HSP, a mighty tool for formulation applications

Application note | Version March 2019

Field of applications

Formulation | Pharmaceutical industry | Cosmetics | Inks | Food Industry | Lubricant

Executive summary

Many practical chemical products are actually formulations, i.e. sophisticated mixtures of numerous compounds that can be liquids or solids.

How to select them efficiently without costly and time-consuming tests?

Hansen Solubility Parameters (HSP) are one of the most used prediction tools to perform such selections. The HSP define the material properties in three dimensions, the disperse, the polar and the hydrogen-bonding properties (δ_D, δ_P and δ_H), which are used by formulators to predict the compatibility of compounds in mixture. However, the HSP of most compounds are not known and can be difficult to determine, especially for liquids. Indeed, their values are often not measured experimentally but rather computed on theoretical basis.

In this application note, we show how Inverse Gas Chromatography (IGC) is able to measure the HSP of liquid substances by testing their interaction ability toward 20 different solvents. Our method makes it possible to perform the HSP measurement within a day (including reproducibility tests for each solvents) and using reduced material and solvents amounts. Moreover, the generated IGC data can be imported and directly processed by the HSPiP software used by groups around the world to optimize formulations via HSP techniques. This method can easily be applied to oils, surfactants, polymers above Tg and any liquid additives. As an example, two liquids were analyzed: **Olive Oil** and **PEG400**.

Adscientis
Smart Inverse Chromatography

Objectives

The purpose here is to demonstrate the ability of the Inverse Gas Chromatography (IGC) to determine the Hansen Solubility Parameters (HSP). HSP analysis is a powerful and practical way to better understand issues of solubility, dispersion, diffusion, chromatography and more [1]. In this application note, two liquid-based materials, olive oil and PEG400, are used as an example to express the potent advantages of such technique for the determination of HSP.

Principle

The Hansen Solubility Parameters (HSP) were initially developed by Charles M. Hansen in 1967 as a tool for predicting if one material will dissolve in another and form a solution. Today, they are widely used to predict chemical component compatibilities in mixture and to accelerate the development of formulations of inks, paints, adhesives, cosmetics or pharmaceuticals. HSP divide the total solubility parameter (δ_T) into three individual parts arising from dispersion forces between molecules (δ_D), energy from dipolar intermolecular forces between molecules (δ_P), and hydrogen-bonding (δ_H).
The HSP determinations can be achieved by inverse gas chromatography at infinite dilution conditions (IGC-ID) [2, 3, 4] combined with the HSPiP software developed by Pr. Steven Abbott, Dr Charles Hansen and Dr Hiroshi Yamamoto [5, 6]. Adscientis developed, the Neuronic solution, a method to measure the HSP of liquid substances. In other words, 20 molecular probes (solvents) are injected at very low concentration in a stainless-steel column filled with the substances to be investigated coated onto a suitable packing material. Their retention time is measured. The surface of the support needs to be fully covered (15% -20% in weight). Hence, it is assumed that the support does not contribute to the probe's retention time. This method makes it possible to perform the HSP measurement within a day (including reproducibility tests for each solvents) and using only small amounts of material and solvents. With this method, we measure a mean value and a standard deviation of their retention time (t_N). The specific retention volume (V_g) is then derived from the retention time (t_N) and can be directly imported into the HSPiP software.

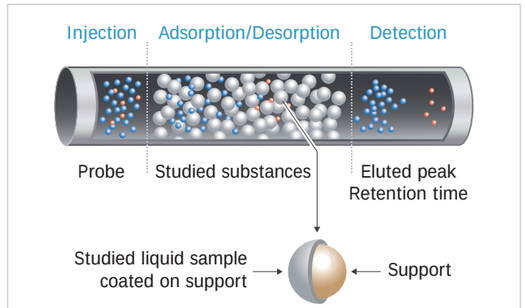

Figure 1 Principle of IGC-ID

Parameters and software to be used for the HSP determinations:

- The net retention time (t_N) of each probe ($t_N = t_R - t_0$, with t_R the retention time of the peak of the probe and t_0 the retention time of a non-retained probe like methane).

- The specific retention volume (V_g) derived from the t_N by the following equation:

$$V_g = \frac{273.15}{T} \cdot \frac{D_c}{m_s} . t_N \quad (1)$$

With T the measurement temperature in K, D_c the corrected carrier gas flow and m_s the weight of deposited sample.

- The HSPiP software provides the algorithm and computation method for the HSP determinations.

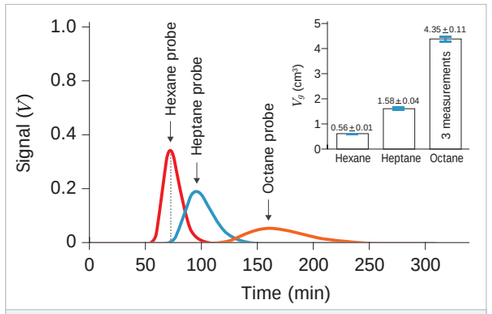

Figure 2 Reproducibility of measurements on 3 different probes (Std. dev. < 2.5%)

Examples

General scope:

Chemical component compatibilities are crucial parameters needed by inks-, paints- adhesives-, cosmetics- and pharmaceuticals- industries and academic labs. Two liquid materials are considered: olive oil and PEG400. To provide good, accurate and reproducible data, Adscientis has defined a thorough procedure for the determination of the HSP. For that, the liquid material was deposited on the chromatographic stationary phase in a thick layer by an impregnation method. For that step, it is important to obtain a homogeneous covering and thick enough layer of the chromatographic support by the liquid material. The HSP values can be determined at ambient or higher temperature depending on the physical state of the substances to be investigate (liquid, pasty or solid).

Results:

The HSP measurements by IGC-ID on olive oil and PEG400 are achieved at 25 °C. The same set of twenty probe molecules is injected on both samples. Each molecule is individually injected several times to measure a mean value and a standard deviation of their retention time ($t_N \pm \Delta t_n$). Equation (1) was then used to compute the corresponding specific retention volume (V_g) of each probe. These values were directly used to compute the HSP values with the HSPiP software.

The software first computates the experimental Flory-Huggins interaction parameter ($\chi^{\infty}_{1,2}$) [1, 3, 6]. The HSP components of the sample, (δ_D), (δ_P) and (δ_H) are then calculated using an iterative method. This iterative method aims at maximizing the correlation coefficient (R^2) fit value between experimental $\chi^{\infty}_{1,2}$ and calculated $\chi^{\infty}_{1,2}$ values based on the "distance" between the HSP values of the probes and the current estimate HSP values of the sample. The algorithm uses all the available probes to compute the δ_D, δ_P and δ_H values that are best fitting the experimental $\chi^{\infty}_{1,2}$ value.

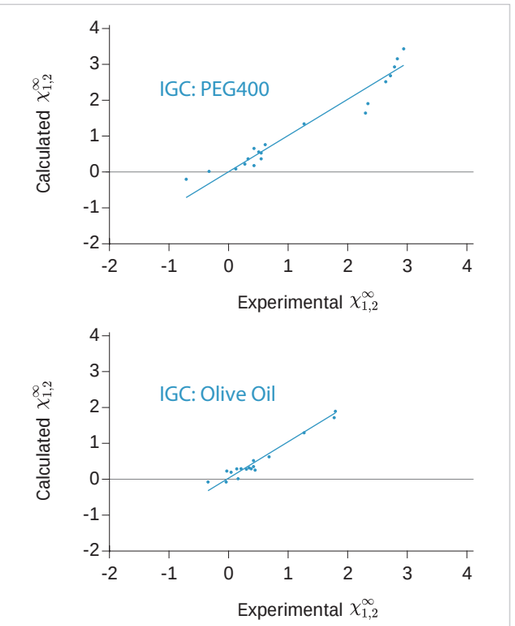

Figure 3 Example of HSP computation for PEG400 (top) and Olive Oil (bottom)

The final regression graphs for the computation of the three components of PEG 400 and olive oil are also done on the complete set of solvents used as probes. The computation of the three HSP of PEG400 and Olive Oil are respectively shown on Figure 3 (top) and Figure 3 (bottom). The best fitting Hansen Solubility parameters of PEG400 and olive oil computed with the HSPiP software are gathered in Table 1.

Sample	δ_D	δ_P	δ_H	R^2
PEG400	21.1	10.2	8.4	0.944
Olive oil	17.0	0.3	4.1	0.961

Table 1 HSP measured at 25°C for both samples (given in $MPa^{1/2}$)

Conclusions

This short note demonstrates the ability of Inverse Gas Chromatography to determine accurately the Hansen Solubility Parameters of two liquid materials: olive oil and PEG400. This method has great flexibility as it can obviously be extended to any kind of non-volatile liquid materials. Hence, IGC is a direct and rapid technique, needing really small quantities of products, to determine the HSP with good reproducibility and accuracy.

Furthermore, its combination with the HSPiP computation software makes it a powerful tool to obtain information on the compatibility of a liquid material with another. Finally, within a day, the specific retention time of 20 molecular probes can be determined by IGC and computed in the software for the calculation of the HSP. We expect this method to hasten and improve significantly the ability to formulate intelligently new materials formulation.

References

ref 1. C. Hansen, *Hansen Solubility Parameters: A user's handbook, Second Edition,* **2007**, Boca Raton, Fla: CRC Press

ref 2. Adscientis, Technical sheet on IGC-ID, **2017**

ref 3. S. Abbott, *IGC Science: Principles and Practice,* **2018**

ref 4. www.adscientis.com

ref 5. www.stevenabbott.co.uk/practical-chromatography/hsp.php

ref 6. www.hansen-solubility.com/HSPiP/

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