- These slides contain animations, when the PowerPoint file is played
- The content gradually appears with clicks
- Questions appear before their answers

Green Chemistry and Living in the Desert

Water

- Staying alive – drinking
- Clean water for drinking, what are the problems?
- How is water sterilized, chlorine, UV, ozone
- How is water purified? Distillation, reverse osmosis, deionization, charcoal.
- Drink containers - Recycling
- Cooling off – Swimming pool chemistry
- Chlorine, pH, buffers, water hardness
- Cleaning – detergents, dishwashing, laundry
- Biodegradation, algal blooms, eutrophication

Cooling Off – Swimming Pools

- Going for a swim is a great way to cool off!
- Keeping a swimming pool both safe and aesthetically pleasing requires careful maintenance of the water
- Chemistry plays a critical role in doing this

What are some problems that a pool can have?

Cooling Off – Swimming Pools

What are some problems that a pool can have?

Poor Appearance?	Remedy
Dirt, leaves, insect bodies, other solids	Filtration
Scale buildup	Decrease dissolved salts
Green water	Chlorination
Corrosion of metal parts	Balance pH
Strong smell	Chlorination

Safety/Effects on people?	
Transmit disease	Chlorination
Burn eyes	Balance pH
Bleach hair/clothes	Chlorination
Turn hair green	Chelating agent
Too cold/hot	

Let's look at some of these in more detail

Swimming Pool Chemistry

Maintaining pool chemistry involves using chemicals to control the following:

- Chlorination
- pH
- Buffer level
- Stabilizer level
- Dissolved salts/Water hardness

Some chemicals may need to be added less frequently:

- Algaecide
- Water clarifier/flocculant
- Copper remover
- Phosphate remover

Swimming Pool Chemistry - Chlorination

What does chlorine do?

- Chlorine is a disinfectant
- The aim is to kill any organisms in the pool and to inactivate viruses
- A relatively low level of chlorine in the water is quite effective at killing bacteria, parasites, fungi, algae, and destroying viruses without causing much problem for human swimmers

Other less commonly used disinfection methods include:

- Bromine
- Ozone
- UV light
- Hydrogen peroxide/UV light

Swimming Pool Chemistry - Chlorination

Chlorine (Cl_2)

- While chloride (Cl^-) is necessary for all know species of life, chlorine (Cl_2) is poisonous to most living organisms
- Chlorine is a yellow-green gas! bp -34 °C

Wikipedia - chlorine

So how are all these things "chlorine"?:

https://images.app.goo.gl/euFU3TK4k8XqtMrL6

https://images.app.goo.gl/g5nie2hbBK6CseaE6

Swimming Pool Chemistry - Chlorination

- Chlorine reacts with water to form hypochlorous acid:

$$Cl_2(g) + H_2O \rightleftarrows HOCl + H^+ + Cl^-$$

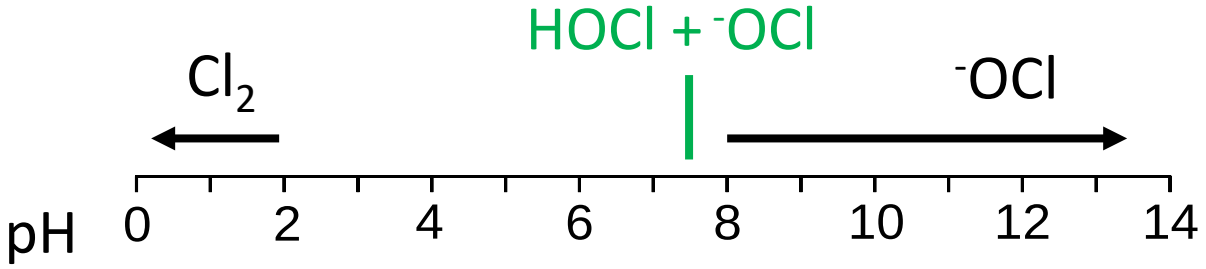
- Hypochlorous acid is in equilibrium with its dissociated form:

$$HOCl \rightleftarrows + H^+ + OCl^-$$

- Which species are present in water is highly dependent on pH

- At pH 7.5 (typical pool pH) and 25 °C, the amounts of hypochlorous acid (HOCl) and hypochlorite ion ($^-$OCl) are about equal
- In strongly acidic water (low pH [~2]) chlorine is mostly present as dissolved Cl_2
- In basic water (pH > 8) chlorine is mostly present as hypochlorite ion ($^-$OCl)

Swimming Pool Chemistry - Chlorination



- At pH 7.5 (typical pool pH) and 25 °C, the amounts of hypochlorous acid (HOCl) and hypochlorite ion ($^-$OCl) are about equal
- In strongly acidic water (low pH [~2]) chlorine is mostly present as dissolved Cl_2
- In basic water (pH > 8) chlorine is mostly present as hypochlorite ion ($^-$OCl)
- The sanitizing effect is better when there is more HOCl/Cl_2 present
- However, Cl_2 will escape at some rate from the system

Swimming Pool Chemistry - Chlorination

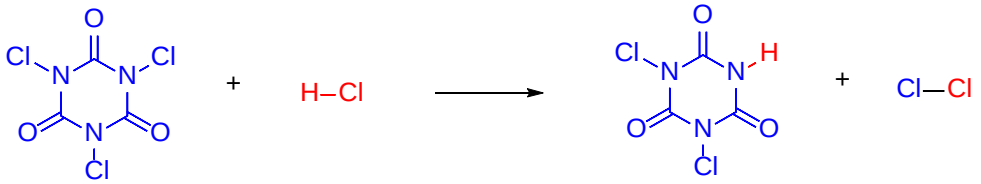
So, what are these?:

- This “Chlorine” is solid calcium hypochlorite ($Ca(OCl)_2$)
- Reaction with acid in the pool will generate HOCl, which is in equilibrium with Cl_2

- This “Chlorine” is an aqueous solution of sodium hypochlorite (NaOCl)
- Unlike calcium hypochlorite, it is not stable in solid form and is always used as a solution

Swimming Pool Chemistry - Chlorination

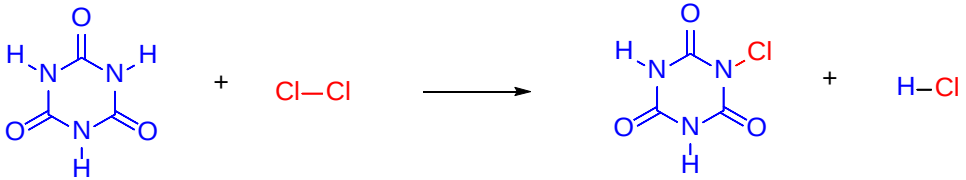
- These tablets are made from trichloroisocyanuric acid
- These react with acid to form chlorine (Cl_2)



- The same reaction occurs to release all three chlorines

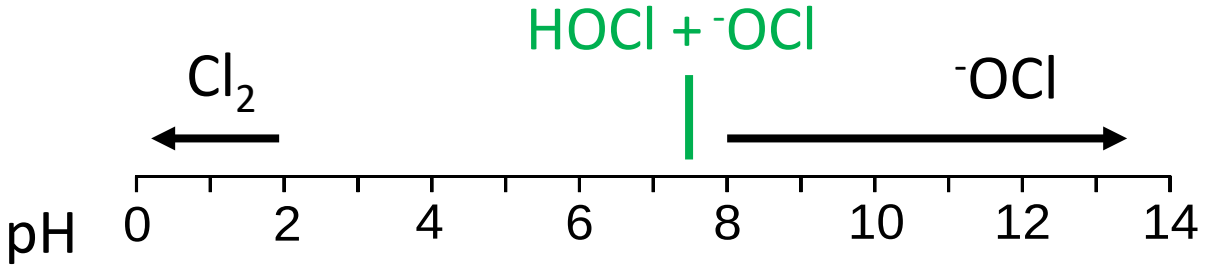
Swimming Pool Chemistry - Stabilizer

- The reverse reaction of chlorine release can also occur to add Cl to isocyanuric acid



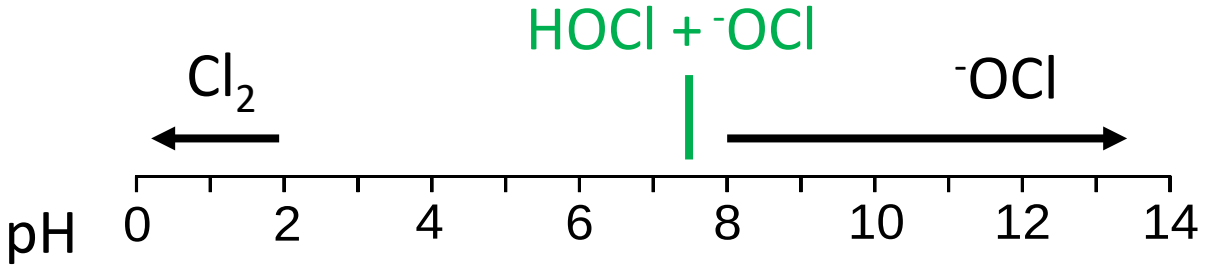
- Cyanuric acid is added to the pool as a “stabilizer”, it reversibly binds some of the free chlorine, effectively giving a slower release, so giving a slower loss of chlorine

Swimming Pool Chemistry - pH



- Hypochlorite ion ($^{-}$OCl) is not as effective at sanitizing as hypochlorous acid/chlorine
- This means the water should not be too basic (high pH) as it will lower the sanitizing power of the chlorine
- However, when there is more Cl_2 present in the water, it can leave the water as a gas and be lost
- So, there is a balance between having a decent amount of "free" chlorine present and it being lost as a gas from the water, this is controlled by the pH

Swimming Pool Chemistry - pH



- But the water can't just be any pH, the swimmers will not tolerate the water if it is too basic or too acidic
- When eye irritation occurs in a swimming pool the most likely cause is low pH (acidic). Human tears have pH ~7.0-7.4. That is a good target for the pool.
- Low pH (acidic) also speeds corrosion of metal parts in the pool

https://images.app.goo.gl/9wa2qBCKq54bMmbZA

Swimming Pool Chemistry - pH

How is pH adjusted?

Lower the pH – make it more acidic

- Most commonly - add concentrated hydrochloric acid!
  Aka “muriatic acid”

Isn’t that dangerous?

- Yes! Contact with skin will cause immediate burns, contact with eyes will cause catastrophic damage
- Additionally, the fumes coming from concentrated HCl are noxious and corrosive
- Safer solid acid sources such as $NaHSO_4$ are also available, however they are generally much more expensive

Swimming Pool Chemistry - pH

How is pH adjusted?

<u>Increase the pH</u> – make it more basic

- Most commonly - add solid Na_2CO_3
- Could add e.g. NaOH, but Na_2CO_3 is sufficiently basic and more easily handled, safer, and stable for storage

Swimming Pool Chemistry - Buffer

A buffer is typically used with the pool water

- Aka "total alkalinity" increaser
- This is usually solid sodium bicarbonate ($NaHCO_3$)

What is a buffer? Why is it used?

- Adding a small amount of acid or base to the pool can cause a large swing in pH. Similarly, the pH can vary widely when the acid concentration changes for other reasons
- A buffer helps to maintain a near constant pH, even when sizable amounts of acid or base are added:

$$CO_3^{2-} \xleftarrow{^-OH} HCO_3^- \xrightarrow{H^+} H_2CO_3$$