

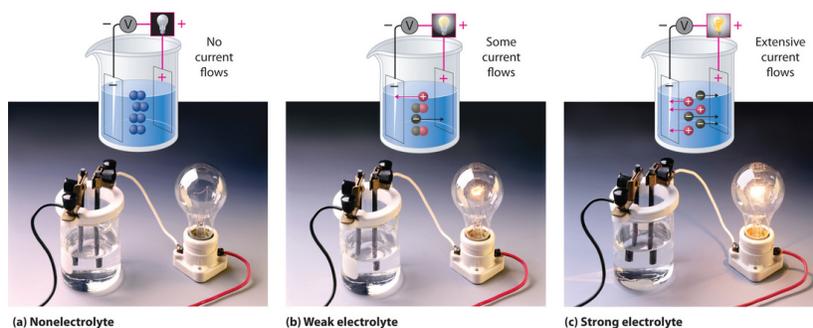
## The Wild Ionists

### Skills to Develop

- Discuss the significance of electrolytes and osmosis

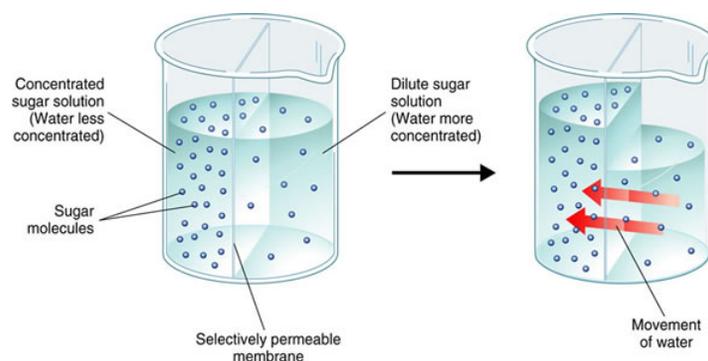
Faraday proved that pure water doesn't conduct electricity, but conductivity increases when some types of solutes are added. These solutes are called **electrolytes**. For a long time, people thought that the ions that let water conduct electricity (to conduct, charged particles must move, such as electrons through a metal wire or ions through solution) were formed by the electricity.

Svante Arrhenius was the son of a minor university employee in Sweden. For his doctoral research, he wanted to study whether molecular weights of compounds could be measured using the conductivity of their solutions (a subject his adviser told him not to work on—he often ignored his advisers' advice). To do this, he needed to understand how the conductivity of electrolyte solutions depends on concentration, but he found that his data were unexpectedly confusing. Wisely, he realized that explaining the conductivities would actually be more interesting and useful than his original plan to measure molecular weights. He found that the electrolytes fell into 2 types: strong and weak. **Strong electrolytes** (like salt and HCl) easily conduct electricity, and their conductivity is proportional to the concentration. **Weak electrolytes** (like vinegar and ammonia) conduct electricity much less, but their conductivity is not directly proportional to concentration. As concentration decreases, conductivity does too, but conductivity/mass of solute increases. He proposed that electrolytes had an active state (that conducts) and an inactive state (that doesn't conduct electricity); strong electrolytes were entirely in the active state, while weak electrolytes would have some molecules in the active state and some in the inactive state. As a weak electrolyte solution was diluted, the % of molecules in the active state would increase toward 100%. But this was vague, and his advisers didn't like it and gave him a very low grade. Because the grade was so low, he had to travel and do research without pay in other labs for many years to establish himself, instead of becoming a professor himself.



A demonstration of the electrolytes' electrical conductivity based on their strength.

Arrhenius travelled and met other scientists. A professor named Ostwald helped introduce him. He became friends with Nernst (who would later do some important work on thermodynamics and electrochemistry). Nernst was a wild young man who thought about becoming an actor, had scars from fighting, and often got very drunk. He also began to correspond (write letters) with van't Hoff, whom we mentioned [earlier](#). Van't Hoff had moved on from carbon chemistry and was studying osmosis. **Osmosis** occurs when water moves across a membrane (like the membrane of a biological cell) to go from a dilute solution on one side to a concentrated solution on the other. This can create a pressure difference. This is how some antibiotics kill bacteria: the bacteria explode from the pressure because the solution outside the cell is more dilute than the solution inside the cell. Van't Hoff found that the osmotic pressure depends on the concentration of the solutions, but for electrolytes, there's an extra "fudge factor"; the concentration seems higher than expected. It appeared that the electrolytes were breaking into pieces, and these pieces increase the apparent concentration of the solution when determining osmotic pressure. Arrhenius noticed that the "fudge factor" in Van't Hoff's data was related to the fractions in Arrhenius' active states.



An illustration of osmosis.

At this time, electrons hadn't been discovered yet. People thought that ions form in solution only when electricity is passed through. However, Arrhenius realized that electrolytes must be splitting into charged pieces (ions) when they dissolved, even without electricity, because these charged pieces affected van't Hoff's osmotic pressure measurements. The idea that salt, which forms so eagerly from the elements, would split up completely in water, seemed crazy to most scientists. (Now, we know that splitting into ions vs splitting into atoms is very different!) But Ostwald, Nernst and van't Hoff agreed with Arrhenius, and they were called "the wild army of the Ionists". They convinced other chemists pretty quickly that this new theory of ionization was correct.

### Acknowledgement

This discussion was inspired by first chapter of the book *Cathedrals of Science* by Patrick Coffey.

### Outside Link

- [CrashCourse Chemistry: Water and Solutions](#) (13 min)

### Contributors and Attributions

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