

CY 722 Novel Materials

2004

Syllabus

Chemistry today: an overview- molecular materials, functional materials, nanomaterials, new techniques for microscopic investigation.

Clusters, gas phase spectroscopy, metallic clusters, tools for their study.

Fullerenes, discovery and electronic structure, spectroscopy, chemistry, derivatives, novel properties, superconductivity, orientational ordering, associated properties

Carbon nanotubes and onions, other forms of carbon.

Organic monolayers, LB films, self assembly, techniques to study thickness, molecular properties, chemistry with LB and SAM films, novel polymeric materials, conducting polymers.

Metal-carbon clusters, metallocarbohedrenes, gas phase chemistry.

Semiconductor nanocrystals, quantum dots, electronic structure, spectroscopy.

Mesoporous solids, new materials for catalysis.

Single molecule chemistry.

Functional molecular systems.

References: Current periodicals.

Lecture schedule

Lecture 1. Chemistry then and now: historical introduction to chemical discoveries. Modern aspects of discovery.

Instrumentation

Lectures 2-10. Essential tools for modern chemistry outside regular classrooms

Vacuum technology – general principles

UHV instrumentation

Electron microscopic techniques

Supersonic nozzle beam spectroscopy

Mass spectrometry and modern advances

Scanning probe microscopies

Electron spectroscopies

Essential vibrational spectroscopies

Intense photon sources and modern tools

Assorted techniques for material characterisation:

Transport properties, solid state structure, surface structure, surface area, etc.

Lectures 11-15: Fullerenes, nanotubes and other forms of carbon

Lectures 16-20: Clusters

Lectures 21-25: Nanomaterials

Lectures 26-30: Monolayers

Lectures 31-40: New materials and properties (guest lectures)

Biomaterials

Advances in Polymeric Materials

Thermal Transport in Nanofluids

Advances in Photonic Materials

Ionic liquids

Organic conductors

Porous silicon

Lecture 40-42: New materials and new phenomena, recent advances

Topics for presentations

1. Ionic liquids
2. Sol-gel method for nanomaterials
3. Inorganic fullerenes
4. Diamond like carbon
5. Combinatorial inorganic chemistry
6. Computational materials science
7. Microwave synthesis of inorganic solids
8. Photocatalysis with nanoparticles
9. Catalysis with size selected clusters
10. DNA-tagged nanoparticles
11. Nano: Bio synthesis
12. Inorganic biomimetics
13. Soft synthesis of solids
14. Supramolecular chemistry

First presentation starts on 2nd week of February

1. Presentation for 30 minutes.
2. Questions for 30 minutes.
3. Presentations to be ready in powerpoint format on the day of the seminar.
4. Presentation materials to be xeroxed, made into a file and submitted.
5. Presentations to be based on at least 5 most recent papers of high impact factor.
6. You are expected to know the peripheral subject areas.
7. Presentations constitute 40% of the total marks.
8. Presentations may have to be repeated, if not done properly.

General rules of the course

If you are not available, please inform over email.

If you are late, please do not come for the class.

If you plan to miss more than 3 lectures, please do not take the course.

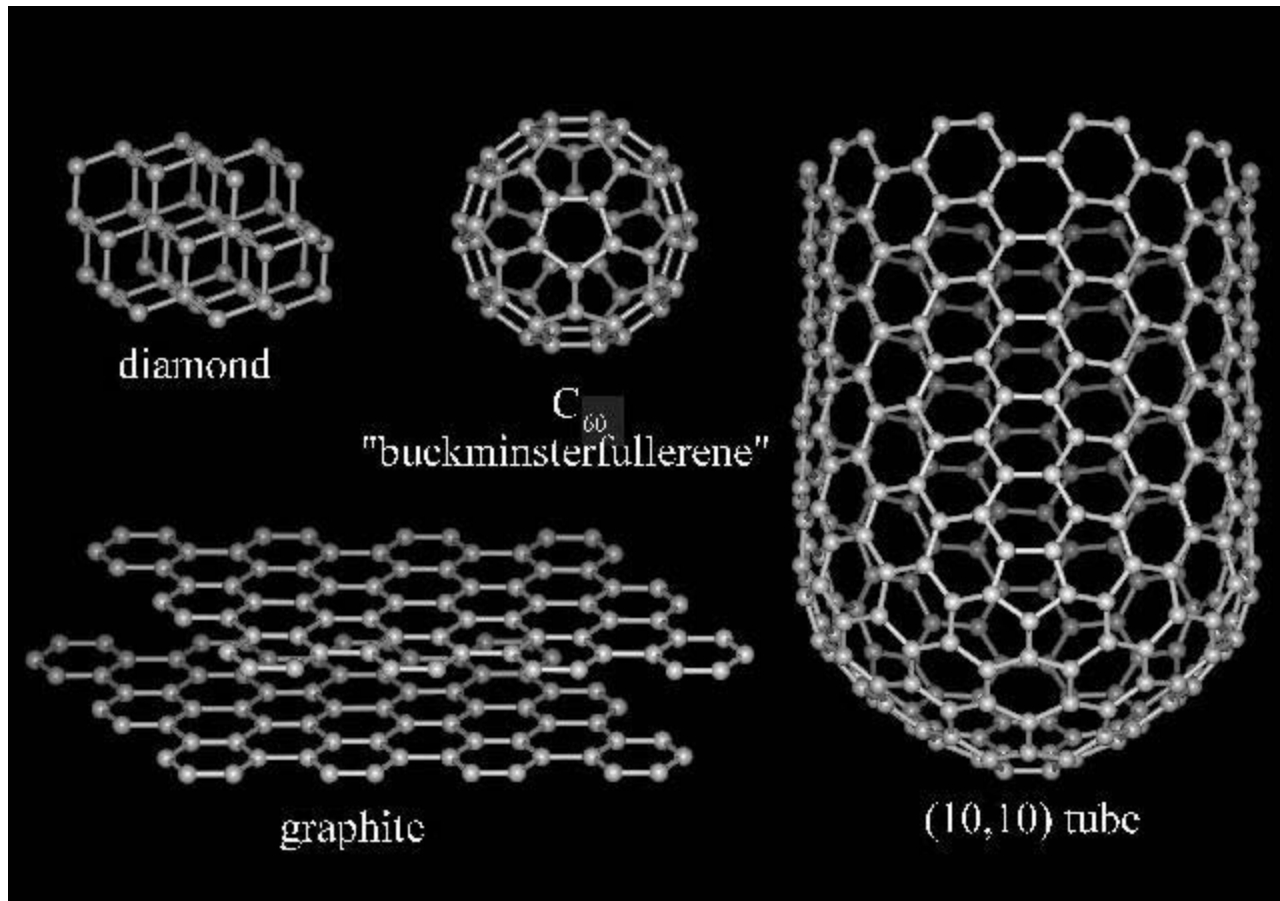
Acronym	Technique
<u>AEAPS</u>	Auger Electron Appearance Potential Spectroscopy
<u>AES</u>	Auger Electron Spectroscopy
<u>AFM</u>	Atomic Force Microscopy
<u>APECS</u>	Auger Photoelectron Coincidence Spectroscopy
<u>APFIM</u>	Atom Probe Field Ion Microscopy
<u>APS</u>	Appearance Potential Spectroscopy
<u>ARPES</u>	Angle Resolved Photoelectron Spectroscopy
<u>ARUPS</u>	Angle Resolved Ultraviolet Photoelectron Spectroscopy
<u>ATR</u>	Attenuated Total Reflection
<u>BEEM</u>	Ballistic Electron Emission Microscopy
<u>BIS</u>	Bremsstrahlung Isochromat Spectroscopy
<u>CFM</u>	Chemical Force Microscopy
<u>CHA</u>	Concentric Hemispherical Analyser
<u>CMA</u>	Cylindrical Mirror Analyser
<u>CPD</u>	Contact Potential Difference
<u>CVD</u>	Chemical Vapour Deposition
<u>DAFS</u>	Diffraction Anomalous Fine Structure
<u>DAPS</u>	Disappearance Potential Spectroscopy
<u>DRIFT</u>	Diffuse Reflectance Infra-Red Fourier Transform
<u>EAPFS</u>	Extended Appearance Potential Fine Structure
<u>EDX</u>	Energy Dispersive X-ray Analysis
<u>EELS</u>	Electron Energy Loss Spectroscopy
	Ellipsometry, see <u>RDS</u>
<u>EMS</u>	Electron Momentum Spectroscopy
<u>EPMA</u>	Electron Probe Micro-Analysis
<u>ESCA</u>	Electron Spectroscopy for Chemical Analysis
<u>ESD</u>	Electron Stimulated Desorption
<u>ESDIAD</u>	Electron Stimulated Desorption Ion Angle Distributions
<u>EXAFS</u>	Extended X-ray Absorption Fine Structure
<u>FEM</u>	Field Emission Microscopy
<u>FIM</u>	Field Ion Microscopy
<u>FTIR</u>	Fourier Transform Infra Red
<u>FT RA-IR</u>	Fourier Transform Reflectance-Absorbance Infra Red

<u>HAS</u>	Helium Atom Scattering
<u>HDA</u>	Hemispherical Deflection Analyser
<u>HEIS</u>	High Energy Ion Scattering
<u>HREELS</u>	High Resolution Electron Energy Loss Spectroscopy
<u>IETS</u>	Inelastic electron tunneling spectroscopy
<u>KRIPES</u>	k-Resolved Inverse Photoemission Spectroscopy
<u>ILS</u>	Ionisation Loss Spectroscopy
<u>INS</u>	Ion Neutralisation Spectroscopy
<u>IPES</u>	Inverse Photoemission Spectroscopy
<u>IRAS</u>	Infra-Red Absorbption Spectroscopy
<u>ISS</u>	Ion Scattering Spectroscopy
<u>LEED</u>	Low Energy Electron Diffraction
<u>LEEM</u>	Low Energy Electron Microscopy
<u>LEIS</u>	Low Energy Ion Scattering
<u>LFM</u>	Lateral Force Microscopy
<u>MBE</u>	Molecular Beam Epitaxy
<u>MBS</u>	Molecular Beam Scattering
<u>MCXD</u>	Magnetic Circular X-ray Dichroism
<u>MEIS</u>	Medium Energy Ion Scattering
<u>MFM</u>	Magnetic Force Microscopy
<u>MIES</u>	Metastable Impact Electron Spectroscopy
<u>MIR</u>	Multiple Internal Reflection
<u>MOCVD</u>	Metal Organic Chemical Vapour Deposition
<u>MOKE</u>	Magneto-Optic Kerr Effect
<u>NIXSW</u>	Normal Incidence X-ray Standing Wave
<u>NEXAFS</u>	Near-Edge X-ray Absorption Fine Structure
<u>NSOM</u>	Near Field Scanning Optical Microscopy
<u>PAES</u>	Positron annihilation Auger Electron Spectroscopy
<u>PECVD</u>	Plasma Enhanced Chemical Vapour Deposition
<u>PEEM</u>	Photo Emission Electron Microscopy
<u>Ph.D.</u>	Photoelectron Diffraction
<u>PIXE</u>	Proton Induced X-ray Emission
<u>PSD</u>	Photon Stimulated Desorption

<u>RAIRS</u>	Reflection Absorbtion Infra-Red Spectroscopy
<u>RAS</u>	Reflectance Anisotropy Spectroscopy
<u>RBS</u>	Rutherford Back Scattering
<u>RDS</u>	Reflectance Difference Spectroscopy
<u>REFLEXAFS</u>	Reflection Extended X-ray Absorption Fine Structure
<u>RFA</u>	Retarding Field Analyser
<u>RHEED</u>	Reflection High Energy Electron Diffraction
<u>RIFS</u>	Reflectometric Interference Spectroscopy
<u>SAM</u>	Scanning Auger Microscopy
<u>SEM</u>	Scanning Electron Microscopy
<u>SEMPA</u>	Scanning Electron Microscopy with Polarisation Analysis
<u>SERS</u>	Surface Enhanced Raman Scattering
<u>SEXAFS</u>	Surface Extended X-ray Absorption Spectroscopy
<u>SHG</u>	Second Harmonic Generation
<u>SH-MOKE</u>	Second Harmonic Magneto-Optic Kerr Effect
<u>SIMS</u>	Secondary Ion Mass Spectrometry
<u>SKS</u>	Scanning Kinetic Spectroscopy
<u>SMOKE</u>	Surface Magneto-Optic Kerr Effect
<u>SNMS</u>	Sputtered Neutral Mass Spectrometry
<u>SNOM</u>	Scanning Near Field Optical Microscopy
<u>SPIPES</u>	Spin Polarised Inverse Photoemission Spectroscopy
<u>SPEELS</u>	Spin Polarised Electron Energy Loss Spectroscopy
<u>SPLEED</u>	Spin Polarised Low Energy Electron Diffraction
<u>SPM</u>	Scanning Probe Microscopy
<u>SPR</u>	Surface Plasmon Resonance
<u>SPUPS</u>	Spin Polarised Ultraviolet Photoelectron Spectroscopy
<u>SPXPS</u>	Spin Polarised X-ray Photoelectron Spectroscopy
<u>STM</u>	Scanning Tunnelling Microscopy
<u>SXAPS</u>	Soft X-ray Appearance Potential Spectroscopy
<u>SXRD</u>	Surface X-ray Diffraction
<u>TDS</u>	Thermal Desorption Spectroscopy
<u>TEAS</u>	Thermal Energy Atom Scattering
<u>TIRF</u>	Total Internal Reflectance Fluorescence
<u>TPD</u>	Temperature Programmed Desorption
<u>TPRS</u>	Temperature Programmed Reaction Spectroscopy
<u>TXRF</u>	Total Reflection X-ray Fluorescence
<u>UHV</u>	Ultra High Vacuum
<u>UPS</u>	Ultraviolet Photoemission Spectroscopy
<u>XANES</u>	X-ray Absorption Near-Edge Structure
<u>XPD</u>	X-ray Photoelectron Diffraction
<u>XPS</u>	X-ray Photoemission Spectroscopy
<u>XRR</u>	X-ray Reflectometry
<u>XSW</u>	X-ray Standing Wave

Lecture 1

The process of scientific discovery: Then and Now



Allotropes of carbon

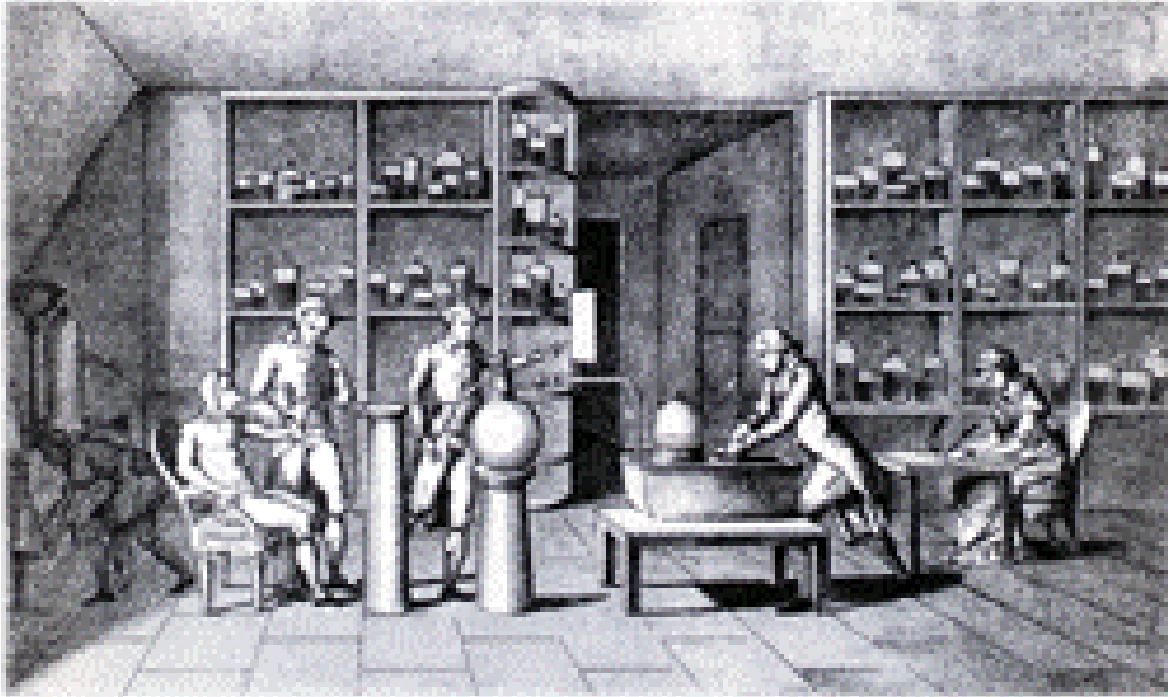
Essay on a Manner of Determining the Relative Masses of the Elementary Molecules of Bodies, and the Proportions in Which They Enter into These Compounds, Amedeo Avogadro, *Journal de Physique* 73, 58-76 (1811)

The first hypothesis to present itself in this connection, and apparently even the only admissible one, is the supposition that the number of integral molecules in any gases is always the same for equal volumes, or always proportional to the volumes. Indeed, if we were to suppose that the number of molecules contained in a given volume were different for different gases, it would scarcely be possible to conceive that the law regulating the distance of molecules could give in all cases relations as simple as those which the facts just detailed compel us to acknowledge between the volume and the number of molecules.

Memoir on the Nature of the Principle which Combines with Metals during their Calcination and which Increases their Weight

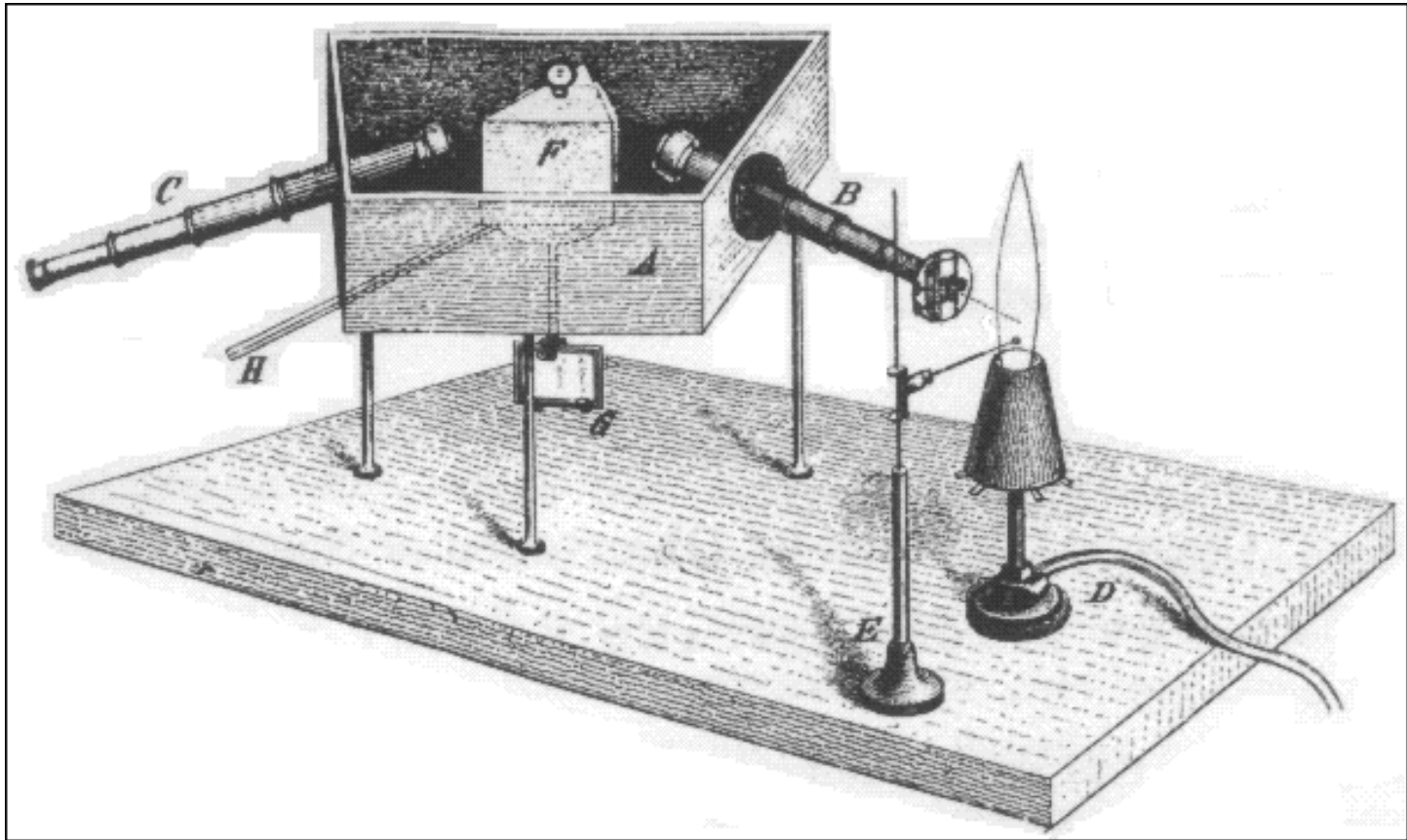
Antoine Laurent Lavoisier, Mémoires de l'Académie Royale des Sciences for 1775, 520-6 (published in 1778).

.....and I will confine myself today to a particular case and limit myself to showing that the principle which combines with metals during their calcination, which increases their weight and constitutes them in the state of a calx, is nothing other than the most salubrious and purest portion of the air and such that, if the air, after having engaged in a metallic combination, becomes free again, it appears in an eminently respirable state more capable than the air of the atmosphere of sustaining ignition and combustion.



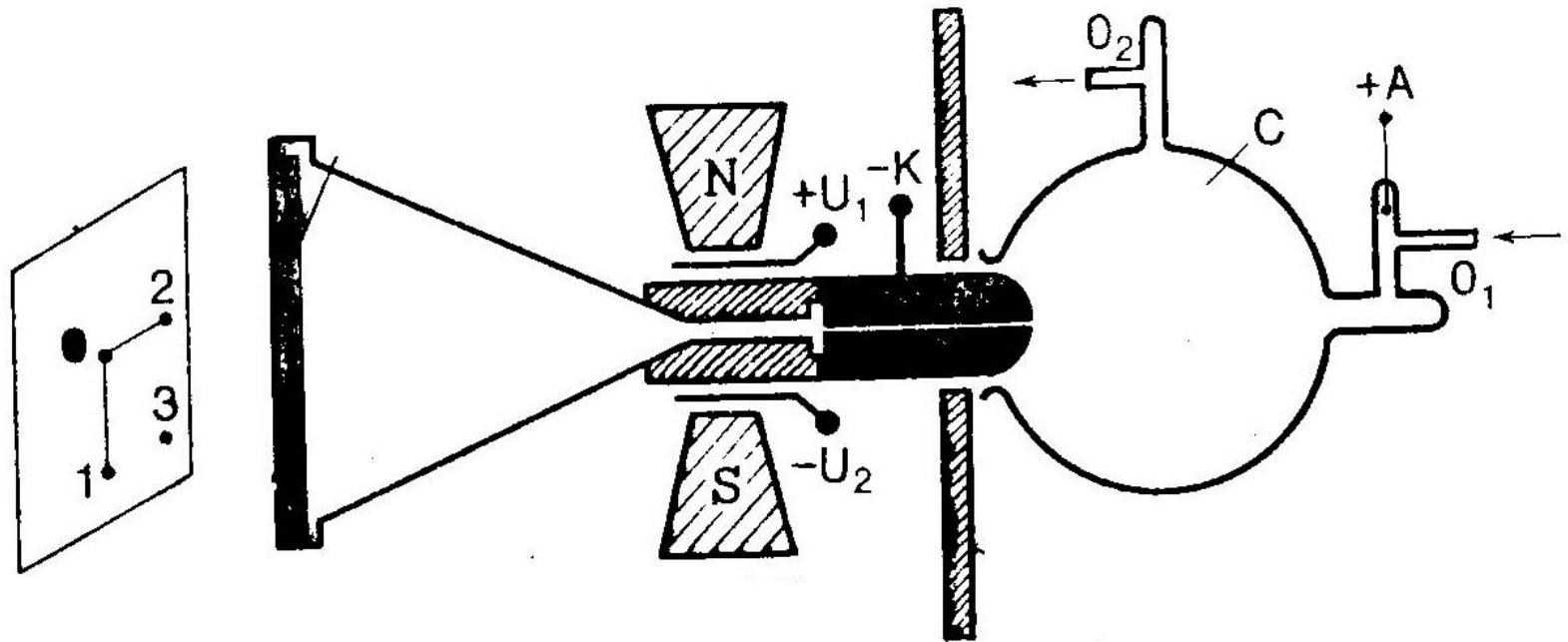
Laoisier's laboratory

First, to assure myself that precipitated mercury per se was a genuine metallic calx, that it gave the same results, the same species of air on reduction according to the ordinary method (that is, to use the customary expression, with the addition of phlogiston), I mixed an once of this calx with 48 grains of powdered charcoal and introduced the mixture into a little glass retort of 2 cubic *pouces* or more capacity. This I placed in a reverberatory furnace of proportionate size. The neck of this retort was about a pie and 3 to 4 lignes in diameter and was bent in various places by means of an enameler's lamp in such a manner that its end was disposed beneath an ample glass bell filled with water **and inverted in a tub of the same. The apparatus which is here before the eyes of the Academy will suffice to illustrate its operation.** This apparatus, simple as it is, is even more accurate in that it has neither joints nor lute nor any passage through which the air may escape.....



Bunsen's spectrograph

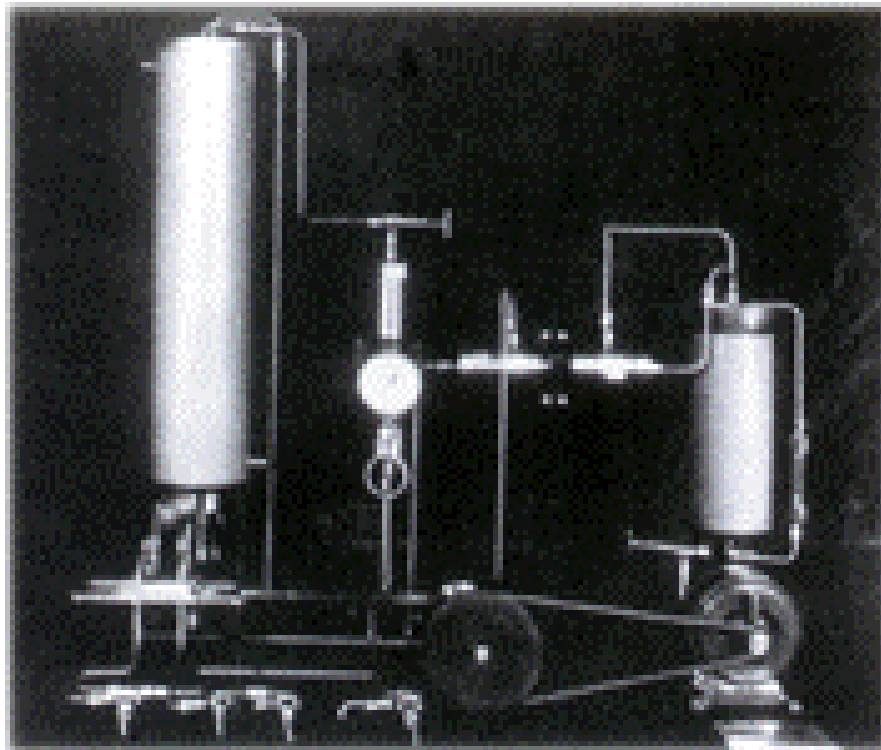
Figure 3-1 shows the apparatus we used for the observation of spectra. A is an internally blackened box with a trapezoidal bottom resting on three legs; the two oblique side walls, which form an angle of about 58° with each other, carry the two small telescopes B and C. The eyepiece of the first is removed and replaced by a plate in which a slit formed by two brass edges is adjusted at the focus of the objective lens. The lamp D is arranged before the slit so that the rim of the flame is on the axis of tube B. Somewhat below the spot where the axis meets the rim, there is the end of the loop formed in a fine platinum wire, which is held by arm E. The little pearl of the dry chlorine compound to be investigated is melted to this loop. Between the objective lenses of telescopes B and C is the hollow prism F of 60° refractive angle; it is filled with carbon disulphide. The prism rests on a brass plate that can be rotated on a vertical axis.



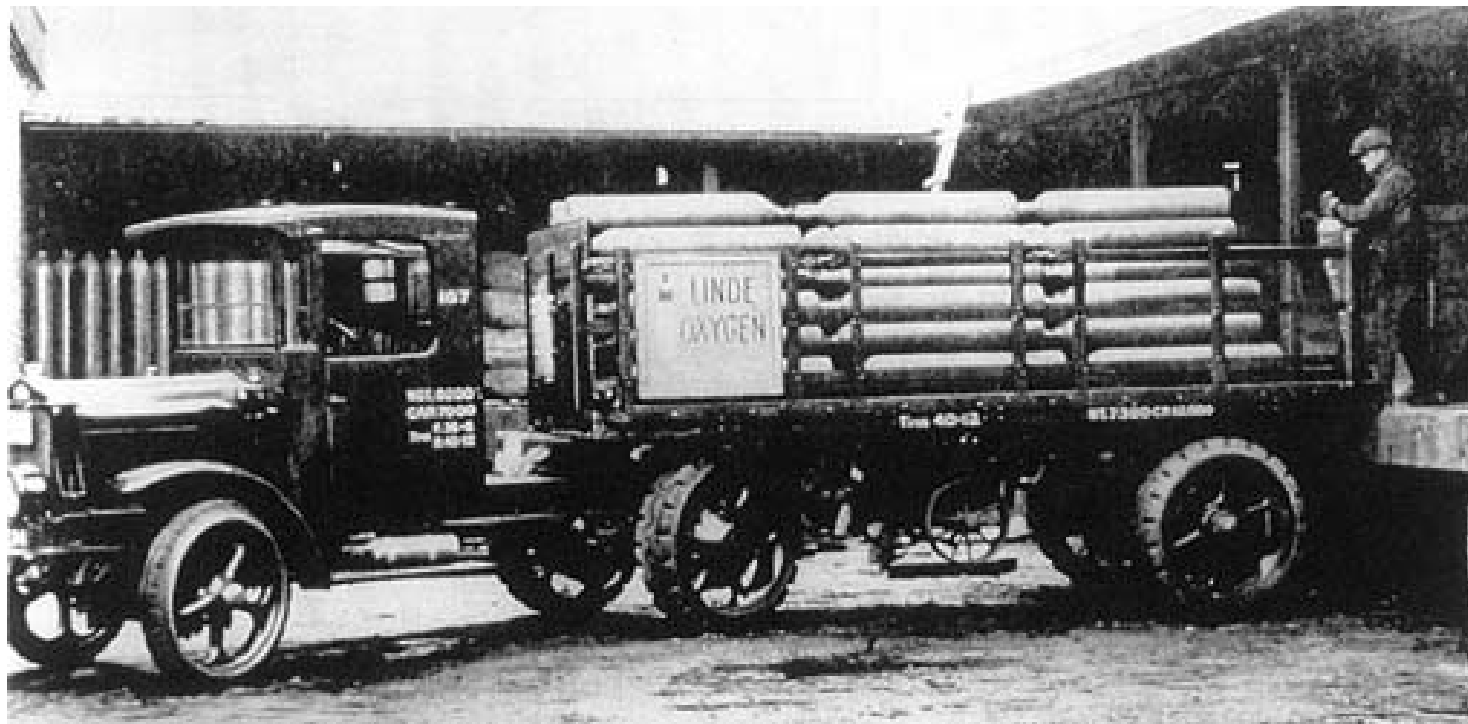
Thomson's mass spectrometer



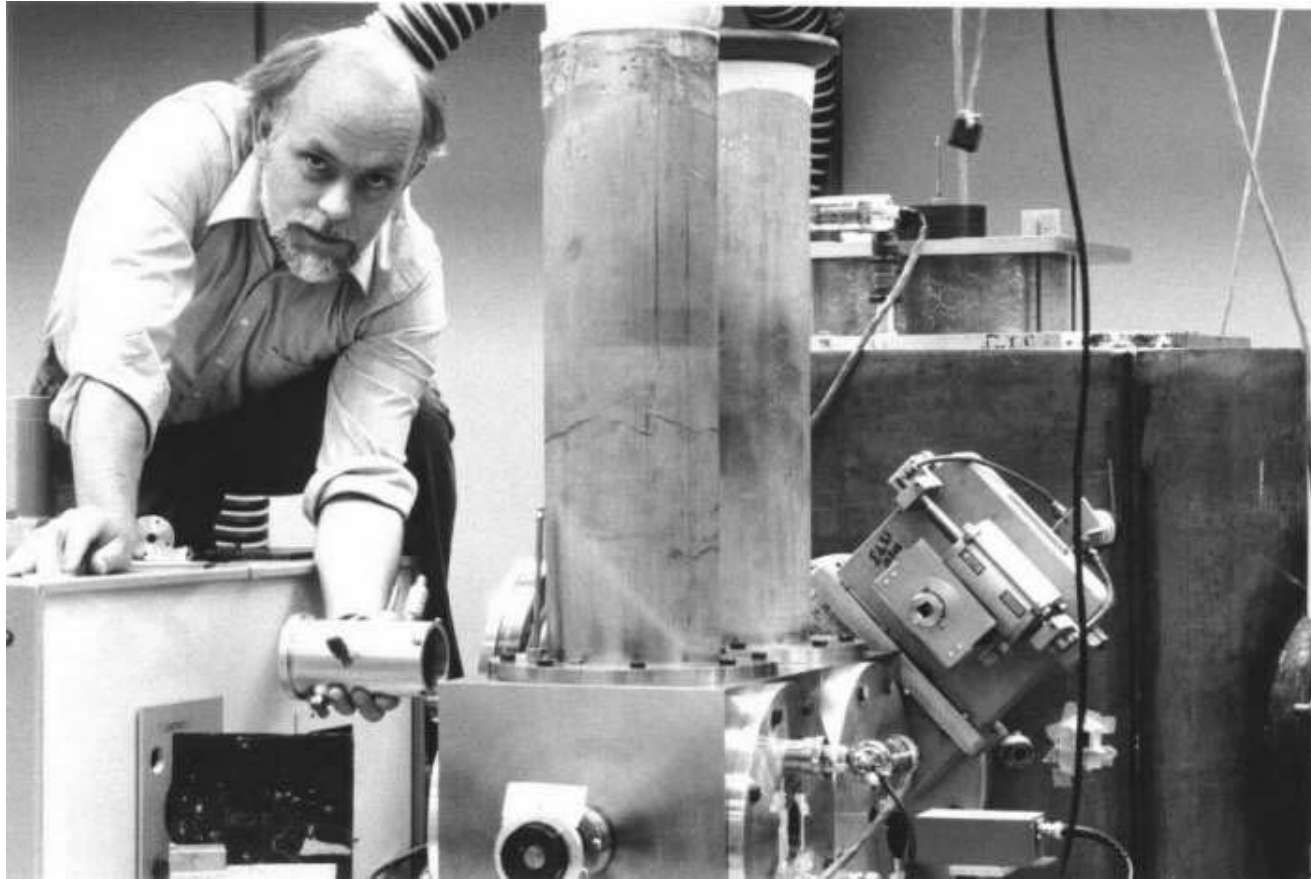
Aston's mass spectrometer



Haber's ammonia production apparatus.



Linde's oxygen cylinders



Smalley's machine

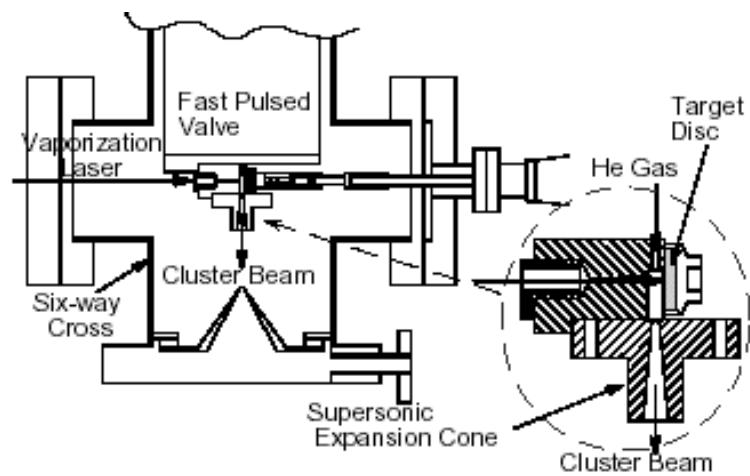


Fig. 1 Schematics of cluster beam source apparatus

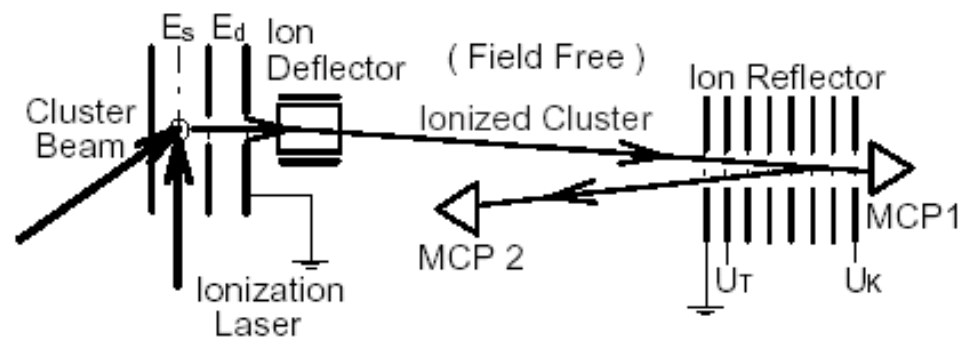


Fig. 2 Schematics of reflectron TOF mass spectrometer



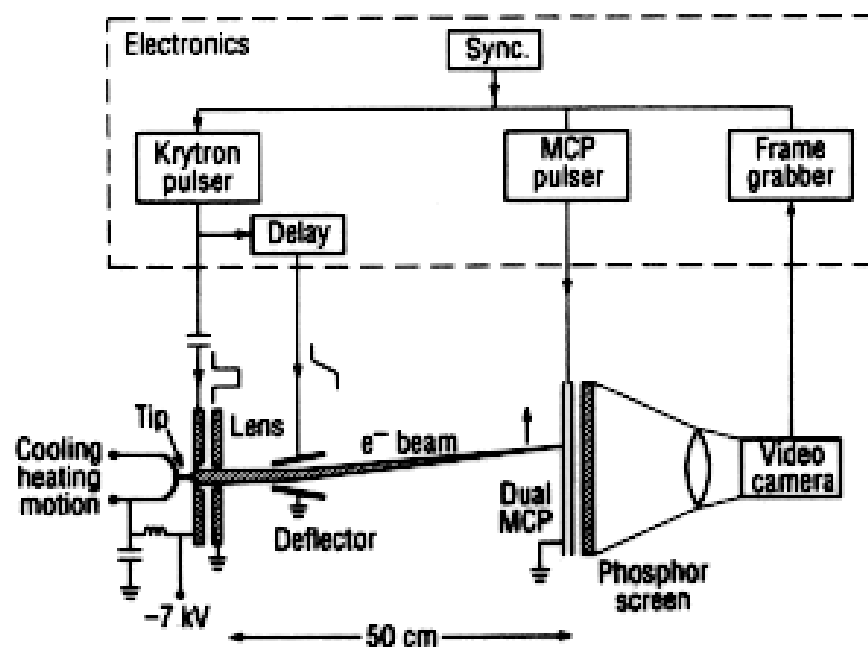
A typical modern day TOF-MS lab

Real-Time Observation of the Vibration of a Single Adsorbed Molecule

Fumiya Watanabe, Gary M. McClelland, Harry Heizelmann
IBM Research Division, Almaden Research Center, San
Jose, CA 95120

The newly developed femtosecond field emission camera was used to observe the time dependence of field emission through a single copper phthalocyanine molecule adsorbed on a tungsten tip. In many of the individual 212-picosecond-long recordings, the field emission was found to oscillate with a frequency between 5×10^{10} and 20×10^{10} hertz. The oscillations, which were not observed from a bare tip, are believed to arise from the vibration of a single molecule with respect to the surface. Numerical simulations confirmed the statistical significance of the data. SCIENCE VOL. 262 PP.1244-1247 19 NOVEMBER 1993

Fig. 2. The femtosecond field emission camera is shown here not to scale; the tip-lens distance is 0.7 cm. Field emission is temporally resolved by sweeping the electron beam across the screen. MCP, microchannel plate; Sync., synchronizing pulse.



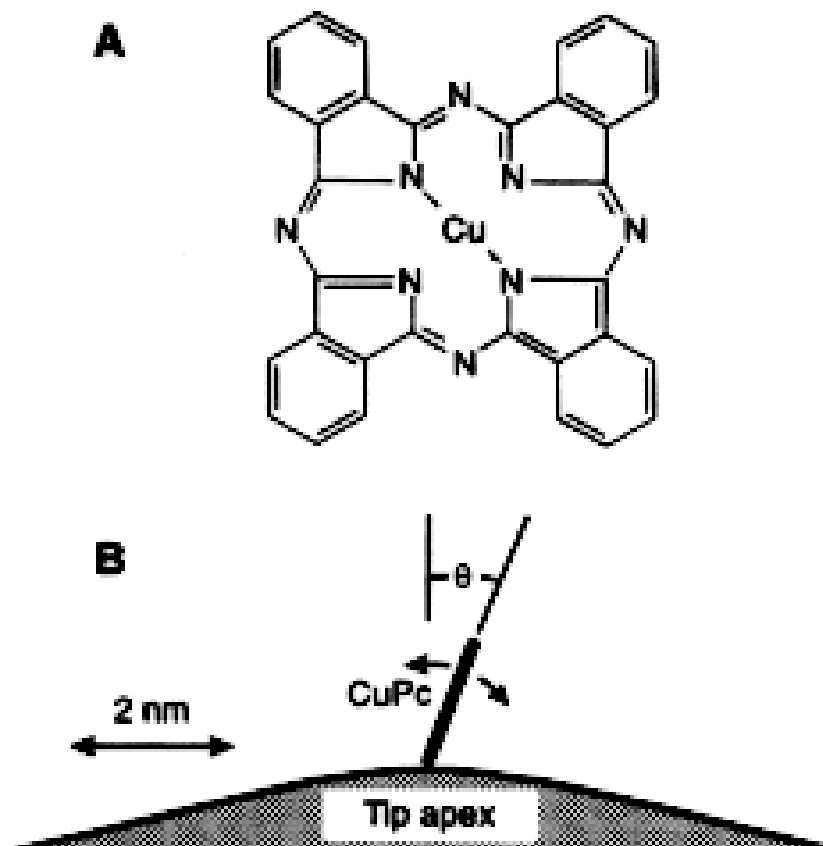


Fig. 3. (A) The CuPc molecule. (B) Schematic of a CuPc molecule (viewed edgewise) adsorbed on the end of a tungsten tip, showing a possible observed vibrational motion. The perpendicular orientation is energetically favored by high electric fields.

Summary

Science at the frontiers of discovery requires new instrumentation and experimental brilliance makes breakthroughs. Adaptation of instrumentation to new objectives has always been central to science. The process of discovery is even more difficult today.