1 The influence of temperature on refractive index

For refractive index measurements an accurate temperature control and/or measurement is required, because temperature is one of the most influencing factors on the refractive index of a given sample.

Example:

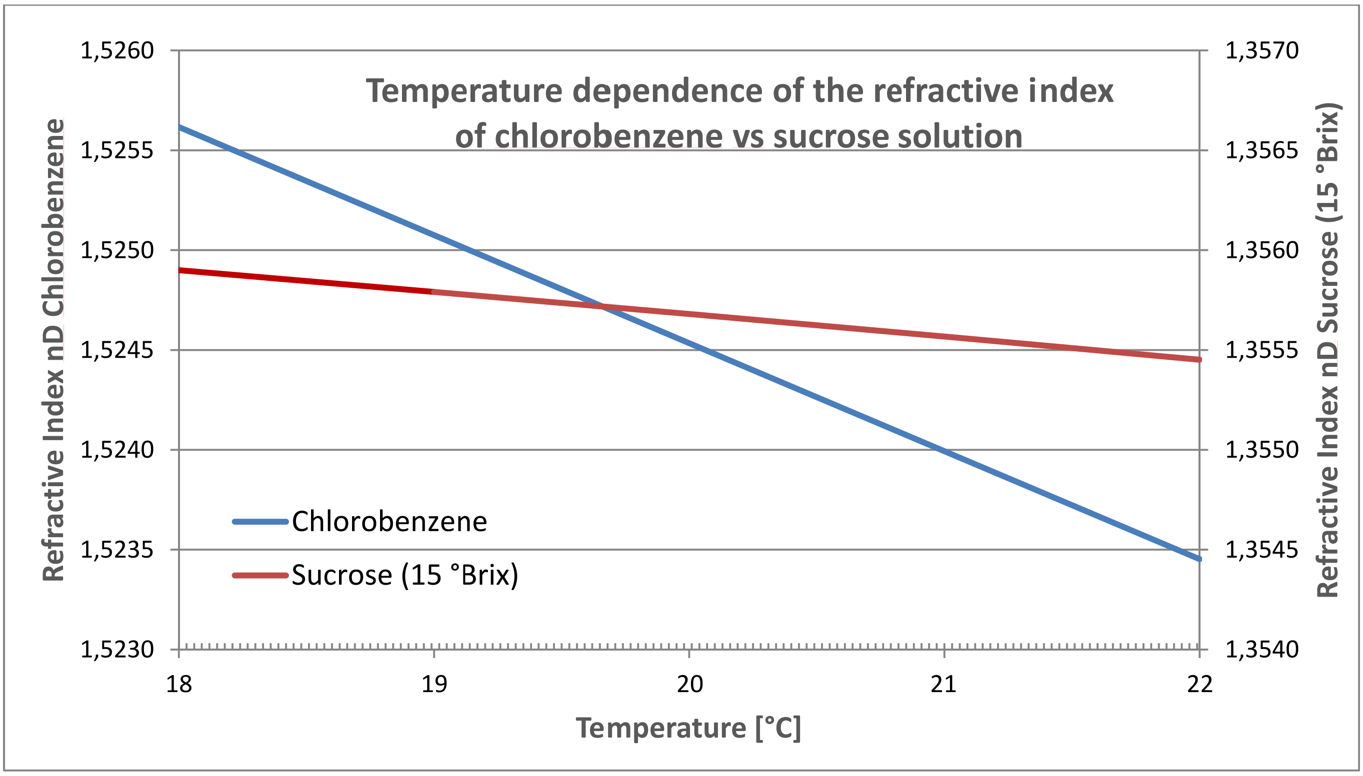


Figure 1: Influence of temperature on the refractive index of chloro-benzene and sucrose solution.

From figure 1 it can be learned, that the temperature dependence of the refractive index is specific for a given sample. Each different material has different temperature dependence of the refractive index. In order to get comparable refractive index results, a standard temperature has to be defined. Standard temperatures are often 20°C or 25°C, e.g. in Pharmacopeias.

Due to this temperature influence on the refractive index, Abbemat refractometers offer a precise temperature control and the possibility to perform a temperature check/adjustment with the Abbemat T-check.

1.1 Correct syntax for refractive index

Temperature and wavelength must be known to get a correct refractive index. These two parameters have major influence on the refractive index. The correct syntax for refractive index, which is conventionally abbreviated as “n” is n_λ^T wherein T stands for the temperature and λ for the wavelength.

Example:
The refractive index of water at 20°C and a measuring wavelength of 589.3 nm has to be written as

$$n_{589}^{20} = 1.33299$$

If the wavelength is 589.3 nm (the so called sodium D-Line), often a D is used instead of the wavelength, resulting in

$$n_D^{20} = 1.33299$$

Sometimes, also the temperature is omitted, resulting into n_D, only, and finally, if subscript is not available, in nD. Even this is a very common writing, important information on the temperature got lost.

2 Refractive index of water – Measurement and Adjustments at Temperatures other than 20°C

Many people know a value of 1.3330 nD as the refractive index of water and may assume that this is a general temperature independent constant. But that´s not correct. The refractive index of water depends on the temperature as well. The value of 1.3330 is the refractive index of water at 20°C (correctly written as n_{589}^{20}).Therefore the reference index of 1.3330 is only correct at 20°C. If the temperature is 25°C for instance, the refractive index n_{589}^{25} of water is 1.3325.

In the following table are refractive indexes of water at different temperatures according to Tilton & Taylor are given:

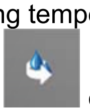
T[°C]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
10	1.333689	1.333684	1.333679	1.333674	1.333669	1.333664	1.333658	1.333653	1.333648	1.333642
11	1.333637	1.333631	1.333626	1.333620	1.333615	1.333609	1.333603	1.333598	1.333592	1.333586
12	1.333580	1.333574	1.333568	1.333562	1.333556	1.333550	1.333544	1.333538	1.333532	1.333526
13	1.333519	1.333513	1.333507	1.333500	1.333494	1.333487	1.333481	1.333474	1.333468	1.333461
14	1.333455	1.333448	1.333441	1.333434	1.333427	1.333421	1.333414	1.333407	1.333400	1.333393
15	1.333386	1.333379	1.333372	1.333364	1.333357	1.333350	1.333343	1.333335	1.333328	1.333321
16	1.333313	1.333306	1.333298	1.333291	1.333283	1.333275	1.333268	1.333260	1.333252	1.333244
17	1.333237	1.333229	1.333221	1.333213	1.333205	1.333197	1.333189	1.333181	1.333173	1.333165
18	1.333157	1.333148	1.333140	1.333132	1.333124	1.333115	1.333107	1.333098	1.333090	1.333082
19	1.333073	1.333064	1.333056	1.333047	1.333039	1.333030	1.333021	1.333012	1.333004	1.332995
20	1.332986	1.332977	1.332968	1.332959	1.332950	1.332941	1.332932	1.332923	1.332914	1.332904
21	1.332895	1.332886	1.332877	1.332867	1.332858	1.332849	1.332839	1.332830	1.332820	1.332811
22	1.332801	1.332792	1.332782	1.332773	1.332763	1.332753	1.332743	1.332734	1.332724	1.332714
23	1.332704	1.332694	1.332684	1.332674	1.332664	1.332654	1.332644	1.332634	1.332624	1.332614
24	1.332604	1.332594	1.332583	1.332573	1.332563	1.332552	1.332542	1.332532	1.332521	1.332511
25	1.332500	1.332490	1.332479	1.332469	1.332458	1.332447	1.332437	1.332426	1.332415	1.332404
26	1.332394	1.332383	1.332372	1.332361	1.332350	1.332339	1.332328	1.332317	1.332306	1.332295
27	1.332284	1.332273	1.332262	1.332251	1.332239	1.332228	1.332217	1.332206	1.332194	1.332183
28	1.332171	1.332160	1.332149	1.332137	1.332126	1.332114	1.332102	1.332091	1.332079	1.332068
29	1.332056	1.332044	1.332032	1.332021	1.332009	1.331997	1.331985	1.331973	1.331961	1.331949
30	1.331938	1.331926	1.331914	1.331901	1.331889	1.331877	1.331865	1.331853	1.331841	1.331829
31	1.331816	1.331804	1.331792	1.331779	1.331767	1.331755	1.331742	1.331730	1.331717	1.331705
32	1.331692	1.331680	1.331667	1.331655	1.331642	1.331629	1.331617	1.331604	1.331591	1.331578
33	1.331566	1.331553	1.331540	1.331527	1.331514	1.331501	1.331488	1.331475	1.331462	1.331449
34	1.331436	1.331423	1.331410	1.331397	1.331384	1.331371	1.331357	1.331344	1.331331	1.331318
35	1.331304	1.331291	1.331278	1.331264	1.331251	1.331237	1.331224	1.331210	1.331197	1.331183
36	1.331170	1.331156	1.331142	1.331129	1.331115	1.331101	1.331088	1.331074	1.331060	1.331046
37	1.331033	1.331019	1.331005	1.330991	1.330977	1.330963	1.330949	1.330935	1.330921	1.330907
38	1.330893	1.330879	1.330865	1.330851	1.330836	1.330822	1.330808	1.330794	1.330779	1.330765
39	1.330751	1.330736	1.330722	1.330708	1.330693	1.330679	1.330664	1.330650	1.330635	1.330621
40	1.330606	1.330592	1.330577	1.330562	1.330548	1.330533	1.330518	1.330503	1.330489	1.330474

Figure 2: Temperature dependence of the refractive index of water according to Tilton & Taylor, relative to air for a measuring wavelength of 589.3 nm

2.1 What does this mean for measurements / adjustments with the Abbemat 3000?

The Abbemat 3000 has no temperature control and therefore the refractive index is measured at the actual temperature (usually a little bit above room temperature). If the measuring temperature is 26.2°C for example, the measured refractive index should be 1.3324 (ref. previous table, the Abbemat 3000 shows 4 decimals only, therefore the result will be rounded).

Note: If you set the temperature with a temperature controlled Abbemat to 26.2°C you should get the same reading (of course in the given accuracy range).

If the measured result deviate more than +/- 0.0001 a water adjustment has to be performed. An adjustment is also required, if the measuring temperature has changed. A water adjustment can easily be performed by tapping on the quick access button  on the main screen of the Abbemat: Just clean the prism carefully and apply a few drops of demineralized water, then press .

What happens during the adjustment?

The refractive index of water is set according to the current temperature. For above example, if the temperature is 26.2°C the refractive index will be set to 1.3324, which is the refractive index of water at 26.2°C. This means, the Abbemat internally has stored the temperature dependence of the refractive indexes of water and automatically set the correct refractive index for the given temperature (ref. above table).

Remember:

As the temperature dependence is specific for each different sample, usually a standard temperature is defined (20°C or 25°C, see above).

3 Temperature corrected methods

Why do we have an Abbemat 3000 without temperature control, if the refractive index is influenced by temperature, especially if this influence is specific for a given sample? Does this make any sense?

Yes, the idea is to accelerate the concentration measurement of binary solutions. With the Abbemat 3000 it´s not necessary to wait for the temperature control to the set temperature, so the customer could save time.

Most of the methods are valid at 20°C. They are defined by measuring a dilution series of a particular substance, e.g. sucrose dissolved in water at a fixed temperature. From these data a two-dimensional function – valid at 20°C - can be generated allowing the determination of the concentration of the sample.

The preparation of such a method is simple. Such correlations can be found in the literature usually being valid at a certain temperature only. This is well established and most of the implemented methods of our Abbemat refractometers are based on this principle.

In contrast to the higher Abbemat models, the Abbemat 3000 is doing a mathematical temperature correction and is not temperature controlled:

Consider a given sucrose solution of e.g. 10°Brix. By definition °Brix is a sucrose scale expressing the mass concentration of a given sucrose solution in g sucrose per 100 solution. A 10°Brix solution contains 10 g sucrose in 100 g solution.

If we have this solution of 10°Brix and change the temperature from e.g. 15°C to 25°C. The concentration of the solution will not change, the solution still contains 10 g sucrose in 100 g solution, because nothing was added or removed to/from the solution. But if the temperature will be changed, the refractive index of the solution will change.

If the temperature dependence of the refractive index for sucrose solutions at different concentrations is known, the °Brix (sucrose concentration) of an unknown sucrose solution can be calculated by measuring the refractive index and the corresponding temperature precisely.

The ICUMSA (International Commission for Uniform Methods of Sugar Analysis) has published these dependencies and corrections for sucrose, fructose, glucose and invert sugar, in the Standard SPS-3.

This data is used by the Abbemat 3000 to correct the Brix readings as described before: The temperature at the Abbemat 3000 is not controlled, but measured very precisely. Additionally the refractive index is measured at the actual temperature. With these data it is applying the required correction according to ICUMSA SPS-3 and is displaying the correct concentration, respectively °Brix.

This measurement is faster because no temperature control is required (approx. 5s) and an accuracy of 0.05°Brix can be achieved with the Abbemat 3000.

The temperature and concentration dependency of the refractive index of a sample has to be known very well for temperature correction as described before. This is hardly to find in literature and very elaborating to develop in the laboratory. Furthermore a 3-dimensional mathematical fit is necessary to calculate the temperature corrected concentration.

These are the reasons why just a few sugar methods (data published in SPS-3) are available for the Abbemat 3000 currently. Other methods, e.g. being valid at 20°C only, cannot be used with the Abbemat 3000 model.