

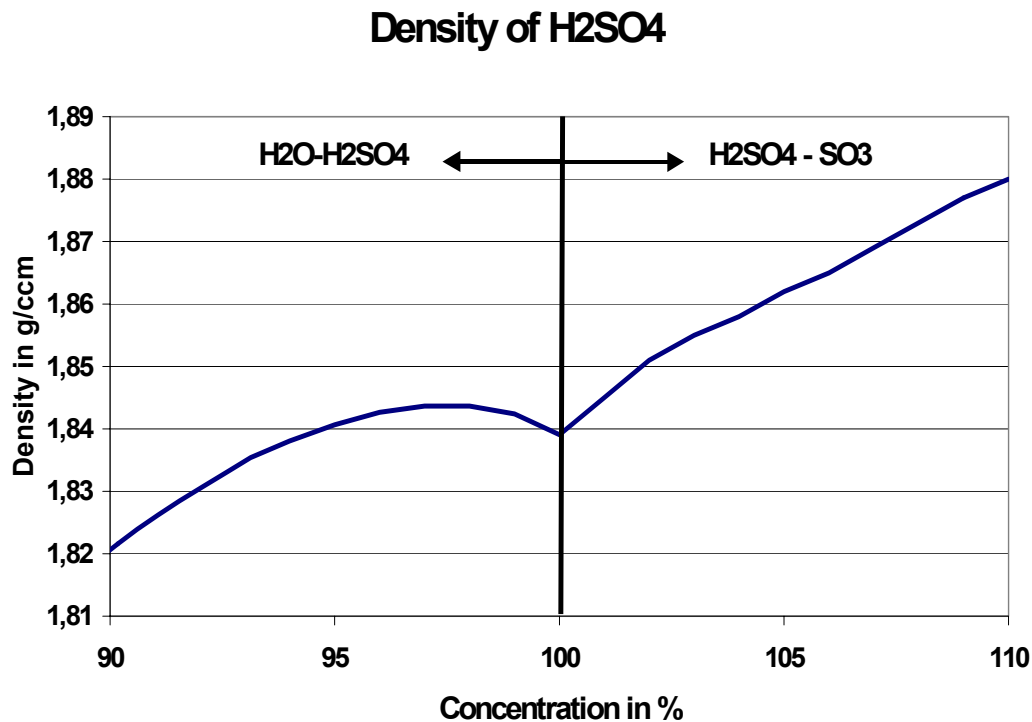


**Concentration  
Measurement  
of Acids  
with Neutrons**

## Concentration Measurement of Acids with Neutrons.

The concentration measurement of acids with neutrons is an interesting alternative which is used particularly when

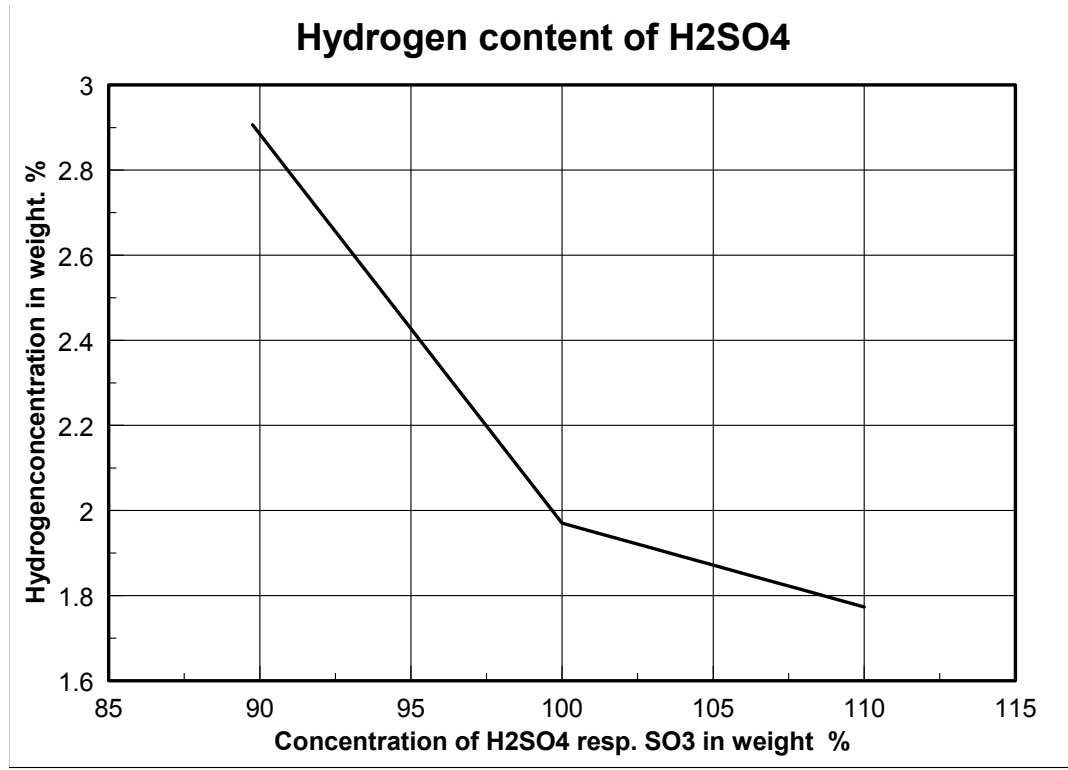
- the function includes a turning point, so that one may get different concentration values with the same density. This is the case, for example, with sulfuric acid ( $\text{H}_2\text{SO}_4$ ) or hydrofluoric acid (HF).



- the acids are heavily contaminated by inorganic substances (e.g. metal oxide).
- when the concentration of a substance with high absorption cross-section for neutrons has to be determined, e.g. boric acid ( $\text{H}_3\text{BO}_4$ ).

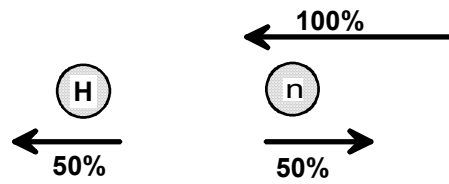
## The Solution: The Measurement of the concentration of hydrogen

By measuring the hydrogen content of the acid, a definite and reliable information about the concentration is achieved.

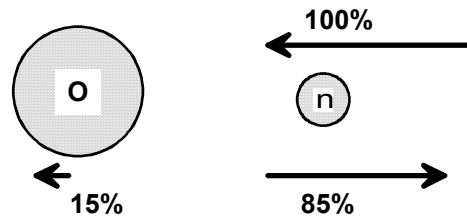


## The Principle of Measurement

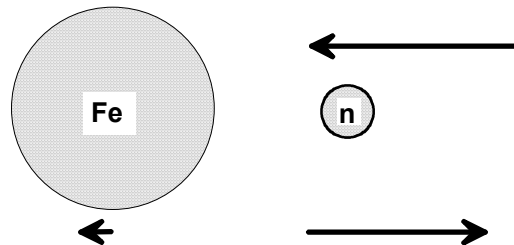
Neutrons are nuclear elements which are electrically neutral, i.e. without electrical charge. For this reason, the absorption does not occur at the electron shell of the atom, as with gamma radiation, but in the nucleus. The absorption capability of most atom cores for neutrons (apart from a few exceptions, such as boron and cadmium), however, is very low. The major influence is caused by the energy loss through scattering according to the principle of the elastic impact on the atom core. Scattering at the hydrogen core, which has about the same mass as the neutron, causes the neutron to lose approx. 50 % of its kinetic energy. Scattering on bigger atom cores causes a much smaller energy loss.



Loss of energy on a hydrogen core: Approx. 50%



Loss of energy on a oxygen core: Approx. 50%



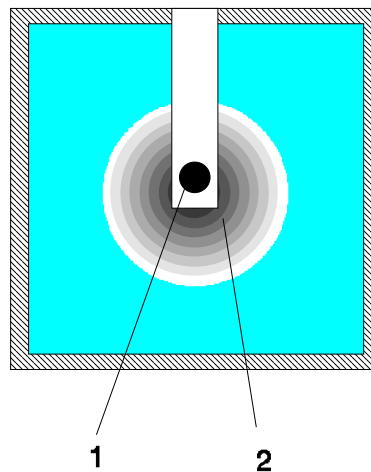
Loss of energy on a iron core: Approx. 50%

### Energy loss of neutrons

After about 18 - 20 scatterings on a hydrogen core, a neutron with a energy of 2 MeV has lost so much energy that its energy matches the thermal energy of the surrounding matter (= thermal neutron or slow neutron).

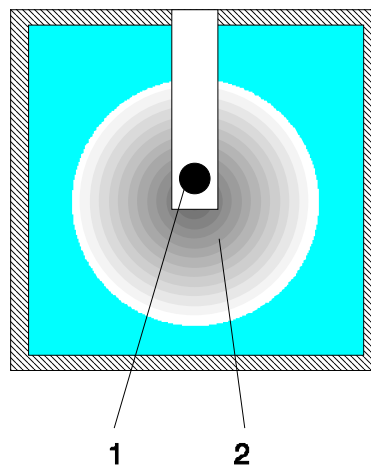
## a) Measuring Method with Neutron Moderation

Fast neutrons are emitted by a neutron source (Am/Be-241). These neutrons are moderated at the hydrogen cores of the product and thus reduced to thermal energy. The higher the hydrogen concentration in the environment of the neutron source, the higher the concentration of thermal neutrons. A detector featuring a detection sensitivity for thermal neutrons (He3 counter tube) is installed in the same housing as the neutron source. The higher the concentration of thermal neutrons in the environment of the detector, the higher the emitted count rate. Thus, the measuring system performs an indirect measurement of the hydrogen concentration.



Neutron source in a product with high H-concentration (schematic illustration). There is a high concentration of thermal neutrons in the environment of the source.

- 1 neutron source
- 2 thermal neutrons

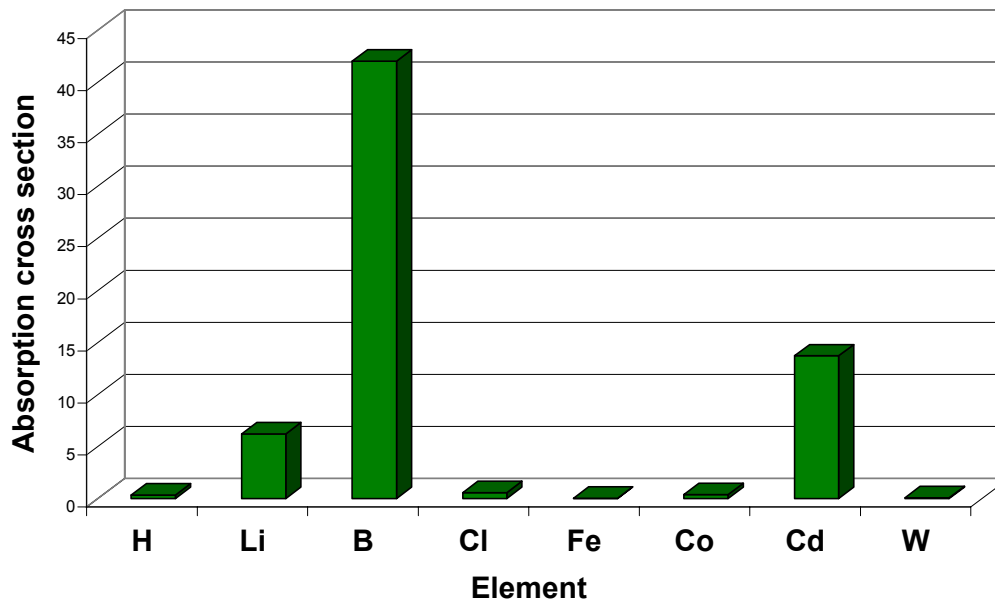


Neutron source in a product with low H-concentration (schematic illustration). The concentration of thermal neutrons in the environment of the source is lower, the diameter of the "neutron cloud", however, is greater.

## b) Utilization of Neutron Absorption

If thermal neutrons collide with cores having a high absorption cross-section for neutrons (e.g. boron, cadmium, chlorine), the neutrons will be absorbed by the atom cores. The concentration of the thermal neutrons decreases drastically with rising concentration of this component.

### Absorption cross - sections for slow neutrons

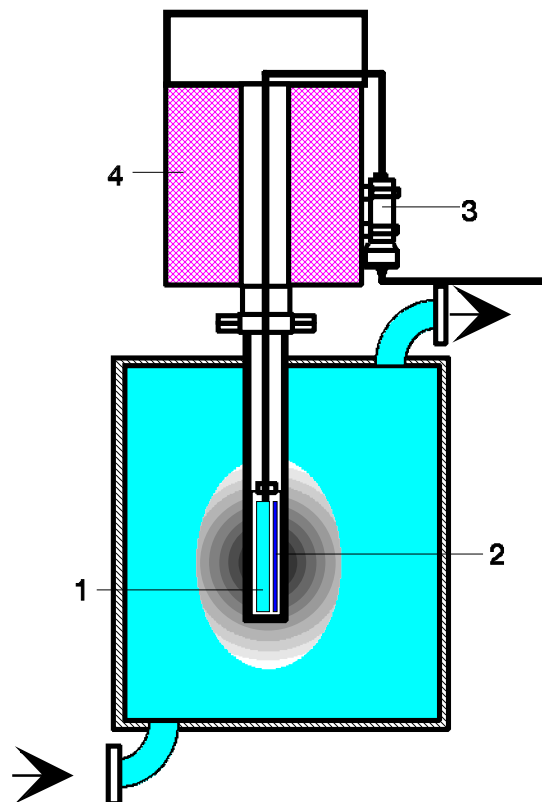


## Technical Versions

### a) Measurement with Immersion Probe

An extremely high accuracy can be reached with an immersion probe. Detector and neutron source are installed in a common housing. Both devices are inserted into the product to be measured in a protective pipe (max. product temperature 120°C, with air cooling up to 160°C). The detector signal is transmitted to a preamplifier and from there to the evaluation unit. Due to the fact that the detector is nearly completely surrounded by the product to be measured, the accuracy that can be achieved is very high.

Evaluation unit



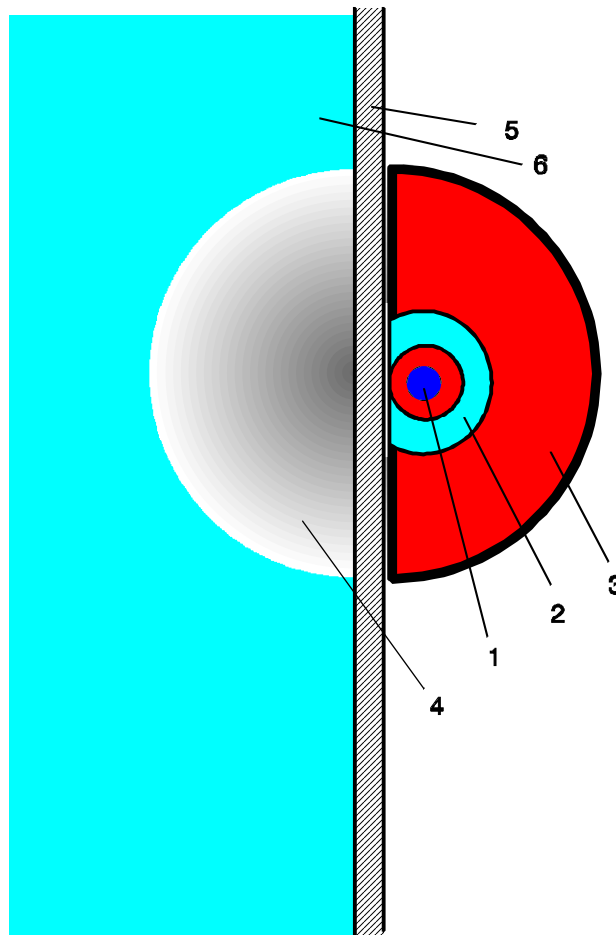
Flow direction

*Setup with immersion probe*

1	detector	2	neutron source
3	preamplifier	4	shielding

### b) Measurement with Surface Probe

A surface probe may be used when an installation in the vessel is not possible. Since the temperatures are lower in this case, the preamplifier is incorporated in the detector housing. An additional reflector reflects the neutrons emitted away from the vessel, and thus the sensitivity of the measuring system is improved.



*Setup with surface probe*

1 neutron source	2 reflector
3 PE shielding	4 moderated neutrons
5 vessel wall	6 product

## Accuracies of the Measurement

The neutrons are not emitted regularly but as a consequence of nuclear transformations. The time distribution of the emission is therefore subject to statistical laws.

For continuous measurements, a sliding average is calculated from the count rate supplied by the detector. (A special evaluation unit is available for discontinuous measurements.)

The longer the time selected for averaging, the lower the statistical measurement error. In general, the statistical error is given as 2- $\sigma$  deviation.

The following accuracies were achieved in practice with an immersion probe arrangement:

### **H<sub>2</sub>SO<sub>4</sub> - H<sub>2</sub>O mixture: Range: 65 - 100 % H<sub>2</sub>SO<sub>4</sub>**

Time constant: 120 s

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Statistical error:  $\pm 0.25$  % H<sub>2</sub>SO<sub>4</sub>

**Measurements up to a range of over 100 % (free SO<sub>3</sub>) are possible.**

**HF-H<sub>2</sub>O mixture:**      **Range: 65  $\pm$  80 % HF**  
Time constant: 120 s  
Statistical error:  $\pm 0.35$  % HF

**H<sub>3</sub>BO<sub>3</sub> H<sub>2</sub>O mixture:** up to  $\pm 200$  ppm B

## Evaluation Unit

The evaluation unit LB 444 has been employed with success in a large number of density measuring installations.

- The dialog-guided calibration ensures simple handling. The influence of temperature-associated density variations on the measuring signal can be corrected by an additional temperature correction (temperature signal PT 100 or current signal 0/4 - 20 mA).
- Up to four different calibration data sets can be stored for various products for each measuring channel. The calibration data are stored in an Flash E-Prom and will be saved in the event of a power failure without additional buffer battery.
- A built-in "watch-dog" signals trouble in the instrument, ensuring a high reliability and safety of the entire measuring system.

Hints for Installation:

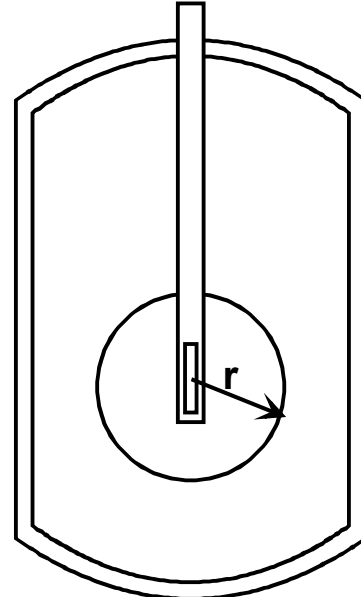
A protection pipe for the detector has to be built in for the installation in a container.

The inner diameter of the protection pipe has to be at least 51mm and at the most 55 mm.

A certain minimum volume must be available at the measuring point which is constantly filled with the product. In this area, there should be no parts i. e. Stirrer which could influence the measurement. The minimum measurements can be seen in the following table.

Conc. in %	r in mm
70	200
80	210
90	250
100	270
110	290

There should be no welding seams on the inside which could decrease the inner diameter.



The material of the protection pipe has to be resistant to the acid or the protection pipe should be painted with an acid resistant coating. The material of the coating should not contain hydrogen. (i. e. PTFE).

The wall thickness of the protection pipe along the measurement should be >500 mm approx. 5 mm + coating. In the other areas, a larger wall thickness is allowed.

In order to mount the shielding, a flange must be attached on top. Measurements see scaled diagram.

**If the temperature in the protection pipe can reach > 120°, the detector must be cooled with air or nitrogen.**

The measuring system is not mass produced permitted for operation in explosion hazardous areas. By pressurising with corresponding pressure monitoring (option), an installation in Ex-area is possible.