼ salt (chemical name sodium chloride) which is found in underground deposits close to their factory; and
- ▼ limestone (chemical name calcium carbonate), which is quarried in Derbyshire.

The lime cycle

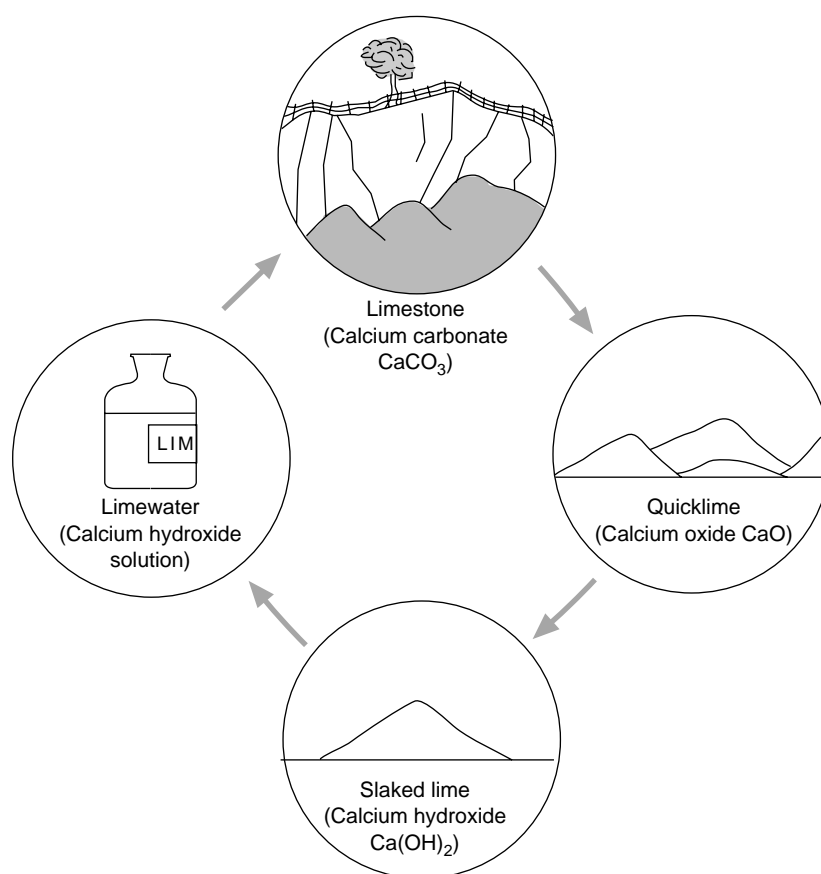


Fig 1 The Lime cycle

Figure 1 shows a cycle of chemical reactions starting with limestone. These turn limestone into other substances and finally back to calcium carbonate. Some of these reactions are used by Brunner Mond when it makes sodium carbonate.

Experiment

You can try some of these reactions yourself. You must wear eye protection.

1. Take a small chip of calcium carbonate and place it on a clean tin lid standing on a heatproof mat. Heat the chip strongly for a few minutes using the hottest part of a roaring Bunsen flame, Figure 2. Note the burner air hole should be open, and remember that the hottest part of a Bunsen flame is just beyond the blue cone.

Part 3

Manufacturing sodium carbonate

Material for 14–16 year old students

Manufacturing sodium carbonate

You might be surprised to find that a million tonnes of sodium carbonate is made and sold in the UK each year. This is about 20 kg (20 bags of sugar) for every man, woman and child in the country. However, it is unlikely that you or your family have bought any at all, although a few people might find a small packet of 'washing soda' under the sink. This is sodium carbonate and is still used by a few people to soften water or to help clean the oven or the drains. You will have used sodium carbonate indirectly, though, as 90 per cent of it is used to make glass.

Question

1. Make a list of at least 10 things you have used or bought in the last week which use glass. You can probably think of lots more than 10, so try to make your list as varied as possible.

All the sodium carbonate made in the UK comes from one company – the Brunner Mond company based in Northwich in Cheshire. The company makes sodium carbonate from limestone (calcium carbonate, CaCO_3) and salt (sodium chloride, NaCl) using coke (made from coal) as a fuel. The map in *Figure 1* shows where these raw materials are found.

Fig 1 The locations of some mineral deposits in the UK

Part 4

Manufacturing sodium carbonate by the Solvay process

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An overview of the process for post-16 students

Manufacturing sodium carbonate by the Solvay process

Sodium carbonate is used by many different industries as a raw material and about one million tonnes is produced each year in the UK – all of it by the Brunner Mond Company in Northwich, Cheshire. Also produced in smaller quantities is sodium hydrogencarbonate as well as calcium chloride as a by product, a little of which can be sold.

Industrially, sodium carbonate is usually referred to as ‘soda ash’ and is produced and sold in two grades:

- ▼ ‘light ash’ – a fine powder; and
- ▼ ‘heavy ash’ which has a bigger particle size and is more dense, making it more efficient to transport.

Sodium hydrogencarbonate is used in:

- ▼ water treatment;
- ▼ as an additive in food and drinks – eg baking powder;
- ▼ for blowing foams such as expanded polystyrene;
- ▼ in pharmaceutical products as an antacid;
- ▼ in personal care products such as toothpaste; and
- ▼ as an additive in animal feeds.

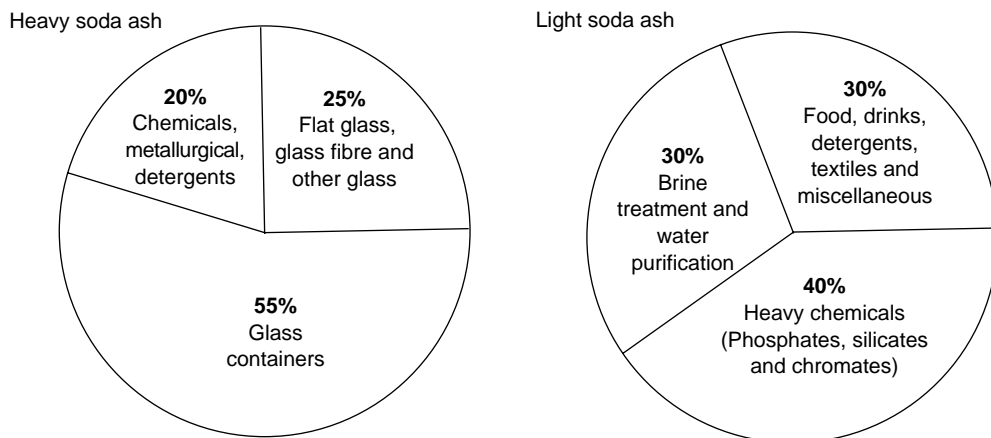


Fig 1 The uses of sodium carbonate
Exact percentages will vary with economic and social factors

Figure 1 gives an approximate breakdown of the uses of light and heavy ash but these are subject to change depending on a number of social and economic factors. For example in a recession, fewer cars and houses are built, which reduces the demand for glass. Importation of alcoholic drinks from the continent due to more liberal customs regulations has led to a decrease in the number of glass bottles made in the UK and thus a drop in demand for heavy ash.

Part 5

The thermodynamics and equilibria involved in the Solvay process for producing sodium carbonate

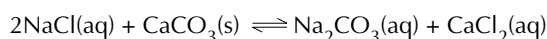
Material for post-16 students

The thermodynamics and equilibria involved in the Solvay process for producing sodium carbonate

Thermodynamic aspects of the process

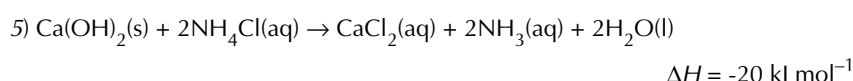
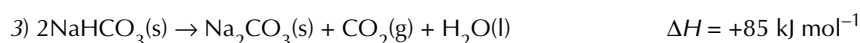
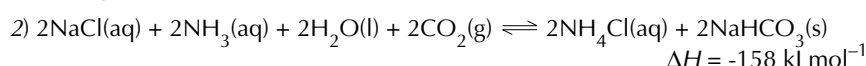
This is an old process dating from the late 19th century. It is also known as the ammonia-soda process. It uses two raw materials: sodium chloride and calcium carbonate.

The overall reaction:



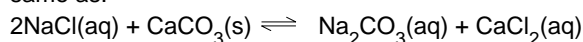
is endothermic ($\Delta H = +20 \text{ kJ mol}^{-1}$, $\Delta G = +60 \text{ kJ mol}^{-1}$)

and the equilibrium lies well to the left. So the production of sodium carbonate must be undertaken by an indirect route. The actual series of reactions used is:



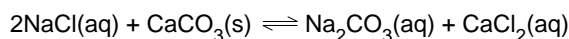
Questions

1. (a) Show that the overall effect of the five reactions above is the same as:



You can do this by adding up the five equations above – *ie* adding all the species on the left of the arrows, adding all the species on the right of the arrows and then cancelling all the species that occur on both the left and the right.

- (b) Hess's Law states that the enthalpy change for any reaction is independent of the route by which that reaction occurs. So adding the enthalpy changes of the five reactions above should give the enthalpy change of



Add up the enthalpy changes of reactions 1 – 5 above to calculate a value for ΔH for the overall reaction. Comment on the value you obtain.

The overall reaction requires an input of heat energy. This is provided by burning coke.

