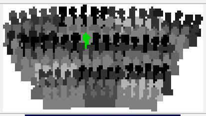
Contributions to Human Knowledge, References, Activities

PHYSICAL SCIENCES

	Nobel Prize awarded every year for Physics and Chemistry
	Membership: *Was Member, American Physical Society, New York* *Member, Institute of Physics, London & Chartered Physicist (see copy)* *Member, Indian Physics Association, Mumbai, India* *Active Member, The New York Academy of Sciences (see copy)*

SPECIALIZATION IN DIATOMIC MOLECULAR SPECTROSCOPY

DISCOVERY OF NSe MOLECULE
REFERENCES

Electronic Spectrum of NSe

K.V. Subbaram and D. Ramachandra Rao

Chemical Physics Letters (Netherlands), Vol.4, No. 10, pp. 653-655 (1970)

A2π — X2π system of 14N 80Se and 14N 78Se

K.V. Subbaram and D. Ramachandra Rao

Journal of Molecular Spectroscopy *(USA), Vol.36, pp. 163-182 (1970)*

DISCOVERY OF TWO NEW BAND SYSTEMS IN N_2 MOLECULE

References

Two New Band Systems in the Near Ultraviolet Spectrum of N_2

P.K. Carroll and K.V. Subbaram

Canadian Journal of Physics (Special Issue dedicated to Dr. G. Herzberg, *Nobel Laureate*, *Chemistry*, 1978, on the occasion of his *70th* birthday), Vol. *53*, No. *19*, pp. *2198-2209* (*1975*)

FURTHER, THE WORK WAS INCLUDED AS SEC. 3.9 IN

The Spectrum of Molecular Nitrogen

Alf Lofthus and Paul H. Krupenie

Journal of Physical and Chemical Reference Data, Vol. 6, No.*1*, p. *136* (*1977*)

Published by the *American Chemical Society and the American Institute of Physics for the National Bureau of Standards*, Washington D.C., *USA*

Follow-Up Research Work

The work on *Two New Band Systems in the Near Ultraviolet Spectrum of* N_2 was followed up by Professor R.S.Mulliken (*Nobel laureate*, *Chemistry*, *1966*), as given below:

PRE-DISSOCIATION AND Λ-DOUBLING IN THE EVEN-PARITY RYDBERG STATES OF THE NITROGEN MOLECULE

Robert S. Mulliken (*Nobel Laureate*), *Department of Chemistry*, *University of Chicago*, Chicago, Illinois *60637*

Journal of Molecular Spectroscopy, Vol. *61*, pp. *92-99* (*1976*)

and another paper by the same author follows the above paper in the said journal.

JOURNAL OF MOLECULAR SPECTROSCOPY 61, 92-99 (1976)

Predissociation and Λ-Doubling in the Even-Parity Rydberg States of the Nitrogen Molecule

ROBERT S. MULLIKEN Nobel laureate

Department of Chemistry, University of Chicago, Chicago, Illinois 60637

Predissociations in the $y\ ^1\Pi_g$ and $x\ ^1\Sigma_g^-$ Rydberg states of N_2 (configurations $1\pi_u^{-1}4p\sigma$ and $1\pi_u^{-1}3p\pi$, respectively) and their likely causes, are discussed. Peaking of rotational intensity at unusually low J values, without sharp breaking off, is interpreted as due to case c^- or case c^+ predissociation. Λ doubling in the y state, attributed to interactions with the $x\ ^1\Sigma_g^-$ state and with another, $^1\Sigma^+$, state of the same electron configuration as x, is analyzed. From this analysis the location of the (unobserved) $^1\Sigma_g^+$ state, here labeled x', is obtained. It is concluded that the predissociation in the Π^+ levels of the y state is an indirect one mediated by the interaction with x' coupled with predissociation of x' by a $^1\Sigma_g^-$ state dissociating to $^4S + ^2P$ atoms; combined, however, with perturbation of the y state by the $k\ ^1\Pi_g$ Rydberg state (configuration $3\sigma_g^{-1}4d\pi$), whose Π^+ levels are completely predissociated.

I. INTRODUCTION

Among the Rydberg states of the nitrogen molecule above 13.0 eV, just two of even parity have long been known, $x\ ^1\Sigma_g^-$ and $y\ ^1\Pi_g$. A third, $k\ ^1\Pi_g$, has recently been dis-covered (*1*). These states are known from emission bands as follows: $x\ ^1\Sigma_g^- \rightarrow a'\ ^1\Sigma_u^-$ (fifth positive bands), $y\ ^1\Pi_g \rightarrow a'\ ^1\Sigma_u^-$ (Kaplan's first system), $y\ ^1\Pi_g \rightarrow w\ ^1\Delta_u$ (Kaplan's second system), $k\ ^1\Pi_g \rightarrow a'\ ^1\Sigma_u^-$ (Carroll–Subbaram second system), and $k\ ^1\Pi_g \rightarrow w\ ^1\Delta_u$ (Carroll–Subbaram first system). All these systems show evidences of predissociation.

For brevity the various systems will be referred to as x–a', y–a', y–w, k–a', and k–w. A consideration of electron configurations leaves no reasonable doubt that states x, y, and k have the respective electron configurations $A\ 3p\pi_u$, $A\ 4p\sigma_u$, and $X\ 4d\pi_g$, where A refers to the first excited state $\cdots 1\pi_u\ ^33\sigma_g^2$, $^2\Pi_u$, and X to the ground state $\cdots 1\pi_u^4$, $3\sigma_g$, $^2\Sigma_g^+$, of N_2^+, and united-atom n values are used for the Rydberg MO's. Potential curves for the x, y, k, and certain other even-parity states relevant to the following discussion are shown in Fig. 1.

The $y\ ^1\Pi_g$ state shows anomalous behavior in the spacings of its rotational and vibrational levels (*2*). These anomalies have now been fully explained as the results of a homogenous mutual (vibronic) perturbation between the y and $k\ ^1\Pi_g$ states. Carroll and Subbaram (*1*) have carried out a deperturbation analysis which shows the rotational and vibrational constants of the unperturbed y and k-levels to be close to those of their respective parent ions X and A, a relation which is somewhat disguised in the observed perturbed states.

In the $y\ ^1\Pi_g$ state two vibrational levels $v = 0$ and 1 have long been known, but recently $v = 2$ has also been discovered (*1*). For the $k\ ^1\Pi_g$ state, only $v = 0$ and 1 have

Salient features of the follow-up work by Professor R.S. Mulliken on the Nitrogen Molecule that provided the theoretical spine to the experimental work.

Extract from the above original publication of Professor R.S. Mulliken

"A third, $k^1\Pi g$," has recently been discovered (1). These states are …

$k^1\Pi g$ —› $a'\,^1\Sigma\ u^-$ (Carroll-Subbaram second system), and,

$k^1\Pi g$ —› $w^1\Delta u$ (Carroll-Subbaram first system).

All these systems show evidences of "predissociation."

Note

In scientific literature, it is a practice to name the most important and significant contributions after the scientists who made discoveries. The naming is done by peers and senior scientists, who have spent their lifetime in research work, as a recognition and an honour to fellow scientists. This reference remains in the world scientific literature, ratified by the scientific community, and outlives the original contributor/s. As such, in this particular instance, it is the Nobel laureate, Professor R.S. Mulliken, who identified and not only followed up but also named the two new emission systems discovered in the Nitrogen molecule after the two authors of the published work, one author of which is the COTW. It is a matter of pride for the present discoverers that the future researchers on the Nitrogen molecule would refer to their work. It may be mentioned that very few Indians have received such recognition and honour in the world scientific literature.

RECENT FOLLOW-UP WORK ON THE ABOVE SYSTEMS OF N_2

References

Observation of the $y^1\pi g$ — $c'4^1\Sigma u^+$ and $k^1\Pi g$ — $c'4^1\Sigma u^+$ systems of N_2

Arno de Lange, Wim Ubachs

Chemical Physics Letters (Netherlands), 310, pp. 471-476 (1999)

Highly excited states of gerade symmetry in molecular nitrogen

Arno de Lange, Rudiger Lang, Wim van der Zande, Wim Ubachs

Journal of Chemical Physics (USA), Vol. 116, No. 18, pp. 7893-7901 (2002)

References

Atomic and molecular emission from microwave discharge through beryllium chloride

K.V. Subbaram, R. Vasudev, and William E. Jones

Journal of the Optical Society of America, Vol. 65, No. 3, pp. 318-319 (1975)

First Observation of $BeAr^+$ and $BeKr^+$ molecules: The $A^2\Pi$ — $X^2\Sigma^+$ Band Systems in Emission
K.V. Subbaram, J.A. Coxon, and W.E. Jones
Canadian Journal of Physics (Special Issue dedicated to Dr. G. Herzberg, Nobel Laureate, on the occasion of his 70th birthday), Vol.53, No. 19, pp.2016-2022 (1975)

First Observation of $BeXe^+$ Molecule: The $A^2\ \Pi$ —$X^2\Sigma$ Band System in Emission
J.A. Coxon, W.E.Jones, and K.V. Subbaram
Canadian Journal of Physics, Vol. 53, No. 20, pp. 2321-2325 (1975)

Investigations of metal ion – rare gas pairs by optical spectroscopy:

High resolution analysis of the $A^2\Pi r$ — $X^2\Sigma^+$ system of $BeAr^+$ K.V. Subbaram, J.A. Coxon, and W.E. Jones
Canadian Journal of Physics, Vol. 54, No. 15, pp. 1535-1544 (1976)

Electronic spectra of metal ion — rare gas pairs:
High resolution analysis of the $A^2\Pi r$—$X^2\Sigma^+$ system of $BeKr^+$
J.A. Coxon, W.E. Jones, and K.V. Subbaram
Canadian Journal of Physics, Vol. 55, No. 3, pp. 254-260 (1977)

Follow-up of above work

Recovery of the long range potential in $BeAr^+$ by potential inversion methods

James H. Goble (University of Berkeley), Dennis C. Hartman, and John S. Winn

The Journal of Chemical Physics, Vol. 67, No. 9, pp. 4206-4211 (1977)

Also see the following paper by the above authors in

The Journal of Chemical Physics, Vol. 66, p. 363 (1977)

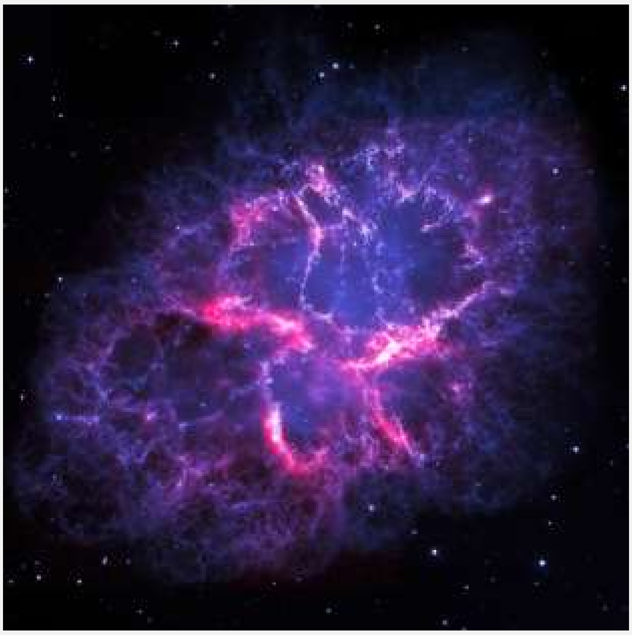
MOST RECENT RELEVANT INFORMATION CONCERNING THE NOBLE GAS BASED MOLECULES IN SPACE

News Item (*Photograph* and *Narration*)

Courtesy: *NatureWorldNews.com*, *December 13, 2013*

CRAB NEBULA HOME TO FIRST NOBLE-GAS BASED MOLECULE EVER SEEN IN SPACE

By Tamarra Kemsley



*Deep inside the **Crab Nebula**, researchers have discovered*

the first evidence ever of a noble gas-based compound in space.

(Photo : ESA / Herschel / PACS / MESS Key Programme Supernova Remnant Team ;

NASA, ESA and Allison Loll / Jeff Hester (Arizona State University)

Narration (*from the Newspaper*)

Deep inside the Crab Nebula, researchers have discovered the first evidence ever of a noble gas-based compound in space.

A wallflower, argon is so reluctant to join with others that its name is the Greek word for "inactive." The element comes from the group known as noble gases, which includes helium and other similarly independent spirits.

However, according to a new study published in the journal *Science*, argon appears to have found a friend. Using the Herschel space observatory, researchers detected signs of a molecule known as argon hydride in the nebula first noted by Chinese astronomers almost 1,000 years ago.

"At first, the discovery seemed bizarre," said lead researcher Michael Barlow from University College London. "With hot gas still expanding at high speeds after the explosion, a supernova remnant is a harsh, hostile environment, and one of the places where we least expected to find a noble-gas based molecule."

Apparently, this was exactly what argon needed to get out of its comfort zone, the researchers found. "The strange thing is that it is the harsh conditions in a supernova remnant that seem to be responsible for some of the argon finding a partner with hydrogen," said Paul Goldsmith of NASA's Jet Propulsion Laboratory, Pasadena, Calif.

Argon hydride is created when argon ions react with hydrogen molecules, though the two are usually found in completely different parts of a nebula.

"But we soon realized that even in the Crab Nebula, there are places where the conditions are just right for a noble gas to react and combine with other elements," Barlow said.

For these and other reasons, the researchers note the study is as much about the nebula as it is about argon.

"This is not only the first detection of a noble-gas based molecule in space, but also a new perspective on the Crab Nebula," said Göran Pilbratt, Herschel project scientist at the European Space Agency. "Herschel has directly measured the argon isotope we expect to be produced via explosive nucleosynthesis in a core-collapse supernova, refining our understanding of the origin of this supernova remnant."

NEWS ITEM (*NARRATION*)

Courtesy: ***THE INDEPENDENT***, *SUNDAY, DECEMBER 2013*

CRAB NEBULA: NOBLE GAS MOLECULES DETECTED IN SPACE FOR THE FIRST TIME

Noble gas molecules have been detected in space for the first time ever, a team of astronomers has announced.

The detection was made in the Crab Nebula, the remnants of a star that exploded 1,000 years ago and is 6,500 light years away, using the SPIRE (Spectral and Photometric Imaging Receiver) on board the European Space Agency's Herschel Space Observatory.

The noble gases (argon, helium, neon, xenon, radon, and krypton) are chemically unreactive, and therefore do not easily combine with other elements. In the right circumstances, they can form molecules, although this had only ever been achieved on Earth in laboratory conditions.

However, noble gas molecules in the form of argon hydride ions have now been detected outside the laboratory, in space.

"Discovering argon hydride ions here was unexpected because you don't expect an atom like argon, a noble gas, to form molecules, and you wouldn't expect to find them in the harsh environment of a supernova remnant," said Professor Mike Barlow from University College London who led the study.

Initially, Barlow's team of astronomers was looking to examine how exploding stars create such huge amounts of dust. But when studying emission lines (the wavelengths emitted by molecules spinning in space), the team noticed some unexpected readings.

The light coming from some regions of the Crab Nebula was showing "extremely strong and unexplained" peaks in intensity, ranging from 618 GHz to 1235 GHz. Upon consulting the databases of known properties of molecules, the scientists concluded that these wavelengths could only be coming from spinning molecular ions of argon hydride. The team further concluded that only the argon-36 isotope could rotate at such a rate.

Scientists had previously hypothesized that the elements created by supernovas should include a lot of argon-36 and no argon-40, which was supported by the discovery.

Professor Matt Griffin from Cardiff University said: "Here we see the excellent performance of the Herschel-SPIRE spectrometer, the expertise of the instrument team in producing the highest quality data, and the tenacity and vision of the scientists analyzing it, all coming together to make an intriguing new discovery."

NEWS ITEM (*NARRATION*)

Courtesy: ***BUSINESS LINE***, *CHENNAI*, *INDIA*, *24 APRIL 2014*

MISSING NOBLE GAS TO BE REDISCOVERED: THE GAS XENON MAY BE RESTING IN EARTH'S BELLY

The missing noble gas Xenon did not leave the earth's atmosphere and disappear into space but may be resting at the earth's core, a thrilling new study reveals.

Xenon is a noble gas. Like other noble gases such as Helium and Neon, it is mostly chemically inert. According to Chinese researchers, the mystery about where the gas vanished may finally be resolved.

The scientists believe that Xenon might have chemically reacted with iron and nickel in the earth's core where it is held. The earth's core, which contains about one-third of the planet's mass, is made of iron and nickel. According to Yanming Ma, a computational physicist at Jilin University in Changchun, China, the earth's core is more likely to hold the missing Xenon.

Ma and his colleagues reasoned that if the structures of iron-xenon compounds are different, they could form a compound.

Their research suggested that at the extreme temperatures and pressures found in earth's core, Xenon can bond with both iron and nickel. "We do hope future high-pressure experiments can be carried out to confirm our predictions." Ma was quoted as saying in media reports.

Comment by the presenter: The first observation by this presenter and his colleagues of spectra attributed to $BeXe^{+}$ molecular ion in the laboratory was possible by passing Xenon gas at relatively higher pressures over beryllium chloride powder in a discharge tube. (Reference already given)

Offer: There are some diatomic molecules / molecular ions that are possible to be produced and identified in the laboratory experiments with beryllium as one of the atoms. This presenter is willing to correspond with anyone who is interested in proceeding with the expected research work, with a detailed experimental plan.

Citation & Honour: Dr.G.Herzberg, Nobel laureate through a commendation letter (written in 1978) about the discoveries

(*see below*).

Although Dr. Subbaram has not worked in my laboratory I have on several occasions had an opportunity to meet him and have heard one or two of his papers. I believe that he has done some very fine work in molecular spectroscopy culminating in the discovery of three new molecular ions, namely $BeAr^+$, $BeKr^+$ and $BeXe^+$. Since I am myself engaged in a long-range program on molecular ion spectra I was particularly impressed by the results of Subbaram and his collaborators on three quite unexpected ions which have interesting and clear-cut spectra. Subbaram's discovery of the spectrum of NSe is also noteworthy. In addition, while working with Professor Carroll at University College, Dublin, he discovered jointly with him two new band systems of the nitrogen molecule which have entered the literature under their names. Since nitrogen is one of the most important molecules the additional information gained from these new band systems is of considerable interest.

G. Herzberg

G. Herzberg

Dr.G.Herzberg is a Nobel laureate.

Note

The above recommendation letter written sometime back by a Nobel laureate (Dr. G. Herzberg) to an Indian university, and follow-up work by another Nobel laureate (Professor R.S. Mulliken) were considered worthless by Indian scientist-academics.

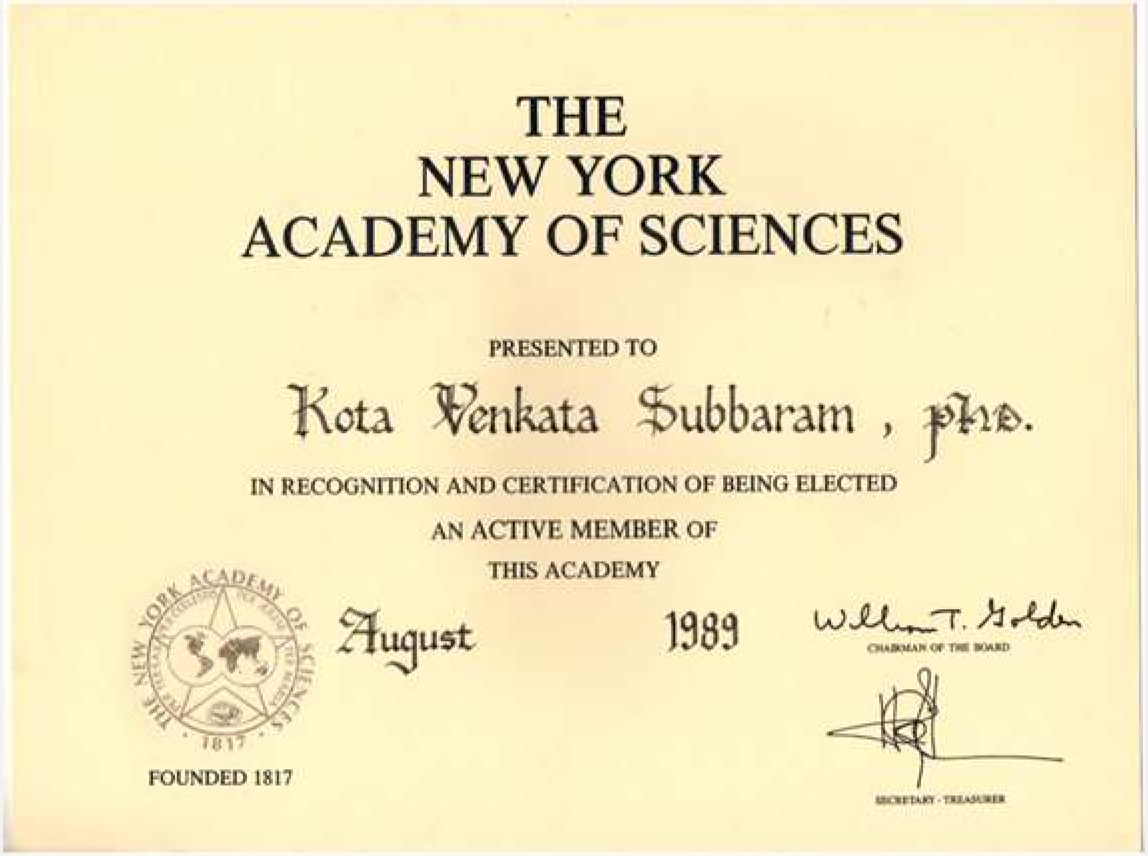

THE INSTITUTE OF PHYSICS

This is to certify that

has been elected

a Member of The Institute of Physics

By Resolution of the Council



THE
NEW YORK
ACADEMY OF SCIENCES

PRESENTED TO

Kota Venkata Subbaram, PhD.

IN RECOGNITION AND CERTIFICATION OF BEING ELECTED

AN ACTIVE MEMBER OF

THIS ACADEMY

THE NEW YORK ACADEMY OF SCIENCES · 1817 ·

August 1989

William T. Golden

CHAIRMAN OF THE BOARD

FOUNDED 1817

SECRETARY - TREASURER

****