Low Energy Neutron Cross Section per Hydrogen Atom

(N. Otsuka, 2019-11-22, Memo 4C-3/415 (Rev.))

During recent intensive compilation of the thermal neutron scattering related data, some compilers met "cross section per hydrogen", which definition has not been clear. After reviewing several examples (see next page), I now interpret that for a compound $H_nA_iB_jC_k\ldots$:

- Total cross section *per hydrogen* = $[\sigma - (i\cdot\sigma_A + j\cdot\sigma_B + k\cdot\sigma_C + \ldots)]/n$
- Scattering cross section *per hydrogen* = $[\sigma - (i\cdot\sigma_A + j\cdot\sigma_B + k\cdot\sigma_C + \ldots)]/n - \sigma_a$

where σ is the total cross section of the compound, σ_A is the free atom cross section of the element A, σ_a is the hydrogen absorption cross section. As the neutron energy increases, the "cross section per hydrogen" should approaches to the free atom hydrogen cross section (~20.5 barn) at the asymptotic region (~0.5 eV) for which E.Melkonian Phys.Rev.76(1949)1750 EXFOR 11150 mentions that

> "At about the energy spacing of vibration energy levels (0.5 eV) there is a sudden, rapid increase in cross section with decreasing neutron energy".

We propose the following REACTION code for the cross section per hydrogen:

- (1-H-WTR(N,TOT),,SIG,,HYD) for "hydrogen total cross section in the water"
- (1-H-WTR(N,THS)1-H-WTR,,SIG,,HYD) for "hydrogen scattering cross section in the water"

at the neutron energy where the cross sections are different from those for free hydrogen atoms.

See the following pages for examples of this quantity.

Dictionary 34 (Modifiers)
HYD hydrogen part of the quantity

Dictionary 236 (Quantities)
,SIG,,HYD Cross section of hydrogen in hydride molecule

Proposed addition to LEXFOR "**Thermal-neutron scattering**":

Cross section of hydrogen in hydride molecule

Cross sections of hydride molecule are often reported as "cross section per hydrogen (proton)". It means the free atom (gas) cross sections of the elements other than hydrogen are subtracted and then divided by the number of hydrogen atoms in the molecule. The cross section should approach to the free hydrogen cross section (~20.5 b) at the asymptotic region (~1 eV). Above this energy, cross sections should be compiled as those for free hydrogen atoms. The unit code B is used even if the authors give the cross section in b/atom.

REACTION coding: HYD in SF8.

***Example 1*: EXFOR 30229.005 (Fig.3 of S.B.Herdade et al., R,INDC(BZL)-2,22,1969)**

Scattering cross section of water is plotted in Fig.3 and tabulated in Table II.

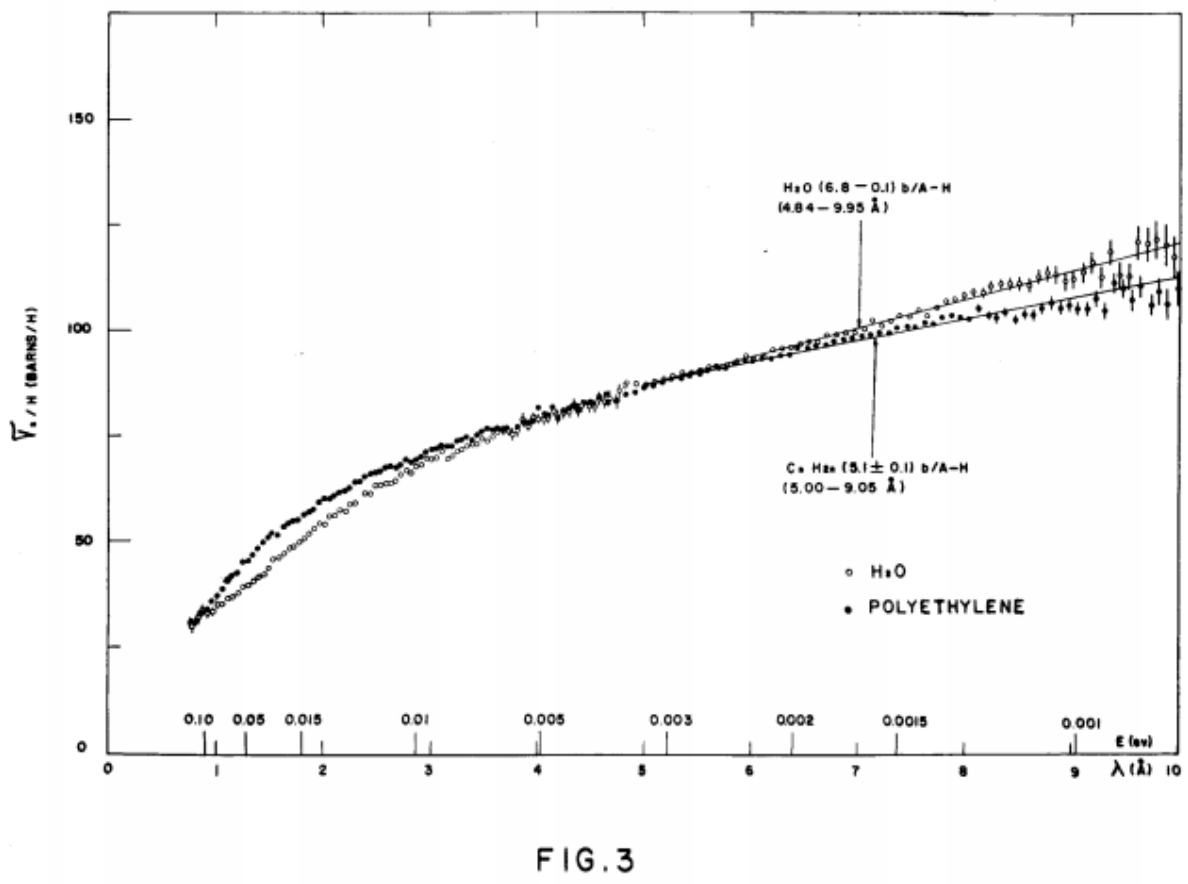


FIG. 3

The authors relates σ_s/H ("scattering cross section per hydrogen atom") and total cross section per H_2O (σ_T) in Eq.(1) of the report by

$$\sigma_T = \sigma_x + 2\sigma_a + 2(\sigma_s/H),$$

where σ_x is the free atom total cross section of oxygen (~3.7 b) and σ_a is the absorption cross section of hydrogen (~0.3 b at 0.0253 eV). Note that the oxygen absorption cross section is very small (~0.0002 b at 0.0253 eV).

Example 2: EXFOR 11150 **(Fig. 16 of E. Melkonian, J,PR,76,1750,1949)**

The measured cross sections for various hydrocarbon compounds (which are plotted individually in other figures and must be compiled by NNDC) are collected in Fig.16.

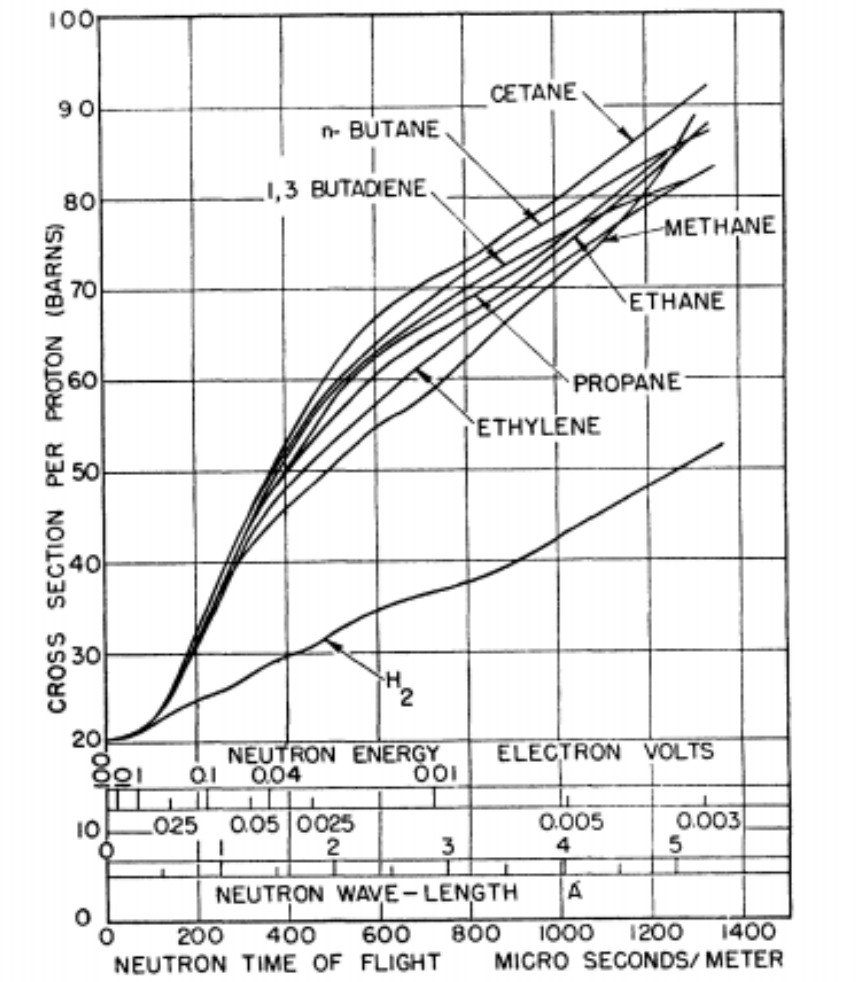


FIG. 16. A composite graph showing the slow neutron cross section of H in the hydrocarbons studied and in H_2 gas. Approximate corrections for the effect of thermal the translational motion have been made for the gas scatterers as described in the text.

All cross sections reach to the free hydrogen cross section (~20.5 b) at the high energy side. The authors mention "The carbon cross section has been taken as 4.70 barns". This implies that that the authors subtracted the carbon contribution from the measured cross section of the molecule.

***Example 3*: EXFOR 23424.005 (Fig.4 bottom of U.Schmidt, J,AKE,12,385,1967)**

Total cross section of hydrogen in $ZrH_{0.56}$ is plotted in Fig.5.

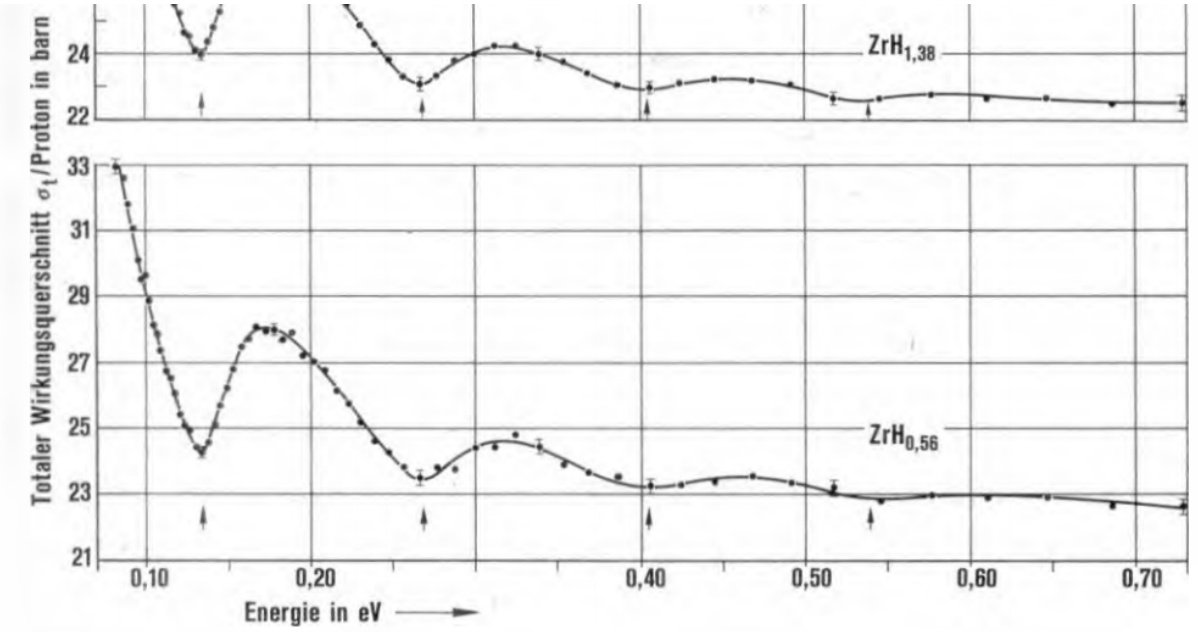


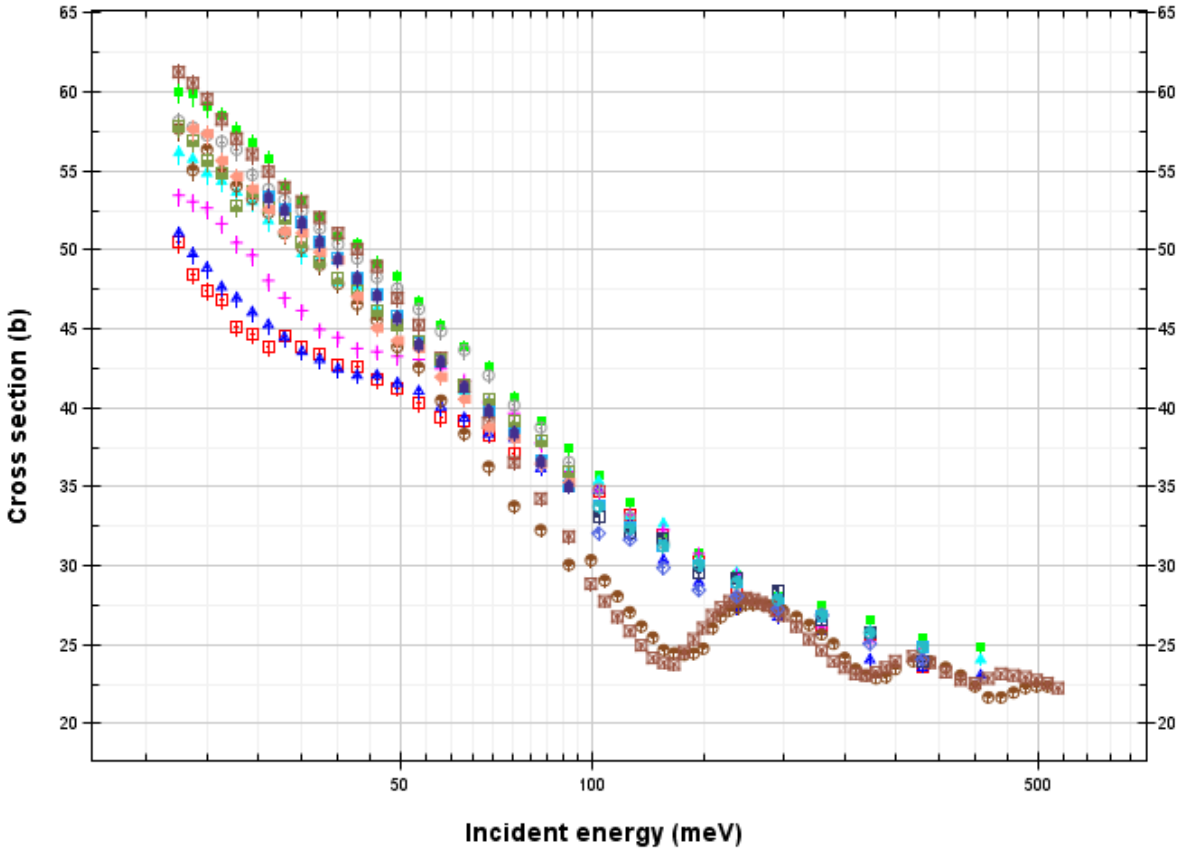
Fig. 5: Der totale Wirkungsquerschnitt des Protons in Zirkoniumhydriden verschiedener H-Konzentration

Fig. 5: Total hydrogen cross-section in zirconium hydrides with various H-concentrations

The quantity in Fig.5 would be interpreted as the total cross section of $ZrH_{0.56}$ minus total cross section of zirconium normalized to one hydrogen.

***Example 4*: EXFOR 21146 (Fig.3 of B.Broecker., P,EANDC(E)-66,52,1966)**

Total cross sections of various hydrides (organic compounds, ammonium saltes, metal hydrides) are compiled.



These data sets are compiled from a progress report without detailed description. But the asymptotic value is similar to Example 3 case (~22.5 b).