POTATO CLOCK

A. OVERVIEW

Subject	Chemistry
Age	6-10
Duration	60 minutes
Content	Electrochemical cells – potato clocks and redox reactions.
Goals	Students will: 1. Understand reduction and oxidation reactions involve the exchange of electrons. 2. Define reduction potential. 3. Relate electrochemical cells to redox reactions.
Objectives	After completing this section, students will explain the contents of a Galvanic Cell.
Materials	Potato clock kit and instruction sheet Potatoes, soft drink, fruit juice etc., voltmeter, bulldog clips.
Introduction	Background reading – Oxidation and reduction reactions, reduction potentials and Galvanic cells.
Practical	Students will assemble Potato Clock kit with potatoes and other foodstuffs as electrolytes.
Class discussion	Potatoes and foodstuffs as electrochemical cells.
Extensions	Open ended discussion/investigation.

B. BACKGROUND READING

Set the background reading as a homework assignment the day before the planned potato clock lesson. The reading covers reduction and oxidation reactions and electrochemical cells.

Review

Start the lesson by reviewing the reading.
Points to ensure are understood

- Reduction and oxidation reactions involve the exchange of electrons.
- Electrodes are positive (cathode/oxidation reaction) and negative (anode/reduction reaction).
- Different metals have different inherent reduction potentials which define their tendency to be oxidised or reduced relative to hydrogen and each other.
- Electrochemical cells exploit a balanced reduction reaction and oxidation reaction to induce flow of electrons and thus electricity.

Reading material

Reduction/Oxidation
When metals form ions they are said to undergo reduction as they lose electrons to from positive ions.
e.g. $Zn \rightleftharpoons Zn^{2}+ + 2e^{-}$
When metal ions revert to their metal state they are said to undergo oxidation as they gain electrons.
e.g. $Cu^{2+} + 2e^{-} \rightleftharpoons Cu$
Note the arrows go in both directions as the reaction continues in both directions. At equilibrium although the reactions continue there is no change in the net amount of ion or metal.
To remember the names of these reactions use OIL RIG.
OIL RIG – oxidation is loss, reduction is gain

Reduction potential
Each metal has an intrinsic reduction potential.
Reference values are available based on the tendency of hydrogen to be reduced to hydrogen ions; also called the standard electrode. Reduction potential is expressed as a voltage. Thus, hydrogen's reduction potential is written as E° (V)=0.00.
If all the equations are written with the reduced state to the right these values are easily applied. Note dominant direction of the arrows.

$Cu^{2}+ + 2^{e-} \rightleftharpoons Cu$ E° (V)=+0.34
Positive reduction potential – tendency to be reduced
$Zn^{2+} + 2^{e-} \rightleftharpoons Zn$ E° (V)=-0.76
Negative reduction potential – tendency to be oxidised

Galvanic cell
This is an electrochemical cell named after Luigi Galvani.
A Galvanic cell consists of two half-cells. Each half-cell consists of electrodes, for example, plates of zinc and copper, and an electrolyte, for example, aqueous solutions of zinc sulfate and copper sulfate. There is also a salt bridge between the two electrolyte solutions.
As above, the copper atoms have a higher reduction potential than the zinc atoms. The zinc atoms are oxidized to zinc ions releasing electrons that flow from the zinc electrode (the more negative - anode) to the copper electrode (the more positive - cathode) along the wire.
$Zn \rightleftharpoons Zn^{2}+ + 2e^{-}$
These electrons are 'consumed' by a copper ion plating onto the copper electrode. This is the reduction step.
$Cu^{2}+ + 2^{e}- \rightleftharpoons Cu$
The electrolyte provides a source of Cu2+ ions and allows the Zn2+ to enter the solution.
The salt bridge allows each half-cell's charge to be balanced without mixing the solutions. If the solutions were mixed the reaction would be purely chemical and would not require electrons to travel through the wire. If the charges were not balanced the zinc electrode (the anode) would rapidly have an abundance of Zn2+ positive ions. This would not allow the flow of electrons.

C. Class discussion

Once the class has tried a variety of foodstuffs, bring the class back together to discuss how the potato and metal strips function like a Galvanic Cell.
- Copper strip is the cathode - reduced to Cu – E° (V)=+0.34
- Zinc strip is the anode – oxidised to Zn2+ - E° (V)=-0.76
- The oxidation of zinc releases electrons that travel along the wires towards the copper cathode
- Potato provides the electrolyte
- The chemical involved is dilute phosphoric acid.
- This acts as a supplier of non-reactive ions that carry electrons from one electrode to the other. Hydrogen ions are 'given' electrons by the oxidation of zinc to the ion and 'give' those electrons away in the reduction of copper ions to copper metal.
- There is no need for a separate salt bridge as the chemicals in the potato are able to balance the charge.
- Why are some foods better than others?
- The more ions there are in the salt bridge/electrolyte, the faster the reaction.
- Acidity is the measure of free H+ ions in solution. The more acidic a substance is the more free H+ ions available. The faster the reaction, the more electrons generated and the higher the voltage generated.

D. Practical

Each group of students requires 1 kit and 1 instruction sheet. Select the relevant information from the instructions if necessary.
Each group will also need 2 potatoes and 1 variety of foodstuffs to trial as electrolytes.
You may wish to provide the class with a voltmeter. If the 'clock-ends' of the wires are connected to bulldog clips the voltage across each system can be measured. Ask the class to rate the foodstuffs according to their ability to act as an electrolyte.
Go through the safety warnings advised in the instructions with the class before assembly.
Check each group's finished model and supervise the class' test runs.

E. Extension

Why does the power not last forever?
What commercial practices exploit the differences in reduction potential of different metals? HINT – when is one metal coated with another
Research one commercial application and present to the class
Why are two potatoes/pots used?
- HINT – compare voltage and current
- HINT – compare series and parallel circuits

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