

The CTD - Conductivity, Temperature and Depth

Teacher manual



This booklet was made by young
volunteers. (Freiwilliges Soziales Jahr
in Wissenschaft, Technik und
Nachhaltigkeit)



A note on the work sheets:

- *Working time: approx. 1 to 1½h depending on version and preparation (time without preparation of bottle in experiment 2 school version)*
- *The text printed in italic is only written in this document but not on the working sheets for students. Solutions of questions are underlined additionally.*
- *The experiments are available in two different versions: The first version is performed in the student laboratory and may require special equipment. The second version should be done with ordinary school equipment.*
- *When working with bigger groups and more than one supervisor it can be practical to divide into two groups (e.g. the teams of the first game). Then one group works on the first experiment und the work sheet on electrical conductivity. The other group works on the second experiment (and maybe the additional task). Before explaining the CTD the students should share their gained knowledge with the other group.*

Game:

Material: Balls (approx half as many balls as there are students, we recommend balls the size of (table) tennis balls), wrist or stopwatch

The students divide into two groups of the same size. Start and finish of a route are determined and marked if required. It should have the length of a team standing in row behind each other with approx. an arm's length space between them.

The students must transfer a balls from the start to the finish by following these rules:

A ball can only be handed over by bending forwards and giving the ball through one's own legs to the next player.

The ball may not be thrown or rolled.

The player who has the ball may not walk or run. He or she may also not have more than one ball.

The opposing players may try to hinder the team at handing over the ball, but the team can try to protect their own ball.

The ball may only used by the group who got it from the supervisor.

It is the aim to get as many balls into the finish as possible within one minute.

The balls that came into the finish can be rolled back to the start. Neither the own nor the opposing team may hinder that.

1. Round:

There are no balls

2. Round:

Each team gets a ball.

3. Round:

Each team gets half as many balls as there are players in the team. (In case of a lack of balls just considerably more than in the second round.)

This game aims to explain the functioning of a conductivity measurement.

The balls represent the ions solved in water. Thus the less balls are in the game the less salt (ions) is solved in water. The electrical conductivity measurement is symbolised by the counting of balls in the finish. It does not matter how fast the students work, if there are less balls in the game less will end up in the finish. Thus the measured "conductivity" is smaller than playing with many balls.

This can be transferred to the conductivity measurement of salt water. (A change in the distance would mean a change in the cell constant, which is determined for every measuring instrument and influenced by the distance between the electrodes and the size thereof.)

The impact of salt

All living creatures are adapted to a certain range of salinity - human beings included. Thus we can only drink water with low salt content. Saltwater leads us to vomiting. Survivors of a shipwreck, who drink saltwater despite the fact, will die of thirst faster than if they had drunken none.

Of course the salinity has a great effect on water organisms. Jelly fish, for instance, would not survive in tap water since it does not contain enough salt. In the Baltic Sea the impact of salinity is shown by the formation of the halocline, the result of a strong vertical salinity gradient. But how is the salinity measured in water?

Experiment 1: It's the mixture (school version)

Tools: Beaker, aluminium foil, 3 cables, small lamp with bulb socket, 4 crocodile clips, 4.5V monobloc battery, tea spoon (or spatula)

Chemicals: distilled water, table salt

Method:

- First read the whole method description.
- Fold two stable strips out of aluminium foil.
- Build the following circuit.

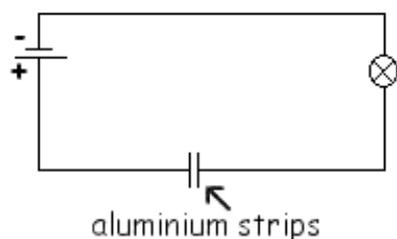


Figure 1: circuit diagramm

- Put both aluminium strips into the dry salt. Make sure they do not touch each other. Note your observation.
- Attach both strips to the edge of the beaker. Avoid the strips touching each other. Fill the beaker with distilled water. Note your observation.
- Remove the strips, add one to two tea spoons of salt, stir carefully and attach the strips again. Note your observation.

Note: If the lamp does not turn on, try more salt or a different lamp. Since there might be gaseous chlorine or hydrogen produced, only close the circuit for a few minutes.

Experiment 1: It's the mixture (lab version)

Tools: conductivity meter (or salinometer) , scale, 200ml-beaker, small beaker to put on scale, stirring rod, spatula.

chemicals: distilled water, table salt

Method:

- First read the whole method description.
- Write down every measured value! Note the measurement unit
- Measure the conductivity of dry salt.
- Rinse the sensor with distilled water.
- Fill the 200ml-beaker with distilled water.
- Measure the conductivity of the water.
- Add salt in steps of 2g and stir carefully. Measure after every step. You should rinse the sensor after every measurement.

Measurements:

Electrical conductivity of dry salt: 0 mS/cm

| | | | | |
|------------------------------------|--------|---------|---------|---------|
| Solved salt in g: | 0 | 2 | 4 | 6 |
| Conductivity in mS/cm ¹ | 0,0016 | 15,3381 | 28,9420 | 41,7479 |

¹ At 20 °C und 0 dbar (at sea level); Calculations with formulas of Teos-10.

The electrical conductivity

The electrical conductivity is a term that can be found in the context of electrical current. It indicates how good a certain matter can conduct electricity. Electrical current is characterized by the fact that electrically charged particles (charge carriers) move along a charge gradient (voltage). For that free charge carriers are necessary.

Salts consist of charged particles, namely ions. In a solid condition these ions are bound in the ion lattice.

Water consists of molecules which do not divide into a positive and a negative part. Thus they are neutral to their environment.

Can you explain your observations in the experiment?

Pure water:

No charge carriers available since water consists of neutral molecules. Thus there is no electrical current.

Pure salt:

Ions are made of charged particles and therefore potential charged carriers, but they cannot move in the ion lattice. Therefore there is no movement of charge carriers (, thus no electrical current).

Saltwater:

Ions are solved in water, therefore the ion lattice is destroyed and charge carriers that can move around freely are available. Thus the salt water conducts the electrical current which can be measured.

Unfortunately the conductivity does not only depend on the salinity. What could also have an impact on it?

Temperature, pressure and the type of ions have an impact on the electrical conductivity. (The composition of salts in the sea is approximately the same everywhere.)

Pressure and water depth

Everybody knows this phenomenon: The deeper one dives into the water the bigger is the pressure on the ears. But why?

Experiment 2: Quite some pressure! (school version)²

Tools: 2 balloons, sealing tape, 4 similar plastic bottles, modelling clay (the one that does not harden), 2 short flexible tubes (approx. 5cm long), scissors, 2 pegs, 1 small tub, watering can

Chemicals: water

Method:

- First read the whole method description.
- Cut the bottles as you can see in the right-hand illustration.
- Put the four bottles together, so that you have a huge bottle (approx. height about 1m). Seal it with tape.
- Cut a hole into to plastic wall at the top and at the bottom end. It should have about the same diameter as the flexible tube.
- Put one end of the tubes approx. 2cm into the wholes and seal with modelling clay and tape.
- Blow some air into the balloons, twist the ends and close them with pegs. Put the opening of the balloons onto the other end of the tubes and seal it with tape.
- Put the bottle in the tub and fill it with a watering can. The water level should be 10cm higher than the top tube.
- First open the top peg, than the bottom.

Note: After the observation at the bottom balloon is made, twist and close the balloon again, otherwise it might burst. If the results of top and bottom balloon are the same, try again with more air in the bottom balloon or a higher water column.

Questions:

1. What did you observe?
2. What can you conclude from that?

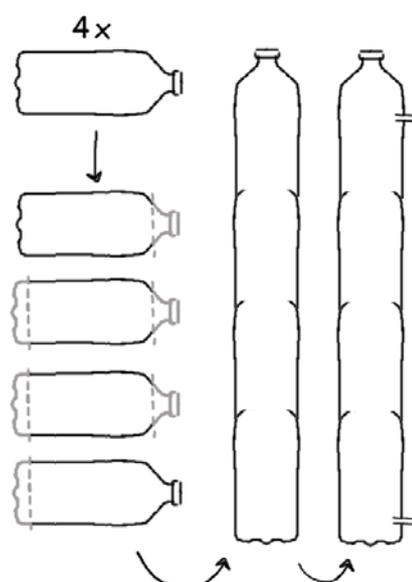


Figure 2: Sketch on how to cut the bottle and where to put the flexible tubes

² Compare anonymous under the youtube user name „SoCoolScienceShow“: !!!NEW WATER PRESSURE EXPERIMENT!!! (2012)

Experiment 2: Quite some pressure! (lab version)

Tools: 2 balloons, cylinder with a length of approx. 1,25m and two (or more) nozzles, watering can, 2 (or more) pegs

Chemicals: water

Method:

- First read the whole method description.
- Blow some air into the balloons, twist the ends and close them with pegs. Pull the end of the balloons over the nozzles.
- Fill the cylinder with water. (The water level should be approx 10cm over the top nozzle.)
- From top to bottom open the pegs and observe.

Note: Some balloons burst because of high water pressure, so it is best to twist the balloon at the bottom again soon after the observation is made.

Questions:

1. What did you observe?
2. What can you conclude from that?

Answers to the questions of experiment 2

To question 1:

After the peg is removed the top balloon discharges the air. The bottom balloon, however, fills with water.

To question 2:

The skin of the balloon always tries to shrink back to its original size. As long as the balloons are closed, the inner air pressure counteracts the shrinking. But when the balloons are opened there is a pressure balancing through the opening of the balloon.

At the top balloon the counter-pressure of the water is so small that the inner air can escape.

At the bottom balloon the water pressure is so high that the water even enters the balloon.

Further explanations

There are many different possibilities to measure pressure. There are mechanical and electrical pressure measuring instruments. Usually these instruments work with a membrane or a moveable component and a chamber filled with gas. This has a certain volume when exposed to a certain pressure. By a change of pressure the flexible component is moved or stretched. Also the volume changes. E.g. the extension or compression of a membrane can be measured by the help of electrical resistor.

We feel pressure on our ears, because there are different pressures on each side of our eardrum. On the outside the pressure rises when we dive under water. On the inside of the ear the atmospheric pressure stays. This way the eardrum is "dented" und thus strained. In extreme cases the eardrum can even break.

Pictures from the experiment (lab version)



Figure 3 (left):
*experiment set-up
with 3 balloons, red
balloon deflates*

Figure 4 (top): *green
balloon deflates as well.*



Figure 5: (middle):
*yellow balloon shortly
after removing the
peg.*



Figure 6 (bottom):
*(see figure 4) after a
few minutes.*

Additional task (for fast groups)

The density ρ of water is about $1\,000\text{ kg/m}^3$, the acceleration of free fall g about 10 m/s^2 . The water depth is h in m.

The formula for pressure p is:

$$p = \rho \cdot g \cdot h$$

Whereas the pressure is calculated in the measurement unit Pascal (Pa).

- Calculate the pressure for:

$$h_1 = 1\text{ m}$$

$$p_1 = 10\,000\text{ Pa}$$

$$h_2 = 2\text{ m}$$

$$p_2 = 20\,000\text{ Pa}$$

$$h_3 = 10\text{ m.}$$

$$p_3 = 100\,000\text{ Pa}$$

- There is another measurement unit for pressure: $1\text{ bar} = 100\,000\text{ Pa}$. The most common unit in oceanography is dbar (decibar). Convert the pressures from above into dbar.

$$p_1 = 10\,000\text{ Pa} = 0,1\text{ bar} = 1\text{ dbar}$$

$$p_2 = 20\,000\text{ Pa} = 0,2\text{ bar} = 2\text{ dbar}$$

$$p_3 = 100\,000\text{ Pa} = 1\text{ bar} = 10\text{ dbar}$$

- Can you think of a reason why in oceanography pressure is usually stated in dbar?

The pressure in dbar matches roughly the water depth.

- What impact has a change in density on pressure? And what impact has it on the water depth?

A higher density results in a higher pressure. However, it does not have an impact on the water depth. This is the reason why pressure is not the same as water depth.

The CTD

The CTD is a probe, which measures conductivity, temperature and pressure, the latter matching water depth. Those probes usually measure continuously, so that researchers can create temperature and salinity profiles. In the central Baltic Sea such a profile, depending on the season, could look like this:

Profile A: Summer

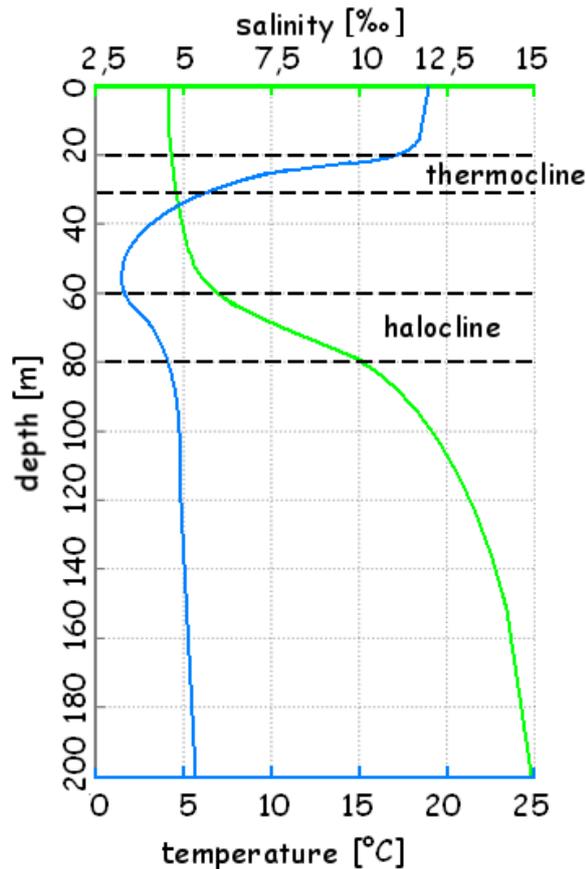


Figure 7: Seasonal presentation of temperature und salinity in the central Baltic Sea³

Profile B: Winter

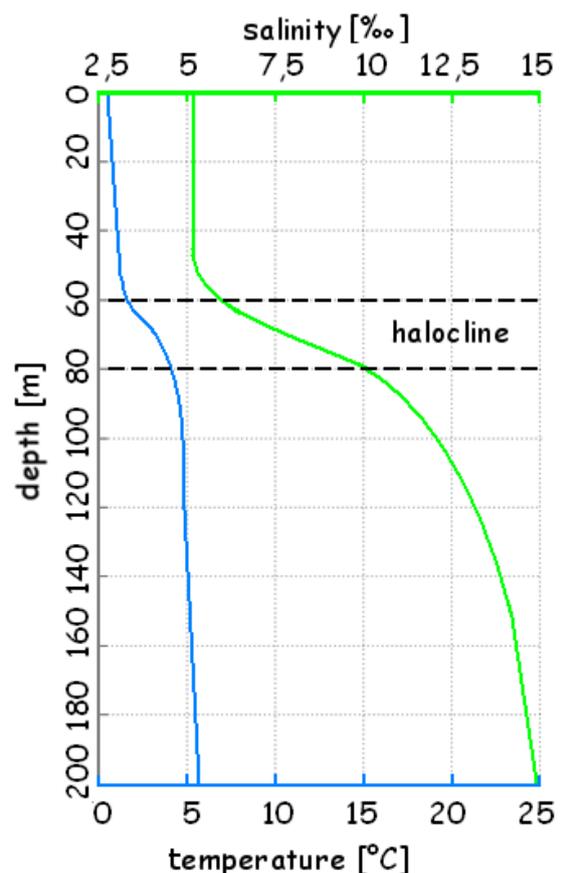


Figure 8: Seasonal presentation of temperature und salinity in the central Baltic Sea⁴

Tasks:

1. These profiles show the summer and winter situation. Can you assign the profiles to the seasons? Give reasons for your decision.
2. Mark the thermocline and the halocline. (These are thin layers in which the temperature (thermo-) or salinity (halo-) respectively changes more rapidly than in the layer above or below).

³ compare Matthäus (1996) Fig. 32

⁴ Loc. cit.

Solutions to the profiles:

1. Reason:

In summer the sun heats water more strongly than in winter. Therefore the temperature at the surface is higher. The surface water stays above because of its lower density. This is way a thermocline and a colder interlayer beneath are formed.

2. (See figure).

The CTD is used for nearly every measurement in marine research, because it reflects basic hydrographical conditions.

This is the reason why there are many different kinds of CTDs depending on the application area. For example, there are small portable CTD which only have one sensor for each physical quantity.

On board of research vessels (r/v) they usually are measured twice. Often the ship-CTDs have other sensors, too, for example, oxygen sensors. The sensors are combined with a rosette of water samplers, which are tubes that can be closed at a determined point to bring water samples from a certain depth to the surface.

Since they are big and heavy the CTDs set to the water via a winch.



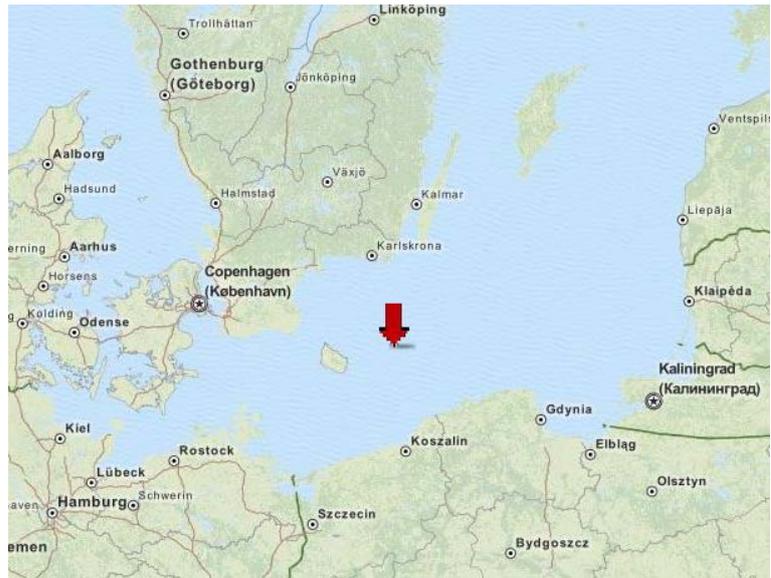
Figure 9: CTD of r/v Elisabeth Mann Borgese with rosette of water samplers



- 1.) pressure sensor from below
- 2.) conductivity sensor from below
- 3.) temperature sensor from below
- 4.) serial data output for PC
- 5.) No. 4 with sealing
- 6.) control lamp
- 7.) magnet switch
- 8.) lifting body
- 9.) sensors
- 10.) cage for protection
- 11.) rope

Figure 10: labelled portable CTD

CTDs are also used for long-term monitoring. In May 2013 on a monitoring expedition this profile was measured at 55° 15' north und 15° 59' east (see map):



Station TF0213 06.05.2013

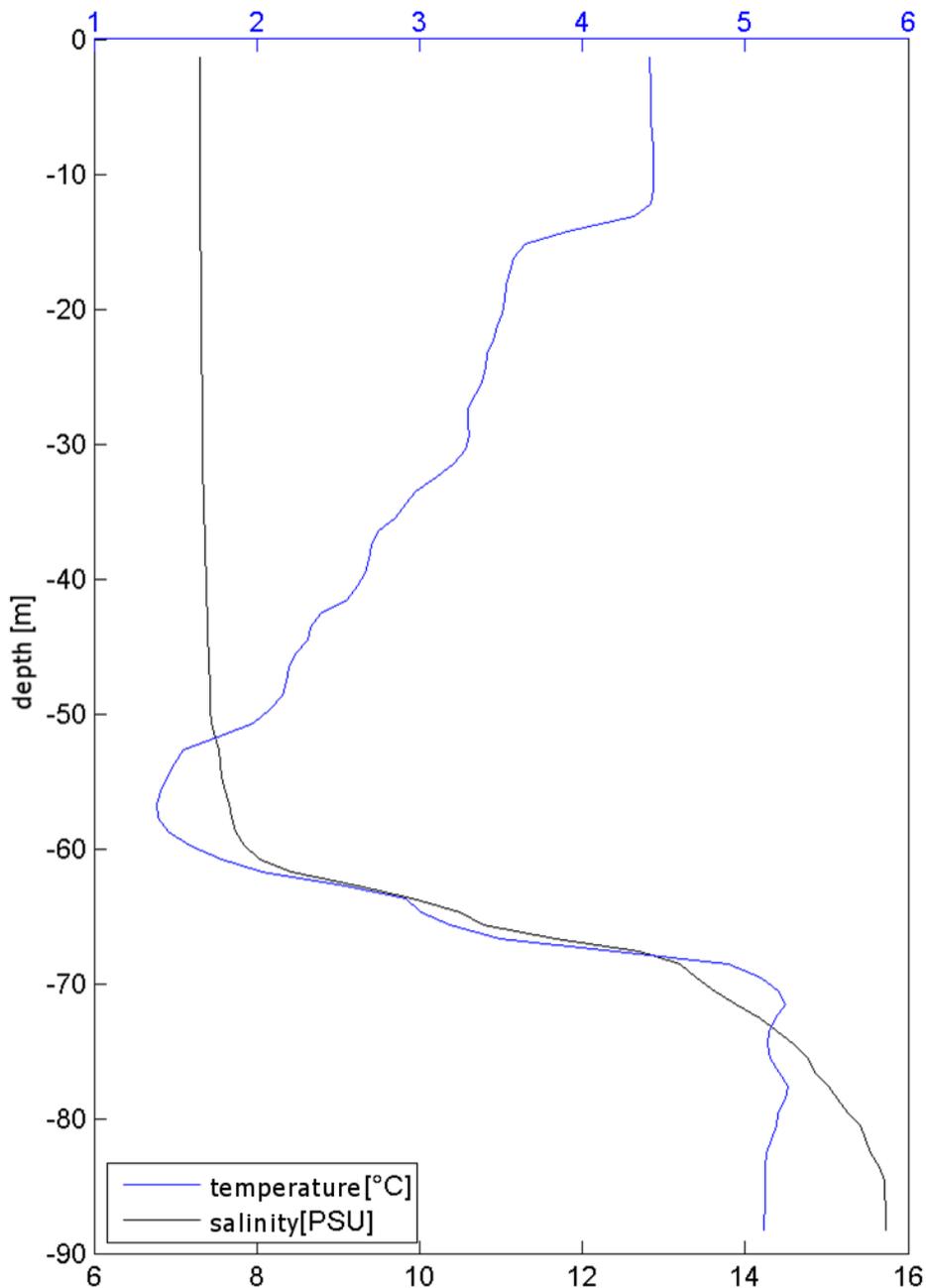


Figure 11: western Baltic Sea with station TF0213

Figure 12: profile of station TF0213 at the 6th of May 2013

Bibliography

Print media:

Erbrecht, R., König, H., Karlheinz Martin, K., Pfeil, W. und W. Wörstenfeld (1999).
Das große Tafelwerk. Mechanik der Flüssigkeiten und Gase. 1. Auflage.
Berlin. Volk und Wissen Verlag, S. 78, ISBN 978-3-06-020760-2

Matthäus, W. (1996). Temperatur, Salzgehalt und Dichte. In: Rheinheimer, G.
(Hrsg.). Meereskunde der Ostsee, 2. Auflage. Berlin; Heidelberg:
Springer-Verlag. S. 75-80. ISBN 978-3-59351-9

McDougall T.J. und P. M. Barker (2011): Getting started with TEOS-10 and the
Gibbs Seawater (GSW) Oceanographic Toolbox, SCOR/IAPSOWG127, 28
Seiten, ISBN 978-0-646-55621-5

Online media:

Anonym unter dem youtube-Nutzernamen „SoCoolScienceShow“(2012). !!!NEW
WATERPRESSURE EXPERIMENT!!!. Zugriff am 12.05.14 unter:
<https://www.youtube.com/watch?v=jS3OlpHCRLk&noredirect=1>

Gumpert, N. (2014). Erbrechen auslösen. Wie oder wodurch kann man Erbrechen
auslösen?. Zugriff am 05.06.14 unter [http://www.dr-
gumpert.de/html/erbrechen_ausloesen.html](http://www.dr-gumpert.de/html/erbrechen_ausloesen.html)

Rösch, N. Überarbeitet von Bickel, S., Fransbach, K. und K. Kiefer(2010). Wozu
braucht man Wasser. Auch Tiere brauchen Wasser - Wassertiere. Zugriff
am 12.05.14 unter:

[http://www.uni-
duesseldorf.de/MathNat/Biologie/Didaktik/WasserSek_I/wozu_braucht
_man_wasser/dateien/tier/tier.html](http://www.uni-duesseldorf.de/MathNat/Biologie/Didaktik/WasserSek_I/wozu_braucht_man_wasser/dateien/tier/tier.html)

Schaffner, T. Inhaltlich Verantwortlicher Burkacky, O. Im Wasser verdurstet.
Zugriff am 05.06.14 unter:

[http://www.chemiestudent.de/seite/wissenswertes-
Im+Wasser+verdurstet-15.html](http://www.chemiestudent.de/seite/wissenswertes-Im+Wasser+verdurstet-15.html)

Schmidt, B. (2010). Drucksensoren. Zugriff am 02.06.2011 unter:

<http://userpages.uni-koblenz.de/~physik/informatik/Sensoren/druck.pdf>

Schmidt, M.(2001). Die elektrische Leitfähigkeit. Zugriff am 05.06.14 unter:

http://www.cumschmidt.de/s_leitf_el01.htm#thema_ionenleiter

Spektrum Akademischer Verlag (2001). Osmoregulation. Zugriff am 12.05.14 unter:

<http://www.spektrum.de/lexikon/biologie-kompakt/osmoregulation/8484>

Tillmann, A. (Red.)(2009). Elektrische Leitfähigkeit - Versuche mit Wasser und Kochsalz. Zugriff am 02.06.2011 unter:

<http://www.kids-and-science.de/experimente-fuer-kinder/detailansicht/datum/2009/08/10/elektrische-leitfaehigkeit-versuche-mit-wasser-und-kochsalz.html>

Wiegand, B. (2014). Risiken beim Tauchen. Zugriff am 03.06.14 unter:

http://www.planet-wissen.de/sport_freizeit/wassersport/tauchen/gefahren_tauschen.jsp