Maurice Cosandey

President of the Swiss Association of Chemistry Olympiad
Federal Institute of Technology
Lausanne, Switzerland

CHEMISTRY

Some Simple Demonstrations in Classroom

2006
1. Neutralization in extremely diluted solutions.

1.1. Neutralization NaOH - HCl, without buffering action.

Half fill two 250 mL beakers with distilled water. Put a glass rod in one of them. See figure. Bring two flasks, one of HCl 0.1 M or 0.2 M, and one of NaOH same concentration. Open the flasks, and lay them down near the beakers.

Dip the glass rod into the acid flask and get it out. One or two drops of the acidic solution remains on the rod. Put the rod into the solution where it came from.

Repeat the same operation with the same rod bringing one drop of the NaOH solution into the second beaker. See figure.

Pour one drop of Bromthymol Blue into each beaker. The solutions become blue on the left and yellow on the right. The pH values are about 4 and 10.
Dip the glass rod into the flask of NaOH, then into the acidic solution (yellow). The solution turns blue. If not repeat the operation with a second drop of NaOH.

Repeat this transfer operation by dipping the rod into the HCl flask then into any blue beaker, which turns yellow. Repeat the transfer if the blue colour persists.

This to and fro motion can be repeated nearly indefinitely..

1. 2. Difficult search of neutrality (Continuation of 1. 1.).

The last motions can be repeated many times. The neutral green colour will never be obtained barring an extraordinary luck ... But the neutrality can be obtained by another way. Empty half the water out of the acidic beaker. Pour slowly the blue solution into the acidic beaker. With a bit of luck the green can be obtained. The solution is neutral then : pH 7.

1. 3. No buffering action (Continuation of 1. 2.).

Continue adding the blue solution : the mixture turns blue. Conclusion : the mixture is extremely sensitive to any excess of acid or base. In other words it is not a buffer solution. We will now show that tap water resists to the addition of acids or bases.
1. 4. Impurities from pure and tap water.

Half fill two 250 ml beakers, one with distilled water, the second with tap water, which must be a bit chalky. Add two drops Bromthymol blue in each beaker. The pure water turns yellow, and tap water blue. Ask the students why! What is the impurity contained in both waters?

<table>
<thead>
<tr>
<th>Pure water</th>
<th>Tap water</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Yellow" /></td>
<td><img src="image2" alt="Blue" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pure water</th>
<th>Tap water</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Yellow" /></td>
<td><img src="image4" alt="Blue" /></td>
</tr>
</tbody>
</table>

Explain that:

1) Carbon dioxide CO$_2$ from the air is slightly soluble in water making an acid (H$_2$CO$_3$)
2) Chalky water contains Calcium and a base (HCO$_3^-$). With beginning students the teacher may “lie” and say that the dissolved substance is Ca(OH)$_2$.

1.5. Buffer action of tap water (Continuation of 1.4.).

Take hold of the beaker with blue tap water (chalky water) and pour its water slowly into pure water. When about 20% has been transferred, the mixture becomes green (or neutral).

<table>
<thead>
<tr>
<th>Pure water</th>
<th>Tap water</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5" alt="Yellow" /></td>
<td><img src="image6" alt="Blue" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pure water</th>
<th>Tap water</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image7" alt="Yellow" /></td>
<td><img src="image8" alt="Blue" /></td>
</tr>
</tbody>
</table>

Have the student observe that this green mixture “resists” to further addition of acids or bases. It remains green if more tap water is added. It acts as a buffer, as a car bumper:

Explain that the green mixture is not very sensitive to the amount of acid or base added. And this is very different from what was shown with pure water in § 1. 2. and 1. 3..

Better: Repeat all operations from § 1.1. with tap water instead of pure water. When a green solution has been obtained, the solution keeps green even if the to- and fro motion is continued. This proves that chalky water has a good buffer action.
2. Neutralization of solid NaOH + conc. HCl.

Be careful! This reaction is violent!

Put a couple of solid NaOH grains in a big test tube (at least 15 cm long). Take hold of a concentrated HCl solution (35%). Pour one drop into the test tube, not more than two! When the drop touches the first NaOH grain, a violent reaction starts with a noise of punched tyre.

Add another drop, then another one: each time the same noise happens. But the test tube gets hotter and hotter. It soon cannot be held. Put it in an support (big beaker for example)

![Diagram of NaOH and HCl reaction]

Add more HCl drop by drop, stirring. Same noise at each new drop! But suddenly the noise stops: the reaction is over! Ask the audience: What is the small white deposit?
Show that it is simply salt NaCl by filling up the tube with water: the salt disappears.

3. Gas phase neutralization: \(\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}\)

Get a glass bell which must be air tight (an upside down beaker will not do) and a glass plate somewhat bigger than the diameter of the bell, plus two small beakers (< 50 ml).

Half fill the first beaker with HCl 35% and the second with \(\text{NH}_3\) 25%.

Proceed quickly! Put the two beakers in the middle of the glass plate. Cover them with the the glass bell. A white smoke (\(\text{NH}_4\text{Cl}\)) appears in the bell which soon gets deposited on the plate.

![Diagram of NH3 and HCl reaction]

Wait about 30 minutes. Remove the bell under the hood. Remove the beakers and throw away their content. Observe the glass plate, which is covered by a white powder except under the beakers. The deposit of ammonium chloride \(\text{NH}_4\text{Cl}\) may be tasted on the tongue.
4. Proton transfer from H$_2$SO$_4$ to NaCl then to H$_2$O.

Get a 150 ml conical flask equipped with a rubber stopper, punched by a doubly curved glass tube, See figure. The stopper must be air tight!

Put enough sea salt (NaCl) to cover the bottom of the flask. Add 50 ml H$_2$SO$_4$ 96% and close the flask quickly with the stopper and the doubly curved glass tube. The other end of the curved glass tube must plug into a tall beaker filled with water.

The HCl gas formed in the conical flask pushes air that bubbles into the water. Then the bubbles seem to have some difficulty crossing the water, because they are made of HCl which gets dissolved into the water. After a couple of minutes the gaseous emission slows down. Surprisingly enough, water goes up into the tube against the gas current. The water return proceeds all of a sudden with extreme violence.

Later

The corresponding reactions are all proton transfers. In the flask H$_2$SO$_4$ produces:

\[
\text{H}_2\text{SO}_4 + \text{NaCl} \rightarrow \text{NaHSO}_4 + \text{HCl}
\]  

(2)

which is a proton transfer from H$_2$SO$_4$ to the Cl$^-$ ion from NaCl:

\[
\text{H}_2\text{SO}_4 + \text{Cl}^- \rightarrow \text{HSO}_4^- + \text{HCl}
\]  

(3)

In the large beaker a second proton transfer happens from HCl to H$_2$O:

\[
\text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^-
\]  

(4)

N.B. The water return may not happen if the stopper is not absolutely air tight. Old stoppes often fail to succeed.
5. Coloured flames.

Take hold of a cotton bud (Q-tip) by one end. Wet the other end, and dip it into some calcium chloride CaCl$_2$ powder.

Place this sample into the lower external zone of a Bunsen burner flame: the flame becomes orange - red, and this colour lasts a long time. The flame may be observed through a spectroscope: numerous red and orange lines, plus one green one.

- Take care. Don’t place the sample inside the flame: the central stem would burn!
- If the colour dies down, dip the tip once more into the CaCl$_2$ powder.
- The yellow colour and line of the Sodium flame never happens with this technique, which is an improvement with respect to the traditional platinum wire technique.
- If the Q-tip gets dry, it can be wetted again with a pissette.
- And if the Q-tip gets dry and burns, forget it and start again with a new one!

Variations.

Other chlorides can be used with the same method, as they are generally easily volatilized.

LiCl yields a dark purpur red flame, with only one line in the red part of the spectrum.

NaCl yields a yellow flame with the famous yellow D-line.

KCl yields a pale whitish light whose spectrum is hard to observe. It has one pale line in the red and one in the violet, plus the yellow line due to sodium impurities.

SrCl$_2$ yields an intense and bright red colour, with many lines in the red and orange.

CaCl$_2$ produces a reddish colour which soon disappears, as CaCl$_2$ gets quickly dissolved into the water of the Q-tip and cannot be easily vaporized.

BaCl$_2$ gives a pale yellowish green flame which soon disappears, as BaCl$_2$ is soon transformed into the oxide BaO which is not volatile, and therefore does not colour the flame.

CuCl$_2$ gives a green flame, with plenty of yellow or blue sparks which are due to the progressive pyrolysis of CuCl$_2$ in CuCl and CuO.

A. Take hold of the two tips of a match between two fingers. Place the middle of the match inside the blue cone of the flame in the lowest possible position. See A. The only burning part of the match is in the outer part of the flame, The inner part does not burn! It contains a cold mixture of methane CH\(_4\) and air.

B. Variant: Take hold of the non-burning tip of another match. And place the bud in the center of the blue cone, as in B. The wood will burn but not the bud. It is made of a mixture of paste and KClO\(_3\).

The following setup demonstrates that the flame produces CO\(_2\) et H\(_2\)O according to:

\[
\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \tag{5}
\]

Cover and insert the flame into a big glass balloon. The flame goes out and some mist appears inside. Stop the gas. Remove the balloon. Close the balloon with a cork stopper. Pour some chalk water inside. Stir: the water gets turbid. This is due to the carbon dioxide from the flame. It reacts with chalk water (solution of Ca(OH)\(_2\)) producing a white precipitate CaCO\(_3\)

\[
\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} \tag{6}
\]
7. Combustion of gasoline.

Wrap a porcelain capsule with an aluminium foil. Pour some drops of usual car gasoline into the capsule. Gasoline is a mixture of \( C_8H_{18} \) and other hydrocarbons. Throw quickly a match on fire. The gasoline catches fire quickly and gives off some black smoke rich in charcoal. This is due to an imperfect combustion.

Most molecules \( C_8H_{18} \) are burning completely according to the global equation:

\[
2 \, C_8H_{18} + 25 \, O_2 \rightarrow 16 \, CO_2 + 18 \, H_2O \quad (7)
\]

But a small percentage of \( C_8H_{18} \) are burning imperfectly and produce Charcoal according to:

\[
2 \, C_8H_{18} + 9 \, O_2 \rightarrow 16 \, C + 18 \, H_2O \quad (8)
\]

Point out that:

1. The combustion is not immediate. It takes some time for each group of 2 molecules of gasoline to get vaporized and find the 25 molecules \( O_2 \) needed for the reaction.
2. \( O_2 \) attacks the gasoline molecule by first removing the \( H \) atoms, and then, if enough \( O_2 \) is available and only then, Carbon atoms are oxidized.

Comment.

The aluminium foil is not necessary. Gasoline burns in any environment. The foil simply allows a quicker cleaning operation. The flame produces a dark deposit on the support. If it is aluminium, this does not cause any problem. But if it is on procelain charcoal deposits adheres on it and resists to cleaning.
8. Principle of the internal combustion engine

Bring a cylindrical glass container about one liter volume (without a lip - a beaker will not do). The best container is an old coffee box from scrap. Prepare in advance a thick cardboard disc with about the same diameter as the container; punch a hole 1 cm wide in the middle of the disk. Cover the opening of the container with the punched disk.

Explain that the volume of the chamber (1000 cc) is about the same as in a car. It contains 200 ml O₂, which is about 0.009 mol O₂.

To get a perfect combustion this requires 12.5 times less gasoline, i.e. 0.007 mol or 0.1 g, or 4 drops.

Take hold of a 1 milliter syringe. Fill it with gasoline. Inject the flask with 3 - 4 drops gasoline through the hole of the disk. Wait half a minute until the drop is evaporated. Throw a match through the hole without touching the edge: The gaseous mixture explodes nearly noiseless and projects the cover a couple of centimeters in the air.

3 drops gasoline

Wait vaporization

Variants.
The number of drops can be changed. With less than 2 drops, nothing happens. With more than 8 drops, the explosion misfires. With about 20 drops, the mixture burns like a candle when the disk is removed.
9. Combustion of Magnesium Mg

Hold a bit of magnesium ribbon 3 - 5 cm long with a pair of pliers or tongs. Set fire to it in the outer part of a Bunsen burner flame. Inside the flame magnesium melts without burning. The flame is dazzling and rich in UV light. Don’t look directly on the flame! Going blind is a risk!

\[ 2 \text{Mg} + \text{O}_2 \rightarrow 2 \text{MgO} \quad (9) \]

![Magnesium ribbon](image)

Save the ashes (MgO) in a test tube containing 5 ml water. Boil it and add two drops of Bromthymol blue. The solution turns blue, even though all is not dissolved. A base has been formed: magnesium hydroxide Mg(OH)\(_2\).

\[ \text{MgO} + \text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 \quad (10) \]

This base Mg(OH)\(_2\) can be dissolved with 3 ml HCl 2 M by slight heating.

\[ \text{Mg(OH)}_2 + 2 \text{HCl} \rightarrow \text{MgCl}_2 + 2 \text{H}_2\text{O} \quad (11) \]

![Magnesia](image)

P.S. It must be mentioned that the basicity of the solution is also due to the presence of Mg\(_3\)N\(_2\) in the magnesia, which forms NH\(_3\) when reacting with water:

\[ \text{Mg}_3\text{N}_2 + 6 \text{H}_2\text{O} \rightarrow 3 \text{Mg(OH)}_2 + 2 \text{NH}_3 \quad (12) \]
10. Burning other metals.

a. Cerium. The flint for cigarette lighters is made of Cerium Ce, which burns by rubbing:

\[ 2 \text{Ce} + 3 \text{O}_2 \rightarrow 2 \text{Ce}_2\text{O}_3 \]  \hspace{1cm} (13)

b. Iron. Steel wool burns in air, when put in a flame. The combustion is slow burning but may be stoked up by blowing on it. The equation is:

\[ 3 \text{Fe} + 2 \text{O}_2 \rightarrow \text{Fe}_3\text{O}_4 \]  \hspace{1cm} (14)

Comments.

- Protect the table and the surroundings against stains from sparks.
- Don’t try to make stoechiometric calculations: the change of weight is negligible!.
- \( \text{Fe}_3\text{O}_4 \) is made of one atom Fe(II) and two atoms Fe(III). This substance is sometimes called magnetic oxide because \( \text{Fe}_3\text{O}_4 \) is attracted by a magnet like iron. Its developed formula can be given by: \( \text{O} = \text{Fe}-\text{O}-\text{Fe}-\text{O}-\text{Fe} = \text{O} \).
- Don’t confuse this combustion and the more usual rust formation. Rust is \( \text{Fe}_2\text{O}_3 \).
- Rust formation is an electrochemical process requiring four conditions: 1) a charcoal impurity at the surface of an iron piece, 2) one drop of water, 3) air and 4) carbon dioxide in the air. If one of these four substances is missing, iron does not rust.
- Three different iron oxides are known: \( \text{FeO} \), \( \text{Fe}_2\text{O}_3 \) et \( \text{Fe}_3\text{O}_4 \). The most stable is \( \text{Fe}_3\text{O}_4 \) at high temperatures.
11. Black powder

Black powder is a mixture of saltpeter \( \text{KNO}_3 \), charcoal \( \text{C} \) and sulfur \( \text{S} \).
When set on fire it reacts according to the Liebig equation (1859):

\[
2 \text{KNO}_3 + 3 \text{C} + \text{S} \rightarrow \text{K}_2\text{S} + \text{N}_2 + 3 \text{CO}_2.
\]

(15)

The theoretical mass proportions are: 74.8\% \text{KNO}_3, 13.3\% \text{C} (wood charcoal), and 11.9\% \text{S}.

To prepare black powder, mix in a porcelain mortar enough ingredients so that the total mass is 40 g. Add enough water to get a paste. Grind it thoroughly until no more yellow sulfur grain is to be seen. It may be long! Then let it dry in the air for one night. On the next day the mixture may adhere on the mortar. Remove it with a knife.

Never grind the initial mixture of saltpeter, charcoal, and sulfur when dry! Danger: it may explode!

To set fire into the black powder, deposit a little amount on a wire-mesh impregnated with ceramic. Take hold of a Bunsen burner and direct the flame on the powder. The powder takes a couple of seconds to set fire. It produces a simple but nice pyrotechnic effect.

Safety problems

- Never mix saltpeter, charcoal, and sulfur when dry. In 2001 an Irish teacher lost one eye while doing it. Anyway water dissolves saltpeter which is more homogeneously distributed in the mixture this way.

- Dry black powder can be kept indefinitely in a closed bottle. It is not sensitive to moderate shocks, and will not spontaneously set fire, as nitroglycerine.

Comments.

- Use an old wire mesh: ignition damages the mesh.

- In the dictionary black powder is made of 75\% saltpeter, 15\% charcoal and 10\% sulfur. Charcoal is then in excess.

- Drawback, not to tell the students. The chemical analysis of ashes and other residues reveals no \( \text{K}_2\text{S} \) but \( \text{K}_2\text{CO}_3 \) and \( \text{K}_2\text{S}_2\text{O}_3 \), which is hard to explain without using \( \text{O}_2 \) from the air.
12. Chlorate rocket.

Take hold of a small combustion tube (Ø 6 mm), a tooth pick and a wooden pair of tongs. Fill the bottom of the tube with potassium chlorate $\text{KClO}_3$, on about 5 mm thick. Hold the tube with the tongs near the aperture. Heat the bottom up in a Bunsen flame. Chlorate smelts then decomposes and gives off oxygen bubbles $\text{O}_2$.

At this very moment get the tube out of the flame, and introduce quickly the tooth pick nearly burning (with just a red spot). It burns with brightness and vigour in the gas coming out of the decomposition. But if it is pushed down into the liquid chlorate itself, it produces such a powerful reaction that it looks like a rocket starting.

- The reaction producing oxygen $\text{O}_2$ is

$$2 \text{KClO}_3 \rightarrow 2 \text{KCl} + 3 \text{O}_2$$  (16)

But there is a simultaneous side reaction producing perchlorate $\text{KClO}_4$ and chloride $\text{KCl}$:

$$4 \text{KClO}_3 \rightarrow \text{KClO}_4 + 3 \text{KCl}$$  (17)

- This reaction may be used for preparing large amounts of gas $\text{O}_2$. But it is too vigorous. It can be slowed down by adding an equal volume of $\text{MnO}_2$ or $\text{Fe}_2\text{O}_3$ to the chlorate $\text{KClO}_3$, before heating it up. The reaction is also more regular and does not produce any $\text{KClO}_4$. It starts also at a lower temperature.

- $\text{KClO}_3$ was used in the 19th century for analyzing the C and H content in organic substances. All that has to be done was measuring the mass of $\text{CO}_2$ and $\text{H}_2\text{O}$ produced by the combustion of the organic substance : Gay - Lussac method. As the reaction of $\text{KClO}_3$ was too vivid, this compound was later replaced by copper oxide $\text{CuO}$.
13. Printed circuits and redox reactions.

This demonstration requires thin plastic foils covered with copper such as those used by
electroicians to make up printed circuits. They are for sale in Switzerland at Conrad
(www.conrad.ch), under the name Isel® plates 10x16 cm, reference 52.62.53-12.

Cut a strip of this foil with scissors in orderto get at least one strip thin enough to enter a large
test tube with ease. Usually a piece 50 mm long and 15 mm broad will be all right.

Write your initials on the copper face with a black waterproof ink or a marker for every
surfaces. The black layer must be thick enough: repeat the marking. Dry for une minute.

Take hold of two identical large test tube. Pour a solution of HCl 35% in the first and the same
volume of H₂O₂ 30% in the second tube. Pour the first solution into the second.
Throw the copper strip in the mixture. Take care: a strong reaction happens which heats a alot,
producing a blue-green color and a great amount of bubbles. Non protected copper is quickly
attacked and destroyd. After a couple of seconds transfer the solution into the second test tube
to check the strip. Repeat this to and fro motion until the unprotected copper has disappeared.
Then, after maybe 10 seconds, remove the strip and throw it into water.

Wash, rinse and dry the strip with paper. Remove the black vernish with acetone. The copper
letters appears freely as printed on the plate.

The equation of the reaction is:

\[ \text{Cu} + 2 \text{H}^+ + \text{H}_2\text{O}_2 \rightarrow \text{Cu}^{2+} + 2 \text{H}_2\text{O} \]  \hspace{1cm} (18)

Comment.

- The bubbles are due to a side reaction, the self decomposition of H₂O₂ into H₂O et O₂.
- The whole operation is more delicate than it may seem. The strip must not stay too long in the
  solution. Otherwise the black paint is also attacked and dissolved. The experimenter must be
carefully check the progress of the reaction.

A special equipment is to be used for this demonstration, namely two test tubes, a small one and a bigger one, both being punched through the bottom. Both must be closed by a one-hole rubber stopper. Bring also two high and thin beakers 150 or 200 mL and fill one with tap water.

Before starting the demonstration explain that:
- when putting such a punched tube into a beaker, the same proportion of water is removed, whatever the level of water in it. The small tube picks up always say 5% of the water, and the big one always 10%.
- the beaker on the left will represent the reagents, and that the beaker on the right represents the products.
- the demonstration implies transporting simultaneously 5% of the left hand side reagents and 10% of the right hand side products, each one towards the other beaker.

Plunge simultaneously both tubes into the two beakers. Wait until the water is on a level with outside. Block the rubber holes with a finger. Get the filled tubes out of their beaker, cross the arms and empty them in the other beaker. Repeat the operation as soon as possible. Observe the levels in the beakers. The beaker on the left of which 5% is picked up at every move tends quickly to be 2/3 full. The beaker on the right tends quickly to be 1/3 full.

This “game” can be continued as long as one wants it. The equilibrium is obtained when the same volume of water is picked up by both test tubes.

This is a good demonstration that the equilibrium is a dynamic phenomena.
15. Chemical equilibrium

Cobalt(II) chloride $\text{CoCl}_2\cdot6\text{H}_2\text{O}$ is a rose red powder that is soluble into water. The aqueous solution contains the ion $[\text{Co(H}_2\text{O})_6]^{2+}$ which is pale rose.

$$\text{CoCl}_2\cdot6\text{H}_2\text{O} \rightarrow [\text{Co(H}_2\text{O})_6]^{2+} + 2\text{Cl}^- \quad (19)$$

Surprisingly $\text{CoCl}_2\cdot6\text{H}_2\text{O}$ produces an intense blue colour in ethanol due to equation (20):

$$2\text{CoCl}_2\cdot6\text{H}_2\text{O} \rightarrow [\text{Co(H}_2\text{O})_6]^{2+} + [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O} \quad (20)$$

The blue colour of $[\text{CoCl}_4]^{2-}$ hides the pale rose of $[\text{Co(H}_2\text{O})_6]^{2+}$ in the solution. But adding water $\text{H}_2\text{O}$ into the blue alcoholic solution will soon turn it to a pale rose colour

$$[\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O} \rightleftharpoons [\text{Co(H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \quad (21)$$

This reaction (21) is an equilibrium and this can be easily demonstrated.

**Procedure.**

Take 3 identical test tubes. Take some water in the first tube then a pinch of Cobalt chloride. Stir to dissolve. Observe the rose colour. Do the same with the other tubes but with ethanol (or isopropanol) instead of water to obtain two blue solutions.

Take one of the blue solutions and add one or two drops of water: the colour turns reddish, according to (21). Compare with the two other tubes. Stop when the tube is still a little bit bluish.

This solution may be used to show that the reaction (21) is an equilibrium. To show that the reaction can be inversed, heat the rose test tube with a Bunsen flame. The solution turns blue again. Put it under the tap water flow: the solution turns rose again.

**Thermodynamic comment.**

Reaction (21) is exothermic towards the right side. But it leads to less independent species: 5 ions on the right hand side instead of 7 on the left. So the entropy decreases. Therefore the inverse and endothermic reaction (towards left) is favored at HT, as it is accompanied by an entropy increase.
16. Quick production of soap.

Put a couple of solid NaOH grains in a test tube, then water until it is level with the surface of the solid. Stir. NaOH will slowly dissolve and the solution heats up. The concentrated solution may be turbid, due to impurities of Na₂CO₃ which is not soluble in NaOH solutions.

Add twice as much vegetable oil (olive, corn, peanut, etc.). Oil floats without reacting. Tell the audience that saponification happens only at the interface oil - NaOH. Here this interface is a minimum. In the industry it is enlarged by emulsifying the oil into the NaOH solution. Anyhow the operations lasts many hours.

Add a volume of ethanol equal to the NaOH solution. Observe the three superimposed phases. Stop the tube with a stopper and stir violently by turning over the tube many times. The three phases get homogenized in a couple of seconds and the whole mixture congeals quickly in a semi-solid soap which fills up the tube.

To get the soap out of the tube, remove the stopper. Heat the bottom of the tube in a Bunsen flame. Heat very slowly. Ethanol boils soon and its vapour pushes the soap block out of the tube. The warm mass can be cast in the hand to make a bar of soap.

Comment.

Ethanol is miscible both with oil and with water or aqueous solutions. Its presence allows a molecular contact between NaOH and the oil. As the reaction rate is proportional to the interface oil-NaOH, the reaction is nearly instantaneous when carried out in alcohol.
17. Stretching polythene

Bring freezing bags like those used in every kitchen for saving food in the freezer. They are made of polyethylene (or polythene or PE).

Cut up bands of plastic as long as the bag width and about one centimeter wide with scissors. Avoid scratches and irregularities which may induce failures later on. Observe that the plastic sheet is nearly transparent.

Seaz one band between the thumb and fore finger. Stretch the strip very very slowly : it gets longer and thinner. It also becomes transparent. When the strip has doubled its length, it suddenly looks impossible to lengthen it any more. It has now a remarkable tensile strength. At this time the polymer chains are all parallel to one another.

Comments.

- Ethene or ethylene is formed of molecules CH\(_2\)=CH\(_2\). Its polymerization produces long linear chains of polyethylene or polythene PE : -CH\(_2\)-CH\(_2\)-CH\(_2\)-CH\(_2\)- etc. The initial foil contains such chains bent and randomly distributed. After stretching they are alined parallelly in the same direction : the whole has a greater tensile strength.

- Polymerization is carried out in the industry by two methods :
  - at high pressure (400 bars) in the presence of traces of O\(_2\) as catalyzer : the polymer is then called PELD or polythene low density.
  - at ordinary pressure with the so-called Ziegler-Natta catalyzer (mixture TiCl\(_3\) + Al(C\(_2\)H\(_5\))\(_3\)), the polymer obtained is then called polythene high density (PEHD).
18. Optical activity.

This demonstration requires special plastic films called polaroid or “Polarizing Films” which can be bought in A4 dimension at : http://www.3Dlens.com, at 7 € a piece. These films have the property of transforming ordinary light into polarized light. This can be shown by superimposing two of them. Light gets through if they are parallel. But the whole is opaque if they are crossed at right angle.

It is worth the trouble explaining this strange behaviour to the audience before going further. Light can be assimilated to a rope attached to a distant wall and hold in one hand. With the other hand give a sharp knock on the rope. It produces a wave which moves to the wall.
The polarizing film is like a grid or a comb astride on the rope. Only those waves which are parallel to the grid pass away and go on to the wall. With two such grids the wave will never pass through if they are perpendicular to one another.

Grid with vertical bars

The wave gets through

Grid with horizontal toothes

The wave is stopped by the grid

Grid with horizontal toothes

Propagation of the deformation wave

Grid with vertical toothes

Propagation of the wave

Whatever the direction of the knock the wave is stopped by one grid
When looking at a lamp emitting only one colour through two crossed polarizing films no light go through. The whole is dark. And this is still the case when water or a salty solution is inserted between the two foils. And yet if a sugar solution is used instead light comes through again. Extinction can be reobtained by rotating one of the films. See figure.

This simply shows that sugar (and all optically active substances) acts on the polarizing plane of the light, somewhat like a worker using a screwdriver.

\[22\]

**Comments.**

- **Shape of the cuvette.**
The sugar solution must be placed in a container with flat and parallel faces. Flask, bottles and other non prismatic containers will not be suitable. Extinction can be reobtained. The angle of rotation depends on the thickness of the solution.

- **Choosing the colour.**
Do not use white light emitting lamps. Sugar molecules do not rotate equally all components of light. Blue light is more rotated than red. So extinction will never be obtained with white light. The little coloured lamps used for Christmas trees suit perfectly. Green is better, as it corresponds to the maximum of the eye sensitivity.
19. Spontaneous self ignition

Put some ammonium thiocyanate NH\textsubscript{4}CNS in a porcelain crucible. Throw then a tiny amount of sodium chlorite NaClO\textsubscript{2}. A spontaneous flame jet is evolved when the chlorite touches the thiocynate. If not add one drop water (not two !) When the first flame starts more chlorite can be added. Each time a new flame will happen that never lasts more than one second... The equation is:

\[
\text{NH}_4\text{CNS} + \text{NaClO}_2 \rightarrow \text{NaCl} + \text{N}_2 + 2\text{H}_2\text{O} + \text{S} \tag{22}
\]

The mixture gets hot and yellow because of the sulfur. But this sulfur reacts with more chlorite if in excess according to:

\[
\text{NaClO}_2 + \text{S} \rightarrow \text{NaCl} + \text{SO}_2. \tag{23}
\]

As a consequence SO\textsubscript{2} is produced which has a punching odour ! Take care !

Comments.

- Sodium chlorite NaClO\textsubscript{2}.
  1. Sodium chlorite is not easy to find. it may be ordered by Acros, code number 223.235.000, and it costs 50 € for 500 grams. Furthermore this compound is sensitive to air oxidation, which transforms it into the inactive sodium chlorate.

  2. Do not confuse Chlorite, Chloride and Chlorate. Sodium chlorate is NaClO\textsubscript{3}.

- Thiocyanate. Ammonium thiocyanate can be replaced by potassium thiocyanate.

Nitroglycerine \( C_3H_5(NO_3)_3 \) is synthetized from glycerol \( C_3H_5(OH)_3 \) according to:
\[
C_3H_5(OH)_3 + 3HNO_3 \rightarrow C_3H_5(NO_3)_3 + 3H_2O \tag{24}
\]

But take care. It is not \( HNO_3 \) that attacks glycerol (or glycerine), but \( NO_2^+ \) produced by:
\[
HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^- \tag{25}
\]

The following procedure has been by about 100 students each year in my high school lab for 25 years. There has never been any failure or accident.

**Procedure.**

Pour 3 ml concentrated \( HNO_3 \) (65%) in a dry test tube, then the double (6 ml) of concentrated \( H_2SO_4 \) (96%) in another tube. Pour \( H_2SO_4 \) into \( HNO_3 \). Do mix up thoroughly by pouring to-and-fro many times. This mixing warms up. Dip the tube into a 150 ml beaker filled with ice.

When the tube is colder than 10°C, add 10 drops glycerine with a 5 ml syringe into the liquid mixture. This produces a turbid mixture which remains near the surface. Pour the liquid with a to and fro motion for homogenizing the solution. As the nitration reaction is exothermic the liquid should stay in the ice for at least 5 minutes. The temperature should never exceed 10°C.
At the end the turbid mixture should be dropped into the rest of the ice. The ice melts and dissolves the excess of acids plus the remaining glycerine that has not been nitrated. Stir with the empty test tube. A large drop of oil will soon be observed on the bottom of the beaker: nitroglycerine.

Get rid of the ice, and of the greatest part of the liquid. Pour the remaining liquid plus the oil into a filter paper and a funnel. The aqueous solution goes through the filter. At the end a large drop of oil remains in the filter.

Take hold of a 10 microlitres capillary (Blaubrand 708709) and dip it into the oil drop in the filter. Don’t punch the filter paper. A tiny droplet of oil stays in the tip of the capillary, about 1 microlitre. Hold the capillary with a pair of pliers or tongs horizontally at about 30 cm above the table. Place the droplet of nitroglycerine in the non-gripped end. See figure.

Put quickly a burning Bunsen burner just under the droplet and get away quickly. Within a couple of seconds, the capillary explodes with a sharp noise.

The explosion may happen according to equations like:

\[
\begin{align*}
2 & \text{C}_3\text{H}_5(\text{NO}_3)_3 \rightarrow 5 \text{H}_2\text{O} + 5 \text{CO}_2 + \text{CO} + 2 \text{NO} + 2 \text{N}_2 \\
2 & \text{C}_3\text{H}_5(\text{NO}_3)_3 \rightarrow 5 \text{H}_2\text{O} + 3 \text{CO}_2 + 3 \text{CO} + 4 \text{NO} + \text{N}_2 \\
2 & \text{C}_3\text{H}_5(\text{NO}_3)_3 \rightarrow 5 \text{H}_2\text{O} + \text{CO}_2 + 5 \text{CO} + 6 \text{NO}
\end{align*}
\]

At the end the excess in nitroglycerine may be eliminated simply by opening the filter on a wire-mesh. The sharp end of a Bunsen burner flame is directed on the drop of oil. It burns smoothly like wax when the wet paper is dry enough.