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GENERATION OF THE EMITTANCE DATA FOR DIFFERENT TEMPERATURES, TOTAL PRESSURES AND MOLAR RATIOS FOR A CO_2-H_2O MIXTURE AT HIGH PRESSURES

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Abstract. *This paper is a sequence of a previous work, in which it was studied the emittance for different factors for a CO_2 and H_2O mixture. The emittance for chemical species in a participating media, like the one that is under investigation in this study composed of CO_2 and H_2O, is the ratio of the total emitted radiation in a chosen path that it is not absorbed by, over the radiation emitted by a black body at the same temperature. It depends on the path chosen, and it varies due to certain characteristics of its state, such as its temperature, total pressure and molar fraction. The goal of this paper is to expand the results from previous studies and to introduce a new simplification of the process by changing the discretisation with the increase of the pressure, and comparing the results to see the impact in the final results. In order to do so, it will be generated results of the emittance of the two gases CO_2 and H_2O for a different set of combinations of molar fractions of the mixture, temperatures, ranging from 300 K to 2500 K and total pressures equals and over the atmospheric value. The last study, due to the increase of the computational costs with the increase of the total pressure using a fixed discretisation, was limited to 10 atm. Here, it will be expanded to even higher pressures until 40 atm. Using this range of temperature (from 300 K to 2500 K) and total pressure (equal and beyond the atmospheric) we can use the Lorentz profile to calculate the absorption coefficient over the desired spectrum length. Then, using the absorption coefficients it is possible to calculate the emittance values for a specific arrangement. The idea is to evaluate the influence of each of these variables over the total value of the emittance and compile a database of the results. The emittances here presented are calculated using a Fortran code and uses the high resolution spectral database HITEMP-2010 as a base to calculate the absorption coefficients. The results obtained in this study can be later on used to generate new WSGG correlations and be studied to make new models to facilitate and validate calculations in the area of thermal radiation.*

Keywords: *Thermal radiation; Emittance; HITEMP-2010.*

1. INTRODUCTION

The event of radiation in a participating medium is a well studied case in theory. But in numerical studies if one considers all the possible effects, it starts to become a computational problem and with a heavy cost study due to all the calculations necessary. So, in order to reduce computational cost and consequently the time required, it is necessary to do some simplifications to the models.

One of the main difficulties is due to the phenomenon of line broadening in participating gases, that is, when the gases that are in the way of the photons interact with them. The line broadening happens when the energy status of the molecules are perturbed due to some factors and it can absorb photons in different wavenumbers. The types of broadening are natural broadening, where it is intrinsic to the uncertainty motion and energy of the molecules and it is usually small comparing to the others and can often be neglected; Doppler broadening, where it is related to the motion of the atoms and it is important only for high temperatures such as higher than 2500 K; Stark broadening, which can be important when there are electric fields; and collision broadening, due to the collisions between the molecules. In the scope of the present study, the main factor is the collision because of the chosen range of pressures and temperatures (Howell *et al*., 2016).

The emittance is the ratio of the total emitted radiation in a chosen path that is not absorbed by a participating medium, over the radiation emitted by a black body at the same temperature. In a previous study (Etges *et al.*, 2022) where the medium considered was a mixture of two well known chemical species to compound participating media, CO_2 and H_2O, with different pressures and temperatures, it was found that the increase of pressure also increased the emittance. In contrast, for an increase of temperature, the emittance started to decrease.

The goal of this paper is to extend the previous study of generating the emittance of a combination of CO_2 and H_2O for pressures beyond the previous ones, and to do so and to surpass the high computational cost. In the present study a varied discretization is used for the spectral lines according to the total pressure. This kind of discretization will be compared to check the confiability of the results found here. The emittances that are computed in the present study can be later explored in future studies to develop new global gas models correlations, in particular for the WSGG (Weighted-Sum-of-Gray-Gases model) coefficients (Dorigon *et al.*, 2013).

2. SPECTRAL MODELING

The main equation that describes the variation of the radiative intensity in a participating medium is the radiative transfer equation (RTE). For a non-scattering medium, such as one that does not have ash or other particles to disperse the radiation rays, the RTE is given by

$$\frac{dI_\eta(x)}{dx} = -\kappa_\eta(x) I_\eta(x) + \kappa_\eta(x) I_{\eta b}(x) \,, \tag{1}$$

where I_η and I_η are the spectral intensity and the blackbody radiation intensity at the local position; and κ_η is the local absorption coefficient for a participating gas. The blackbody radiation intensity can be found by the Plank's distribution

$$I_{\eta b} = \frac{2C_1\eta^3}{exp(C_2\eta/T)-1} \,, \tag{2}$$

where C_1 is the first Planck's constant and η is the wavenumber. The equation to calculate the absorption coefficient is given by

$$\kappa_\eta = N Y C_\eta \,, \tag{3}$$

where N is the gas molar density, Y is the mole fraction of the gas and the C_η is the absorption cross-section.

The gas molar density can be determined as

$$N = \frac{pN_A}{R_u T} \,, \tag{4}$$

where p is the pressure, N_A is the avogadro number, R_u is the universal gas constant and T is the temperature.

The equation to find the absorption cross section using the Lorentz profile is the following

$$C_\eta = \sum_{k=1}^{k} \frac{S_k}{\pi} \frac{\gamma_k}{\gamma_k^2 + (\eta - \eta_k)^2} \,, \tag{5}$$

where S_k is the integrated line intensity, γ_k is the line half width and η_k is the wavenumber. The integrated line intensity is given by the following equation

$$S_k = S_k(T_{ref}) \frac{Q(T_{ref})}{Q(T)} \frac{exp(-C_2 E_k/T)}{exp(-C_2 E_k/T_{ref})} \frac{[1-exp(-C_2 \nu_k/T)]}{[1-exp(-C_2 \nu_k/T_{ref})]} \,, \tag{6}$$

where Q is the total internal partition sums, C_2 is the second Planck's constant, E_k is the energy of the lower state and ν_k is the energy difference between the initial and the final state. The line half width γ_k can be described as

$$\gamma_k = \left(\frac{T_{ref}}{T}\right)^{\eta_c} p_c \gamma_{self,k} + (p - p_c)\gamma_{air,k} \,, \tag{7}$$

where T_{ref} is the reference temperature (296 K), η_c is the temperature dependence coefficient, p_c is the partial pressure of the species c, $\gamma_{self,\,k}$ is the line self-broadening and $\gamma_{air,\,k}$ is the broadening caused by air.

The objective of this paper is to analyze the total emittance of different scenarios. To calculate the emittance, one can employ the following equation

$$\epsilon = \frac{\int_{\eta=0}^{\infty} I_{\eta b}(T)[1-exp(-\kappa_{p\eta,a} p_a S)d\eta}{\sigma T^4 / \pi}, \tag{8}$$

where $\kappa_{p\eta,a}$ is the pressure absorption coefficient, p_a is the partial pressure of the absorbing species, S is the path and σ is the Stefan-Boltzmann constant.

3. METHODOLOGY

To be able to calculate the emittances, one first needs to have the absorption cross-section of the data required. In order to calculate the absorption cross-sections of a chemical species within their defined conditions, it was used a Fortran code developed by the study group of the Laboratory of Thermal Radiation at UFRGS (LRT). This code uses the data from high-temperature molecular spectroscopic database (HITEMP2010) to obtain the following parameters: the total internal partition sums (Q), the energy difference between the initial and the final state (ν_k), the energy of the lower state (E_k), the integrated line intensity (S_k), the temperature dependence coefficient (η_c), the line self-broadening ($\gamma_{self,k}$), the broadening caused by air ($\gamma_{air,k}$), the wavenumber (η_k). With this data it is possible to calculate the absorption cross-sections (Rothman *et al*., 2010).

To calculate the absorption cross-sections over the above specified characteristics, it was used the Lorentz profile, which has some limitations, like not being recommended for use under pressures below the atmospheric or for temperatures over 2500 K. If the conditions studied surpass these limitations, it is recommended the use of Voigt's profile to correct the deviations from the other modes of broadening. Then, due to the Lorentz profile methodology chosen, the temperature's range studied are within its limits, from 300 K to 2500 K in steps of 100 K, and so for the pressure values used, equal or above the atmospheric to be able to use this profile, with pressures of 1.0, 2.0, 5.0, 10, 20 and 40 atm. The molar fractions chosen are 0.1 and 0.2 for CO_2 and 0.2 for H_2O, due to the common appearance of such combinations.

The spectral range chosen to evaluate was from 0 to 25000 cm^{-1}; in this study, differently from the previous one (Etges *et al.*, 2022) it was used a variable discretization. For a pressure of 1 atm a total of 375000 points were used to discretize the spectrum. Then, with the increase of the pressure, the discretization was reduced accordingly to the inverse proportionality of the pressure. So, for the 2 atm pressure, the discretization used was of 187500 points, for 5 atm was 75000 and so on. The cutoffs used in the calculations using the Lorentz profile were based on the line half-width, with 30000 γ_k for CO_2 and 3000 γ_k for H_2O (Coelho *et al.*, 2021).

It is interesting to notice that changing each one of these characteristics described above has a different reaction in the absorption cross-section of the CO_2 and H_2O. For example, increasing the pressure generally causes the erratic oscillations to be smoothen, as can be seen in Fig. 1. In the other way, increasing the temperature generally elevates the value of the absorption cross-section for the H_2O, as shown in the first image of Fig. 2.

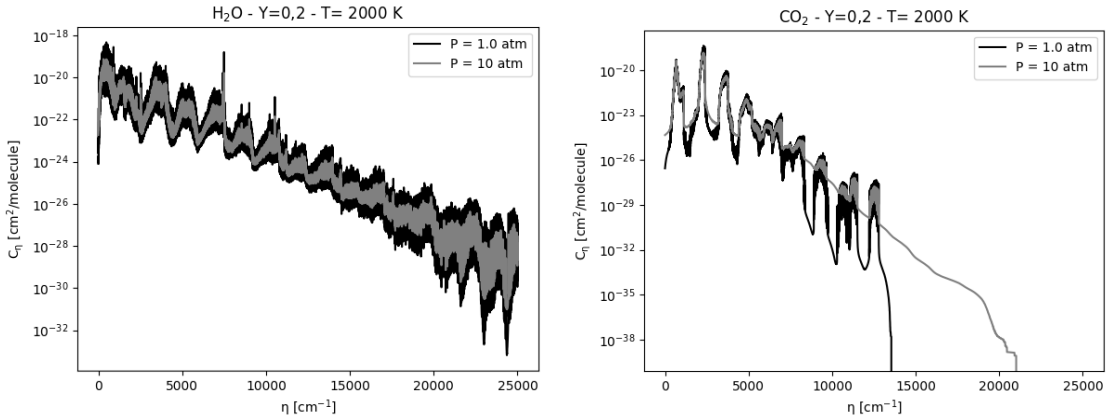

Figure 1. **The impact of increasing the pressure for H_2O on the left and for CO_2 on the right.**

Once the absorption cross-sections results were ready, it was possible to calculate the emittances. It was used another Fortran code developed by the LRT, and it was generated for path lengths of the range from 0.001 m to 30 m.

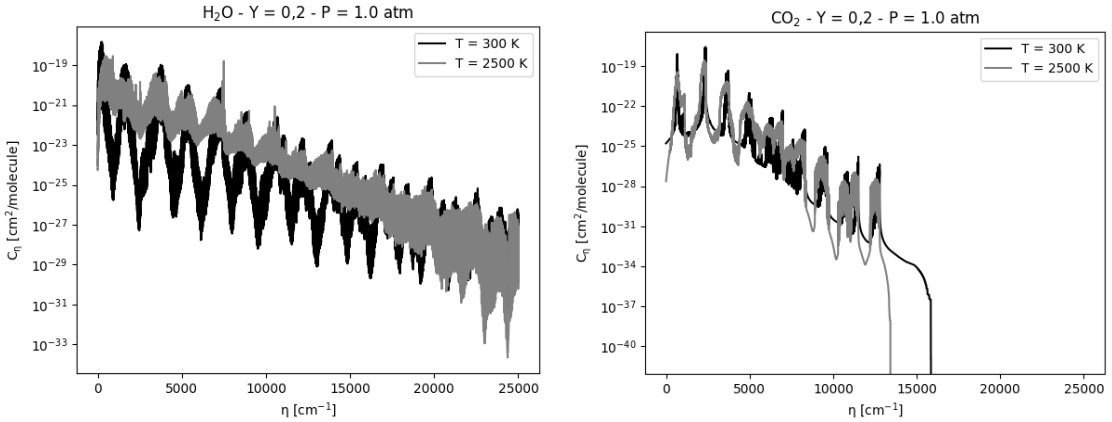

Figure 2. **The impact of increasing the temperature for H_2O on the left and for CO_2 on the right.**

4. RESULTS AND DISCUSSION

In this section the results will be presented and analyzed. The first section is about a fixed mixture of CO_2 and H_2O both with a molar fraction of 0.2. In the second, the molar fractions are different for each chemical species, 0.2 for H_2O and 0.1 for CO_2. In the third the results will be compared to the results of the previous study showing if the variable discretization is valid. The graphs are for a 1.0 m path.

4.1 $H_2O + CO_2$ Mixture with a molar fraction of 0.2 for both

The results are shown in Tables 1, 2, 3, 4, 5 and 6 for a combination of some temperatures and paths, each of the tables representing different pressures. Figure 3 shows the emittance as a function of the temperature for different pressures.

Table 1. **Emittance values for some paths and temperatures for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for both at 1.0 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.12122 E-01	0.80230 E-02	0.52547 E-02	0.23712 E-02	0.10977 E-02	0.54414 E-03
0.1 m	0.20218	0.16660	0.12719	0.82723 E-01	0.50843 E-01	0.30917 E-01
1.0 m	0.40793	0.39503	0.33709	0.25440	0.17724	0.11931
10 m	0.62553	0.65762	0.62684	0.53373	0.43323	0.34029
20 m	0.68666	0.73320	0.70818	0.62290	0.53044	0.43523
30 m	0.72167	0.77734	0.75068	0.67354	0.58855	0.49365

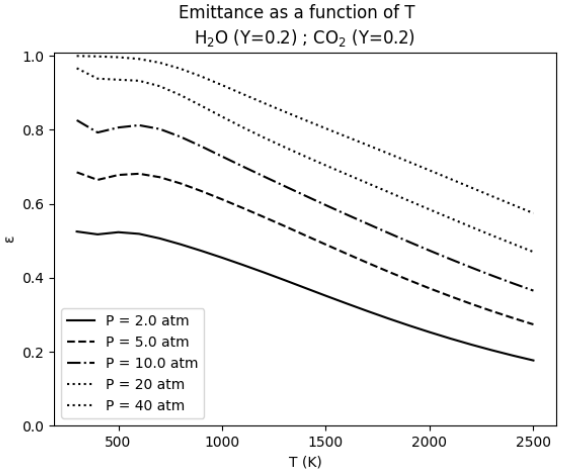

Figure 3. **Emittance as a function of the temperature for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for both and different pressures, for 1.0 m path.**

Table 2. **Emittance values for some paths and temperatures for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for both at 2.0 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.23250 E-01	0.15360 E-01	0.10160 E-01	0.46325 E-02	0.21603 E-02	0.10763 E-02
0.1 m	0.29731	0.25955	0.19012	0.12383	0.77162 E-01	0.47913 E-01
1.0 m	0.52496	0.52317	0.45434	0.35121	0.25285	0.17646
10 m	0.74950	0.78013	0.74010	0.64564	0.54793	0.44749
20 m	0.82191	0.85711	0.80729	0.72956	0.64569	0.54686
30 m	0.86611	0.89735	0.84099	0.77464	0.69826	0.60063

Table 3. **Emittance values for some paths and temperatures for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for both at 5.0 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.53393 E-01	0.33853 E-01	0.23101 E-01	0.10982 E-01	0.52341 E-02	0.26378 E-02
0.1 m	0.43594	0.41413	0.31017	0.20768	0.13261	0.84014 E-01
1.0 m	0.68529	0.67806	0.61203	0.48978	0.37124	0.27381
10 m	0.93787	0.94036	0.86123	0.77719	0.69032	0.58743
20 m	0.98525	0.98125	0.91140	0.84589	0.76891	0.66790
30 m	0.99619	0.99249	0.93558	0.88032	0.80799	0.70778

Table 4. **Emittance values for some paths and temperatures for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for both at 10 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.95725 E-01	0.57855 E-01	0.39738 E-01	0.20115 E-01	0.99108 E-02	0.50871 E-02
0.1 m	0.55788	0.53421	0.42144	0.29452	0.19509	0.12738
1.0 m	0.82606	0.80630	0.72805	0.59622	0.47346	0.36512
10 m	0.99866	0.99482	0.93268	0.85901	0.77570	0.67182
20 m	0.99999	0.99926	0.96327	0.91093	0.83758	0.73646
30 m	0.99999	0.99964	0.97475	0.93404	0.86783	0.77072

Table 5. **Emittance values for some paths and temperatures for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for both at 20 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.15960	0.97032 E-01	0.62814 E-01	0.34531 E-01	0.17973 E-01	0.95251 E-02
0.1 m	0.70119	0.65390	0.54097	0.39443	0.27332	0.18620
1.0 m	0.96677	0.93566	0.83544	0.70382	0.58459	0.46998
10 m	0.99999	0.99975	0.97213	0.91813	0.84181	0.73901
20 m	0.99999	0.99994	0.98592	0.95174	0.88997	0.79610
30 m	0.99999	0.99997	0.99145	0.96577	0.91245	0.82598

Table 6. **Emittance values for some paths and temperatures for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for both at 40 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.24511	0.16110	0.94173 E-01	0.54578 E-01	0.30381 E-01	0.16899 E-01
0.1 m	0.86920	0.79700	0.67041	0.50231	0.36365	0.25944
1.0 m	0.99988	0.99650	0.92103	0.80372	0.69051	0.57458
10 m	0.99999	0.99999	0.99110	0.95753	0.89454	0.79969
20 m	0.99999	0.99999	0.99692	0.97733	0.92942	0.84839
30 m	0.99999	0.99999	0.99851	0.98450	0.94418	0.87132

Analyzing Table 1, it is possible to observe that the emittance values vary with the path length independently of the temperature. For the shortest paths, the emittance values are the lowest if compared with the longer paths, in all the temperatures exposed here. Now, comparing the emittance for different temperatures, it is possible to notice that, for the longer paths, when it is increased from 300 K to 500 K, the emittance value also increases, but if we continue to

increase the temperature beyond this value, the emittance starts to decrease. This initial erratic phenomena of the emittance in lower temperatures also proves to be more accentuated in some intermediate pressures but with an even more elevated pressure, it stabilizes and as the pressure increases, the emittance starts to just decrease with the increase of temperature.

Now comparing Tables 1 to 6 all together, one can see that the emittance increases with the increase of the pressure for all the path lengths and temperatures. Also, it is interesting to point out that for the higher pressures the emittance values for the lower temperatures and longer paths are very close to 1. Finally, analyzing Fig 3 one can see the behavior described above in a graph. It is possible to notice, once again, that for the lower pressures, when increasing the temperature from a lower value such as 300K, it increases a certain value before starting to decrease. For a high pressure of 40 atm, the behavior of the emittance just decreases with the increase of the temperature. These conclusions were also found in the previous study, corroborating the extension of the results.

4.2 $H_2O + CO_2$ Mixture with a molar fraction of 0.2 for H_2O and 0.1 for CO_2

The results are shown in Tables 7, 8, 9, 10, 11 and 12 for a combination of some temperatures and paths, each of the tables representing different pressures. Figure 4 shows the emittance as a function of the temperature for different pressures.

Table 7. **Emittance values for some paths and temperatures for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for H_2O and 0.1 for CO_2 at 1.0 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.10361 E-01	0.60269 E-02	0.32283 E-02	0.14207 E-02	0.66385 E-03	0.33556 E-03
0.1 m	0.18393	0.15177	0.11378	0.71284 E-01	0.42135 E-01	0.24687 E-01
1.0 m	0.38896	0.37806	0.32173	0.23938	0.16519	0.11067
10 m	0.60394	0.63079	0.60874	0.52361	0.42637	0.33557
20 m	0.66224	0.70113	0.68968	0.61268	0.52316	0.43049
30 m	0.69412	0.74272	0.73293	0.66327	0.58127	0.48918

Table 8. **Emittance values for some paths and temperatures for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for H_2O and 0.1 for CO_2 at 2.0 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.20088 E-01	0.11789 E-01	0.63541 E-02	0.28037 E-02	0.13161 E-02	0.66730 E-03
0.1 m	0.27874	0.24222	0.17606	0.11192	0.68212 E-01	0.41445 E-01
1.0 m	0.50364	0.50396	0.43952	0.33894	0.24289	0.16861
10 m	0.72254	0.74415	0.72045	0.63540	0.54094	0.44302
20 m	0.79016	0.81991	0.78917	0.71898	0.63902	0.54317
30 m	0.83318	0.86261	0.82354	0.76412	0.69232	0.59778

Table 9. **Emittance values for some paths and temperatures for $H_2O + CO_2$ mixture with a molar fraction of 0.2 for H_2O and 0.1 for CO_2 at 5.0 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.46646 E-01	0.27521 E-01	0.15184 E-01	0.68499 E-02	0.32459 E-02	0.16547 E-02
0.1 m	0.41407	0.39598	0.29517	0.19409	0.12210	0.76709 E-01
1.0 m	0.66065	0.64989	0.59248	0.47983	0.36489	0.26909
10 m	0.91128	0.91179	0.84075	0.76496	0.68389	0.58436
20 m	0.97219	0.96641	0.89202	0.83459	0.76418	0.66620
30 m	0.99070	0.98447	0.91821	0.87056	0.80446	0.70672

The results once again show the same behavior as the previous sub-chapter. Analyzing Table 7, it is possible to observe that the emittance values vary with the path length independently of the temperature. For the shortest paths, the emittance values are the lowest if compared with the longer paths, in all the temperatures exposed here. Now, comparing the emittance for different temperatures, it is possible to notice that, again, for the longer paths, when it is increased from 300 K to 500 K, the emittance value also increases, but if we continue to increase the temperature beyond this temperature, the emittance starts to decrease.

Now comparing Tables 7 to 12 all together, one can see that the emittance increases with the increase of the pressure for all the path lengths and temperatures. Finally, analyzing Fig 4 one can see the same behavior described above in a graph. It is possible to notice, once again, that for the lower pressures, when increasing the temperature from a lower

value such as 300K, it increases a certain value before starting to decrease. For a high pressure of 40 atm, the behavior of the emittance just decreases with the increase of the temperature. These conclusions were also found in the previous study, corroborating the extension of the results.

Table 10. **Emittance values for some paths and temperatures for H_2O + CO_2 mixture with a molar fraction of 0.2 for H_2O and 0.1 for CO_2 at 10 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.84323 E-01	0.49630 E-01	0.28169 E-01	0.13143 E-01	0.63301 E-02	0.32552 E-02
0.1 m	0.52993	0.51184	0.40549	0.28123	0.18427	0.11927
1.0 m	0.79395	0.76942	0.70313	0.58431	0.46639	0.36062
10 m	0.99611	0.98820	0.91434	0.84710	0.77075	0.67011
20 m	0.99992	0.99829	0.95226	0.90333	0.83496	0.73576
30 m	0.99999	0.99939	0.96801	0.92901	0.86624	0.77035

Table 11. **Emittance values for some paths and temperatures for H_2O + CO_2 mixture with a molar fraction of 0.2 for H_2O and 0.1 for CO_2 at 20 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.14230	0.85759 E-01	0.49421 E-01	0.24384 E-01	0.12103 E-01	0.63223 E-02
0.1 m	0.66754	0.62360	0.51950	0.38199	0.26429	0.17896
1.0 m	0.94729	0.90620	0.80901	0.68811	0.57560	0.46489
10 m	0.99999	0.99961	0.96577	0.91174	0.83914	0.73812
20 m	0.99999	0.99989	0.98289	0.94854	0.88865	0.79560
30 m	0.99999	0.99996	0.98928	0.96361	0.91154	0.82557

Table 12. **Emittance values for some paths and temperatures for H_2O + CO_2 mixture with a molar fraction of 0.2 for H_2O and 0.1 for CO_2 at 40 atm pressure.**

	300 K	500 K	1000 K	1500 K	2000 K	2500 K
0.001 m	0.22173	0.14402	0.80923 E-01	0.42679 E-01	0.22201 E-01	0.11932 E-01
0.1 m	0.83522	0.75926	0.63975	0.48718	0.35518	0.25370
1.0 m	0.99948	0.99133	0.90062	0.78717	0.68141	0.57014
10 m	0.99999	0.99998	0.98882	0.95453	0.89295	0.79878
20 m	0.99999	0.99999	0.99590	0.97575	0.92834	0.84745
30 m	0.99999	0.99999	0.99795	0.98347	0.94320	0.87028

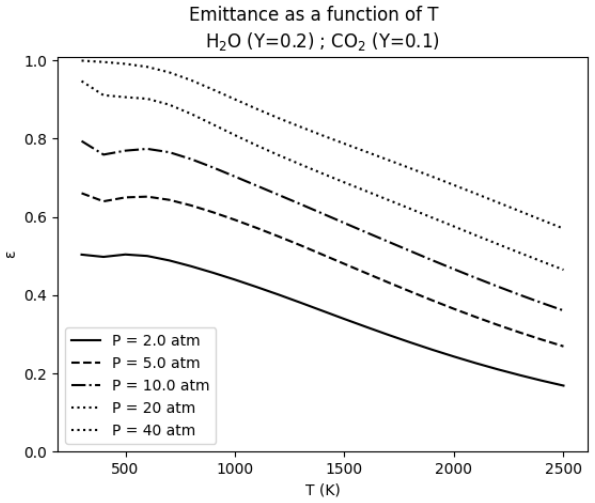

Figure 4. **Emittance as a function of the temperature for H_2O + CO_2 mixture with a molar fraction of 0.2 for H_2O and 0.1 for CO_2 and different pressures, for 1.0 m path.**

4.3 Comparison between the different kinds of discretization

The previous study used a fixed discretization of 375000 points to calculate the emittance for different values of pressure. Due to that, with relative high pressures, the time needed to compute the results was much longer. In this present paper, it was used a variable discretization that is inversely proportional to the pressure and, with the reduced number of points, it was possible to also reduce the computational time needed, without compromising the accuracy of the results, as it is shown in Fig 5. It shows two graphs, one for each combination of molar fractions of the mixture of chemical species, and for each graph, compares the results for three different pressures above the atmospheric.

This demonstrates that, in these cases, it is possible to simplify the process of generating the absorption cross-section by reducing the number of points analyzed once their accuracy is very similar to the one with a fixed discretization and with a more elevated number of points.

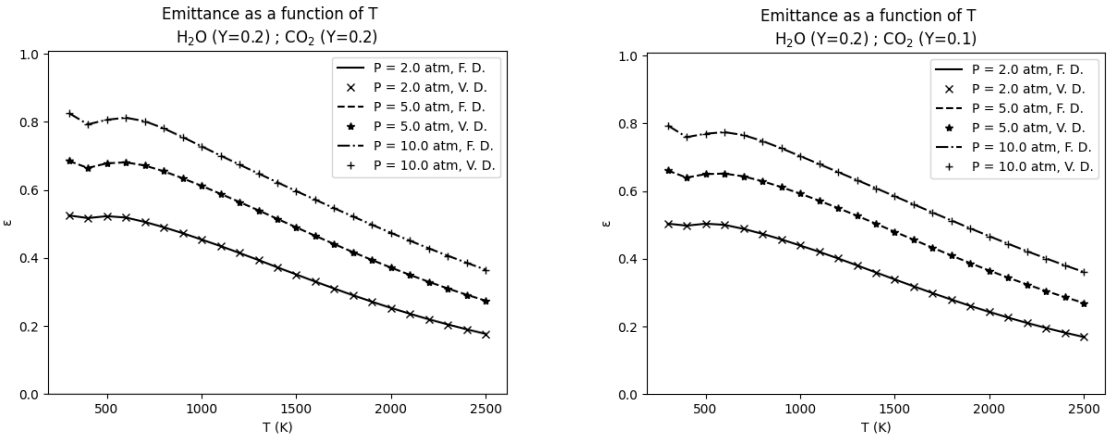

Figure 5. **Comparison between the emittances as a function of the temperature for H_2O + CO_2 mixture with a molar fraction of 0.2 for both (left) and with a molar fraction of 0.2 for H_2O and 0.1 for CO_2 (right), for different pressures, for 1.0 m path for differents discretizations (Variable discretization - V. D., Fixed Discretization - F. D.)**

5. CONCLUSIONS

Comparing the results found in this study, for pressurized conditions, with the previous one, at atmospheric pressure, the present results show the same behavior of the emittance. The emittance value increases for all scenarios with the increase of the path length. Also, the same behavior is observed with the increase of the pressure for all the cases. At last, with the increase of the temperature, the inverse trend is noticed, that is, the emittance values decrease for all the cases, at least from 600 K.

Comparing the first and the second cases, it is possible to see that increasing the molar fraction of CO_2 by just 0.1 makes the emittance also slightly increase, independently of the path, pressure or temperature.

Also, it is important to notice that a reduction of the discretization is valid and can reduce time of processing and still be used as a good approximation, since the results with a more refined discretization take much more time to be obtained, for the increase of pressure extends the wing of the spectral lines.

In summary, analyzing the results, increasing the path length or the molar fraction causes an increase of the emittance value. On the other hand, increasing the temperature leads to a reduction of the emittance value. For further studies, one can expand the range of the variables approached, implement Voigt's profile and consider other chemical species.

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8. RESPONSIBILITY NOTICE

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