lecture 21.10.2010

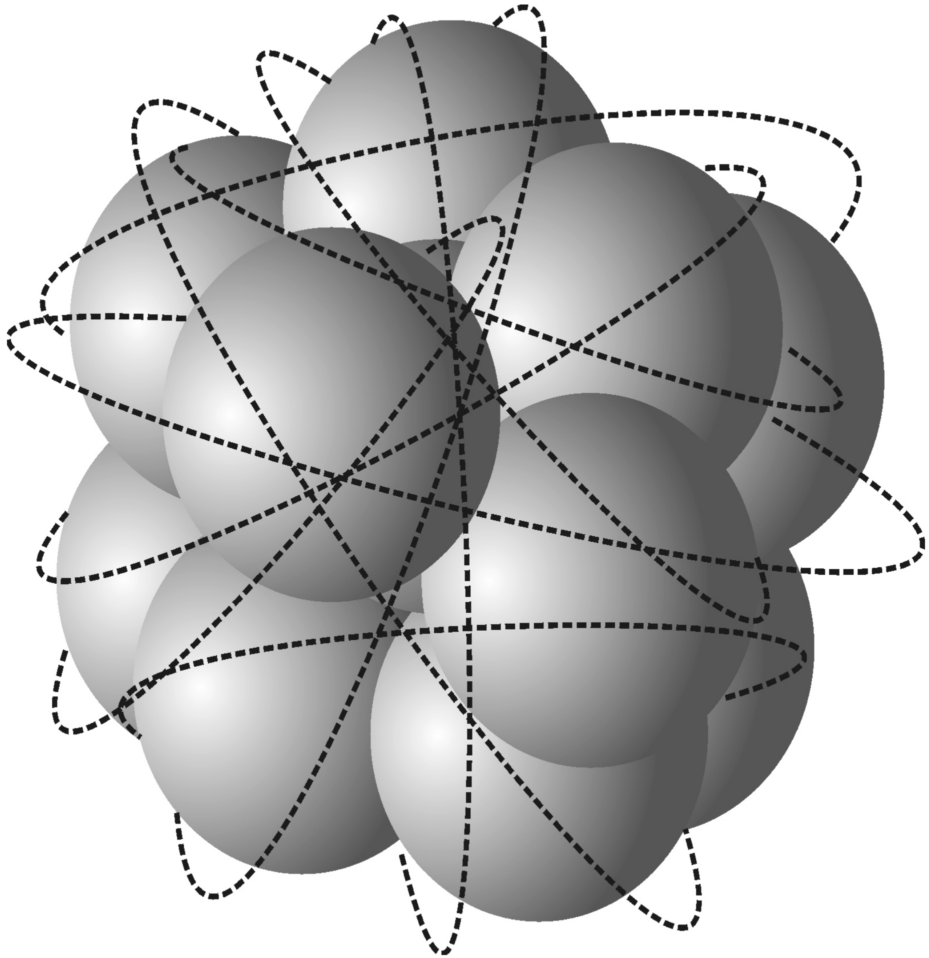
we had in the last week:

- introduction into atomic physics, relevance
- introduction into cluster physics

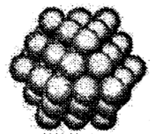
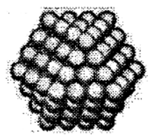
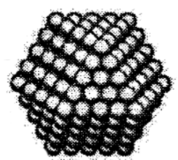
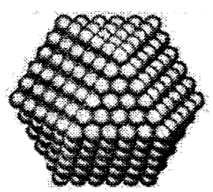
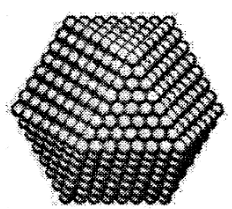
today:

- few more remarks on cluster physics
- atomic physics: history
- preparation of atomic beams
- selected examples with ultracold beams

A cluster of simple metal atoms can be considered as a metallic quantum dot. In the corresponding bulk materials the electrons need much more space.



size-dependence

Full-shell Clusters	Total Number of Atoms	Surface Atoms (%)
1 Shell 	13	92
2 Shells 	55	76
3 Shells 	147	63
4 Shells 	309	52
5 Shells 	561	45
7 Shells 	1415	35

Electronic shell structure of metal clusters

example: Al_N
3 electrons per atom

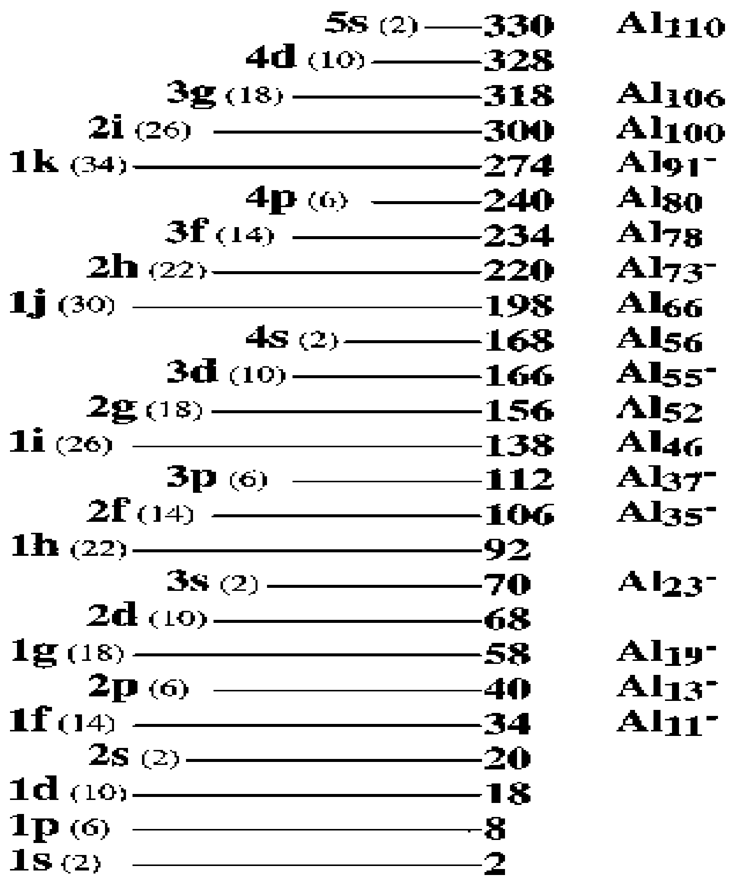


FIG. 1. Spherical shell closings and the corresponding closed shell neutral and negative clusters of trivalent Al. The number in the parentheses after each shell index indicates the occupation number, $2(2l + 1)$.

will be derived later in this lecture

photoelectron spectroscopy

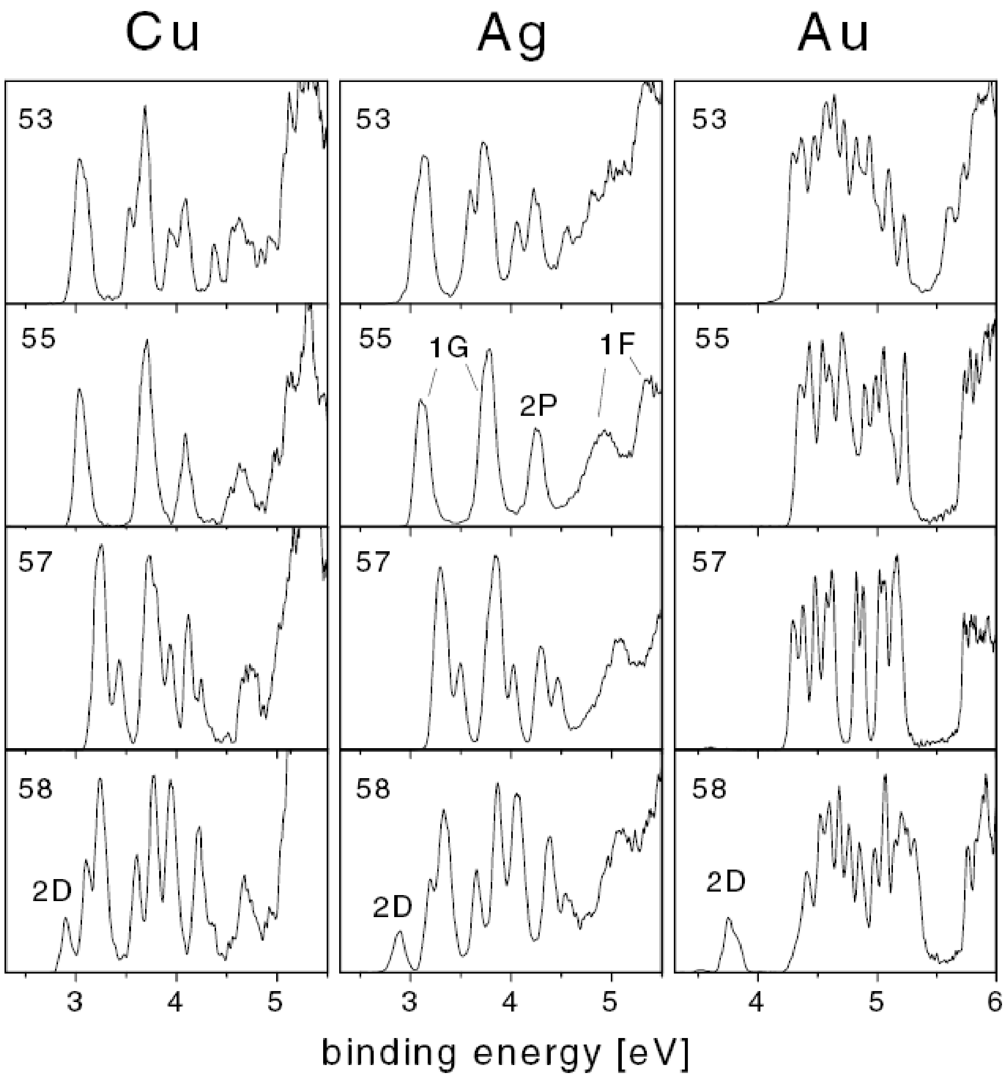
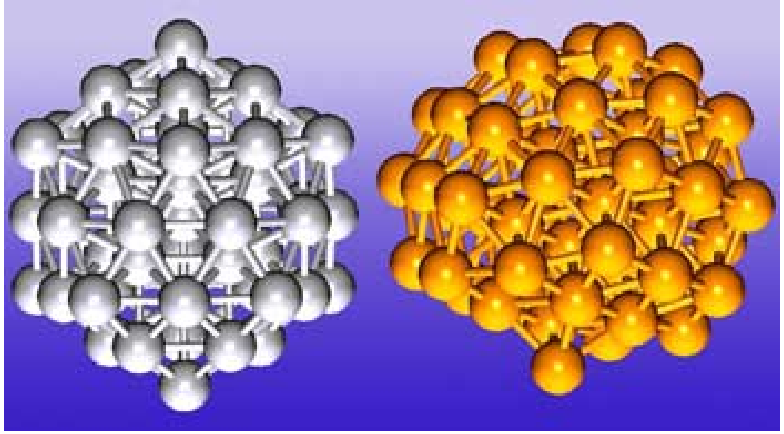


FIG. 1. Photoelectron spectra of Cu_n^-, Ag_n^-, and Au_n^- ($n =$ 53, 55, 57, 58) obtained at a photon energy of 6.42 eV.



Hakkinenet al., PRL 93 093401(2004)

beginning of atomic physics:

- Leuklipp 440 v Chr, Demokrit 460-370 v Chr
  ατομοσ   'completely undivisible' (gänzlich unteilbar).
  idea: outside the atom emty space
- Epikur 341-271 v Chr: atom -- gravity (Schwere)
- later the idea of 'atom' has been forgotten for centuries
- for the church the reinvention of the atom has been too materialistic; in 1348 Nicolas von Antrecourt had to retract (widerrufen) his ideas on the atomic nature
- break-through from the 17th century on mainly by chemists (weighing, reactants and products)
- 19. Jht. Clausius, Maxwell, Boltzmann: p, T, specific result from atomic cillisions

few historical key experiments

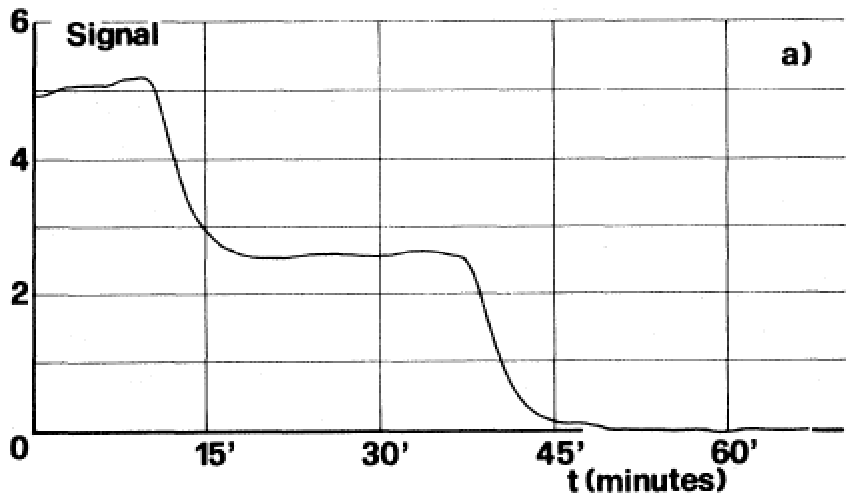
modern Millikan experiment **with magnetic levitation**

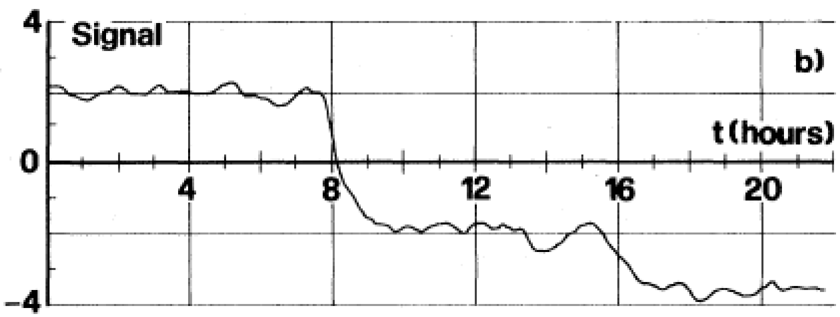
Electric Neutrality of Matter

G. Gallinaro, M. Marinelli, and G. Morpurgo
Istituto di Fisica, Università di Genova, Genova, Italy, and Istituto Nazionale di Fisica Nucleare—Sezione di Genova, Italy
(Received 18 April 1977)

With the use of a new feedback levitation electrometer (with an increase in sensitivity by 10^3 in comparison to our previous graphite experiments) iron objects of mass $\sim 2\times10^{-4}$ g have been explored for fractionally charged quarks and/or a possible electron-proton charge difference. Upper limits found were $N(\text{quarks})/N(\text{nucleons}) < 3\times10^{-21}$ and $(Q_p - |Q_e|)/Q_p < 10^{-21}$. The present "sensitivity" is $\sim 10^7$ times that of the original Millikan experiment.

VOLUME 38, NUMBER 22 PHYSICAL REVIEW LETTERS 30 MAY 1977





a) charges in the charge of a steel sphere with 3.3×10^{-5} g
Residual charge smaller than 1/40 e

b) rotating cylinder with 2.5×10^{-4} g.
Charge changes from +1 to -1 and -2

Results:

- upper limit N(quarks)/N(Nucleons) smaller than 3×10^{-21}
- $(Q_p-Q_e)/Q_p$ smaller than 10^{-21}
- sensitivity 10^7 times Millikan

Basics of atom (and molecular) spectroscopy - how to overcome effects of motion and collisions

one aim: to do undisturbed spectroscopy to learn, e.g., about line widths (lecture tomorrow by Prof. Bauer)

Doppler-reduced spectroscopy: blackboard script

Introduction to supersonic beam expansion: blackboard script

preparation of ultracold atomic beams
by supersonic jet expansion

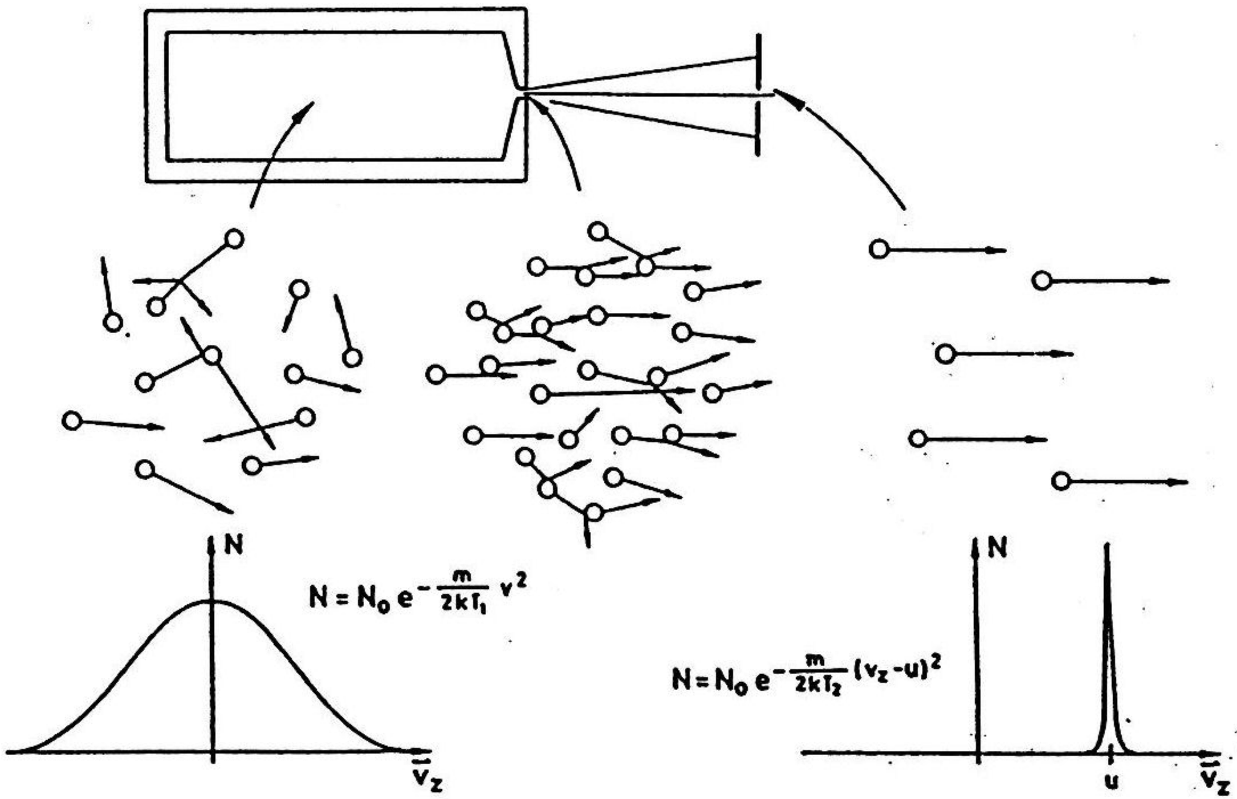


Fig. 8: Die mikroskopische Ursache für die Temperaturerniedrigung und Clusterbildung bei der adiabatischen Expansion [13]. Im Ausgangsbehälter herrscht vor der Expansion thermisches Gleichgewicht. Die ungerichtete Geschwindigkeitsverteilung der Teilchen ist durch die Maxwellverteilung bestimmt. Bei der Expansion des Gases durch eine Düse kommt es durch Stöße mit den anderen Gaspartikeln zur Abnahme der inneren Energie zu Gunsten der Expansionsgeschwindigkeit *u*. Die Relativgeschwindigkeit im kalten Molekularstrahl nimmt stark ab, wodurch die "kalten" Atome zu Clustern zusammenlagern.