استكشاف مستويات الإثارة الاهتزازية الرنانة من الهيدروجين بزوايا [0º-180º] الحدودية من خلال مراقبة المقاطع العرضية التفاضلية

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الملخص العربي :

لإجراء التجربة لاستكشاف مستويات الإثارة الاهتزازية الرنانة من الهيدروجين، من خلال مراقبة المقاطع العرضية التفاضلية، ثم استخدام أطياف تنائي ذو الحزمة المتقاطعة المعدلة في التجربة الحالية .

انطلقت التجربة من خلال إثارة الالكترونات مباشرة من الكاثود (تنجستن ساخن)   ثم أختار شعاع الإلكترون الاحادي من قبل جهاز احادي اللون ثم يشار إليه الي منطقة التفاعل. وتستمر العملية باستخدام شعاع غاز ايضا يتم عبور حزمة الغاز هذه مع شعاع الإلكترون المذكورة بزوايا قائمة. وتتضمن ايضا التجربة استخدام جهاز مزدوج لتحليل الإلكترونات المتناثرة.

في هذه التجربة كان الهدف استكشاف مستويات الإثارة الاهتزازية الرنانة من الهيدروجين بزوايا الحدودية من خلال مراقبة المقاطع العرضية التفاضلية . أن الإشارة المكتشفة هي مجموع الإلكترونات المتناثرة عن طريق النطاق   داخل الزوايا الصلبة نفسها، وفي الطاقة المتبقية المحددة تظهر التجربة مجموعة فعالة للغاية   (%١٠٠) من الإلكترونات المتناثرة الي الوراء.

من خلال النتائج نلاحظ أنه كان هناك نقص طويل الأمد في بيانات المقاطع العرضية التفاضلية التجريبية، والبيانات من التوزيع الزاوي للإثارة الاهتزازية للهيدروجين، علي الزوايا الحدودية من 0الى 180 .

علاوة علي ذلك قد تبدأ إمكانية أدراج التوزيع الزاوي الحالي الكامل للإلكترونات (نظرية مونتي كارلو) المتطورة من خصائص تفريغ الهيدروجين وخصائص النقل الغازي.

لقد شغلت النتائج التي تم الحصول عليها من خلال هذه التجربة هذه البيانات الفراغية الطويلة الأجل، قد ضمنت هذه النتائج والبيانات المزيد من التطور في هذا المجال٠

"Exploring the resonant vibrational excitation levels of hydrogen at border angles [0º-180º] by observing the differential cross sections"

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Abstract:

In this research, the experience of exploring the vibrant levels of vibration for hydrogen, through the monitoring of differential sections, was used for the modified cross-brochield. The experiment begins by extracting electrons from hot tungsten directly[u1] cathode. The electron beam is selected by monochrome and then pointed into the interaction region . the same time sends a beam of gas to be vertical at 90◦ with the previous electrons beam. As the experiment includes the use a double Trochoidal electron monochromatic (TEM[u2]) device for the analysis of the scattered electron multiplier for the detecting of the scattered electrons. In this experiment, the objective was obtaining the DCS at border angles of 0◦ and 180

The signal detected is a sum of inelastically scattered electrons at 0º and 180º, within the same solid angles, and at the given residual energy. The experiment shows a very efficient (100%) collection of the backward scattered electrons. Through the results we note that when measuring vibration excitement of hydrogen gas long-term deficiency for angular distribution of electrons as well as lack of experience differential cross sections (DCS[u4][u3]) .

Keywords:
Vibrational, resonant, excitation levels, electron, energy, hydrogen, differential cross sections (DCS), Integral cross sections (ICS).

1 – Introduction

- Some scientists have applied sufficient energy resolution to the beam experiment, to resolve rotational structure, connected to vibrational excitation. The range of 20^0 to 120^0 was covered with the measurements of the differential cross sections (DCS) for individual vibrational–rotational excitations. The result were extrapolated and the integral cross sections (ICS) are determined. [13]

- Swarm experiments performed by Crompton and England And others, with v=o → 1 excitation, have provided integral vibrational –excitation cross sections. There is a big difference between the beam results and the swarm data, in the near-treshold energy area. [10][11] Morrison et al have carried out a number of vibrational close-coupling calculations on the scattering of electrons on the hydrogen molecule, and the result of the cross section v=0 → 1, mostly matched the crossed beams experiments. Nishimura did a measurement for the differential cross sections in the range from 20^0 to 120^0 and derived the integral $v = 0 → 1$ excitation DCS, at energies above 2.5 eV, which matched to some extent with the previous results. [10]

- Buckman and Brungen did the cross section measurements and scattering calculations, for a series of absolute elastic and vibrational-excitation cross sections. These experiments, which included measurements of vibrational excitation ratios to elastic scattering, were placed on the absolute scale. This was done by using the relative flow technique and by careful examination of the transmission of elastic and inelastic electrons. [16]

- The electron-molecule scattering systems, especially the molecular hydrogen, have been subjected to many experimental and theoretical studies. Well known scientists, like Schultz, Trajmar and Brunger and Buckman, have all covered the topic. First, Ramien in 1931[4]. did the first vibrational-excitation cross section measurements in H_2, at 3.5 and 7 eV, which were later confirmed by Engelhardt and by Phelps and Shultz.

A p wave nature of the measurement results (minimum at 90^0) performed in the range from 10^0 to 120^0, on electrons which have excited the v=1

vibrational state of H_2, have confirmed the $^2\Sigma_u^+$ state resignation for this shape resonance. [5][6]

- Absolute differential cross sections are set for the range of energies of 1 up to 5 eV, while the angular range is set from 5^0 to 130^0. These measurements have shown a good agreement with the vibrational close-coupling calculations. [17]

- A table of results for the forward-to-backward scattered electrons for the v=0 → 1 level excitation of the H_2 molecule is given below, with the estimated sta3tistical error bar of ±5 %.

TABLE I. DCS and ICS for the $v = 0 \to 1$ vibrational excitation of H_2 by electron impact.

E_a (eV)	DCS ratio $0^\circ/180^\circ$	DCS $(10^{-18} cm^2 sr^{-1})$		ICS $(10^{-18} cm^2)$
		0°	180°	
1.0	1.54	1.59	1.03	7.8
1.5	1.97	4.97	2.52	26.7
2.5	2.01	9.14	4.55	39.5
5.0	1.33	8.02	6.03	32.7

- The results are placed on the absolute scale of the differential cross section, adjusting them to the most recent and more complete DCS values, reported by Brunger et al [17], which cover the range from 5° to 130°.
- More recently, Schmidt has conducted the experiments in order to examine and measure the transport parameters (the drift speed and the diffusion coefficients) in the electric and magnetic fields. The vibrational-excitation cross sections obtained from this experiment were higher than those earlier swarm results, above 0.6 eV. [18]

- In this experiment, the objective was obtaining the DCSs at border angles of 0^0 and [u5]180^0.

2- Experimental setup[u6]

- For performing the experiment for exploring the resonant vibrational excitation levels of H_2, by observing the differential cross sections, a modified crossed-beam double trochoidal spectrometer has been be used in the present experiment.

[u7]
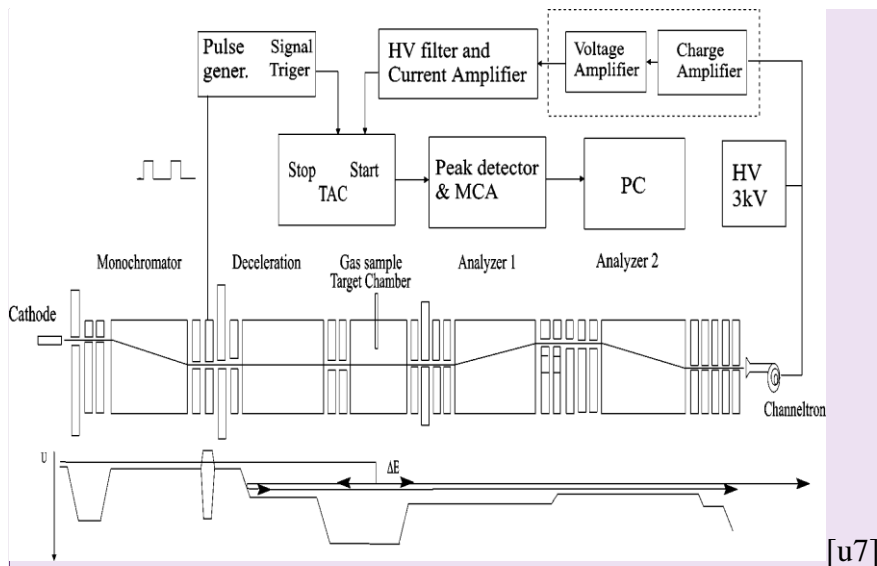
Experimental setup.

- The process starts by extracting the electrons from a directly heated hairpin tungsten cathode. The selection of the monoenergetic electron beam is done by the trochoidal electron monochromator and then pointed into the interaction region.

- The process continues with using a gas beam as well. This gas beam is crossed with the mentioned electron beam at right angles.

- The experiment includes the use of a double TEM device for the analysis of the scattered electrons, as well as a channel electron multiplier for the detecting of the scattered electrons.

- The signal detected is a sum of in elastically scattered electrons at $0°$ and $180°$, within the same solid angles, and at the given residual energy. The experiment shows a very efficient (100%) collection of the backward scattered electrons.

- These electrons are reflected on the potential barrier found at the monochromator exit. The reason for this finding lies in the presence of the longitudinal magnetic field, needed for the proper TEM operations.

- Both electrons scattered at $0°$ and those scattered at $180°$ share a part of the same trajectory on their route towards the analyzer system and the detector. The difference is that the electrons scattered at $0°$, travel straight to the mentioned analyzer system and the detector, however the $180°$ scattered inelastic electrons, reflected on the potential barrier on the collision chamber, follow a backward trajectory, and reach the interaction region again.

- Afterwards, they follow the same path as the electrons scattered at $0°$. The distance they travel is, therefore, longer, as is the time for which they reach the analyzer system and the detector. This fact is crucial for differentiating the two groups of electrons, and it is done by measuring their time-of-flight spectra.

- An asymmetric square-shaped pulse generator of 1.18 MHz is used for chopping the electron beam. This produces square pulses of 50 ns, separated by 800 ns. The pulses are 2 V high. The signal is superimposed on one of the monochromator electrodes. The electrode potential is what keeps the signal on for 50 ns.

- The collision can happen during the pulse on, and the signal is used as the stop trigger for the TAC (time-to-amplitude-converter). On the other hand, the start signal for the TAC is generated from the channelTron.

- The procedure was successfully applied for the separation of the forward and backward scattered electrons from the N_2 molecule. The distinction is possible in the case of slow moving electrons. However, in the case of faster moving, more energetic electrons, the backward scattered electrons

are reflected quickly, and they very closely follow the forward scattered electrons, so the two contributions have overlapping times.

- Because the backward scattered electrons, with high energy move more quickly, it is necessary to decrease their speed before they get to the collision region, by also extending the low velocity moving time.

- A device for decreasing the speed of these electrons is placed in front of the collision region. It consists of two parallel plates, 20 mm long. The backward scattered electrons spend up to 100 ns in this device, and in this way, their velocity is reduced and traveling time increased. After exiting the device, they enter the collision region again and from there move to the detector.

- A fast charger amplifier processes the signal from the chanelltron, and so do the voltage amplifier, and high-voltage filter. The signal created, is used as the start signal for the TAC. The signal from the TAC is loaded to the pulse-height analyzer (PHA) and the multichannel analyzer (MCA). The results of the time-of-flight spectra created in this way are analyzed by an online computer.

- Theoretical predictions of Morgan et al. [12] are shown in Fig. 1 by a dashed line, but they disagree with all experimental results at low scattering angles.
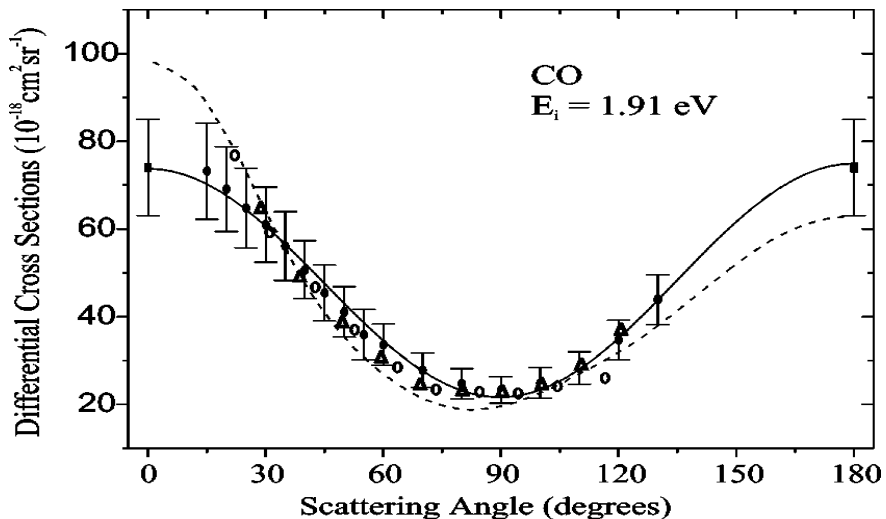
Fig 1. Angular distribution of electrons from 2P resonant extitation of CO at 1.91 eV. Points at 0° and 180° are our data. Closed circles are data of Gibson *et al.* [11]. Open circles are data of Earhart *et al.* [4] and triangles of Tronc *et al.* [18]. The solid curve is the fit by Read's theory [5] and the dashed curve Morgan's [12] theory.

Total absolute uncertainties of our data are obtained by a quadrature sum of our statistical uncertainties at 5% and absolute uncertainty of Gibson's *et al.* [11] measurements to which normalization has been performed. As it can be seen from Fig. 1, all experimental data agree well that this angular distribution is fully symmetric around 90°. From Read's theory [5], this conclusion supports the fact that the contribution of the *p*p partial wave is dominant in the energy region of 2P resonance in CO.

3- Results and discussions

- The experiment is performed for the controlled incident electron energies of 1.0, 1.5,2.5 and 5.0 eV, for the v=0 → 1 vibrational level excitation.
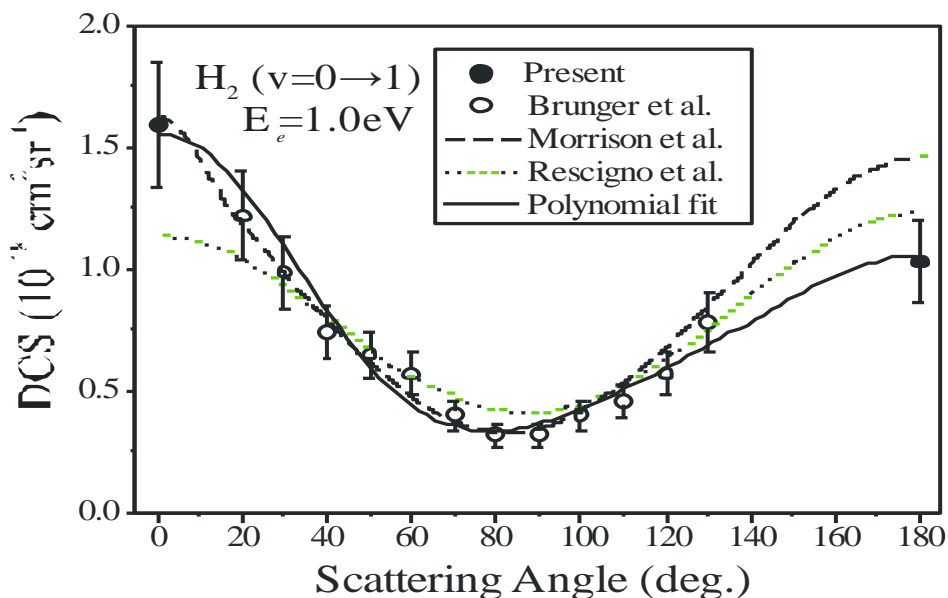

Fig 2 . Differential cross-sections for the rovibrational excitation of H_2 (*v*=0–1) at incident energy of 1.0 eV: (●) Present results; (○) Brunger et

al.[17]; (– –) Morrison et al.[12]; (…) Rescigno et al.[13]; (——) Legendre polynomials fit.

- First, the initial value of the DCS at 0° is obtained by the Legendre polynomials during the normalization process.
- Then the DCS value at 180° is determined by using the forward-to-backward DCS ratio, for every individual electron energy (1.0, 1.5, 2.5 and 5.0 eV).

- By applying successive interpolation procedure to the complete set of data, the overall angular distribution is determined.
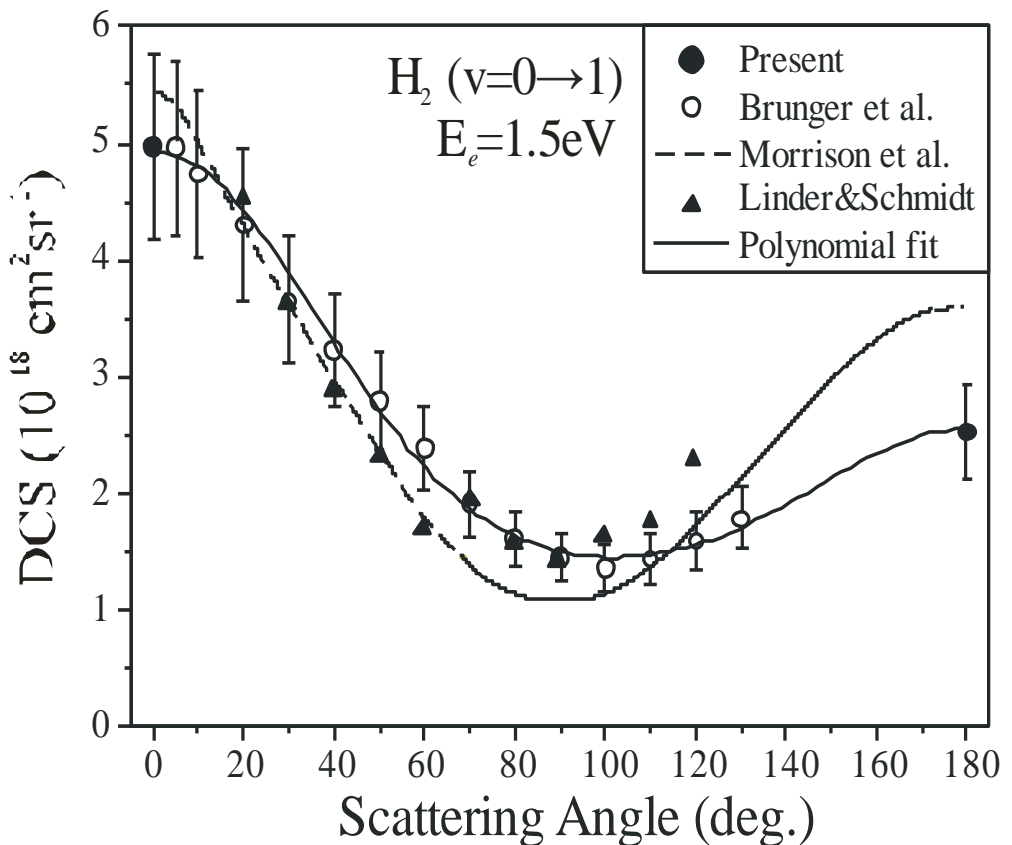

Fig 3. Differential cross-sections for the rovibrational excitation of H_2 (v=0–1) at incident energy of 1.5 eV: (●) Present results; (○) Brunger et al.[17]; (– –) Morrison et al.[12]; (▲) Linder and Schmidt [8]; (——) Legendre polynomials fit.

- The present results obtained for electron energies of 1, 1.5, 2.5 and 5 eV are shown in figures 2, 3, 4 and 5, respectively. They are compared with the other available data from the literature. As it can be seen from the figures, the overal agreement between different data sets is good.
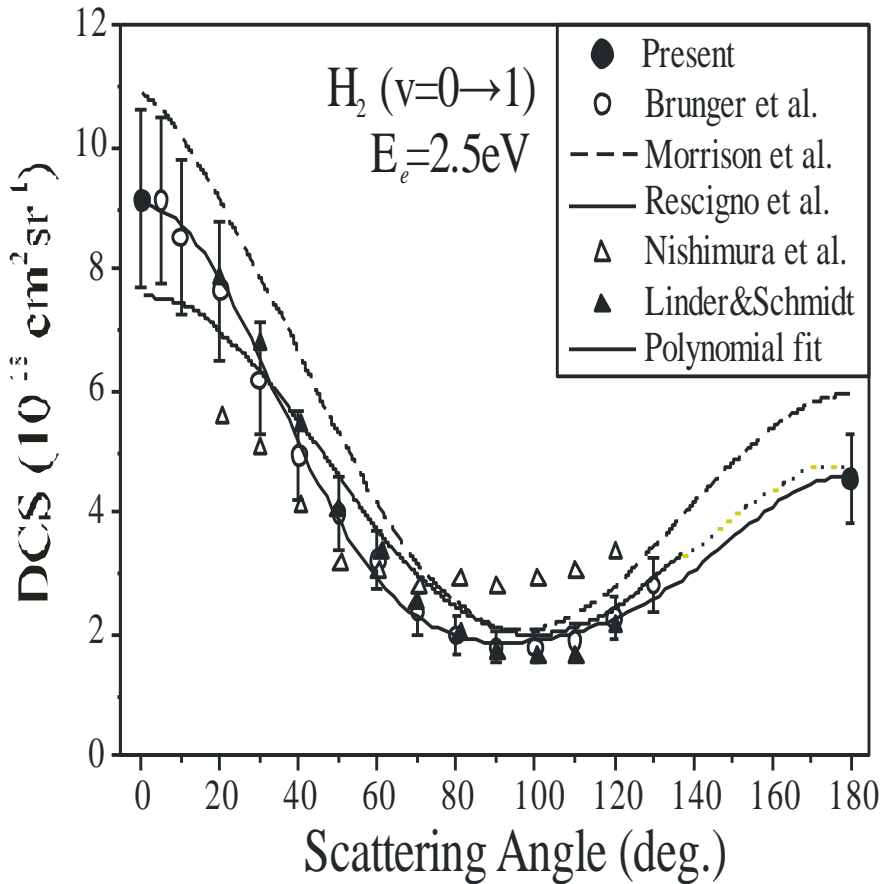

Fig 4. Differential cross-sections for the rovibrational excitation of H_2 ($v=0$–1) at incident energy of 2.5 eV: (●) Present results; (○) Brunger et al.[17]; (▲) Linder and Schmidt [8];   (△) Nishimura et al.[14]; (– –) Morrison et al.[12]; (…) Rescigno et al.[13]; (—) Legendre polynomials fit.
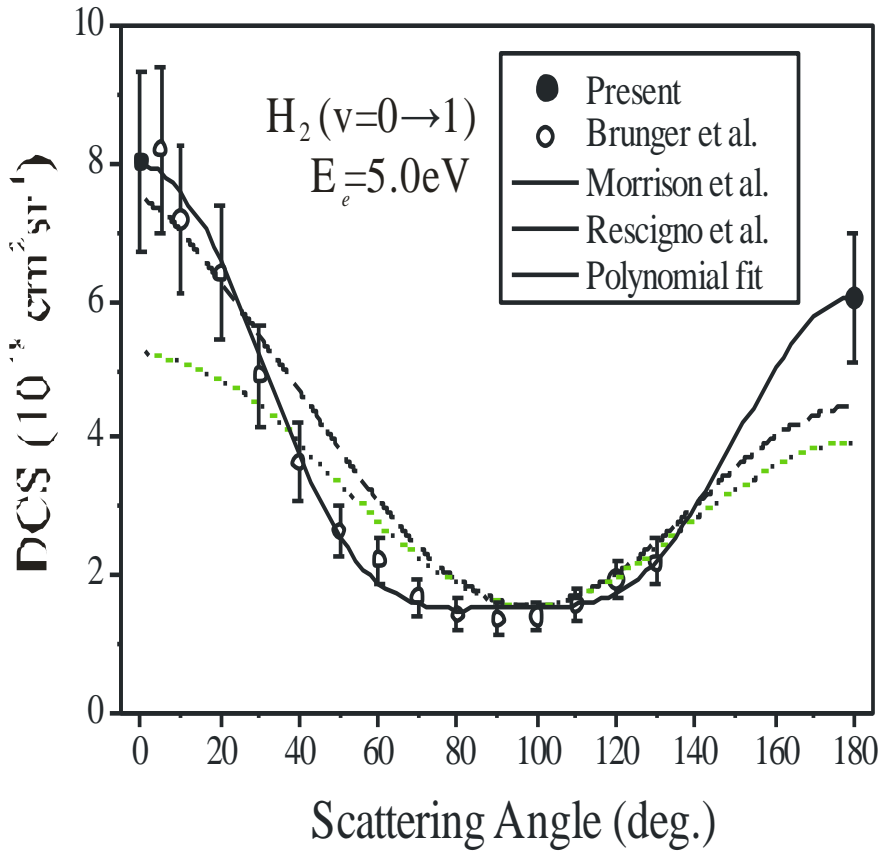
Fig 5. Differential cross-sections for the rovibrational excitation of H_2 (v=0–1) at incident energy of 5.0 eV: (●) Present results; (○) Brunger et al.[17]; (– –) Morrison et al.[12]; (…) Rescigno et al.[13]; (—) Legendre polynomials fit.

- Estimated errors in DCS values include error bars of the signal separation, which is 5%, together with the 15% error bars of the normalization data, and the error from the extrapolation procedure. The extrapolation procedure error bars include the 6% for the E_e= 1.0 eV. The same error bars were 2% in all other cases (at 90% confidence level). The total error is found to be 17%, in the case of E_e= 1.0 eV, and 16% in all other cases.
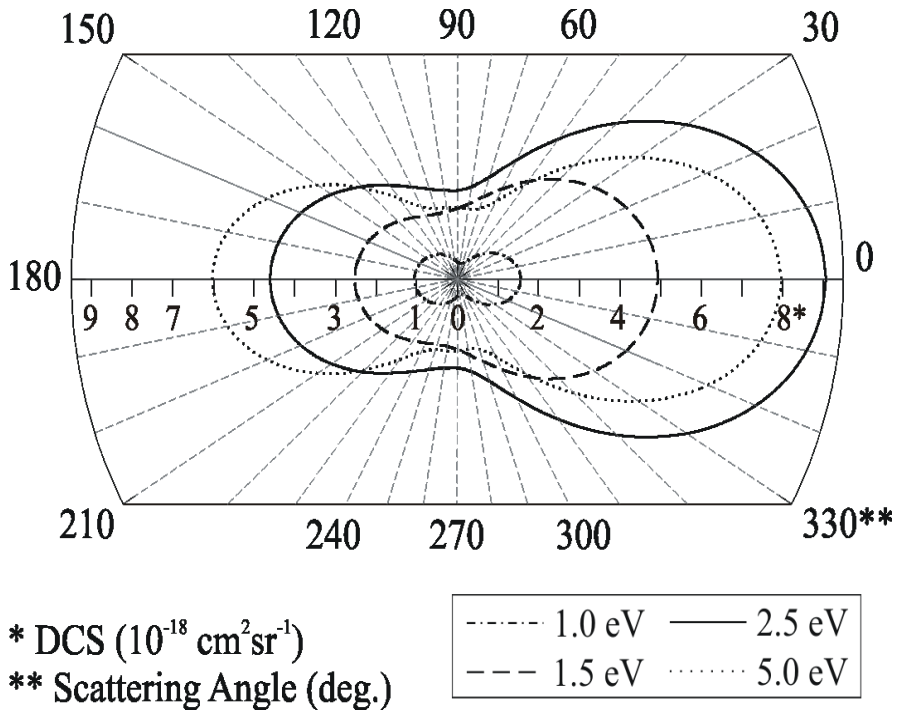
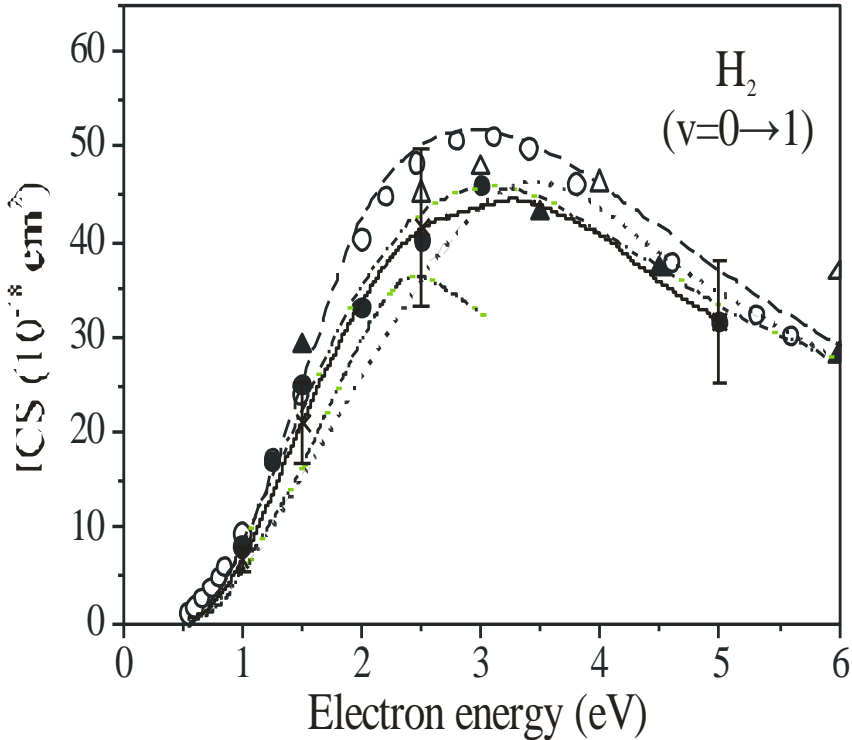Fig 6. Summary of the Differential cross sections of the hydrogen molecule in a polar plot.

Fig 7. Integral cross-sections for vibrational excitation (v=0–1) of H_2. from threshold to 6 eV. (—) Present results; (○) Ehrhardt et al.[7]; (▲) Linder and Schmidt [8]; (△) Nishimura et al.[13]; (●) Brunger et al.[17]; (—) Morrison et al.[12]; (– –) England et al.[11]; (- - -) Rescigno et al.[13]; (- - -) Schmidt et al.[18]

- The procedure further includes the determination of the integral cross sections for the corresponding electron energies. The results of the last fit of the data, presented by the solid lines, are used as the angular distribution of the scattered electrons in order to get the mentioned integral cross sections (ICS). The error bars for the ICS are found to be 27% for $E_e=1.0$, and 20% for all other cases.

- The ICS values are then compared with the previous experimental and theoretical results and the results are compared for both the cross-beam experiments and the swarm results. The different sets of the ICS data correspond each to other satisfactory, and are within the limits of the error bars.

Table II. Vibrational excitation (v=0–1) DCS and ICS of H_2; present results and Brunger et al. [17] data..

E (eV)	DCS (10^{-18} cm^{2}sr^{-1})		Ratio 0°/180°	ICS (10^{-18} cm^2)	
	0°	180°		Present results	Brunger et al.
1.0	1.59	1.03	1.54	8.5(7.8)	8.0
1.25	/	/	/	15.7	16.9
1.5	4.97	2.52	1.97	23.2(26.7)	25.0
2.0	/	/	/	35.4	33.2
2.5	9.14	4.55	2.01	42.5(39.51direkt)	40.1
3.0	/	/	/	44.8	45.9
3.5	/	/	/	44.8	/
4.0	/	/	/	41.8	/
4.5	/	/	/	36.7	/
5.0	8.02	6.03	1.33	32.4(32.7)	31.1

4- Conclusions

There was a long-term shortfall in experimental DCS data, and data from angle distribution of vibrant excitement to hydrogen, on border angles from 0 to 180

In this experiment, the objective was obtaining the DCS at border angles of 0◦ and 180◦.

The results obtained through this experiment have been performed long-term void, and have included further development in this area

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