Section 5: Collisions

AE435

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2 Electron-Atom Collisions

Contents

2.1 Elastic

Severe energy dependence for each species, and little resemblance between species. Recall previous discussed resonance of orbit radius with electron wavelength. Resulting (Ramsauer effect) causes the dramatic dips in Fig 4-3. Also get severe angular dependence, see Fig 4-4. Far from constant-diameter billiard ball model.

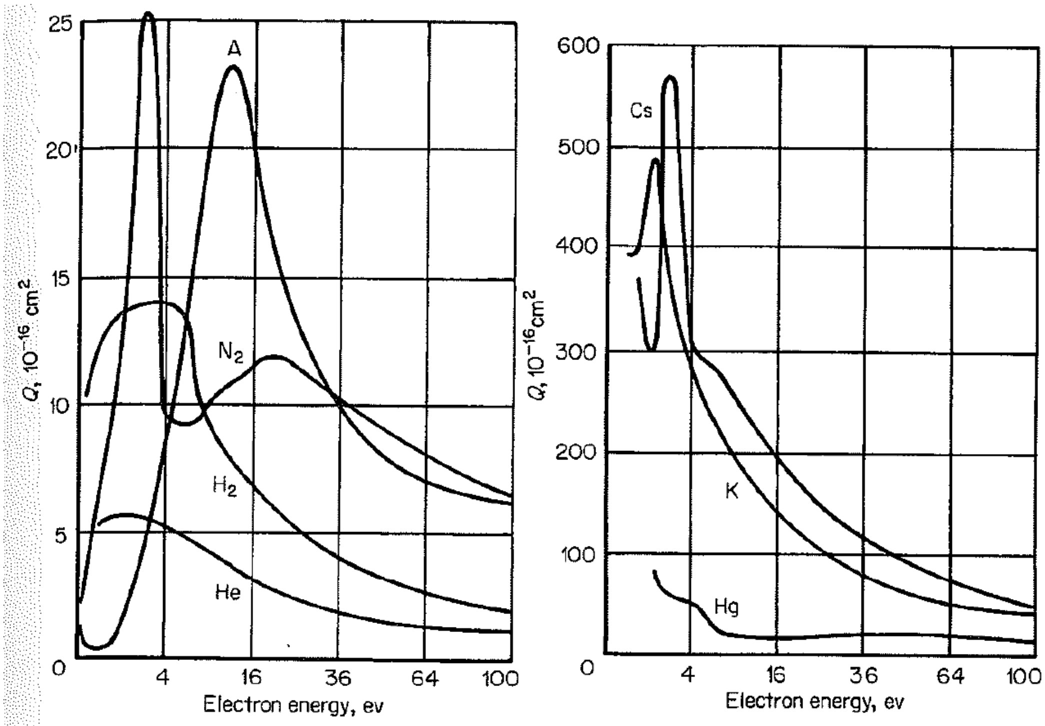

Fig. 4-3 Energy dependence of electron-atom elastic cross sections. *(From R. B. Brode, Rev. Mod. Phys., vol.* 5, *p.* 257, 1933, *and H. Margenau and F. P. Adler, Phys. Rev., vol.* 79, *p.* 970, 1950.)

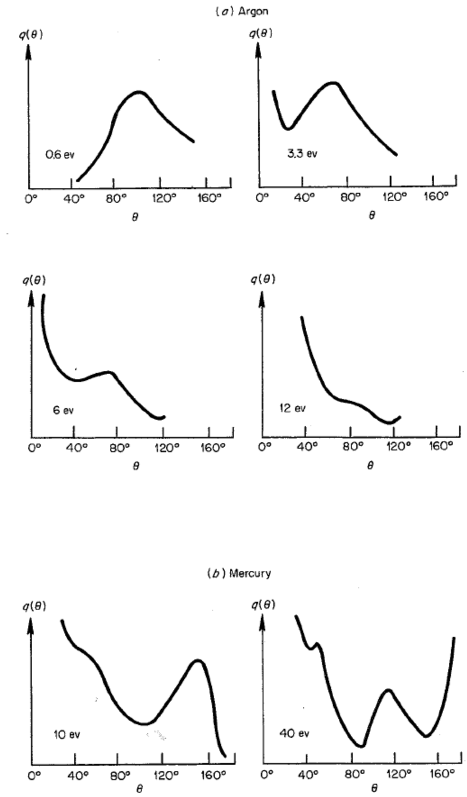

Fig. 4-4 Angular dependence of electron-atom elastic cross sections in argon and mercury. (*From E. C. Bullard and H. S. W. Massey, Proc. Roy. Soc., ser. A, vol.* 130, *p.* 579, 1931, and *E. C. Childs and H. S. W. Massey, ibid., vol.* 141, *p.* 473, 1933.)

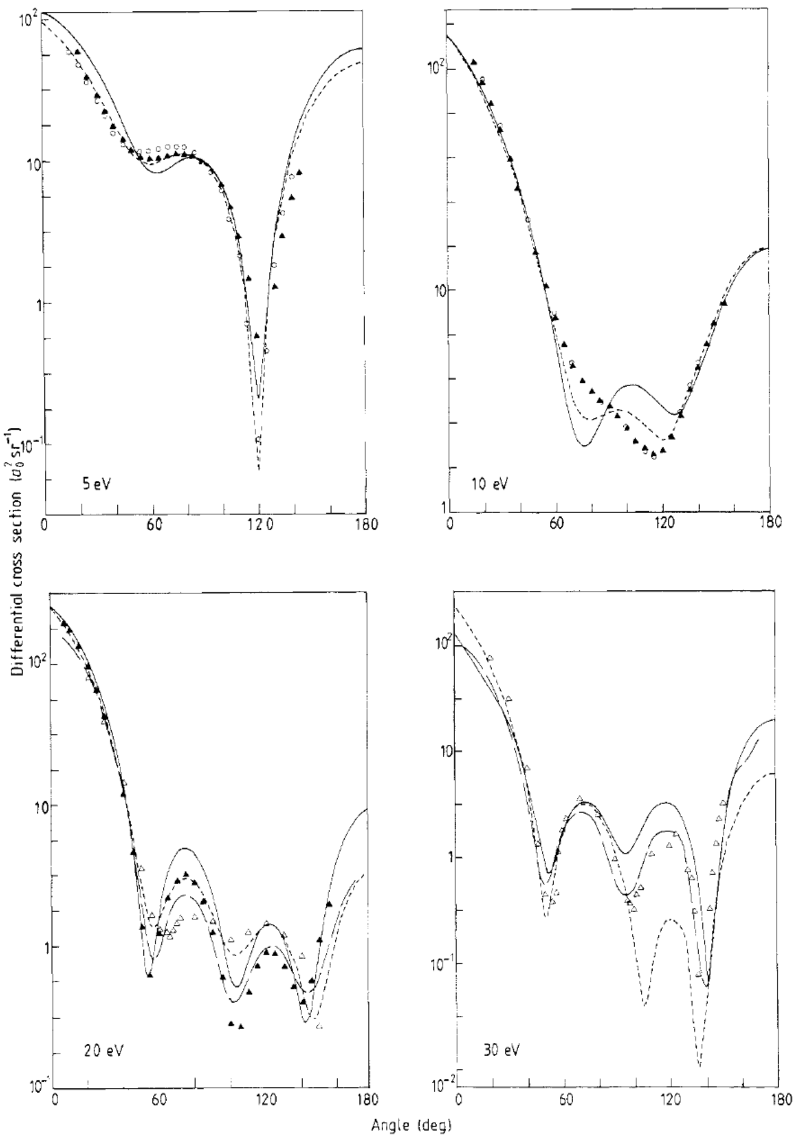

Figure 8. Differential cross sections for elastic scattering of electrons from xenon: ——, present results; — — —, McCarthy *et al* (1977); -----, Sin Fai Lam (1982); ▲, Jost (1982); ○, Register *et al* (1980); △, Williams and Crowe (1975).

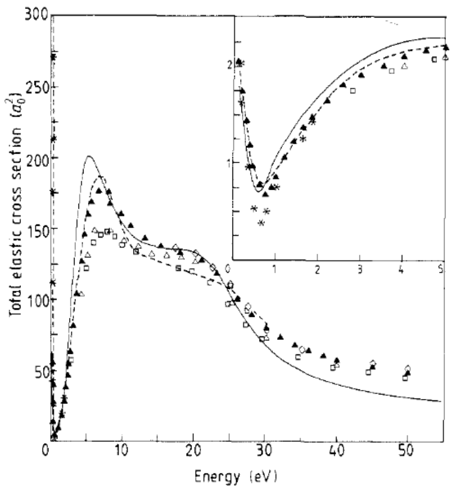

Figure 9. Total elastic cross sections for electron scattering from xenon: ——, present results; -----, Sin Fai Lam (1982); □, Dababneh *et al* (1980); ∗, Gus'kov *et al* (1978); ▲, Jost *et al* (1983); △, Nickel *et al* (1983); ◇, Wagenaar and de Heer (1980).

Bohr radius squared (units)

2.2 Inelastic

Most important reactions for EP. Includes excitation (bound-bound transition)

And ionization (bound-free transition)

Both reactions require a certain threshold amount of energy, called the excitation potential or ionization potential . In the above,

- An electron with energy greater or equal to the excitation or ionization potential
- An excited atom (bound electron boosted to higher-energy orbit)
- An ion (bound electron ejected from valence shell)

Typical excitation cross-sections for

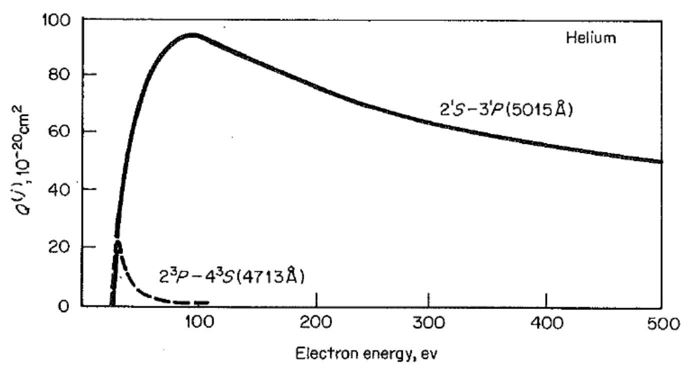

Fig. 4-5 Typical electron-atom excitation cross sections vs. energy. *(From L. Lees, Proc. Roy. Soc., ser. A, vol.* 137, *p.* 173, 1932.)

- "allowed" transition (by quantum mechanics rules) is the upper line; falls as
- "forbidden" transition is lower line; fall as

Note that cross-section drops to zero below ; simply conservation of energy (can't excite if impact energy is insufficient)

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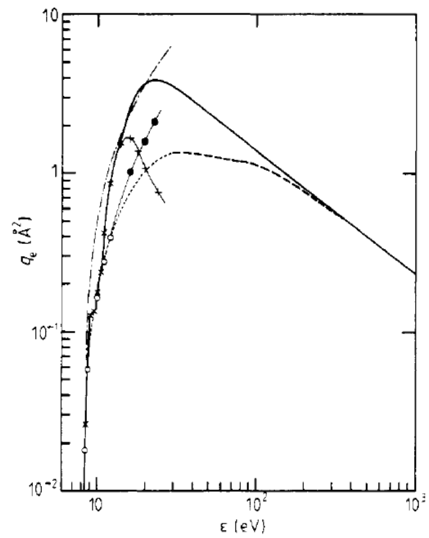


Figure 5. Total excitation cross-sections in xenon. $V_e = 8.32$ eV. (———–) Dixson and von Engel (1968); (—●—) Pfau and Rutscher (1969); (○) Schaper and Scheibner (1969); (+) Makabe and Mori (1978); (– – –) de Heer *et al* (1979); (- - - -) extrapolation between the values of Schaper and Scheibner (1969) and de Heer *et al* (1979); (×) Specht *et al* (1980); full curve, q_e recommended values.

Typical ionization cross-sections for

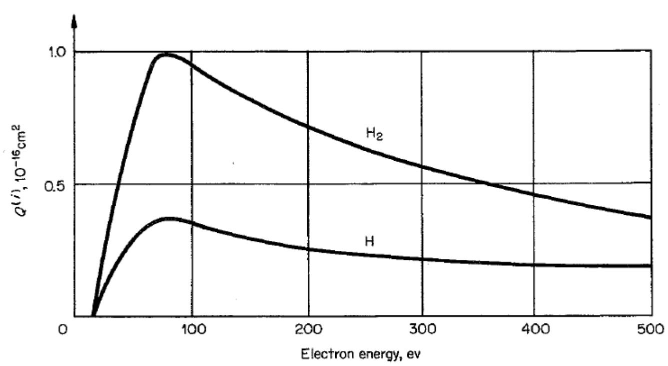
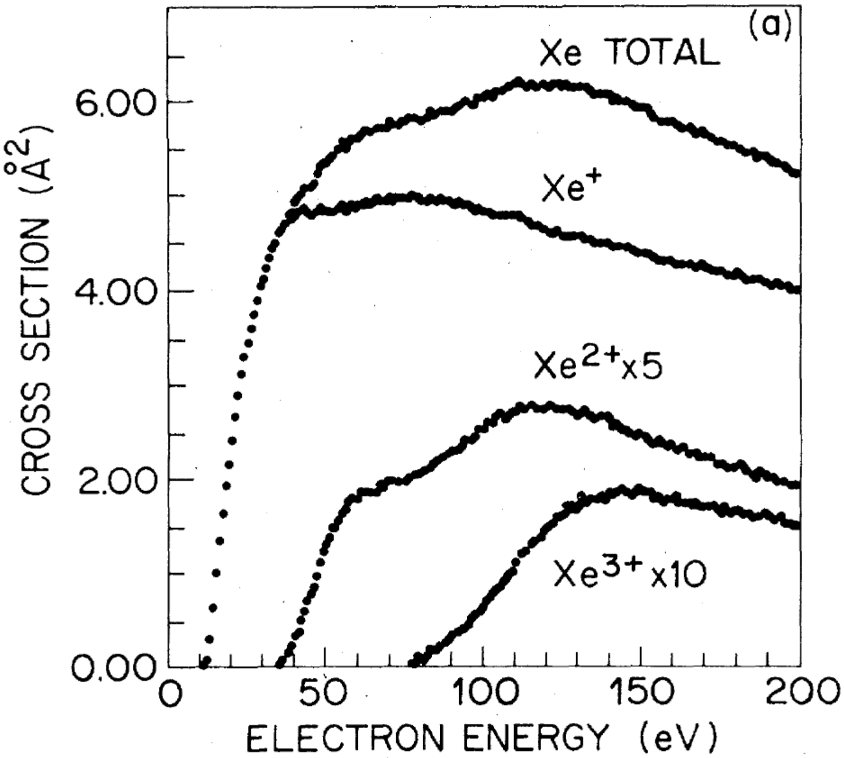


Fig. 4-6 Typical ionization cross sections vs. electron energy. *(From R. E. Fox, Westinghouse Elec. Corp., Res. Rept., 60-94439-4-R2, Aug. 15, 1956.)*

- Molecular hydrogen (upper line)
- Atomic hydrogen (lower line)



Robert C. Wetzel, Frank A. Baiocchi, Todd R. Hayes, and Robert S. Freund Phys. Rev. A 35, 559 ? Published 1 January 1987

Calculating the excitation and ionization rates: mean electron speed is almost always much higher than mean neutral speed.

So the collision rate in a gas with number density na, is

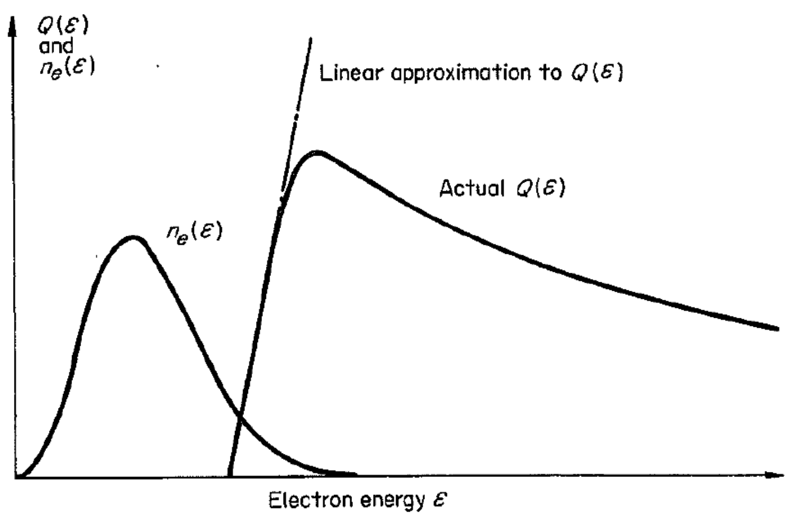


Fig. 4-7 Folding of inelastic cross section with electron energy distribution by linear approximation.

Fig 4-7 shows

- typical cross section Q
- Electron energy distribution function, (e.g., might be Maxwellian)
- EEDF tails off around the peak of Q , you can make a linear approximation in the collision rate integral (5.17)
- Also note, only the high-energy tail of the EEDF participates in these processes (e.g., excitation, ionization)