Name:

Environmental Chemistry: Water	**Objectives**
19. Environmental Chemistry - Water	-define hardness in water -define temporary hardness in water -define permanent hardness in water -identify the causes temporary and permanent hardness in water -explain how deionisation is achieved using ion exchange resins -describe a test that can be carried out on scale deposits in a kettle -describe how hardness can be removed by boiling and by ion exchange -account the relative purity of deionised and distilled water -describe the treatment of water under the following headings: sedimentation, flocculation, filtration, chlorination, fluoridation and pH adjustment -describe how sewage is treated (primary, e.g. settlement, screening; secondary, e.g. bacterial breakdown; tertiary, e.g. reduction of level of phosphates and nitrates) -be aware of the high cost of tertiary treatment of water -discuss the role of nutrients in the eutrophication of water **-discuss how pollution can be caused by uncontrolled use of nitrate fertilizers** **-describe the polluting potential of heavy metals from batteries in the absence of recycling** **-discuss pollution by heavy metal ions in water – especially Pb2+, Hg2+ and Cd 2+** **-describe how heavy metal ions in water – especially Pb2+, Hg2+ and Cd 2+ can be removed from industrial effluent by precipitation** -recall that there are EU limits for various chemical species in water (two examples, e.g. nitrates, phosphates, specific metal ions) -outline the basic principles of the following instrumental methods of water analysis: • pH meter (analysis of river and lake water) • **AAS [cf. flame tests, absorption spectra (unit 1.4)] (analysis of heavy metals in water e.g. lead, cadmium)** • colorimetry (analysis of (i) lead in water (ii) fertilisers -carry out a colorimetric experiment to estimate free chlorine in swimming-pool -water or bleach (using a colorimeter or a comparator) -determine the total suspended and total dissolved solids (expressed as p.p.m.) by filtration and evaporation respectively -determine pH and test water for anions -estimate the total hardness of water using ethylenediaminetetraacetic acid (edta) (balanced ionic equation required) **-define biochemical oxygen demand (BOD)** **-estimate dissolved oxygen by redox titration** -describe the effect of organic chemical pollutants e.g. sewage industrial waste, silage, milk

Hardness in Water:

Def^n: **Hard Water** is water that will not easily form a lather with soap. Hardness in water is caused by Ca^{2+} and Mg^{2+} ions dissolved in the water.

When hard water reacts with soap, a scum is formed.

G. Galvin

There are two types of water hardness:

1. **Temporary Hardness:**
   Def^n^: **Temporary Hardness** is hardness that can be removed by boiling the water.
   Temporary Hardness is due to the presence of the hydrogencarbonate ion (HCO_3)

   Formation of temporary water hardness:

   $$H_2O + CO_2 \rightarrow H_2CO_3 \quad \text{then} \quad H_2CO_3 + CaCO_3 \rightarrow Ca(HCO_3)_2$$

   water + carbon dioxide → carbonic acid   carbonic acid + calcium carbonate → calcium hydrogencarbonate

   Removal of temporary water hardness (boiling):

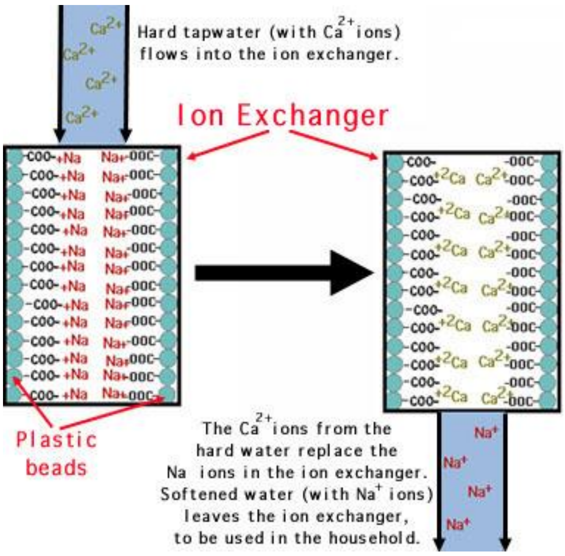
   $$Ca(HCO_3)_2 \rightarrow CaCO_3 \downarrow + CO_2 + H_2O$$

   calcium hydrogencarbonate → calcium carbonate + carbon dioxide + water

2. **Permanent Hardness:**
   Def^n^: **Permanent Hardness** is harness which cannot be removed by boiling the water.
   Permanent Hardness is due to the presence of calcium sulphate ($CaSO_4$) or magnesium sulphate ($MgSO_4$).

Methods of Removing Hardness from Water:

1. **Distillation:** Water is boiled. All dissolved solids which cause water hardness are left behind in the residue. This is too expensive to do on a large scale.
2. **Using Washing Soda:** Washing soda (hydrated sodium carbonate, $Na_2CO_3.10H_2O$) reacts with Ca^{2+} ions in the water to form calcium carbonate, which is insoluble in water.
3. **Ion Exchange Resin:** The Ca^{2+} and Mg^{2+} ions in water are exchanged for Na^+ ions, which do not cause water hardness. Because this resin exchanges positive ions, we call this a **cation exchange resin**.



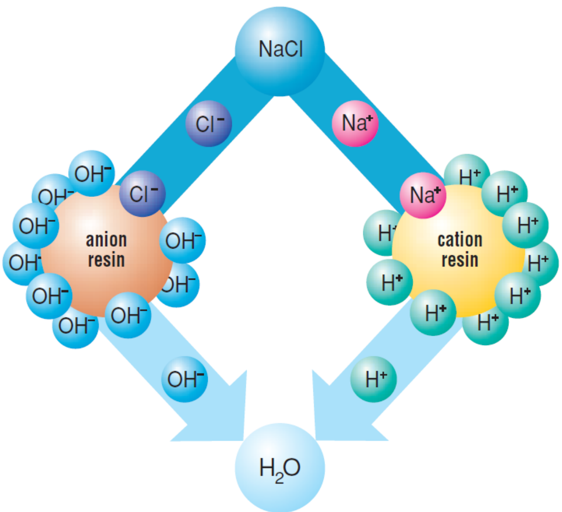
Producing Deionised Water:

All ions need to be removed from water. A cation exchange resin is used to remove positive ions, along with an anion exchange resin to remove negative ions.

The cation exchange resin swaps all positive ions for **H^+** ions.

The anion exchange resin swaps all negative ions for **OH^-** ions.

The **H^+** and **OH^-** ions combine to form **H_2O**.

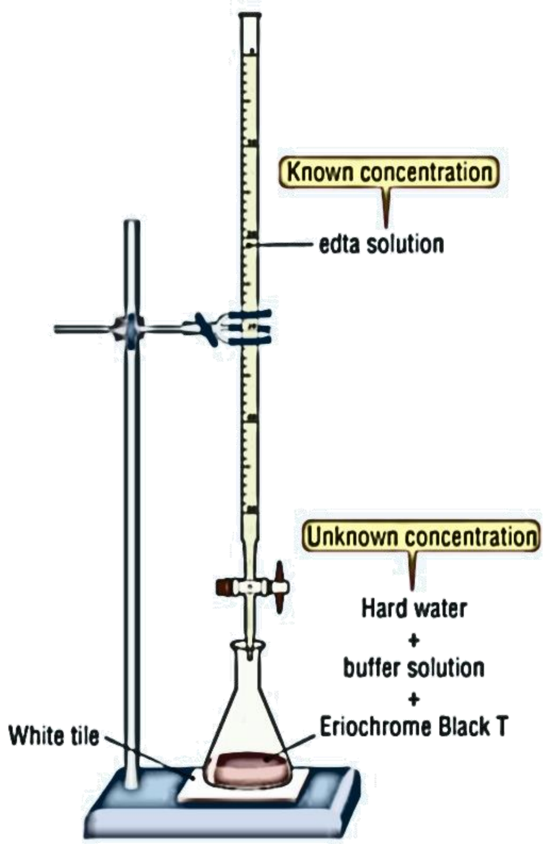


Deionised vs Distilled Water:

Deionised water has all suspended and dissolved solids removed, but there may still be gases dissolved in the water. Distilled water is the purest form of water as all suspended and dissolved solids, along with any dissolved gases are removed from the water.

Advantages and disadvantages of Hard Water:

	Advantages	Disadvantages
1.	Provides calcium for teeth and bones	Blocks pipes, leaves scale on kettles and boilers
2.	Nicer taste	Wastes soap
3.	Good for brewing and tanning leather	Produces scum



Experiment: *To determine the total hardness in a water sample using EDTA (ethylenediaminetetraacetic acid)*

EDTA's full name needs to be remembered. EDTA reacts with Ca^{2+} and Mg^{2+} ions in water, removing the hardness.

EDTA and Ca^{2+} (we will only talk about Ca^{2+} and not Mg^{2+} from now on to keep things simpler) react in a **1:1 ratio**.

pH Buffer 10 needs to be used (this keeps the pH at a constant value of 10) as EDTA only reacts with Ca^{2+} at a pH of 10. Also, the indicator used only works at pH values 8-10.

Indicator used is **Eriochrome Black T.** Colour change is **wine red to blue**.

EDTA needs to be stored in a plastic container, as EDTA reacts with the ions in glass.

Concentration of total water hardness is given in ppm $CaCO_3$ (M_r = 100)

Remember, ppm = mg/L

Water Treatment:

1. **Screening:** Water passed through wire mesh to remove floating debris.
2. **Flocculation:** Aluminium Sulphate added. This makes small suspended particles coagulate (stick together) into larger particles.
3. **Sedimentation/Settling:** Water flows into the bottom of tanks. Suspended solids settle to the bottom. Clear water flows out of the top.
4. **Filtration:** Water passed through sand beds to remove last suspended solids.
5. **Chlorination:** Chlorine added to kill bacteria. Too much will cause a bad tase. Not enough will allow bacteria to survive.
6. **Fluoridation:** Fluoride added to water to prevent cavities in teeth.
7. **pH Adjustment:** Sulphuric acid is added to water of it too basic. Too much sulphuric acid can cause corrosion of pipes. Calcium hydroxide is added if water is too acidic. Too much calcium hydroxide can cause an increase in water hardness.

Experiment: *To determine the total suspended and total dissolved solids in a water sample in ppm.*

A known volume of water is passed through filter paper. The filter paper is then dried in an oven. The increase in mass of the filter paper is used to calulate the total suspended solids in ppm.

A known volume of filtered water is evaporated. The increase in mass of the evaporating basin is used to calculate the total dissolved solids in ppm.

Water Pollution:

Bacteria feed on organic matter in water. They use up the dissolved oxygen in the water during this process, causing other organisms to die.

Def^n: **Biochemical Oxygen Demand (BOD)** is the amount of dissolved oxygen used up by organisms (in ppm) when a sample of water is left in the dark for 5 days at 20^{o}C.

Def^n: **Eutrophication** is the enrichment of water with nutrients, leading to excessive growth of algae and other plants.

Heavy metals (Pb^{2+}, Cd^{2+}, Hg^{2+}) are toxic. They are removed using **precipitation reactions**.

Experiment: *To measure the amount of dissolved oxygen in a sample of water by means of a redox titration.*

We use the **Winkler Method**. The sample bottle must have so air in it, to avoid extra oxygen dissolving in the sample.

1. Add manganese sulphate, then alkaline potassium iodide. A brown precipitate is formed in the bottle. If a white precipitate is formed, this means that there is no dissolved oxygen in the water sample.
2. Add sulphuric acid. The brown precipitate dessolves, leaving a clear red/brown solution of iodine.
3. Titrate the iodine solution (water sample) against sodium thiosulphate (in burette).

Indicator is starch. Colour changes are red/brown to straw yellow (then add starch) to blue/black to colorless.

The ratio of O_2:$S_2O_3^{2-}$ is 1:4.

Sewage Treatment:

1. **Primary Treatment (Physical):** Large solids are removed by screening and small suspended solids are removed by settling.
2. **Secondary Treatment (Biological):** The **Activated Sludge Process** is used. Bacteria is added to the waste in a tank which is being stirred and aerated. The waste is digested by the bacteria.
3. **Tertiary Treatment (Chemical):** Nitrates and Phosphates are removed from the waste. Nitrates are removed using denitrifying bacteria. Phosphates are removed using precipitation reactions.

Instrumental Methods of Water Analysis:

1. **pH Analysis:** pH can be measured using a pH sensor.
2. **Atomic Absorption Spectroscopy (AAS):** Used to detect the concentration of heavy metals in water. Works on the principal that each element has its own unique absorption spectrum, so that element absorbs specific frequencies of light. The amount of light absorbed tells us the concentration of that element, e.g. lead.
3. **Colorimetry:** Used to measure the concentration of coloured substances. Works on the principle that the more light the coloured solution absorbs, the higher its concentration.

Experiment: *To estimate the concentration of free chlorine in swimming pool water using a colorimeter*

1. 5 standard calcium hypochlorite solutions of are made up (1ppm, 2ppm, 3ppm, 4ppm, 5ppm).
2. A DPD tablet is added to each of the 5 solutions. Solutions turn pink.
3. Colorimeter is used to measure the aborbance of each solution.
4. The absorbances (y axis) and concentrations (x axis) are plotted on a graph.
5. A DPD tablet is added to the swimming pool water sample to be tested and its absorbance is measured.
6. The graph is used to find the concentration of free chlorine in this water ample, based on its absorbance value.