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Refractive index of hexafluoroethane (C_2F_6) in the 300–150 nm wavelength range

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Abstract

The refractive index of hexafluoroethane (C_2F_6) has been measured by Fabry–Perot interferometry down to 152.4 nm.

1. Introduction

Cherenkov radiation, emitted in an optical medium of refractive index n when a charged particle moves with a velocity which exceeds the velocity of light c/n in the medium, is used for particle identification. As the spectrum of Cherenkov light varies as λ^{-2} and mostly lays in the VUV, the ideal radiator medium must be transparent in the VUV. It must also have a chromatic dispersion low enough to prevent chromatic correction and if possible a fairly high index value at atmospheric pressure. Experimentalists working at the development of ring imaging Cherenkov counters (RICH counters) in the WA89 experiment at CERN, using a gas radiator, point out the interest of precise measurement of refractive indices of fluorocarbon gases in the VUV.

First we measured refractive indices of carbon tetrafluoride (CF_4) in the 280–140 nm wavelength range [1]. The chromatic dispersion obtained led us to conclude that in Cherenkov detectors the use of CF_4 achromatisation devices cannot be avoided. In the present paper, we give results for hexafluoroethane (C_2F_6). The measurements of Gault and Shepherd [2] in the visible wavelength range and the values obtained by a first order extrapolation from index measurements of liquid C_2F_6 at wavelengths down to 180 nm by Ypsilantis and Seguinot [3,4] seemed to be very encouraging: the refractive index is high and the chromatic dispersion should remain in an acceptable range.

2. Experimental setup

The measurements have been performed with a Fabry–Perot interferometer (FP), according to an experimental technique previously described [5,6]. The performances of the magnesium fluoride FP have been related in a previous paper [7]. The light source is a platinum hollow cathode lamp with a magnesium fluoride window.

The errors on pressure, temperature and spacer thickness are small compared to the errors produced by the measurement of the fractional part of the recorded fringes. The statistical treatment of about sixteen measurements for each wavelength allows us to estimate the accuracy on $n-1$ to about 0.2%.

3. Results and discussion

The measured refractive indices are given at standard temperature and pressure conditions (0°C and 760 mm Hg) using the virial coefficient deduced from Dymond and Smith [8]. Our experimental results are given in Table 1. The vacuum wavelengths of measurement points appear in the first column and our measured values of $(n-1)\ 10^6$ in

Table 1
C_2F_6 (hexafluoroethane) refractivity expressed as $(n-1)\times10^6$. Comparison with the results of Gault and Shepherd

Wavelength [nm]	Present work	Gault & Shepherd	Sellmeier fitting
152.472	995.7		995.4
162.172	973.3		970.0
177.709	937.7		939.3
191.616	916.0		916.1
205.003	903.5		904.0
222.331	888.9		888.9
244.080	875.1		874.8
266.024	864.4		864.2
283.11	858.5		857.7
447.27		822.9	827.5
587.72		816.0	819.8
668.0		813.6	817.4
706.71		812.7	816.5

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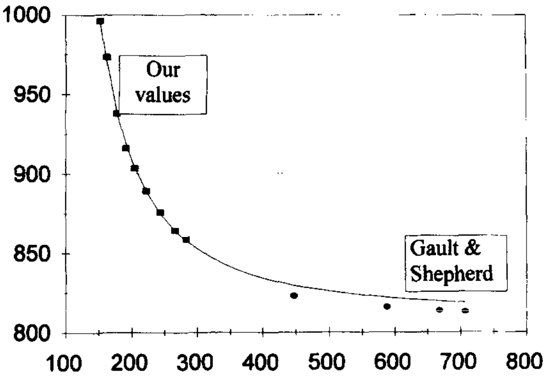

Fig. 1. The refractivity of C_2F_6 (hexafluoroethane) expressed as $(n-1)\times 10^6$ is plotted versus the wavelength in nm. The solid line corresponds to the Sellmeier formula fitted with our measurements.

the second. In the third column we present the results of the Cauchy formula of the dispersion curve fitted by Gault and Shepherd [2] in the visible range. Their formula is given for 15°C and 760 mm Hg temperature and pressure conditions, so the results have been temperature corrected to allow comparisons.

Using our measurements, we fit a one-term Sellmeier formula:

$$n-1=\frac{A\times 10^{-6}}{\lambda_0^{-2}-\lambda^{-2}},$$

where $A=0.18994$ and $\lambda_0^{-2}=2.33313\times 10^{-4}$ for wavelengths expressed in nm units. The fitted values are given in the last column.

$\lambda_0=65.47$ nm is a single wavelength which represents the whole absorption spectrum in the far UV. It corresponds to an excitation potential $E_0=18.82$ eV. Obviously it is not possible to give an effective physical meaning to this value.

In Fig. 1 we have plotted these results; the solid line represents the interpolated values obtained from the Sellmeier formula. The results of Gault and Shepherd [2] are lower than our values, the discrepancy being about 5×10^{-6} (6%). The discrepancy may be enhanced by the fact that these last values are not included in the Sellmeier fitting. Besides, Gault and Shepherd [2] used a gas of which the impurity may reach 1.5% while in the present work the gas impurity is given to be about a few ppm.

For liquid C_2F_6, Ypsilantis and Seguinot [3,4] propose a linear energy variation of the refractive index, using measurements in the 180–250 nm wavelength range (5–7 eV). In extrapolating their formula and using their Lorenz–Lorentz equation to obtain refractive indices for gases, their values are about 8% lower than our own measurements for the shortest wavelength (152.4 nm) and about 3% lower for the highest wavelength (283.1 nm) assuming that their n values are given at 0°C and 760 mm Hg. These discrepancies point out the problem of extrapolating refractive indices in the far UV. The linearity of the energy variation of the refractive index does not correspond to the Sellmeier-type variation law that we obtain.

4. Conclusion

To compare C_2F_6 and CF_4 dispersive properties, we calculate the Abbe number for 162, 157 and 152 nm. For both gases we obtain identical values: 43. This value is to be compared to that of helium, which is the least dispersive gas known, for the same wavelength triplet: 78.

These results point out the fact that from a chromatical point of view, helium is still the most suitable gas. At the present time in Cherenkov detectors achromatisation devices are necessary.

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