# Landolt Reaction (Iodine Clock Reaction)

**Chemicals:**

Potassium iodate ($KIO_3$)
Sodium sulfite ($Na_2SO_3$)
Ethanol ($C_2H_5OH$)
Concentrated sulfuric acid ($H_2SO_4$)
Transparent dishwashing liquid
Starch
Deionized water

**Equipment:**

Two 500-mL volumetric flasks
Three 100-mL volumetric flasks
Measuring cylinders
Beer mug (500 mL)
Coca Cola bottle (500 mL) (preferably a glass bottle)
Four empty mineral water bottles or four 300-mL beakers

**Safety:**

**Potassium iodate ($KIO_3$):**


H272 – 315 – 319 – 335,
P220 – 261 – 305 + 351 + 338

H272  May intensify fire, oxidizer.
H315  Causes skin irritation.
H319  Causes serious eye irritation.
H335  May cause respiratory irritation.
P220  Keep/Store away from clothing/combustible materials.
P261  Avoid breathing dust/fumes/gas/mist/vapors/spray.
P305 + 351 + 338  IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing.

**Sodium bisulfite ($Na_2SO_3$):**

No hazard pictograms, no hazard and precautionary statements.

**Ethanol ($C_2H_5OH$):**

H225
P210

H225  Highly flammable liquid and vapor.
P210  Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.

**Concentrated sulfuric acid** ($H_2SO_4$)**:**

H314 – 290
P280 – 301 + 330 + 331 – 310 – 305 + 351 + 338

H314  Causes severe skin burns and eye damage.
H290  May be corrosive to metals.

P280 Wear protective gloves/protective clothing/eye protection/face protection.
P301 + 330 + 331 IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P310 Immediately call a POISON CENTER/doctor/… .
P305 + 351 + 338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing.

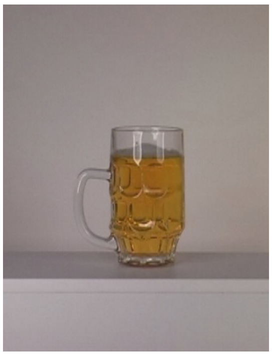
**Starch:**

No hazard pictograms, no hazard and precautionary statements.

**Conclusion:**

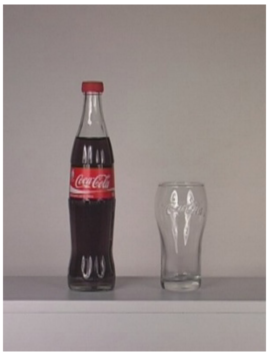
It is necessary to wear safety glasses and protective gloves, because every contact with eyes or skin should be avoided. It is highly recommendable to work in a fume hood. Of course, you should never fill chemicals into beverage bottles in the laboratory. This is only "allowed" in chemical shows (for the effect "Turning water into beer" etc.).

## Procedure and Observation:



**"Brewing of Beer"**: 2.15 g of potassium iodate are dissolved in warm deionized water, the solution is transferred in one of the 500-mL volumetric flasks and filled up with deionized water to the mark (solution A). 0.58 g of sodium sulfite, 5 mL of ethanol and 2 g of conc. sulfuric acid are also dissolved in deionized water, the solution is transferred in the second 500-mL volumetric flask and filled up with deionized water to the mark (solution B). 125 mL of solution A as well as solution B are mixed with 125 mL of deionized water in each case (so that you have two solutions with a volume of 250 mL each) and poured into two small mineral water bottles or beakers. For starting the experiment 15 mL of transparent dishwashing liquid are put in the beer mug. 250 mL of solution A and 250 mL of solution B are poured simultaneously with dash into the mug.

The reaction to artificial beer (a solution with yellow-brown color) will start in a few seconds. The typical foam head of beer is produced by the dishwashing liquid.




**"Coke Production"**: 6.08 g of potassium iodate are dissolved in warm deionized water, the solution is transferred in one of the 100-mL volumetric flasks and filled up with deionized water to the mark (solution A). 2.06 g of sodium sulfite and 2.28 g of conc. sulfuric acid are also dissolved in deionized water, the solution is transferred in the second 100-mL volumetric flask and filled up with deionized water to the mark (solution B). Finally, 1.00 g of starch are dissolved in boiling water, the solution is transferred in the third 100-mL volumetric flask and filled up with deionized water to the mark (solution C). 10 mL of solution A and 235 mL of water are filled in one of the mineral water bottles. 10 mL of solution B, 5 mL of solution C and 230 mL of water are filled in a second mineral water bottle. The solutions are filled one after the other in the Coke bottle and the closed bottle is then thoroughly shaken.

After a few seconds, the colorless mixture suddenly turns dark brown (the color is comparable to that of coca cola).

## Explanation:

Iodate ions react slowly with bisulfite ions whereby iodide ions are generated:

$$IO_3^- + 3\ HSO_3^- \rightarrow I^- + 3\ HSO_4^-.$$

This is the rate determining step. The iodate ions in excess will oxidize the iodide ions generated in the reaction above to form iodine which is responsible for the yellow brown color of the solution (similar to the color of beer):

$$IO_3^- + 5\ I^- + 6\ H^+ \rightarrow 3\ I_2 + 3\ H_2O.$$

In a subsequent fast reaction, the iodine is reduced immediately back to iodide ions by the bisulfite ions:

$$I_2 + HSO_3^- + H_2O \rightarrow 2\ I^- + HSO_4^- + 2\ H^+.$$

Only when the bisulfite is fully consumed, the iodine will survive (i.e., the reduction by the bisulfite ions cannot take place anymore). This explains the time delay in the change of the solution´s color.

In the case of the “coke production” starch is added to the solution. The surplus of iodine results together with the dark blue color of the starch-iodine complex in the dark brown color of the solution.

**Disposal:**

The solutions can be disposed of down the drain with running water.

## Catalytic Decomposition of Hydrogen Peroxide

**Chemicals:**

Hydrogen peroxide solution (30 % w/w)
Catalase solution (1 % w/w) or crude potato extract (peeled raw potato, deionized water, crushed ice)
Red food dye
Transparent dishwashing liquid
Egg

**Equipment:**

Ice glass cup
Measuring cylinder
Pasteur pipettes
Empty mineral water bottle or 50-mL beaker
(food grater, 200-mL Erlenmeyer flask, cheese cloth or cotton tea filter, beaker)
Wooden splint
Lighter

**Safety:**

**Hydrogen peroxide solution ($H_2O_2$):**

H271 – 332 – 302 – 314
P220 – 261 – 280 – 305 + 351 + 338 – 310

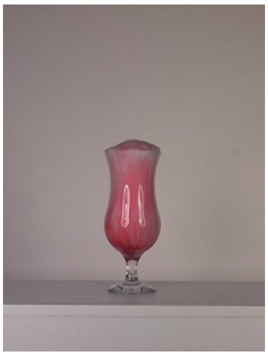
H271 May cause fire or explosion; strong oxidizer.
H332 Harmful if inhaled.
H302 Harmful if swallowed.
H314 Causes severe skin burns and eye damage.
P220 Keep/Store away from clothing/…/combustible materials.
P261 Avoid breathing dust/fumes/gas/mist/vapors/spray.
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P305 + 351 + 338: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact

lenses if present and easy to do. Continue rinsing.
P310 Immediately call a POISON CENTER/doctor/… .

**Conclusion:**

It is necessary to wear a lab coat, safety glasses and protective gloves, because every contact with eyes or skin should be avoided. It is highly recommendable to work in a fume hood. Of course, you should never fill chemicals into beverage bottles in the laboratory. The only exceptions are chemical shows.

**Procedure and Observation:**



**"Strawberry Ice cream":** Dishwashing liquid, a little bit of egg white, 20 droplets of red food dye and approx. 1 mL of catalase solution are thoroughly mixed in the glass cup. Subsequently, 5 mL of hydrogen peroxide solution are added out of a mineral water bottle or a beaker.

A foamy red and white substance rises in the glass cup. The mixture looks like a strawberry sundae. The needed amounts of the substances depend upon the size and shape of the cup; therefore, you have to find out the ideal proportions by "trial and error." The presence of an oxidizing gas such as oxygen can be detected by the glowing splint test.

If no catalase solution is available crude potato extract can be used instead: Approx. 20 g of peeled raw potato are finely grated by means of a food grater. The paste is scraped into a 200-mL Erlenmeyer flask and 25 mL of ice-cooled deionized water are added. The flask is swirled in intervals for about 15 min. Subsequently, the suspension is filtered through a sheet of cheese cloth or a cotton tea filter into a chilled beaker.

**Explanation:**

Hydrogen peroxide in aqueous solution exhibits in principle a strong tendency to decompose into water and oxygen (disproportionation):

$$2\ H_2O_2|w \rightarrow 2\ H_2O|l + O_2|g$$

$$\Sigma\mu^\ominus: \quad -268.0 \quad > \quad -474.2 \quad \text{kG (kJ mol}^{-1}\text{)}$$

$$\Rightarrow \text{chemical drive } \mathcal{A}^\ominus: +206.2 \text{ kG}$$

Necessary chemical potentials ($T$ = 298 K, $p$ = 100 kPa):

| Substance | Chemical potenzial $\mu^\ominus$ [kG] |
|---|---|
| $H_2O_2$\|w | –134.0 |
| $H_2O$\|l | –237.1 |
| $O_2$\|g | 0 |

The chemical drive of the reaction is positive, i.e. it can run spontaneously in principle. The decomposition rate at room temperature is, however, immeasurably small. But the rate can be appreciably increased by the addition of a catalyst such as the enzyme catalase. The oxygen generated by the decomposition reaction creates bubbles in the soapy liquid thereby turning it into foam.

The cytoxin hydrogen peroxide is one of the by-products of many cellular reactions. Aerobic cells protect themselves against peroxide by the action of the enzyme catalase. Therefore, catalase is nearly ubiquitous among animal organisms, especially it is found in liver and red blood cells. But catalase also occurs in plant tissues, and is especially abundant in plant storage organs such as potato tubers, corms, and in the fleshy parts of fruits. The detailed structure of catalase differs from one organism to another, but the general quaternary structure is analogous to hemoglobin in that catalase is tetrameric and each polypeptide chain, composed of more than 500 amino acids, contains an iron-centered porphyrin ring. However, in contrast to hemoglobin, catalase utilizes Fe(III). This iron can formally be oxidized to Fe(V) in the oxidation-reduction cycle responsible for the catalytic activity, but the processes at the active site of the enzyme are not understood very well.

## Disposal

The foamy substance can be disposed of down the drain with running water.