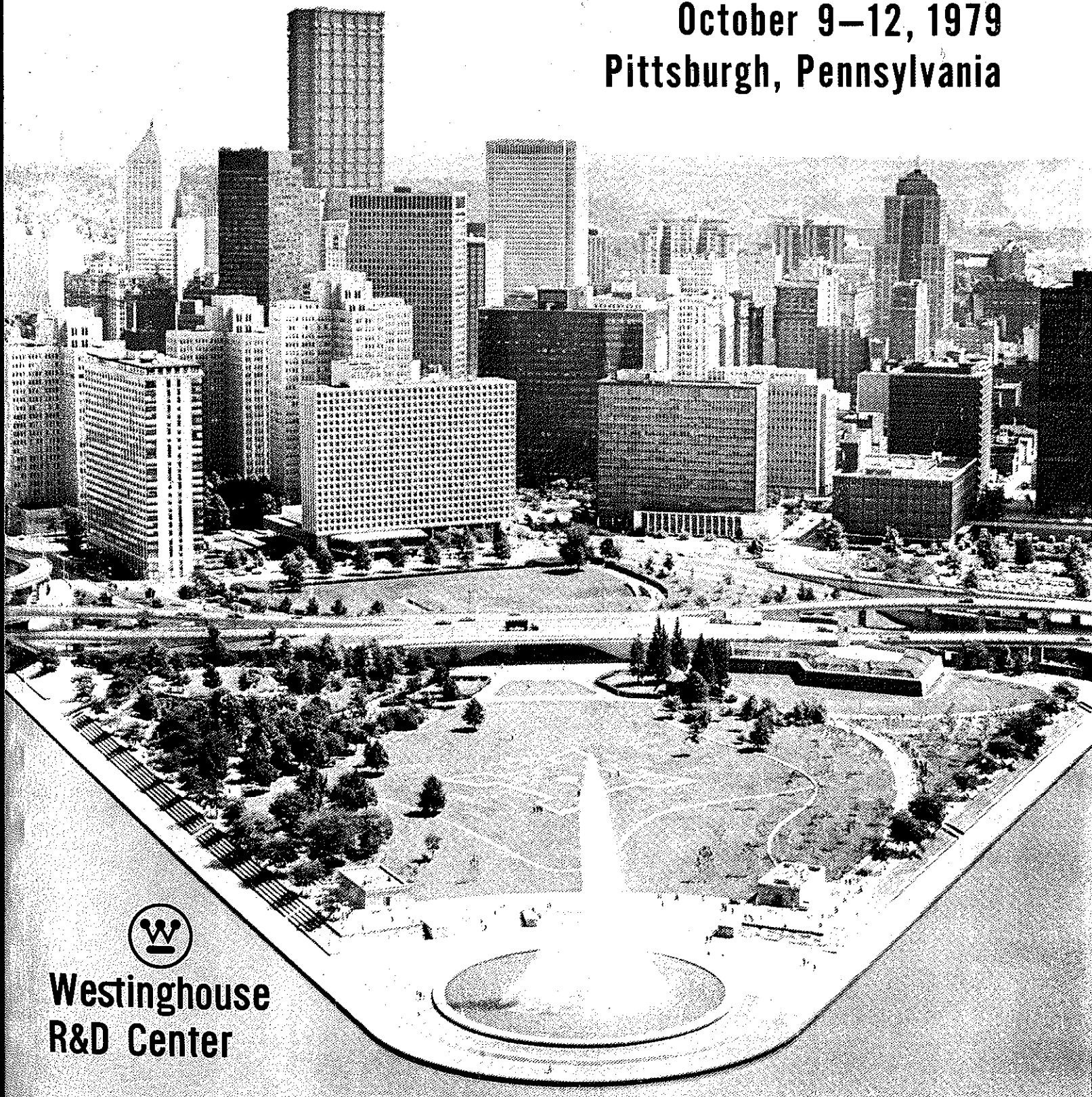
Thirty-Second Annual
GASEOUS ELECTRONICS CONFERENCE

October 9–12, 1979
Pittsburgh, Pennsylvania



Westinghouse R&D Center

A TOPICAL CONFERENCE OF THE AMERICAN PHYSICAL SOCIETY

Thirty-Second Annual
Gaseous Electronics Conference
October 9-12, 1979

32nd GASEOUS
ELECTRONICS CONFERENCE

Program and Abstracts

A Topical Conference of
The American Physical Society

Sponsored by:

Westinghouse R&D Center
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Division of Electron
and Atomic Physics

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The local committee express their gratitude to the numerous individuals in various departments of the Westinghouse R&D Center whose efforts have contributed to the conference. Special thanks go to K. W. Moelk and R. J. Grimes of the Graphic Arts Department and A. Terek of the Drafting Department for their willing advice and cooperation in producing this booklet and other conference literature, and to A. M. Tomasic and L. A. Arthrell for performing most of the typing.

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32nd ANNUAL GASEOUS ELECTRONICS CONFERENCE

PROGRAM

OCTOBER 8, 1979 MONDAY EVENING, 7:30 – 10:00 P. M.

REGISTRATION
Kings Garden South.

MIXER (CASH BAR)
Le Bateau.

SESSION AA: ARCS AND FLOWS

Chairperson: D. T. Tuma, Carnegie-Mellon University — Ballroom 3

AA-1	GAS FLOW AND ARC PHENOMENA IN A DOUBLE NOZZLE FLOW SYSTEM W. Tiemann	(7 min)
AA-2	FLOW FIELDS WITHIN A LAMINAR AXIAL-FLOW ARC T.Y. Li, D.M. Benenson and D.P. Malone	(7 min)
AA-3	TRANSIENT BEHAVIOR OF GAS BLAST ARCS IN SF_6 AND N_2 D.T. Tuma	(7 min)
AA-4	BISTABLE MODES IN HORIZONTAL HIGH PRESSURE MERCURY PLUS IODINE ARCS D.K. McLain and R.J. Zollweg	(7 min)
AA-5	MHD GENERATOR PLASMA CONDUCTIVITY AND PERFORMANCE CALCULATIONS V. Yousefian, J. Wormhoudt, M.H. Weinberg and C.E. Kolb	(7 min)

SESSION AB: RARE GAS AND MERCURY HALIDE KINETICS I

Chairperson: J. C. Hsia, AVCO Everett Research Laboratory — Ballroom 4

AB-1	SUPERSONIC FLOW ELECTRONIC TRANSITION LASERS B. Forestier and B. Fontaine	(20 min)
AB-2	DESTRUCTION OF XeCl(X) MOLECULES BY RARE GAS AND HCl COLLISIONS R.W. Waynant and J.G. Eden	(7 min)
AB-3	RADIATIVE LIFETIME AND COLLISIONAL QUENCHING KINETICS FOR THE XeCl (B 1/2) STATE C.H. Fisher, R.E. Center and J.P. McDaniel	(7 min)
AB-4	TEMPORAL FLUORESCENCE MEASUREMENTS FOR E-BEAM EXCITED XeCl R.W. Waynant and L.J. Palumbo	(7 min)
AB-5	STUDY OF THE Xe_2Cl^* BLUE-GREEN TRANSITIONS IN E-BEAM PUMPED HIGH PRESSURE Ar/Xe/RCl MIXTURES K.Y. Tang, D.C. Lorents and D.L. Huestis	(7 min)

COFFEE BREAK 10:00 – 10:30 A. M.

SESSION BA: ARC DIAGNOSTICS AND MODELING

Chairperson: J. F. Waymouth, GTE Sylvania — Ballroom 3

BA-1 RADIAL AND AXIAL PARTICLE DISTRIBUTIONS IN METAL HALIDE ARCS
Th. Zaengel and E. Groiss (7 min)

BA-2 AXIAL SEGREGATION IN HIGH PRESSURE MERCURY DISCHARGES WITH NaI AND TlI AS ADDITIVES
H.-P. Stormberg (7 min)

BA-3 EMISSION SPECTRA OF HgI $B^2\Sigma$-$X^2\Sigma$ IN COLLISION BROADENED HIGH PRESSURE Hg-HgI ARCS
W.M. Keeffe and H.L. Rothwell (7 min)

BA-4 LASER INDUCED FLUORESCENCE STUDIES OF Sc(I) IN 400 WATT Sc-Na-Hg ARC TUBES
F.M. Ryan and C.T. Johnson (7 min)

BA-5 LASER INDUCED FLUORESCENCE SPECTROSCOPY OF Sc
L.H. Taylor and R.W. Liebermann (7 min)

BA-6 A THEORETICAL INVESTIGATION OF THE PULSED HIGH PRESSURE SODIUM ARC
C.L. Chalek and R.E. Kinsinger (7 min)

BA-7 TEMPERATURE MEASUREMENT FOR ARCS IN SF_6
E. Schulz-Gulde (7 min)

SESSION BB: RARE GAS AND MERCURY HALIDE KINETICS II

Chairperson: R. C. Sze, Los Alamos Scientific Laboratory — Ballroom 4

BB-1 ELECTRON QUENCHING OF RARE GAS FLUORIDE EXCIPLEX MOLECULES
D.W. Trainor and J.H. Jacob (7 min)

BB-2 A MULTILEVEL MODEL OF XeF GROUND STATE KINETICS
S.F. Fulghum, M.S. Feld and A. Javan

BB-3 A MODEL OF XeF LASER OSCILLATION WITH A MULTILEVEL GROUND STATE
S.F. Fulghum, M.S. Feld and A. Javan
(16 min)

BB-4 XeF* PRODUCTION EFFICIENCY IN 300 ns SELF-SUSTAINED DISCHARGES
L.E. Kline, L.J. Denes and S.G. Leslie (7 min)

BB-5 X-RAY SUSTAINED DISCHARGE FOR THE STUDY OF LUMINESCENCE KINETICS
J. Degani, M. Rokni and S. Yatsiv (7 min)

BB-6 GAIN, ABSORPTION AND SATURATION FLUX MEASUREMENTS IN AN HgBr LASER
J.E. Celto and E.J. Schimitschek (7 min)

BB-7 EXCITATION KINETICS IN MERCURIC HALIDE DISSOCIATION LASERS
R. Burnham (7 min)

LUNCH 11:40 A. M. – 1:30 P. M.

SESSION CA: ELECTRODE EFFECTS AND VACUUM ARCS I
Chairperson: L. M. Burrage, McGraw Edison — Ballroom 3

CA-1 PLASMA-WALL INTERACTIONS IN TOKAMAKS AND LOW ENERGY ION SPUTTERING AS A POTENTIAL IMPURITY SOURCE
J. Bohdansky (20 min)

CA-2 MASS SPECTROMETRIC INVESTIGATION OF LASER-INITIATED VACUUM ARCS
M. Krishnan and J.L. Hirshfield (7 min)

CA-3 MEASUREMENTS OF ARC ROOT CHARACTERISTICS RELEVANT TO CONTAMINATION INDUCED FLASH-OVERS
H. Mercure, M.G. Drouet, L. Lamarche (7 min)

CA-4 THE ROLE OF ELONGATED METAL PARTICLES IN ELECTRIC BREAKDOWN IN VACUUM
G.A. Farrall and F.G. Hudda (7 min)

CA-5 ARC CATHODE SPOT CLASSIFICATION BASED ON THEORETICAL REASONING
G.H. Ecker (7 min)

CA-6 XUV RADIATION AND IONIC RECOMBINATION AT THE CATHODE OF LOW PRESSURE AND VACUUM ARCS
M.G. Drouet (7 min)

CA-7 THE CURRENT-VOLTAGE CHARACTERISTICS OF THE VACUUM ARC
M.G. Drouet (7 min)

CA-8 BREAKDOWN IN THE ANODE SHEATH OF THE VACUUM ARC
M.G. Drouet

SESSION CB: ELECTRON DISTRIBUTIONS AND TRANSPORT
Chairperson: A. E. Greene, Los Alamos Scientific Laboratory — Ballroom 4

CB-1 THE SPIKE IN THE VELOCITY DISTRIBUTION OF SLOW ELECTRONS
W.P. Allis (7 min)

CB-2 ELECTRON TRANSPORT IN Ar-H_2 MIXTURES
G.N. Haddad and R.W. Crompton (7 min)

CB-3 NEW ELECTRIC FIELD SCALING LAW FOR SWARM EXPERIMENTS
P. Kleban, L. Foreman and H.T. Davis (7 min)

CB-4 NEGATIVE ARGON IONS AND DRIFT VELOCITY v_D OF EXCESS ELECTRONS IN DENSE ARGON
A. Leycuras and J. Larour (10 min)

CB-5 ELECTRON MOBILITIES IN DENSE GASES
T.F. O'Malley (7 min)

CB-6 INFLUENCE OF EXCITED STATES ON ELECTRON TRANSPORT PROPERTIES IN ARGON
W.F. Bailey, G. Duke and A. Garscadden (7 min)

CB-7 ELECTRON SWARM PARAMETERS IN CO_2 LASER PLASMAS
R.A. Sierra, H.L. Brooks and K.J. Nygaard (7 min)

CB-8 LOW E/N EXCITATION AND IONIZATION IN Ar, Kr AND Xe
S.A. Lawton, L.T. Specht and T.A. DeTemple (7 min)

COFFEE BREAK 2:55 – 3:15 P. M.

SESSION DA: ELECTRODE EFFECTS AND VACUUM ARCS II

Chairperson: G. Ecker, Ruhr University, Bochum — Ballroom 3

DA-1 THE INFLUENCE OF AXIAL MAGNETIC FIELDS ON THE VACUUM ARC ION CURRENT DISTRIBUTION
J.V.R. Heberlein and D.R. Porto (7 min)

DA-2 THE PHYSICS OF THE RETROGRADE MOTION OF THE ELECTRIC ARC IN A MAGNETIC FIELD
M.G. Drouet (7 min)

DA-3 CONDUCTIVITY MEASUREMENTS IN THE INTERELECTRODE PLASMA OF A COAXIAL GEOMETRY PULSED VACUUM ARC
J.S. Sullivan and R. Dollinger (7 min)

DA-4 MICROWAVE ABSORPTION IN THE VACUUM ARC
M. Rosenfeld and R. Dollinger (7 min)

DA-5 NUMERICAL SIMULATION OF A PLANAR HIGH VACUUM ARC
J.L. Shohet, P.D. Pedrow and L.M. Burrage (7 min)

DA-6 ANODE SPOT FORMATION IN THE TRANSITION FROM VACUUM TO ATMOSPHERIC PRESSURE ARCS
D.R. Porto, J.V.R. Heberlein, D. Bhasavanich and C.W. Kimblin (7 min)

DA-7 ANALYSIS OF THE ANODE BOUNDARY LAYER OF A HIGH INTENSITY ARC
H.A. Dinulescu and E. Pfender (20 min)

DA-8 POST-ARC MODEL OF CURRENT INTERRUPTION IN VACUUM
S.E. Childs and A.N. Greenwood (7 min)

SESSION DB: ION TRANSPORT, BREAKDOWN AND CORONA

Chairperson: L. E. Kline, Westinghouse R & D Center — Ballroom 4

DB-1 KINETIC THEORY OF DRIFT-TUBE EXPERIMENTS
L.A. Viehland, S.L. Lin and E.A. Mason (20 min)

DB-2 MOBILITY AND DIFFUSION OF PROTONS AND DEUTERONS IN HELIUM - A RUNAWAY EFFECT
S.L. Lin, I.R. Gatland and E.A. Mason (7 min)

DB-3 H^+ and D^+ IONS IN He: OBSERVATIONS OF A RUNAWAY MOBILITY
F. Howorka, F.C. Fehsenfeld and D.L. Albritton (7 min)

DB-4 CURRENT BUILDUP IN TRIGGERED LOW PRESSURE SPARK GAPS
E.J. Lauer, R.E. Melendez and S.S. Yu (7 min)

DB-5 CONDITIONS FOR SELF-BREAKDOWN IN LOW PRESSURE SPARK GAPS
S.S. Yu, E.J. Lauer and D.M. Cox (7 min)

DB-6 CONTINUOUS CURRENT IN THE POSITIVE POINT-PLANE CORONA IN AIR. I: EXPERIMENTAL
M. Hirsh, R. Abbott and G. Hartmann

DB-7 CONTINUOUS CURRENT IN THE POSITIVE POINT-PLANE CORONA IN AIR. II: THEORETICAL
M. Hirsh, R.S. Sigmond and G. Hartmann

(15 min)

DINNER 5:00 – 7:30 P. M.

OCTOBER 9

TUESDAY EVENING 7:30 P. M.

SESSION E: WORKSHOP ON KINETICS OF RARE GAS MONOHALIDES AT ELEVATED TEMPERATURE

Moderator: M. J. W. Boness, AVCO Everett Research Laboratory

Ballroom 2

THIS WORKSHOP WILL INCLUDE DISCUSSIONS OF ELECTRON QUENCHING AND ATTACHMENT PROCESSES, OPTICAL ABSORPTION PHENOMENA AND THE LOCATION AND COUPLING BETWEEN THE UPPER LEVELS, (B AND C STATES). THESE ISSUES AND THEIR TEMPERATURE RELATED EFFECTS WILL BE DISCUSSED AS THEY PERTAIN TO ELECTRON-BEAM, ELECTRIC DISCHARGE AND PHOTOLYTICALLY EXCITED RARE GAS MONOHALIDES WITH PARTICULAR EMPHASIS ON XeF, KrF AND XeCl. THE PREARRANGED SPEAKERS AND THEIR TOPICS ARE LISTED:

INTRODUCTION

M.J.W. BONESS
AVCO EVERETT RESEARCH LABORATORY

TEMPERATURE DEPENDENCE OF DISSOCIATIVE ATTACHMENT

P. J. CHANTRY
WESTINGHOUSE R&D CENTER

ELECTRON QUENCHING AND DISSOCIATIVE ATTACHMENT PROCESSES

D. W. TRAINOR
AVCO EVERETT RESEARCH LABORATORY

ENERGY CURVE CALCULATIONS FOR XeF AND XeCl

M. KRAUSS
NATIONAL BUREAU OF STANDARDS

ABSORPTION MEASUREMENTS IN XeCl

L. F. CHAMPAGNE
NAVAL RESEARCH LABORATORY

KINETICS OF PHOTOLYTICALLY EXCITED XeF

D. L. HUESTIS
SRI INTERNATIONAL

AND H. T. POWELL
LAWRENCE LIVERMORE LABORATORY

ENERGY EXTRACTION IN XeF

J. C. HSIA
AVCO EVERETT RESEARCH LABORATORY

SESSION FA: ION REACTIONS

Chairperson: J. J. Leventhal, University of Missouri — Ballroom 3

FA-1 NEGATIVE ION-UF_6 ELECTRON TRANSFER REACTIONS: DETAILED MODELLING OF RATE AND DIFFUSION COEFFICIENTS IN THE FLOWING AFTERGLOW
G.E. Streit and T.W. Newton

FA-2 FLOWING AFTERGLOW STUDIES OF NEGATIVE ION-UF_6 ELECTRON TRANSFER REACTIONS
G.E. Streit and T.W. Newton
(15 min)

FA-3 SIFT STUDIES OF CLUSTER IONS
N.G. Adams and D. Smith (20 min)

FA-4 LABORATORY MEASUREMENTS OF STRATOSPHERIC SODIUM ION REACTIONS
R.A. Perry, A.A. Viggiano, D.L. Albritton, E.E. Ferguson and F.C. Fehsenfeld (7 min)

FA-5 CONVERSION OF ATOMIC TO MOLECULAR IONS IN He, Ne, AND Ar AT TEMPERATURES FROM 78-300K
A.K. Chen, R. Johnsen and M.A. Biondi (7 min)

FA-6 MEASUREMENT OF THE RATE COEFFICIENTS AND THEIR TEMPERATURE DEPENDENCE FOR THE BIMOLECULAR AND TERMOLECULAR CHARGE TRANSFER REACTIONS OF He_2^+, Ne_2^+, AND Ar_2^+
C.B. Collins and F.W. Lee (7 min)

SESSION FB: SHEATH EFFECTS AND DISCHARGE STABILITY

Chairperson: W. L. Nighan, United Technologies Res. Labs. — Ballroom 4

FB-1 STUDY OF THE CATHODIC REGION OF A DISCHARGE
E. Marode, Tran Ngoc An, G. Fournier, P. Segur, S. Pareathumby (7 min)

FB-2 PREDICTIONS OF CATHODE SHEATH CHARACTERISTICS IN HELIUM GLOW DISCHARGES
R.R. Mitchell, L.E. Kline and L.J. Denes (7 min)

FB-3 CATHODE SHEATH ENERGY DEPOSITION IN PULSED HELIUM DISCHARGES
M.J. Pechersky, S.G. Leslie and L.E. Kline (7 min)

FB-4 QUANTITATIVE CORRELATION OF ATTACHMENT STRENGTH WITH THE ONSET OF ARCING IN RARE GAS-HALIDE DISCHARGES
L.J. Denes, P.J. Chantry and L.E. Kline (7 min)

FB-5 ELECTRODE SURFACE RELATED ARCING IN HIGH PRESSURE SELF-SUSTAINED GLOW DISCHARGES
L.J. Denes, W.R. Gass, I.E. Kanter and L.E. Kline (7 min)

FB-6 STREAMER GROWTH IN AN E-BEAM SUSTAINED DISCHARGE
P.S. Rostler and D.H. Douglas-Hamilton (7 min)

FB-7 FRACTIONAL POWER TRANSFER AND ION FORMATION RATES IN OXYGEN AND OXYGEN-IODINE MIXTURES
J.W. Dettmer and A. Garscadden (7 min)

COFFEE BREAK 10:10 – 10:30 A. M.

SESSION GA: POSITIVE ION REACTIONS
Chairperson: R. L. C. Wu, Wright State University — Ballroom 3

GA-1 INFORMATION FROM EXOTHERMIC RATE CONSTANTS MEASURED AS A FUNCTION OF E/P
W.B. Clodius and S.B. Woo (7 min)

GA-2 KINETIC-ENERGY DEPENDENCE OF THE PRODUCT RATIOS OF THE REACTION OF N^+ IONS WITH O_2
F. Howorka, I. Dotan, F.C. Fehsenfeld and D.L. Albritton (7 min)

GA-3 CHARGE-TRANSFER AND ASSOCIATION REACTIONS INVOLVING MERCURY AND RARE-GAS IONS
R. Johnsen and M.A. Biondi (7 min)

GA-4 AB INITIO CHARACTERIZATION OF THE HIGH-BARRIER ADIABATIC PATHWAY FOR THE $O^+(N_2,N)NO^+$ REACTION
D.G. Hopper (7 min)

GA-5 EXPERIMENTS ON ENERGY DISPOSAL IN CHARGE TRANSFER AT NEAR THERMAL ENERGY
T.R. Govers, G. Mauclaire and R. Marx (20 min)

GA-6 ELECTRON TRANSFER AND EXCITATION IN LOW ENERGY N_2^+ - ALKALI ATOM COLLISIONS
J.L. Barrett and J.J. Leventhal (7 min)

GA-7 QUASI-RESONANT CHARGE TRANSFER AT THERMAL ENERGIES IN THE RARE GASES
J.D.C. Jones, D.G. Lister, K. Birkinshaw and N.D. Twiddy (7 min)

GA-8 COLLISIONS OF IONS WITH LASER-EXCITED RYDBERG ATOMS
K. Macadam, D. Crosby and R. Rolfes (10 min)

GA-9 REACTIONS OF Ne^{++} AND Kr^{++} WITH SOME ATOMS AND MOLECULES
D. Smith and N.G. Adams (7 min)

SESSION GB: GLOW DISCHARGES
Chairperson: R. Bleekrode, Philips Research Laboratories — Ballroom 4

GB-1 ELECTRON DENSITY PROFILES IN POSITIVE COLUMNS WITH DIFFUSION LOSS
G.L. Rogoff (20 min)

GB-2 RADIAL DISTRIBUTION OF ELECTRON DENSITY AND EXCITED ATOMS IN A PLASMA COLUMN PRODUCED BY A SURFACE WAVE
M. Moisan, R. Pantel, A. Ricard and W.P. Allis (20 min)

GB-3 THE PLASMA DENSITY DISTRIBUTION IN A MEDIUM PRESSURE FLOWING POSITIVE COLUMN
J.S. Chang and S. Karpik (7 min)

GB-4 ABSORPTION, DISPERSION AND STRAY LIGHT MEASUREMENTS NEAR RESONANCE OF λ = 5875,97 Å AND λ = 5875,62 Å He-LINES IN A GLOW DISCHARGE USING A TUNABLE DYE LASER
H. Odenthal and J.F. Uhlenbusch (7 min)

GB-5 ELECTROPHORESIS AT HIGH E/P
J.H. Ingold (7 min)

GB-6 SIMPLIFIED MODELS FOR LOW PRESSURE AC DISCHARGES
M.J.C. van Gemert and J.-P. Morel (7 min)

GB-7 AN ELEMENTARY MODEL OF THE AC-DISCHARGE-BALLAST INTERACTION
J.F. Waymouth (7 min)

LUNCH 12:20 – 2:00 P. M.

OCTOBER 10, 1979 WEDNESDAY AFTERNOON, 2:00 P. M.

SESSION H: DISCHARGE CHEMISTRY
Chairperson: W. A. Fitzsimmons, National Research Group — Ballroom 2

H-1 THE EFFECT OF CHEMICAL PROCESSES ON THE ELECTRON TEMPERATURE OF A MEDIUM PRESSURE, RARE GAS, RADIO FREQUENCY DISCHARGE
Y. Ichikawa, G.L. Ogram, R.M. Hobson, J.S. Chang and S. Teii (7 min)

H-2 EFFECT OF OXYGEN AND HYDROGEN ON ELECTRON BEAM DISCHARGES IN ATMOSPHERIC PRESSURE CO_2 MIXTURES
P. Bletzinger and C.A. DeJoseph, Jr. (7 min)

H-3 LOW-ENERGY PROCESSES INDUCED BY AN ELECTRON BEAM IN OXYGEN
G. Fournier, J. Bonnet, J. Bridet, J. Fort and D. Pigache (7 min)

OCTOBER 10, 1979 WEDNESDAY AFTERNOON, 2:30 P. M.

SESSION I: WORKSHOP ON PLASMA CHEMISTRY AND EXCITED STATE REACTIONS
Chairperson: W. A. Fitzsimmons, National Research Group — Ballroom 2

I-1 THE INTERFACE BETWEEN PLASMA PHYSICS AND PLASMA CHEMISTRY
A.T. Bell (15 min)

I-2 CHARACTERISTICS OF GLOW DISCHARGES IN He-CF_4/NF_3 MIXTURES
S. Griffin, N. Ianno, J.T. Verdeyen and B.E. Cherrington (15 min)

I-3 SOME EXAMPLES OF PLASMA CHEMISTRY IN FAST PULSED HIGH E/P ELECTRICAL DISCHARGES IN GASES
L.A. Rosocha (15 min)

I-4 PRODUCTION OF $O(^1S_0)$ IN ELECTRON BEAM EXCITED O_2 DOPED ARGON
J.W. Keto, C-Y Kuo and C.F. Hart (15 min)

I-5 PLASMA-ASSISTED SURFACE CHEMISTRY
J.W. Coburn and H.F. Winters (15 min)

I-6 PLASMA CHEMISTRY FOR TRACE IMPURITY ANALYSIS
M.W. Siegel (15 min)

SESSION JA: E-BEAM AND NUCLEAR PUMPED LASERS

Chairperson: R. Burnham, Naval Research Laboratory — Ballroom 3

JA-1 406 nm Ar-N_2 LASER
J.G. Eden (7 min)

JA-2 STUDY OF VUV FLUORESCENCE AND LASING IN ELECTRON BEAM EXCITED XENON
M.J.W. Boness and C. Duzy (7 min)

JA-3 NUCLEAR EXCITED CO_2 LASER PLASMA
N.W. Jalufka and F. Hohl (7 min)

JA-4 $^{235}UF_6$ FISSION FRAGMENT LASING OF Ar-Xe
R.J. DeYoung, Y.J. Shiu and M.D. Williams (7 min)

JA-5 MECHANISMS OF THE ATOMIC CARBON NUCLEAR PUMPED LASER @1.454 μ IN He-CO_2 MIXTURES
M.A. Prelas and G.H. Miley

JA-6 KINETIC PROCESSES IN THE ATOMIC CARBON LASER @1.45 μ IN A POSITIVE COLUMN DISCHARGE
M.A. Prelas, M.S. Zediker and G.H. Miley (10 min)

SESSION JB: IONIZATION AND RECOMBINATION

Chairperson: H. H. Michels, United Technologies Res. Labs. — Ballroom 4

JB-1 CROSS SECTION OF THE PROCESS $NO_2 + e \rightarrow NO_2^{++} + 3e$ FROM THRESHOLD UP TO 180 eV
H. Helm, Y.B. Kim, T.D. Märk, J. Ramler, G. Sejkora and K. Stephan (7 min)

JB-2 THE MEASUREMENT OF ELECTRON IMPACT IONIZATION CROSS SECTION OF VIBRATIONALLY EXCITED OXYGEN
B. Evans, R.M. Hobson, A Yau and J.S. Chang (7 min)

JB-3 ELECTRON-ION DISSOCIATIVE RECOMBINATION MEASUREMENTS IN HIGH PRESSUREY MERCURY DISCHARGES
S.E. Moody and R.E. Center (7 min)

JB-4 DISSOCIATIVE RECOMBINATION RATES FOR Ar_3^+
J.W. Keto and C-Y Kuo (7 min)

JB-5 ELECTRON TEMPERATURE DEPENDENCE OF THE RECOMBINATION OF ELECTRONS WITH DIMER AND TRIMER IONS
M. Whitaker, M.A. Biondi and R. Johnsen (7 min)

JB-6 ON THE DISSOCIATIVE RECOMBINATION OF VIBRATIONALLY EXCITED O_2^+ IONS
E.C. Zipf (7 min)

JB-7 FALLOFF OF TOTAL DISSOCIATIVE RECOMBINATION GROSS SECTION WITH v
T.F. O'Malley, A.J. Cunningham and R.M. Hobson (7 min)

JB-8 MEASUREMENTS OF DR AND DE CROSS SECTIONS FOR VIBRATIONALLY EXCITED H_2^+ IONS
J.W. McGowan (7 min)

COFFEE BREAK 9:50 — 10:10 A. M.

SESSION KA: VARIOUS LASERS AND LASER DISCHARGES
Chairperson: L. A. Weaver, Westinghouse R & D Center — Ballroom 3

KA-1 OPERATING CHARACTERISTICS OF CYLINDRICAL AND ANNULAR GEOMETRY, DISCHARGE-HEATED COPPER VAPOR LASERS
T. KAN AND D. BALL (7 MIN)

KA-2 KINETICS STUDIES OF THE SELENIUM (^1S) → (^3P) LASER SYSTEM
W.M. TROTT, J.K. RICE AND J.R. WOODWORTH (7 MIN)

KA-3 ELECTRON COOLING MECHANISMS IN RECOMBINATION LASER PLASMAS
W.L. BOHN AND P. WAEGLI (7 MIN)

KA-4 E-BEAM INITIATED DISCHARGES IN HIGH PRESSURE Hg VAPORS
L.A. SCHLIE, L.E. JUSINSKI, R.D. RATHGE, D.L. DRUMMOND AND R.A. HAMIL (7 MIN)

KA-5 MODEL OF STEP-WISE EXCITATION AND IONIZATION IN Na/Xe DISCHARGE
W.L. MORGAN (7 MIN)

KA-6 TRANSVERSE ELECTRODELESS RF DISCHARGE EXCITATION OF HIGH-PRESSURE LASER GAS MIXTURES
C.P. CHRISTENSEN, N. DJEU AND F.X. POWELL (7 MIN)

KA-7 RADIAL GAIN PROFILES IN CO_2 WAVEGUIDE LASERS
R.M. THOMSON (7 MIN)

SESSION KB: PHOTON REACTIONS
Chairperson: S. R. Leone, National Bureau of Standards — Ballroom 4

KB-1 RADIATIVE LIFETIMES OF $\tilde{A}^2\pi_u$ LEVELS IN CO_2^+ AND CS_2^+
R.C. DUNBAR AND D.W. TURNER (7 MIN)

KB-2 EXCITED SPECIE ABSORPTION IN THE UV WING OF THE KrF^* BAND
J.G. EDEN, R.S.F. CHANG AND L.J. PALUMBO (7 MIN)

KB-3 ELECTRONIC STRUCTURE AND PHOTOABSORPTION OF THE Hg_2^+ DIMER ION
H. H. MICHELS AND R.H. HOBBS (7 MIN)

KB-4 MERCURY CADMIUM GAIN/ABSORPTION MEASUREMENTS
A. MANDL, D. KLIMEK, J. JACOB, B. SRIVASTAVA AND M. KOVACS (7 MIN)

KB-5 PHOTOIONIZATION OF EXCITED STATES OF THE RARE GASES
C. DUZY AND H.A. HYMAN (7 MIN)

KB-6 MULTIPHOTON IONIZATION OF Cs_2 DIMERS THROUGH DISSOCIATIVE MOLECULAR STATES
C.B. COLLINS, J.A. ANDERSON, F.W. LEE, D. POPESCU AND I. POPESCU (7 MIN)

KB-7 PREDISSOCIATION PHOTOFRAGMENT SPECTROSCOPY OF CH^+
P.C. COSBY, H. HELM AND J.T. MOSELEY (7 MIN)

KB-8 ZERO CORE-CONTRIBUTION CALCULATION OF MULTI-CHANNEL PHOTODETACHMENT OF ATOMIC NEGATIVE IONS
W.B. CLODIUS, R.M. STEHMAN AND S.B. WOO (7 MIN)

KB-9 DYE LASER PHOTODETACHMENT OF NO_2^-
S.B. WOO, E.M. HELMY, P.H. MAUK AND A.P. PASZEK (7 MIN)

BUSINESS MEETING 11:45 A. M. — 12:15 P. M. — Ballroom 4

LUNCH 12:15 — 1:30 P. M.

OCTOBER 11, 1979

THURSDAY AFTERNOON 1:30 P. M.

SESSION L: NEGATIVE ION REACTIONS
Chairperson: N. G. Adams, University of Birmingham

Ballroom 2

L-1 PHOTODISSOCIATION OF CO_3^- REVISITED
P.C. Cosby, J.T. Moseley, G.P. Smith, L.C. Lee, R.V. Hodges and J.R. Peterson (7 min)

L-2 FORMATION AND ENERGETICS OF THE EXCITED AND GROUND STATES OF NO_3^-
R.L.C. Wu and T.O. Tiernan (7 min)

L-3 STUDIES OF ELECTRON DETACHMENT FOR NEGATIVE HALIDE ION-MOLECULAR COLLISIONS
L.D. Doverspike and R. L. Champion (7 min)

L-4 VIBRATIONAL PRODUCT STATE DISTRIBUTIONS OF ION-MOLECULE REACTIONS BY INFRARED CHEMILUMINESCENCE IN A FLOWING AFTERGLOW
S.R. Leone, T.S. Zwier, V.M. Bierbaum and G.B. Ellison (20 min)

L-5 CROSS SECTION FOR THE REACTION $O^- + O_2 \rightarrow O_2^- + O$ AT RELATIVE KINETIC ENERGIES 0.04 - 2 eV
S.L. Lin, J.N. Bardsley, I. Dotan, F.C. Fehsenfeld and D.L. Albritton (10 min)

L-6 THE ROLE OF H_2SO_4 IN STRATOSPHERIC NEGATIVE-ION CHEMISTRY
A.A. Viggiano, R.A. Perry, D.L. Albritton and F.C. Fehsenfeld (7 min)

OCTOBER 11, 1979

THURSDAY AFTERNOON/ EVENING

LABORATORY TOUR 3:00 – 6:30 P. M.

WESTINGHOUSE R & D CENTER

(Bus Transportation)

SOCIAL HOUR: 7:00 P. M.

BANQUET: 8:00 P. M.

} Dining Room (14 th. Floor), Westinghouse Building

OCTOBER 12, 1979

FRIDAY MORNING, 9:00 A. M.

SESSION MA: METASTABLE REACTIONS

Chairperson: R. A. Sierra, University of Missouri, Rolla — Ballroom 3

MA-1 EXCITATION TRANSFER FROM He AND Ar METASTABLE ATOMS TO N_2
A. Ricard, J. Jolly, D. Pagnon and M. Touzeau (20 min)

MA-2 EXCITATION OF Cd, Zn, AND Sr BY A BEAM OF ACTIVE NITROGEN
D.W. Fahey, W.F. Parks and L.D. Schearer (7 min)

MA-3 QUENCHING CROSS SECTIONS FOR Ar ($^3P_{2,0}$), Kr ($^3P_{2,0}$), AND Xe ($^3P_{2,0}$) BY H_2 AND D_2
W. Allison, J.W. Sheldon and E.E. Muschlitz, Jr. (7 min)

MA-4 CROSSED ATOMIC BEAM AND THEORETICAL STUDIES OF ENERGY TRANSFER IN HeNe
P.E. Siska (7 min)

MA-5 DETERMINATION OF THE F_3S-F AND F_5S-F BOND ENERGIES
T. Kiang and R.N. Zare (7 min)

SESSION MB: ATTACHMENT

Chairperson: C. L. Chen, Westinghouse R & D Center — Ballroom 4

MB-1 EFFICIENT H^- AND D^- PRODUCTION IN DISCHARGES
A. Garscadden, W.F. Bailey and G. Duke (7 min)

MB-2 DISSOCIATIVE ATTACHMENT FROM VIBRATIONALLY EXCITED HCL AND HF
M. Allan and S.F. Wong (7 min)

MB-3 ELECTRON ATTACHMENT RATES IN CL_2
R.C. Sze, A.E. Greene and C.A. Brau (7 min)

MB-4 ELECTRON DISSOCIATIVE ATTACHMENT RATE CONSTANTS FOR F_2 AND NF_3 AT 300 AND 500°K
D.W. Trainor and J.H. Jacob (7 min)

MB-5 ELECTRON ATTACHMENT IN NF_3, CCL_4, AND $HgBr_2$
H.L. Brooks, R.A. Sierra, J. Fletcher and K.J. Nygaard (7 min)

MB-6 TEMPORARY NEGATIVE ION STATES OF FLUORINE SUBSTITUTED ETHYLENES
P.D. Burrow, N.S. Chiu and K.D. Jordan (7 min)

MB-7 ELECTRON ATTACHMENT TO CHLOROFLUOROMETHANES AND CHLOROFLUOROETHANES USING THE ELECTRON SWARM METHOD
D.L. McCorkle, A.A. Christodoulides, L.G. Christophorou and I. Szamrej (7 min)

COFFEE BREAK 10:05 – 10:30 A. M.

SESSION NA: ENERGY TRANSFER PROCESSES

Chairperson: A. Ricard, Universite' de Paris-Sud — Ballroom 3

NA-1 AN AFTERGLOW METHOD FOR STUDYING COLLISION PROCESSES INVOLVING ATOMS OF LOW VAPOR PRESSURE METALS
D.W. Ernie and H.J. Oskam (7 min)

NA-2 IONIZING COLLISIONS BETWEEN PAIRS OF EXCITED ALKALI ATOMS
D. Hudson (7 min)

NA-3 VIBRATION-ELECTRONIC ENERGY TRANSFER PROCESSES INVOLVING HIGH VIBRATIONAL LEVELS OF CO MEASURED IN AN ELECTRICALLY EXCITED CO LASER SYSTEM
S.W. Kim, E. Gulari and E.R. Fisher (7 min)

NA-4 KINETIC AND ABSORPTION STUDIES ON OH*: $A^2\Sigma^+$ (λ=308 nm) RADICAL IN E-BEAM EXCITED Ar-H_2O MIXTURES
F. Collier, J.B. Leblond, F. Hoffbeck, P. Cottin (7 min)

NA-5 VIBRATIONAL LEVEL DEPENDENT RELAXATION OF CO (v=1-16) BY CO_2
B.D. Green, G.E. Caledonia and R.E. Murphy (7 min)

NA-6 COLLISIONAL RELAXATION OF ELECTRONICALLY EXCITED URANIUM ATOMS IN GASES
H-L Chen and C. Borzileri (10 min)

SESSION NB: ELECTRON SCATTERING

Chairperson: E. C. Zipf, University of Pittsburgh — Ballroom 4

NB-1 ABSOLUTE DIFFERENTIAL CROSS SECTIONS (DCS) FOR ELASTIC ELECTRON-HELIUM SCATTERING FOR 5 TO 200 eV IMPACT ENERGIES
D.F. Register and S. Trajmar

NB-2 ABSOLUTE DIFFERENTIAL CROSS SECTIONS (DCS) FOR ELASTIC AND VIBRATIONALLY INELASTIC SCATTERING OF ELECTRONS BY CO_2 AT 4, 10, 20 AND 50 eV
D.F. Register, H. Nishimura and S. Trajmar (15 min)

NB-3 CROSS SECTIONS FOR ELECTRON IMPACT EXCITATION OF THE $3s^4P$ AND $2p^44p$ STATES OF ATOMIC NITROGEN
D. Spence and P.D. Burrow (7 min)

NB-4 ELECTRON IMPACT EXCITATION OF ATOMIC OXYGEN
P.J. Espy, P.W. Erdman and E.C. Zipf (7 min)

NB-5 EXCITATION OF THE $C^3\Pi_u$ STATE OF N_2 BY SLOW ELECTRONS
K. Tachibana and A.V. Phelps (7 min)

NB-6 ELECTRON-IMPACT EXCITATION OF TRIPLET ELECTRONIC STATES OF THE CO MOLECULE
A.R. Filippelli, F.A. Sharpton and C.C. Lin (7 min)

NB-7 LONG-LIVED HIGH-RYDBERG MOLECULES FORMED BY ELECTRON IMPACT
S.M. Tarr, J.A. Schiavone and R.S. Freund (7 min)

ADJOURN 11:45 A. M.

SESSION AA

9:00 A.M.-9:50 A.M., Tuesday, October 9, 1979

Ballroom 3

ARCS AND FLOWS

Chairperson: D. T. Tuma
Carnegie-Mellon University

AA-1 Gas Flow and Arc Phenomena in a Double Nozzle Flow System - W.TIEMANN, Siemens R&D Center, FRG, - - The physical phenomena in cold and arc heated double - nozzle gas flows have been investigated by shadow and holographic interference methods. The cold gas flow - a basis to the understanding of arc heated flows - shows a variety of gasdynamic phenomena: stagnation point flow, vortex flow, shock waves between and inside the nozzles, compression waves and strong turbulence at the nozzle outlet. Flow velocities have been determined quantitatively. In the case of arc heated flows three stages of increasing interaction between arc and gas flow have been observed. At lower currents the interference pattern still shows a cold gas flow around the arc. At higher currents a rarefaction wave expands from the arc into the high pressure volume. For still higher current levels at first arc heated gas and then even plasma flows back into the high pressure storage supply.

AA-2 Flow Fields Within a Laminar Axial-Flow Arc*- T.Y. LI, D.M. BENENSON and D.P. MALONE, State University of New York at Buffalo--Measurements of local flow fields within a laminar flow plasma have been obtained using laser velocimetric methods (an extension of[1]). The experiments were carried out in an atmospheric 75A arc having mass flow of 0.1g/s. The flow channel was 10mm diameter and ∿15cm long. Aluminum oxide particles, initially 30 μm diameter, were injected upstream of the cathode. Radial distributions of the axial velocity were obtained at axial stations (Z) 3.4cm and 6.0cm downstream of (below) the cathode. Centerline axial velocity was ∿42m/s at both stations, about 20 percent greater than theoretical predictions. The flow field at Z = 3.4cm contains a relatively high velocity core, possibly due to jet effects. The velocity distribution at Z = 6.0cm more closely resembles the parabolic profile expected for fully developed plasma flow.

*Supported by National Science Foundation Grant ENG 76 17009.

[1]A.S. Nat, D.P. Malone, and D.M. Benenson, 1978 IEEE ICOPS, Monterey, California 1978.

AA-3 Transient Behavior of Gas Blast Arcs in SF_6 and N_2. D. T. TUMA*, Carnegie-Mellon University and Brown Boveri Research Center. -- Axial profiles of temperature, area, electric field, and plasma velocity for SF_6 and N_2 gas blast arcs are determined from the one-dimensional mass, momentum, and energy conservation equations as the arc current goes through zero and a linearly increasing reverse voltage is applied across the arc. Turbulent viscosity and radial turbulent energy exchange are found to be necessary mechanisms to explain the superior interrupting capability of SF_6 over N_2. The interrupting zone for both N_2 and SF_6 arcs occurs in the throat region and extends downstream from it. An SF_6 arc is found to experience a sharp decrease in both area and temperature in the interrupting zone near current zero, while in an N_2 arc only the temperature decreases sharply. The strong turbulent viscosity in the SF_6 arc reduces the plasma velocity to subsonic levels all along the arc at small currents, while in N_2 the plasma velocity downstream of the nozzle throat stays supersonic through current zero.

*Supported in part under NSF Grant No. ENG-7826377

AA-4 Bistable Modes in Horizontal High Pressure Mercury plus Iodine Arcs - D. K. McLAIN and R. J. ZOLLWEG, Westinghouse R&D Center--The two-dimensional numerical model of convection in horizontal arcs confined by a cylindrical quartz envelope[1] has been applied to a somewhat constricted mercury plus iodine discharge. Over a certain range of applied transverse magnetic field two stable modes of operation are found for the steady state (dc) arc. The arc core is displaced slightly below the tube axis in the first mode with modest convection velocities (downward) and nearly isothermal quartz envelope temperatures. In the second mode, the core resides at the bottom adjacent to the quartz tube which is excessively heated. The arc core is effectively excluded from a region 3 to 6 mm below the axis of a 9 mm radius tube for any value of magnetic field.

[1]D.K. McLain and R.J. Zollweg, Bull. of APS 24 (2) 121 (1979).

AA-5 MHD Generator Plasma Conductivity and Performance Calculations - V. YOUSEFIAN, J. WORMHOUDT, M.H. WEINBERG, and C.E. KOLB, Aerodyne Research, Inc.* - A computer program is presented which is capable of analyzing the complex physical, chemical equilibrium, and chemical kinetic processes which occur in a coal-fired MHD generator. The program calculates a full description of the operation of model MHD channels, including plasma conductivity and generator efficiency. Among the effects included in the model are those of ash-derived negative ions, coal type and related parameters, equivalence ratio, chamber pressure, air preheat temperature, staged combustors, and rate-controlled chemistry. Included in example conductivity and performance predictions are cases involving newly added options of magnetic field tailored to limit Hall field, heat losses from combustor and channel, and diffusion-controlled heterogeneous slag condensation.

*Supported by US ERDA Contract No. EX-76-C-01-2478

SESSION AB

9:00 A.M.-10:05 A.M., Tuesday, October 9, 1979

Ballroom 4

RARE GAS AND MERCURY HALIDE KINETICS I

Chairperson: J. C. Hsia
AVCO Everett Research Laboratory

AB-1 Supersonic Flow Electronic Transition Lasers. B. FORESTIER, B. FONTAINE, Institute of Fluid Mechanics Aix-Marseille U. 13003 Marseille, France -- Several high power quasi C.W. ultraviolet or visible laser emissions (XeF, NeII, FI, XeCl) have been achieved from an electron beam excited active medium in supersonic flow at low temperature (65 - 80 or 120 K) and high density (up to 2 amagats). The characteristics of the laser emissions and the temperature lowering influence will be emphasized. Some emissions in our experimental conditions are specific to low temperature operation, or favoured by lowering the temperature (XeCl 3081,83 - 3079,35 Å/FI - 7130, 7310, 7550 Å/NeII - 3481,95 Å). More details will be given in the XeCl case for which the power (30 KW cm^{-2}), the specific energy extracted (1 J/l) and the intrinsic efficiency (2,5%) are increased by temperature lowering. Results of an interferometric study of aerodynamic perturbations in the laser cavity and of their influence on the u.v. or visible laser beam scattering will be discussed. This influence seems to be not so severe that it is important in the development of high repetition rate or continuous wave hybrid lasers, as is the case for the well-known infrared vibrational lasers.

-Supported by DRET.-

AB-2 Destruction of XeCl(X) Molecules by Rare Gas and HCl Collisions† - R. W. Waynant and J. G. Eden*, Naval Research Laboratory, Washington, D. C. 20375--Collisional destruction of ground state (X) XeCl molecules has been studied by using a frequency-doubled tunable dye laser to probe e-beam excited Ne (or Ar)/Xe/HCl plasmas. Tuning the dye laser from ~ 304 to 309 nm enabled the examination of ground state collisional decay for vibrational levels from 0 to 6. Following the termination of the 3 ns FWHM e-beam pulse, the temporal evolution of the dye laser absorption was recorded. From the exponential decay of the absorption, the rate constants for destruction of XeCl (X, v=0) molecules at 300°K by Ne, Ar, Xe and HCl have been determined to be $1.0 \cdot 10^{-13}$, $6.0 \cdot 10^{-14}$, $5.6 \cdot 10^{-12}$ and $2.2 \cdot 10^{-11}$ cm^3-sec^{-1}, respectively. The temperature dependence of these rate constants (T = 300-375°K) has also been investigated and is consistent with the XeCl (X) dissociation energy of 240 cm^{-1} determined by Tellinghuisen and co-workers.[1]

†Work supported in part by DARPA.
*Present address: Department of Electrical Engineering, University of Illinois, Urbana, IL 61801.
1. J. Tellinghuisen, J. M. Hoffman, G. C. Tisone and A. K. Hays, J. Chem. Phys. 64, 2484 (1976).

AB-3 Radiative Lifetime and Collisional Quenching Kinetics for the XeCl (B 1/2) State-C.H. FISHER, R.E. CENTER, and J.P. MCDANIEL, MSNW*--A state-selective, laser-induced-fluorescence technique has been used to determine the radiative lifetime and collisional quenching kinetics for the XeCl (B 1/2) state. Chlorine atoms are formed by flash photolysis of a mixture of Cl_2 and Xe in a rare gas diluent. After a delay to allow recombination of Xe and Cl atoms, ground state XeCl molecules are excited to the B 1/2 state with a short 308 nm laser pulse. The subsequent fluorescence decay is monitored as a function of concentration of quenching species. The collision partners Ne, Ar, Xe, and HCl have been studied.

*Supported by DOE Contract No. ES-77-C-06-1022.

AB-4 Temporal Fluorescence Measurements for E-Beam Excited XeCl† - R. W. Waynant and L. J. Palumbo, Naval Research Laboratory, Washington, D. C. 20375--Observations of the temporal history of the 308 nm fluorescence from XeCl (B→X) have been made by exciting Ne (or Ar)/Xe/HCl (or Cl_2) mixtures with a 2 ns wide, 1400 A/cm^2 Febetron beam. Because of their different characteristic times for forming XeCl*, the ion and neutral channels are resolved in this short pulse experiment. By systematically varying constituent gas pressures the relative contributions from the ion and neutral channels can be adjusted so that either is dominant (or both are comparable). The fitting of a time-dependent computer model, which accounts for heavy particle and electron kinetics, to the fluorescence measurements provides estimates of rate constants for several processes in the neutral and ion formation chains.

†Work supported in part by DARPA.

AB-5 Study of the Xe_2Cl^* Blue-Green Transitions in E-Beam Pumped High Pressure Ar/Xe/RCl Mixtures. K.Y. TANG, D.C. LORENTS, and D.L. HUESTIS, Molecular Physics Laboratory, SRI International.--The broad blue-green emission continuum ($\lambda = 490 \pm 45$ nm) has been investigated in the e-beam pumped high pressure gas mixtures Ar/Xe/RCl, where RCl = Cl_2, HCl, and CCl_4. This emission was previously assigned[1] to the transition $Xe_2Cl^* \rightarrow 2Xe + Cl$. Formation and decay of Xe_2Cl^* were studied using time-resolved fluorescence. Our preliminary results are summarized as follows: (1) e-beam excitation produces Xe_2Cl^* with high efficiency for Xe $\geq$ 100 torr, (2) the radiative lifetime of Xe_2Cl^* is on the order of 100 ns, (3) quenching of Xe_2Cl^* by Ar and Xe is insignificant but quenching by the halogen donors is rapid, and (4) the blue-green transition shows intrinsic gain.

[1]D.C. Lorents, D.L. Huestis, M.V. McCusker, H.H. Nakano, and R.M. Hill, J. Chem. Phys. 68, 4657 (1978).

Research supported by SRI Internal Research and Development Program.

SESSION BA

10:30 A.M.-11:40 A.M., TUESDAY, OCTOBER 9, 1979

BALLROOM 3

ARC DIAGNOSTICS AND MODELING

CHAIRPERSON: J. F. WAYMOUTH
GTE SYLVANIA

BA-1 Radial and Axial Particle Distributions in Metal Halide Arcs

Th. Zaengel, Philips Res. Labs., Aachen, Germany
E. Groiss, Philips Res. Labs., Eindhoven, The Netherlands --

Absolute local densities of groundstate In [$^2P^o_{1/2}$] and metastable Tl [$^2P^o_{3/2}$] atoms have been determined by electronic Raman scattering in high pressure mercury discharge lamps with metal halide additives. Using Kr^+-laser lines, scattering is performed about 4 nm from resonance in its blue wing. As compared to the Ar^+-laser used earlier*, the larger cross sections [$\approx 10^{-27}$ m^2] and the negligible absorption in the blue wing strongly improve the statistical accuracy and allow measurements over the entire arc volume. The measured densities [$10^{19} - 10^{22}$ m^{-3}] show strong radial and axial variations caused by temperature gradients and associated demixing effects. The experimental results are compared with calculations**, which consider various diffusion effects (incl. ambipolar diffusion) and vertical convection.

* L. Vriens, M. Adriaansz, Philips Res.Repts. 31,193 (1976)
**H.P. Stormberg, paper presented at the same conference

BA-2 Axial Segregation in High Pressure Mercury Discharges with NaI and TlI as Additives

H.-P. Stormberg, Philips Res. Labs., Aachen, Germany --

A theoretical model for the axial segregation in cylindrical high pressure mercury discharge lamps with metal halide additives has been evaluated regarding various diffusion effects and the vertical convection of mercury. The radial and axial concentration profiles $n_i(r,z)$ of the different species are calculated by an interation procedure using the r and z dependent equation of continuity. The model is applied to the case of NaI and TlI additives and shows the strong influence of ambipolar diffusion on the axial segregation especially for Na, for which the demixing is always more pronounced than for Tl and I. Furthermore the radial concentration profiles are also influenced by the mercury convection. The numerical results are compared with particle densities obtained spectroscopically.

BA-3 Emission Spectra of HgI $B^2\Sigma$-$X^2\Sigma$ in Collision Broadened High Pressure Hg-HgI Arcs - WILLIAM M.KEEFFE, and HAROLD L. ROTHWELL, GTE Sylvania Lighting Center--A structureless emission band observed in high pressure metal halide-mercury vapor arc light sources is identified as the highly collision broadened HgI $B^2\Sigma$-$X^2\Sigma$ system. The spectra is obtained in a wall stabilized 60 Hz arc containing mercury and mercuric iodide operating at 3 amp. Typical densities are: $4 \times 10^{17}cm^{-3}$ for Hg, $2 \times 10^{16}cm^{-3}$ for I, $\sim 10^{13}cm^{-3}$ for HgI and 10^{14}-$10^{15}cm^{-3}$ for electrons. From phase resolved spectra taken at core temperatures $4000^{\circ}K < T_c < 6000^{\circ}K$, a temperature dependence is shown which is in good agreement with computed simulated intensity distributions using Franck-Condon factors and r-Centroids obtained by Cheung and Cool [1] and a simple classical oscillator broadening model. The band system is demonstrated as a useful diagnostic for extending temperature profile measurements of these arcs to cooler regions inaccessible to atomic emission diagnostics [2].

[1] N - H Cheung and T. A. Cool, JQSRT 21, 397 (1979).
[2] W. M. Keeffe et al, Bull. Am. Phys. Soc. 21,846(1976).

BA-4 Laser Induced Fluorescence Studies of Sc(I) in 400 Watt Sc-Na-Hg Arc Tubes - F.M. RYAN and C.T. JOHNSON, Westinghouse R&D Center, Pgh., PA 15235--Tunable laser induced fluorescence was used to study density profiles of neutral scandium inside operating 400 watt metal halide arc tubes. Radial fluorescence intensity profiles and derived species densities were obtained for Sc(I) at different times during the A.C. current cycle of the arc. A dye laser was tuned slightly off the resonant $3d4s^2 \rightarrow 3d^24p$ transition at 301.5 nm to achieve nearly optically thin absorption. Laser induced fluorescence was monitored for the $3d^24p \rightarrow 3d^24s$ transition at 548.4 nm. Conversion kinetics of Sc(I) to Sc(II) was deduced in the arc as a function of arc current by monitoring the Sc(I) density-current relationship. The theoretical calculation employed to derive densities from fluorescence intensity is described in an accompanying paper by L. H. Taylor and R. W. Liebermann.

BA-5 Laser Induced Fluorescence Spectroscopy of Sc - L. H. TAYLOR and R. W. LIEBERMANN, Westinghouse R&D Center, Pgh., PA 15235--The development of tunable lasers provides a new method for determining the density of particles in a given atomic or molecular state. The laser induces transitions from a lower to an upper level and the spontaneous emission from the upper level to an arbitrary lower level is measured. The theory for this technique has been developed for the excitation of neutral Sc by a dye laser. By assuming thermalization of closely lying levels and by taking temperature profiles calculated or measured elsewhere, the rate equations can be solved to give the Sc density as a function of the measured fluorescence intensity. The theory has been applied to measurements[1] on 400 watt metal halide arc tubes to deduce atomic Sc densities, and to determine the sensitivity of the technique to experimental parameter changes. The results indicate that bleaching of the gas may be troublesome in this technique.

1. See the accompanying paper by F. M. Ryan and C. T. Johnson.

BA-6 A Theoretical Investigation of the Pulsed High Pressure Sodium Arc. C.L. CHALEK and R.E. KINSINGER, General Electric Co. CR&D--A mechanism for color improvement of high pressure sodium discharge lamps when operated in a high-frequency pulsed mode has previously been suggested.[1] The mechanism involves enhanced radiation outside the D-line, from a transient high temperature "channel", during application of the power pulse. A time-dependent model for wall-stabilized LTE arcs[2] has been used to examine the pulsed sodium vapor arc. Arc properties including temperature, electrical conductivity, and optically-thick and thin radiation fluxes were calculated as functions of radius and time. The calculated radial electrical conductivity distributions indicate that at least 70% of the current is channeled through the central quarter of the overall volume. This results in high central arc temperatures and distinctly non-parabolic radial temperature distributions. These calculations offer strong support for the conclusions of Johnson & Rautenberg on the color improvement mechanism.

[1] P.D. Johnson and T.H. Rautenberg, J. Appl. Phys. 50, 3207 (1979).
[2] R.E. Kinsinger, Bull.Am.Phys.Soc. 20, 241 (1975).

BA-7 Temperature Measurement for Arcs in SF_6.

E. SCHULZ-GULDE, Institut für Plasmaphysik der Universität Hannover, Federal Republic of Germany

Steady-state wall-stabilized arcs having canal diameters of 2.1, 3.2, 5, and 8 mm were operated in SF_6 at a pressure of 1 b, at currents between 20 and 200 A. Photoelectric intensity measurements of S I, S II, F I, and F II lines were carried out end-on along a line of sight coinciding with the arc axis. Temperatures ($10000\ K \leq T \leq 19000\ K$) and fluorine to sulfur concentration ratios $M = [F]/[S]$ ($15 \leq M \leq 45$) were determined from various combinations of the measured line intensities in conjunction with computed equilibrium plasma composition data, by means of an iterative procedure. The axis temperatures were found to fit the following relationships, $T_a = A_r(I/\pi r^2)^B$ and $T_a = C(I/r)^B$, where I is the total arc current, r the canal radius, A_r a parameter dependent on the canal radius, and $B \approx 1/3$ and C are constants.

SESSION BB

10:30 A.M.-11:40 A.M., TUESDAY, OCTOBER 9, 1979

BALLROOM 4

RARE GAS AND MERCURY HALIDE KINETICS II

CHAIRPERSON: R. C. SZE
LOS ALAMOS SCIENTIFIC LABORATORY

BB-1 Electron Quenching of Rare Gas Fluoride Exciplex Molecules*, Daniel W. Trainor and J.H. Jacob, AVCO Everett Res. Lab., Inc.-- Electron quenching rate constants for the deactivation of ArF*, KrF* and XeF* have been measured using a steady-state analysis of sidelight fluorescence resulting from electron beam excitation of rare gas/fluorine mixtures. Under these attachment-dominated experimental conditions, the electron number density, n_e, is determined by $S_{eb}/k_{ATT}[F_2]$, where S_{eb} is the source term describing the production rate of electron-ion pairs by the electron beam and k_{ATT} is the electron dissociative attachment rate constant for the reaction $e+F_2 \rightarrow F^- + F$. The electron density was varied, therefore, by varying the electron beam current density and by changing the fluorine density. At 300°K, electron quenching rate constants were obtained with values near 2, 2, and 4 x 10^{-7} cm^3/sec for ArF*, KrF* and XeF* respectively.

*This work supported by DOE under contract DE-AC08-79p40103 and by DARPA under contract N00014-75-C-0062.

BB-2 A Multilevel Model of XeF Ground State Kinetics- S.F. FULGHUM, M.S. FELD and A. JAVAN MIT*- A 10 vibrational level, 4 parameter model of XeF ground state VT and dissociation processes has been fit to recent experimental data on XeF in a He buffer. The experiments determine an overall vibrational equilibration rate and dissociation rate for the vibrational manifold by probing the population in v"=0 and 1 after producing XeF in a non-equilibrium state by photodissociation of XeF_2. The results of the model can be interpreted in terms of an effective lifetime for a vibrational level, defined as the ratio of its equilibrium population to a constant rate feeding into it. Using the 4 parameters determined by the fit and a 1 atm. He buffer, these values are about 11, 4 and 1.3 nsec for v"=2, 3 and 4, respectively. The effects of these parameters on laser efficiency will be discussed.

*Work supported by the Office of Naval Research

BB-3 A Model of XeF Laser Oscillation with a Multilevel Ground State- S.F. FULGHUM, M.S. FELD and A. JAVAN MIT*- A model for multiline XeF laser oscillation has been developed which considers the relaxation kinetics associated with a 10 level ground state vibrational manifold. The XeF excited state is modeled as two vibrationally coupled levels which give rise to laser oscillation on the 0-3, 0-2 and 1-4 vibrational transitions. The model is being used to explore the effects on laser behavior and efficiency of experimentally derived parameters for ground state VT rates and dissociation rates. Utilizing these experimental rates and typical laser parameters, it predicts that the 0-2 transition will not lase in long pulse situations and that the 0-3 transition will dominate. The distribution of output power between 0-3 and 1-4 as a function of output coupling, excited state vibrational coupling and temperature will be discussed.

*Work supported by the Office of Naval Research

BB-4 XeF* Production Efficiency in 300 ns Self-Sustained Discharges*, L. E. KLINE, L. J. DENES, and S. G. LESLIE, Westinghouse R&D Center--We have measured the XeF fluorescence intensities I(B→X) at 350 nm and I(C→A) at 470 nm in mixtures with $p(NF_3)$=0.1 to 0.3 Torr, p(Xe)=0.3 to 10 Torr, and p(He)=500 to 1500 Torr. The maximum current density was 160 A/cm^2 (120 J/ℓ in the 300 ns pulse). Both I(B→X) and I(C→A) increase as $p(NF_3)$ and p(He) increase, and as p(Xe) increases up to 1 Torr. I(B→X) is constant and I(C→A) falls for p(Xe)>1 Torr. I(B→X)/I(C→A) increases as current density and p(Xe) increase, and decreases as p(He) increases. Our kinetics model predicts that Xe^+-F^- recombination dominates XeF* production. Theory and experiment agree well if we assume that only XeF*(B) is produced initially. The other dominant mechanisms in the model are B to C transfer by He, B and C quenching by Xe, and B and C mixing by electrons. An electron mixing rate coefficient $k=2\times10^{-8}$ cm^3/s is inferred. The predicted XeF* production efficiency (1-6%) increases with p(Xe) due to more efficient energy channeling, and with $p(NF_3)$ due to an increase in the Xe* and Xe^+ production rates. The predicted fluorescence efficiency is 0.5-3% in approximate agreement with experiment.
*Work supported in part by U.S. Army BMDATC.

BB-5 X-Ray Sustained Discharge for the Study of Luminescence Kinetics. J. DEGANI, M. ROKNI and S. YATSIV Hebrew University, Jerusalem*. We use X-ray irradiation and X-ray sustained discharge for inducing luminescence in high pressure gases and for studying the kinetics of excitation processes. It is difficult to maintain a continuous self sustained discharge at high gas pressures due to a strong tendency for arcing. A non self sustained discharge supported by the X-ray ionization is a convenient tool for exciting luminescence and for studying its kinetics at these pressures. The method was applied to a mixture of xenon and HgX_2 vapour (X-Br,Cl,I). The rates of electron impacts excitation at different electric fields, the quenching of HgX luminiscence by HgX_2 molecules, and the rates of electron attachment were measured. A moderate degree of electron attachment was found to be important for obtaining strong luminiscence. The intensity emission between the electrodes was not uniform. Conspicuous peaks were observed close to both electrodes. This is a striking illustration for the formation of space charge at these locations for high pressure gases containing electron attaching species.

*Supported by the U.S. - Israel Binational Foundation

BB-6 Gain, Absorption and Saturation Flux Measurements in an HgBr Laser - J. E. CELTO and E. J. SCHIMITSCHEK, Naval Ocean Systems Center, San Diego, CA -- Exposing a mixture of 900 torr Ne, 100 torr N_2 and 2.3 torr $HgBr_2$ (corresponding temperature 155°C) to a UV-preionized, transverse electric discharge, we produced gain on the $B \rightarrow X$ transition of the HgBr radical by dissociative excitation.[1,2] Two discharge devices were built with an active gain length of 60 cm each. One was run as an oscillator (with mirrors) and the other one as an amplifier. By plotting the amplified output intensity against input intensity and using the steady-state approximation for an amplifier with distributed loss, we arrived at the following data: small signal gain, g_o 6.6%/cm; absorption α_o 0.3%/cm; saturation intensity I_{sat} 200 KW/cm^2. The amplifier data will be compared with the performance of an HgBr oscillator applying Rigrod's expression [3] for variable output coupling.

[1] E. J. Schimitschek and J. E. Celto, Optics Lett. 2, 64 (1978).
[2] R. Burnham, Appl. Phys. Lett. 33, 156 (1978).
[3] W. W. Rigrod, IEEE J. Quantum Electron. QE-14, 377 (1978).

BB-7 Excitation Kinetics in Mercuric Halide Dissociation Lasers - R. Burnham, Naval Research Laboratory, Washington, D. C. 20375--Time-resolved measurements of the HgX(B-X) fluorescence from 10 nsec discharge pulses in gas mixtures of the mercuric halides (HgX_2) with nitrogen and rare gases have been carried out in order to determine the formation mechanisms for the excited states in the mercuric halide dissociation lasers. These fluorescence measurements reveal two distinct excitation channels. The first channel produces excitation only during the discharge pumping pulse. This excitation appears likely to result from electron-impact ionization of HgX_2 followed by dissociative recombination with electrons to form HgX(B). The second excitation mechanism involves dissociative excitation of HgX_2 in collisions with metastable states of nitrogen and xenon. This mechanism produces HgX(B) fluorescence following the termination of the electrical pumping pulse. Measurements of the decay rate of the fluorescence yield total rates for collisional deactivation of metastable N_2 and Xe of the order of 3×10^{-10} cc/sec. The relative importance of the two excitation channels to the operation of the mercuric halide dissociation lasers will be discussed.

SESSION CA

1:30 P.M.-2:55 P.M., TUESDAY, OCTOBER 9, 1979

BALLROOM 3

ELECTRODE EFFECTS AND VACUUM ARCS I

CHAIRPERSON: L. M. BURRAGE
McGRAW EDISON

CA-1 Plasma-Wall Interactions in Tokamaks and Low Energy Ion Sputtering as a Potential Impurity Source - J. BOHDANSKY, Max-Planck-Institut für Plasmaphysik Association EURATOM-IPP D-8046 Garching/München -- Plasma-wall interactions in fusion devices influence both the plasma and the surface behavior. In present day devices, especially tokamaks, the influence on the plasma is of principal interest. In this respect two processes at the surface are important, hydrogen recycling and impurity release. The understanding of the interaction between the plasma and these surface effects is poor because complicated transport processes in the outer plasma region make it difficult to correlate the mutual effects. Current research in this field is split along 3 lines, computer simulation, in-situ measurements and an investigation of the surface effects. In this paper the plasma induced surface effects are discussed and especially low energy ion sputtering as an unavoidable impurity release mechanism is treated in detail.

CA-2 Mass Spectrometric Investigation of Laser-Initiated Vacuum Arcs.* M. KRISHNAN and J.L. HIRSHFIELD, Yale U.—The temporal evolution of energy distributions and relative abundances of ions of different mass to charge ratio in laser-initiated vacuum metal arcs of carbon, copper and iron is described. The arc is initiated by focussing a 1J, 100 nsec CO_2 laser pulse onto a metal target in vacuum. The laser produced plasma triggers kiloampere current pulses of millisecond duration from the negatively biased target to the grounded vacuum vessel walls. The ion energy and abundance measurements were made using a specially constructed single focussing sector ion momentum analyzer in tandem with a multigrid energy analyzer. The instrument offers high resolution ($m/\Delta m = 110$) so that different charge states of a given ion or else isotopic species of equal charge are readily separated and analyzed. The wide dynamic range ($\sim 10^3$) and high time resolution ($\sim 1\mu$sec) of the instrument enable the ion distributions of the initial rapidly expanding non-Maxwellian laser ions as well as the subsequent slower, thermal discharge ions, to be measured.

*Supported by NSF Grant ENG76-22430 and by DOE Contract EG-77-S-4363.

CA-3 Measurements of Arc Root Characteristics Relevant to Contamination Induced Flashovers - H. MERCURE, M.G. DROUET, L. LAMARCHE, Sciences de base, IREQ, Varennes, Québec -- Contamination induced flashovers of high-voltage insulators have been the subject of extensive laboratory and field studies. However, the physical characteristics of the current and the electric field at the arc attachment point on the polluted insulator surface are not well established. An experimental technique has been developed to measure the surface current distribution as the arc propagates on a saline solution. Wet pollution levels < 0.5 mg/cm^2 are produced and controlled using standard deposition procedures. DC arcs, 0.1 to 10 A, are swept with the polluted surface as cathode at speeds < 100 m/sec. This diagnostic method will allow a direct measurement of the arc current distribution, which can yield the dimensions of the arc root and the current density.

CA-4 The Role of Elongated Metal Particles in Electric Breakdown in Vacuum - G. A. FARRALL and F. G. HUDDA, GE R and D Center* - Electric fields required for the levitation of individual copper particles typically 2 mm in length and having diameters ranging from 0.037 to 0.25 mm were measured in vacuum and found to lie in the range 500 to 1000 V/mm. Results are generally in good agreement with the analysis by Felici (1) for cylinders of infinite length initially at rest on a plane. Further, the motion of individual particles of aluminum, copper, and gold were studied in a transient electric field using a stroboscopic technique. Levitation fields for such particles are far smaller than those required for normal field initiated breakdown. The role of particle motion in breakdown ignition will be discussed.

*Supported by EPRI Research Project RP754-1

[1] N. J. Felici, Review Generale de L'Electricite 75, 1145 (1966).

CA-5
Arc cathode spot classification based on theoretical reasoning. G.H. ECKER, Ruhr-Universität, Bochum, Germany -- In the literature, experimental observations and model concepts of different researchers seem to indicate a large number of possible spot operation modes. On the other hand, already 20 years ago, analysis of spot operation pointed to only a few basic distinct modes of operation. More recent and more refined calculations of different authors produce a larger number of modes depending on, whether the spot is stationary, moving, on a smooth or rough surface, explosive or governed by individual phenomena. Nevertheless, the number of basic modes is still quite limited, since some of the seemingly different spots are governed by the same physical effects. For instance, the high current density spot mode at a smooth surface and the explosive individual spot mode are basically identical.

CA-6 XUV Radiation and Ionic Recombination at the Cathode of Low Pressure and Vacuum Arcs - M.G. DROUET, Sciences de base, IREQ, Varennes, Québec -- The influence of the ambient arc chamber pressure on the magnitude of both the cathode erosion and the wall current has been studied using results obtained by Kimblin (1974) for 100 to 500 A arcs struck between Cu, Ag or Carbon electrodes in N_2, He or Ar at a pressure p varying from 10^{-4} torr to atmospheric. It is found that the wall current I varies as $I = I_o \exp(-\sigma p R)$; R, the distance between the arc and the wall, varying from 0.5 to 13.5 cm. The values obtained for σ correspond to the photoionization cross-section of the ambient gas used. This leads to a determination of the wave length of the ionizing radiation. The radiation is found to correspond to that produced in the recombination of multicharged ions, up to Ag^{3+}, Cu^{5+} and C^{2+}, of the electrode material used. It is these same ions which, expanding freely in vacuum, have been measured by Davis and Miller. Decrease of cathode erosion, resulting from a reduced expansion of the cathode spot plasma, occurs at a lower pressure than the reduction of the wall current which remains high due to a contribution from the photoionized background gas.

CA-7 The Current-Voltage Characteristics of the Vacuum Arc - M.G. DROUET, Sciences de base, IREQ, Varennes, Québec -- The arcing voltage over the range 0 - 6 500 A has been represented by the equation $E(t) = A + \Phi(t).I$; A is highly dependent on the cathode material and $\Phi(t)$ varies with all discharge parameters and with time.

It is proposed that A corresponds mainly to the cathode voltage drop and is associated with the power used in the production, at the cathode, of the metallic plasma which feeds the arc. $\Phi(t)$ corresponds to the anode fall voltage and its h.f. fluctuations compensate for the time variations in the kinetic energy $\Phi_o(t)$ and the density $n(t)$ of the metallic plasma expanding from the cathode spots, thus maintaining constant the current collected at the anode:

$$I = e \cdot S \cdot n(t) \cdot \Phi_o^{\frac{1}{2}}(t) \cdot R^{-2}[1 - \exp - \Phi(t)/\Phi_o(t)]$$

this relation accounts for the correlation observed by Daalder between $\Phi(t)$ and the ion flow in the arc $n(t)$, $\Phi_o(t)$; it is in agreement with the results of Kimblin regarding the dependence on the anode surface S. The R^{-2} relation is also observed although magnetic confinement of the plasma affects the isotropic expansion and for large current $\Phi(t)$ varies as R^{+1}. Furthermore as $\Phi(t)/\Phi_o(t) << 1$, I varies as $\Phi(t)$ as observed (Kimblin, Mitchell).

CA-8 Breakdown in the Anode Sheath of the Vacuum Arc - M.G. DROUET, Sciences de base, IREQ, Varennes, Québec -- The results of Mitchell and also of Kimblin indicate that, for current up to 35 kA (I) and contact separation up to 2 cm (R), anode spot formation occurs for a constant value of the product I x R. This, coupled with the modified expression for the anode current

$$I = e.S.\ n(t)\ \Phi_o^{\frac{1}{2}}(t) \cdot R^{-2}\ [1 - \exp \Phi(t)/\Phi_o(t)]$$

reveals that the formation of the anode spot corresponds to a constant value of the voltage $\Phi(t)$ across the anode sheath. This suggest that the transition from the diffuse to the constricted anode mode is not triggered, as is usually thought, by anode melting, but rather by a breakdown in the anode sheath.

SESSION CB

1:30 P.M.-2:55 P.M., TUESDAY, OCTOBER 9, 1979

BALLROOM 4

ELECTRON DISTRIBUTIONS AND TRANSPORT

CHAIRPERSON: A. E. GREENE
LOS ALAMOS SCIENTIFIC LABORATORY

CB-1 The Spike in the Velocity Distribution of Slow Electrons. W.P. ALLIS, JILA, University of Colorado and Laboratoire de Physique des Gaz et des Plasmas*, Université Paris-Sud, 91405 Orsay.-- It was shown by G.A. Baraff and S.J. Buchsbaum[1] that a line singularity called a spike occurs in semi-conductors and gases in which inelastic collisions are important. We show that the spike has the form $\ell n(v_d/v-v_z)$, v_d = drift velocity, when the excitation cross-sections are assumed to be step-functions of the electron energy at the excitation potentials V_x and have a milder form when the cross-section is continuous at V_x. These singularities produce poorly convergent Legendre expansions so that the customary use of only two terms is inadequate.

*Supported by the Bureau of Standards in Boulder and the C.N.R.S. in France.

[1]Phys. Rev. 130, p. 1007 (1963).

CB-2 Electron Transport in Ar-H_2 Mixtures
G.N. HADDAD, and R.W. CROMPTON, Australian National University. - The transport coefficients v_{dr} and $D_\perp/\mu$ have been measured in mixtures of hydrogen and argon at various concentrations. By using the Lin et al.[1] moment theory it has been shown that for these mixtures the use of the solution of the Boltzmann equation based on the two term Legendre expansion of the velocity distribution function introduces no significant error in the analysis of the transport data. Previous discrepancies between calculated and measured transport coefficients in argon-hydrogen mixtures at low E/N appear to have been due to a combination of insufficiently accurate experimental data and the particular cross sections used in the analysis. With some adjustments to previously published cross sections, principally the momentum transfer cross section for argon, all the experimental data have been fitted to within ± 2%.

[1]Lin, S.L., Robson, R.E. and Mason, E.A. Submitted to J. Chem. Phys.

CB-3 New Electric Field Scaling Law for Swarm Experiments - P. KLEBAN, Univ. of Maine; L. FOREMAN* and H. TED DAVIS*, Univ. of Minnesota -- We generalize the familiar result that V_d (drift velocity) and pD (pressure x diffusion coefficient) are functions only of E/p (E = electric field). Our new E scaling applies rigorously to systems with scattering cross-sections related by a multiplicative constant. We find the scaling holds approximately, with a factor of six, by comparing low E electron swarm diffusion and drift data in gaseous CH_4 and SiH_4. This suggests strongly that the low energy ($\lesssim$ 1ev) effective elastic and inelastic electron cross-sections for these molecules have approximately the same shape and differ approximately by the same factor. We also present results of model calculations of V_d for electrons in gaseous CH_4-Ar vs. CH_4-He mixtures that obey the scaling approximately.

*Supported in part by the National Science Foundation.

CB-4 Negative Argon Ions and Drift Velocity v_D of Excess Electrons in Dense Argon. A. LEYCURAS and J. LAROUR, Univ. P. et M.Curie, Paris, France.- A^- ions are not observed at low density at any energy. At densities between the triple point and the critical point, it seems that v_D indicates the existence of A^- ions of life duration longer than 10^{-12} s at the triple point and at least a hundred times longer at the critical point. In particular remarkable features of v_D are its asymtotic behaviour at high field strengths and the corresponding value : less than ten times the sound velocity in the same conditions. This fact and others suggest that the electron motion is bound to one atom for a time corresponding to the time between two efficient collisions of this atom with neighbouring atoms. This concept leads to a collision assisted hopping model of the electron transport which we develop. We arrive at an expression which allows a calculation of v_D at any temperature and field strength if v_D is known at the same density. If v_D is known over a wide field range the e-A potential can be calculated for a certain e-A distance range at that density.

CB-5 Electron Mobilities in Dense Gases.† Thomas F. O'Malley, U. of W. Ontario. -- A simple model is derived for the anomalous density dependence of electron mobilities by applying the energy shift and broadening of multiple scattering theory plus the uncertainty principle to the transport equations. The shift when properly applied immediately predicts the observed positive and negative effects observed in Ar, while the exponential decrease observed in H_2, CO_2 and He are found to result from a combination of their negative energy shift and the broadening which together push the electron distribution function down to localized negative energy states. Applications to the theory of amorphous semiconductors are also discussed.

† Supported by NSF Grant No. INT77-11301.

CB-6 Influence of Excited States on Electron Transport Properties in Argon. W.F. BAILEY, G. DUKE and A. GARSCADDEN, A.F. Aero Propulsion Laboratory and A.F. Institute of Technology - It has been shown that the metastable states of argon and other rare gases have large cross-sections for excitation to higher levels and for ionization.[1] Thus the excited species act like a low ionization impurity in the discharge. The effects of small concentration of metastables, 0.01 to 0.1%, on the electron transport properties of the gas have been calculated using solutions of the Boltzmann transport equation which included collisions of the second kind. It is found that the electron drift velocity is substantially increased even by small concentrations of metastable states. The conclusions also depend on the fractional ionization. These results are expected to apply generically to other gases and should be of value in determining electron density from conductivity measurements, and also of interest to discharge models treating cumulative ionization.

[1] M.R. Flannery "Calculation of Electron Impact Cross-Sections from Metastable States" AD #A062163

CB-7 Electron Swarm Parameters in CO_2 Laser Plasmas.* R.A. SIERRA, H.L. BROOKS, AND K.J. NYGAARD, University of Missouri-Rolla.--We have measured electron drift velocities and ionization and attachment coefficients in gas laser mixtures containing He, N_2, and CO_2 with density ratios of 0:1:4, 3:1/4:1, and 0:1:1. Where applicable, we make comparison with the results of Lowke et al.[1] and find good agreements below 30 Td. The range of E/N in the experiment was from 1-100 Td with total pressures from 50-600 Torr.

*Supported in part by The Los Alamos Scientific Laboratory.

[1]J.J. Lowke, A.V. Phelps, and B.W. Irwin, J. Appl. Phys. 44, 4644 (1973).

CB-8 Low E/N Excitation and Ionization in Ar, Kr and Xe - S.A. LAWTON, McDonnell-Douglas Research Labs, St. Louis, MO, L.T. SPECHT and T.A. DeTEMPLE, U. of Ill.*--Using a pulsed swarm apparatus, low field ionization coefficients were measured in Ar, Kr and Xe in the region $.5\text{-}4\times10^{-16}$V-cm^2. The data are shown to be consistent with two ionization contributions, direct and photoelectron, and reduced as such using solutions of the transport equation yielding a revised set of threshold inelastic cross sections.

*Supported by NSF, USAF and JSEP

SESSION DA

3:15 P.M.-4:50 P.M., Tuesday, October 9, 1979

Ballroom 3

ELECTRODE EFFECTS AND VACUUM ARCS II

Chairperson: G. H. Ecker
Ruhr University, Bochum

DA-1 The Influence of Axial Magnetic Fields on the Vacuum Arc Ion Current Distribution - J.V.R. HEBERLEIN and D.R. PORTO, Westinghouse R&D Center--The ion current distribution from a 165 A dc vacuum arc was measured by an arrangement of concentric cylinders of different heights surrounding copper electrodes. Additional flat plate collectors were placed behind the anode and, in some experiments, also behind the cathode. Axial magnetic fields to 100 mT were applied, and changes of the ion current distributions due to this field were recorded. The results show that with increasing magnetic field (1) the total ion current decreases, (2) the fraction of ions moving in the forward direction increases, whereas the ion currents to the cylindrical collectors strongly decrease, (3) the fraction of ions collected behind the cathode plane increases, and (4) that the absolute value of the ion current to each collector is influenced by the potential of the adjacent collectors. These observations can be explained by assuming that the path of the individual ion is determined not only by direct interaction with the magnetic field, but also by electrostatic sheaths of increasing thickness. Measurements of floating collector potentials, showing an increasing influence of a fixed collector potential on the floating potential of the adjacent collector, support this interpretation.

DA-2 The Physics of the Retrograde Motion of the Electric Arc in a Magnetic Field. M.G. DROUET, Direction Sciences de base, IREQ, Varennes, Québec, Canada JOL 2PO. --It will be shown that both the asymmetrical magnetic confinement and the resulting anisotropic expansion of the high energy cathode spot plasma are responsible for the retrograde motion of an arc; the forward motion is attributed to the action of the transverse magnetic field on the arc column. This theory accounts for (a) the transition of the motion from retrograde to forward, (b) the influence on the direction of motion of the magnitudes of the arc current and external transverse magnetic field and the nature and pressure of the background gas and (c) the fact that the regressing boundary of the cathode foot is observed to be parallel to the applied field lines. In addition, this theory falls within the general framework of a new understanding of the physics of the vacuum arc whereby the intense ohmic heating of the microspot region (0.1 μm, 1 A, 1 μs) at the cathode surface leads to the formation of a high temperature metallic plasma, $> 10^5$ K. Conversion of the thermal kinetic energy of the plasma into directed energy results in a rapid, 10^4 ms^{-1}, expansion of the plasma.

DA-3 Conductivity Measurements in the Interelectrode Plasma of a Coaxial Geometry Pulsed Vacuum Arc - J. S. SULLIVAN and R. DOLLINGER, State University of New York at Buffalo*--The radial electric field in a coaxial copper electrode pulsed vacuum arc was measured using capacitive probes and voltage probes for arc currents as high as 8 kA. The electrodes consist of a 1 cm diameter cylindrical rod cathode positioned on the axis of a hollow cylinder anode that is 17.8 cm in diameter and 10 cm high. The arc current is supplied by discharging a 1 mF, 300 kJ capacitor through the arc. Plots of electric field vs time, arc current and voltage were obtained. Travel times of the initial burst of electrons to the anode were also obtained. The electric field was found to be dependent on arc current and fields as high as 6500 V/m were measured. Conductivities on the order of $10^2\ \Omega^{-1}/m$ were obtained. It was also determined that the conductivity of the interelectrode plasma was dependent on the electron ion collision frequency which was calculated to be on the order of $10^9/s$.

* This work was partially supported by Electric Power Research Institute and Sandia Laboratories.

DA-4 Microwave Absorption in the Vacuum Arc - M. ROSENFELD, R. DOLLINGER, State University of New York at Buffalo*--Microwave experiments performed on a vacuum arc device consisting of coaxial electrodes indicate a 10 GHz signal propagating through the plasma experiences power attenuation in excess of 20 db below the critical density (i.e. $N_c = 10^{12} cm^{-3}$). Unlike the classical discharge where reflection signals coincide with a drop in transmission for plasma densities exceeding N_c, transmission in the vacuum arc dropped prior to the microwave reflection and remained so after reflection had ceased. Similar absorption effects occurred in reflectionless arcs where critical densities were not achieved. This anomalous absorption observed in the plasma is believed to be partly the result of a large collision rate (possibly electron-neutral) relative to the microwave frequency.

* Supported in part by the Electric Power Research Institute and Sandia Laboratories.

DA-5 Numerical Simulation of a Planar High Vacuum Arc.* J.L. SHOHET, The University of Wisconsin, and P. D. PEDROW and L. M. BURRAGE, McGraw-Edison Company.--A 2-dimensional numerical simulation of a planar vacuum arc is made using the Los Alamos wave code. The arc is assumed to be composed of equal numbers of electrons and ions, with density of 10^{14} particles per cm^3. Initial temperatures of both species are 1 eV. Drift velocities, corresponding to experimental measurements, are assumed for both ions and electrons. The simulation does not include the cathode spot region, and therefore no internal electric field is assumed. Initial calculations show a uniform motion of plasma with no drastic changes in density and temperature. However, the calculations have only covered time scales of less than the time required to pinch the plasma column inward. Results from long time calculations will be presented.

*Work supported in part by the Electric Power Research Institute and in part by the National Science Foundation under Grant ENG 77-14820 and by the U.S. Department of Energy under Contract No. ET-78-S-02-5069.

DA-6 Anode Spot Formation in the Transition from Vacuum to Atmospheric Pressure Arcs - D.R. PORTO, J.V.R. HEBERLEIN, D. BHASAVANICH and C.W. KIMBLIN, Westinghouse R&D Center--D.C. arcs of 50 to 700A have been established between copper electrodes at various ambient N_2 pressures of 10^{-6} to 100 torr. The electrode activity was recorded using high speed photography, and the arc voltage, arc current and wall ion current were recorded oscillographically. The experiments extend the range of parameters previously studied,[1] and confirm that anode spot formation occurs at shorter electrode spacings with increasing pressure, and that the pressure associated with anode spot formation at a particular electrode spacing is essentially independent of anode current density. They also show that the anode phenomena are relatively insensitive to electrode separation speed. The overall data can now be presented in arc appearance diagrams which depict graphically the electrode separation at which anode activity occurs as a function of pressure, with current as a parameter. In particular, the arc appearance diagrams support a relationship between anode spot formation and pressure induced cathode spot ion starvation.

[1]C.W. Kimblin; J. Appl. Phys., 45, 5235 (1974).

DA-7 Analysis of the Anode Boundary Layer of a High Intensity Arc - H.A. DINULESCU and E. PFENDER, Univ. of Minn.*--A one-dimensional analysis of the anode boundary layer of an atmospheric pressure, high intensity argon arc reveals substantial deviations from Local Thermodynamic Equilibrium (LTE) in this layer. The temperature of the heavy species approaches the temperature of the anode in the immediate vicinity of the anode surface, whereas the electron temperature remains sufficiently high to ensure the required electrical conductivity. Temperature and density gradients in the anode boundary layer contribute substantially to the electric current so that the potential drop across the boundary layer becomes negative. The main voltage drop which is in the order of 1 volt is essentially confined to the sheath which is several orders of magnitude smaller than the anode boundary layer. Therefore, the anode boundary layer, with a thickness in the order of 0.1 mm, may be considered as the anode fall region which is of practical importance as far as anode fall measurements are concerned.

*Supported by NSF grant ENG 77-04108.

DA-8 Post-Arc Model of Current Interruption in Vacuum S. E. CHILDS and A. N. GREENWOOD, R.P.I.*--The purpose of this investigation is to obtain a better understanding of the mechanism whereby current interrupting devices of the vacuum type reignite when pushed to the limit of their interrupting capability. A theoretical model for the post-arc behavior of a vacuum interrupter is described. The interelectrode gap is characterized by an ion sheath and a quasi-neutral plasma region. With rising recovery voltage, the sheath expands across the gap. Equations, based upon the transition model of Andrews and Varey[1], are solved numerically to determine the post-arc current, sheath length, and electric field. Initial results indicate that the electric field at the former anode surface peaks within 1μs of current zero. Knowledge of the electric field and the energy input permit an analysis of possible breakdown mechanisms at the electrode surface. Experimental verification is in progress.

*Supported by DOE Contract ET-78-S-02-5013.A000

[1]J. G. Andrews and R. H. Varey, Physics of Fluids, Vol. 14 (1971) pp. 339-343.

SESSION DB

3:15 P.M.-4:40 P.M., TUESDAY, OCTOBER 9, 1979

BALLROOM 4

ION TRANSPORT, BREAKDOWN AND CORONA

CHAIRPERSON: L. E. KLINE
WESTINGHOUSE R&D CENTER

DB-1 Kinetic Theory of Drift-Tube Experiments-L.A. VIEHLAND, S.L. LIN*, and E.A. MASON*, Parks Coll. of St. Louis U.--A general kinetic theory is presented for polyatomic ions and neutrals. Some attention is given to formal aspects: assumptions about the experiments; the kinetic equation governing the ion distribution functions; the moment equations that directly govern the measurable quantities; the basis functions used to convert these to infinite sets of coupled algebraic equations; and the truncation-parameterization scheme used to obtain the transport coefficients in a systematic series of rapidly converging approximations. However, more attention is given to a numerical test of the theory and to a discussion of the physical meaning of the first approximation results: an equation for the reduced mobility; a generalized version of the Wannier formula for the mean relative kinetic energy; and a generalized version of the Einstein relations between mobility and diffusion.

*Brown University, Providence, R.I.

DB-2 Mobility and Diffusion of Protons and Deuterons in Helium - A Runaway Effect*- S.L. LIN,† I.R. GATLAND,‡ and E.A. MASON,† Brown U.† and Georgia Tech‡ -- The mobility and diffusion of H^+ and D^+ ions in He gas are calculated classically, based on an accurate ab initio interaction potential. Comparison with corresponding quantal calculations of the zero-field mobility of H^+ in He as a function of temperature shows that quantum effects are negligible above 50 K, and are only 3% at 10 K. Calculations as a function of electric field strength at fixed gas temperature indicate a runaway effect, in which the ions cannot lose enough momentum by collisions to achieve a steady-state average velocity. The drift-tube measurements of Howorka, Fehsenfeld, and Albritton (following paper) are consistent with this interpretation. This appears to be the first report of runaway ions, although runaway electrons in plasmas are well known.

*Supported by NSF Grants CHE 78-09332† and CHE 76-84181‡

DB-3 H^+ and D^+ Ions in He: Observations of a Runaway Mobility.* F. HOWORKA,[+] F. C. FEHSENFELD, and D. L. ALBRITTON, NOAA Aeronomy Lab, Boulder CO 80303--The mobilities of H^+ and D^+ ions in He have been measured over a range of ratios of electric field strength E to helium number density N with a selected-ion flow-drift tube. It is found that, at E/N greater than about 40 Td (1 Td = 10^{-17} V cm^2), the apparent mobilities exhibit an unusual increase with increasing E/N that is attributed to the breakdown of a steady-state drift velocity, i.e., a "runaway mobility". Furthermore, the widths of the arrival-time histograms indicate that the same effect is occurring for the diffusion coefficients. These observations support the predictions of this effect by Lin, Gatland and Mason (preceding paper) from their kinetic-theory calculations using an ab initio potential for the H^+ - He interaction.

*Supported in part by DNA. [+]University of Innsbruck, Austria.

DB-4 Current Buildup in Triggered Low Pressure Spark Gaps - E.J. LAUER, R. E. MELENDEZ, S.S. YU, LLL*-- The initial current density in a strongly triggered low pressure spark gap is given by the Child-Langmuir expression. However, with time, a positive background is built up by ionization processes which leads to a continuous enhancement of the space-charge limited current density. The current buildup is studied with several numerical and analytic models. In a spark gap with V_d = 250 kV, d = 2.5 cm, 0.15 torr H_2, the current is predicted to build up 100 fold in less than 80 ns.

*Work jointly performed under USDOE by LLL, contract W-7405-Eng-48 & DARPA (DoD), ARPA Order #3718, monitored by NSWC under N60921-79-PO-W0035.

DB-5 Conditions for Self-Breakdown in Low Pressure Spark Gaps - S.S. YU, E.J. LAUER, D.M. COX, LLL*-- Theoretical predictions of the low pd branch of the Paschen curve for spark breakdown are reported. The time-dependent 1-D model includes effects of ionization by electrons, ions and energetic neutrals, charge exchange, secondary electron emission from the cathode due to impact of ions and neutrals, and back scattering of electrons from the anode. pd scaling is explicitly verified. The dependence of breakdown conditions on gap voltage, cathode surface, and the atomic processes in the gap are studied.

*Work performed jointly under USDOE by LLL, contract W-7405-Eng-48 and DARPA (DoD) ARPA Order No. 3718, monitored by NSWC contract No. N60921-79-PO-W0035.

DB-6 Continuous Current in the Positive Point-Plane Corona in Air. I: Experimental- M. HIRSH and R.ABBOTT, Univ. of Minn., Morris, and G. HARTMANN,Labo. Physique des Décharges(CNRS),ESE,91190 Gif-sur-Yvette,FRANCE-- With increasing voltage, the positive point- plane corona in air is known to display three different forms below spark breakdown. Above the onset voltage V_o the current consists of random "burst pulses"; at higher voltages these pulses merge into a quasicontinuous glow discharge; at still higher voltages preonset streamers are superimposed on the continuous glow current. We have studied the continuous component I_c of this current in laboratory air, for point radii r_o between 6 and 75 μm and inter-electrode gaps from 3 to 40 mm. Throughout the glow and streamer regimes, the current obeys a Townsend-like law $I_c = CV(V-V_o')$, where $V_o'>V_o$; both C and V_o' vary with electrode geometry, gas density, and humidity. Over these same regimes, the spatial distribution of I_c at the plane is axially symmetric and varies approximately as $\cos^5\theta$ (θ is the angle between the discharge axis and the line joining the anode tip to the point of measurement on the plane). The measured values of V_o' support the expected result that the axial length of the ionization zone, r_i, at $I_c=0$ is approximately independent of electrode separation for a given point; r_i varies from about 200μm for a 6μm point to about 400μm for the 75μm point.

DB-7 Continuous Current in the Positive Point-Plane Corona in Air. II: Theoretical- M. HIRSH, Univ. of Minn.,Morris; R. S. SIGMOND, Norges Tekn. Högskole,Trondheim, NORWAY; G. HARTMANN, Labo. Physique des Décharges (CNRS), ESE,91190 Gif-sur-Yvette, FRANCE-- An approximate numerical solution has been obtained for the current-voltage relationship in the positive point- plane corona described in the preceding paper. In the calculation, the interelectrode region is divided into two zones; in the ionization zone, the field is assumed to vary according to Laplace's equation, while in the remainder of the gap the field satisfies the Poisson equation. The space charge variation employed in the calculation was obtained from the observed spatial dependence of positive- ion current described in the accompanying experimental paper. As boundary conditions on the anode field, a point roughly at the center of the ionization zone was selected at which the field was assumed to maintain a constant value of 31 kV/cm, independent of current. This assumption is approximately equivalent to selecting a field at the anode such that the Townsend integral $\int(\alpha-\eta)dr$ over the ionization zone remains constant as the discharge current varies; this maintains a steady state if secondary ionization processes are current-independent. Calculated I-V characteristics agree well with experiment for assumed positive-ion mobilities in the range 2-2.5 $cm^2/V\text{-}s$ at STP.

SESSION E

7:30 P.M.-10:00 P.M. (APPROX), TUESDAY, OCTOBER 11, 1979

BALLROOM 2

WORKSHOP ON KINETICS OF RARE GAS MONOHALIDES AT ELEVATED TEMPERATURE

THIS WORKSHOP WILL INCLUDE DISCUSSIONS OF ELECTRON QUENCHING AND ATTACHMENT PROCESSES, OPTICAL ABSORPTION PHENOMENA AND THE LOCATION AND COUPLING BETWEEN THE UPPER LEVELS, (B AND C STATES). THESE ISSUES AND THEIR TEMPERATURE RELATED EFFECTS WILL BE DISCUSSED AS THEY PERTAIN TO ELECTRON-BEAM, ELECTRIC DISCHARGE AND PHOTOLYTICALLY EXCITED RARE GAS MONOHALIDES WITH PARTICULAR EMPHASIS ON XeF, KrF AND XeCl. THE PREARRANGED SPEAKERS AND THEIR TOPICS ARE LISTED ON THE FACING PAGE.

CHAIRPERSON: M.J.W. BONESS
AVCO EVERETT

INTRODUCTION

M.J.W. Boness
AVCO Everett Research Laboratory

TEMPERATURE DEPENDENCE OF DISSOCIATIVE ATTACHMENT

P. J. Chantry
Westinghouse R&D Center

ELECTRON QUENCHING AND DISSOCIATIVE ATTACHMENT PROCESSES

D. W. Trainor
AVCO Everett Research Laboratory

ENERGY CURVE CALCULATIONS FOR XeF AND XeCl

M. Krauss
National Bureau of Standards

ABSORPTION MEASUREMENTS IN XeCl

L. F. Champagne
Naval Research Laboratory

KINETICS OF PHOTOLYTICALLY EXCITED XeF

D. L. Huestis
SRI International

AND H. T. Powell
Lawrence Livermore Laboratory

ENERGY EXTRACTION IN XeF

J. C. Hsia
AVCO Everett Research Laboratory

SESSION FA

9:00 A.M.-10:15 A.M., WEDNESDAY, OCTOBER 10, 1979

BALLROOM 3

ION REACTIONS

CHAIRPERSON: J. J. LEVENTHAL
UNIVERSITY OF MISSOURI, ST. LOUIS

FA-1 Negative Ion-UF_6 Electron Transfer Reactions: Detailed Modelling of Rate and Diffusion Coefficients in the Flowing Afterglow.* G.E. STREIT and T.W. NEWTON, Los Alamos Scientific Lab.**--In the normal manner of analyzing flowing afterglow experiments, a plot is made of log reactant ion intensity vs reactant neutral flow. The slope of the resulting line is directly related to the rate coefficient. In studies of reactions involving gases with typical atmospheric masses, such a plot does yield a nearly straight line. However in our experiments with UF_6 neutral reactant and UF_6^- as the product ion, the same plot exhibits significant curvature. A computer model of the flowing afterglow which includes the effective ion diffusion coefficients as a function of reaction progress satisfactorily models the curvature and demonstrates that the production of a low mobility ion in an ion-molecule reaction complicates the analysis used to derive rate coefficients.

*Submitted by N.C. Blais
**Work performed under the auspices of the U.S. Department of Energy.

FA-2 Flowing Afterglow Studies of Negative Ion-UF_6 Electron Transfer Reactions.* G.E. STREIT and T.W. NEWTON, Los Alamos Scientific Lab.**--Quantitative rate constant measurements have been made in a room temperature flowing afterglow for the electron transfer from SF_6^-, F^-, Cl^-, Br^-, and I^- to UF_6. In all cases the only ionic product is UF_6^-. Our values of the rate constants for the listed reactions are (in units of 10^{-9} cm^3/molecule·s): 0.9, 1.7, 1.7, 1.2, and 1.0 respectively. The apparatus, experimental techniques and difficulties associated with UF_6, and the results will be discussed. Comparisons with previous work on SF_6^- and Cl^- will be made.

*Submitted by N.C. BLAIS.
**Work performed under the auspices of the U.S. Department of Energy.

FA-3 SIFT Studies of Cluster Ions - N.G.ADAMS and D.SMITH, U.of Birmingham, England --We have used the SIFT technique[1] to study the rates of production and the reactions of several cluster ion species. In particular, a detailed study of the association reactions of CH_3^+ ions with several molecules, X, has been carried out over the temperature range 100-500 K. These reactions are often very rapid implying long lifetimes for the excited complexes $(CH_3X^+)^*$. The astrophysical implications of these[2] data will be discussed briefly. In other experiments, $H_3O^+(H_2O)_{0,1,2}$ ions were injected into the SIFT and their[3] reactions studied with D_2O. Hydrogen-deuterium exchange was very fast in these reactions and the product ion distributions were consistent with the formation of long-lived complexes in which complete scrambling of the H and D atoms occurred. The implications of these data will be discussed briefly.

[1]N.G.Adams and D.Smith, Int.J.Mass Spectrom.Ion Phys. 21, 349 (1976).

FA-4 Laboratory Measurements of Stratospheric Sodium Ion Reactions-R. A. PERRY, A. A. VIGGIANO, D. L. ALBRITTON, E. E. FERGUSON, and F. C. FEHSENFELD, NOAA/ERL, Aeronomy Laboratory--The switching reactions of Na^+ with N_2, CO, CO_2, HCl, SO_2, HNO_3 and H_2O have been studied at 300 K in a flowing afterglow apparatus. Thermochemical values and rate constants for the Na^+ cluster ions will be reported. In order of increasing stability, the ions are $Na^+ \cdot N_2$, $Na^+ \cdot CO$, $Na^+ \cdot CO_2$, $Na^+ \cdot HCl$, $Na^+ \cdot SO_2$, $Na^+ \cdot HNO_3$, and $Na^+ \cdot H_2O$. The implication of the measurements to the positive ion chemistry of the stratosphere and mesosphere will be discussed.

FA-5 Conversion of Atomic to Molecular Ions in He, Ne, and Ar at Temperatures from 78-300 K - A. K. CHEN, R. JOHNSEN, and M. A. BIONDI, Univ. of Pittsburgh* -- Three-body associations reactions of the form $R^+ + 2R \rightarrow R_2^+ + R$ (R = rare gas) have been studied in a variable temperature drift tube - mass spectrometer apparatus. We find $k(He^+, He) = (1.1 \pm 0.1)$ and $(1.8 \pm 0.2) \times 10^{-31}$ cm^6/sec at 300 K and 78 K, respectively, yielding a $T^{-0.38}$ temperature dependence. For (Ne^+, Ne) the $^2P_{3/2}$ and $^2P_{1/2}$ ionic states (distinguished by their different mobilities) exhibit the same rate coefficient $(6.4 \pm 1.2) \times 10^{-32}$ at 300 K but different values, (16 ± 3) and $(3.5 \pm 1.8) \times 10^{-32}$, respectively, at 78 K. By contrast, at 300 K, $k(Ar^+, Ar) = (27 \pm 3)$ and $(2 \pm 1) \times 10^{-32}$ for $^2P_{3/2}$ and $^2P_{1/2}$ ions, respectively, while at 78 K both ionic states yield the same coefficient $(52 \pm 5) \times 10^{-32}$. The results are compared to those of previous investigators.

*Work supported by U. S. Army Research Office under Grant DAAG29-77-G-0079.

FA-6 Measurement of the Rate Coefficients and Their Temperature Dependence for the Bimolecular and Termolecular Charge Transfer Reactions of He_2^+, Ne_2^+, and Ar_2^+*. C.B. COLLINS and F.W. LEE, Univ. of Texas at Dallas--This work continues[1] the measurement in afterglows of e-beam discharges into high pressure gas mixtures of rate coefficients for energy transfer reactions of inert gas ions. The bimolecular and termolecular rates of reaction of He_2^+, Ne_2^+, and Ar_2^+ with selected reactants have been measured. The bimolecular rates were found to agree with the NOAA results[2] when available. The termolecular rates and their temperature dependence could be interpreted in terms of a simple classical model of the frequency at which the presence of third bodies changed glancing collisions of the reactants into inwardly spiralling orbits.

*Research supported by NSF Grant ENG78-16930.

1. F.W. Lee, C.B. Collins and R.A. Waller, J. Chem. Phys., 65, 1605 (1976); F.W. Lee and C.B. Collins, J. Chem Phys., 65, 5189 (1976); 67, 2798 (1977); 68, 1391 (1978); 68, 3025 (1978); 70, 1275 (1979).
2. D.K. Bohme, N.G. Adams, M. Mosesman, D.B. Dunkin, and E.E. Ferguson, J. Chem. Phys., 52, 5094 (1970).

SESSION FB

9:00 A.M.-10:10 A.M., WEDNESDAY, OCTOBER 10, 1979

BALLROOM 4

SHEATH EFFECTS AND DISCHARGE STABILITY

CHAIRPERSON: W. L. NIGHAN
UNITED TECHNOLOGIES RESEARCH LABORATORIES

FB-1 Study of the cathodic region of a discharge
E. MARODE, TRAN NGOC AN, Supelec C.N.R.S. 91190 Gif/yvette
G. FOURNIER, ONERA 92320 Chatillon, P.SEGUR, S.PAREATHUMBY
Centre de Physique Atomique 31000 Toulouse FRANCE --
Three methods giving the distribution function of electrons in a highly non uniform field has been developed in order to study the properties of the cathode fall in a electrical discharge. Two of them are related to the Boltzmann equation, the third with Monte Carlo statistical analysis. The Boltzmann equation is used in an integral form which does not require a series expansion of the solution. As a consequence this method can be applied to highly divergent fields. The Monte Carlo method has the advantage of the flexible introduction of data and it does not use extented computation time. The three methods predict a similar behavior of the discharge cathode fall and give an evaluation of the neutral species excitation rate by electron collisions. The future development of this study should yield a self consistant solution for the entire cathodic region.

FB-2 Predictions of Cathode Sheath Characteristics in Helium Glow Discharges*-R. R. MITCHELL, L. E. KLINE, and L. J. DENES, Westinghouse R&D Center--We used a one-dimensional, steady-state model to study power loading in the cathode fall region of helium glow discharges. The model includes electron and positive ion drift and diffusion, recombination, ionization, and field distortion by space charges. The electrons are assumed to be in equilibrium with the field and gas heating is not treated. With literature values for the transport coefficients and the coefficients of recombination, ionization, and secondary electron emission, the model gives good quantitative agreement with published measurements of field versus position at low pressure ($\sim$0.3 to 2.0 torr) over the range $10^{-6} \lesssim j/p^2 \lesssim 10^{-4}$ A/cm^2 torr^2. We conclude that gas heating is not significant in this regime and that the assumption of electron equilibrium with the electric field, though not strictly true, is adequate for the model. Because power loading is proportional to p^3, gas heating will be increasingly important at higher pressures in this range of j/p^2.

*Work supported by U. S. Army BMDATC.

FB-3 Cathode Sheath Energy Deposition in Pulsed Helium Discharges - M.J. PECHERSKY, S.G. LESLIE, and L.E. KLINE, Westinghouse R&D Center--We have measured the energy deposited in the cathode sheath in a UV preionized, self-sustained discharge by measuring the velocity of the cathode shock wave and applying shock tube theory. The velocity of the shock wave was measured using a Michelson Interferometer and an STL image converter camera. The electrode spacing was 2 cm and the transverse dimensions were 2 cm x 75 cm. For a 1000 torr helium discharge with a pulse length of 100 nsec (FWHM) and a total energy input of 8.6 J, the measured shock wave Mach No. at a distance of 1 cm from the cathode was 1.05. The sheath energy was inferred by performing shock tube calculations in which the total energy into the discharge was held constant at 8.6 J with varying amounts being partitioned between the cathode sheath and the positive column. The corresponding specific energy loading in the cathode sheath was found to be 4560 J/ℓ-atm as compared with 19.5 J/ℓ-atm in the positive column. The sheath energy loading was also estimated to be 4030 J/ℓ-atm by extrapolating the experimental results of Warren.[1]

[1]R. Warren, Phys. Rev. 98, 1650 (1955).

FB-4 Quantitative Correlation of Attachment Strength with the Onset of Arcing in Rare Gas-Halide Discharges* L. J. DENES, P. J. CHANTRY, and L. E. KLINE, Westinghouse R&D Center, Pgh., PA 15235--We have measured the maximum arc-free current in self-sustained 300 ns discharges in FD:Xe:He mixtures of p(FD):3:1000 Torr as a function of p(FD), the partial pressure of the fluorine donor, FD. Donors studied include SF_6, NF_3, C_2F_6, and CF_4 for which $\eta/p(FD)$ varies by a factor of 100. η is the attachment coefficient. In all cases, at low values of p(FD), arcing occurs at current densities of $\sim$100 A/cm^2, with the arc precursor filaments orginating from the cathode region. At a particular value of p(FD), however, the maximum achievable arc-free current density drops precipitously to values $\lesssim$10 A/cm^2 and for higher p(FD) values the precursor filaments originate from the anode region. This critical value $p_c(FD)$ varies from $p_c(SF_6)$ = 0.26 Torr to $p_c(CF_4)$ = 17 Torr. Nevertheless, the corresponding calculated η at this critical pressure is $\sim$20 cm^{-1} in all cases, suggesting that η is the key parameter which controls the maximum arc-free current density in these high pressure discharges.

*Supported by U.S. Army BMDATC and Westinghouse Systems Development Div.

FB-5 Electrode Surface Related Arcing in High Pressure Self-Sustained Glow Discharges*, L. J. DENES, W. R. GASS, I. E. KANTER and L. E. KLINE, Westinghouse R&D Center-- We have studied the effects of electrode surface finish on threshold current for arcing in 300 ns self-sustained glow discharges in NF_3:Xe:He = 0.2:3:1000 Torr mixtures. A variety of electrode materials were contoured and given a mirror-like polish to remove surface protrusions. Microscopic inspection of the surfaces typically showed many ($\gtrsim 10^4/cm^2$) small (1-10 μm) 'pits' and a few ($<1/cm^2$) larger ones. The samples were tested on a small (25 cm^3) discharge apparatus of optimized electrode geometry and electrical circuitry. Arcing showed little dependence on electrode material. On the other hand, arc damage was concentrated at the sites of the larger (>10 μm) pits. Removal of these random defects increased the maximum current density from ∿50 to ∿150 A/cm^2. Photographic evidence suggests that arcing begins in the sheath regions. Theory predicts that the sheath thickness decreases with increasing current density (10 μm at 50 A/cm^2, 5 μm at 150 A/cm^2). We conclude, therefore, that arcing will occur under conditions where the sheath thickness is comparable to the scale of the largest surface void defects.

*Supported by U.S. Army BMDATC and W Systems Dev. Div.

FB-6 Streamer Growth in an E-Beam Sustained Discharge. P.S. ROSTLER and D.H. DOUGLAS-HAMILTON, Avco Everett Res. Lab. Inc.*-- The electron-beam sustainer (EBS) discharge has many applications, especially in high power gas lasers. The most important instability in such discharges is the streamer, a column of hot gas which resembles an arc more than the classic electron spark breakdown of the self sustaining discharge. In this paper, high speed framing camera (22,800 frames/sec) observations of streamer formation and growth in an EBS discharge will be reported. We have theoretically modelled a streamer as a column of gas resistively heated to a temperature (∿6000°K) at which thermal ionization significantly raises the conductivity and hence the current. This model predicts exponential growth. The magnitude and parametric scaling of the calculated growth rate will be discussed and compared with experiment.

* Supported by Air Force Aero Propulsion Laboratory, Air Force Systems Command, USAF, WPAFB, F33615-78-C-2013.

FB-7 Fractional Power Transfer and Ion Formation Rates in Oxygen and Oxygen-Iodine Mixtures. J.W. DETTMER and A. GARSCADDEN, A.F. Weapons Laboratory, Kirtland AFB NM and A.F. Aero Propulsion Laboratory, Wright-Patterson AFB, Ohio - A set of cross-sections[1] consistent with experimental transport properties and ionization coefficients for oxygen has been used with a numerical solution of the Boltzmann transport equation to calculate fractional power transfer in oxygen. In order to more realistically model discharges, we have estimated the influence of O_2 singlet delta metastable concentrations on the ionization rates and on attachment and detachment. Oxygen-iodine mixtures with small concentrations of iodine have then been included in ion formation rate calculations. The influence of the metastable states and also the effects of the strong electronegative gas on the stability and energy loading of electron beam discharges are also considered.

[1] A.V. Phelps, Private Communication

SESSION GA

10:30 A.M.-12:20 P.M., WEDNESDAY, OCTOBER 10, 1979

BALLROOM 3

POSITIVE ION REACTIONS

CHAIRPERSON: R.L.C. Wu
WRIGHT STATE UNIVERSITY

GA-1 Information from Exothermic Rate Constants Measured as a Function of E/p. W.B. CLODIUS and S.B. WOO, Univ. of Del.--The inherent limitations which attend the inference of a cross section, σ, from its rate constants, K, come from two sources--(a)the smoothness of the kernal, g, and (b)the uncertainties of K. These limitations can be studied quantitatively. Russ et al[1] have studied the maximum permissible number of parameters in any representation of σ that can be evaluated from drift tube measurements of K for endothermic reactions. We recently did a similar study for exothermic reactions and found that for the same amount of uncertainty in K many more parameters are available in any representation of σ. For example, we found that a 15% standard deviation on K implies a maximum of about 9 parameters for σ, regardless of the dynamic range of K. A least squares approach was used to verify the above findings. Numerical examples were studied including the effect of the buffer gas. Differences with the findings for endothermic reactions are compared and explained.

[1]C. Russ, M. V. Barnhill,III, and S. B. Woo, J. Chem. Phys. 62, 4420 (1975)

GA-2 Kinetic-Energy Dependence of the Product Ratios of the Reaction of N^+ Ions with O_2.* F. HOWORKA,[+] I. DOTAN,[‡] F. C. FEHSENFELD, and D. L. ALBRITTON, NOAA Aeronomy Lab, Boulder CO 80303--The energy dependence of the product ratios of the reaction

$$N^+ + O_2 \rightarrow O_2^+ + N + 2.5 \text{ eV} \quad (52\%)$$
$$\rightarrow NO^+ + O + 6.7 \quad (41\%)$$
$$\rightarrow O^+ + NO + 2.3 \quad (7\%)$$

have been measured in a selected-ion flow-drift tube at relative kinetic energies 0.04 - 2.5 eV. At room temperature, the above ratios agree well with previous flow-tube values, but not with earlier ion-cyclotron-resonance values. At higher energies, O_2^+ becomes the dominant product ion and the ratios agree with previous crossed-beam results.

* Supported in part by DNA. [+]University of Innsbruck, Austria. [‡]The Weizmann Institute, Israel.

GA-3 Charge-Transfer and Association Reactions Involving Mercury and Rare-Gas Ions* - R. JOHNSEN AND M. A. BIONDI, U. Pittsburgh.--A drift tube - mass spectrometer apparatus has been used to determine thermal-energy rate coefficients for reactions of the type $R^+ + Hg \rightarrow R + Hg^+$ and $R_2^+ + Hg \rightarrow 2R + Hg^+$ (R = rare gas). The results at 300 K are:

reaction	k(cm^3/sec)	reaction	k(cm^3/sec)
$He^+ + Hg$	2.5(-9)	$He_2^+ + Hg$	4.5(-10)
$Ne^+ + Hg$	< 5(-13)	$Ne_2^+ + Hg$	5 (-11)
$Ar^+ + Hg$	< 5(-13)	$Ar_2^+ + Hg$	< 1(-12)
$Kr^+ + Hg$	< 1(-12)	$Kr_2^+ + Hg$	< 1(-12)
$Xe^+ + Hg$	< 1(-13)	$Xe_2^+ + Hg$	5(-10)

notation: $(-x) = 10^{-x}$

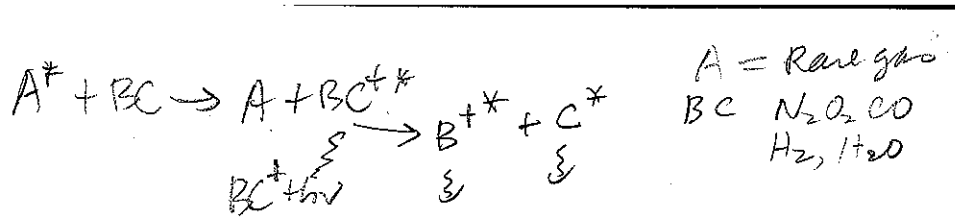
In a xenon-mercury mixture, the sequence $Hg^+ \rightarrow XeHg^+ \rightarrow Hg_2^+ \rightarrow XeHg_2^+ \rightarrow Hg_3^+$ produces triatomic mercury ions with three-body rate coefficients of 4 and 1(-31) cm^6/sec for steps 1 and 4, respectively, and two-body coefficients of ~ 5(-10) cm^3/sec for steps 2 and 4. The rate coefficient for $Ar_2^+ + Xe \rightarrow 2Ar + Xe^+$ is 5(-10) cm^3/sec.

*Work supported by ARPA/ONR (N000-14-76-C0098).

GA-4 Ab Initio Characterization of the High-Barrier Adiabatic Pathway for the $O^+(N_2,N)NO^+$ Reaction. D.G. Hopper, Science Applications, Inc.* -- Ab initio computations by the multi-configuration self-consistent field (MCSCF) method have been made for the repulsive $^4\Sigma^-$ co-linear pathway for the reaction of O^+ with nitrogen to yield NO^+,N, where all reactants and products are in their electronic ground states. The ab initio theoretical reaction exothermicity is 0.94 eV, which compares to an experimental value of 1.10 eV. The saddle-point for this co-linear surface is predicted to be at 7.31±0.5 eV relative to $O^+ + N_2$ and to be characterized by critical values of R_{NN} and R_{NO} which are about 0.5 and 0.4 a.u. respectively, greater than the equilibrium N_2 and NO^+ diatomic bond lengths. The implications of this high-barrier mechanism will be discussed in relationship to other mechanisms for the $O^+ + N_2$ reaction[1].

*Supported in part by US AFOSR.

[1]D.G. Hopper, J. Amer. Chem. Soc. 100, 1019 (1978).



IP(A) > IP(BC)
Excess energy what happened KE can take up ½–1 eV

GA-5 Experiments on Energy Disposal in Charge Transfer at Near Thermal Energy. T. R. GOVERS, G. MAUCLAIRE, and R. MARX. Laboratoire de Résonance Electronique et Ionique, Université de Paris-Sud, 91405 Orsay, France,--Energy disposal in charge exchange between rare gas ions and small molecules (mainly diatomics and triatomics) at near thermal energy is studied by emission spectroscopy and ICR. The first method identifies excited products emitting between 185 nm and 600 nm and measures their relative abundance and vibrational energy distribution. In the second, more recent experiments ICR techniques have been adapted to provide information on product kinetic energies, in addition to overall reaction rates and product distrubutions.[1] Translationally and/or vibrationally excited products are common, as are departures from energy-resonance and Franck-Condon criteria. The system $Ar^+ + H_2O$ will be discussed as an example.[2]

1. G. Mauclaire et al, J. Chem. Phys. 70, 4017 (1979).
2. R. Derai et al., Chem. Phys. (in press, 1979).

GA-6 Electron Transfer and Excitation in Low Energy N_2^+ - Alkali Atom Collisions* - J.L. BARRETT and J.J. LEVENTHAL, U. of Missouri-St. Louis--Inelastic collisions between N_2^+ ions and alkali atoms (Li, Na and K) have been investigated using a crossed beam apparatus and spectroscopic analysis of collision-produced radiation (180-850 nm). Collision-induced excitation to the lowest alkali atom excited state was observed to compete favorably with near resonant charge transfer to $N_2(C)$. The vibrational state distributions within $N_2(C)$ from N_2^+ - K collisions are in accord with a vertical transition model, while the distributions resulting from N_2^+ - Li and Na collisions are not. These results will be discussed within the framework of a surface crossing model[1] developed to describe such collisions. Absolute cross sections for the observed processes are also reported.

*Supported by ONR Contract No. N00014-76-C-0760

[1]J.D. Kelley, G.H. Bearman, H.H. Harris, and J.J. Leventhal, J. Chem. Phys. 68, 3345 (1978).

GA-7 Quasi-Resonant Charge Transfer at Thermal Energies in the Rare Gases

J.D.C.JONES, D.G.LISTER, K.BIRKINSHAW and N.D.TWIDDY
U.C.W., Aberystwyth, Wales.

Abstract

A selected ion flow tube (SIFT) apparatus has been used to study thermal energy charge transfer reactions between isotopic species in each rare gas, Ne, Ar, Kr and Xe. The results obtained are in agreement with theoretical calculations.

The theoretical rate constant as a function of temperature has been calculated from the known velocity distribution in the S.I.F.T. and a theoretical charge transfer cross section which takes into account curved trajectories at low energies. This modification is essential to compare low energy rate constant results with theory. The results are also compared with other experimental data, and good agreement is found.

GA-8 Collisions of Ions with Laser-Excited Rydberg Atoms.* K. MACADAM, D. CROSBY, and R. ROLFES, University of Kentucky.--Preliminary experimental results will be reported on ℓ-changing collisions between laser-excited Na Rydberg atoms and He^+ ions for comparable ionic and electron-orbital velocities. Enormous cross sections, on the order of 10^7 Å^2, are observed for transfer from specific Na(nd) target states ($n \approx 25$) to np and nf final states. We obtain the results on a new crossed ion/atom beam apparatus that uses a N_2/dye laser system for stepwise pumping of a Na beam. Detection by time-resolved field ionization permits the identification of collisionally produced final states.

* Supported in part by the Research Corporation and the National Science Foundation.

GA-9 Reactions of Ne^{++} and Kr^{++} with Some Atoms and Molecules - D.SMITH and N.G.ADAMS, U.of Birmingham, England --Following a detailed study of the reactions of the ground and excited metastable states of Xe^{++} and Ar^{++}[1,2], we have carried out a study of the reactions of Ne^{++} and Kr^{++} ions with rare gas atoms and several molecules in a SIFT apparatus at 300 K. The reactions with molecules are all fast, near to the collisional limit, and all proceed via single charge transfer, whereas the rate coefficients for reaction with the rare gas atoms vary greatly from immeasurable in our experiments ($\lesssim 5 \times 10^{-13} cm^3 s^{-1}$) up to the collisional limit ($\gtrsim 10^{-9} cm^3 s^{-1}$). Single charge transfer is again the most common mechanism in the atom reactions, but in the Ne^{++} reactions with Kr and Xe, double charge transfer channels are evident and a fraction of the product Kr^{++} and Xe^{++} ions are shown to be in excited states. The atom reactions can be interpreted in terms of a simple model involving the crossing of potential curves at favourable internuclear separations.

[1]N.G.Adams,D.Smith and D.Grief, J.Phys.B. 12,791 (1979)

[2]D.Smith, D.Grief and N.G.Adams, Int.J.Mass Spectrom.Ion Phys. 30, 271, (1979).

SESSION GB

10:30 A.M.-12:10 A.M., WEDNESDAY, OCTOBER 10, 1979

BALLROOM 4

GLOW DISCHARGES

CHAIRPERSON: R. BLEEKRODE
PHILIPS RESEARCH LABORATORIES

GB-1 Electron Density Profiles in Positive Columns with Diffusion Loss. GERALD L. ROGOFF, Westinghouse R&D Center--A simple yet exact characteristic equation has been derived[1] for steady-state longitudinally-uniform positive columns in which the electron density n_e is given by the continuity equation $D\nabla^2 n_e+\nu n_e+kn_e^2=0$ with the coefficients independent of position and with $n_e=0$ at the boundaries, which can be of arbitrary cross-sectional shape. The coefficients ν and k may be positive or negative and can each represent the net effect of various production and loss processes. The general equation contains a dimensionless quantity S (the integral of $-\nabla^2 n_e/n_e$ over the cross section) which provides information about the shape of the density distribution. For a circular cross section the variation of the density profile and S have been determined numerically for all possible relative magnitudes and combinations of signs of ν and k. S varies from large positive values for diffuse columns (for $k<0$, i.e., with electron loss by volume recombination) to large negative values for constricted columns (for $\nu<0$, i.e., with loss by attachment). For $\nu<0$, the results predict that no steady-state profiles are available with attachment-dominated loss at the location of maximum n_e.

[1]G.L. Rogoff, Bull. Am. Phys. Soc. 24, 126 (1979).

GB-2 Radial Distribution of Electron Density and Excited Atoms in a Plasma Column Produced by a Surface Wave, M. MOISAN, R. PANTEL, A. RICARD and W.P. ALLIS, U. Montréal.--We have observed the radial distribution of excited atoms in an Argon plasma produced by a surface wave. The measurements are made by recording both radial emission and absorption of spectral lines. Depending on the gas pressure (50-350 mTorr), on the electron density and on the plasma diameter, the radial distribution of excited atoms is either flat or has a minimum on the axis and a maximum near the tube wall. This behaviour is explained theoretically by showing that the excitation rate is proportional to $n(r)E^2(r)$ where r is the radius, n(r) is the electron density and $E^2(r)$ the electric field intensity of the surface wave. The radial distribution of electrons is known only through a calculation assuming ambipolar diffusion. In particular, it is shown that, whatever the profile of E(r), n(r) can always be fairly well approximated by a Bessel function J_o. Most of the observations were repeated on a positive column of the same diameter and operated under the same pressure. The possibility of obtaining different radial distributions of excited atoms could be of interest for applications (laser, plasma chemistry).

GB-3 The plasma density distribution in a medium pressure flowing positive column--J.S. Chang McMaster University, S. Karpik York University, Canada -- A numerical analysis has been done for for the plasma density distribution in a diffusion controlled flowing positive column. The case of viscous flow in a cylindrical discharge tube has been considered. The present work covers the range of ambipolar diffusion Reynolds number from 0 to 100, and nondimensional discharge region length from 0.1 to 10. The numerical results show that: (1) plasma density distribution obtained by the slug flow model (Romig 1960) leads to large error; (2) the radial density profile upstream and downstream of the location of maximum plasma density is wider and narrower, respectively, then the zeroth order Bessel profile; (3) the electron temperature inside the discharge region agrees well with that predicted by Chang (1978).

M.F. Romig (1960) Phys.Fluids 3,129.
J.S. Chang (1978) J.Appl.Phys. 49,1287.

GB-4 Absorption, Dispersion and Stray Light Measurements near Resonance of λ = 5875,97 Å and λ = 5875,62 Å He-Lines in a Glow Discharge using a Tunable Dye Laser

H. ODENTHAL and J. F. UHLENBUSCH

Universität Düsseldorf F.R.G.

To determine the temperature of neutral He-atoms in the positive column of a glow discharge in He ($I \leq 120$ mA, p =1-10 Torr, R=1 cm) absorption- and stray-light-profiles of the Doppler broadened lines at 5875,62 Å and 5875,97 Å were measured. The results in the pressure and current regime given above show that the temperature is nearly the same in radial and longitudinal direction of the discharge and varies between 340 K to 750 K. The light source for these investigations was a tunable dye-laser with a bandwidths of 2 MHz and a scanning range of about 30 GHz. The determination of the absolute population density in the 2^3P-level of He-atoms was done by resonance interferometric measurements on the He-line at 5875,62Å using a micro-processor controlled Michelson interferometer. At 1 Torr discharge pressure and currents between 30 and 120 mA the density varies from $3 \times 10^9 cm^{-3}$ to 5×10^{10} cm^{-3}

GB-5 Electrophoresis at High E/p. J.H. INGOLD, General Electric Co.--The theory of electrophoresis is fairly well understood at low E/p where the axial pressure difference in the positive column of a rare gas discharge is observed to vary inversely with gas pressure. However, this behavior is not observed at high E/p, and the theory of electrophoresis at high E/p is not well understood. In the present paper, the history of electrophoresis is reviewed briefly, and a possible explanation for the departure from dependence on inverse pressure at high E/p is offered. The explanation lies in the realization that the positive column at high E/p and about 1 torr pressure is neither a Schottky type (high pressure, diffusing ions) nor a Tonks-Langmuir type (low pressure, freely-falling ions), but is somewhere between.

GB-6 Simplified Models for Low-Pressure AC Discharges. M.J.C. van GEMERT and J.-P. MOREL, Philips Research Laboratories, Eindhoven The Netherlands. --Three models are presented for low pressure ac-discharges. They are based on the simultaneous time dependent solution of the spatially averaged forms of the electron continuity equation and the electron energy equation. Simple analytical relations are used to represent the discharge parameters such as ionization frequency, ambipolar diffusion coefficient and electron energy losses. The models differ in the number of approximations used in the two equations. Our discharge model yields a physical interpretation of the Francis equations[1]. Tests are presented for a fluorescent lamp type of discharge at 50, 500 and 10.000 Hz in a resistance loaded circuit.

1) V.J. Francis, Fundamentals of Discharge Tube Circuits, John Wiley and Sons, Inc., New York (1948).

GB-7 An Elementary Model of the AC-Discharge-Ballast Interaction - JOHN F. WAYMOUTH, GTE Sylvania, Danvers, Mass. 01923--The general equation for an alternating current discharge-ballast circuit combining inductive and capacitive impedances is $V_D(i,di/dt) = Voc(t)-L(i)\,di/dt+q(t)/C$. The simultaneous solution of this equation together with one giving the explicit dependence of the discharge voltage drop V_D on i and di/dt gives the discharge current and voltage waveforms as a function of alternating current phase angle. The exact solution requires an accurate discharge model including all energy exchange, ionization, and recombination processes. In this work, an elementary discharge model is employed using the relationship $(1/\sigma)\,(d\sigma/dt) = -1/\tau + (1/\tau)\,(E/Eo)^n$, where σ is plasma conductivity, τ is ambipolar diffusion time constant, E is axial voltage gradient, Eo is the steady-state maintaining voltage gradient, and n has a value between one and two. This relationship is applicable for supply frequencies such that $(1/E)\,(dE/dt) \ll \nu_x$, where ν_x is the inelastic collision frequency of electrons in the plasma. A successive-approximation solution has been developed and applied to the case of discharge lamps operated on 60 hz ballasts with non-sinusoidal open circuit voltage and non-linear inductive and capacitive impedances.

SESSION H

2:00 P.M.-2:30 P.M., WEDNESDAY, OCTOBER 10, 1979

BALLROOM 2

DISCHARGE CHEMISTRY

CHAIRPERSON: W. A. FITZSIMMONS
NATIONAL RESEARCH GROUP

H-1 The Effect of Chemical Processes on the Electron Temperature of a Medium Pressure, Rare Gas, Radio Frequency Discharge - Y. ICHIKAWA, G.L. OGRAM, R.M. HOBSON, York University, Canada, J.S. CHANG, McMaster University, Canada, S. TEII, Musashi Institute of Technology, Japan -- The recent positive column theory of Ichikawa et al (1979) has taken into account the effect of various chemical processes on the production, loss and interconversion of metastable and ion species. The experimental measurements have been made in a 4 cm i.d. r.f. discharge tube for He, Ne and Ar. An electrostatic triple probe was used to monitor the electron temperature and plasma density, and a mass spectrometer was used to analyse the ion species. Metastable densities were measured using a self absorption technique. The results show that: (1) the abundance ratios of the atomic and diatomic ions agree reasonably well with those predicted theoretically for gas pressures above about 1 torr; (2) for lower pressures a larger relative diatomic ion concentration than predicted was observed. This is attributed to the effect of excited species on molecular ion production becoming important at lower pressures; (3) the electron temperature in the positive column has a complicated pressure dependence due to the variation of the relative importance of various processes, but agrees well with the theory.

H-2 Effect of Oxygen and Hydrogen on Electron Beam Discharges in Atmospheric Pressure CO_2 Mixtures. P. BLETZINGER, Aeropropulsion Laboratories, WPAFB, Ohio C.A. DeJOSEPH, JR., Universal Energy System, Dayton, OH Electron-beam generated plasmas in gas mixtures of the type used in high pressure CO_2 lasers have been investigated in a high-purity closed-cycle flowing gas system. The generation of dissociative products in our experiment was very small using only CO_2 with various N_2 or He background pressures. The addition of very small amounts of O_2 and or H_2 caused dramatic increases of these products as measured by off-line infrared analysis The addition of less than 1% of O_2 increased the amount of some nitrogen oxides generated by more than 10 times. As expected, added H_2 decreased the amount of CO by a factor of 10, but also increased N_2O about 5 times with O_2 present. No HNO_2 or HNO_3 was detected, however these species could be playing an important role in the discharge chemistry and in the generation of the end-products observed. Other discharge products detected with H_2 added were CH_4 and HCN. CO generation and loss rates were measured on-line with a tuneable diode laser. Attempts were made to construct simple models for some of the observed processes.

H-3 Low-Energy Processes Induced by an Electron Beam in Oxygen.- G. FOURNIER, J.BONNET, J.BRIDET, J.FORT, and D.PIGACHE, ONERA France -- The rate coefficients for low-energy processes in oxygen result from a distribution function which is computed with a cascade code. The predictions of this code are compared with experimental measurements of the ozone fraction generated by a 110 keV electron beam in oxygen at 1.13 bar. Typical conditions are: Flow rate = 250 cm^3/s, beam current = 300 mA, pulse duration = 100 μs, repetition rate = 10 Hz. Moderate production rates are investigated in order to avoid increasing gas temperature. For a chamber temperature of 300 K, the ozone yield is 2.2×10^{-5} g per Joule deposited in the gas for an ozone fraction of a few 10^{-4} (such an efficiency is not competitive with present industrial ozonizers). A satisfactory agreement of theory with experiment is achieved when it is assumed that dissociative attachment, 8.4 eV excitation and dissociative ionization drive one ozone per collision whereas 6 eV excitation drives two (but this choice is not unique to fit experiment within the error bars).

SESSION I

2:30 P.M.-5:00 P.M. (APPROX), WEDNESDAY, OCTOBER 10, 1979

BALLROOM 2

WORKSHOP ON PLASMA CHEMISTRY AND EXCITED STATE REACTIONS

PLASMA CHEMISTRY HAS EXPERIENCED A RESURGENCE OF ACTIVITY NOTABLY IN THE AREAS OF INDUSTRIAL APPLICATIONS SUCH AS PLASMA-SURFACE INTERACTIONS USED TO CLEAN AND ETCH SEMICONDUCTOR SURFACES; AND THE LARGE SCALE PRODUCTION OF SPECIFIC CHEMICALS SUCH AS OZONE FOR WASTE WATER TREATMENT. THIS WORKSHOP CAN AT BEST CONCENTRATE ON ONLY A FEW OF THE VERY INTERESTING ASPECTS OF THIS BROAD SUBJECT. THE WORKSHOP WILL INCLUDE THE PRESENTATIONS BY SIX SPEAKERS. ABSTRACTS OF THEIR TALKS ARE GIVEN IN THE FOLLOWING PAGES.

CHAIRPERSON: W. A. FITZSIMMONS
NATIONAL RESEARCH GROUP

I-1 The Interface Between Plasma Physics and Plasma Chemistry - A. T. BELL, U. California, Berkeley--The progress of chemical reactions in a plasma involves a large number of elementary processes. Quantitative descriptions of the kinetics of plasma-chemical processes are difficult to develop and require significant amounts of basic data. One of the most significant elements needed is the nature of the electron energy distribution function and its dependence on variables controlled in the laboratory. The nature of the relationships between the basic laws of plasma physics and chemistry will be discussed and areas requiring additional research will be identified.

I-2 Characteristics of Glow Discharges in He-CF_4/NF_3 Mixtures. S. GRIFFIN, N. IANNO, J.T. VERDEYEN, B.E. CHERRINGTON.* Gaseous Electronics Laboratory, University of Illinois, Urbana, IL 61801--Glow discharges in highly electronegative gases have become very important due to their use in plasma etching of semiconductors. This paper will present the results of a study which attempts to correlate the basic discharge parameters, spontaneous emission, electron density, and radiation temperature, with the surface reaction. Enhancement is seen in the 704 nm. free fluorine emissions when helium is substituted for a fluorine donor, CF_4 or NF_3, in the discharge. This enhancement is due to a resonant transfer process from the helium metastable to excited fluorine ($He^* + CF_4(NF_3) \rightarrow He + CF_3(NF_2) + F^{**}$). However, it is found that this enhancement does not follow the etch rate which implies that free fluorine and $CF_3(NF_2)$ do not play a dominant role in the surface reaction. A similar enhancement of electron density is seen under the same conditions. The 704 nm. emission is found to saturate under high excitation in a RF discharge indicating a probable saturation of helium metastable density.

*Work supported by the Joint Services Electronics Program

I-3 Some Examples of Plasma Chemistry in Fast Pulsed High E/p Electrical Discharges in Gases - L.A. ROSOCHA, National Research Group, Inc., Madison, Wisconsin -- A simple general model for analyzing pulsed electrical discharge chemical reactors is reviewed. Our theoretical description of transient electrical discharges treats the simultaneous solution of the problems of plasma conductivity, electron and ion temperatures, and kinetic processes appropriate to the gas under consideration by making use of data concerning electron and ion drift velocities, the Townsend ionization coefficient, cross-sections for electron processes, and kinetic rate equations for the particular discharge system. The coupling of the driving electrical circuit to the output of desired discharge products is explored by a review of three specific chemical reactors which have been theoretically modeled and experimentally studied: (1) the pulsed molecular N_2 laser (photons), (2) the pulsed ozonizer (O_3), and (3) the pulsed helium discharge (excited states).

I-4 Production of $O(^1S_0)$ in Electron Beam Excited O_2 Doped Argon*--J. W. Keto, Chien-Yu Kuo, and C. F. Hart, The University of Texas at Austin--We have studied the production of $O(^1S_0)$ as a function of dopant density, total pressure, and electron beam current. Over these conditions we have determined the populations for $O(^3P)$ and O_3 from the $O(^1S_0)$ lifetime. We have found rapid energy transfer from argon excimers and charge transfer from molecular ions with the latter being the predominate channel for formation of $O(^1S_0)$. We discuss model calculations which are in reasonable agreement with the experimental results.

*Work supported by Research Corporation and JSEP under AFOSR contract F-49620-77-C-0101.

I-5 Plasma-Assisted Surface Chemistry - J.W. COBURN and H.F. WINTERS, IBM Research Lab, San Jose, CA--The rate at which an active gas reacts with a solid surface can be greatly increased by simultaneously irradiating the surface with energetic particles, primarily ions, and sometimes electrons. This so-called radiation-enhanced gas-surface chemistry[1] is a major factor in determining the chemistry resulting from exposing a surface to a reactive gas plasma as is done in such rapidly growing technologies as plasma etching, plasma ashing or plasma polymerization. This phenomenon has been studied using an ion beam and fluxes of chemically active gases directed onto clean surfaces. When the active gas forms a volatile product with the surface (i.e., $Si + 2F_2 \rightarrow SiF_4$) the gas-surface reaction rate can be determined from the etch rate of the surface. It has been found that one energetic (2000 eV) Ar ion can result in the formation of as many as 25 to 30 SiF_4 molecules. A description of this phenomenon will be given and examples of its importance in plasma etching[2] will be given.

[1]J. W. Coburn and H. F. Winters, J. Appl. Phys. 50, 3189 (1979).
[2]J. W. Coburn and H. F. Winters, J. Vac. Sci. Technol. 16, 391 (1979).

I-6 Plasma Chemistry for Trace Impurity Analysis - M. W. SIEGEL, Extranuclear Labs. Inc., Pittsburgh, PA.--An often distressing reality in plasma studies is the domination of the ion spectrum by trace impurities. Recently this fundamental distress has been turned into practical advantage by the introduction of "chemical ionization" ion sources for analytical mass spectrometry. Typically, primary ionization methods have been electron impact at ≃ 1 torr, and β-ray ionization at ≃ 1 atm, followed by ion-molecule reactions to ionize the trace samples. Faced with the very difficult problem (due to metal wall effects) of quantifying trace hydrogen in helium, we developed a quartz walled microwave discharge ion source which seems to be both analytically useful and fundamentally interesting. The desired "reagent ions" are He_2^+, which on neutralization provide essentially the same exothermicity as He^+, but whose molecular nature provides a rich array of charge transfer channels unavailable to He^+. Thus while $He^+ + H_2 \rightarrow$ products has a reported rate constant $< 1 \times 10^{-13}$ cm^3/sec, the reactions $He_2^+ + H_2 \rightarrow$ products proceed at 5.3 $\times 10^{-10}$ cm^3/sec. In particular, the channel $He_2^+ + H_2 \rightarrow HeH^+$ has proven well suited for quantification of H_2 in He. Contrary to published reports, He_2H^+ is not observed.

SESSION JA

9:00 A.M.-9:55 A.M., THURSDAY, OCTOBER 11, 1979

BALLROOM 3

E-BEAM AND NUCLEAR PUMPED LASERS

CHAIRPERSON: R. BURNHAM
NAVAL RESEARCH LABORATORY

JA-1 406 nm Ar-N_2 Laser[†] - J. G. EDEN*, Naval Research Laboratory, Washington, D.C. 20375--Intense lasing on the 0-3 transition of the $N_2(C \rightarrow B)$ band at 405.9 nm has been observed by exciting Ar/5% N_2 gas mixtures with a long pulse (~ 0.5 μs) coaxial electron beam. The experimental apparatus consists of a cylindrical diode of 250 cm^3 volume and 50 cm length driven by 250 kV low-inductance Marx generator. Lasing on the violet line occurs following bottlenecking of the 0-1 and 0-2 vibrational transitions. With ~ 8% output coupling, a maximum output energy of 2.2 mJ (200 ns FWHM pulse) has been obtained at 406 nm, which is comparable to that extracted (for optimum mirror transmission) on the 358 and 380 nm laser transitions. The prospect of realizing stimulated emission on the blue 0-4 transition at 434 nm will be discussed.

[†]Work supported in part by DARPA

*Present address: Department of Electrical Engineering, University of Illinois, Urbana, IL 61801.

JA-2 Study of VUV Fluorescence and Lasing in Electron Beam Excited Xenon*- M.J.W.BONESS and C. DUZY, Avco-Everett Research Laboratory, Inc. -- An experimental and theoretical study of VUV radiation in electron beam excited xenon was undertaken. Fluorescence was observed with efficiencies approaching 50% for pressures above 1 atm. and modest cell currents ($\leq$ 5A/cm^2). For lower pressures or higher pumping currents, the efficiency was greatly decreased. A theoretical model was developed which accurately reproduced the fluorescence pulse shapes and efficiencies for pressures $\geq$ 1 atm. and over the entire range of cell currents (1-15 A/cm^2). Lasing was observed at pressures $\geq$ 2 atm., but the presence of premature laser pulse termination reduced efficiencies to < 1%. Similar behavior occurred with mixtures of xenon and helium or argon. Several possible causes of this premature pulse termination were investigated.

*Work supported by U. S. Department of Energy.

JA-3 Nuclear Excited CO_2 Laser Plasma - N.W. JALUFKA, and F. HOHL, NASA Langley Research Center--The behavior of a direct nuclear-pumped ^3He-N_2-CO_2 laser amplifier has been investigated. A CW CO_2 laser operating at 10.6 μm and at a power level of 100 mWatts was used to probe the CO_2 laser mixture during irradiation by neutrons from a fast-burst reactor. The laser cell consisted of a 2.5 cm ID by 70 cm long quartz tube with flat NaCℓ windows. This cell was placed inside a 60 cm long by 15 cm O.D. C_2H_2 moderator. The beam from the probe laser was directed through the cell and was detected by an AuGe detector. No gain was measured with this cell for CO_2 concentration up to 20%. Absorption occurred during the reactor pulse and for several milliseconds into the afterglow and reached 100% for a 20% concentration of CO_2. This result implies that the lower laser level is strongly pumped by the nuclear discharge. The convolution of the excitation cross-sections for the lower lying vibrational levels in CO_2 with the electron energy distribution at several temperatures suggest electron excitation is responsible for filling the lower laser level.

JA-4 $^{235}UF_6$ Fission Fragment Lasing of Ar-Xe - R.J. DEYOUNG, Miami U.*; Y.J. SHIU, Hampton, Inst.†; and M.D. WILLIAMS, NASA Langley Research Center--Nuclear-pumped gas lasers have been pumped with both fissionable coatings and the volumetric $^3He(n,p)^3H$ reaction. There is considerable interest in exciting a gas laser by the $^{235}UF_6(n,ff)FF$ reaction since at sufficient densities of $^{235}UF_6$, there is no need for an external source of neutrons (nuclear reactor). Lasing from two gas mixtures excited by 165 MeV fission fragments is reported here. Fission fragments were emitted from a coating of several uranium compounds which formed on the inner surface of a quartz tube after repeated reactor pulses on UF_6 fillings. Xe lased at 2.65μm in a 600 Torr Ar-Xe(3%) mixture. Xe was also lased (weakly) at 2.027μm when the Ar diluent was replaced by ^4He. The different lasing wavelengths for different diluent gases can be explained by the lower laser level kinetics. An investigation of the spontaneous emission indicates that the 2.027 μm lower laser level in Ar-Xe is efficiently populated by the 1.542 and the 3.37μm transitions which does not occur for He-Xe mixtures.
Details of the lower level kinetics will be presented.
Supported by NASA Grant NSG 1396* and NSG 1596†

JA-5 Mechanisms of the Atomic Carbon Nuclear Pumped Laser @ 1.454μ in He-CO_2 Mixtures, M. A. PRELAS and G H. MILEY, Fusion Studies Lab., Univ. of Ill.*, Urbana, IL--The atomic carbon nuclear pumped laser, $C(3p\ ^1P_1) \rightarrow C(3s\ ^1P_1^o)$ has demonstrated significant delays (1-5 ms) between the laser signal and the excitation pulse.[1] This effect occurs in gas mixtures like He-CO_2 (vs He-CO) requiring a multiple step process to populate the upper laser level (ULL), $C(3p\ ^1P_1)$. Simultaneous observation of the laser output and spontaneous emission of transitions cascading into the ULL have eliminated radiative recombination as an important mechanism. Other measurements, combined with theoretical modeling, show that to explain the delay and its pressure dependence, CO_2 must be dissociated into a vibrationally excited CO state which subsequently relaxes to ground state CO. This process is then followed by the reaction[2] $He(2^3S) + CO \rightarrow C(3p\ ^1P_1) + O + He$.

*Supported by NSF Grant ENG-7801726.

1. M. A. Prelas, et al., Progress in Astronautics and Aeronautics, Vol. 61, AIAA, (1978).
2. J. B. Atkinson and J. H. Sanders, J. Phys. B. (Proc. Phys. Soc.), Ser. 2, Vol. 1, p. 1171 (1968).

JA-6 Kinetic Processes in the Atomic Carbon Laser @ 1.45μ in a Positive Column Discharge, M.A. PRELAS, M. S. ZEDIKER, and G. H. MILEY, Fusion Studies Lab., Univ. of Ill., Urbana, IL 61801--The atomic carbon laser at 1.45μ in mixtures of He and CO_2 oscillates in the afterglow about 12μs after the peak power deposition with electrical pumping (positive column discharge, 1μs (FWHM), 900 W/cm^3 deposited) [1] while with nuclear pumping ($^{10}B(n,\alpha)^7Li$, 12 ms (FWHM), 30 W/cm^3) oscillation occurs up to 5 ms after peak power deposition.[2] Experiments and modeling were performed in order to explain this difference. Results show that the two share a common pumping mechanism: 1) CO_2 is dissociated into CO* + O followed by the relaxation of CO* into CO; 2) the upper laser level (ULL) is populated by $He(2^3S) + CO \rightarrow C(3p\ ^1P_1) + He + O$; and 3) the dominant loss mechanism of the ULL is collisional de-excitation-$C(3p\ ^1P_1) + M \xrightarrow{k} C + M + \Delta E$, ($k \sim 1 \times 10^{-12}$ cm^3/sec). The difference between the delay times is explained by differences in the dynamics of respective metastable concentrations and added vibrational states created in the discharge.

1. J. B. Atkinson and J. H. Sanders, J.Phys.B. (Proc. Phys. Soc.), Ser 2, Vol 1, p 1171 (1968).
2. M. A. Prelas, et al., APL, 31, 428 (1977).

SESSION JB

8:30 A.M.-9:50 A.M., THURSDAY, OCTOBER 11, 1979

BALLROOM 4

IONIZATION AND RECOMBINATION

CHAIRPERSON: H. H. MICHELS
UNITED TECHNOLOGIES RESEARCH LABORATORIES

JB-1 Cross section of the process $NO_2 + e \rightarrow NO_2^{++} + 3e$ from threshold up to 180 eV

H.HELM, Y.B.KIM, T.D.MÄRK, J.RAMLER, G.SEJKORA and K.STEPHAN, Innsbruck University (Austria)--

Electron impact ionization of nitrogen dioxide has been studied as a function of electron energy with a double focussing mass spectrometer and an improved Nier type electron impact ion source using the new deflection mass spectrometry technique. In the course of this study it became possible to establish the existence of the doubly charged NO_2 ion produced via electron impact. Relative partial cross sections for the production of NO_2^{++} and the cross section ratio NO_2^{+}/NO_2^{++} will be reported.

Using n.th root extrapolation the following ionization potentials have been derived:

NO_2^{+} : (10.4 ± 0.3) eV and

NO_2^{++} : (35.0 ± 0.5) eV.

Supported by Öst.Fonds Förd.Forsch., Pr.S-18/08

JB-2 The Measurement of Electron Impact Ionization Cross Section of Vibrationally Excited Oxygen - B. EVANS, R.M. HOBSON, York University, A. YAU, Herzberg Institute, NRC J.S. CHANG, McMaster University,-- The shock heated molecular beam technique was used to obtain a vibrationally excited oxygen beam. The experimental range of the present work covers vibrational temperatures of 6000°K to 12000°K with electron energies from 50-500eV. A mass spectrometer was used to measure the ionization and dissociative ionization cross sections. The vibrational distribution of oxygen in argon has been calculated by considering atomic recombination and collisional de-excitation in the expansion. The results from theory and experiment indicate that: (1) the non-equilibrium vibrational distribution created by the nozzle expansion may have an effect on the cross section for high initial densities; (2) the maximum in the ionization cross section is shifted (due to vibrational excitation) to higher electron energies; (3) the relative cross section increases at higher vibrational temperatures; (4) the effect of vibrational excitation on the ionization cross sections decreases with increasing electron energy.

JB-3 Electron-Ion Dissociative Recombination Measurements in High Pressure Mercury Discharges*-S.E. MOODY and R.E. CENTER, MSNW--The dissociative recombination rate coefficient has been measured in high pressure mercury discharges using a two photon ionization scheme. Mercury has been suggested as a potential excimer laser. It readily lends itself to efficient discharge excitation in comparison with the rare gases because the energy of the lowest excited states is less than half the ionization potential. Theoretical modelling calculations indicate that the dissociative recombination rate coefficient determines the electron density in the high pressure discharge in the absence of wall effects. Previous measurements of this rate constant differ by two orders of magnitude.[1,2] Since the electron density and discharge stability depend directly upon this process, a new measurement has been made. Our preliminary data indicate that the dissociative recombination rate coefficient is of the order of $10^{-7}/cm^3$ per second at an E/Hg of 2×10^{-16} Volts-cm^2.

*Supported by US DOE Contract ES-77-C-06-1022

[1]M.A. Biondi, Phys. Rev. 90, 730 (1953).
[2]P. Dandurand and R.B. Holt, Phys. Rev. 82, 868 (1951).

JB-4 Dissociative Recombination Rates for Ar_3^+.*
J. W. Keto and Chien-Yu Kuo, The University of Texas at Austin--We have measured the rates for dissociative recombination for argon molecular ions from 10-6000 Torr by observing the decay in absolute intensity of the fluorescence from $Ar^*(3p^5 4p)$ dissociative products. By summing over all significant products we determine the total electron recombination rate and individual branching fractions. At low pressures we find good agreement with the results of Biondi;(1) but at higher pressures we find the rate increases nearly a factor of 4, which we attribute to the formation of cluster ions.

*Supported by Research Corporation and JSEP under AFOSR Contract F-49620-77-C-0101.

[1]Yueh-Jaw Shiu and M. A. Biondi, Phys. Rev. A17, 868, (1978).

JB-5 Electron Temperature Dependence of the Recombination of Electrons with Dimer and Trimer Ions.* - M. WHITAKER, M. A. BIONDI and R. JOHNSEN, U. Pittsburgh. - A microwave afterglow - mass spectrometer apparatus has been used to investigate the dependence on electron temperature of electron capture by $CO^+ \cdot CO$ dimer and $CO^+ \cdot (CO)_2$ trimer ions. We find that, for $T_+ = T_n \simeq 300K$, $\alpha[CO^+ \cdot CO] = (1.3 \pm 0.3) \times 10^{-6} (T_e/300)^{-0.35}$ and $\alpha[CO^+ \cdot (CO)_2] = (2.0 \pm 0.3) \times 10^{-6} (T_e/300)^{-0.27}$ cm^3/sec over the range $300\ K \leq T_e \leq 7000\ K$. Thus, the energy dependence is closer to the $\sim T_e^{-\frac{1}{2}}$ variation predicted and observed for electron capture by simple molecular ions than the very weak energy dependence $\sim T_e^{0}$ noted when cluster ions involving polar molecules (e.g. $H_3O^+ \cdot (H_2O)_n$ and $NH_4^+ \cdot (NH_3)_n$) are involved. However, it is substantially weaker than the T_e^{-1} dependence postulated for $\alpha[N_2^+ \cdot N_2]$ from a synthesis of various experimental results.

*Supported, in part, by the Army Research Office/DNA (DAAG-29-78-G-044) and the National Aeronautics and Space Administration (NGL-39-011-137).

JB-6 On the Dissociative Recombination of Vibrationally Excited O_2^+ Ions-E. C. ZIPF, Univ. of Pittsburgh-The production of metastable $O(^1S)$ atoms by the dissociative recombination of O_2^+ ions has been studied in a laboratory plasma-spectroscopy experiment. The specific dissociative recombination coefficient for $O(^1S)$ formation has a value of 2.15×10^{-8} cm^3 sec^{-1} corresponding to an $O(^1S)$ quantum yield of 11% at an apparent temperature of 296°K in agreement with the earlier but less comprehensive measurements of Zipf.[1] By using a variety of gas mixtures in order to modify the vibrational population of the O_2^+ ions and laser-induced photofluorescence techniques, it was found that laboratory O_2^+ plasmas are vibrationally excited and that O_2^+ ions in the $v'=4$-16 vibrational levels are the chief source of the observed $O(^1S)$ atoms. The specific $O(^1S)$ dissociative recombination coefficient for O_2^+ ions in the lowest vibrational levels of the ground state ($v' \leq 3$) is much smaller (4.2×10^{-9} cm^3 sec^{-1}). Preliminary electron heating experiments indicate that the specific $O(^1S)$ recombination coefficient decreases with increasing electron temperature.

[1]E. C. Zipf, Bull. Am. Phys. Soc., 15, 418, 1970.

JB-7 Falloff of Total Dissociative Recombination Cross Section with v. T. F. O'Malley, U. W. Ontario, A. J. Cunningham, U. Texas, R. M. Hobson, York U.--The falloff of the DR rate with the temperature T_v as observed for the rare gas ions[1] implies that the cross section falls off with v. Theory confirms that this cross section falloff is expected if the dissociating state's curve crosses the ground FC region.[2] In contrast the total DR cross section for N_2^+ has been found[3] to be independent of v, and the same appears true[4] for O_2^+. We point out that all these results are consistent. One need only show that the rare gases (unlike the atmospheric gases) have no additional curve crossings near the right hand v=1 turning point, the effect of which would be to keep the total cross section up for v=1 and 2. We show that the existence of such crossings is very improbable for any of the heavy rare gas ions.

1. A.J. Cunningham & R.M. Hobson, Phys Rev 185,98,1969.
2. T.F. O'Malley, Phys Rev 185,101,1969.
3. E.C. Zipf, Bul. APS 24,129,1979.
4. A.J. Cunningham & R.M. Hobson, J Phys B 5,2320,1972.

JB-8 Measurements of DR and DE Cross Sections for Vibrationally Excited H_2^+ Ions. J.Wm. McGOWAN, University of Western Ontario, Canada N6A 3K7.* -- Merging beams of electrons and vibrationally excited H_2^+ ions have been used for simultaneous measurements of dissociative recombination DR and dissociative excitation DE cross-sections of H_2^+. The effects of spiraling electrons on the low center of mass energy collisions is discussed. From the experimental data a limit on the maximum value of the intersection angle between the two beams was found to be in the vicinity of 1°. Both cross-sections are measured over an energy interval from less than 0.1 eV to 10 eV. The value of the DR cross-section at 0.1 eV was 1.3×10^{-14} cm^2 with an energy dependence of $E^{-1.1\pm0.1}$. For DE the value of the cross-section at 0.1 eV was 7.5×10^{-15} cm^2. Both cross-sections show a dependence upon H_2^+ vibrational excitation.

*Supported by US DOE and Canadian Natural Science and Engineering Research Council.

SESSION KA

10:10 A.M.-11:20 A.M., THURSDAY, OCTOBER 11, 1979

BALLROOM 3

VARIOUS LASERS AND LASER DISCHARGES

CHAIRPERSON: L. A. WEAVER
WESTINGHOUSE R&D CENTER

KA-1 Operating Characteristics of Cylindrical and Annular Geometry, Discharge-Heated Copper Vapor Lasers*, T. Kan and D. Ball, Lawrence Livermore Lab.--Discharge heated copper vapor lasers have been operated with cylindrical discharge and annular discharge geometries in large diameter tubes ($\leq$3" dia.) and high buffer gas pressures ($\sim$200 Torr). The effect of Tube geometry, buffer gas type and pressure, and excitation circuit impedance on laser performance has been experimentally studied. These measurements are correlated to the predictions of a circuit code which models the dynamic impedance of the laser plasma in order to calculate laser excitation parameters and electrical power flow in the circuit.

*Supported by DOE Contract no. W-7405-ENG-48

KA-2 Kinetics Studies of the Selenium (^1S) $\rightarrow$ (^3P) Laser System - W.M. TROTT, J.K. RICE, J.R. WOODWORTH, Sandia Laboratories*--The proposed selenium lasers, operating at 4887 Å ($^1S \rightarrow {}^3P$) or 7767 Å ($^1S - {}^1D$) have attracted considerable interest as possible efficient, high energy, storage lasers. We shall report the results of an experimental study which examined in detail the formation and decay of the upper laser level, Se(^1S), in these systems. The Se(^1S) was formed by VUV photolysis of OCSe with the 172 nm beam from an Xe_2^* laser. Photoelectrons produced in the excited OCSe/Se(^1S) medium were measured directly by microwave transmission. The time history of the Se(^1S) population was measured with an absolutely calibrated PM tube and filter combination. Preliminary results indicate that the Se(^1S) photoionization cross section is small at 172 nm, near 5×10^{-21} cm^2. However, electrons produced by this effect can undergo heating and multiplication, causing rapid quenching of the Se(^1S) population. Methods of controlling this problem, the remaining quenching rates and the quantum yields for producing Se(^1S) from OCSe at the high VUV intensities appropriate to a laser system will also be discussed.

*This work supported by the U.S. Department of Energy.

KA-3 Electron Cooling Mechanisms in Recombination Laser Plasmas. W.L. BOHN and P. WAEGLI, DFVLR-I. Techn. Phys., Stuttgart, Germany F.R. --A hydrodynamic computer code was written to simulate the expansion of a laser produced plasma in the presence of a background gas. In contrast to a free expansion the background gas inhibits the rapid decrease in electron density and strong electron cooling occurs in the region where the plasma diffuses into the background gas. The description of the diffusion region includes ambipolar diffusion, heat conduction, heating by recombination and electron collisional cooling. Calculated temperature and density profiles result in inversion of several laser transitions. Typical inversion times of up to 100 μsec are obtained in agreement with recently published experimental results[1]. Implications for the development of short wavelength recombination lasers are discussed.

[1] W.T. Silfvast, et.al. Conf. on Laser Engineering and Applications, May 30-June 1, 1979 (Paper No. 9.10)

KA-4 E-Beam Initiated Discharges in High Pressure Hg Vapors - L. A. SCHLIE, L. E. JUSINSKI, R. D. RATHGE, D. L. DRUMMOND, and R. A. HAMIL, AFWL, Kirtland AFB, New Mexico - Studies are reported of stable glow discharges in high pressure Hg vapors ($\leq$ 2 amagats) produced by a 20 nsec ionizing electron beam pulse. The discharges were very stable and operated for 4-5 usec after the e-beam initiating pulse at E/N values up to 8 $X_2 10^{-17}$ $V \cdot cm^2$ and discharges current densities of 4 A/cm^2. Power loadings of 3-6 KW/cm^2 were typically obtained. An electron recombination coefficient of 7.4×10^{-9} $cm^3 \cdot sec^{-1}$ was measured. Strong continuum radiation from both the visible (4900 Å) and u-v (3350 Å) bands of molecular Hg were observed. Absorption measurements from 4000 to 6764 A are presented. No gain in this spectral region was ever detected. A peak absorption cross section at 4800 Å was estimated to be 2×10^{-16} cm^2. The implication of this absorption on other potential laser systems employing Hg as a buffer gas, like CdHg, TlHg, and Hg-halides, are discussed.

KA-5 Model of Step-Wise Excitation and Ionization in Na/Xe Discharge-W.L. Morgan, Lawrence Livermore Lab.* --A detailed computational model of the steady state high power Na/Xe discharge[1] has been developed. This model includes 15 excited Na states and a pseudo-state simulating all higher bound states, all electron impact excitation and ionization processes, inverse ionization, and dissociative recombination. The Boltzmann equation, including e-e collisions, is solved simultaneously with the bound state rate equations. This model has been used to investigate the role of step-wise excitation and ionization, dissociative recombination, and collisional radiative recombination in the discharge as a function of E/N. The role of Na*-Xe collisional processes has also been studied.

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under contract number W-7405-ENG-48

[1]H.L. Rothwell, D. Leep, and A. Gallagher, J. Appl. Phys., 49, 4396 (1978)

KA-6 Transverse Electrodeless RF Discharge Excitation of High-Pressure Laser Gas Mixtures; C.P. CHRISTENSEN, U. of Southern Calif., N. DJEU, and F.X. POWELL, Naval Research Lab.--RF excitation of several high-pressure laser gas mixtures using the transverse electrodeless discharge geometry has been investigated. Homogeneous, high-level excitation of small gas volumes (~1 cm^3) has been achieved at atmospheric pressures for periods of several microseconds. Applications of this discharge technique to pumping of Ar-Xe, He-Xe, F, XeF, and CO_2 laser transitions has been studied.

KA-7 Radial Gain Profiles in CO_2 Waveguide Lasers - R.M.THOMSON, Leeds U.*, U.K. -- This paper reports the results of computer calculations based on a kinetic and transport process model of longitudinally excited CO_2 waveguide lasers. The following physical processes are simulated in the model: (i) electron vibrational excitation of N_2 and CO_2; (ii) vibrational energy transfer in inelastic collisions among N_2, CO_2 and He; (iii) thermal conduction of translational energy; (iv) thermal conduction/diffusion of vibrational energy; (v) loss of vibrational energy in molecule-wall collisions; and (vi) electron drift and diffusion, attachment, and ionisation. The results of calculations are presented for CW waveguide laser amplifiers showing the radial dependence of small signal gain, temperature, vibrational temperatures, and electron density. For certain values of the input power the radial gain profile is predicted to have a maximum not on the axis of the waveguide, but at a point between the axis and the wall. This indicates an explanation for the experimentally observed phenomena of waveguide lasers operating on doughnut-shaped intensity profile modes, and for the suppression of simpler modes by increasing the input power or wall temperature.

*Supported by Procurement Executive, MOD sponsored by DCVD

SESSION KB

10:10 A.M.-11:40 A.M., THURSDAY, OCTOBER 11, 1979

BALLROOM 4

PHOTON REACTIONS

CHAIRPERSON: S. R. LEONE
NATIONAL BUREAU OF STANDARDS

KB-1 Radiative Lifetimes of $\tilde{A}^2\pi_u$ Levels in CO_2^+ and CS_2^+ - R. C. DUNBAR and D. W. TURNER, Case West Res. U. and Oxford U. - An electric field drift method was used to measure wavelength-resolved radiative lifetimes of CO_2^+ and CS_2^+ produced by HeI radiation. No significant variation in lifetime was found across the $\tilde{A}^2\pi_u \rightarrow \tilde{X}^2\pi_g$ system. The $\tilde{A}^2\pi_u \rightarrow \tilde{X}^2\pi_g$ system in CS_2^+, on the other hand, does show evidence of wavelength-dependent variation of the radiative lifetime.

KB-2 Excited Specie Absorption in the UV Wing of the Kr_2F^* Band† - J. G. EDEN*, R. S. F. CHANG** and L. J. PALUMBO, Naval Research Laboratory, Washington, D. C. 20375--An intracavity laser technique has been used to study the absorption of e-beam excited Ne/Kr/F_2 gas mixtures (T = 196 and 300°K) in the "blue wing" of the Kr_2F^* emission continuum. Comparing the experimental results with the predictions of a computer kinetics model, the species primarily responsible for absorption have been identified as Ne_2^+, Kr_2^+ and Kr_2F^*. The absorption cross-sections for Ne_2^+ and $Kr_2F^*(Kr_2^+F^-)$ at 358 nm have been estimated to be $8.1 \cdot 10^{-19}$ and $5.4 \cdot 10^{-18}$ cm^2, respectively. Also, the rate constant for quenching of Kr_2F^* by F_2 was measured to be $(4.1 \pm 0.5) \cdot 10^{-10}$ cm^3-sec^{-1} at 300°K and $(3.0 \pm 0.5) \cdot 10^{-10}$ cm^3-sec^{-1} at 196°K.

†Work supported in part by DARPA.
*Present address: Department of Electrical Engineering, University of Illinois, Urbana, IL 61801.
**NRC-NRL Postdoctoral Research Associate

KB-3 Electronic Structure and Photoabsorption of the Hg_2^+ Dimer Ion - H.H.MICHELS and R.H.HOBBS, United Technologies Research Center* -- A study of the electronic structure and photoabsorption characteristics of the Hg_2^+ dimer ion has been carried out to determine the relative importance of this species in the analysis of loss mechanisms in laser systems based on Hg chemistry. This study included detailed density functional calculations of the potential energy curves for Hg_2^+ and prediction of the absorption bands. These calculations were carried out employing a relativistic hamiltonian, explicitly treating both core and valence electrons. Core approximations were not employed and all orbitals were iteratively adjusted within a relativistic SCF framework. We find $D_e \sim 0.7$ eV, $\omega_e \sim 90 cm^{-1}$ and $R_e \sim 3.2 \mathring{A}$ for the ground $A^1/_2u$ state. This ion exhibits strong photoabsorption ($\sigma \sim 1.0 \mathring{A}^2$) for the $A^1/_2u \rightarrow B^1/_2g$ transition at $\lambda \sim 910$ nm. The only other predicted absorption is for wavelengths shorter than 250 nm.

*Supported in part by AFOSR under Contract F49620-77-C-0064.

KB-4 Mercury Cadmium Gain/Absorption Measurements - A. MANDL, D. KLIMEK, J. JACOB, B. SRIVASTAVA and M. KOVACS, Avco Everett Res. Lab., Inc.* -- Studies of HgCd* at 550°C produced in an E-beam preionized quasi-stable discharge have indicated high fluorescence efficiencies ~0.5 with $[HgCd^*] \sim 10^{16}$ cm^{-3}. Spectra of the emission from a discharge pumped Cd/Hg/Ne mixture clearly show the HgCd* continuum. Measurements of the gain/absorption for a 40 cm optical path have been made over the HgCd* continuum using an Ar ion laser. Various mixtures of Cd/Hg/Ne were tried but gain was never observed. The maximum absorption was observed at the blue end of the continuum (457 nm) and decreased to ~1% per pass at the red end of the continuum (517 nm). These results are in qualitative agreement with the optically pumped HgCd* gain/absorption studies of Komine, West and Strappaerts.[1]

*Supported by U. S. Department of Energy Contract #ES-77-C-02-4275

[1]Komine, West and Strappaerts, G.E.C.,AA-5,10/78

KB-5 Photoionization of Excited States of the Rare Gases.* C. DUZY and H. A. HYMAN, Avco Everett Research Lab., Inc.-- Photoionization cross sections have been calculated for excited states of the rare gases (Ne,Ar,Kr,Xe). The method, which is similar to that used earlier[1], involves a central-field approximation, including the Hartree-Fock effective charge of the ionic core together with the dipole-induced core polarization potential. In the present work, the polarizability is regarded as a parameter, to be determined from a least-squares fit of calculated binding energies to the experimentally-known energies of the excited atomic states. Results of the calculations will be presented, and the role of photoionization of excited rare gases in excimer laser systems will be discussed.

*Work supported by the Department of Energy.

[1]H. A. Hyman, Appl. Phys. Letters 31, 14 (1977).

KB-6 Multiphoton Ionization of Cs_2 Dimers Through Dissociative Molecular States*. C. B. COLLINS, J. A. ANDERSON, and F. W. LEE, Univ. of Texas at Dallas, D. POPESCU and I. POPESCU, Central Inst. of Physics of Romania--Hybrid resonances observed in the multiphoton absorption spectrum of cesium and rubidium dimers have contributed to an improved understanding of the interatomic potentials of the heavy alkalis.[1,2] Such resonances generally occur through unbound molecular states and those reported here have been excited by superimposed beams from two separately tunable dye lasers. The wavelength of one was fixed on an atomic transition resonance while the other was scanned through the visible wavelengths. The spectrum for the photolysis of Cs_2 into each energetically possible product state was determined over the range 445-640 nm.

*Conducted as part of the U.S.-Romanian Cooperative Program in Science and Technology, supported by NSF Grant INT76-18982.

1. C.B. Collins, B.W. Johnson, M.Y. Mirza, D. Popescu, and I. Popescu, Phys. Rev. A10, 813 (1974).
2. C.B. Collins, S.M. Curry, B.W. Johnson, M.Y. Mirza, M.A. Chellehmalzadeh, J.A. Anderson, D. Popescu and I. Popescu, Phys. Rev. A14, 1662 (1976).

KB-7 Predissociation Photofragment Spectroscopy of CH^+.* P.C. COSBY, H. HELM,** and J.T. MOSELEY, Molecular Physics Laboratory, SRI International.--Predissociation of CH^+ to $C^+ + H$ has been observed in the region of 3500 Å. The frequencies of 37 discrete transitions are measured together with their linewidths and the energy of the photofragments. Each of the predissociations occurs within 350 cm^{-1} of the dissociation. The most reasonable attribution of these observations is to predissociation of the $A^1\Pi$ and $a^3\Pi$ states. If this is correct, then the number of quasi-bound levels which could contribute to interstellar radiative association of $C^+(^2P) + H(^2S)$ is much larger than previously expected. Near threshold predissociation is also observed at visible wavelengths and a second predissociation process occurring 1 to 2 eV above the dissociation limit is observed at both uv and visible wavelengths.

*Research supported by NSF and AFOSR.
**Max Kade Foundation Fellow.

KB-8 Zero Core-Contribution Calculation of Multi-Channel Photodetachment of Atomic Negative Ions. W.B. CLODIUS, R.M. STEHMAN, and S.B. WOO, U. of Del.--The zero core-contribution model was applied to study the photodetachment of atomic negative ions having an outermost s or p orbital, neglecting the existence of multi-channel processes.[1] This method is now extended to handle transitions to atomic levels with the same orbital configuration as the ground atomic state. Effects due to fractional parentage, nonstatistical branching ratios and the statistical population of the ionic states are accounted for. Configuration mixing due to the electrostatic interaction of the electrons is not examined. The absolute photodetachment cross section is calculated as a function of photon energy. Comparison with experimental data is made for the following negative ions: B, Ga, In, Tl, C, Ge, P, As, Sb, Bi, O, Te, Cl, Br, and I. Agreement is better than 60% for all ions except for the elements of the Boron column where the difference is about a factor of two.

*Supported in part by NSF.

[1]R. M. Stehman and S. B. Woo, to be published in Phys. Rev. A, July 1979.

KB-9 Dye Laser Photodetachment of NO_2^- - S.B. WOO, E. M. HELMY†, P.H. MAUK, A. P. PASZEK, U. of Delaware.*-- Photodetachment cross section of NO_2^- will be reported. Dye laser photodetachment of NO_2^- is done in a drift tube. Photodetached electrons are detected. Ions are mass identified. Before entering the photodetachment region, ions are thermalized through 10^5 collisions with the neutral gas at thermal energies. Thermalizing time is about 0.5 ms. Laser multi-pass configuration is used to increase effective number of photons. Peroxy isomers are not detected. The threshold energy is 2.33 $\pm$ 0.1 eV, unless the cross section near the threshold is less than 4×10^{-20} cm^2. The cross section is of the order of 1×10^{-19} cm^2 for a range of a few tenths of an eV from the threshold. It then rises quickly to about 6×10^{-18} cm^2 at 4 eV. The absolute calibration of the preliminary data is estimated to be 50%.

*Supported by NSF Grant No. AIM-77-18324

†And Delaware State College

SESSION L

1:30 P.M.-2:50 P.M., THURSDAY, OCTOBER 11, 1979

BALLROOM 2

NEGATIVE ION REACTIONS

CHAIRPERSON: N. G. ADAMS
UNIVERSITY OF BIRMINGHAM

L-1 Photodissociation of CO_3^- Revisited.* P.C. COSBY, J.T. MOSELEY, G.P. SMITH, L.C. LEE, R.V. HODGES, and J.R. PETERSON, Molecular Physics Laboratory, SRI International. --Conflicting data regarding the CO_3^- bond dissociation energy has prompted additional investigation of its photodissociation. The drift tube was used to form CO_3^- both from O^- and O_3^-. Results obtained over a wide range of drift distances and pressures indicate that photodissociation in the controversial 1.8-2.2 eV region results from transitions out of the CO_3^- ground state. At high pressures, collisional quenching of the photoexcited ions was observed, indicating a predissociation lifetime of order 10^{-6} s. No evidence was found for collisional dissociation of the photoexcited ions exiting the high pressure drift region. Preliminary experiments on the photofragment spectroscopy of CO_3^- observed structure superimposed on a continuum in the wavelength dependence of O^- photofragments. In addition, photon-induced collisional dissociation was observed at 2600 eV having this same structure. The implications of these data on the CO_3^- bond energy will be discussed.
*Research supported by AFOSR and ARO.

L-2 Formation and Energetics of the Excited and Ground States of NO_3^- - R.L.C. Wu and T.O. Tiernan, Wright State University.*--Excitation functions for collision - induced dissociation reactions of NO_3^- yielding the products (O^-, NO_2) and (NO_2^-, O) respectively, have been studied using ion beam techniques. The projectile ion, NO_3^-, was produced in these experiments by electron impact on various gaseous mixtures, including O_3/N_2O, O_3/NO, O_3/NO_2, O_2/NO_2, O_2/N_2O, and O_2/NO. The dissociation energies measured for NO_3^- ions formed from the O_3/N_2O mixture are $D^o(O^- - NO_2) = 4.8 \pm 0.1$ eV, and $D^o(NO_2^- - O) = 3.8 \pm 0.1$ eV, whereas some fraction of the NO_3^- ions produced by the O_3/NO mixtures exhibit much lower dissocation energies, namely, $D^o(O^- - NO_2) = 1.8 \pm 0.15$ eV, and $D^o(NO_2^- - O) = 1.0 \pm 0.1$ eV. These observations suggest that a long-lived excited state of NO_3^- * is formed in the latter case. Information relating to the structures of these ions was obtained by using isotopically-labelled ions, for example, $N^{16}\,{}^{16}O\,{}^{18}O_3^-$ and $N^{18}\,{}^{18}O\,{}^{16}O_3^-$ in the CID experiments.

*Supported by AFOSR Contract F44620-76-C-007

L-3 Studies of Electron Detachment for Negative Halide Ion-Molecular Collisions.
L. D. DOVERSPIKE and R. L. CHAMPION,
The College of William and Mary* -- Absolute total electron detachment cross sections have been measured for (Cl^-, Br^-) in collisions with a number of different molecules. These measurements cover the collision energy range from detachment threshold up to approximately 150 eV. Relative elastic differential cross sections as well as the differential cross sections for the fast neutrals produced in the detachment process have been measured for some of the above systems. The experiments establish that, in most cases, the thresholds for direct electron detachment lie well above the electron affinities of the relevant halides. More interestingly it appears that the known temporary negative ion states of some of the target molecules may play a prominent role in the detachment process in this energy range.

*Supported in part by US DOE
Contract DE - AS05 - 79ER10371

L-4 Vibrational Product State Distributions of Ion-Molecule Reactions by Infrared Chemiluminescence in a Flowing Afterglow,* S. R. LEONE,† T. S. ZWIER, V. M. BIERBAUM, and G. B. ELLISON, National Bureau of Standards and University of Colorado.--A flowing afterglow constructed to obtain infrared chemiluminescence signals has been used to study vibrational product state distributions from several ion-molecule reactions. By proper modulation of the ion density, signals can be obtained specifically from the ion-molecule reaction of interest in the absence of neutral reaction product signals and other spurious effects. Systems studied include $O^- + CO \rightarrow CO_2(v) + e^-$, $C\ell^- + HBr$, $HI \rightarrow HC\ell(v) + Br^-$, I^-, and $CN^- + HC\ell$, HBr, $HI \rightarrow HCN(v) + C\ell^-$, Br^-, I^-. In the $C\ell^- + HI$ reaction, the fractions of product $HC\ell$ with states v = 0, 1, and 2 are 0.5, 1.0, and 0.5 respectively. Comparison of these results with analogous neutral reactions shows that distributions in the products of ion-molecule reactions are very similar to those for analogous neutral reactions.

*Supported by the Air Force Office of Scientific Research.

†Staff member, Quantum Physics Division, National Bureau of Standards.

L-5 Cross Section for the Reaction $O^- + O_2 \rightarrow O_2^- + O$ at Relative Kinetic Energies 0.04 - 2 eV* - S. L. LIN Brown Univ., J. N. BARDSLEY, U. Pittsburgh, I. DOTAN, Weizmann Inst. Sci., Rehovot, Israel, F. C. FEHSENFELD, and D. L. ALBRITTON, NOAA--The cross section for the charge-transfer reaction of O^- with O_2 is determined in the relative kinetic energy range from 1 eV (threshold) to about 3 eV using a combination of experimental and theoretical ion-swarm techniques. Reaction rate constants are measured in a helium-buffered flow-drift tube in the range $50 \leq (E/N) \leq 110$ Td, where E is the dc electric field strength, N is the helium gas number density, and 1 Td $\equiv 10^{-17}$ V cm^2. Velocity distributions are computed using Monte Carlo techniques for O^- ions drifting in helium at these E/N values. These distributions and the drift-tube rate constants define the reaction cross section at low collision energies, a region in which it has been difficult to make reliable ion-beam measurements.

*Research supported, in part, by the Advanced Research Projects Agency, monitored by ONR (N000-14-76-C-0098), and the Defence Nuclear Agency.

L-6 The Role of H_2SO_4 in Stratospheric Negative-Ion Chemistry-A. A. VIGGIANO, R. A. PERRY, D. L. ALBRITTON, and F. C. FEHSENFELD, NOAA/ERL, Aeronomy Laboratory--Gas-phase ion-molecule reactions involving H_2SO_4 and a variety of positive and negative ions have been studied using a flowing afterglow apparatus. All of the negative ions studied react rapidly with H_2SO_4 to form HSO_4^-. These reactions establish a lower limit for the electron affinity of HSO_4:4.5 eV. The results will be reported and their implication to stratospheric negative ion chemistry discussed.

SESSION MA

9:00 A.M.-10:05 A.M., FRIDAY, OCTOBER 12, 1979

BALLROOM 3

METASTABLE REACTIONS

CHAIRPERSON: R. A. SIERRA
UNIVERSITY OF MISSOURI, ROLLA

MA-1

Excitation transfer from He and Ar metastable atoms to N_2. A.RICARD, J.JOLLY, D.PAGNON and M.TOUZEAU. Lab. Physique Plasmas, Univ. Paris-Sud. 91405 ORSAY-FRANCE.

Rare gas metastables and vibrationaly excited N_2 have been separately created in low pressures (1-10 Torr) glow discharges and mixed in a 50 m sec^{-1} velocity flow tube. The reaction flame is characterized by the emission of negative and positive bands of N_2 which have been analysed by high resolution emission spectroscopy. With helium, N_2^+ (B, v') levels are populated from N_2 (X, v) by the Penning transfer reaction. Concentrations of N_2^+ (B) up to v' = 6 have been measured and the vibrational distribution of N_2 (X,v) has been calculated by using the inverse Frank-Condon matrix q^{-1} (v',v). Vibrational temperatures from 300 to 11000 K have been determined with a precision better than 20 %. With argon, N_2 (C, v_1 and B, v_2) levels are excited by a non vertical process. The branching ratio was found to be 80 % for N_2 (C) and 20 % for N_2 (B). The vibrational excitation of N_2 (C) is growing with the vibrational excitation of N_2 (X). The rotational structure of N_2 (C, v_1) is largely out of equilibrium with an equivalent temperature T = 2100 K.

MA-2 Excitation of Cd, Zn, and Sr by a Beam of Active Nitrogen-D.W. FAHEY, W.F. PARKS, and L.D. SCHEARER, UNIV OF MISSOURI-ROLLA*--Excitation of the electronic levels of Cd, Zn, and Sr is observed when these metal vapors collide with a thermal-energy, active nitrogen beam. The beam is extracted from a glow discharge in pure N_2. The active beam component is inferred to be vibrationally excited N_2 in the $A^3\Sigma_u^+$ electronic state. The ratio of intensities of the emission lines in each element was measured. The excitation rates of the Cd and Zn target levels were found to depend exponentially on their energies indicating an effective temperature of near 4000°K. We believe that this temperature is related to the vibrational temperature of the N_2 ($A^3\Sigma_u^+$) states which excite Cd and Zn in energy transfer collisions. The excitation rates of the Sr levels did not show an exponential energy dependence which is a result consistent with $N_2(A^3\Sigma_u^+)$ as the active species. In a beam transmission experiment, we found the total quenching cross-section for $N_2(A^3\Sigma_u^+)$ on Sr to be 2.3×10^{-16} cm^2. The potential of such an emission study as a sensitive diagnostic is noted.

*Research supported by the Office of Naval Research.

MA-3 Quenching Cross Sections for Ar ($^3P_{2,0}$), Kr ($^3P_{2,0}$), and Xe ($^3P_{2,0}$) by H_2 and D_2. W. ALLISON, J.W. SHELDON*, and E.E. MUSCHLITZ, JR., Univ. of Florida**-

Absolute cross sections for quenching of the heavier rare gas metastable atoms by H_2 and D_2 have been measured. The apparatus, which has been described previously[1,2], employs a velocity-selected metastable atom beam and a collision chamber containing the target gas. Unlike the previous measurements, both the gas pressure and the length of the collision chamber are varied. The results obtained at a collision energy of 0.040 eV are: for Ar*, Kr*, and Xe* on H_2, 6.2, 2.9, 2.8 Å^2 respectively, and for D_2, 6.2, 4.2, 3.0 Å^2 respectively.

*Permanent Address: Dept. of Physical Sciences, Florida International University.

**Supported by the National Science Foundation

1. M.E. Gersh and E.E. Muschlitz, Jr., J. Chem. Phys. 59, 566 (1973).
2. J.W. Sheldon and E.E. Muschlitz, Jr., J. Chem. Phys. 68, 5288 (1978).

MA-4 Crossed Atomic Beam and Theoretical Studies of Energy Transfer in HeNe.† P. E. SISKA, Univ. of Pittsburgh---Thermal energy scattering experiments on He*(2^1S) + Ne have yielded Ne* product angular distributions in the $3s_2$, $3s_4$, $3s_1$, and $4d_n$ states. One-electron model potential calculations of the incoming and outgoing $^1\Sigma^+(0^+)$ potential curves account qualitatively for the observed state distribution; the same model also yields potentials that compare well with elastic scattering results on He* + Ne[1] and metastable Ne* + He[2]. Experimentally the exoergic $3s_4$ and $3s_1$ states do not appear until the threshold (47 meV) for the endoergic $3s_2$ state is reached. The calculations show an avoided crossing between a curve correlating diabatically with a $3s_1$ state and the (diabatic) $3s_2$ curve at an interatomic distance smaller than that at which $3s_2$ crosses the incoming curve as well as close passage of $3s_2$ and $3s_4$ curves. This implies that the exoergic states drain flux away from $3s_2$, the well-known upper laser level in neon. Multichannel scattering calculations will be reported.

†Research supported by the National Science Foundation.

[1]T. Fukuyama and P. E. Siska, XI ICPEAC (Kyoto, 1979), to be published.
[2]T. Fukuyama and P. E. Siska, Chem. Phys. Lett. 39, 418 (1976).

MA-5 Determination of the F_3S-F and F_5S-F Bond Energies T. KIANG AND R. N. ZARE, Stanford U.*--The chemiluminescent spectrum of electronically excited metal monofluoride is obtained for the reactions of metastable calcium and strontium with SF_4 and SF_6 under single-collision conditions. A spectroscopic analysis is combined with time of flight measurements to determine the relative kinetic energies of the reactants producing each product state. Energy balance permits one to place upper and lower bounds on the F_3S-F and F_5S-F bond energies. Using known heats of formation, the bond energies of F_nS-F can then be deduced for n=0-5.

*Supported by U.S. Army Grant DAAG-29-77-G-0151

SESSION MB

9:00 A.M.-10:10 A.M., FRIDAY, OCTOBER 12, 1979

BALLROOM 4

ATTACHMENT

CHAIRPERSON: C. L. CHEN
WESTINGHOUSE R&D CENTER

MB-1 Efficient H^- and D^- Production in Discharges
A. GARSCADDEN, W.F. BAILEY and G. DUKE, A.F. AERO Propulsion Laboratory and A.F. Institute of Technology, Wright Patterson AFB, Ohio 45433. Numerical solutions of the Boltzmann transport equation have been used to calculate H^- and D^- production in discharge plasmas. The recent availability of vibrational- and rotational-state dependences of dissociative attachment in electron hydrogen[1] and electron-deuterium[2] collisions has permitted the estimation of the effects of vibrational temperature on the fractional power transfer into dissociative attachment. The strong dependence of the cross-sections on internal energy causes a strong dependence of negative ion production on vibrational temperature, as well as on the discharge parameter E/N. This suggests methods to optimize negative ion production. Parameters are given for processing the gas to optimize vibrational excitation and subsequent dissociative attachment; these conditions can be arranged by temporal or spatial control of E/N.

1 J.M. Wadehra and J.N. Bardsley, Phys. Rev. Letters 41, 1795 (1978)
2 J.N. Bardsley, private communication

MB-2 Dissociative Attachment from Vibrationally Excited HCℓ and HF - M. ALLAN and S.F. WONG, Yale U. *--A large increase of dissociative attachment cross sections with temperature was observed previously for several molecules. The cross sections for individual vibrational and some rotational levels were recently obtained in hydrogen and this detailed information allowed us to better understand the mechanism and detailed comparison with theory.[1] Here we report preliminary results on dissociative attachment cross sections in HCℓ and HF for different initial vibrational levels. The apparatus is an electron impact mass spectrometer described previously.[1] In the 0.75 eV region in HCℓ the $Cℓ^-$ cross section increases more than tenfold for each increase in vibrational quantum number. In the 2.5 eV region in HF the F^- cross section exhibits a similar but weaker effect. The present theory of the vibrational dependence on dissociative attachment in H_2 appears inapplicable to these molecules because no short-lived negative ion state has been established in these energies. Thus a new mechanism is required to explain the present observations.

*Supported in part by NSF.
[1]M. Allan and S.F. Wong, Phys.Rev.Lett. 41, 1791 (1978).

MB-3 Electron Attachment Rates in Cl_2 - R. C. SZE, A. E. GREENE, and C. A. BRAU, Los Alamos Scientific Lab*--We have examined the attachment of electrons to Cl_2 in a mixture of a few hundred ppm Cl_2 in nitrogen and argon gases at pressures of 10 to 60 psia by measuring the decay of current through the gas. In N_2 we can vary the electron mean energy from 0.8 to 1.2 eV, while in Ar the electron mean energy can be varied 2.5 to 4.5 eV. Theoretical calculations have been performed using a Boltzmann code and the cross sections of Kurepa and Belic. Our results indicate reasonable agreement between theory and experiment and the work of Rokni et al. in the middle and higher electron mean energy range.

*Work performed under the auspices of the U. S. DOE.

MB-4 ELECTRON DISSOCIATIVE ATTACHMENT RATE CONSTANTS FOR F_2 AND NF_3 AT 300 AND 500°K, DANIEL W. TRAINOR AND J.H. JACOB, AVCO Everett Res. Lab., Inc.--Electron attachment to F_2 and NF_3 has been studied in an electron-beam-controlled gas-discharge apparatus over a range of E/P values (2-10 kV/cm-atm). These experiments were performed in gas mixtures containing small amounts of the halide molecules ($\lesssim$ 1%) in an atmosphere of N_2. The N_2 buffer determined the average electron energy. At 300°K, values of the dissociative attachment rate constants at an average electron energy near 1.0 eV for F_2 and NF_3 were found to be near 4.5 and 4.3×10^{-9} cm^3/sec. These results compare favorably with the rate constants deduced from the absolute cross sections reported by Chantry[1]. At 500°K, the attachment rate constants were 5.7 and 5.4 x 10^{-9} cm^3/sec for F_2 and NF_3. The increase of the attachment rate of F_2 is greater than that predicted by Hall[2].

1. P.J. Chantry, 31st GEC (1978); private communication (1979).
2. R.J. Hall, J. Chem. Phys. 68, 1803 (1978).

MB-5 Electron Attachment in NF_3, CCl_4, and $HgBr_2$.* H.L. BROOKS, R.A. SIERRA, J. FLETCHER**, and K.J. NYGAARD, University of Missouri-Rolla.--We have determined the electron attachment rate in NF_3, CCl_4, and $HgBr_2$ using He and N_2 as buffer gases. The principle of our method is to produce a pulse of photoelectrons and study the evolution of the resulting swarm. We find the electron drift velocity from the swarm transit time and the attachment coefficient from the attenuation. The range of gas temperature was from 50-150°C. Results will be presented for E/N from 1-30 Td.

*Supported in part by ONR.

**Permanent address: Flinders Univ. Bedford Park, S.A.

MB-6 Temporary Negative Ion States of Fluorine Substituted Ethylenes - P.D. BURROW, N.S. CHIU, U. of Nebraska and K.D. JORDAN, U. of Pittsburgh*--The electron affinities for addition of an electron into the lowest unfilled π^* orbitals of the fluoroethylenes have been measured by electron transmission spectroscopy.[1] Contrary to the predictions of simple induction and resonance arguments, we find that the negative ions are destabilized with increasing numbers of fluorine atoms. The vertical electron affinities range from -1.78 eV for ethylene to -3.0 eV for tetrafluoroethylene. These results will be described in light of the analogous effects of fluorination on the filled orbitals.

*Supported by the Petroleum Research Fund.

[1]L. Sanche and G.J. Schulz, Phys. Rev. A5, 1672 (1972).

MB-7 Electron Attachment to Chlorofluoromethanes and Chlorofluoroethanes Using the Electron Swarm Method* -- D.L. McCORKLE, A.A. CHRISTODOULIDES, L.G. CHRISTOPHOROU and I. SZAMREJ, U. of Tenn.--Electron attachment rate constants as a function of pressure-reduced electric field were measured in mixtures with nitrogen for CCl_3F, $CClF_3$, 1,1,1-$C_2F_3Cl_3$, 1,1,2-$C_2F_3Cl_3$, 1,1-$C_2F_4Cl_2$ and 1,2-$C_2F_4Cl_2$ using the electron swarm method. From these and similar data on CCl_2F_2, total electron attachment cross sections, $\sigma_a(\varepsilon)$, as a function of electron energy were determined for these compounds using new electron energy distribution functions for nitrogen. For all compounds except $CClF_3$, three maxima in $\sigma_a(\varepsilon)$ were found: <0.05, 0.25, 0.75 eV (CCl_3F); 0.07, 0.30, 0.93 eV (CCl_2F_2); <0.05, 0.16, 0.65 eV (1,1,1-$C_2F_3Cl_3$); <0.05, 0.25, 0.73 eV (1,1,2-$C_2F_3Cl_3$); <0.05, 0.25, 0.80 eV (1,1-$C_2F_4Cl_2$); and <0.05, 0.33, 0.95 eV (1,2-$C_2F_4Cl_2$). Only one pronounced maximum in $\sigma_a(\varepsilon)$ for $CClF_3$ was observed at 1.4 eV. Substituent effects on the number and position of negative ion resonances and on the magnitude of $\sigma_a(\varepsilon)$ for the chlorofluoromethanes and chlorofluoroethanes will be discussed.

*Research sponsored by DOE contract EY-76-S-05-4703.

SESSION NA

10:30 A.M.-11:35 A.M., FRIDAY, OCTOBER 12, 1979

BALLROOM 3

ENERGY TRANSFER PROCESSES

CHAIRPERSON: A. RICARD
UNIVERSITÉ DE PARIS-SUD

NA-1 An Afterglow Method for Studying Collision Processes Involving Atoms of Low Vapor Pressure Metals.* D.W. ERNIE and H.J. OSKAM, University of Minnesota.-- A cylindrical hollow cathode discharge tube, constructed of the metal to be studied and containing the desired rare gas, is pulsed to produce a discharge containing sputtered metal atoms in the vapor phase. Time resolved emission and absorption spectroscopy is used to monitor the species in the afterglow and to determine the excitation mechanism for the excited metal ions and the diffusion coefficient of the ground state metal atoms. A theoretical model describing the time dependence of the metal atom density was developed. Measurements have been performed on a helium-copper system. Ground state copper atom densities on the order of 10^{11} atoms/cm^3 have been achieved in the discharge and their time/ dependence agrees with the theoretical model. A diffusion coefficient of 430 cm^2Torr/sec has been determined for copper atoms in helium. Results of studies on the energy transfer mechanisms between helium excited species and copper will be discussed.

*Work supported by the National Science Foundation (Grant # ENG78-25933).

NA-2 Ionizing Collisions between pairs of Excited Alkali Atoms - D. Hudson, NSWC/WOL - It has been observed, that a model based on classical momentum transfer cross sections gives reasonable values for Penning processes involving metastable - metastable collisions. We have applied this model, which uses the polarizabilities of the atomic states involved, to collisions between excited Na - Na and K - K systems. For low lying levels, the model predicts a faster than n^4 increase in the Penning ionization cross sections, while for larger values of n $15 < n < 20$, the rate of increase is less rapid. The variation of cross section with n and l will be presented and the results compared with Monte - Carlo calculations.

NA-3 Vibration-electronic Energy Transfer Processes Involving High Vibrational Levels of CO Measured in an Electrically Excited CO Laser System - S.W. Kim, Esin Gulari, and E.R. Fisher, Wayne State Univ.--Intracavity modulation of a CO laser system while observing sidelight IR and visible/uv emission have been used to study vibration-electronic energy transfer processes in $CO/N_2/O_2/He$ mixtures. Emission from the electronic systems, CN (violet), N_2(second positive), and C_2 (Swan) have been observed over a range of operating conditions using this technique. Observation of the spontaneous IR first overtone spectra demonstrate that intracavity modulation preferentially perturbs high lying vibrational states in CO. Calculations show that the plasma properties, i.e. electron density and temperature, are unaffected by the modulation. Therefore direct observation of vibration-electronic energy transfer involving high lying vibrational states is possible. From a comparison of detailed model calculations and and experimental relaxation times, we are able to set lower limits for the vibration-electronic transfer rates for the above electronic bands excited directly by high lying vibrational states of CO.

NA-4 Kinetic and Absorption Studies on OH* : $A^2\Sigma^+$ (λ=308 nm) Radical in e-beam Excited Ar-H_2O Mixtures (+) F. COLLIER, J.B. LEBLOND, F. HOFFBECK, P. COTTIN - Laboratoires de Marcoussis - We undertook this study to assess the possibility of obtaining gain on the allowed transition OH* : A-X (λ=308 nm, τ=0, 8 μs) from collisional dissociation of the R-OH molecule by e-beam excited rare gases. After a brief investigation, the Ar-H_2O system appeared to be the best OH* donor. The constants of each kinetic step were determined from the fluorescence decay time. We used the $C^3\Pi_u \rightarrow B^3\Pi_g$ (λ=337 nm, τrad.=40 ns) emission of N_2 as the Ar^+ and Ar* kinetic step tracer in an Ar-H_2O-N_2 mixture. We have calibrated the fluorescence OH*(A) yield measurements using the $N_2(C)$: Ar-N_2 emission as absolute reference. Using this calibration, we have calculated OH*(A) formation branching ratios both for $Ar^+ + H_2O$ and for Ar* + H_2O. A kinetic model was established, well correlated with experience, giving the time evolution of the OH* absolute population. Moreover, a time resolved transient absorption measurement at 300 nm and 308 nm was made. The 300 nm measurement gave the absorption value of the continuum due to argon in the OH* emission area. The 308 nm one permitted the calculation of the OH (X) population and branching ratio in the $Ar^+ + H_2O$ reaction. (+) Work supported by DRET.

NA-5 Vibrational Level Dependent Relaxation of CO (v = 1-16) by CO_2 - B. D. GREEN and G. E. CALEDONIA, Physical Sciences Inc. and R. E. MURPHY, Air Force Geophysics Laboratory* -- The technique of time resolved Fourier spectroscopy has been used to determine rate constants for the processes $CO(v) + CO_2 \rightarrow CO(v-1) + CO_2$ where the vibrationally excited CO is created through electron irradiation of Ar/CO_2 mixtures. The CO production mechanism, predominantly dissociative recombination of CO_2^+, is found to produce CO excited to as much as v = 19. The CO(v) deactivation rate constants are deduced from examination of the time histories of the vibrational population distribution. From a Stern-Volmer analysis, the residual quenching not due to CO_2 is attributed entirely to CO (v = 0) relaxation of CO(v) and radiative decay. Experimentally determined upper bounds for the $CO(\Delta v=1)$ transition probabilities for spontaneous emission have been obtained for levels 7-12.

*Support by US AFOSR Project 2310G409 and DNA sub-task I25BAXHX 632.

NA-6 Collisional Relaxation of Electronically Excited Uranium Atoms in Gases* HAO-LIN CHEN and C. BORZILERI, Lawrence Livermore Laboratory--In an effort to gain some understanding of the mechanisms whereby electronically excited levels of heavy atoms are collisionally deactivated in gases, we have measured the rates for electronic relaxation for excited uranium atoms via the method of laser induced fluorescence. Using a modified small angle scattering experiment, we will show that relaxation of the lowest lying metastable electronic states of uranium ($^5K_5^o$ and $^5L_7^o$ states) in hydrogen and methane appears to proceed by near resonant E-to-R or E-to-V/R energy transfer process. We have also measured the rates for electronic relaxation for highly excited uranium atoms in gases. In general, the level density of uranium in the region near 2 eV and above is considerably greater than that near the low lying metastables. We will demonstrate that relaxation of these high lying electronic states by foreign gases appears to proceed by an interstate-mixing process where the excited uranium atoms transfer their excitation to their neighboring levels by collisions. For a given collision partner, quenching cross sections or probabilities are also found to increase with increasing energy of excitation.

*Work performed under the auspices of the U.S. Dept. of Energy by Lawrence Livermore Laboratory under contract No. W-7405-#NG-48.

SESSION NB

10:30 A.M.-11:40 P.M., Friday, October 12, 1979

Ballroom 4

ELECTRON SCATTERING

Chairperson: E. C. Zipf
University of Pittsburgh

NB-1 Absolute Differential Cross Sections (DCS) for Elastic Electron-Helium Scattering for 5 to 200 eV Impact Energies*. D. F. Register and S. Trajmar, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91103--Measurements have been carried out for electron He differential elastic scattering under conditions which represent significant improvements over previous experiments. Below 20 eV the data are normalized by a phase shift analysis while above 20 eV the absolute scale is determined by normalizing to a semi-empirically derived integral elastic cross section. The DCS are believed accurate to 5% at low energies and to 9% at high energies.

*Work supported by NASA Contract No. NAS7-100.

NB-2 Absolute Differential Cross Sections (DCS) for Elastic and Vibrationally Inelastic Scattering of Electrons by CO_2 at 4, 10, 20 and 50 eV*. D. F. Register, H. Nishimura+ and S. Trajmar, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91103--Elastic and vibrationally inelastic scattering of electrons by CO_2 have been measured at 4, 10, 20 and 50 eV. The elastic scattering has been normalized against He using a relative flow technique and the vibrational scattering has been calibrated against the elastic. High resolution electron optics (1020 eV) and an unfolding procedure yields DCS for energy loss features at .083, .159, .172, .240, .258, .291, .317, .332 and .348 eV which are in good agreement with Danner's[1] results at 4.2 eV and Poe's Two Potential Theory[2] at 50 eV.

*Work supported by NASA Contract No. NAS7-100.

+Permanent address: Dept. of Physics, Niigata University, Niigata 950-21, Japan.

1. Dr. Danner, Ph.D. Thesis, Freiburg (1970).
2. R. T. Poe, private communication.

NB-3 Cross Sections for Electron Impact Excitation of the $3s\,^4P$ and $2p^4\,^4P$ States of Atomic Nitrogen.* D. SPENCE, Argonne National Laboratory and P. D. BURROW, U. of Nebraska.--Using a modified trapped-electron technique[1] in a crossed beam arrangement we have measured the electron impact excitation cross section of the $3s\,^4P$ and $2p^4\,^4P$ states of atomic nitrogen, produced in a microwave discharge, in the region close to threshold. The $3s\,^4P$ state peaks at threshold, within our resolution of about 120 meV, reaching a maximum value of about 2.5×10^{-16} cm^2, then decreases monotonically to half this value 0.5 eV above threshold. The cross section of the $2p^4\,^4P$ state increases monotonically from threshold in agreement with theory,[2] to which we normalize our measurements.

*Work performed under the auspices of the U.S. Department of Energy.

[1] D. Spence, Phys. Rev. A 12, 2353 (1975).
[2] K. A. Berrington, P. G. Burke, and W. D. Robb. J. Phys. 8, 2500 (1975).

NB-4 Electron Impact Excitation of Atomic Oxygen-- P.J. ESPY, P.W. ERDMAN, and E.C. ZIPF, Univ. of Pittsburgh--The cross sections for the excitation of the λ98.9 nm [$2p^3P$ - $3s'\ ^3D^o$] and λ102.7 nm [$2p^3P$ - $3d\ ^3D^o$] vacuum ultraviolet multiplets of atomic oxygen by electron impact have been measured. The experiment, which employed a 1/3-meter normal incidence monochromator with a 5670 g/mm concave grating and a programmed, electrostatically focused electron gun, was carried to an altitude of 135 km by a Nike-Orion sounding rocket (31.003 UA) in order to take advantage of the earth's natural supply of atomic oxygen. In this manner many of the difficulties that have impeded laboratory work on this reactive gas were overcome. For an incident electron energy of 25 eV the λ98.9 nm and λ102.7 nm cross sections were 8.4×10^{-18} cm^2 and 9.4×10^{-18} cm^2, respectively. These results are compared with several theoretical estimates, and the implications for the cascade model of OI radiative transport are discussed.

NB-5 Excitation of the $C^3\Pi_u$ State of N_2 by Slow Electrons* - K. Tachibana and A. V. Phelps, JILA, U. of Colorado and NBS -- Excitation rate coefficients for the $N_2(C^3\Pi_u)$ state were obtained from measurements of the absolute intensity of the 2nd positive system emitted when electrons drift through N_2 in the presence of an electric field. The drift tube, detector, calibration, and corrections for nonuniform detection sensitivity and for ionization have been described[1]. A monochromator resolved the 0-0, 1-0, 2-0 and 3-6 bands of the 2nd positive system from Vegard-Kaplan bands. Measured quenching and electron excitation rate coefficients agreed with those of Legler[2]. A cross section set consistent with these results includes vibrational excitation cross sections derived from $N_2(A^3\Sigma_u^+)$ excitation rate coefficients and $C^3\Pi_u$ state cross sections based on Finn, Arts, and Doering[3].

*Supported in part by DARPA/ONR.

[1]S. A. Lawton and A. V. Phelps, J. Chem. Phys. 69, 1055 (1978); D. Levron and A. V. Phelps, Bull. Am. Phys. Soc. 24, 129 (1979).
[2]W. Legler, Z. Physik 173, 169 (1963).
[3]T. G. Finn, J. F. M. Arts and J. P. Doering, J. Chem. Phys. 56, 5632 (1972).

NB-6 Electron-Impact Excitation of Triplet Electronic States of the CO Molecule.* A. R. Filippelli, F. A. Sharpton† and Chun C. Lin, University of Wisconsin.-- The emission bands of the 3A system ($c^3\Pi \rightarrow a^3\Pi$), the Third Positive system ($b^3\Sigma^+ \rightarrow a^3\Pi$), the Triplet system ($d^3\Delta_i \rightarrow a^3\Pi$), and the Asundi system ($a'^3\Sigma^+ \rightarrow a^3\Pi$) produced by electron excitation of the CO molecule have been studied. Beam currents below 60 μamps and gas pressures less than 10 mTorr were used in the measurements. The excitation functions show a narrow peak near the threshold, characteristic of the triplet electronic states. From the measured intensities of these bands we have obtained the excitation cross sections for the electronic states by using the Franck-Condon factor approximation. At an incident electron energy of 20 eV, the excitation cross sections for the $b^3\Sigma^+$ and the $d^3\Delta_i$ states are 2.4×10^{-18} cm^2 and 2.5×10^{-18} cm^2, respectively, in reasonable agreement with the theoretical values based on the Born approximation with Rudge's modification for treating electron exchange.

*Work supported by the Air Force Office of Scientific Research.

†Present address: Northwest Nazarene College, Nampa, Id.

NB-7 Long-Lived High-Rydberg Molecules Formed by Electron Impact. S.M. TARR, J.A. SCHIAVONE, and R.S. FREUND, Bell Laboratories, Murray Hill--High-Rydberg (HR) molecular states of H_2, D_2, N_2, CO, and CO_2 have been excited by electron impact. While previous studies focused on HR atomic fragments formed by molecular dissociation, this work finds that a small fraction of the HR molecules does not dissociate and survives the 10^{-4} μsec flight to the detector. Time-of-flight distributions, principal quantum number distributions, and absolute cross sections for excitation to HR molecular states have been measured over a several eV electron energy range near threshold. The energy dependence exhibits a sharp peak near threshold, similar to that previously reported for electron-impact excited HR states of rare gas atoms, but very different from the behavior observed for formation of HR atoms by molecular dissociation.

INDEX TO ABSTRACTS

NOTES

32nd GASEOUS ELECTRONICS CONFERENCE

October 9-12, 1979; Pittsburgh, Pennsylvania

LIST OF REGISTERED ATTENDEES

ABBOTT, Rod; University of Minnesota, Morris, MN.
ADAMS, Nigel G.; University of Birmingham, Birmingham, England.
ALBRITTON, Daniel Lee; N.O.A.A., Boulder, CO.
ALLAN, Michael; Yale University, New Haven, CT.
ALLIS, William P.; Cambridge, MA.
ALLISON, W.; University of Florida, Gainesville, FL.
AL SAATI, Zeini J.; Carnegie-Mellon University, Pittsburgh, PA.
ALVAREZ, Ignacio; Instituto de Fisica, UNAM, Mexico.
ANDERSON, Jay H.; University of Illinois, Urbana, IL.
ANEKWE, Clement I.; West Virginia University, Morgantown, WV.
BABCOCK, R. V.; Westinghouse R&D Center, Pittsburgh, PA.
BAILEY, Wm. F.; A. F. Institute of Technology, Dayton, OH.
BARDSLEY, J. N.; University of Pittsburgh, Pittsburgh, PA.
BARRETT, John L.; University of Missouri, St. Louis, MO.
BASTIEN, F.; Laboratoire de Physique des decharges, CNRS-E.S.E., France.
BEATTY, Earl C.; JILA, Boulder, CO.
BELL, Alexis T.; University of California, Berkeley, CA.
BENEDICT, Rett; DARPA/STO, Arlington, VA.
BENENSON, David M.; SUNYAB, Amherst, NY.
BERGMAN, Richard C.; Calspan Corp., Advanced Technology Center, Buffalo, NY.
BERGMAN, Rolf S.; General Electric, Photolamp Department, Cleveland, OH.
BHASAVANICH, D.; Westinghouse R&D Center, Pittsburgh, PA.
BHATTACHARYA, Ashok; General Electric, Lighting Business Grp., Cleveland, OH.
BIONDI, M. A.; Dept. of Physics and Astronomy, Univ. of Pgh., Pittsburgh, PA.
BLETZINGER, Peter; AFAPL/POE-3, Wright-Patterson Air Force Base, OH.
BOHDANSKY, Josef; MPI-Plasmaphysik, Garching bei Munchen, Germany.
BOHN, W. L.; DFVLR, Stuttgart, Germany F. R.
BONESS, John; Avco-Everett Research Laboratory, Everett, MA.
BORTNER, M. H.; General Elec. Co., Space Sciences Lab., Philadelphia, PA.
BRADFORD, Robert S., Jr.; TRW DSSG, Los Angeles, CA.
BRAU, Charles A.; Los Alamos Scientific Laboratory, Los Alamos, NM.
BROOKS, Howard; Physics Dept., Univ. of Missouri at Rolla, Rolla, MO.
BROWNE, T. E., Jr.; Consultant, Westinghouse R&D Center, Pittsburgh, PA.
BULLIS, Robert H.; United Tech. Res. Ctr., East Hartford, CT.
BURNHAM, Ralph; Naval Research Laboratory, Ft. Washington, MD.
BURRAGE, L. M.; McGraw Edison R&D Center, Franksville, WI.
BURROW, Paul D.; University of Nebraska, Lincoln, NB.

CHALEK, Carl; General Electric CRD, Schenectady, NY.
CHAMPAGNE, L. F.; Naval Research Laboratory, Washington, DC.
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