7-5-2005

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A. R.P. Rau
Louisiana State University

Recommended Citation

Rau, A. (2005). Historical notes on feshbach and shape resonances. *Physics Today, 58* (2), 13.
https://doi.org/10.1063/1.1897510

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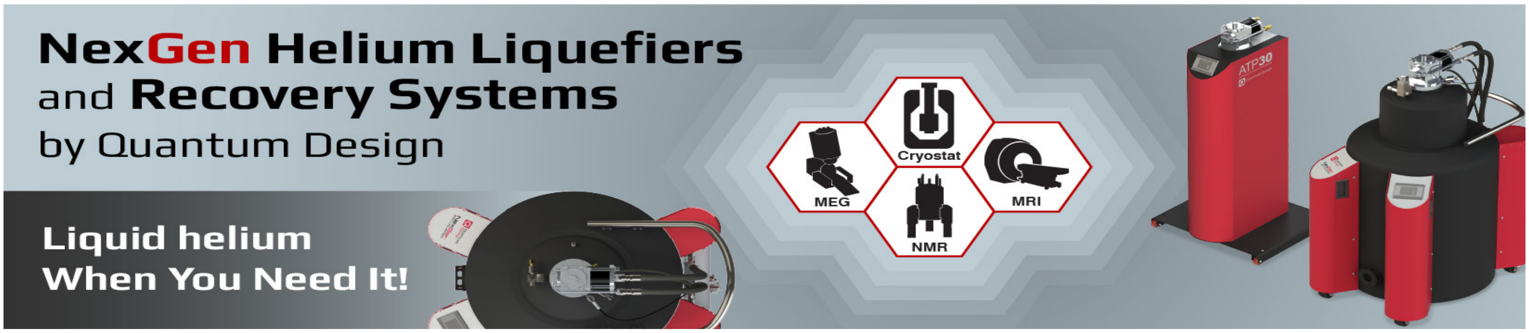
Citation: Physics Today **58**, 2, 13 (2005); doi: 10.1063/1.1897510
View online: https://doi.org/10.1063/1.1897510
View Table of Contents: https://physicstoday.scitation.org/toc/pto/58/2
Published by the American Institute of Physics



chemistry, notwithstanding all the good theoretical work performed in chemistry departments roughly since the publication of the distinguished text in 1935 by Linus Pauling and E. Bright Wilson, *Introduction to Quantum Mechanics: With Applications to Chemistry* (McGraw-Hill).

Burke Ritchie
Livermore, California

Historical Notes on Feshbach and Shape Resonances

In his interesting Reference Frame piece (PHYSICS TODAY, August 2004, page 12), Daniel Kleppner relates Herman Feshbach's reaction to the term "Feshbach resonance" and gives a capsule account of the topical and vital role this phenomenon plays in today's explorations of cold collisions of fermions and bosons, and of condensates of atoms and molecules. Readers may be interested in the earlier history and why atomic physicists began to use a term that Feshbach himself dismissed as jargon.

In the Los Alamos experiment of Howard Bryant's group on photoabsorption by the negative ion of hydrogen, two prominent resonances were seen at photon energies of about 10.95 eV. This energy marks the position of the first excited state of the hydrogen atom above the single bound state of the negative ion.

One narrow resonance occurs just below the threshold of that excitation, whereas the second, broad one occurs just above. Their physical mechanisms are different and, following the paradigm set by that historic experiment, it has become customary to refer to the two types of resonance, both common in atomic and molecular physics, as Feshbach and shape resonance, respectively. That is, a resonant coupling just below the relevant threshold, leading to narrow profiles, is distinguished from those lying just above the threshold to which they are most strongly coupled, and typically broad.

The two types of resonances are most naturally viewed in state and coordinate space, respectively. Feshbach resonances are thought of in terms of the superposition of two quantum states, one with discrete and one with continuum character, leading to a temporary quasi-bound state that manifests itself as a resonance in that continuum channel. The independent and almost simultaneous work in nuclear physics by Feshbach using the language of projection operators and in atomic physics by Ugo Fano using the language of superposition of wave functions serves for their technical description.

Shape resonances, on the other hand, may be associated with the shape of a trapping potential in real, coordinate space. Most often, the trapping potential is an angular momentum potential that combines with the internal one to create intervening barriers to low-energy particles. The resulting pictures often display "two-valley" potentials. In the case of the negative ion of hydrogen, such a barrier has been described in terms of the hyperspherical coordinates of that three-body system. Examples of such shape resonances abound in low-energy scattering of electrons from molecules.

For more discussion and references, including to recent applications in mesoscopic condensed matter systems, see my pedagogical mini-review in *Physica Scripta*, volume 69, page C10, 2004.

A. R. P. Rau
(arau@phys.lsu.edu)
Louisiana State University
Baton Rouge