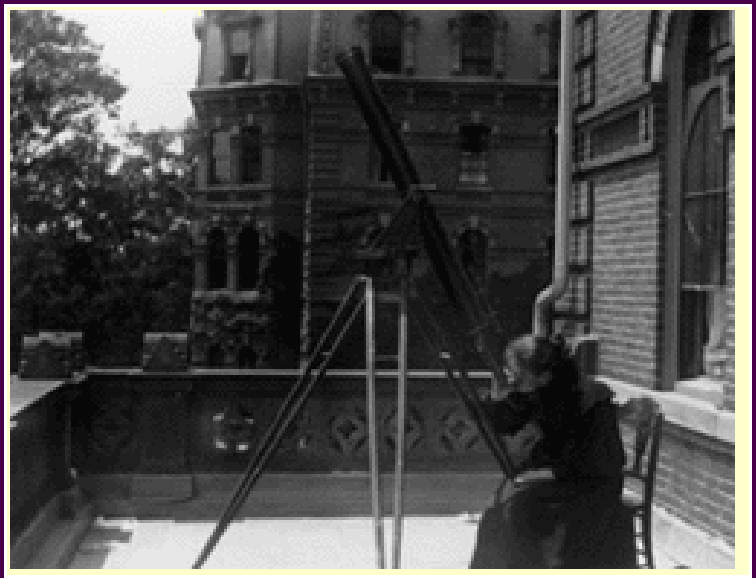
Electronic Supplementary Material (ESI) for Chemical Society Reviews.

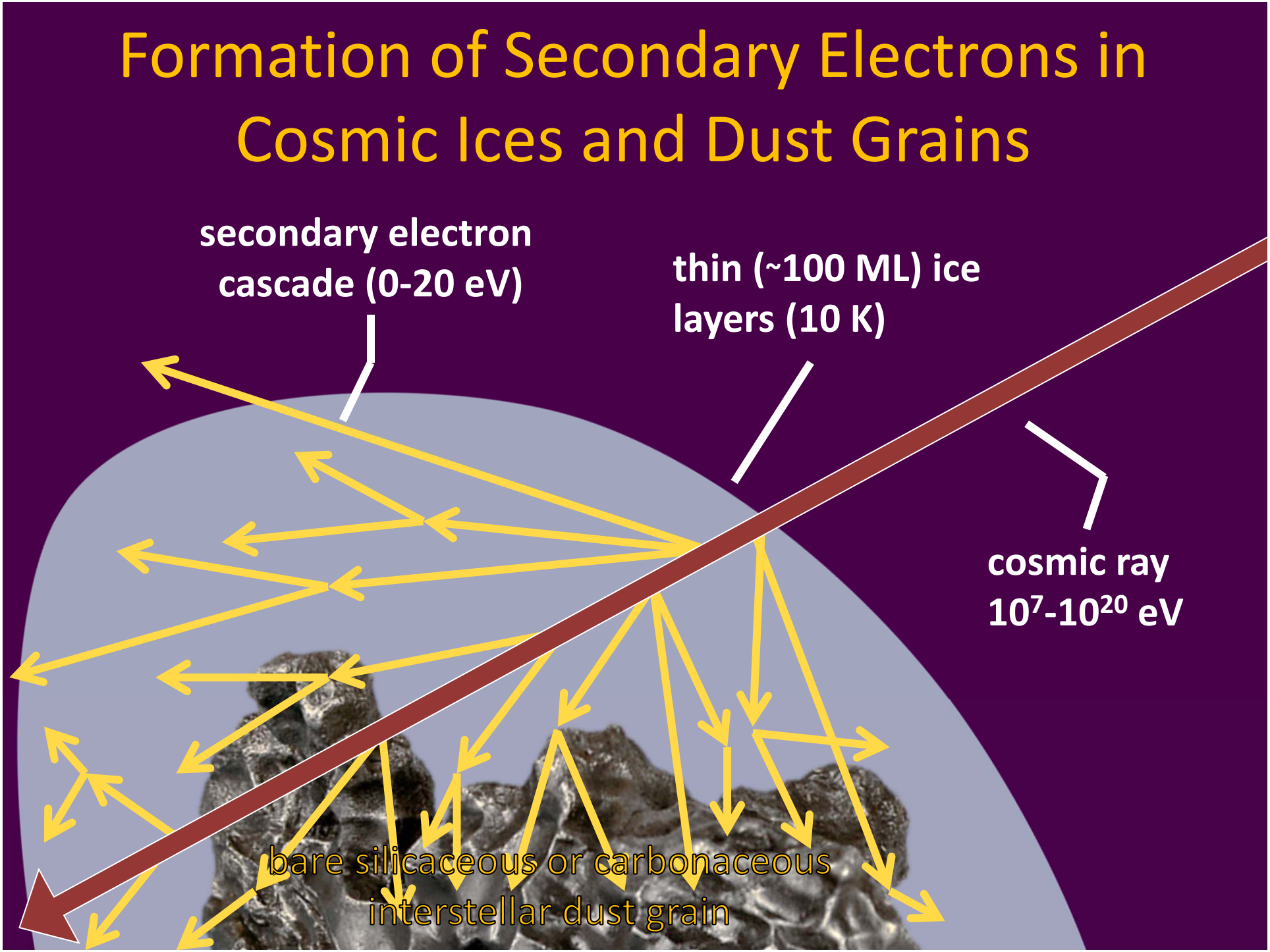
Annie Jump Cannon (1863-1941)

- Graduated from Wellesley College 1884

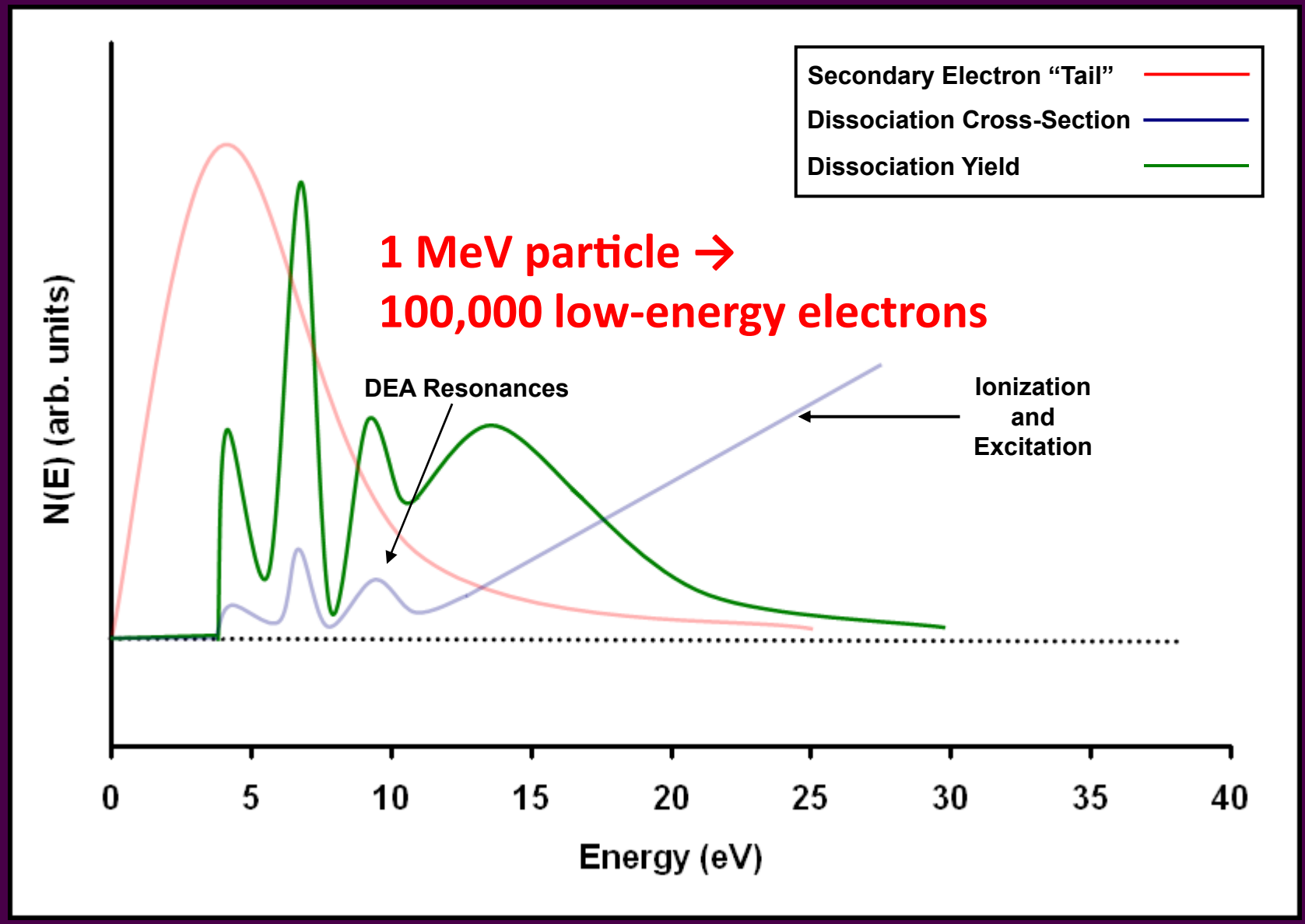


- Likely discoverer of the still enigmatic spectral diffuse interstellar bands (DIB) (~ 1918)
- Stellar classification: “OBAFGKM”
- Classified 350,000 stars
- Became a “special student” of astronomy at Radcliffe College (1894)
- First woman to receive an honorary degree from Oxford (1925)

Formation of Secondary Electrons in Cosmic Ices and Dust Grains

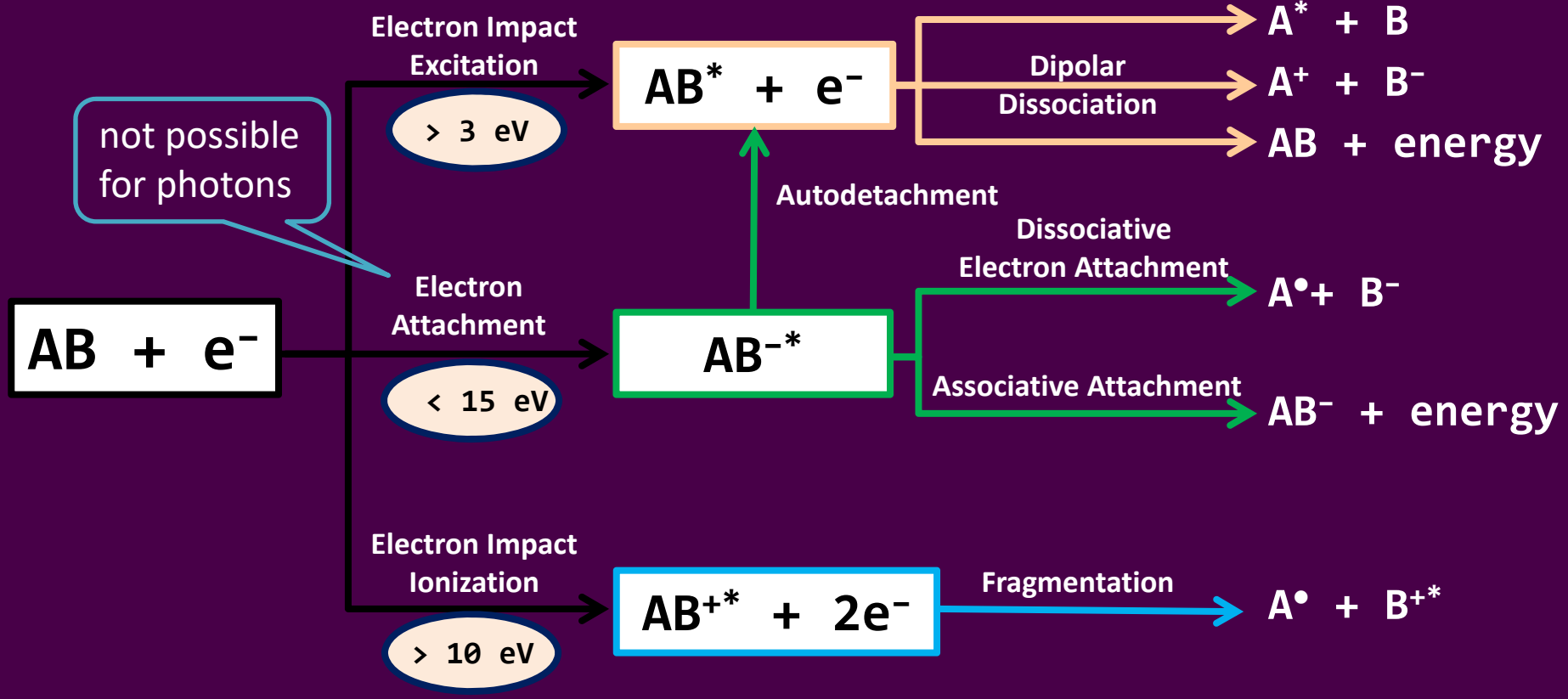


Importance of Low-Energy Electrons

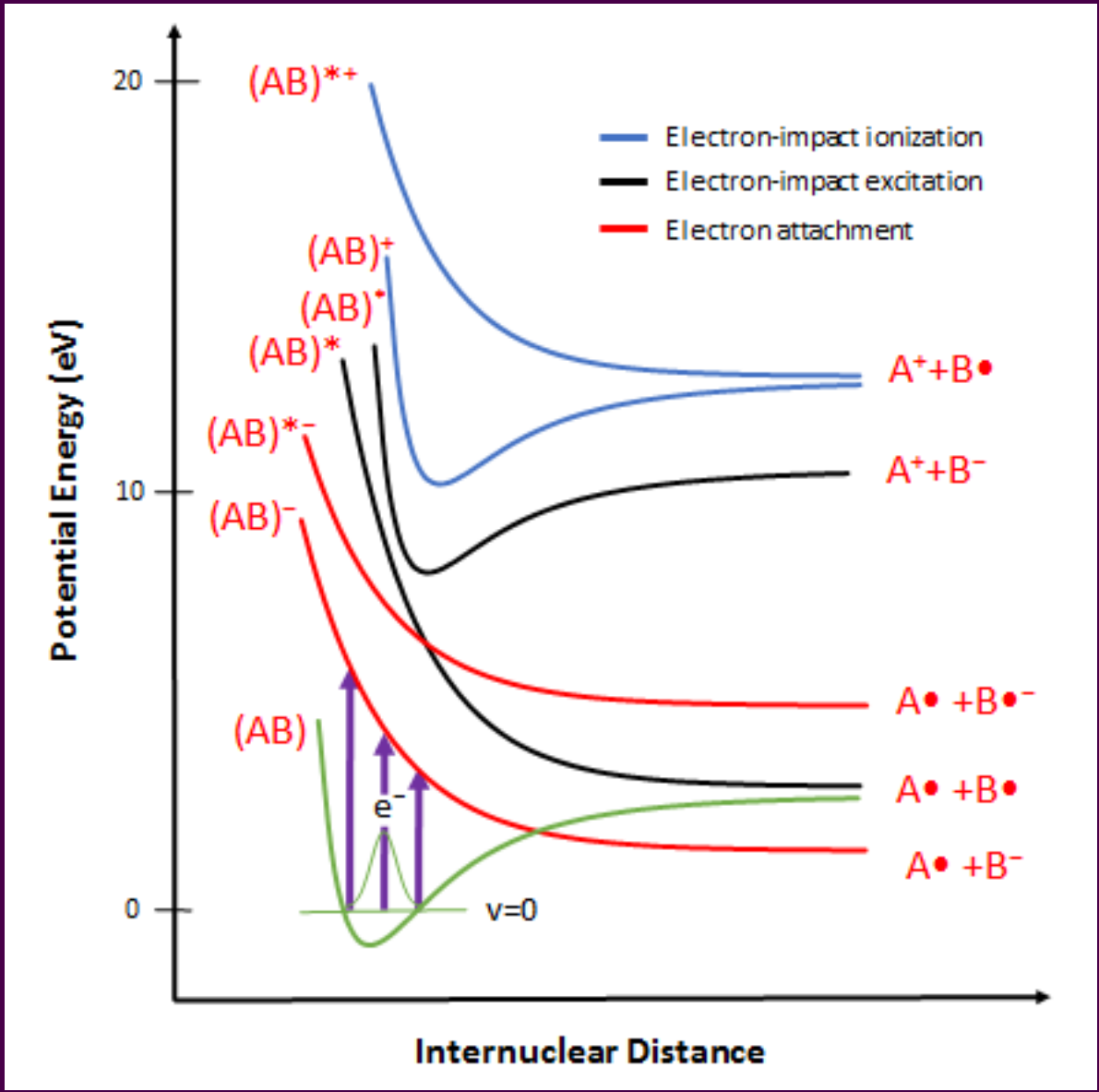


C. Arumainayagam et al., *Surface Science Reports* 65 (**2010**) 1–44.

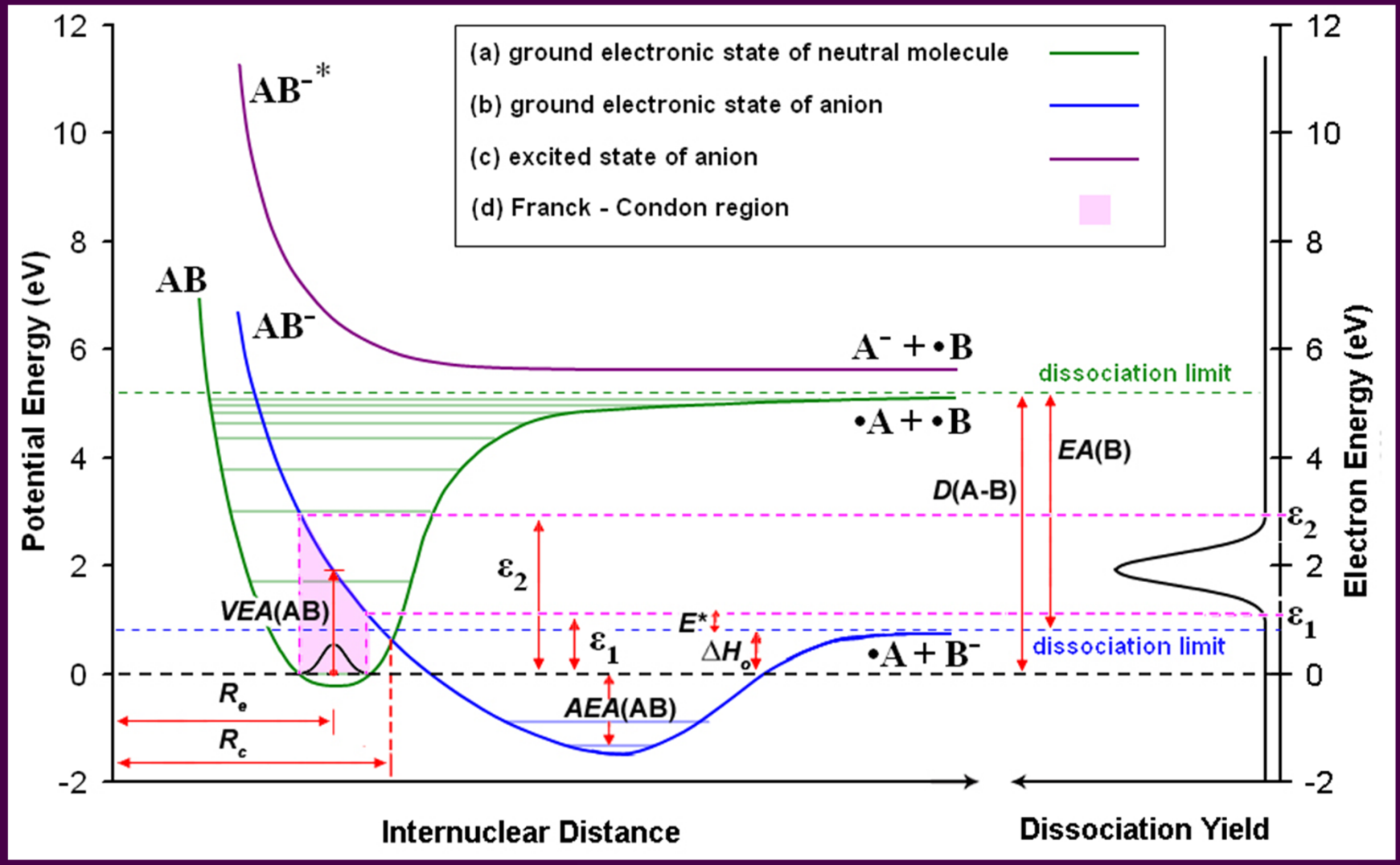
Electron-induced Dissociation Mechanisms



Electron-induced Dissociation Mechanisms



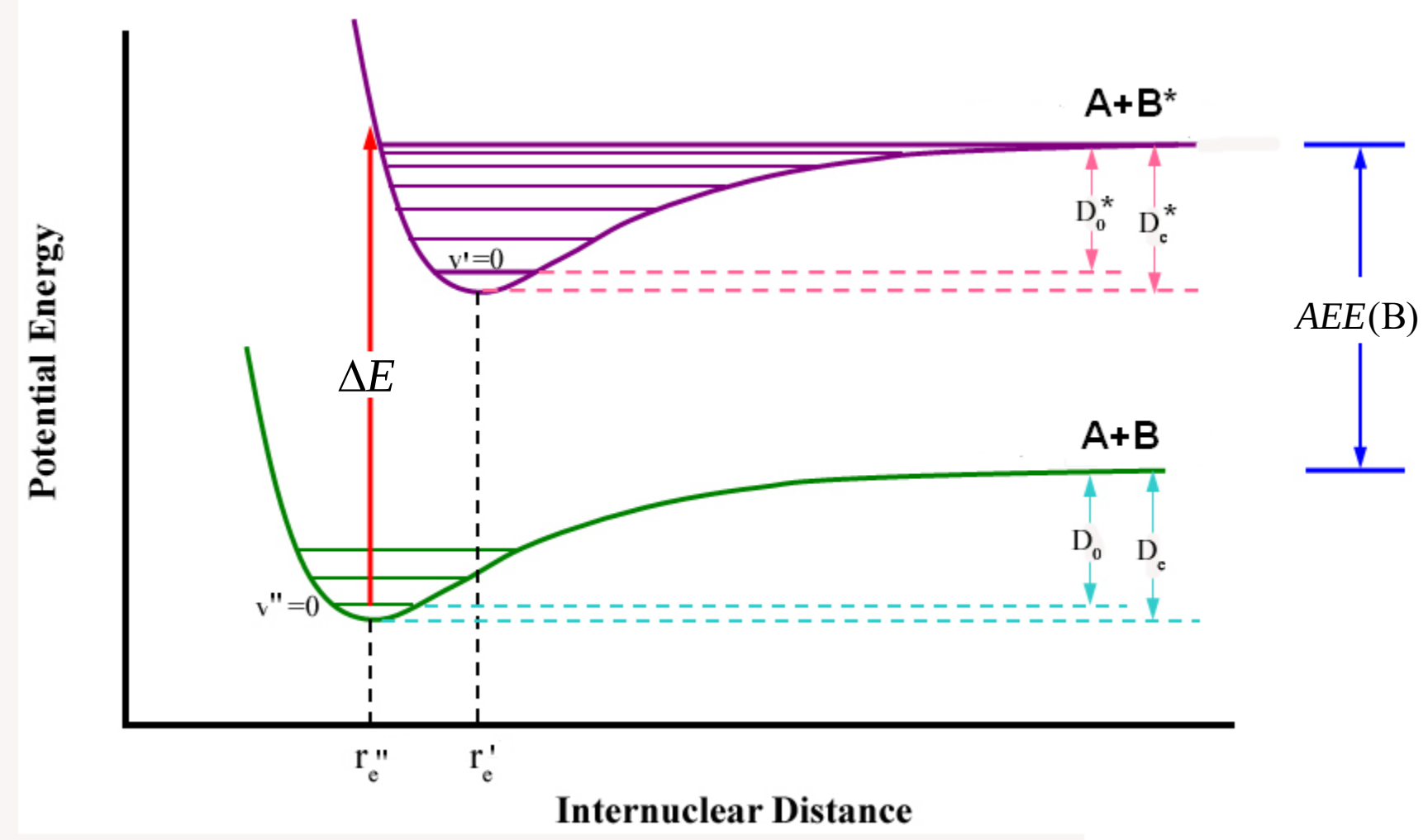
Breaking a 3.5 eV Bond with a 0 eV Electron



Threshold Energy: $\Delta H_{o}(\mathrm{B}^{-}) = D(\mathrm{A}-\mathrm{B}) - EA(\mathrm{B})$

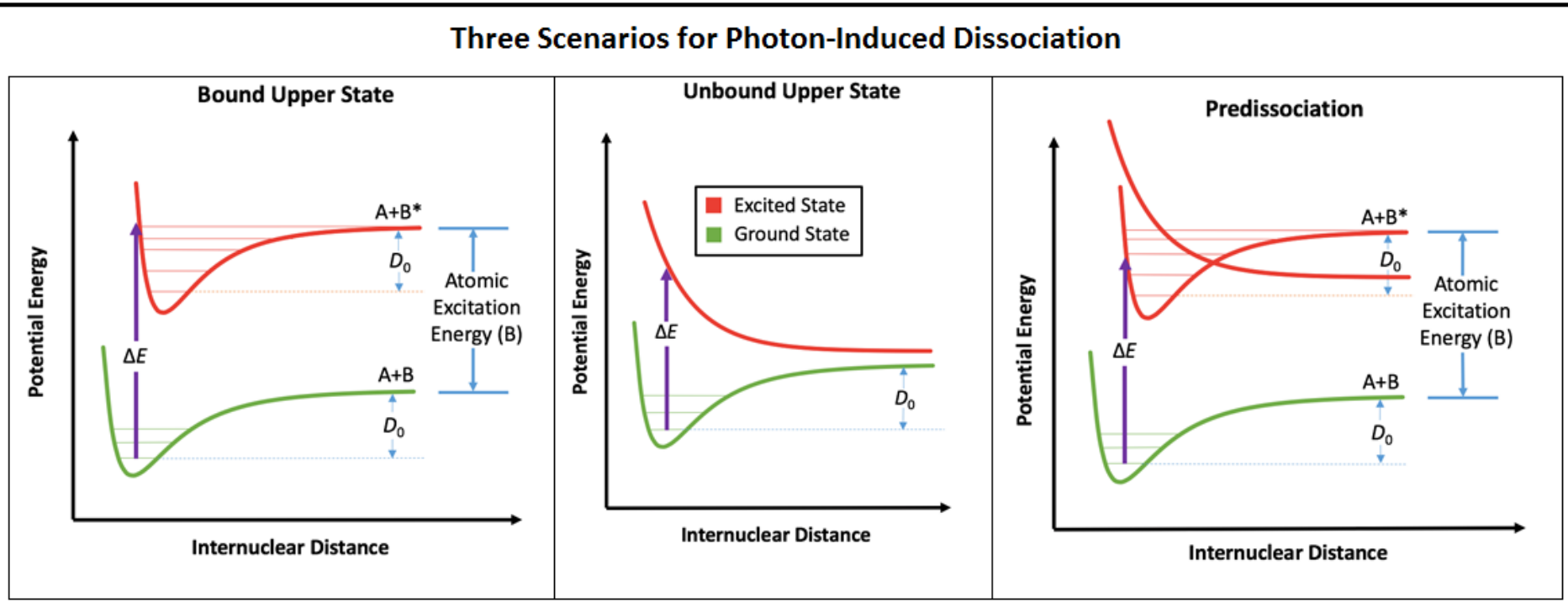
C. Arumainayagam *et al.*, *Surface Science Reports* 65 (**2010**) 1–44.

Photon-Induced Dissociation

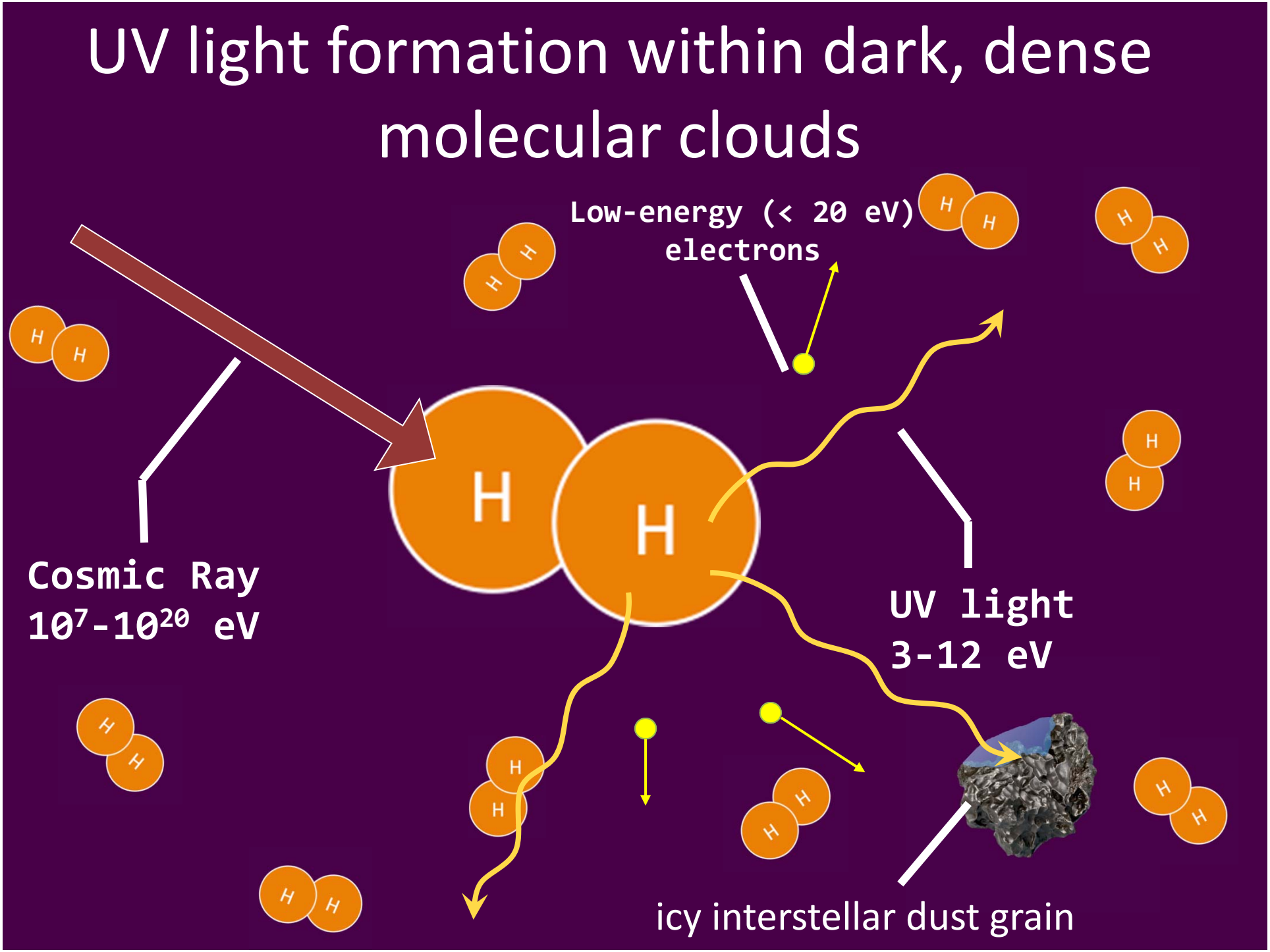


Threshold Energy: $\Delta E = D_o(A-\mathrm{B}) + AEE(\mathrm{B})$

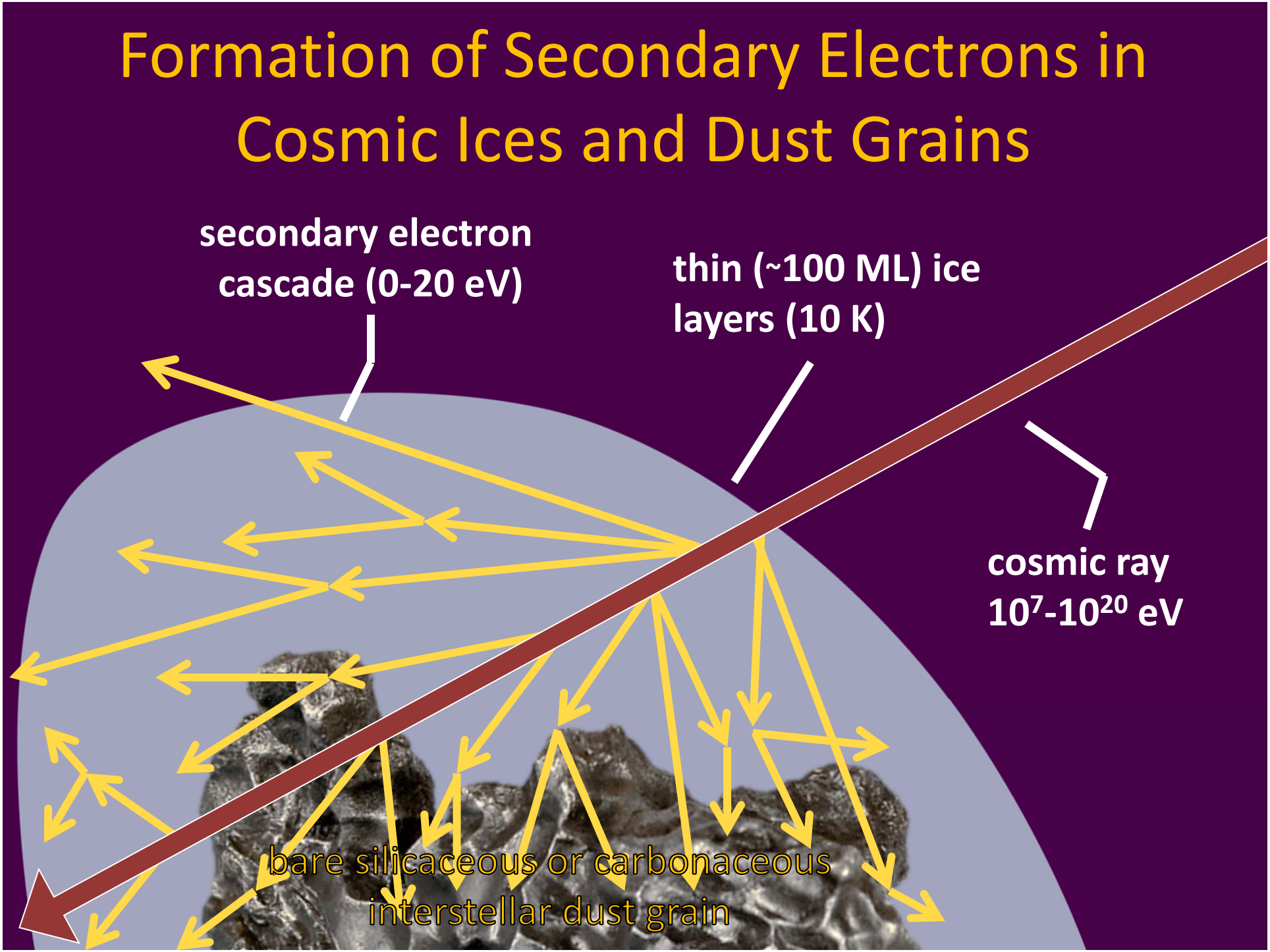
Photon-Induced Dissociation



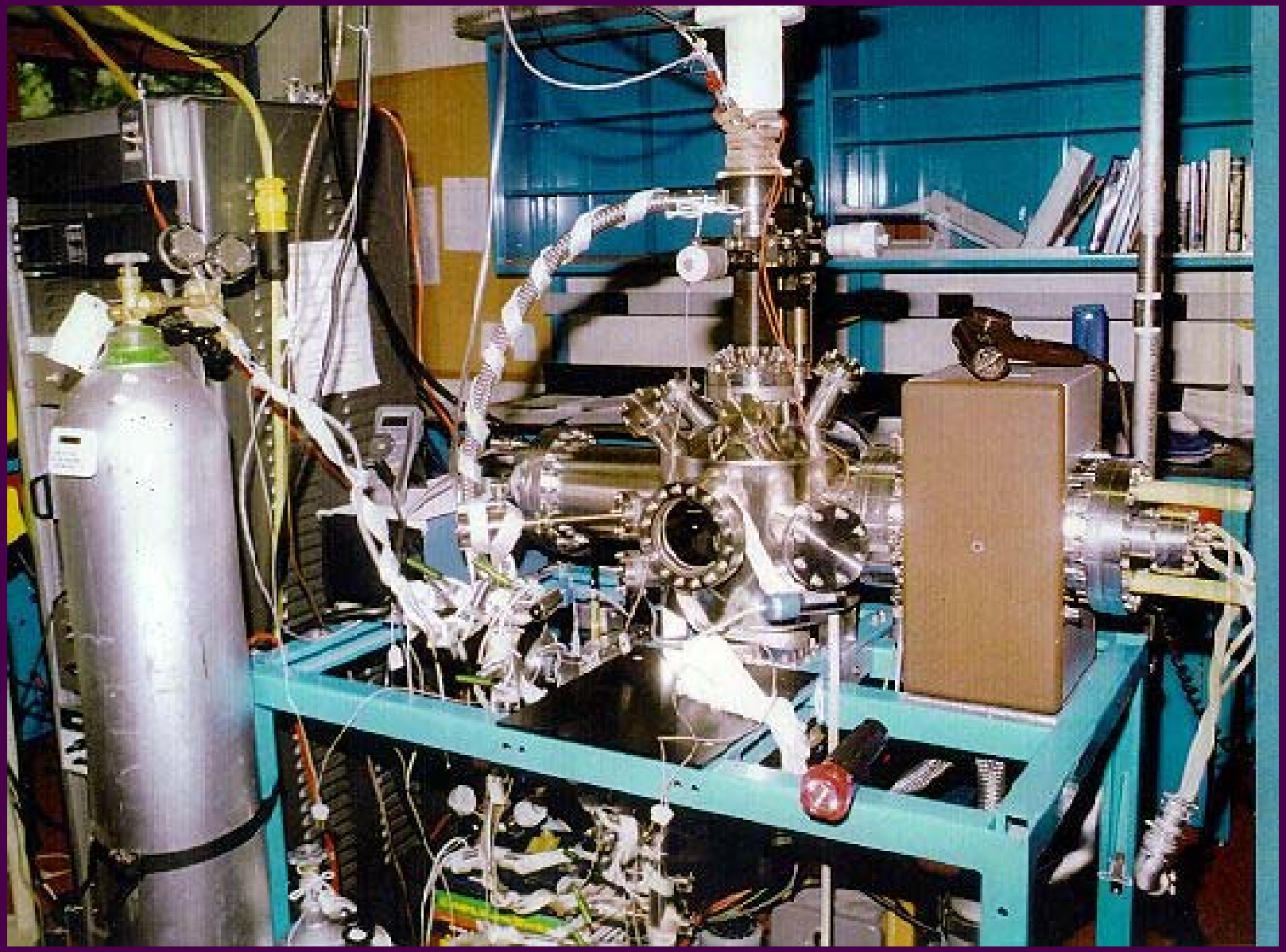
UV light formation within dark, dense molecular clouds



Formation of Secondary Electrons in Cosmic Ices and Dust Grains

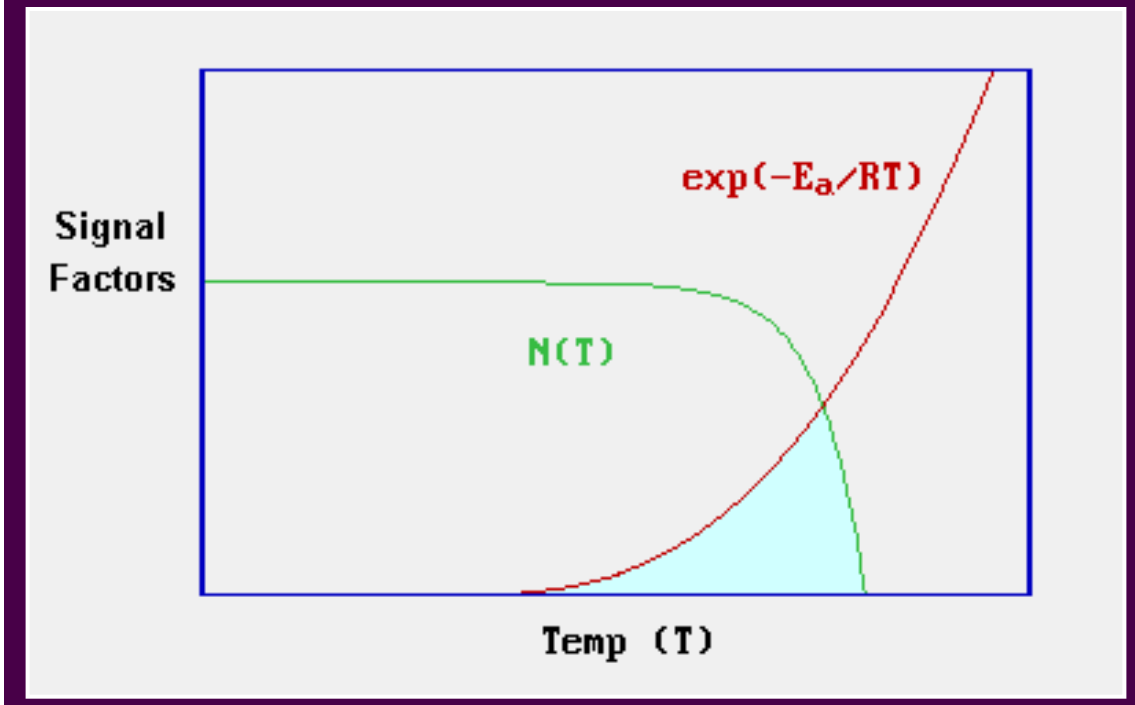


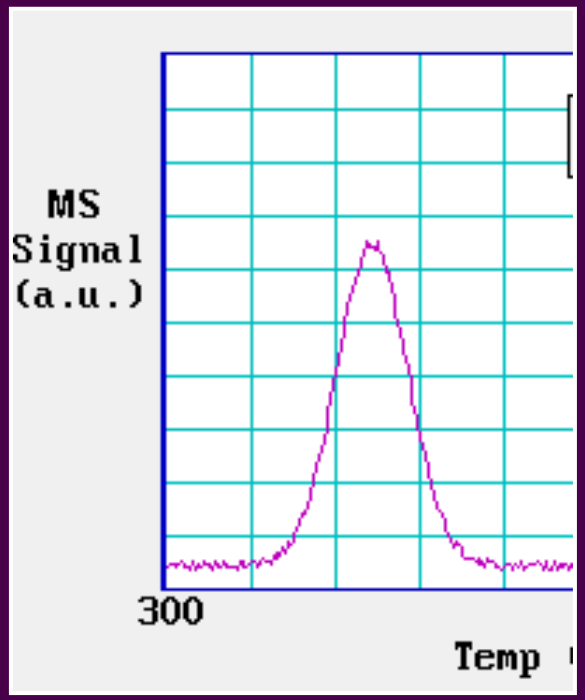
UHV Chamber at Wellesley College



Temperature-Programmed Desorption (TPD)

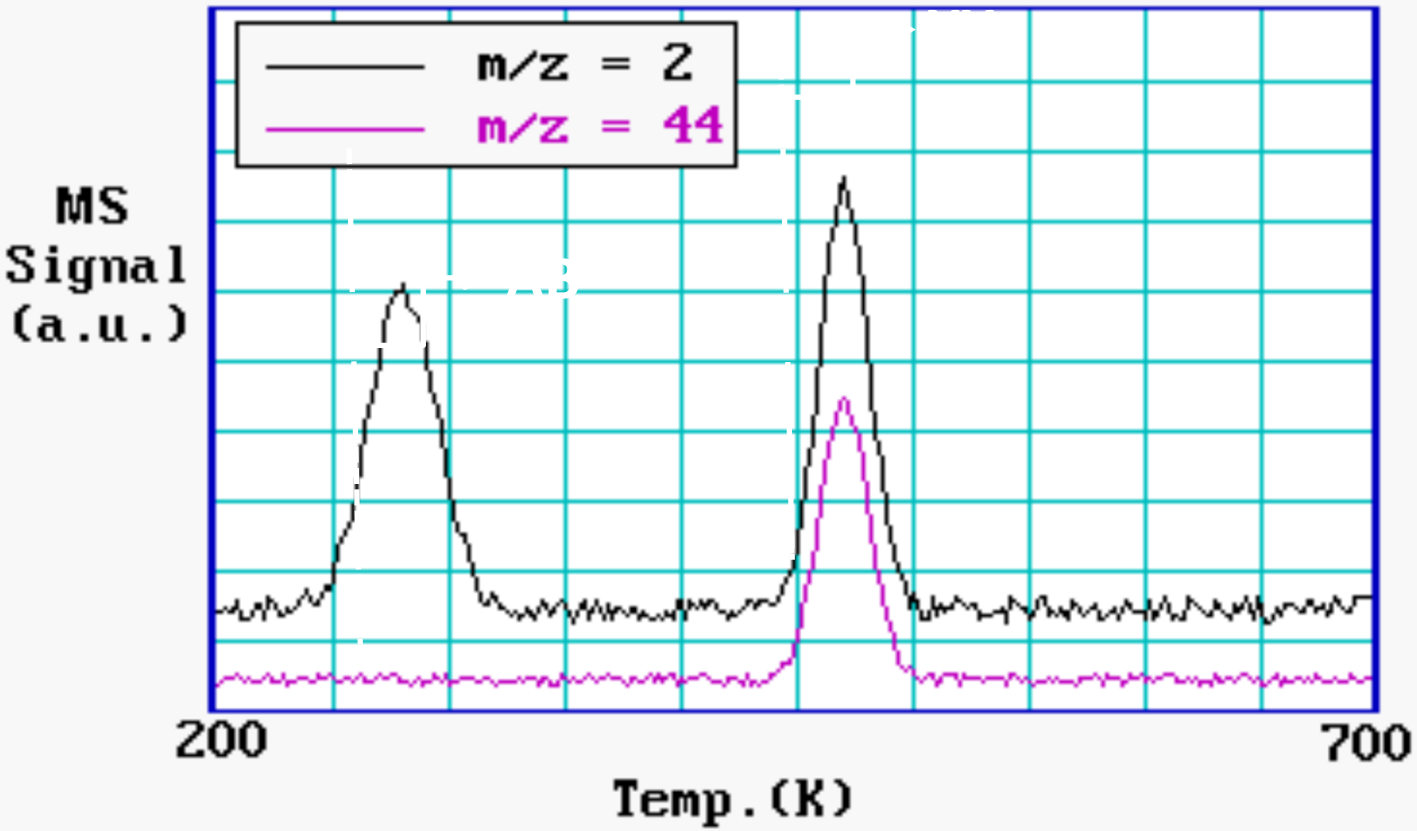
MS signal= $R = kN = A\, e^{\frac{-E_a}{RT}} N$





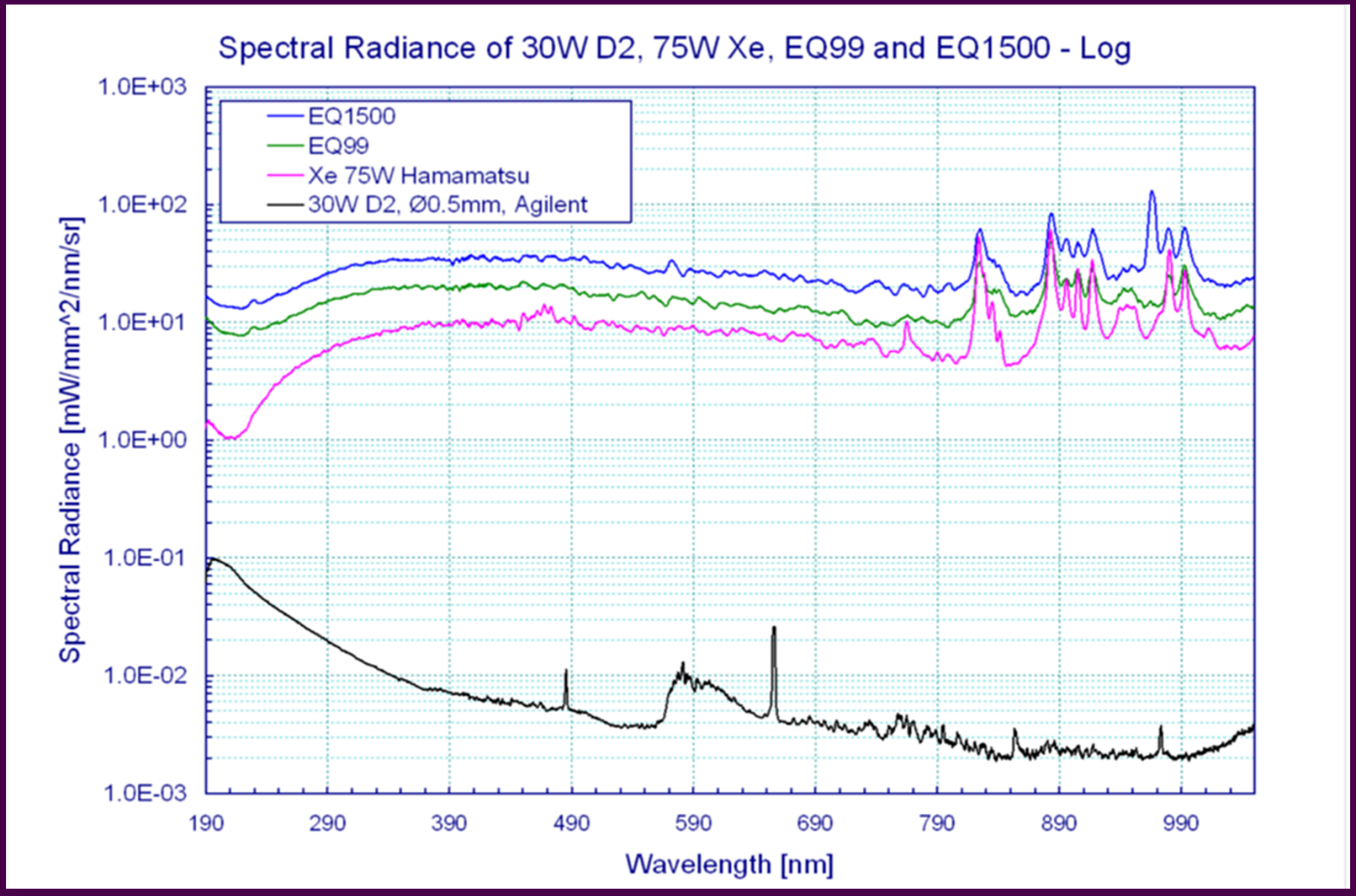
Figures: http://www.chem.qmul.ac.uk/surfaces/scc/scat5_6.htm

Tempature Programmed Desorption
How to Identify Desorption Peaks

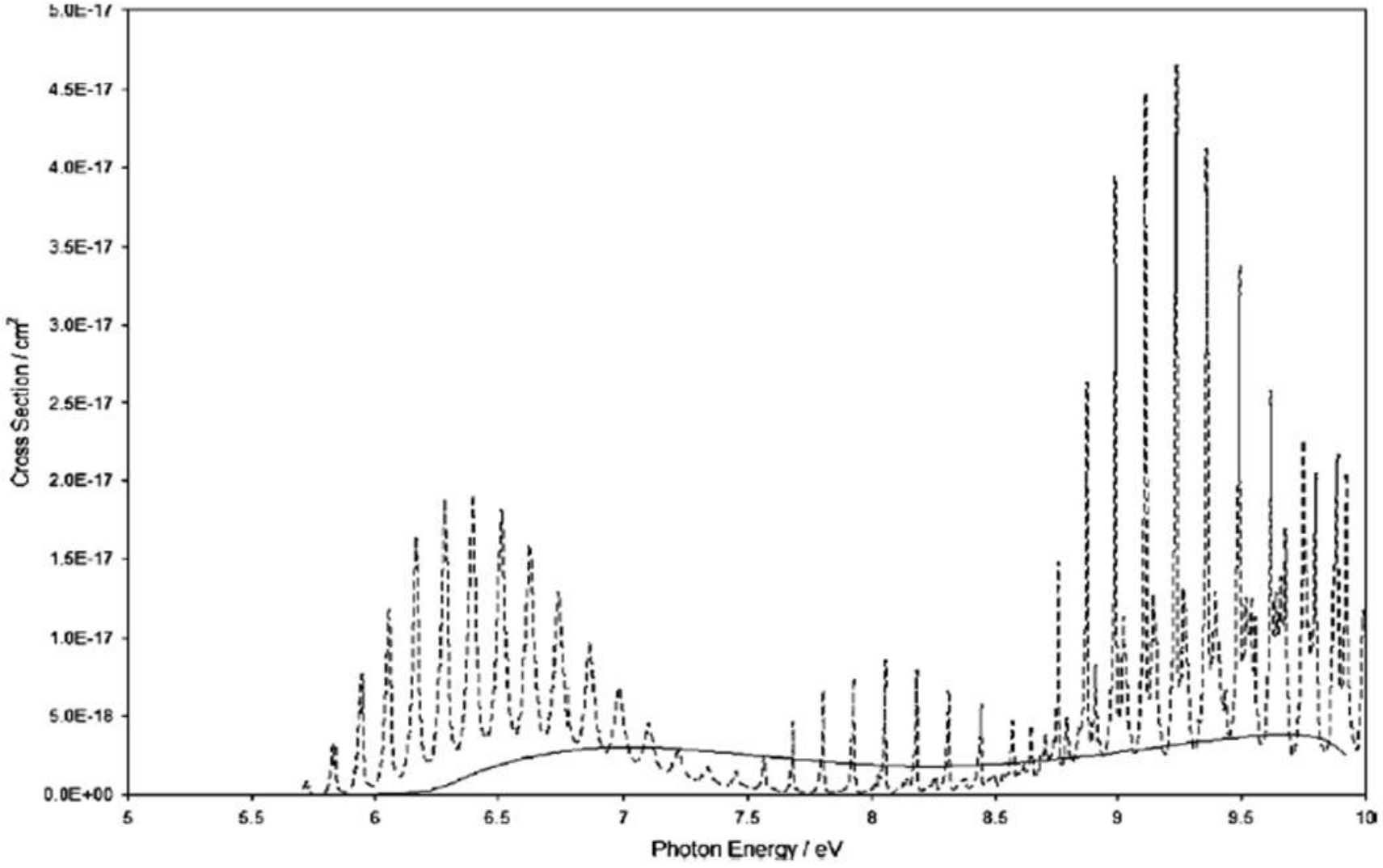


Figures: http://www.chem.qmul.ac.uk/surfaces/scc/scat5_6.htm

Extremely Bright < 8 eV Photon Source: Laser-Driven Plasma: EQ 1500



UV Absorption Spectrum of Condensed Ammonia



Mason, N.J. et. al, *Faraday Discussions*, 2006.

Mean Free Path Calculation for a 7 eV Photon

$$\lambda = \frac{1}{n\sigma}$$

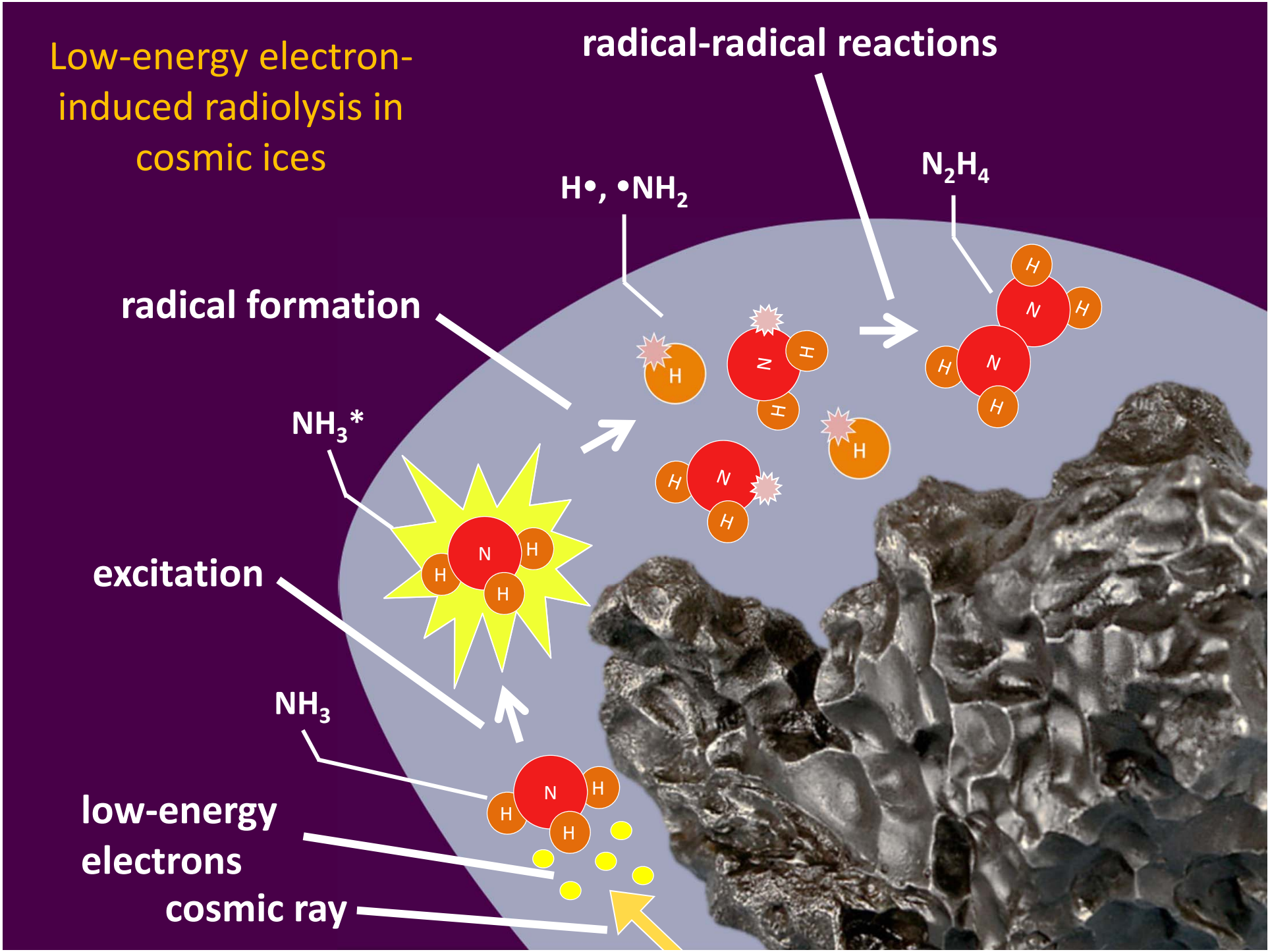
$$= \frac{1}{(\text{number of molecules per cm}^3)(\text{photon absorption cross section in cm}^2)}$$

$$= \frac{1}{\left(\frac{\text{density in g/cm}^3}{\text{molar mass in g/mole}}\right)\left(\begin{matrix}\text{number of molecules}\\ \text{per mole}\end{matrix}\right)\left(\begin{matrix}\text{photon absorption}\\ \text{cross section in cm}^2\end{matrix}\right)}$$

$$= \frac{1}{\left(\frac{0.68\ \text{g/cm}^3}{17\ \text{g/mole}}\right)(6.02 \times 10^{23}/\text{mole})(2 \times 10^{-18}\text{cm}^2)}$$

$$= 0.2 \text{ microns}$$

Most, if not all, of the ice mantle surrounding dust grains will be susceptible to photochemistry


Low-energy electron-induced radiolysis in cosmic ices
radical-radical reactions
H•, •NH2
N2H4
radical formation
NH3*
excitation
NH3
low-energy electrons
cosmic ray

Role of low-energy electrons in the synthesis of prebiotic molecules

THE JOURNAL OF CHEMICAL PHYSICS **148**, 164702 (2018)

Glycine formation in CO_2:CH_4:NH_3 ices induced by 0-70 eV electrons

Sasan Esmaili, Andrew D. Bass, Pierre Cloutier, Léon Sanche, and Michael A. Huels[a)]
Département de Médecine Nucléaire et Radiobiologie, Faculté de Médecine et des Sciences de la Santé, Université de Sherbrooke, Sherbrooke, Quebec J1H5N4, Canada

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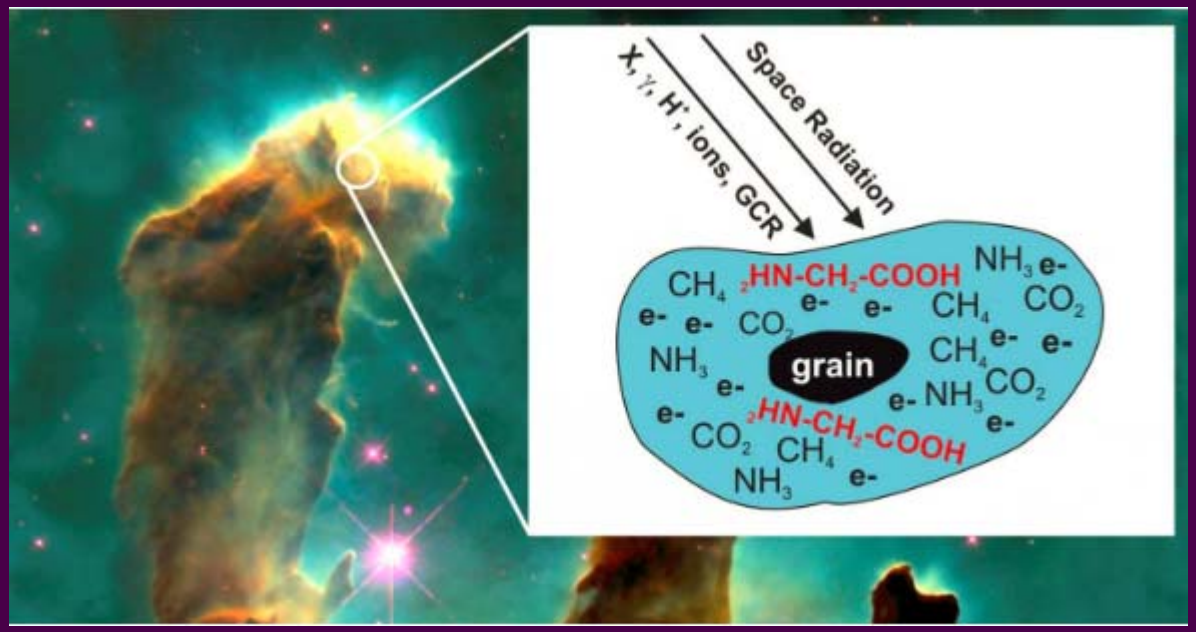
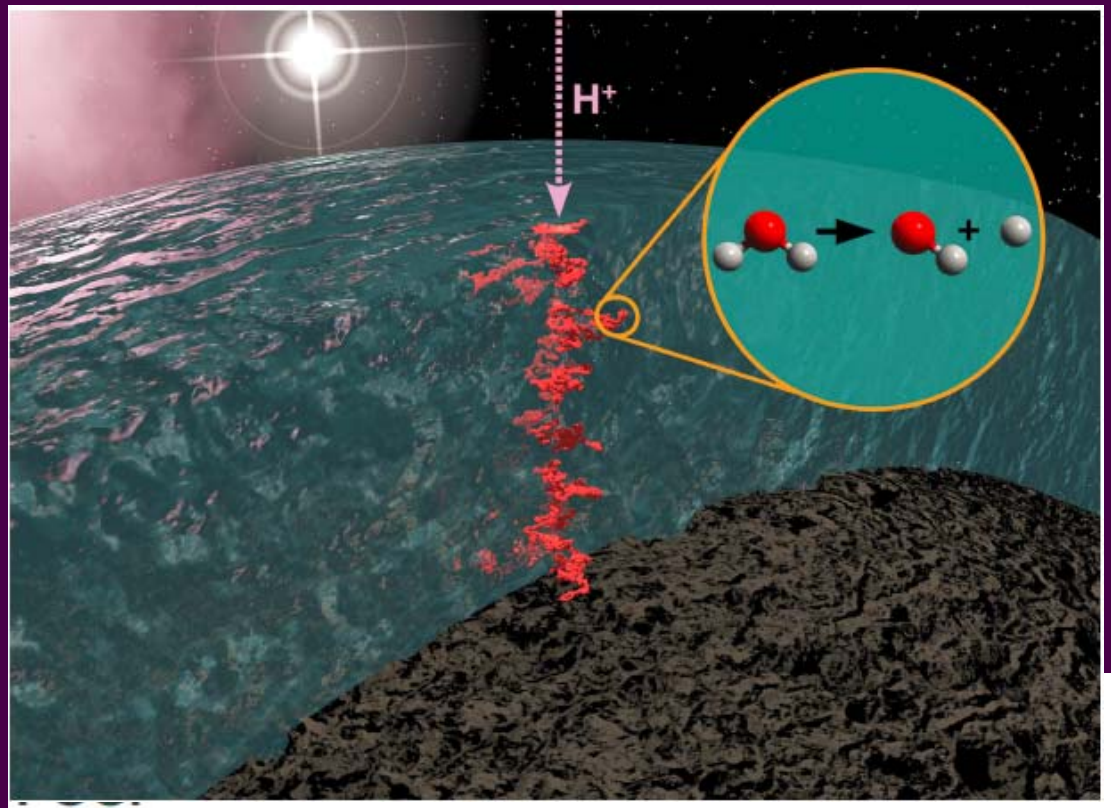


https://www.eurekalert.org/multimedia/pub/168851.php



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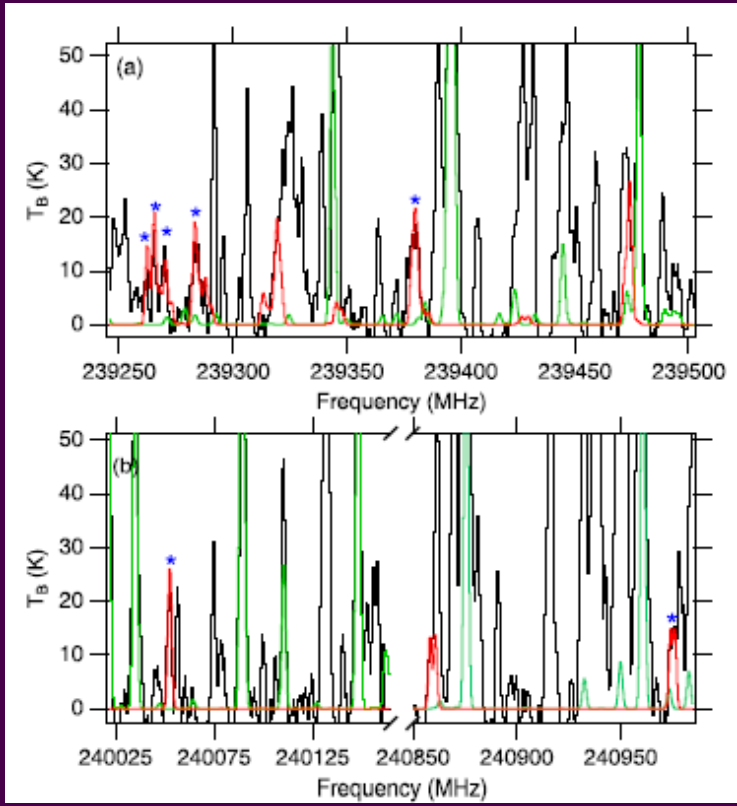
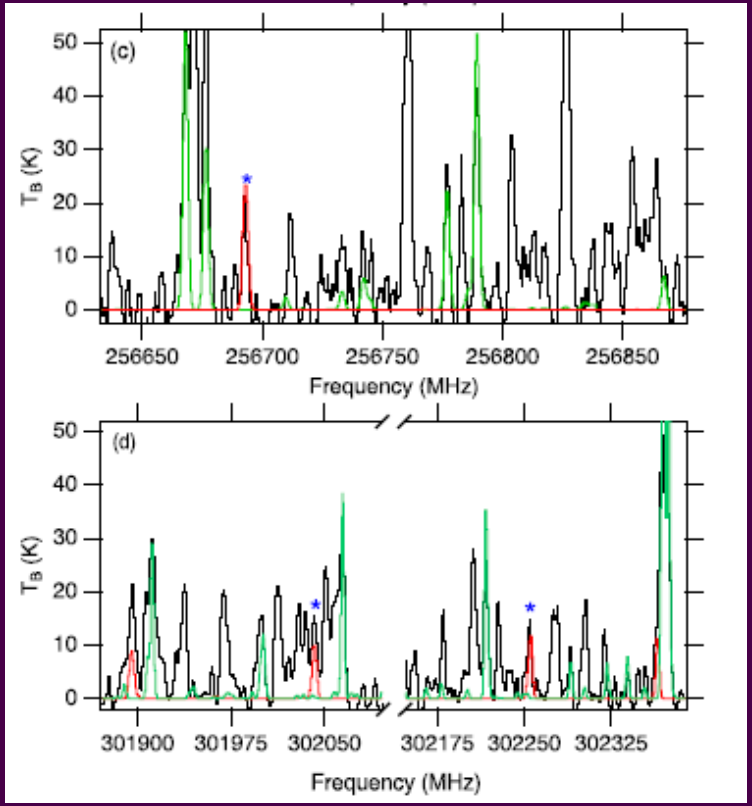
A general method for the inclusion of radiation chemistry in astrochemical models

Christopher N. Shingledecker *[a] and Eric Herbst[ab]

December 2017: Identification of Methoxy methanol in the ISM [~10 quadrillion miles away]





Black: Overall microwave spectrum of NGC 6334I

Red: Simulated rotational spectrum of methoxymethanol

Green: Simulations of species that are major contributors to the overall spectrum

Brett A. McGuire *et al* 2017 *ApJL* **851** L46; James O. Chibueze *et al* 2014 *ApJ* **784** 114