TWENTY-FIFTH ANNUAL
GASEOUS ELECTRONICS CONFERENCE

A TOPICAL CONFERENCE OF THE A.P.S.

Co-sponsored by:

Division of Electronic and Atomic Physics
American Physical Society

Division of Atomic and Molecular Physics
Canadian Association of Physicists

Assisted by:

Canadian National Research Council

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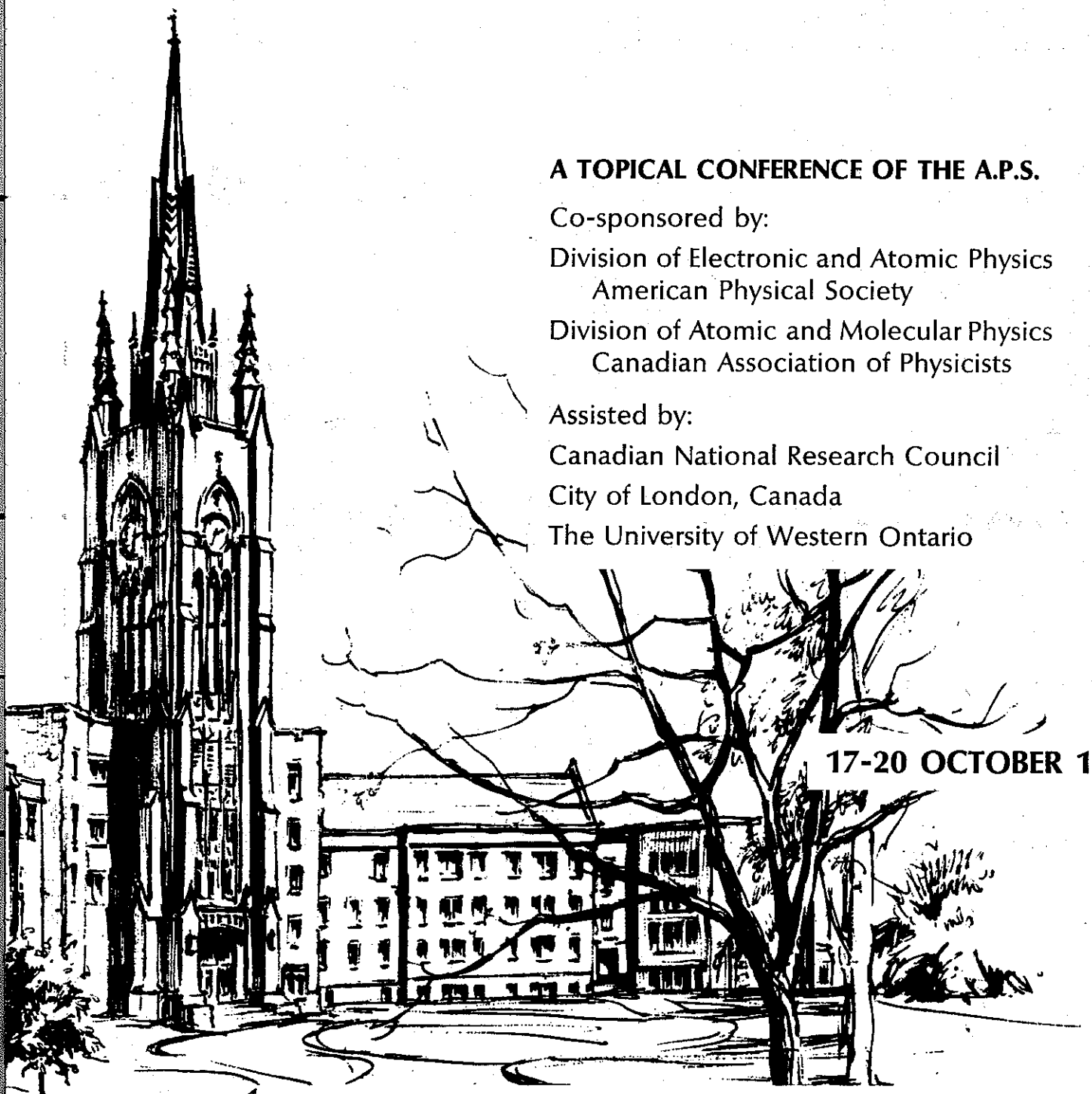


17-20 OCTOBER 1972

THE UNIVERSITY OF WESTERN ONTARIO, LONDON, CANADA

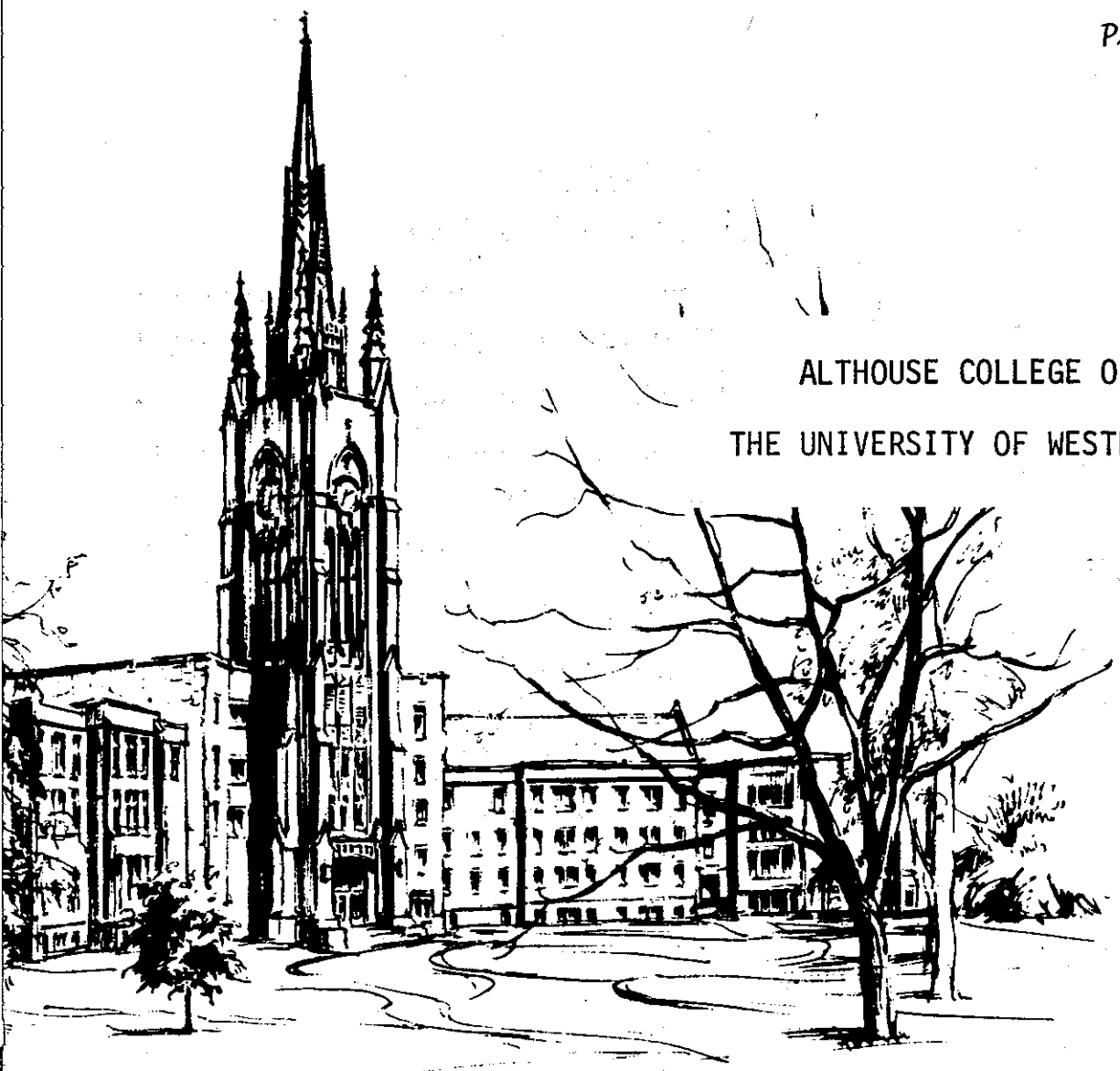
TWENTY-FIFTH ANNUAL GASEOUS ELECTRONICS CONFERENCE

WITH SYMPOSIA ON

ARCS AND GASEOUS PLASMA LASERS

17-20 OCTOBER 1972

Silver Anniversary Program



ALTHOUSE COLLEGE OF EDUCATION

THE UNIVERSITY OF WESTERN ONTARIO

REGISTRATION

Holiday Inn, Downtown (Lobby)

Monday 16 October	19h30-22h00
Tuesday 17 October	19h30-22h00

Althouse College of Education (Lobby)

Tuesday 17 October	8h00-10h00
Wednesday 18 October	8h00-17h00
Thursday 19 October	8h00-12h00

MIXER AND TOUR

Labatt's Brewery
150 Simcoe Street, London

Monday 16 October	20h00-23h00

PROGRAM

ARC SYMPOSIUM

Tuesday, 17 October

SESSION AA. FLOW EFFECTS IN ARCS

8h30-10h15 Room 174 Chairman: B. Ahlborn
University of British Columbia

AA1. DOWNSTREAM CONDITIONS IN A CONSTRICTED ARC WITH RADIAL INJECTION
C.J. Cremers and H.S. Hsia

AA2. A SEMI-EMPIRICAL CORRELATION FOR THE CONFINED-DISCHARGE PLASMA GENERATOR
J.R. Mahan and Wayne L. Smith

AA3. EXPERIMENTS WITH BLUFF-BODY STABILIZED ELECTRODELESS ARCS
D.R. Keefer and J.A. Saxton

AA4. STATIC AND DYNAMIC CHARACTERISTICS OF AXIAL FLOW ARCS IN SF_6 AND NITROGEN GAS
D.R. Topham

AA5. VOLTAGE GRADIENTS IN TURBULENT ARCS
I.P. Shkarofsky

SESSION BA. EQUILIBRIUM IN ARCS

10h45-12h30 Room 174 Chairman: J. Uhlenbusch
Technischen Hochschule Aachen

BA1. CONDUCTANCE TIME CONSTANT MEASUREMENTS ON AN ATMOSPHERIC PRESSURE CASCADE ARC
R.W. Anderson and R.L. Phillips

BA2. INVESTIGATION OF NONEQUILIBRIUM IN TRANSIENT ARCS
R.W. Anderson and S.W. Bowen

BA3. LOCAL THERMAL EQUILIBRIUM IN A PULSED ARC
A.A. Cenkner, Jr., and D.M. Benenson

BA4. HIGH PRESSURE NONEQUILIBRIUM PLASMA NOZZLE FLOWS WITH AXIAL CURRENT
S.W. Bowen

BA5. LTE AND RELATIVE TRANSITION PROBABILITIES OF ATOMIC SCANDIUM
J.C. Morris and P.L. Patterson

BA6. INFLUENCE OF AMBIPOLAR DIFFUSION ON DEPARTURE FROM LTE IN A CESIUM DISCHARGE
B. Sayer, J.C. Jeannet and J. Berlande

SESSION CA. BUSINESS MEETING ARCS GROUP

14h00-14h30 Room 174 Chairman: J.C. Morris
National Bureau of Standards

SESSION CA. TIME VARYING ARCS

14h30-15h45 Room 174 Chairman: M.G. Drouet
Hydro-Quebec

CA1. THE DYNAMIC CHARACTERISTICS OF THE ARC IN A D.C. INTERRUPTER
J.P. Novak, V. Fuchs

CA2. CHARACTERISTICS OF TIME VARYING CERIUM ELECTRODE STABILIZED ARC
Stephen Levy and John E. Creedon

CA3. TEMPERATURE MEASUREMENTS IN ALTERNATING CURRENT ARCS
M.R. Gillette and D.M. Benenson

CA4. FLUCTUATIONS IN DRAWN ARCS AT ATMOSPHERIC PRESSURE
Eoin W. Gray

SESSION DA. MAGNETIC EFFECTS IN ARCS

15h45-18h00 Room 174 Chairman: D.M. Benenson
State University of New York, Buffalo

DA1. A LOW FREQUENCY ELECTROMAGNETIC INSTABILITY IN AN INTENSELY IRRADIATED PLASMA
W.B. Thompson

DA2. WAVE PROPAGATION AND ABSORPTION IN A MAGNETICALLY CONFINED ARC PLASMA
C.E. Nielsen

DA3. KINETICS OF MAGNETICALLY INDUCED ARC MOTION FROM 1 TO 760 TORR
R.P. Carter and D.L. Murphree

DA4. DIRECT DISPLAY OF THE CURRENT DENSITY PROFILE OF A MAGNETIC FIELD DRIVEN ARC
M.G. Drouet and R. Beaudet

DA5. THE INTERACTION WITH AXIAL MAGNETIC FIELDS OF Cu, Cr, Ag and C VACUUM ARCS
C.W. Kimblin

DA6. MAGNETICALLY INDUCED INSTABILITY IN AN ARGON DISCHARGE
R.H.S. Hardy

Wednesday, 18 October

SESSION HA. ELECTRODE EFFECTS

14h00-15h15 Room 174 Chairman: R. Dethlefsen
ITE Power Equipment

HA1. UNIFIED ANALYSIS OF VOLTAGE DROP, CURRENT DENSITIES AND ELECTRON TEMPERATURE IN THE CATHODE SPOT
G.H. Ecker

HA2. CONTROLLED TRANSPIRATION COOLING OF THE ANODE IN A HIGH INTENSITY ARC
C.V. Boffa and E. Pfender

HA3. INVESTIGATION OF THE BOUNDARY LAYER IN FRONT OF A TRANSPIRATION-COOLED ANODE
J.V. Heberlein and E. Pfender

HA4. EROSION AND IONIZATION AT CATHODE SPOTS OF CARBON VACUUM ARCS
C.W. Kimblin

SESSION JA. ARC TRANSPORT PROPERTIES

15h45-17h00 Room 174 Chairman: U. Bauder
Georgia Tech

JA1. TEMPERATURE VERSUS RATE OF COOLING FOR COLD-WALL CONFINED PLASMA JETS
M.P. Freeman

JA2. RF ARGON PLASMAS UP TO 40 ATM SEEDED WITH W AND UF_6
Ward C. Roman

JA3. TEMPERATURE AND EMISSION MEASUREMENTS ON MERCURY-TIN IODIDE ARCS
J.J. de Groot and A.G. Jack

JA4. THE ELECTRON-NEUTRAL TRANSPORT CROSS SECTION OF MERCURY
J.C. Morris and J.H. Walker

JA5. - VALUES OF SOME ArII LINES IN THE VUV
S.K. Srivastava and G.L. Weissler

JA6. ABSOLUTE INTENSITY MEASUREMENT ON A URANIUM ARC IN THE VACUUM-ULTRAVIOLET REGION
J.M. Mack, Jr., H.D. Campbell, R.T. Schneider

PROGRAM

GASEOUS LASER SYMPOSIUM

Tuesday, 17 October

SESSION EB. CO LASERS

20h30-22h30 Room 229 Chairman: M. Bhaumik
Northrup Research and Technology Laboratory

EB1. HIGH PRESSURE ELECTRICAL CO LASERS
R.E. Center and G.E. Caledonia

EB2. TRANSIENT OSCILLATOR ANALYSIS FOR A CO LASER
W.B. Lacina

EB3. VIBRATIONAL RELAXATION IN CO LASERS
M.L. Bhaumik, W.B. Lacina and M.M. Mann

EB4. VIBRATIONAL KINETIC RATES FOR CARBON MONOXIDE AT 77° K
L.A. Schlie and A.R. Filipelli

EB5. AN EFFICIENT THRESHOLD FOR CO LASER OPERATION
S.D. Rockwood and R.O. Hunter

EB6. KINETIC MODEL OF CO ELECTRIC DISCHARGE GAS LASERS
L.S. Bender, R.J. Hall, B.R. Bronfin

EB7. CW LASER ACTION FROM CO PUMPED BY ELECTRIC DISCHARGE IN SUPERSONIC FLOW
J.A. Shirley, L.R. Boedeker, B.R. Bronfin

EB8. CRYOGENICALLY COOLED CARBON MONOXIDE TEA LASER DYNAMICS
T. Kan and L. Champagne

Wednesday, 18 October

SESSION HB. LASERS GENERAL I

14h00-15h20 Room 229 Chairman: P.K. John
University of Western Ontario

HB1. TIME DEPENDENT COPPER VAPOR LASER CALCULATIONS
C.P. Holmes

HB2. THE CSe_2/O_2 CARBON MONOXIDE CHEMICAL LASER
Curt Wittig and Ian W.M. Smith

HB3. TRANSVERSE-EXCITATION PULSED HCN LASER
D.L. Jassby and M.F. Lam

HB4. INFRARED LASER POSSIBILITIES IN NORMALLY NON-LASING GASES
W.H. Christiansen

HB5. STATIONARY POPULATION INVERSIONS OF ATOMIC LEVELS IN A DECAYING HYDROGEN PLASMA FLOW
P. Hoffman and W.L. Bohn

HB6. VIBRATIONAL QUENCHING RATES FOR HF(v=1) IN $C_nH_{n+2}(n \leq 4)$, C_3H_6, and ClF_3 MIXTURES
J.K. Hancock and W.H. Green

Wednesday, 18 October

SESSION JB. LASERS GENERAL II

15h40-17h00 Room 229 Chairman: J.W. Sargent
Gen-Tec, Ltd. Quebec

JB1. INTERFEROMETRIC MEASUREMENTS FOR PLASMA PATH CHANGES IN A WATER VAPOR LASER
W.J. Schade, Jr.

JB2. AFTERGLOW INVERSION MECHANISMS IN THE TEA HE-NE LASER
R. Arrathoon

JB3. SPECTROSCOPIC INVESTIGATIONS OF METAL CARBONYL DISCHARGES
Allen K. MacKnight and George W. Rhodes

JB4. PRESSURE AND CURRENT DEPENDENCE OF OUTPUT POWER FOR THE PULSED XeIV ION LASER
W.W. Simmons and R.S. Witte

JB5. OUTPUT POWER CHARACTERISTICS OF THE PULSED XeIV ION LASER
H.S. Ames and W. W. Simmons

JB6. PRODUCTION AND STABILITY OF UNIFORM HIGH PRESSURE GAS DISCHARGES IN THE PRESENCE OF EXTERNAL IONIZATION
Alan E. Hill and Allen K. MacKnight

Thursday, 19 October

SESSION KB. CO_2 LASERS I

8h30-10h15 Room 229 Chairman: W.J. Wiegand, Jr.
United Aircraft
Research Laboratories

KB1. COLD CATHODE ELECTRON BEAM SUSTAINED HIGH PRESSURE CO_2 AND CO LASERS
R.O. Hunter, G. Sullivan, W. Beggs and J. Benze

KB2. A RADIAL MODE TEA-CO_2 LASER
L. W. Casperson and C. Romero

KB3. THE PROPERTIES OF A MAGNETOPLASMA LASER
R.H. Bullis, T.L. Churchill and W.L. Nighan

KB4. NANOSECOND PULSE GENERATION AT 10.6 μ
J.F. Figueira, W.H. Reichelt, E. Foley and C.A. Fenstermacher

KB5. PULSE AMPLIFICATION IN THE LASL ELECTRON BEAM PUMPED CO_2 LASER SYSTEM
W.H. Reichelt, J.F. Figueira, C.E. Landahl, E.O. Swickard, T.F. Stratton and C.A. Fenstermacher

KB6. CO_2 AMPLIFIER ENERGY EXTRACTION - COMPARISON OF THEORY AND EXPERIMENT
G.T. Schappert and T.F. Stratton

SESSION LB. PLASMA AND COLLISION PHENOMENA IN LASERS

10h45-12h30 Room 229 Chairman: A.I. Carswell
York University

LB1. POPULATION INVERSION CALCULATIONS USING NEAR RESONANT CHARGE EXCHANGE AS A PUMPING MECHANISM
D.L. Chubb and J.R. Rose

LB2. SIMULTANEOUS TWO-WAVELENGTH OPERATION OF THE HF CHEMICAL TEA LASER AND ITS USE AS A PROBE OF COLLISIONS PROCESSES OCCURRING IN THE LASER PLASMA
Regina J. Cody and Herschel S. Pilloff

LB3. PULSE PERTURBATION MEASUREMENTS OF V-V AND V-T PROCESSES IN CO_2 GLOW DISCHARGES
M.C. Gower and A.I. Carswell

LB4. VIBRATIONAL ENERGY TRANSFER FROM HF AND DF TO CO_2
T.A. Dillon and J.C. Stephenson

LB5. ELECTRON DISTRIBUTION AND LASING EFFICIENCY OF VIBRATIONALLY EXCITED DIATOMIC GAS
W.P. Allis, H.A. Haus

LB6. ELECTRON ENERGY DISTRIBUTION IN GASEOUS DISCHARGES WITH EXTERNAL SOURCES
R. Lo and G.H. Miley

LB7. PENNING IONIZATION IN A He-Cd dc DISCHARGE UNDER OPTIMUM LASER CONDITIONS
W.T. Silfvast

SESSION MB. CO_2 LASERS II

14h00-15h45 Room 229 Chairman: A. Garscadden
Aerospace Research Laboratories
Wright Patterson Air Force Base

MB1. COMPARISON OF DIRECT AND DISCHARGE PUMPING IN CO_2 LASERS
W.A. Proctor and G.H. Canavan

MB2. PLASMA CONDITIONING BY UV PREIONIZATION IN A CO_2 GAS LASER
O. Judd and J. Wada

MB3. THE INFLUENCE OF TRANSVERSE GAS FLOW UPON HIGH PRESSURE-HIGH PULSE REPETITION RATE GLOW DISCHARGES
G.S. Dzakowic and S.A. Wutzke

MB4. CHARGE PARTICLE PRODUCTION INSTABILITY IN CO_2 LASER DISCHARGES
W.L. Nighan, R.A. Haas and W.J. Wiegand

MB5. INFLUENCE OF DISCHARGE PROCESSES ON MOLECULAR LASER STABILITY
W.J. Wiegand, W.L. Nighan and R.A. Haas

MB6. A HEURISTIC APPROACH TO He-CO_2 LASER KINETICS
P. Avivi, F. Dothan-Deutsch, L. Friedland and H. Keren

MB7. INFLUENCE OF CO ON THE POPULATION INVERSION IN CO_2 LASERS
P. Avivi, F. Dothan-Deutsch, L. Friedland and H. Keren

SESSION NB. ELECTRON BEAM LASERS

16h15-18h00 Room 229 Chairman: C.A. Fenstermacher
Los Alamos Scientific Laboratory

NB1. AN ATMOSPHERIC PRESSURE CO_2 LASER INITIATED BY A COLD-CATHODE GLOW-DISCHARGE ELECTRON GUN
A. Crocker, H. Foster and H.M. Lamberton

NB2. HIGH VOLTAGE LARGE AREA PLASMA ELECTRON GUN
B.B. O'Brien, Jr.

NB3. HIGH POWER ELECTRON BEAM, STABILIZED CO LASER
M.M. Mann, G.L. McAllister, R.G. Eguchi and G. Hasserjian

NB4. CHARACTERISTICS OF HIGH PRESSURE CARBON DIOXIDE LASER AMPLIFIERS PUMPED WITH ELECTRON BEAM
W.T. Leland, M.J. Nutter, J.P. Rink and C.A. Fenstermacher

NB5. THEORETICAL STUDIES OF THE ELECTRON BEAM CONTROLLED CO_2 LASER
A.M. Lockett III

NB6. RANGE ENHANCEMENT OF 135 keV ELECTRONS FROM APPLIED ELECTRIC FIELDS IN DENSE GAS
J.P. Rink, C.A. Fenstermacher and W.T. Leland

NB7. ELECTRON BEAM TRANSPORT IN LASER DISCHARGES
Dale B. Henderson

WEDNESDAY EVENING 18 OCTOBER

AN EVENING AT THE STRATFORD FESTIVAL

Buses leave for Stratford between 17h00-17h30 from the front of Althouse College of Education.

A buffet will be served at 18h30 at the Victoria Inn, immediately behind the Festival Theatre.

"King Lear" is playing at the Festival Theatre, starting time 20h30.

THURSDAY EVENING 19 OCTOBER

RECEPTION AND BANQUET

A reception hosted by the University of Western Ontario will take place at 18h30 in the McIntosh Gallery.

Silver Anniversary Banquet will be held in the Great Hall, Somerville House, at 20h00. The City of London will be the host.

PROGRAM

TWENTY-FIFTH ANNUAL

GASEOUS ELECTRONICS CONFERENCE

Tuesday, 17 October

SESSION AC. HEAVY PARTICLE INTERACTIONS I

8h30-10h30 Room 200 Chairman: T. Dean Gaily
Univ. of Western Ontario

AC1. ROTATIONAL EXCITATION OF CO^+ ($A^2\Pi$) FORMED IN Li^+-CO COLLISIONS
H.I.S. Ferguson and R.P. Lowe

AC2. ROTATIONAL POPULATION DISTRIBUTION OF THE $B^2\Sigma$ STATE OF N_2+ EXCITED IN ALKALI ION-N_2 COLLISIONS
R.E. Mickle, H.I.S. Ferguson and R.P. Lowe

AC3. EXCITATION OF HELIUM IN Li^+-He COLLISIONS
A.J. Cole and R.P. Lowe

AC4. EXCITATION AND IONIZATION OF HELIUM BY FAST PROTONS AND BY THEIR ASSOCIATED SECONDARY ELECTRONS
D.M. Bartell and G.S. Hurst

AC5. MODEL FOR VUV EMISSION AND ENERGY PATHWAYS FOLLOWING PROTON EXCITATION OF HELIUM
G.S. Hurst, D.M. Bartell and E.B. Wagner

AC6. COUPLED-STATE CALCULATIONS OF He^{2+}-H COLLISIONS
A. Msezane and D.F. Gallaher

AC7. SUPERELASTIC COLLISIONS OF VIBRATIONALLY EXCITED H_2^+ WITH ATOMS AND MOLECULES
F.A. Herrero and J.P. Doering

AC8. REACTIONS OF ATOMIC OXYGEN WITH IONIC SPECIES
J.A. Rutherford and D.A. Vroom

AC9. A STUDY OF THE REACTIONS $H_2^+ + He \rightarrow HeH^+ + H$ AND $HeH^+ + H \rightarrow H_2^+ + He$
D.A. Vroom and J.A. Rutherford

SESSION BC. HEAVY PARTICLE INTERACTIONS II

11h00-12h30 Room 200 Chairman: John V. Dugan
NASA Lewis Research Center

BC1. INVESTIGATION OF ASSOCIATIVE DETACHMENT REACTIONS USING THE SF6 SCAVENGER TECHNIQUE
T.O. Tiernan, C. Lifshitz and J.C. Haartz

BC2. NEGATIVE ION REACTIONS IN N_2O AT LOW ENERGIES
R. Marx and G. Mauclaire

BC3. THERMAL ENERGY CHARGE-TRANSFER OF Ne^+ WITH VIBRATIONALLY EXCITED N_2
D.L. Albritton, Y.A. Bush, F.C. Fehsenfeld, E.E. Ferguson, T.R. Govers, M.McFarland and A.L. Schmeltekopf

BC4. THERMAL ENERGY CHARGE TRANSFER REACTIONS OF RARE-GAS IONS TO DIATOMIC AND SIMPLE POLYATOMIC MOLECULES
James B. Laudenslager and Michael T. Bowers

BC5. EFFECTS OF NH_3 AND SF_6 ON IONS IN THE ATMOSPHERE
B.T. McClure and C.W. Erickson

BC6. INFORMATION FROM RATE CONSTANTS MEASURED AS A FUNCTION OF E/p
C. Russ, M. Barnhill and S.B. Woo

SESSION CC. HEAVY PARTICLE INTERACTIONS III

14h00-15h45 Room 200 Chairman: E. Rothe
Wayne State University

CC1. PROTON AFFINITIES OF SOME ATMOSPHERIC GASES
H.W. Rundle, R.S. Hemsworth, D.K. Bohme and H.I. Schiff

CC2. THE CHEMICAL EQUILIBRIUM $NH_2^- + H_2 \rightleftarrows H^- + NH_3$ AND $D_o^o(NH_2\text{-}H)$
R.S. Hemsworth, H.W. Rundle and D.K. Bohme

CC3. EQUILIBRIUM CONSTANTS AND BINDING ENERGIES OF ALKALI METAL IONS WITH INERT GASES
L.G. McKnight and J.M. Sawina

CC4. CLUSTERING OF Ar TO Li^+ AS A FUNCTION OF E/N
G.E. Keller and L.M. Colonna-Romano

CC5. CLUSTERING OF ATMOSPHERIC GASES TO NO^+
J.A. Vanderhoff and J.M. Heimerl

CC6. THERMAL ENERGY RATE CONSTANTS FOR ION-POLAR MOLECULE COLLISIONS AND THEIR DEPENDENCE ON ION KINETIC ENERGY: THEORY AND EXPERIMENT
M.T. Bowers and T. Su

CC7. MOMENTUM TRANSFER CROSS SECTIONS FOR IONS IN POLAR GASES
J.V. Dugan, Jr. and J.L.Magee

CC8. NUMERICAL STUDIES OF CONDITIONS FOR FORMATION OF COLLISION COMPLEXES IN DIPOLE-DIPOLE COLLISIONS
J.V. Dugan, Jr. and R.W. Palmer

SESSION CD. BREAKDOWN AND CORONA

14h00-16h00 Room 229 Chairman: F. Llewellyn-Jones
Swansea, Wales

CD1. CALCULATIONS OF SPACE-CHARGE CONTROLLED BREAKDOWN
L.E. Kline

CD2. FOCAL SPOT SIZE DEPENDENCE OF GAS BREAKDOWN INDUCED BY PARTICULATE IONIZATION
G.H. Canavan

CD3. MEASUREMENTS OF CURRENT AND ACCOMPANIED RADIATION EMISSION DURING IMPULSE BREAKDOWN OF A COAXIAL GAP
H. Albrecht and W.H. Bloss

CD4. AXIALLY SYMMETRIC IONIZING POTENTIAL WAVES IN STRONG ELECTRIC FIELDS
R. Klingbell and D.A. Tidman

CD5. CONFINEMENT REGIME OF RADIOFREQUENCY BREAKDOWN AND DISCHARGE
A.J. Hatch and C.F. Shelby

CD6. MICROWAVE BREAKDOWN OF SF_6
S.J. Tetenbaum, A.D. MacDonald and H.W. Bandel

CD7. OZONE GENERATION IN A CORONA DISCHARGE
M.B. Awad and G.S.P. Castle

CD8. SOME SURFACE EFFECTS CAUSED BY H.F. DISCHARGE
A.D. Sulimin, V.G. Yakovenco, L.S. Morozova, O.I. Yakovlev, S.A. Neustroev, Yu.V. Basikhin

SESSION DD. GLOW DISCHARGES I

16h15-18h00 Room 200 Chairman: T.D. Holstein
Univ. of California, Los Angeles

DD1. ANALYTICAL STUDY OF THE DIFFUSION CONTROLLED POSITIVE COLUMN
L. Oster and A.V. Phelps

DD2. NUMERICAL STUDY OF THE DIFFUSION CONTROLLED POSITIVE COLUMN
E.F. Jaeger, J.T. Mariska, L. Oster and A.V. Phelps

DD3. CALCULATIONS AND MEASUREMENTS ON Cs-Ar AND Na-Ne LOW PRESSURE D.C. DISCHARGES
H. van Tongeren

DD4. DENSITY OF EXCITED ATOMS UNDER NON-EQUILIBRIUM CONDITIONS
C. Van Trigt and J.B. Van Laren

DD5. ELECTRON KINETIC PROCESSES IN N_2 DISCHARGES
W.F. Bailey and W.H. Long

DD6. NITROGEN POSITIVE COLUMN MODEL
W.H. Long, Jr., and W.F. Bailey

DD7. CUMULATIVE IONIZATION IN NITROGEN
W.F. Bailey, W.H. Long, Jr., P. Bletzinger and A. Garscadden

SESSION ED. GLOW DISCHARGE II

20h30-22h15 Room 200 Chairman: Alan Watson
Univ. of Western Ontario

ED1. GLOW DISCHARGE MASS SPECTROMETRY WITH SPUTTER-INJECTION OF TRACE ELEMENTAL SPECIES
J.W. Coburn, E. Taglauer and Eric Kay

ED2. POSITIVE ION RATIO MEASUREMENTS IN NOBLE GAS GLOW DISCHARGES
R.L. Fitzwilson and L.M. Chanin

ED3. THE GLOW TO ARC TRANSITION
Michael A. Lutz

ED4. THE EFFECT OF ELECTRON DE-EXCITATION AND SELF-ABSORPTION ON THE INTENSITY OF THE Hg 2537Å LINE IN Hg+Ar DISCHARGES
T.J. Hammond and C.F. Gallo

ED5. CHARACTERISTICS OF HIGH PRESSURE PULSED GAS DISCHARGE
R.L. Schriever

ED6. ELECTRON TEMPERATURE VARIATIONS IN DEEPLY MODULATED PLASMA COLUMNS
C.J. Burkley and M.C. Sexton

ED7. FISSION FRAGMENT PRODUCED PLASMAS
R.A. Walters and R.T. Schneider

Wednesday, 18 October

SESSION F. SPECIAL PROGRAM ON APPLICATIONS OF GASEOUS ELECTRONICS

8h30-12h30 Room 200 Chairman: David J. Rose
MIT

8h30 F1. APPLICATIONS OF GASEOUS ELECTRONICS TO LASER TECHNOLOGY
A.V. Phelps, JILA

9h10 F2. GASEOUS ELECTRONICS IN DISCHARGE LAMPS
John F. Waymouth, G.T.E. Sylvania

9h50 F3. SOME ASPECTS OF GASEOUS ELECTRONICS IN THE UPPER ATMOSPHERE
G.G. Shephard, York University

10h30-10h45 COFFEE BREAK

10h45 F4. COMPOUND STATES IN DIATOMIC MOLECULES - A REVIEW
G.J. Schulz, Yale

11h25 SPECIAL PRESENTATION TO ERICH E. SOEHNGEN

11h40 F5. NON-EQUILIBRIUM EFFECTS IN ARC PLASMAS
J. Uhlenbusch, Technischen Hochschule Aachen

SESSION G. GEC BUSINESS MEETING

OVER LUNCH

IN ALTHOUSE COLLEGE CAFETERIA

13h00-14h00, Chairman: G.H. Dunn, JILA

SESSION HC. METASTABLES PANEL

14h00-17h00 Room 200 Chairman: H. Hotop
JILA and Freiburg

HC1. METASTABLE HYDROGEN ATOM QUENCHING COLLISIONS
J.A. Medeiros, F.W. Byron, Jr., and R.V. Krotkov

HC2. DEEXCITATION OF FAST He*(2^1S), He*(2^3S), AND Ne*(^3P) IN VARIOUS GASES
J.T. Moseley, J.R. Peterson, D.C. Lorents and M. Hollstein

HC3. QUENCHING EFFECT OF HELIUM 2 MICRON LIGHT ON A WEAK HELIUM DISCHARGE
A.C. Tam, H. Tang and W. Happer

HC4. EXCITATION TRANSFER FROM 2P ATOMIC STATES TO MOLECULAR STATES IN HIGH PRESSURE HELIUM
P.E. Theiss and G.H. Miley

HC5. VELOCITY DEPENDENCE OF THE CROSS SECTION FOR THE QUENCHING OF $^3P_{0,2}$ ARGON IN COLLISIONS WITH MOLECULAR OXYGEN
M.E. Gersh and E.E. Muschlitz, Jr.

HC6. QUENCHING OF VIBRATIONALLY-EXCITED N_2 BY N_2O
M.E. Whitson, Jr., G.R. Cook and R.J. McNeal

HC7. QUENCHING OF VIBRATIONALLY-EXCITED N_2 BY ATOMIC OXYGEN
R.J. McNeal, M.E. Whitson, Jr., and G.R. Cook

HC8. CHEMIIONIZATION IN COLLISIONS BETWEEN He(2^1S) AND He(2^3S) AND H-ATOMS
J.S. Howard, J.P. Riola, R.D. Rundel and R.F. Stebbings

HC9. ASSOCIATIVE IONIZATION IN LOW ENERGY COLLISIONS BETWEEN METASTABLE HELIUM AND H AND D
G.D. Magnuson and R.H. Neynaber

HC10. HeH^+ FORMATION FROM LOW-ENERGY COLLISIONS OF METASTABLE HELIUM AND MOLECULAR HYDROGEN
R.H. Neynaber, G.D. Magnuson and J.K. Layton

Thursday, 19 October

SESSION KC. LIFETIMES AND SPECTRA

8h30-10h15 Room 200 Chairman: S. David Rosner
Univ. of Western Ontario

KC1. RADIATIVE LIFETIMES OF THE $c^1\Pi$, $A^3\Pi$, AND $d^1\Sigma$ STATES OF NH
R. Anderson

KC2. RADIATIVE LIFETIMES OF $N_2^+(A^2\Pi_u)$: THE MEINEL BAND SYSTEM
J.R. Peterson and J.T. Moseley

KC3. EMISSION FROM LONG-LIVED STATES OF N_2^+. RELATION TO $N_2^+ + N_2 \rightarrow N_3^+ + N$
W.B. Maier II and R.F. Holland

KC4. RELATIVE INTENSITY MEASUREMENTS ON THE FOX-DUFFENDACK-BARKER AND ULTRAVIOLET DOUBLET BAND SYSTEMS OF CO_2
J.C. McCallum and R.W. Nicholls

KC5. ELECTRON AND PHOTON EXCITATION OF CF_4
W.A. Brown

KC6. MEASUREMENT OF VIBRATIONAL POPULATION DISTRIBUTIONS IN A HYDROGEN PLASMA
J.A. Burt

KC7. VAN DER WAALS BROADENING OF NEUTRAL ARGON
D.M. Camm, F.L. Curzon, G.H. Copley, S. Lee

KC8. DETERMINATION OF VAN DER WAAL'S BROADENING OF FeI EMISSION LINES INDUCED BY NEUTRAL He
G.H. Copley and D.M. Camm

SESSION LC. NEGATIVE IONS

10h45-12h30 Room 200 Chairman: T.O. Tiernan
Wright-Patterson Air Force Base

LC1. DYE-LASER PHOTODETACHMENT OF OH^- AND OD^-
H. Hotop, T.A. Patterson and W.C. Lineberger

LC2. LASER PHOTODETACHMENT STUDIES OF Cu, Ag, Au, and Pt NEGATIVE IONS
H. Hotop, R.A. Bennett and W.C. Lineberger

LC3. MEASUREMENT OF THE ELECTRON AFFINITY OF NO_2
C.B. Leffert, W.M. Jackson and E.W. Rothe

LC4. MOLECULAR ELECTRON AFFINITIES FROM COLLISIONAL IONIZATION OF CESIUM: SF_6 AND TeF_6
R.N. Compton, C.D. Cooper, W.T. Divver and P.W. Reinhardt

LC5. NEGATIVE ION FORMATION IN OCS
J.P. Ziesel and G.J. Schulz

LC6. TEMPERATURE DEPENDENCE OF ELECTRON ATTACHMENT AT LOW ENERGIES FOR POLYATOMIC MOLECULES
D. Spence and G.J. Schulz

LC7. DISSOCIATIVE ATTACHMENT IN CO_2
P.J. Chantry

LC8. ELECTRON TRANSMISSION IN ATOMIC HYDROGEN
L. Sanche and P.D. Burrow

SESSION MD. AFTERGLOWS I

14h00-15h30 Room 174 Chairman: R. Deloche
Saclay

MD1. AMBIPOLAR TO FREE DIFFUSION: THE TEMPORAL BEHAVIOR OF THE ELECTRONS AND IONS
R.A. Gerber and J.B. Gerardo

MD2. SPATIAL DISTRIBUTIONS AND WALL CURRENTS FOR CHARGED PARTICLES IN IONIZED AIR CONTAINING WATER VAPOR
F.E. Niles, M.D. Kregel and E.L. Lortie

MD3. DECAY OF $Cd(5^3P_1)$ AND $Cd(5^1P_1)$-ATOM DENSITIES IN A Cd-Ne AFTERGLOW
J. Polman and J.E. Van Der Werf

MD4. DIAGNOSTICS OF CESIUM PLASMAS BY A TUNABLE ORGANIC-DYE LASER
D.T. Shaw

MD5. GAS TEMPERATURE AND PARTIAL PRESSURE DEPENDENCE OF ELECTRON-ION KINETICS OF HIGH PRESSURE He, Ne, N_2, AND He-Ne, He-N_2 GAS MIXTURES
W.H. Ellis and G.H. Sanders

MD6. COLUMNAR RECOMBINATION OF FISSION FRAGMENT PRODUCED IONIZATION IN 10 ATM He and 1 ATM Ar-N_2
W.H. Ellis

SESSION ND. AFTERGLOWS II

16h00-18h00 Room 174 Chairman: Sanborn C. Brown
MIT

ND1. ELECTRON ENERGY BALANCE AND DISTRIBUTION FUNCTION IN A HELIUM AFTERGLOW
W.E. Wells, P. Monchicourt, R. Deloche, J. Berlande

ND2. ELECTRON TEMPERATURE MEASUREMENT IN A HELIUM AFTERGLOW
R. Deloche, P. Monchicourt, W.E. Wells, J. Berlande

ND3. THE TEMPERATURE AND PRESSURE DEPENDENCE OF THE LIFE-TIME OF HELIUM SINGLET METASTABLE ATOMS
Sister John C. Hungerman

ND4. EFFECT OF METASTABLES ON STATISTICAL TIME LAGS IN HELIUM
B.M. Lancaster, Jr. and K.J. Nygaard

ND5. STUDY OF THE AFTERGLOW OF AN ELECTRON BEAM-EXCITED DISCHARGE IN HELIUM AT 2000 TORR
C.B. Collins, A.J. Cunningham and B.W. Johnson

ND6. RECOMBINATION OF ELECTRONS WITH DIATOMIC IONS OF THE TWO ISOTOPES OF HELIUM
A. Wayne Johnson and J.B. Gerardo

ND7. DOES He_3^+ CONTRIBUTE SIGNIFICANTLY TO THE TOTAL ELECTRONIC RECOMBINATION IN A 300°K HELIUM PLASMA DOMINATED BY He_2^+ IONS?
A. Wayne Johnson and J.B. Gerardo

ND8. RATE OF IONIZATION BY COLLISIONS BETWEEN TWO HELIUM ATOMIC METASTABLES (2^3S)
A. Wayne Johnson and J.B. Gerardo

Friday, 20 October

SESSION OC. ELECTRON IMPACT EXCITATION

8h30-10h15 Room 200 Chairman: Paul Marmet
Universite Laval

OC1. EXCITATION OF THE 3^3P LEVEL OF HELIUM BY ELECTRON IMPACT
R.J. Anderson, R.H. Hughes and J.H. Tung

OC2. ELECTRON EXCITATION OF H AND H_2
R.A. Mickish and R.M. St. John

OC3. MEASUREMENTS OF ELECTRON EXCITATION CROSS SECTIONS OF THE INDIVIDUAL MAGNETIC SUBLEVELS OF THE ^2P AND ^2D STATES OF POTASSIUM
Jerry E. Solomon, Dale E. Korff, Fred L. Roesler and Chun C. Lin

OC4. ABSOLUTE CROSS SECTIONS FOR ELECTRON IMPACT EXCITATION OF THE H AND K RESONANCE LINES OF CA^+
Paul O. Taylor and Gordon H. Dunn

OC5. SIMULTANEOUS EXCITATION AND IONIZATION OF ARGON BY ELECTRON IMPACT
J.W. McConkey and F.G. Donaldson

OC6. EXCITATION OF BAND EMISSIONS IN NITROGEN BY SECONDARY AND PRIMARY ELECTRONS
Walter L. Borst and Mahmood Imami

OC7. SCATTERING OF ALKALI HALIDES BY LOW ENERGY ELECTRONS
M.G. Fickes, R.C. Slater and R.C. Stern

SESSION OD. AFTERGLOWS III

8h30-10h00 Room 174 Chairman: A.K. Bhattacharya
GE Company

OD1. MEASUREMENTS OF RECOMBINATION OF ELECTRONS WITH H_3^+ AND H_5^+ IONS
M.T. Leu, Manfred A. Biondi and R. Johnsen

OD2. COLLISION PROCESSES OCCURRING IN DECAYING PLASMAS PRODUCED IN HELIUM-HYDROGEN MIXTURES
G.E. Veatch and H.J. Oskam

OD3. MASS SPECTROMETER MEASUREMENTS IN HELIUM-CESIUM AFTERGLOWS
R.S. Bergman and L.M. Chanin

OD4. NITROGEN AFTERGLOW STUDIES AT VARIOUS GAS PRESSURES AND TEMPERATURES
G.N. Hays, C.J. Tracy and H.J. Oskam

OD5. INVESTIGATION OF VIBRATIONAL RELAXATION IN LOW PRESSURE N_2 DISCHARGES
O.Sahni and W.C. Jennings

OD6. PENNING IONIZATION BY $^5S^0$ OXYGEN ATOMS
D.R. Clark

SESSION PC. IONIZATION

10h45-12h30 Room 200 Chairman: J.W. McConkey
Univ. of Windsor

PC1. PHOTOIONIZATION OF N_2O BY SOFT X-RAYS
R.G. Hirsch, R.J. Van Brunt and W.D. Whitehead

PC2. "PHOTOELECTRON" SPECTROSCOPY BY ELECTRON IMPACT-COINCIDENCE MEASUREMENTS OF SCATTERED & EJECTED ELECTRONS IN CO
M.J. van der Wiel and C.E. Brion

PC3. EXCITATION OF THE TRIPLET STATES $e^3\Sigma_u^+$ AND $d^3\Pi_u$ BY ELECTRON IMPACT ON H_2
A. Weingartshofer and E.M. Clarke

PC4. FORMATION OF H_2^+ AND D_2^+ BY ELECTRON IMPACT
P. Marmet, E. Bolduc and R. Carbonneau

PC5. ANALYSIS OF NUMEROUS AUTOIONIZING LEVELS IN CO
R. Carbonneau, E. Bolduc and P. Marmet

PC6. LINE CONTOURS OF EXCITED STATES IN IONIZATION CURVES
E. Bolduc, R. Carbonneau and P. Marmet

PC7. DISSOCIATIVE IONIZATION OF H_2, N_2, NH_3 AND CO_2 BY ELECTRON IMPACT
A. Crowe and J.W. McConkey

PC8. STATISTICAL ERROR IN MOLECULAR CROSS SECTION MEASUREMENTS
G.C. Baldwin and K.J. Miller

SESSION PD. TRANSPORT PROPERTIES

10h30-12h30 Room 174 Chairman: G.E. Veatch
GE Company

PD1. TRANSPORT COEFFICIENTS OF GASEOUS IONS IN AN ELECTRIC FIELD
J.H. Whealton and E.A. Mason

PD2. MOBILITIES OF URANIUM AND MERCURY IONS IN HELIUM
R. Johnsen and Manfred A. Biondi

PD3. LONGITUDINAL DIFFUSION COEFFICIENT AND DRIFT VELOCITY MEASUREMENTS IN H_2O AND D_2O
F.J. Davis and D.R. Nelson

PD4. LONGITUDINAL DIFFUSION COEFFICIENTS OF K^+ IONS IN Ar, N_2 AND CO GAS
E.W. McDaniel, G.M. Thomson, J.H. Schummers, D.R. James, E. Graham and I.R. Gatland

PD5. TRANSPORT PHENOMENA IN NEON DISCHARGES INVESTIGATED WITH ^{20}Na TRACERS
L.C.J. Baghuis, A.M.W. Duys, H.L. Hagedoorn, J.A. v.d.Heide

PD6. SEEDING EFFECT ON THE TRANSPORT PHENOMENA AND COLLISIONAL PROCESSES IN AN IONIZED ARGON GAS
Chih Wu

PD7. PROPERTIES OF PLASMAS SUSTAINED BY A UNIFORM SOURCE OF IONIZATION
J.J. Lowke and D.K. Davies

PD8. IONS AND HIGH-PRESSURE, SPACE-CHARGE-LIMITED ELECTRON CURRENT
J.H. Ingold

SYNCHROTRON RADIATION STUDY GROUP

FRIDAY AFTERNOON, 20 OCTOBER

AND SATURDAY, 21 OCTOBER

IN ROOM 174

ALTHOUSE COLLEGE OF EDUCATION

STARTING TIME 14h00

GASEOUS ELECTRONICS CONFERENCE EXECUTIVE COMMITTEE

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ARC SYMPOSIUM

ABSTRACTS

SESSIONS

AA, BA, CA

DA, HA, JA

17-18 October 1972

SESSION AA

Tuesday morning, 17 October

8h30

Room 174

FLOW EFFECTS IN ARCS

Chairman: B. Ahlborn
University of British Columbia
Vancouver, B.C.

AA1 Downstream Conditions in a Constricted Arc with Radial Injection.* C. J. Cremers and H. S. Hsia, Univ. of Kentucky and J. R. Mahan, VPISU. - The thermal, flow and electrical conditions are presented for the downstream portion of an argon arc with local fluid constriction. The arc is wall stabilized and allowed to become fully developed in a 10 mm dia. water-cooled constrictor. The arc is then constricted further by an inward radial jet. The redevelopment of the flow downstream of the injection slot is investigated by measurements of the pressure drop, wall heat flux and electric field. It is observed that redevelopment procedes roughly as predicted by classical theory. Measuements of the electric field indicate that the region of maximum constriction is limited in extent.

*Research supported in part by the National Science Foundation.

AA2 A Semi-Empirical Correlation for the Confined-Discharge Plasma Generator. J. R. MAHAN and WAYNE L. SMITH, Virginia Polytechnic Institute and State University -- A semi-empirical correlation has been obtained which successfully represents the behavior of confined-discharge plasma generators, both with and without local fluid constriction (LFC), over a limited but useful range of sizes, currents, and mass flow rates. The correlation, developed from both new data and data available in the literature for argon, is in the form of a dimensionless local energy conversion efficiency β which varies universally with a dimensionless axial position ξ such that the overall energy conversion efficiency η is given by

$$\eta = \frac{1}{\xi_o} \int_0^{\xi_o} \beta(\xi) d\xi \ ,$$

ξ_o being the dimensionless length of the plasma generator. The correlation should prove directly useful in the optimal design of argon plasma generators, while providing insight into the physical processes involved in their operation.

AA3 Experiments with Bluff-Body Stabilized Electrodeless Arcs*. D. R. KEEFER and J. A. SAXTON, University of Florida, Gainesville, Florida.--Experiments were performed in an electrodeless arc of four inches diameter in argon. Using an applied frequency of 3.5 MHz, mass flow rates to 0.9 gm/sec were attained at pressures from 2/3 to 1-1/3 atmospheres. A stagnation temperature of 4200°K was obtained with an imput power of 7 KW. Preliminary experiments at 377 KHz produced a stagnation temperature of 5300°K at a nominal input power of 25 KW. The experimental data have been compared with theoretical calculations and indicate that the theory can be used for scaling electrodeless arcs.

*The research reported in this paper was sponsored by Arnold Engineering Development Center, Air Force Systems Command, Arnold Air Force Station, Tennessee, under Contract No. F40600-72-C-0005. Further reproduction is authorized to satisfy the needs of the U. S. Government.

AA4 Static and dynamic characteristics of axial flow arcs in SF_6 and nitrogen gas, D.R. TOPHAM, Dept. of Engineering Science, Oxford, England.--Calculations are presented for the characteristics of SF_6 arcs in constant pressure axial flow and nozzle flow. The results are shown in a non-dimensional form which takes account of the variation of the gas flow conditions and flow geometry. Comparison is made with calculations for nitrogen gas which show good agreement with experimental results.

The calculations indicate that for the same nozzle geometry and gas supply pressure, the low current SF_6 arc has a higher central temperature and smaller diameter with a lower voltage gradient than for a nitrogen arc of the same current.

AA5 VOLTAGE GRADIENTS IN TURBULENT ARCS*--I.P. Shkarofsky, RCA Limited, Research Labs., Quebec. A plausible formulation is offered relating the changes in average voltage gradient in turbulent arcs, to the fluctuations in gas temperature, by Saha's equation. A four-fold increase with flow rate in voltage gradient as observed by Frind and Damsky[1] in an argon arc, can be accounted for by a 20 percent rms fluctuation in gas temperature. The increase also depends on the ratio of electron neutral collision frequency to the total electron collision frequency and thus tends to become smaller as the gas becomes fully ionized.

* Supported by WPAFB, Contract F33-615-72C-1729

1 ARL Reports 66-0073 (1966), 68-0067 (1968) and 70-0001 (1070)

SESSION BA

Tuesday morning, 17 October

10h45

Room 174

EQUILIBRIUM IN ARCS

Chairman: J. Uhlenbusch
Technischen Hochschule Aachen
Aachen, Germany

BA1 Conductance Time Constant Measurements on an Atmospheric Pressure Cascade Arc, R.W. Anderson and R.L. Phillips, Univ. of Mich. —Conductance time constants for the early stages of free decay after current step modulation have been calculated from experimental measurements on a 5 mm diameter cascade arc at atmospheric pressure. The time constants were found by measuring the electrical field response of the asymptotic portion of the arc column to a sudden decrease (crowbar) of arc current. The initially high current was supplied by an inductively compensated capacitor discharge circuit which produced a high current square wave pulse of ~ 2 msec duration. Time constants were measured in both argon and nitrogen for initial currents ranging from 100 to 400 amperes. The initial free decay time constants for nitrogen were found to increase weakly from approximately 25 to 35 μsec over the initial current range considered. The argon time constants decreased from approximately 100 to 60 μsec over the same initial current range.

BA2 Investigation of Nonequilibrium in Transient Arcs, R.W. Anderson and S.W. Bowen, Univ. of Mich. —Transient deviations from local thermodynamic equilibrium (LTE) have been investigated at the centerline of a decaying plasma in a cascade arc after current step modulation. The transient electron temperature and electron density have been determined from the absolute measurement of an atomic line and adjacent continuum intensity. A computer model for the nonequilibrium decay of the arc at the centerline of the cascade was also developed. A nonequilibrium parameter χ was calculated with the aid of a constant density decay assumption at the cascade centerline. Utilizing the combined experimental and theoretical results, the state of the plasma decay at the centerline of an atmospheric pressure argon arc was found to initially be one of excitation, chemical, and thermal nonequilibrium. A similar decay in an atmospheric pressure nitrogen arc was found to closely approximate LTE near the centerline for the times investigated.

BA3 Local Thermal Equilibrium in a Pulsed Arc.* A.A. CENKNER, JR., and D.M. BENENSON, State Univ. of N.Y. at Buffalo--A voltage "step" pulse was applied to a wall stabilized co-axial argon arc initially in steady-state. Experiments were conducted at pressure levels of 510, 820, and 1120 Torr with initial steady-state currents of 195, 180, and 170A, respectively; final steady-state currents were approximately 40A greater than initial values. Pulse rise time was $\sim$ 50 μs; dynamic current response time was $\sim$400 μs. Equilibrium was studied using simultaneous CRT recordings of line and continuum radiation (4158.6A and 4143A, respectively). Based upon transition probability of 1.45×10^6 s^{-1} (NBS), steady-state measurements indicated $\bar{g} \sim 1.8$ at 510 Torr and $\bar{g} \sim 1.63$ at higher pressure levels. Scans of arc radiation, using high speed rotating mirror arrangement (data acquisition time $\leq$ 5 μs), were obtained at several times following initiation of transient. Comparisons of measured and theoretical line and continuum emission coefficients indicated plasma to be in partial local thermal equilibrium to the $3P_6$ level, with $T_e = T_g$.

*Research supported by NSF Grants GK-2886 and GK-24292, and USAFOSR Grant 70-1928.

BA4 High Pressure Nonequilibrium Plasma Nozzle Flows with Axial Current.* S. W. Bowen, NASA, Ames Research Center, Moffett Field, Ca. -- The nonequilibrium neutral atom excited state densities, electron densities, electron and heavy particle kinetic temperatures are numerically computed for steady quasi-one dimension argon and nitrogen plasma nozzle flows having an imposed axial current. The analysis is similar to that given in (1), but has been modified to include the effects of axial current and an electron energy loss to the walls. Solutions are obtained for $1 < p_{stag} < 50$ atm, $10^3 < T_{stag} < 20 \times 10^3$ °K with $-10^3 < I_{axial} < 10^3$ amp. The results indicate that the very large deviations from LTE of N_e, T_e and electronic excitation at zero current increase even more as an axial current is imposed.

*Work supported in part by Dept. Aerospace Engineering Univ. of Mich and by NAS-NRC Associateship.

[1] S. W. Bowen, C. Park, AIAA Jour. 9, pp. 493-499, (1971).

BA5 LTE and Relative Transition Probabilities of Atomic Scandium.* J.C. Morris and P.L. Patterson, National Bureau of Standards.--The relative transition probabilities of some 40 scandium atomic lines ranging in upper energy from 2 to 5 eV have been measured in emission. The excitation source was a constricted mercury arc viewed along the current axis. The temperature and condition of equilibrium was studied using lines which had reached the blackbody ceiling. The precision of the A values is ± 15%. Comparing these results with those obtained using the hook method shows an energy dependant deviation of a factor of 7. Comparing the data with the coulomb approximation method shows differences of as much as 4 orders of magnitude.

*Work supported in part by GTE Sylvania Inc.

BA6 Influence of Ambipolar Diffusion on Departure from LTE in a Cesium Discharge.* B. SAYER, J. C. JEANNET and J. BERLANDE; CEA-Saclay - France. Electron losses by ambipolar diffusion as well as radiative losses are known to induce departure from LTE in an ionized gas. The influence of ambipolar diffusion has been theoretically and experimentally studied for the case of a stationnary discharge in pure cesium ($10^{-2} < P_{Cs} < 10^{-1}$ torr, $5.10^{11} < N_e < 10^{13}$ cm^{-3}, $\Lambda = 1.7$ cm). For a given electron density the electron temperature and the population of excited states are strongly affected by diffusion losses if either N_e or P_{Cs} is low. As a consequence the "excitation temperature", deduced from the ratio of line intensities, can be much lower than the electron temperature. The possible effect of inelastic atom-atom collisions considered by some authors is shown to be negligible under our experimental conditions. It is concluded that a statistical model including diffusion allows a good representation of a cesium discharge(1).

(1) To be published in J. Physique dec. 1972

* Submitted by C. MANUS

SESSION CA

Tuesday afternoon, 17 October

14h00

Room 174

BUSINESS MEETING ARCS GROUP

Chairman: J.C. Morris
National Bureau of Standards
Washington, D.C.

SESSION CA

Tuesday afternoon, 17 October

14h30

Room 174

TIME VARYING ARCS

Chairman: M.G. Drouet
Hydro-Quebec, Institut de Recherche
Varennes, Quebec

CA1 The dynamic characteristics of the arc in a D.C. interrupter. J.P. NOVAK, V. FUCHS, Hydro-Québec Institute of Research, Varennes, Québec.-- The dynamic behaviour of a D.C. arc in a metal plate quenching chamber is discussed. The arc is moving in an external magnetic field and is operating beyond stable conditions. The equations governing the dynamic behaviour of the arc, that is equations describing the time development of current and voltage drop are derived from the external circuit equation and the heat transfer equation of the arc plasma. Measurements of the current-voltage characteristics of the arcs have been performed for currents between 1 and 7kA. The arc length has been varied from 3.2 to 17.4 mm, giving information on the value of the electric field. Typically we found about 17V/cm in the positive column of the arc. A good agreement was found between theory and experiment. It was also shown that the "switching-off" time depends critically on the time constant of the external circuit and the number of plates in the chamber.

CA2 Characteristics of Time Varying Cerium Electrode Stabilized Arc

Stephen Levy & John E. Creedon, AMSEL-TL-BG

Steady state and time varying characteristics of short arc discharges in cerium are described. Cerium, which has the potential for producing the highest efficacy as an additive to mercury discharges, has been found to be difficult to operate in the wall-stabilized configuration. However, using a short arc configuration, both the dc and pulse radiation profiles were found to be stable. Time resolved[1] radial profiles were measured at peak powers up to 20 kilowatts and average powers up to 300 watts. Spectral scans from 0.4 to 0.9 microns and side-on intensities were measured and unfolded to obtain volume emission coefficients. Radiating efficiency, volume emission coefficients, and electrical characteristics are compared with that of xenon short arcs.

[1] S. Levy, Bulletin American Physical Society, Series II, 17, 386 (1972)

CA3 Temperature Measurements in Alternating Current Arcs.* M.R. GILLETTE and D.M. BENENSON, State Univ. of N.Y. at Buffalo--Using a high speed rotating mirror arrangement for rapid acquisition of data, the "instantaneous" radial distribution of temperature was obtained from side-on scans of the continuum radiation (4468A) of an atmospheric argon wall stabilized a-c arc in a 1 cm diameter channel. The drive signal for the synchronous motor was derived by frequency multiplication, amplified, and phase shifted electronically so that the arc could be scanned at any point within the 60 Hz time cycle. Near current zero the temperature computations were based upon the recording of multiple scans and the average value of the resulting waveform. Operating conditions were: current $\approx$ 150A rms, length $\approx$ 10 cm, $\dot{m} \approx 0.1$ g/s. Arc centerline temperatures ranged from about 11,500K at current maximum to about 8,600K at current zero. Minimum centerline temperature (about 8,200K) occurred about 0.22 ms following current zero; such phase differences are in agreement with theories.
*Research supported by National Science Foundation Grant GK-24292.

CA4 Fluctuations in Drawn Arcs at Atmospheric Pressure, Eoin W. Gray, Bell Laboratories, Columbus, Ohio, 43213. The Boddy and Utsumi[1] proposal of two phase system in break arcs has been observed spectroscopically. A metallic vapor phase followed by a second, or gaseous phase where ions from the surrounding gas play a larger part in the arc mechanism was observed. Large amplitude fluctuations in the metallic vapor phase have been detected and were accompanied by increase in the emitted intensity of light coming from PdI, N_2^+ and N_2^*. The intensity from PdII light levelled off indicating that in these fluctuations the arc maintained itself by ionizing the surrounding ambient.

[1]Boddy P. J. and Utsumi T., App. Phys. 42 3369(1971)

SESSION DA

Tuesday afternoon, 17 October

15h45

Room 174

MAGNETIC EFFECTS IN ARCS

Chairman: D.M. Benenson
State University of New York, Buffalo
Buffalo, N.Y.

DA1 A Low Frequency Electromagnetic Instability in an Intensely Irradiated Plasma. W.B. Thompson, Univ. of B.C., Vancouver.--A low frequency transverse instability, the A.C. version of the pinch effect, is described. It occurs in overdense plasmas, near the critical layer, $\omega = \omega_p$, provided the energy density in the radiation field $E^2/8\pi$ is comparable to n kT the thermal energy in the plasma, and may lead to shredding of a radiatively compressed surface.

DA2 Wave Propagation and Absorption in a Magnetically Confined Arc Plasma. C.E.NIELSEN, Ohio State Univ.-- A He arc is operated in a field of 3 kG with a pulsed current of 3500 A peak. Pulse duration is 6 msec, and repetition rate is 10/sec. The incandescent tungsten cathode consists of a central 6 mm rod surrounded by a cylindrical shell 12 mm id and 19 mm od. Oscillating pd between rod and shell produces waves which are observed by single turn loops outside the arc column. Loop signal is maximum for loop normal nearly parallel to arc axis, and null with loop normal $\sim 80^\circ$ from arc axis. Wave amplitude varies linearly with driving current up to the $\sim$1000 A max. used. Speed is $\sim 3 \times 10^7$ cm/sec, and amplitude attenuation $\sim$10x in 10 cm, for 1 - 4 MHz and 2 - 10 torr He. Attenuation varies measurably with pressure, is nearly independent of frequency. No resonance is observed at gyrofrequency. Heating from wave absorption is indicated by increase in 4686 Å He^+ light.

DA3 Kinetics of Magnetically Induced Arc Motion From 1 to 760 Torr.* R. P. CARTER, and D. L. MURPHREE, Mississippi State Univ.--Experimental results are presented on the magnetically induced kinematics of an arc-discharge between concentric-cylindrical electrodes over a wide range of pressure (1 to 760 Torr), arc current (50 to 1000 A) and magnetic field strength (500 to 10,000 G). Electrode spacing was constant at 1.65 cm. The experimentally determined relationships between arc mode of motion (Lorentz or Retrograde) and arc current, voltage, power, pressure and magnetic field strength are graphically presented. Retrograde motion of the arc-discharge at pressures approaching 1.0 atmosphere was observed. Correlation between the arc motion and magnetically induced mass displacement is discussed. High-speed movies showing the effect of the applied magnetic field on the arc shape and kinetics for the extremities of the experimentally obtainable parameters are presented.

*Supported by the National Science Foundation.

DA4 Direct Display of the Current Density Profile of a Magnetic Field Driven Arc. *† M.G. DROUET, IREQ and R. BEAUDET, CREN, Varennes, Canada.--A new method has been developed for the direct display of the profile of the current density of a moving high-current arc. The arc is driven along two rail electrodes by a magnetic field. The electrodes are segmented, and the current density measuring technique is based on the measurement of the voltage developed by the moving arc profile across adjacent parts of the segmented electrodes. Theoretical considerations, experimental results and an analysis of the validity of the technique will be presented. Current profiles have been obtained for arcs between 200 and 1000 amperes driven at velocities between 35 and 700 $m\text{-}sec^{-1}$ at different pressures up to atmospheric in air, N_2, H, He, Ar, CH_4 and SF_6. The profiles are generally characterized by a sharp front followed by an exponential-like decay extending up to several cm in length.

* Submitted by A.G. ENGELHARDT

† Supported in part by a NRC Grant (A-6374).

DA5 The Interaction with Axial Magnetic Fields of Cu, Cr, Ag and C Vacuum Arcs, C. W. KIMBLIN, Westinghouse Research Labs.--Axial magnetic fields to 1 kG have been applied to d.c. vacuum arcs to 5 kA, and the field interaction has been determined by arc photographs, arc voltage observations, and probe studies of both the radial potential distribution and the radial ion currents. In the presence of magnetic fields, arcs between Cu, Cr, Ag and C electrodes are all similar in appearance to Luce[1] arcs. The magnetic field collimates the electrons emitted from each individual cathode spot with the result that the arc current is conducted via multiple luminous columns. Increasing the magnetic field causes 1) rises in the potential of isolated probes immersed in the plasma, 2) reductions in the ion current to the metal walls surrounding the arc, 3) reduction in the anode voltage drop and 4) an increase in the threshold current for anode spot formation. These phenomena are attributed to the creation of radial electric fields which confine to the interelectrode region the energetic ions generated at the cathode spots.

1. J. S. Luce, Proc. 2nd U.N. Intnl. Conf. on the Peaceful Uses of Atomic Energy 31, 305 (1958).

DA6 Magnetically Induced Instability in an Argon Discharge. R.H.S. HARDY, University of Saskatchewan, Regina, Canada.

Observations of a highly structured discharge and current instability in partially-ionized, shock-heated argon ($T \simeq 10^4$ °K, $Ne \simeq 10^{16}$) in the presence of a large transverse magnetic field ($B \simeq$ 10 - 15 kG) are presented and analyzed. Image converter camera photographs show the formation of a series of highly constricted current filaments, which appear at a critical (onset) value of magnetic field or Hall parameter ($\omega \tau \simeq 3$). The photographs also show an increase in turbulence of the discharge as the magnetic field is increased above the critical value. This turbulence is correlated with an increase in electric field fluctuations in the plasma. The experimental results are in agreement with a theory of ionization instability, due to the strong coupling between fluctuations in Joule heating and density fluctuations, in which the growth rate is dependent on the magnitude of the Hall parameter.

SESSION HA

Wednesday afternoon, 18 October

14h00

Room 174

ELECTRODE EFFECTS

Chairman: R. Dethlefsen
ITE Power Equipment
Greensburg, Pennsylvania

HA1 Unified Analysis Of Voltage Drop, Current Densities And Electron Temperature In The Cathode Spot. ECKER, G. H., Ruhr-Universität Bochum, Germany - In the discussion of previous investigations of the cathode spot phenomena [1] the use of a constant value U_c for the cathode drop taken from experimental knowledge and the neglect of multiply ionized ions in the analysis of the plasma ball was criticized. We present here a unified theory which comprises the calculation of the cathode drop U_c simultaneously with the rest of the whole system and which accounts for multiple ionization. The calculation produces consistent results for U_c, the electron temperature T_e and the electron- and ion current densities which are compared with the earlier findings and assumptions. The physical inside in the mechanism of the spot is much improved.

1) Ecker, G. General Electric TIS Report 70-C-21: and 71-C-195 (1971) Schenectady, New York

HA2
Controlled Transpiration Cooling of the Anode in a High Intensity Arc.* C.V. Boffa and E. Pfender, Dept. of Mech. Eng., Univ. of Minn.--In connection with the generation of ultrafine, monodisperse aerosols, an arc plasma torch with controlled transpiration cooling of the anode has been developed. The plenum chamber surrounding the porous anode is subdivided into 4 independent compartments which allow for individual control of the transpiring mass flow rate. In this way, the inherent instabilities of transpiration cooling are eliminated.--The size and temperature distribution of the anode attachment determines the performance of this device as particle generator. A method is described which allows determination of the inside temperature distribution of all four segments. Measured aerosol size distributions show that the mean diameter of the particles can be controlled in the range from 45 Å to approximately 1μ with a logarithmic standard deviation mainly in the range from 1.1 to 1.2.

* This work was supported by the Dept. of HEW, PHS under Grant 5 R01 AP01161-01 and -02.

HA3
Investigation of the Boundary Layer in Front of a Transpiration-Cooled Anode.* J.V. Heberlein and E. Pfender, Dept. of Mech. Eng., Univ. of Minn.--For studies of anode phenomena in high intensity arcs, the region in front of a transpiration-cooled anode is of particular interest. The boundary layer equations are solved numerically for this region adopting a one-dimensional model. The elevated electron temperature in the boundary layer is accounted for by introducing additional terms in the conservation equations of the single fluid model. The range of parameters for which physically meaningful results are feasible is presented for atmospheric pressure argon arcs assuming a current density of 100 A/cm^2 and arc temperatures of 13,000 °K and 14,000 °K.

* This work was supported by NSF under Grant GK-15924.

HA4 Erosion and Ionization at Cathode Spots of Carbon Vacuum Arcs, C. W. KIMBLIN, Westinghouse Research Labs.--Ion currents of ~ 8% of the arc current (100A) can be collected[1] at the metal walls surrounding the cathode spots of copper vapor arcs. The possibility that this effect is limited to non-refractory electrodes has been investigated by establishing 100A arcs between 2.5 cm diam. carbon electrodes. As with copper, the ion current first increases linearly with electrode spacing indicating approximately isotropic propagation of ions and vapor from the cathode region. The ion current reaches a maximum of 10A at a spacing of 1.7 cm. The erosion rate is 0.17 x 10^{-4}g/C independent of electrode spacing. This corresponds to the loss of 1 carbon atom/7.35 electrons and, compared to the ion current, shows that > 70% of the evaporated carbon migrates from the cathode regions in ionized form. Additional observations with silver and chromium cathodes reveal erosion rates of 1.5 and 0.4 x 10^{-4}g/C, maximum ion currents of 8A at 100A, and fractional ionizations of > 60%. It is concluded that the cathode regions of both refractory and non-refractory electrodes have associated with them high ion currents and high fractional ionizations.

1. C.W. Kimblin, Proc. IEEE, 59, 546 (1971).

SESSION JA

Wednesday afternoon, 18 October

15h45

Room 174

ARC TRANSPORT PROPERTIES

Chairman: U. Bauder
Georgia Institute of Technology
Atlanta, Georgia

JA1 Temperature Versus Rate of Cooling For Cold-Wall Confined Plasma Jets, M.P. Freeman, American Cyanamid Co., Stamford, Conn.--The rate of temperature change is computed vs temperature for a nitrogen plasma jet flowing in a smooth cold-walled tube. The (partially reduced) results indicate trends in quenching regimes with changes in size and operating parameters.

To obtain the temperature field, the mass flux is taken to be constant over the cross section and material properties are taken from arc measurements. An exact second order partial differential equation in the heat flow potential may be written for which an approximate reduced analytic solution of wide applicability (exact in the limit of small increments) is seen to arise through serial application of the appropriate Green's function. The initial slope and logarithmic decrement of the total heat flowing in the confined jet is used to establish initial jet center temperature and to adjust the material property, cp/k vs S, function by expanding the S scale to account in some way for the change in effective K due to turbulence. For convenience, the homogeneous hot-core model is assumed at the entrance.

JA2 RF Argon Plasmas Up to 40 atm Seeded With W and UF_6*. WARD C. ROMAN, United Aircraft Research Labs. -- An experimental investigation is discussed in which an rf plasma discharge was seeded with submicron tungsten particles and dilute concentrations of UF_6. RF energy was supplied by a 1.2-MW induction heater operating at 5.4 MHz to an argon discharge contained within a radial-inflow vortex. The test chamber was formed by a water-cooled, fused silica tube (5.7-cm i.d.) and copper end walls spaced 15.5 cm apart. Recent tests were conducted at pressures to 40 atm and up to 180 kW of power deposited into the discharge (flux levels up to 1.4 kW/cm^2). Diagnostics included measurements of (1) plasma size and shape, (2) total radiation, (3) spectral emission in various wavelength bands, and (4) calorimetric power losses with and without seeds present. The results show the various seed materials can be injected steady-state (through on-axis probes located in the end walls) into the plasma at pressures up to 40 atm while maintaining the surrounding peripheral wall relatively free of condensed materials.

*Work supported by Joint AEC-NASA SNSO; Contract SNPC-70.

JA3 Temperature and Emission Measurements on Mercury-Tin Iodide Arcs.* J.J. de Groot and A.G. Jack, Light Division, N.V. Philips, Eindhoven, Netherlands. - Diagnostic work on a mercury - tin iodide arc has enabled the effect of adding tin iodide to a high pressure mercury arc to be demonstrated. As the tin iodide pressure increases to a few hundred Torr the axis temperature decreases from 6000 K to about 5200 K. The temperature profile also changes because the plasma thermal conductivity is enhanced in a given temperature range due to dissociation and recombination of molecules. About 20% of the input power is radiated as continuum in the visible. Emission profile measurements have been made of this continuum and the results are explained with the help of thermodynamic calculations. In the cooler outer mantle the continuum is due to electronic transitions to the ground state in the tin monoiodide molecule. Close to the axis the continuum is due to this molecular radiation and also recombination processes.

(* Submitted by R. Bleekrode.)

JA4 The Electron-Neutral Transport Cross Section of Mercury. J. C. MORRIS and J. H. WALKER, National Bureau of Standards. - The electron-neutral transport cross section and the electrical conductivity of Hg have been determined using a constricted DC Hg arc. This arc has a novel configuration which permits the precise measurement of the pressure, the voltage gradient, the temperature profile, and the total current. For the temperature range 4000 - 7000 °K the electron-neutral transport cross section was found to be 1.17 E - 14 cm^2 with a precision of ± 5% and an absolute accuracy of ± 25%. A description of the apparatus and technique is presented as well as a comparison with other existing data.

JA5 f- Values of some ArII Lines in the VUV:* S.K. Srivastava and G.L. Weissler, Dept.of Phys. U.of So. Calif.,Los Angeles.-- Oscillator strengths of nine Argon II lines in the VUV have been measured using a wall stabalized arc operating in a helium-argon mixture. These lines, 740Å, 730Å, 725Å, 723Å, 718Å, 679Å, 666Å 664Å, and 661Å, are seen superimposed over the argon resonance continuum. The method employs a comparison of the intensity of ArII lines with the intensity of underlying argon continuum whose photoionization cross sections are accurately known[1]. The f-values, so obtained, are 0.013,0.033,0.059,0.024,0.028,0.024,0.016, 0.024 and 0.044 respectively. From various runs, the experimental spread was found to be within ±15%. However, the estimated plus experimental error is within ±30%. These f-values have been compared with the theoretical values of Statz, H.[2], et al. and a large disagreement is found. The discrepancies will be discussed.

*Partially supported by ONR,Contract #53-4869-1564.

1.J.A.R.Samson in "Advances in Atomic & Molecular Physics", Vol.2,pp 177-261; Academic Press Inc., New York: 1966.

2.Statz, H., Horrigan,F.A., Koozekenani,S.H., Tang,C.L., and Koster,G.F., J.App.Physics 36, 2278-2286 (1965);and Koster, G.F.,Statz, H. and Tang,GL.,J.App.Phys.39,4045-4046(1968)

JA6 Absolute Intensity Measurement on a Uranium Arc in the Vacuum-Ultraviolet Region. J.M. Mack, Jr., H.D. Campbell, R.T. Schneider, Univ. of Florida.--It is essential for design considerations concerning the plasma core reactor that the radiative properties of a uranium plasma be determined. Of particular interest is the power radiated by a uranium plasma in the vacuum-ultraviolet, and its significance when compared to the radiation in the remainder of the spectrum. The intensity of a D.C. uranium arc plasma was measured from 1050 Å to 4300Å. The measured intensities were assigned absolute units by comparison with a Deuterium ultraviolet source. For vacuum-ultraviolet measurements LiF windows were used and the spectrograph was evacuated to 10^{-5} atmosphere. The arc was operated in a three atmosphere Helium cover-gas having a typical power input of 1000 watts. The primary plasma constituent was singly-ionized uranium with a partial pressure on the order of .1 atmosphere as determined by absolute-line measurements. Temperature was determined by spectrographic techniques and ranged from 8000°K to 12000°K.

LASER SYMPOSIUM

ABSTRACTS

SESSIONS

EB, HB, JB

KB, LB, MB

NB

17-19 October 1972

SESSION EB

Tuesday evening, 17 October

20h30

Room 229

CO LASERS

Chairman: M. Bhaumik
Northrop Research and Technology Laboratory
Hawthorne, California

EB1 High Pressure Electrical CO Lasers. R. E. CENTER and G. E. CALEDONIA, Avco Everett Research Laboratory. --The electron beam sustained discharge excitation technique has been applied to a 20 liter cryogenically cooled CO laser designed for pulsed operation at pressures up to 1 atmosphere. Multimode, multiline operation of this laser has been demonstrated in CO and N_2/CO mixtures with excitation pulse lengths of up to 80μ secs. Preliminary measurements of the output pulse shape at 1/5 atm pressure and 100°K temperature have been obtained and will be compared with a theoretical model of this system. The kinetic model incorporates the direct excitation of the low vibrational levels of CO with the subsequent transfer of vibrational energy to high vibrational levels. This transfer of energy occurs under conditions of thermal nonequilibrium and is due to the anharmonicity of the CO molecule. A numerical program has been developed for the transient analysis of pulsed oscillator experiments and permits calculations of the temporal variation in gas temperature, vibrational distribution, small signal gain prior to oscillation, efficiency, cavity flow and power output on each lasing transition.

EB2 Transient Oscillator Analysis for a CO Laser*, W.B.LACINA,Northrop Corp.,Northrop Res.& Tech.Center,Laser Tech.Labs.,Hawthorne, Calif.--A molecular kinetic model for an electrically excited(CO,N_2,He,Ar,...)gas mixture has been constructed for the calculation of the radiative characteristics of a CO laser oscillator or amplifier. A computer program for the numerical solution of the steady-state or transient master equation for the diatomic species has been developed to predict vibrational population distributions, gain and saturation parameters, energy transfer and extraction rates, conversion efficiencies, output intensities, and spectral distributions. Radiation calculations are self-consistent with the saturated gains on all oscillating, transitions equal to the losses. The plasma characteristics, described by a Boltzmann distribution, can be adjusted self-consistently as a function of time to account for electron heating for a given temporal input power. Numerical results for a variety of operating conditions will be presented and compared with experimental data, and the importance of VV kinetic processes will be discussed.*This research was supported in part by the ARPA of the Dept of Def. and was monitored by the Office of Naval Res.under contract N00014-72-C-0043.

EB3 Vibrational Relaxation in CO Lasers, M.L. Bhaumik, W.B. Lacina and M.M. Mann, Northrop Corp.--The rates of energy exchange between the large number of vibrational levels involved in CO lasers have been derived by kinetic modeling using both steady state and transient measurements. The steady state experiments involve small signal gain measurements at four different CO concentrations for the transitions $v = 5 \rightarrow v = 4 = 24 \rightarrow v = 23$. In the transient measurements, the time variation of the small signal gain of a particular vibrational-rotational transition was monitored following saturation of a transition between another pair of levels. The results of these experiments will be presented and the limitations of the existing theories of vibrational energy exchange in CO will be described.

*This research was supported in part by the ARPA of the Department of Defense and was monitored by the Office of Naval Research under Contract N00014-72-C-0043.

EB4
Vibrational Kinetic Rates for Carbon Monoxide at 77° K --- L.A. Schlie and A.R. Filipelli, AFWL, Kirtland AFB, N.M., 87117----- The vibrational kinetic rate constants σv, for carbon monoxide in the lower vibrational states have been measured at 77°K by a standard gain-absorption technique. The kinetic rates were determined by carefully measuring the time eveolution and decay of the CO vibrational distribution in a low pressure He-CO pulsed discharge. The vibrational distribution was monitored by a well stabilized CO probe laser employing a reflection grating. The resulting gain and/or absorption curves vs. time are used to compute the corresponding vibrational densities, $N_v(t)$. For small electrical input energies and long times after the cessation of the pulse, the relaxation of the vibrationally excited states occur by collisions with the ground state CO molecules (v=0) in collisions of the type

$$CO(v=j) + CO(v=0) \quad CO(v=j-1) + CO(v=1)$$

For larger input energies and shorter times, reaction rates for higher vibrational states are determined. The rate constants for the above processes are compared to recent experimental results and existing theories.

EB5 An Efficient Threshold for CO Laser Operation, S.D.Rockwood and R.O.Hunter,AFWL/DYT Kirtland,AFB,NM 87117.-- The dynamics of pulsed electrically excited CO lasers has been analysed in detail through a numerical solution of the coupled rate equations governing the time evolution of vibrational level population and intracavity flux. The calculations employ electron excitation rates obtained from solutions for the electron distribution function and the most current date available for V-V and V-T energy transfer rates. The results of these calculations demonstrate a marked increase in the ratio of optical energy output to electrical energy input as the input, E_{in}, is increased beyond 800 joule/liter/atm. At a translational temperature, $T = 300^{\circ}K$ efficiencies $\varepsilon > 50\%$ are observed for $E_{in} > 10^3$ joule/liter/atm. As the gas temperature is lowered $\varepsilon(E_{in})$ shifts in a self-similar fashion to lower values of E_{in} with $\varepsilon \geq 50\%$ attainable for $E_{in} \geq$ 800 joule/liter/atm at $T = 200^{\circ}K$. The theoretical calculations for room temperature operation are supported by experimental results from a cold-cathode electron beam sustained CO laser. This device yields a nominal 1 μsec primary pulse producing electron densities $n_e \approx 7 \times 10^{13}$ cm^{-3} in a .1 liter volume containing 1 atm. of pure CO and has been successfully operated with a sustainer $E/N = 6 \times 10^{-16}$ volt-cm^2 without arcing.

EB6 Kinetic Model of CO Electric Discharge Gas Lasers. L. S. BENDER, R. J. HALL,B. R. BRONFIN, United Aircraft Research Laboratories, E. Hartford, Ct. - A multi-level rate equation model for electrically-pumped CO gas lasers is presented. The analysis includes the mechanisms of V-V and V-T energy transfer, spontaneous and stimulated emission, and electron pumping in CO-N_2-He mixtures. Electron excitation rates are evaluated using Nighan's theory for the electron distribution function and Phelp's values for the excitation cross-sections[1]. A Fabry-Perot lasing cavity is analyzed assuming geometrical optics for both pulsed and CW operation. Quantitites such as the CO-N_2 mixture ratio, electron impact cross-sections and electron distribution function, and V-V exchange rates have been varied to evaluate their effect on predicted small-signal gain coefficients, vibrational state distributions and laser power output. Comparisons with available experimental data are presented.

[1]W. Nighan, Physical Review A,2, 1989 (1970).

EB7 CW Laser Action from CO Pumped by Electric Discharge in Supersonic Flow. J. A. SHIRLEY, L. R. BOEDEKER, B. R. BRONFIN, United Aircraft Research Laboratories, E. Hartford, Ct. - Low-power CW laser emission has been observed on vibrational-rotational transitions of carbon monoxide in the 4.7μ band excited by a continuous 7 MHz rf discharge stabilized directly within a supersonic Mach 2.5 flow, in contrast to previous studies[1,2]. The gas mixtures, typically 5-mol-% CO/95 mol-% Ar, were expanded from a 120 torr plenum at ambient temperature, to a 4 torr downstream cavity, thereby providing the desired low-temperature medium through aerodynamic cooling. The optical cavity axis was oriented perpendicular to the flow direction approximately 3-cm downstream from the exit of a simple two-dimensional wedge nozzle. The electric field was maintained parallel to the flow axis in this region. The supersonic flow channel cross-section was 0.64 cm high and 8.25 cm wide. Spectral data will be presented.

[1]J. W. Rich, et al., Appl. Phys. Lett. 19, 230 (1971).
[2]T. Kan, et al., Appl. Phys. Lett. 20, 137 (1972).

EB8 Cryogenically Cooled Carbon Monoxide TEA Laser Dynamics. T. Kan and L. Champagne, Naval Research Laboratory -- The pulsed laser emission behavior of high pressure CO additive gas mixtures has been studied at 77°K. These measurements were performed in a 1.5 meter long helical TEA laser structure enclosed within a vacuum envelope whose outer surface is cooled to 77°K. Time resolved pulse shape and spectral comparison of room temperature versus 77°K operation showed order of magnitude enhancement of total pulse energy and pronounced pulse stretching with cooling. Pulse trains with widths in excess of 300 microseconds have been recorded for CO-He and CO-Ar mixtures. These results reflect the temperature dependent rates for the vibrational energy exchange and relaxation process. As expected, spatial emission shifts towards the lower vibrational bands and emission below 5 μ has been observed.

SESSION HB

Wednesday afternoon, 18 October

14h00

Room 229

LASERS GENERAL I

Chairman: P.K. John
University of Western Ontario
London, Ontario

HB1 Time Dependent Copper Vapor Laser Calculations. C.P. HOLMES, Air Force Weapons Lab.--A non-equilibrium model for predicting the transient behavior of a pulsed Cu vapor laser has been developed. The model employs the the Boltzmann equation for finding the energy dependent distribution function for electrons in a DC field. The normal energy transfer mechanisms (excitation, ionization, etc.) are included except for electron-electron and electron-ion collisions. The model simultaneously moniters the excited atomic state and ion densities along with the induced photon flux. Results of numerical calculations show that the Maxwellian electron distribution used in the calculations by Leonard[1] is a poor approximation to the solution of the Boltzmann equation. The time behavior of the present model agree to within 10% of the experimental results of Walter et al[2] which is compared to the agreement within factors of three reported by Leonard.

[1]D.A. Leonard, IEEE J. of Quant. Electronics, QE-3, 380 (1966).

[2]W.T. Walter, N. Solimene, M. Piltch, and G. Gould, IEEE J. of Quant. Electronics, QE-2, 474 (1966).

HB2 The CSe_2/O_2 Carbon Monoxide Chemical Laser. CURT WITTIG and IAN W. M. SMITH, U. of Cambridge — The reaction of atomic oxygen with carbon monoselenide:

$$O + CSe \longrightarrow CO + Se + 118 \text{ kcal/mole}$$

produces vibrationally excited CO ($CO^\dagger$) in levels up to v=20. Preliminary results from a CO chemical laser based on this reaction are given. $CSe_2/O_2/He$ mixtures are subjected to a pulsed electric discharge of $\leq 1\mu$sec duration which partially dissociates the mixtures. The chemical reaction that follows the discharge results in the production of $CO^\dagger$ and stimulated emission is observed on P-branch transitions in bands as high as (18,17). Spontaneous emission measurements confirm that the $CO^\dagger$ is produced by chemical reaction following the discharge. A comparison is made to the analogous CS_2/O_2 chemical laser.

HB3 Transverse-Excitation Pulsed HCN Laser,* D. L. JASSBY and M. F. LAM, Univ. of Calif., Los Angeles -- We report the first operation of a pulsed HCN laser excited by transverse discharges. The electrodes consist of 28 pairs of flat aluminum plates, 7.6 cm diam., with a total discharge length of 2.6 m. About 40 discharge spots develop on each resistively loaded cathode, suggesting that brush cathodes would be preferable. Lasing at 337 microns occurs at all pressures between 0.4 and 2.6 torr with a CH_4:N_2 proportion of 1.5:1. The laser output pulse is 5-10 μsec wide when using a 5-μsec current pulse at 14kV, 4 kA. The length of the lasing medium is varied by removing electrode pairs from the circuit. The threshold length of 0.98 m corresponds to a gain of 11%/m. At 0.7 torr the laser energy increases as $(L-0.98m)^2$ where L is the discharge length. This result gives information concerning the relative importance of Doppler and pressure broadening of the 337 μm line.

*Work supported by National Science Foundation GK32628.

HB4 Infrared Laser Possibilities in Normally Nonlasing Gases, W. H. Christiansen, Univ. of Washington.--Possessing no permanent dipole moment, homonuclear molecules such as N_2 & Cl_2 do not have allowed infrared transitions and therefore are not used as lasing molecules. Rather these molecules which store vibrational energy are used in conjunction with infrared active molecules to form a laser system (e.g. N_2-CO_2). While this matching has been highly successful, it limits the available wavelength to those of the radiating molecule. Because of the rapid development of controlled very high pressure electric (external ionization) discharges, it may be possible to induce a dipole moment in these molecules and hence lase them directly. In this paper, the use of strong external electric fields and collisional effects for inducing dipole moments in homonuclear molecules under inversion conditions is considered. The limitations involved and calculation of the possible gains for H_2 & N_2 will be presented. Induced dipole laser characteristics will be discussed and the possibilities of laser action evaluated.

HB5 Stationary Population Inversions of Atomic Levels in a Decaying Hydrogen Plasma Flow. P.HOFFMANN and W.L.BOHN, DFVLR-Institut für Plasmadynamik,Stuttgart,Germany.--
Population inversions of excited atomic levels are predicted theoretically in the quasi-steady state approximation as a function of the fundamental plasma parameters. The mechanism of inversion is analysed in terms of the basic collisional-radiative processes. The major role played by cascading de-excitation is pointed out. The theory has been verified experimentally in a rapid expanding plasma where population inversions have been found for transitions with principal quantum number 4→3, 5→3,6→3,7→3,5→4 and 6→4. Locally resolved measurements of emission lines, electron density and temperature are reported.

HB6 Vibrational Quenching Rates for HF(v=1) in $C_nH_{n+2}(n \leq 4)$,C_3H_6, and ClF_3 Mixtures. J. K. HANCOCK, and W. H. GREEN, Naval Res. Lab.--Standard gas mixtures for HF TEA chemical lasers normally include H_2, or a simple hydrocarbon as a hydrogen source for the fluorine atom abstraction reaction. Such molecules can be expected to have a strong influence on laser performance as the reactant molecules are normally present in greater concentrations than chemically produced HF or any of the short lived atomic or fragmentary species. We report here room temperature collisional quenching rates for HF(v=1) in the presence of a series of hydrogen containing molecules using the laser excited vibrational fluorescence method. The following deactivation cross sections have been measured: H_2(0.040Å^2), CH_4(0.17Å^2), C_2H_6(0.48Å^2), C_3H_8(0.61Å^2), C_4H_{10}(0.82Å^2), and C_3H_6 (1.5Å^2). With the exception of H_2, and CH_4 all of the above are larger than the HF self quenching cross section (0.34Å^2). Reactant molecules containing fluorine, i.e. SF_6, CF_4 have little effect on vibrational distributions due to their small deactivation cross sections. We report one notable exception, ClF_3, with a measured cross section for HF(v=1) deactivation of 0.61Å^2.

SESSION JB

Wednesday afternoon, 18 October

15h40

Room 229

LASERS GENERAL II

Chairman: J.W. Sargent
Gen-Tec, Ltd.
Quebec, Quebec

JB1 Interferometric Measurements for Plasma Path Changes in a Water Vapor Laser, W.J. Schade, Jr., Naval Electronics Laboratory Center.--Laser resonator interferometry was used to measure the change in the resonant wavelength at 78.4μm which resulted from changing the electric current in a water-vapor discharge. The scanning far infrared laser was calibrated with a Michelson interferometer and a He-Ne laser at 633 nm. A reduction of 0.15A in the discharge current caused the optical length of the laser to increase 4.7×10^{-5} cm. The resonant wavelength increased 2.5×10^{-5}μm corresponding to an average change of 3.2×10^{-7} in the refractive index of the laser plasma.

*Submitted by H.H. Caspers

JB2 Afterglow Inversion Mechanisms in the TEA He-Ne Laser.* R. Arrathoon, Princeton Univ. The characteristics of afterglow relaxation in a TEA He-Ne plasma have been examined. Time decay measurements of spontaneous emission intensities indicate that excitation transfer to the He 2^3s metastable level is dominated by recombination processes. Analytic approximations have been formed to describe the behavior of this state. At high helium to neon rations, the theory predicts a rapid build-up of the metastable state population accompanied by relatively slow transfer to the neon 2s levels. Inversion of the Ne 2s-2p populations is expected to occur over times comparable to the metastable level lifetime. These predictions are verified experimentally. At very high electron densities, the model indicates that the He 2^3S population approaches a limiting value determined by superelastic deexcitation. In this region, analogies to the well-known saturation properties of the low pressure He-Ne laser are presented.

*Work supported by USAEC Contract AT(11-1)-3073.

JB3 Spectroscopic Investigations of Metal Carbonyl Discharges, Allen K. MacKnight and George W. Rhodes, Air Force Weapons Laboratory, Kirtland AFB, NM.--In an attempt to produce a room temperature metal vapor laser, the equilibrium vapors of various metal carbonyls have been subjected to a transverse electrical discharge in an optical cavity. The compounds and pressures attainable are $Fe(CO)_5$ (1 to 20 torr), $Cr(CO)_6$ (.1 to 1 torr) and $Ni(CO)_4$ (1 to 650 torr). The UV and visible emissions yield the spectra of the metal in the unionized state and carbon monoxide with fewer than 1% of the lines attributable to the parent carbonyl compound. Applications to laser systems will be discussed.

JB4 Pressure and Current Dependence of Output Power for the Pulsed XeIV Ion Laser. W. W. SIMMONS* and R. S. WITTE, TRW Systems. --Output power dependence of the pulsed XeIV ion laser upon filling pressure and axial tube current is accounted for in the terms of a quasi-static model of the multiply ionized wall-confined plasma. The model employed is an empirical extension of the Langmuir-Tonks theory of the positive column to multiply charged ions, and uses literature derived electron-xenon ionization cross-sections to obtain fractional ionic species densities as a function of electron temperature. A comparison of the predictions of this model with experimental data[1] indicates that population inversion on observed oscillating lines arises predominately through electron impact with an ionic state of lower charge. In addition, collisional de-excitation appears to be more important than radiation trapping in quenching laser action at high currents. The influence of the "pinched" plasma column upon laser output is considered qualitatively.

1] H. S. Ames, Master Thesis, UCLA, 1971

* Present address: Lawrence Livermore Laboratory

JB5 Output Power Characteristics of the Pulsed XeIV Ion Laser. H.S. Ames* and W.W. Simmons+, Electrical Sciences and Engineering Dept., UCLA.--Output power characteristics of a pulsed xenon ion laser are presented as a function of peak axial tube current (.5-2.5 kamps), xenon fill pressure (1.5-15mtorr), and external axial magnetic field (1200 oersted). Detailed measurements were made on the 5353 Å and 4954 Å spectral lines, using a 6 mm I.D., 1 m length discharge tube, and 0.25 μf capacitor charged to 5-10kV. Nominal laser pulse duration was 0.5 μs. It was found: that optimum pressure increased with increasing peak current; that output power levels, but does not fall to zero ("quench"), with increasing current; and that at fixed current the magnetic field increases output power for pressures less than optimum, and vice versa. Similar results were obtained for the other high power blue-green lines; 5008 Å, 5260 Å, and 5395Å.

*Present address: Bell Telephone Labs, Naperville, Illinois.
+Present address: Lawrence Livermore Lab.

JB6 Production and Stability of Uniform High Pressure Gas Discharges in the Presence of External Ionization. Alan E. Hill and Allen K. MacKnight.-- Techniques whereby multi-kilojoule electrical energies/liter-atmosphere have been uniformly applied to large volume-one atmosphere N_2-He discharges will be discussed, and experimental results which provide information at the relative roles of photo-ionization electron avalanche, and photo-electric effects at the cathode in stabilizing these discharges will be presented. Both high E/P (above breakdown) and low E/P regimes are being studied in the presence of external ionization.

SESSION KB

Thursday morning, 19 October

8h30

Room 229

CO_2 LASERS I

Chairman: W.J. Wiegand, Jr.
United Aircraft Research Laboratories
East Hartford, Connecticut

KB1 Cold Cathode Electron Beam Sustained High Pressure CO_2 and CO Lasers.* R.O. HUNTER, G. SULLIVAN, W. BEGGS, and J. BENZE, Air Force Weapons Lab. Results are presented for a CO_2 laser operating at up to 10 atmospheres. The discharge is sustained by a 200 kilovolt cold cathode electron beam which produces an ionizing current of 1-3 amps/cm^2 over 150 cm^2 for 400 nanoseconds. Electron number densities of up to $8x10^{13}/cm^3$ and discharge fields of $E/N = 1.3x10^{-16}$ v-cm^2 have resulted in gain-switched pulses of $\geq$ 1 joule in which 80% of the energy is produced in less than 60 nanoseconds. The output has been limited by breakdown of the KCl windows. The same device has been used to obtain stable discharges in room temperature CO at 4 atmospheres at an E/N of $6x10^{-16}$ v-cm^2. Output energies of $\sim$1 joule have been observed, again with internal damage to the KCl windows. In order to avoid damage to the optics, they have been installed within the high pressure region of a larger device with an electron gun producing $\sim$ .5 amp/cm^2 into a 3x3x100 cm^3 gas volume in pulse lengths of 2-3 μsec.

*Submitted by C.E. RAGAN III.

KB2 A Radial Mode TEA-CO_2 Laser.* L.W. Casperson and C. Romero, Univ. of Calif., Los Angeles.--A new class of lasers is described in which the radiation propagates radially within a disk-shaped amplifying medium. The basic resonator consists of a cylindrical mirror which wraps symmetrically about the z-axis at a radius r_m. Important features of these lasers are the strong focusing of energy and the 360° illumination at the laser axis, which make this region well-suited for applications such as heating and optical pumping. Alignment is automatic and permanent. Our first radial mode laser has a mirror of radius r_m=17cm and employs a pulsed TEA-CO_2 discharge with 3500 one-watt resistors in a close-packed resistive-pin configuration. Radiation is coupled from the laser by means of a conical mirror at the center of the cavity which reflects a portion of the energy outward along the z-axis. Threshold is reached for input energies as low as 20 joules. Output laser pulse widths are approximately 1/2μs with delays of 2 and 5μs in agreement with theoretical calculations. Fabrication of the TEA discharge, mode selection techniques, and operating characterisitics will be discussed.

*Submitted by D.L. Jassby.

KB3 The Properties of a Magnetoplasma Laser.* R. H. BULLIS, T. L. CHURCHILL, AND W. L. NIGHAN, United Aircraft Research Laboratories.--Electron vibrational excitation rates for CO_2 indicate that at energies of 0.2 eV a significant fraction of the electron energy can be transferred to the CO_2 (001) level. This result suggests that small concentrations of CO_2 added to the plasma of a nonequilibrium MHD generator would result in a significant transfer of electron energy to the CO_2 upper laser level. Detailed kinetic analysis of this medium indicates that it is possible to maintain the electron and CO_2 (001) level temperatures significantly above the CO_2 (100) level and static gas temperatures. The MHD plasma electron density and electron temperature have been found to be very sensitive to changes in CO_2 concentration, a result which has been confirmed experimentally. With CO_2 concentrations of 0.5 percent, it has been possible to maintain the electron temperature and density at approximately 0.3 eV and 10^{14}/cc, respectively, suggesting that a population inversion can be achieved when CO_2 is added to an MHD medium.

*This work was sponsored jointly by ARPA and NOL.

KB4 Nanosecond Pulse Generation at 10.6 μ.* J. F. FIGUEIRA, W.H. REICHELT, E. FOLEY, and C.A. FENSTERMACHER, Los Alamos Scientific Lab.--The generation of a single nanosecond pulse of 10.6 μ radiation is described. A TEA CO_2 laser is actively modelocked using an acousto-optical modelocker. By means of an electro-optical switch driven by a laser triggered spark gap, a single pulse from this modelocked train is selected. By this method, pulses 2 ns wide and containing 100 μJ have been generated. Other pulse parameters also will be discussed.

*Work supported by the U. S. Atomic Energy Commission.

KB5 Pulse Amplification in the LASL Electron Beam Pumped CO_2 Laser System.* W.H. REICHELT, J.F. FIGUEIRA, C. E. LANDAHL, E. O. SWICKARD, T. F. STRATTON, and C. A. FENSTERMACHER, Los Alamos Scientific Lab.--Results are reported for the amplification of pulses by and energy extraction from the first two electron beam pumped amplifiers of the LASL kilojoule amplifier system. The first set of measurements refer to the amplification of the gain-switched output of a pin-type TEA laser. These measurements relate to an experimental regime in which almost complete saturation is achieved in the second stage of amplification. Typically 200 nsec, 200 millijoule (mJ) self-modelocked pulses are amplified to 4 joules in the first stage of amplification and to 13 joules in the second stage. The second set of measurements pertain to the amplification (in the same amplifier system) of nanosecond pulses from a mode-locked TEA laser discussed in the previous paper. Typically, 0.08 mJ - 2 nsec pulses are amplified to 8.8 mJ in the first amplifier and to 330 mJ in the second amplifier stage. Changes in pulse shape in passing through the amplifier system are discussed.

*Work supported by the U. S. Atomic Energy Commission.

KB6 CO_2 Amplifier Energy Extraction - Comparison of Theory and Experiment.* G. T. SCHAPPERT and T. F. STRATTON, Los Alamos Scientific Lab.--The experimental results of the previous paper are discussed within the framework of a theoretical model. Energy extraction for various pulse lengths, pulse sharpening, and intensity profiles are calculated and compared with experiment. The characterization of the amplifier by a small signal gain and a saturation parameter is examined. The saturation intensity and its dependence on temperature, pressure and gas mixture is analyzed.

*Work supported by the U. S. Atomic Energy Commission.

SESSION LB

Thursday morning, 19 October

10h45

Room 229

PLASMA AND COLLISION PHENOMENA IN LASERS

Chairman: A.I. Carswell
York University
Downsview, Ontario

LB1 Population Inversion Calculations Using Near Resonant Charge Exchange as a Pumping Mechanism. D.L. CHUBB and J.R. ROSE, NASA Lewis Research Center, Cleveland, Ohio 44135.- Near Resonance charge exchange between ions of a large ionization potential gas such as He or Ne and vapors of metals such as Zn, Cd, Se, or Te has produced laser action in the metal ion gas.[1] The present investigation is a theoretical study of the possibility of obtaining population inversions in near resonant charge exchange systems (Xe-Ca, Xe-Mg, Xe-Sr, Xe-Ba, Ar-Mg, N-Ca). The rate equations for the densities of relevant levels of the laser gas and an electron energy equation are solved in the analysis. Electron excitation rates were calculated using the Bohr-Thomson cross sections. Approximations to experimental values of the electron ionization and the ion-atom charge-exchange cross sections were used. Preliminary results show that it is possible to obtain gains $(N_L/g_L - N_K/g_K)$ greater than $10^{15} m^{-3}$. A megawatt power level MPD arc facility that is being modified to investigate charge exchange laser systems will also be described.

[1]W.T.Silfvast and M.B.Klein, Digest of Tech. Papers of the VII Int. Quantum Electronics Conf., May 1972.

LB2 Simultaneous Two-Wavelength Operation of the HF Chemical TEA Laser and Its Use As a Probe of Collision Processes Occurring in the Laser Plasma. REGINA J. CODY and HERSCHEL S. PILLOFF, Naval Res. Lab. -- A technique for operating a tunable laser simultaneously at two wavelengths has been applied to the infrared HF chemical TEA laser and provides an internal probe of some of the collision processes occurring in the laser plasma. The two output beams are independently tunable, collinear, have mutually perpendicular polarizations, and can be time synchronized. Because the TEM_{oo} modes of the two wavelengths occupy essentially the same volume region in the laser cavity, the effect of stimulated emission on the population inversion between one set of vibrational-rotational (V-R) levels can be coupled through collisions to strongly affect the gain on a different V-R transition which is occurring simultaneously. The characteristics of the laser output at one wavelength have been measured with and without oscillation at the second wavelength. In this way the effects of uniquely perturbing various sets of V-R levels (one set at a time) on the gain of many different transitions in the laser plasma have been studied.

LB3
Pulse Perturbation measurements of V-V and V-T processes in CO_2 glow discharges. M.C. GOWER and A.I. CARSWELL, York Univ., Toronto.-- Short duration 10.6μm laser pulses are used to perturb CO_2 dc excited laser plasmas. By monitoring the changes produced in the CO_2 4.3μm, CO 4.7μm, N_2 1st positive, and CO Angstrom bands from the glow discharge, V-V pumping of $CO_2(\nu_3)$ by CO (produced by dissociation or premixed) and N_2 is directly observed. Visible and infrared data correlate well. When the reciprocal time constant for the transfer process is plotted against pressure a straight line is obtained as predicted by theory. The slope agrees well with published rate constant data from laser induced fluorescence studies. From the intercept of this line it is also possible to estimate an electron deactivation rate for $CO_2(\nu_3)$ and the vibrational levels of CO or N_2. Discharge current changes produced by the perturbation indicate initial heating of the plasma and a subsequent cooling following amplification of the 10.6μm pulse. Absorption of the pulse by the plasma reverses the process. It is possible from the rise and decay times of the current changes to deduce V-T rates for the CO_2 ($10^0 0$) and ($00^0 1$) levels which again agree well with published data.

LB4
VIBRATIONAL ENERGY TRANSFER FROM HF AND DF TO CO_2. T. A. Dillon and J. C. Stephenson, National Bureau of Standards, Quantum Electronics Division, Boulder, CO 80302.

The rates for HF and DF vibrational energy exchange with the asymmetric stretch mode of CO_2 are calculated with a theory incorporating refinements not present in conventional theoretical treatments. The rotational and vibrational degrees of freedom are treated fully quantum mechanically and the exponential (unitary) character of the scattering operator is retained. Translational motion is treated classically by solution of orbit equations with a Lennard-Jones intermolecular potential. Vibrational wavefunctions generated by RKR analysis of spectroscopic data were used for HF and DF. The pure rotational dipole-quadrupole permanent moment interaction is included. Calculations performed at 300°K gave excellent agreement with existing experimental data and clearly illustrate the ability of multiple quanta rotational transitions to cancel very large (1600 cm^{-1}) vibrational energy defects.

LB5 Electron Distribution and Lasing Efficiency of Vibrationally Excited Diatomic Gas, W.P.ALLIS, H.A.HAUS, Research Laboratory, of Electronics, Mass. Inst. of Tech.,Cambridge, Mass.,--Models for an electron plasma and diatomic gas are introduced which permit closed-form solutions of the Boltzmann equation and rate equation for the molecular vibrational excitation. For the purpose of evaluating the energy transfer from the electrons to the molecular gas, the diatomic gas has the level structure of a harmonic oscillator, and is pumped by electrons with energy $u_e + \Delta u$, losing an energy Δu upon collision. A complete set of equations determining the V-I characteristic, molecular pumping rate, and lasing efficiency, is developed.

This work was supported by the Joint Services Electronics Program under Contract DAAB07-C-0300,

LB6 Electron Energy Distribution in Gaseous Discharges With External Sources* R. LO and G. H. MILEY, U. of Ill.--Calculations of electron energy distributions in gases due to an external source of electrons (0.1 to 10 keV) superimposed on an electrical discharge ($0<E/P<10$ v/cm-ton) have been made. Such a situation is of importance to beam initiated laser operation.[1,2] A numerical solution of the electron flux conservation equation has been obtained employing a combination of experimental & Vriens-type cross-sections. For lower external source rates, the low-energy portion of the distribution is found to be similar to the standard Druyvesten distribution, however the high energy portion is a rapidly decaying parabolic shaped tail roughly independent of the electric field for $E/P \lesssim 10$. Some comparisons with select V-I measurements[2] and Monte Carlo calculations[3] are favorable.

1. C. A. Fenstermacher, et al., Appl. Phys. Lett., 20, 56 (1972)
2. T. Ganley, et al., Appl. Phys. Lett., 18, 568 (1971)
3. B. Wang, Trans. Am. Nuc. Soc., 15, No. 2, (1972)

*Work supported in part by the AEC and NASA (NGR 14-005-183)

LB7 Penning Ionization in a He-Cd dc Discharge Under Optimum Laser Conditions. W. T. SILFVAST, Bell Telephone Laboratories.--
Measurements have been made of the excited state densities of neutral He under conditions for optimum laser action for the 4416 Å He-Cd laser in a 2 mm bore discharge tube. The variation of the upper laser level population with He pressure is shown to be related to the He excited state densities which is consistent with the Penning ionization process as an excitation mechanism. The He levels above the normal metastable levels contribute a larger fraction of the laser excitation than was previously estimated.

SESSION MB

Thursday afternoon, 19 October

14h00

Room 229

CO_2 LASERS II

Chairman: A. Garscadden
Aerospace Research Laboratories
Wright Patterson Air Force Base, Ohio

MB1 Comparison of Direct and Discharge Pumping in CO_2 Lasers.* W.A. PROCTOR and G.H. CANAVAN, Air Force Weapons Lab.--Numerical solutions of the electron energy distribution function for a 3/2/1:$He/N_2/CO_2$ mixture at STP, with and without an electric discharge field turned on, are used to compare and contrast the E-beam sustained discharge (EB) method of producing excitation in CO_2 lasers with the direct pumping (DP) method, whereby the kinetic energy of source-produced electrons alone produces the excitation. Cross sections for vibrational excitation of CO_2 and N_2 by electron impact are used to define an effective rate $G(\varepsilon)$ for electrons of energy ε to produce gain-enhancing excitations. For a source yielding 10^{19} electrons/cc/sec at 5eV, the DP distribution function has a minimum where G has a maximum, at which energy an EB distribution for $E/N=2\times10^{-16}$ volt-cm^2 exceeds the DP by 10^4. The disparity in pumping rates (10^{24}/cc/sec for EB vs. 10^{20} for DP) is not due to inefficient use of the total energy input to the gas in DP (EB is only about 10 times better) but occurs, rather, because EB uses electrons more effectively, producing some 10^4 more favorable excitations per source electron than DP does.

*Submitted by WILLIAM A. WHITAKER

MB2 Plasma Conditioning by UV Preionization in a CO_2 Gas Laser. O. Judd and J. Wada, Hughes Research Laboratories - Investigations of a large volume, high pressure plasma conditioning concept that employs preionization of a gas by high energy photons will be reported. Use of this concept in a pulsed CO_2 laser operating at 1 atm gas pressure has produced a conservative volumetric optical energy extraction of 39 J/ℓ atm and a conversion efficiency of 24%. It has been established that the preionization of the gas is dominantly due to volumetric photoionization at wavelengths less than 1000 Å. We have measured the "effective" photon mean free path for ionization in several high pressure gases and find it to be orders of magnitude larger than that predicted by a single step photoionization process based on published photoionization cross sections. A discussion of these measurements and the physical mechanisms related to the photoionization processes in the laser will be presented.

MB3 The Influence of Transverse Gas Flow Upon High Pressure-High Pulse Repetition Rate Glow Discharges. G. S. DZAKOWIC and S. A. WUTZKE, Westinghouse Research Laboratories.--When a transverse discharge CO_2 laser with forced flow is pulsed rapidly, the minimum time between arc-free pulses is substantially greater than the time predicted by the ratio of electrode width to gas velocity. The time to remove the glow discharge products from the interelectrode region appears to limit the maximum pulse rate. We find that the maximum pulse rate is predicted by flow model solutions which incorporate gas pulsation and boundary layer effects. After the discharge some of the decaying plasma suddenly expands upstream and takes longer to flow back through the interelectrode region. Also, to avoid arc formation in the subsequent discharge the plasma in the boundary layer must diffuse to the electrode. The predictions were verified at high pulse repetition rates, using a planar electrode CO_2 laser in a closed-cycle wind tunnel. The dependence of maximum pulse rate (0.1-1 kHz) upon glow discharge energy per unit volume (20-100 j/ℓ) and gas velocity (5×10^2 - 5×10^3 cm/sec) was confirmed by these experiments.

MB4 Charge Particle Production Instability in CO_2 Laser Discharges.* W. L. NIGHAN, R. A. HAAS, AND W. J. WIEGAND, United Aircraft Research Laboratories.--An analysis of the stability of charged particle production processes has been developed for plasma conditions typical of high power CO_2 laser discharges. The results obtained have revealed the effect of electron energy transfer and production and loss processes on the conditions for onset of charged particle production instability. Analysis of stability criteria shows that plasma stability is a critical function of the electron temperature dependence of all electron rate coefficients, particularly those for ionization and attachment. In addition, discharge induced changes in gas composition are found to be of importance. For conditions typical of CO_2 laser mixtures, appearance of the ionization instability requires the presence of negative ions at concentrations approaching that of the electrons, and electron temperature values below approximately 1.0 eV.

*This work was performed in part through the sponsorship of the Office of Naval Research.

MB5 Influence of Discharge Processes on Molecular Laser Stability*. W. J. WIEGAND, W. L. NIGHAN, AND R. A. HAAS, United Aircraft Research Laboratories.--In order to investigate the influence of discharge phenomena on CO_2 laser stability, a model of charged particle production and loss processes has been developed. Results of this study have shown that discharge generated minority species which accumulate in closed-cycle or slow flow systems are very effective at quenching electronic metastable levels which may participate in multistage ionization processes and also affect negative ion populations by influencing detachment processes. Further, minority species do not have sufficient time to achieve significant concentrations in fast flow, open-cycle convection lasers. This result suggests that positive and negative ion kinetic processes in open-cycle, fast flow lasers are substantially different from those in closed-cycle and slow flow lasers. The influence of this conclusion on charged particle production instability for the two classes of CO_2 lasers is analyzed.
*This work was performed in part through the sponsorship of the Office of Naval Research.

MB6 A Heuristic Approach to He-CO_2 Laser Kinetics. P. AVIVI, F. DOTHAN-DEUTSCH, L. FRIED-LAND and H. KEREN, Hebrew U. -- Rate equations have been solved assuming that the ratio between energy transfer rates to the relevant vibration modes which contribute to lasing is insensitive to the electron distribution function. In addition to this assumption measured relaxation constants were used. These constants were obtained in a novel manner. The calculations account for the influence of CO obtained by dissociation in the discharge. Based on the above mentioned assumption and the experimental result alone, it will be shown that a comprehensive picture of the kinetics of the He-CO laser can be obtained which is in good agreement with measured features such as population inversion and vibrational temperature.

MB7 Influence of CO on the Population Inversion in CO_2 Lasers.

P. AVIVI, F. DOTHAN-DEUTSCH, L. FRIEDLAND and H. KEREN, Hebrew U. of Jerusalem. -- The population inversion in a CO_2-He glow discharge has been calculated, taking into account CO produced by dissociation in the discharge. The calculation was based on experimentally determined electron energy distributions and the measured effective relaxation constant of CO_2 (001). It is shown that the population inversion is negligible in the absence of CO. The importance of excitation and relaxation of CO_2 (001) by electrons is stressed.

SESSION NB

Thursday afternoon, 19 October

16h15

Room 229

ELECTRON BEAM LASERS

Chairman: C.A. Fenstermacher
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

NB1 An Atmospheric Pressure CO_2 Laser Initiated by a Cold-Cathode Glow-Discharge Electron Gun. A. CROCKER, H. FOSTER, and H. M. LAMBERTON, Services Electronics Research Laboratory, Baldock, Herts., England. - - A pulsed cold-cathode glow-discharge electron gun[1] has been used at 150 kV to initiate an atmospheric pressure CO_2 laser. The gun operates at a helium pressure of ~ 50 m torr. It is mechanically simple, efficient, requires no high vacuum technology and is undamaged by vacuum failure. A large area beam of electrons is produced with a pulse length which is controlled primarily by the external circuitry. In this experiment electron beam pulses of 6 μsec duration and 50 mA/cm² current density are transmitted through a foil window (15 x 2.5 cm) into a laser gas volume (~2 litre), which is probed by an optical resonator with an active volume of 70 cm³. Laser output pulses of 1.6 J (23 J/l) have been obtained with an applied drift voltage of 40 kV (4 kV/cm/atm). Details of the operating characteristics of the electron gun and laser will be presented.

[1]Designed to meet our requirements and constructed by GEC Ltd., Hirst Research Centre, Wembley, England".

NB2 High Voltage Large Area Plasma Electron Gun* B.B.O'Brien,Jr.,--Northrop Research & Tech. Center,Laser Tech.Labs.Hawthorne,Calif.90250. Measurements have been performed on a low pressure (p∿10μ)high voltage (V∿150kV)plasma discharge with peak current densities of the order of 1 A/cm². This type of discharge is being considered for use as a high energy (∿150 keV) electron gun for E-beam stabilized high pressure gas lasers. The capacitive discharge (C = 0.17μf) has a 15 cm diameter and an adjustable electrode spacing of 8 to 20 cm. The positive voltage current characteristic which depends on the gas pressure has been measured for He, Ar, Xe, and N_2. A given V-I curve can be obtained with all gases by proper choice of the gas pressure. This pressure varies roughly as the inverse of the atomic or molecular mass. The current density is constant within ±20% out to 0.8 of the tube radius. Langmuir probe measurements of the plasma next to the anode show an electron density of the order of $3 \times 10^{10}/cm^3$ and an electron temperature of approximately 1.5 eV.

* This research was supported in part by the Naval Ord.Lab. under Contract N60921-72-C-0334

NB3 High Power Electron Beam, Stabilized CO Laser, M. M. Mann, G. L. McAllister, R. G. Eguchi, and G. Hasserjian, Northrop Corp.--The results of experiments with an electron beam stabilized CO laser show that CO is an attractive candidate for high power devices. Pulse energies of 30J corresponding to a specific energy of more than 100J/liter-atm have already been obtained, and a specific energy of ∿500J/liter-atm appears to be an attainable goal. Peak powers of 700 kW and conversion efficiencies in excess of 25% have been demonstrated. Data showing the effects of electrical excitation rate, gas composition, and temperature will be presented. The results of time resolved spectral measurements showing the temporal development of gain distribution will also be discussed.

*This research was supported in part by the ARPA of the Department of Defense and was monitored by the Office of Naval Research under Contract N00014-72-C-0043.

NB4 Characteristics of High Pressure Carbon Dioxide Laser Amplifiers Pumped with Electron Beam.* W. T. LELAND, M. J. NUTTER, J. P. RINK, and C. A. FENSTERMACHER, Los Alamos Scientific Lab.--Time histories of small signal gain have been measured under a wide variety of discharge conditions and with various mixtures of carbon dioxide, nitrogen, and helium. Comparison of data taken at various pressures up to 1800 torr in a 3/1/1 helium, nitrogen, carbon dioxide mixture indicates that binary collisions account for the dominant interactions involved in the pumping process.

*Work supported by the U. S. Atomic Energy Commission.

NB5 Theoretical Studies of the Electron Beam Controlled CO_2 Laser.* A.M. Lockett III., Los Alamos Scientific Lab.--Comparisons between theoretical calculations and experimental results on the small signal gain and discharge current as a function of electron beam intensity, impressed electric field, gas mixture, pressure and initial temperature are presented. Particular emphasis will be placed on the isolation of the probable origin of the previously reported discrepancies in the calculated small signal gain. Implications for the optimization of operation at high electron beam intensity will be discussed.

*Work supported by the U.S. Atomic Energy Commission.

NB6 Range Enhancement of 135 keV Electrons from Applied Electric Fields in Dense Gas.* J. P. RINK, C. A. FENSTERMACHER, AND W. T. LELAND, Los Alamos Scientific Lab.--Detectors based on recombination limited discharges have been used to measure the relative spacial distribution of primary ionization produced by a beam of 135 keV electrons projected into a gas whose density is equivalent to 340 torr of air. Applied electric fields of 2, 3, and 4 kV/cm are shown to be effective for the extension of the range over which ionization from primaries occurs.

*Work supported by the U. S. Atomic Energy Commission.

NB7 Electron Beam Transport in Laser Discharges*. Dale B. Henderson, Los Alamos Scientific Lab.-- We have developed a new set of computer programs to treat the transport of primary electrons in gas laser configurations. These codes operate in three parts (1) Computation of energy loss and straggling and of scattering and scattering distribution in the metal window and in the gas at various energies; (2) Computation of the energy depositions from a pencil beam of electrons into the media with an applied electric field (to drive the main discharge) with a transverse magnetic field (due to the main discharge) and with a parallel magnetic field (applied to overcome the effects of the transverse field and to help control scattering); (3) Superposition of energy deposition due to various pencil beams to find the deposition in a real geometry with finite dimensions and with field gradients. These codes have been applied to range enhancement experiments, to study the usefulness of applied guide fields, and to find the distribution of ionization in a new 10 kJ CO_2 amplifier stage. These results are discussed as are the operation of the programs and the underlying physics.

*Work performed under the auspices of the U.S.A.E.C.

GASEOUS ELECTRONICS CONFERENCE

ABSTRACTS

SESSIONS

AC, BC, CC, HC
KC, LC, OC, PC
F, G
CD, DD, ED, MD
ND, OD, PD

17-20 October 1972

SESSION AC

Tuesday morning, 17 October

8h30

Room 200

HEAVY PARTICLE INTERACTIONS I

Chairman: T. Dean Gaily
University of Western Ontario
London, Ontario

AC1 Rotational Excitation of $CO^+(A^2\Pi)$ formed in Li^+-CO Collisions*. H.I.S. FERGUSON and R.P. LOWE. University of Western Ontario, London 72, Canada.--The (2,0) band of the Comet-tail system ($A^2\Pi$-$X^2\Sigma$) of CO^+ has been observed in spectra taken of the luminescence resulting from Li^+-CO collisions at 10 millitorr pressure and Li^+ energy from 4 to 15 keV. The spectral resolution was sufficient to enable the rotational population distribution of the upper state to be determined from rotational line intensities. Considerable deviation from a Boltzman distribution at room temperature occurs, with the deviation becoming more marked at lower energy. This behaviour is similar to that previously observed in Li^+-N_2 collisions although the extent of the rotational excitation is not so great. The effect of the much longer radiative half-life of the CO^+ bands will be discussed.

*Supported by the National Research Council of Canada.

AC2 Rotational Population Distribution of the $B^2\Sigma$ State of N_2^+ Excited in Alkali Ion-N_2 Collisions.* R.E.MICKLE, H.I.S. FERGUSON and R.P.LOWE.--University of Western Ontario, London 72, Canada. Spectra of the First Negative band system ($B^2\Sigma$-$X^2\Sigma$) of N_2^+ produced by bombardment of N_2 by Li^+ and Na^+ ions at energies from 0.6 to 10 keV have been used to deduce the rotational population distribution in the v=0 level of the upper state. We have previously reported[1] that the rotational populations derived from such spectra are well represented by a Boltzman distribution at temperatures up to 10^4K. The present results indicate that at high values of K a deviation from a Boltzman distribution occurs for Li^+ excitation at energies above 3 keV. The distribution in v=1 has been observed for the first time and shows a similar but not identical behaviour to v=0.

[1]R.E. Mickle, H.I.S. Ferguson and R.P. Lowe. Abstracts VII ICPEAC, Amsterdam 1971. p.384.

*Supported by National Research Council of Canada.

AC3* Excitation of Helium in Li^+-He Collisions*. A.J. COLE and R.P. LOWE. University of Western Ontario, London 72, Canada.--The optical emission spectrum over the range 3500-7500A produced by collision of Li^+ ions of energy from 1 to 25 keV on a He target gas at 5 millitorr pressure has been observed. Absolute emission cross-sections have been measured for eight of the low-lying members of the $2p\,^1P$-$ns\,^1S$, $2p\,^1P$-$nd\,^1D$ and $2s\,^1S$-$np\,^1P$ series of helium which lie in this wavelength range. The cross-sections show considerable irregular structure over the whole energy range as well as a general increase to higher energies. The variation of intensity with pressure is used in an attempt to correct the results for resonance trapping and excitation transfer.

*Supported by the National Research Council of Canada.

AC4 Excitation and Ionization of Helium by Fast Protons and by their Associated Secondary Electrons.* D.M. BARTELL† and G.S. HURST, Oak Ridge Nat'l. Lab. --The number of ions and the populations of the lowest ten excited states resulting when a fast proton loses a fraction of its energy in helium and when the secondary electrons completely degrade in energy have been calculated. Extensive use is made of recent theoretical publications. Measured quantities for 4-MeV protons such as the energy per ion pair (W value), the magnitude of the Jesse effect, and the energy radiated into the vuv region per unit track length ($d\epsilon/dx$) are consistent with the calculation. This theoretical work has been used as one input for a model of the Jesse effect and vuv emission in helium and was particularly important in suggesting that the 2^1P level in helium is the atomic precursor to the molecular states from which vuv continuum emission and Jesse effects occur.

*Research sponsored by the U.S. Atomic Energy Commission under contract with Union Carbide Corporation.

†Present address: Dept. of Phys., Univ. of Western Ontario, London 72, Ontario, Canada.

AC5 Model for vuv Emission and Energy Pathways Following Proton Excitation of Helium.* G. S. HURST, D. M. BARTELL,† and E. B. WAGNER, Oak Ridge Nat'l. Lab. -- A unifying model for energy pathways, including vuv emission and the Jesse effect, is constructed mainly from recent time dependent studies in the vuv region. Depletion of the key atomic state (2^1P) by three-body collisions yields molecules in both the D and B excited states. The observed fast component in the vuv continuum results when the D state radiates to the ground state. The rate determining step for the slow component is a three-body collision which converts the metastable B molecular state to the radiation A state. In our model the metastable B molecular state stores energy which is utilized in producing Jesse effects when impurities are added to helium, in contrast with previous models which assumed that the energy is stored in atomic metastable states.

*Research sponsored by the U. S. Atomic Energy Commission under contract with Union Carbide Corporation.

†Present address: Dept. of Phys., Univ. of Western Ontario, London 72, Ontario, Canada.

AC6 Coupled-State Calculations of He^{2+}-H Collisions. A. Msezane and D.F. Gallaher - University of Western Ontario, London, Canada. Direct excitation and charge transfer cross sections for the collision between an incident alpha particle and atomic hydrogen have been evaluated using two-state and four-state two centre expansions in the impact parameter approximation. The calculation includes completely the effects of distortion, back coupling and rotational coupling.

AC7
Superelastic Collisions of Vibrationally Excited H_2^+ with Atoms and Molecules. F. A. HERRERO* and J.P. DOERING, The Johns Hopkins University--Superelastic collisions of vibrationally excited H_2^+ ions have been observed with the scattering gases He, Ne, Ar, Kr, Xe, H_2 and N_2. Single and multiquantum transitions have been observed in both the energy-loss (inelastic) and energy-gain (superelastic) parts of the incident ion energy change spectrum. Cross section measurements have been made in the energy range 100-1500 eV and the cross sections are largest in the region 100-500 eV, decreasing slowly towards higher energies. The cross sections for superelastic collisions show approximately the same energy dependence and have approximately the same magnitude as the cross sections for the inelastic process. Both the superelastic and inelastic cross sections increase with target polarizability, being largest for Kr and Xe.

* Present Address: Dept. of Physics, University of Puerto Rico, Mayaguez, P.R. 00708

AC8 Reactions of Atomic Oxygen with Ionic Species.* J. A. RUTHERFORD and D. A. VROOM, Gulf Radiation Technology, San Diego, Ca. -- Ion-neutral reactions involving neutral oxygen atoms have been studied using crossed-beam techniques. The atomic oxygen is formed by thermal dissociation of molecular oxygen at low pressure in an iridium furnace heated to 2100°K. Approximately 20% dissociation of the O_2 is obtained in this manner. This fraction is determined by both experimental observation and normalization to previous measurements. The reaction $H^+ + O \rightarrow H + O^+$ has been studied in the ion energy range from 1 to 500 eV. Good agreement between the present work and that of Stebbings et al.[1] was obtained in the high-energy overlap region. The present data extrapolates well to the thermal value of Fehsenfeld et al.[2] Preliminary measurements have also been obtained for the reaction $N_2^+ + O \rightarrow NO^+ + N$ in the ion energy range from 1 to 4 eV.

*Work supported by the Defense Nuclear Agency under Contract No. DNA001-72-C-0254.

[1]R.F. Stebbings, A.C.H. Smith, and H. Ehrhardt, J. Geophys. Res. 49, 2349 (1964).
[2]F.C. Fehsenfeld and E.E. Ferguson, J. Chem. Phys. 56, 3066 (1972).

AC9 A Study of the Reactions $H_3^+ + He \rightarrow HeH^+ + H$ and $HeH^+ + H \rightarrow H_2^+ + He$.* D. A. VROOM and J. A. RUTHERFORD, Gulf Radiation Technology, San Diego, Calif. -- Cross sections for proton transfer from H_2^+ to He and from HeH^+ to H have been obtained in the laboratory ion energy range 1 to 25 eV. The first of these processes is endothermic for ground state reactants but has been found previously to proceed at low interaction energies if sufficient vibrational energy is present in the H_2^+.[1] The present study extends the investigation of the importance of vibrational energy to higher impact energies. Below 8 eV ion energy, the reaction probability is found to depend strongly on vibrational energy while above this energy the cross section appears to depend mainly on the kinetic energy of the reactants. Transfer of a proton from HeH^+ to H is exothermic and the cross section is found to exhibit a $1/v$ (where v is the velocity of the center of mass) dependence in the low-energy region.

*The study was supported by the Air Force Office of Scientific Research, Contract No. F44620-70-C-0096.

[1] W.A. Chupka and M.E. Russell, J. Chem. Phys. 49, 5426 (1969).

SESSION BC

Tuesday morning, 17 October

11h00

Room 200

HEAVY PARTICLE INTERACTIONS II

Chairman: John V. Dugan
NASA Lewis Research Center
Cleveland, Ohio

BC1 Investigation of Associative Detachment Reactions Using the SF_6 Scavenger Technique. T. O. TIERNAN, C. LIFSHITZ, and J. C. HAARTZ, Aerospace Rsch Labs. W-PAFB, O.--Associative detachment reactions of O^- with H_2, D_2, CO, NO, SO_2, C_2H_2, C_2H_4 and C_2H_6 were observed in a double mass spectrometer by using SF_6 as a scavenger for the detached electrons. Pressure dependences of these processes were studied over the range of collision chamber pressures from ~5 to 90μ. The effects of varying the SF_6/target gas ratio, the collision chamber temperature, and the incident ion energy were also examined. These experiments demonstrate that at 30°C and 0.3eV O^- energy, the SF_6^- product results almost entirely from capture of the electron released in the detachment reaction, while both SF_5^- and F^- are formed solely by dissociative electron transfer from O^- to SF_6. In some instances, other negative ion products were also detected. Rate coefficients for the associative detachment reactions were determined by normalizing the measured relative rates to the previously reported value of $7.0 \times 10^{-10} cm^3/sec$. for the O^-/CO process. This data will be compared with results from flowing afterglow and drift tube experiments.

BC2 Negative Ion Reactions in N_2O at Low Energies. R. MARX and G. MAUCLAIRE, Laboratory de Physico-chimie des Rayonnements, 91-Orsay, France, and F. C. FEHSENFELD, D. B. DUNKIN, and E. E. FERGUSON, NOAA Environmental Research Laboratories, Boulder, Colo. The reaction of O^- with N_2O has been studied as a function of temperature and O^- kinetic energy using ion cyclotron resonance and flowing afterglow techniques. The reaction has a measured rate constant at room temperature of $2.2 \pm 0.4 \times 10^{-10}$ cm^3/sec in the flowing afterglow system and $2.5 \pm 0.5 \times 10^{-10}$ cm^3/sec in the ICR. As the O^- energy is increased the rate constant declines. Over the entire range of energies NO^- is the only observed reaction product. Energy exchange between O^- and N_2O and Ar have also been studied as well as reactions involving the NO^- product of the O^- reaction with N_2O. The present results are compared with previous results.

BC3 Thermal Energy Charge-Transfer of Ne^+ with Vibrationally Excited N_2, D. L. ALBRITTON, Y. A. BUSH, F. C. FEHSENFELD, E. E. FERGUSON, T. R. GOVERS, M. McFARLAND and A. L. SCHMELTEKOPF, NOAA Research Labs., Boulder, Colo. The exothermic charge-transfer reaction $Ne^+ + N_2 \rightarrow N_2^+ + Ne$ was found to be exceedingly slow in a thermalized flowing afterglow at 300°K, $k < 10^{-14}$ cm^3 sec^{-1}. It is very unusual, although not unique, for an exothermic charge transfer producing a molecular ion to be this slow. When the reactant N_2 is vibrationally excited, it is found that the charge-transfer rate is drastically enhanced. At a nitrogen vibrational temperature of 4000°K the rate constant has increased to $\sim 4 \times 10^{-11}$ cm^3 sec^{-1}. A preliminary fit of k vs T_{vib} data indicates that the rate constant (or cross section) is extremely small for N_2 in the first and second vibrational levels (v = 0 and 1) and then jumps to large (normal) values for v = 2, 3, 4,... This appears to be the first observation of a charge-transfer having a sharp dependence on vibrational state. Details of the experiment and the results will be presented.

BC4 Thermal Energy Charge Transfer Reactions of Rare-Gas Ions to Diatomic and Simple Polyatomic Molecules. James B. Laudenslager and Michael T. Bowers, Jet Propulsion Lab. and U.C. Santa Barbara.-- Thermal energy charge transfer rate constants for He^+, Ne^+, Ar^+, and Kr^+ ions reacting with diatomic and simple polyatomic molecules have been measured using an ion cyclotron resonance spectrometer. For thermal energy charge transfer reactions, it appears that the rate constant is strongly dependent on favourable Franck-Condon factors and not on the exothermicity or energy defect of the reaction. The data further indicates that thermal energy charge transfer of rare gas ions to simple molecules in favourable cases leaves the product molecular ions in very specific excited states.

BC5 Effects of NH_3 and SF_6 on Ions in the Atmosphere

B. T. McCLURE and C. W. ERICKSON, Honeywell Corporate Research Center.--Positive and negative ion species produced by tritium beta particles in air at atmospheric pressure have been observed. The mass range up to 175 and frost points corresponding to temperatures as low as $-72^{o}C$ (approximately $2/10^{6} H_2O$ molecules) have been surveyed. The influence of admixtures of NH_3 and SF_6 on relative abundances has been determined qualitatively. Among the positive ions we find that masses 18, 19,36,37,54,55,72 and 73 [H_2O^+, $H^+(H_2O)$, $(H_2O)_n^+$ and $H^+(H_2O)_n$] predominate in room air. The relative importance of the $H^+(H_2O)_n$ series is greater in dryer air. When ammonia is added all species listed above, with the possible exception of H_2O^+, which has the same mass as NH_4^+, are replaced by the analogous species NH_4^+ and $NH_4^+(NH_3)_n$. Among the negative ions we find that masses 16,32,50 and 68 [O^-, O_2^-, $O_2^-(H_2O)$ and $O_2^-(H_2O)_2$] predominate in room air. The addition of ammonia causes little change. As the admixture of SF_6 increases from 7 to 1000 parts per million masses 19,39,59 and 71 [F^-, $F^-(HF)$, $F^-(HF)_2$ and $CF^-(HF_2?)$] become increasingly predominant.

BC6

Information from Rate Constants Measured as a Function of E/p.* C. Russ, M. Barnhill and S.B. Woo, Univ. of Del.--The inherent limitations, which attends the inference of the cross section,σ, from its rate constants,K, come from two sources--(a)the smcothness of the kernel,g, and (b) the uncertainties of K. These limitations can be studied quantitatively by expressing the integral equation into the matrix form through the application of numerical quadrature:

$$\varepsilon_i + K(E/p_i) = \int_0^{\infty} g(v, E/p_i) v\sigma(v) dv \cong \sum_{j=1}^{n} a_{ij} \sigma(v_j) \qquad i=1,2,..M$$

ε_i and $g(v,E/p_i)$ are respectively the error term and the relative speed distribution associated with the i^{th} E/p. a_{ij} is the quadrature coefficient. M is the total number of K-measurements. The matrix equations are used to determine the maximum permissible number of parameters in any representation of σ to be evaluated from measurements of K[1]. We used a displaced Maxwellian with a temperature parameter to represent the kernal,g, and evaluated the number of permissible parameters as a function of ε. We find, for example, that 10 and 20% standard deviation on K imply respectively five and four parameters for σ. Examples are given. Least squares approach are used to verify the above finds independently.

* Work supported in part by ARO-D

1. S. Twomey, J. Franklin Institute, 279, 95-109 (1965)

SESSION CC

Tuesday afternoon, 17 October

14h00

Room 200

HEAVY PARTICLE INTERACTIONS III

Chairman: E. Rothe
Wayne State University
Detroit, Michigan

CC1 Proton Affinities of Some Atmospheric Gases

H.W.Rundle, R.S.Hemsworth, D.K.Bohme and H.I.Schiff
CRESS, York University, Downsview, Ont.

The recently developed analysis of the approach to and attainment of equilibrium for ion-molecule reactions proceeding in a flowing afterglow system has been used to obtain equilibrium constants for a number of proton transfer reactions. These equilibrium constants have been used to determine the relative proton affinities of a number of common gases. Absolute values of the proton affinities may be obtained by comparison of relative values to any well established theoretical or experimental value. In addition to proton affinities, rate constants for the proton transfer reactions have been obtained. The molecules studied include N_2, H_2, CO_2, CH_4, CO, NO and N_2O. The range of equilibrium constants to be reported is 10 to 10^9 corresponding to relative proton affinities of 0.05 to 0.60 eV.

CC2 The Chemical Equilibrium $NH_2^- + H_2 \rightleftarrows H^- + NH_3$ and $D_o^\circ(NH_2\text{-}H)$. R. S. HEMSWORTH, H. W. RUNDLE, and D. K. BOHME, C.R.E.S.S., York University, Downsview, Ontario. The proton transfer reaction $NH_2^- + H_2 \rightleftarrows H^- + NH_3$ has been investigated in a flowing afterglow system independently in both directions at 296 K. The rate constants were found to be: $k_{forward} = 2.3 \pm 0.5 \times 10^{-11}$ cm^3 molecule^{-1} sec^{-1} and $k_{reverse} = 9.2 \pm 2.8 \times 10^{-13}$ cm^3 molecule^{-1} sec^{-1}. Also, conditions of concentration and time could be established at this temperature under which the reaction was in equilibrium. The equilibrium constant determined from equilibrium concentrations was 26±9. This result agrees well with the ratio of rate constants, $k_f/k_r = 25 \pm 10$, determined under non-equilibrium conditions. An equilibrium constant of 26±9 corresponds to a standard free energy change, ΔG°_{296}, of $-1.9^{+0.2}_{-0.3}$ k cal/mole and leads to a value for $D_o^\circ(NH_2\text{-}H)$ of 99.2± 0.9 k cal/mole. This value for D_o° agrees with the values determined with most other methods and, as a consequence, is also consistent with the recent photodetachment value of 0.744±0.022 eV for the electron affinity of NH_2.

CC3 Equilibrium Constants and Binding Energies of Alkali Metal Ions with Inert Gases. L. G. McKNIGHT, and J. M. SAWINA, Bell Telephone Laboratories, Whippany, New Jersey.--Equilibrium constants have been measured for the ion clusters formed between alkali metal ions and inert gases at temperatures between room temperature and -110°C and at pressures between 0.5 and 5 Torr. In general, equilibrium constants for alkali metal ions with an inert gas atoms are much less than 10^{-3} $Torr^{-1}$ at room temperature and increase to as high as $5x10^{-2}$ $Torr^{-1}$ at 225°K for Na^+ in Kr and $6x10^{-1}$ $Torr^{-1}$ at 215°K for Li^+ in Ar. Enough data are available to calculate binding energies ($\Delta H°$) of 5.8 and 4.4 Kcal/mole for $(Na\cdot Kr)^+$ and $(Na\cdot Ar)^+$ and 4.1 Kcal/mole for $(Li\cdot Ar)^+$.

CC4

Clustering of Ar to Li^+ as a Function of E/N. G. E. Keller and L. M. Colonna-Romano, Ballistic Research Laboratories. The clustering of Ar to Li^+ has been studied with a drift tube. The measurements were made at 319°K, Ar pressure 0.5 to 1.5 Torr, for E/N values 9 Td to 24 Td. Under these conditions, the only appreciable reaction is

$$Li^+ + Ar + Ar \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} Li^+(Ar) + Ar \ . \qquad (1)$$

The rate constants and the mobility of $Li^+(Ar)$ were deduced by comparing measured arrival time profiles of the ions with profiles generated by a three-dimensional, numerical drift tube model. Rate constant k_1 is found to remain essentially constant at 1.9×10^{-31} cm^6/sec over the range of E/N used. k_{-1} is found to increase from 2.2×10^{-13} cm^3/sec at E/N = 12 Td to 3.2×10^{-13} cm^3/sec at E/N = 24 Td. The reduced mobility of Li^+ in Ar is found to be 4.6 V cm^2/sec, and the reduced mobility of $Li^+(Ar)$ in Ar is found to be 2.0 V cm^2/sec.

CC5
Clustering of Atmospheric Gases to NO^+. J. A. Vanderhoff and J. M. Heimerl, Ballistic Research Laboratories. A stationary afterglow has been used to measure the room temperature rate coefficients for the clustering of atmospheric gases to NO^+. The reactions studied were of the form

$$NO^+ + X + M \xrightarrow{k} NO^+(X) + M ;$$

where X = N_2, O_2, CO_2, CO, N_2O, and SO_2. Except for SO_2, X ≈ M. With respect to the O_2 reaction only an upper limit could be obtained. The room temperature clustering rate coefficients are:

$X = N_2$	$k = 2.4 \times 10^{-31}$ cm^6/sec
$X = O_2$	$k < 4 \times 10^{-32}$ cm^6/sec
$X = CO_2$	$k = 2.4 \times 10^{-29}$ cm^6/sec
$X = CO$	$k = 1.9 \times 10^{-30}$ cm^6/sec
$X = N_2O$	$k = 2.5 \times 10^{-29}$ cm^6/sec
$X = SO_2$	$k = 2.5 \times 10^{-28}$ cm^6/sec

The collisional breakup reaction

$$NO^+(N_2) + M \longrightarrow NO^+ + N_2 + M$$

has been investigated and limits for the rate coefficient will be discussed.

CC6 Thermal Energy Rate Constants for Ion-Polar Molecule Collisions and Their Dependence on Ion Kinetic Energy: Theory and Experiment. M. T. BOWERS and T.SU, U. of California at Santa Barbara--A classical statistical theory for ion-polar molecule collisions has been developed that accounts for the thermal rotational energy of the polar molecule. Parametric equations are derived for the velocity dependent reaction cross section for capture collisions, $\sigma(v)$, and for the square of the relative collision velocity, v^2, in terms of the average orientation angle of the dipole w.r.t. the line of centers of the collision, $\bar{\theta}$. $\bar{\theta}$ is calculated from the classical potential as a function of r. Macroscopic averaged rate constants are calculated from

$$\bar{k}(v) = \int_0^\infty v\sigma(v)P(v)dv$$

where $P(v)$ is the velocity distribution. Charge transfer, proton transfer and non reactive collision thermal rate constants have been measured using Ion Cyclotron Resonance. Excellent agreement between experimental and theoretical values of $\bar{k}(v)$ and $\bar{\theta}$ are obtained. The dependence of $k(v)$ on kinetic energy has also been measured and also agrees well with theory.

CC7 Momentum Transfer Cross Sections for Ions in Polar Gases. J. V. DUGAN, JR., NASA Lewis Research Center, Cleveland, Ohio 44135, and J. L. MAGEE, University of Notre Dame, Notre Dame, Indiana 46556.

Numerical calculations of total scattering cross sections, σ_s, for ions on dipoles have been used to obtain momentum transfer cross sections, σ_m, as functions of ion velocity, target rotational temperature, and dipole moment.[1] The dependence of σ_m values on ion velocity and target geometry is much less pronounced than for σ_s values. In most cases, σ_m values are less than 50% larger than the capture cross sections, σ_c, because scattering at impact parameters greater than 25 Å is at very small angles. This relationship between σ_m and σ_c contrasts with the Langevin behavior where $\sigma_m/\sigma_c = 1.10$. The energy transfer cross sections of interest for cooling of ions in polar gases are also presented.

[1] J. V. Dugan, Jr. and J. L. Magee, submitted to J. Chem. Physics.

CC8 Numerical Studies of Conditions for Formation of Collision Complexes in Dipole-Dipole Collisions. J. V. DUGAN, JR. and R. W. PALMER, NASA Lewis Research Center, Cleveland, Ohio 44135.

Three-dimensional computer-graphics studies of orientation-dependent forces are extended to multiple reflection behavior in dipole-dipole collisions.[1] The collision pairs DCl-DCl and HCl-HCl are studied for rotational temperatures of 25, 77, and 300° K. The probability of a multiple reflection collision is a very sensitive inverse function of hard-core reflection distance R_c for fixed temperatures. A brief comparison of the results is made with two-dimensional results of Clarke and Smith for CHF_3-CHF_3.

[1] J. V. Dugan, Jr. and R. W. Palmer, to be published in J. Chem. Phys., Sept. 1, 1972.

SESSION CD

Tuesday afternoon, 17 October

14h00

Room 229

BREAKDOWN AND CORONA

Chairman: F. Llewellyn-Jones
University of Wales
Swansea, Wales

CD1 Calculations of Space-Charge Controlled Breakdown. L. E. KLINE, Westinghouse Research Labs. - The spatiotemporal development of charge densities, field, and luminosity are calculated for electron pulse experiments in parallel plane gaps by numerically solving the continuity equations for electrons and ions, and Poisson's equation. Photoemission at the cathode, and photoionization in the gas are also calculated. Experimental electron drift velocity and coefficients for primary ionization, photon excitation, cathode photoemission and gas photoionization are used. The calculated luminosity is unaffected by photoionization for the experimental conditions of Koppitz[1] (N_2,p=300 Torr, d=2cm, αd=44.4). Photoionization strongly affects the calculated luminosity for the experimental conditions of Wagner[2] (N_2:CH_4=9:1, p=90 Torr, d=3cm, αd=27.8). In both cases the initial electron pulse is distorted by its own space charge and anode- and cathode-directed streamers develop, with velocities in very good agreement with measured streamer velocities.

[1]J. Koppitz, Z. Naturforsch, 26a, 900 (1971).
[2]K. H. Wagner, Z. Phys., 189, 465 (1966).

CD2 Focal Spot Size Dependence of Gas Breakdown Induced by Particulate Ionization.* G.H. CANAVAN, Air Force Weapons Lab. In recent experiments[1] at 10.6 μ, Smith "preionized" gases by introducing particulate contaminants which "when irradiated by the laser beam, appeared as small sparks in the focal region"[1]. The laser flux needed to maintain such sparks can be much less than the flux needed to cause air breakdown. If the gas contains particles with size distribution $n(r)\,dr = Ar^{-p}dr/cc$ of radius within dr of r, and the flux for maintenance of the plasma formed by a particle of size r is $F = Br^{-q}$, breakdown by a flux F requires that a particle of size $r_F = (F/B)^{-1/q}$ or larger be found within the focus, which occurs with probability $P \alpha L^4 F^{(p-1)/q}$ for a lens of focal length L. Threshold is defined experimentally as the attainment of some fixed P, which implies $F \alpha L^{4q/(1-p)}$. For q = 1, the exponent p = 5, which is not atypical of room air and perhaps serves to characterize Smith's ill-defined contaminants as well, produces $F\alpha 1/L$ in agreement with Fig. 3 of Ref 1, as well as $P \alpha F^4$ for fixed L, in quantitative accord with the recent observations of P.J. Berger. *Submitted by J.F. JANNI

1. D.C. Smith, App Phys Ltrs 19, 405 (1971).

CD3 Measurements of Current and accompanied Radiation Emission during Impuls Breakdown of a coaxial gap. H. ALBRECHT and W.H.BLOSS, Inst.Physikal.Elektronik,Univ.Stuttgart,Germany. The emitted radiation during breakdown in spark discharges in the nanosec region has been investigated. With a special cirquit 100 nsec pulses up to 10 kV are produced and supplied to a coaxial gap. The correlation between current and radiation is recorded from the early stages of breakdown in various gases (H_2,He,A,N_2,air) at about 760 torr. The results indicate a high intensity nonequilibrium radiation of some spectral lines

CD4 Axially Symmetric Ionizing Potential Waves in Strong Electric Fields.* R. KLINGBEIL and D.A.TIDMAN, U. of Maryland.--A recent analysis of plane IPW's[1] is extended to the case of axial symmetry. This is accomplished by dividing the axially symmetric wave into differential plane wave elements. Poisson's equation is solved in order to obtain the electric field $\vec{E}$ at each element. The continuity equation is used to describe the flow of charge. The cases of infinite and finite conductivity are considered. The velocity of propagation $\vec{V}(\vec{E})$ is calculated and focussing is demonstrated.

* Work supported by the National Oceanic and Atmospheric Administration and in part by the National Science Foundation.

1 R. Klingbeil, D.A. Tidman, and R.F. Fernsler, Phys. Fluids (in press).

CD5 Confinement Regime of Radiofrequency Breakdown and Discharge.* A. J. HATCH and C. F. SHELBY†, Argonne National Laboratory.—A breakdown and discharge regime has been identified in which rf confinement effects play a dominant role. The regime exists in an electric quadrupole field at pressures extending at least three decades below the electron mean-free-path limit of the electron diffusion-controlled rf breakdown and discharge regimes. The regime is characterized by a nearly constant breakdown field which corresponds to a confinement quasipotential well depth Φ of $\sim 1 - 2\frac{1}{2}$ times the ionization potential of the gas and by a spatial distribution of steady-state discharge luminosity which has a maximum in the vicinity of the central nodal point (bottom of the Φ well) in the quadrupole field. The regime is not observed in a dipole electric field—a result that is consistent with rf confinement theory. Breakdown curves and luminosity distributions obtained in a cylindrical cavity system at 902 MHz demonstrate the characteristics of the regime. The breakdown results confirm and extend the earlier results of Self and Boot.[1]

*Under the auspices of the U.S. Atomic Energy Commission.
†Present address: St. Vincent's Seminary, Montebello, Cal.
[1]S. Self and H. Boot, J. Electron. Control 6, 527 (1959).

CD6 Microwave Breakdown of SF_6. S.J. TETENBAUM, A. D. MAC DONALD, and H.W. BANDEL, Lockheed Palo Alto Res. Lab*, - Although there is an extensive literature on the breakdown of SF_6 at dc and low frequencies, no microwave breakdown studies have appeared in the open literature. We have measured pulsed breakdown electric field strengths in an S-band cavity filled with SF_6 at room temperature. The data were taken at a prf of 20 Hz, for effective pulse widths τ of 0.1, 0.2 and 0.6 μsec, and pressures p from 0.01 to 200 Torr. The E_e/p vs. $p\tau$ data do not fall on a single curve for $p\tau$ less than 10^{-7} Torr-sec. This shows that the elastic collision frequency ν_c is a function of electron energy in the energy range appropriate to the breakdown process. We have determined an average value of ν_c of 1.3×10^{10} p sec^{-1} from a comparison of the positions of the minima in the breakdown curves of SF_6 and dry air under the same experimental conditions, and also from a calculation based upon the slope of the breakdown curve at its low pressure end where diffusion losses predominate. Our data are in reasonable agreement with the breakdown predictions of Felsenthal[1] based upon pulsed dc breakdown fields.

*Work supported by Lockheed Independent Research Program.
[1]. P. Felsenthal & J.Proud, Phys.Rev..130.A1705 (1963).

CD7 Ozone Generation in a Corona Discharge, M.B.AWAD, and G.S.P.CASTLE, Faculty of Engineering Science, The University of Western Ontario -- Under normal conditions in air, for a given corona current, the positive polarity discharge generates much less ozone than negative corona. Although this observation is well known, no satisfactory explanation for this phenomenon has been given in the literature. The reason for this difference is offered here based upon the results of an extensive investigation into the mechanisms affecting the formation of ozone in a coaxial wire corona geometry. It is shown that the ozone production is governed both by the total power dissipated in the ionized sheath of the corona and by the strength of the electric field and current density that exists right at the surface of the active electrode. It is shown that by modification of the condition of the electrode surface it is actually possible to generate more ozone with positive than with negative corona, a fact that confirms some previous results such as those reported by Robinson(Trans.Am.Inst. Elec.Engrs., 801, 148, (1961).)

CD8

Some surface effects caused by H.F. discharge

Sulimin A.D.,Yakovenco V.G.,Morozova L.S., Yakovlev O.I.,Neustroev S.A.,Basikhin Yu.V.* (Institute of Inorganic Chemistry,Novosibirsk ,U.S.S.R.)

Formation and growth of filamentous structures -"whiskers" - in the silicon oxide film-aluminium film- sitallic support system under the influence of H.F. discharge in the vapours of tetraethyoxysilane and oxygen was observed. The dependence of "whiskers density" on conditions of aluminium and silicon oxide film condensation was studied. The observed phenomena are accounted for by means of concept of activatable diffusion conditioned by migration and exciton decay.

SESSION DD

Tuesday afternoon, 17 October

16h15

Room 200

GLOW DISCHARGES I

Chairman: T.D. Holstein
University of California, Los Angeles
Los Angeles, California

DD1 Analytical Study of the Diffusion Controlled Positive Column.* L. OSTER** and A.V. PHELPS+, Joint Institute for Laboratory Astrophysics.--A model for a time varying, diffusion controlled positive column[1] with cylindrical symmetry is examined in detail. Volume recombination and cumulative ionization are neglected. Ionization, diffusion, mobility, and thermal conductivity coefficients appropriate to weakly ionized helium are used. Small changes in these coefficients produced significant changes in the character of the solutions. Relatively slow variations in the ionization and diffusion coefficients with density and, therefore, temperature lead to solutions with a maximum in the electron density at the axis whereas a more rapid variation with temperature can lead to a maximum near the cylindrical wall.

*Research supported in part by Advanced Research Projects Agency.
**Dept. of Physics & Astrophysics, Univ. of Colorado.
+Staff Member, Laboratory Astrophysics Division, N.B.S. and Prof. Adjoint, Dept. of Physics and Astrophysics, Univ. of Colorado.
[1]G Ecker, W. Kröll, K.H. Spatschek and O. Zöller, Phys. Fluids, 10, 1037 (1967).

DD2 Numerical Study of the Diffusion Controlled Positive Column.* E.F. JAEGER, J.T. MARISKA, L. OSTER** and A.V. PHELPS+, Joint Institute for Laboratory Astrophysics.--The model of the constant pressure, diffusion controlled positive column is solved numerically for the time and spatial dependence of the electron density and temperature and for the transient current and electric field. The results are consistent with the predictions of the analytical model.[1] The effect of variations in the product of pressure and radius and in the external resistance are considered. While the constant pressure approximation is satisfactory for steady state solutions, it is very difficult to find transient solutions for which the assumptions leading to the constant pressure approximation are valid. A movie showing some of the transient solutions will be shown.

*Supported in part by Advanced Research Projects Agency.
**Dept. of Physics & Astrophysics, Univ. of Colorado.
+Staff Member, Laboratory Astrophysics Division, N.B.S. and Prof. Adjoint, Dept. of Physics and Astrophysics, Univ. of Colorado.
[1]L. Oster and A. V. Phelps, Preceding paper.

DD3 Calculations and Measurements on Cs-Ar and Na-Ne Low Pressure D.C. discharges,* H. van Tongeren, Philips Research Labs., Eindhoven, The Netherlands.--Calculations have been made on a model of the positive column of d.c. discharges in Cs-Ar and Na-Ne mixtures, (P_{Cs}, P_{Na} = 0.1-2mTorr and P_{Ar}, P_{Ne}=5-10Torr). The model includes depletion of the metal atoms in the ground state and radiation trapping[1]. The radial Cs excited state ($6^2P_{1/2,3/2}$) density $n_2(r)$ was determined by absorption measurements using a calculated curve of growth. The experimental $n_2(r)$ values (e.g. at P_{Cs}=0.6mTorr, P_{Ar}=5Torr, R=1.5cm and I=0.2A, $n_2(r)=0.65\times10^{18}$ m^{-3}) agree within 50% with the calculated $n_2(r)$. For Na-Ne discharges, the measured electric fields E were found to agree within 15% with the calculated ones, also in the current regime where E(I) starts to rise with increasing I due to the depletion of Na atoms.

* Submitted by R. Bleekrode

1 For calculations and measurements on T_e and Cs ground state atom density see: H. van Tongeren, Phys.Letters, 37A, 317 (1971).

DD4 Density of Excited Atoms under Non-equilibrium Conditions.* C.VAN TRIGT and J.B. VAN LAREN, Philips Research Labs., Eindhoven, Netherlands.--We present the numerical solutions of the coupled continuity equations for the densities of electrons and of excited atoms in the $3P_{1/2,3/2}$ levels of Na, under non-equilibrium conditions (stationary Na-discharge in ≈ 5 Torr Ne, gas temperature T≈260 °C). The Biberman-Holstein integral equation is numerically solved. The results are compared with those obtained, if simplifying approximations[1,2] are applied in the continuity equations for the excited atoms, showing that the radiative production may be over[1]- and underestimated[2] by a factor 2 at a degree of ionization $\geq$ 0,1.

* Submitted by R. Bleekrode

1 C. Kenty, Phys.Rev. 42, 823 (1932); M.A. Cayless, Brit.J.Appl.Phys. 14, 863 (1963).

2 J.F. Waymouth, F. Bitter, J.Appl.Phys. 27, 122 (1956).

DD5 Electron Kinetic Processes in N_2 Discharges.* W. F. BAILEY and W. H. LONG, Aerospace Research Laboratories, WPAFB, Ohio -- Electron energy distributions have been obtained for electrically excited N_2 by expanding the distribution function in spherical harmonics and numerically solving the Boltzmann equation for conditions typical of glow discharges. Vibrational and electronic excitation of N_2 dominate electron energy exchange processes in the discharge, therefore the effects of these collisions were included in the higher order terms of the expansion. A resulting significant decrease in excitation and ionization is calculated. Also, the inclusion of superelastic collisions in the calculation reveals the important effect of vibrational "temperature" on the electron energy distribution. The calculated electron energy distributions were markedly non-Maxwellian, and the velocity distribution highly anisotropic. The implications of this departure from isotropy to Langmuir probe theory will be discussed.

*Submitted by A. GARSCADDEN

DD6 Nitrogen Positive Column Model.* W.H. LONG, Jr., and W.F. BAILEY, Aerospace Research Laboratories, WPAFB, Ohio.--The macroscopic properties of a medium pressure (1-20 Torr) nitrogen discharge are determined by: a) ambipolar diffusion of charged particles, b) translational heating of the background gas, and c) diffusion of metastable excited states. Electron drift velocity, mean energy and excitation rates are taken from a numerical solution of Boltzmann's equation, coupled to the reduced moment equations of the three species (neutrals, electrons, metastables), and solved by test functions to yield explicit relations between current, electric field, pressure, gas temperature, and tube radius. It is found that two-stage ionization is the dominant charged particle production process above a few milliamps in this pressure range and that the negative characteristic and resulting instability of the discharge are strictly thermal effects. These conclusions are strongly supported by experimental measurements of temperature and sidelight radiation.

*Submitted by W.G. BRAUN.

DD7 Cumulative Ionization in Nitrogen. W. F BAILEY, W. H. LONG, JR., P. BLETZINGER, and A. GARSCADDEN, Aerospace Research Labs, WPAFB,O.-- Measurements of the 3914A ion line intensity versus current in a N_2 glow discharge show a nonlinear behavior. Using the computed electron energy distributions, it is possible to model the discharge including gas flow. The excitation and ionization rates (and 3914A line intensity) are then obtained as functions of discharge current, total pressure and position Comparison with experiment gives a lower limit to the cross section for cumulative ionization The calculations also show its influence on the axial gradients of E, gas temperature and metastable population in the presence of flow above a few milliamps cm^{-2} at pressures >1 Torr. The modelling is sensitive to the gas temperature, therefore the gas temperature was measured from the rotational intensities of the 3914 and 3805A bands and the model checked for consistency.

SESSION ED

Tuesday evening, 17 October

20h30

Room 200

GLOW DISCHARGE II

Chairman: Alan Watson
University of Western Ontario
London, Ontario

ED1
Glow Discharge Mass Spectrometry with Sputter-injection of Trace Elemental Species. J. W. Coburn, E. Taglauer, & Eric Kay, IBM Research Laboratory, San Jose, CA. The mass and energy spectra of ionic species generated by the sputter-injection of trace neutral primarily elemental species into both rf and dc abnormal glow discharges have been used to study ionization[1] and collisional processes for trace species in glow discharges. Sputter-injection of trace species is a convenient controllable method of introducing uniformly almost any combination of elemental species into a glow discharge. Data will be presented showing the extent to which the following ionic species are observed when material X is sputter-injected into a glow discharge of inert gas R : X^+, X^{++}, X_2^+, XR^+, and XR^{++}.

1. J. W. Coburn & Eric Kay. Appl. Phys. Letters 18 435 (1971)

ED2 Positive Ion Ratio Measurements in Noble Gas Glow Discharges.* R.L. FITZWILSON and L.M. CHANIN, University of Minnesota. Molecular-to-atomic ion ratios have been studied in capillary discharges of helium, neon and argon over the normalized pressure range 0.1 to 30 Torr and for discharge currents between 15 and 40 ma. Ions emerging from a small sampling orifice in the wall of the discharge tube were analyzed by a quadrupole mass spectrometer and detected by an ion multiplier. A time-resolved ion sampling technique has been employed to investigate the influence of moving striations on measured ion ratios. Ion ratios were found to be only weakly dependent on discharge current. Functional dependence of measured ratios on discharge pressure may be qualitatively described by multi-component continuity equations.

*Work supported by Air Force Cambridge Research Laboratories.

ED3 The Glow to Arc Transition. MICHAEL A LUTZ Hughes Res. Labs. --The glow to arc transition (GAT) on tantalum has been studied using helium at 0.1 Torr with a specially designed crossed field discharge. An RC circuit (300 μs time constant) provided an initial 10 A/cm^2 over a well defined cathode surface area at a discharge voltage of 500 V. The GAT rate exhibited a life history which can be divided into three phases. The first "conditioning" phase had an initially high, but continually decreasing, GAT rate. The second "operational" phase was characterized by a low (<0.1%), essentially constant GAT rate. The final "terminal" phase occurred after 50,000 pulses, distinguished by a sharply rising GAT rate. These results are in good qualitative agreement with the work of Holliday and Isaacs[1] who used platinum and hydrogen in a different discharge mode with higher voltage. The implication is that the GAT is relatively insensitive to electrode material, ionic species, and discharge voltage. These findings lend additional credence to the hypothesis that insulating surface particles or inclusions are responsible for the GAT.

[1]J.H.Holliday and G.G.Isaacs, Brit.J.Appl.Phys. 17, 1575 (1966).

ED4 The Effect of Electron De-excitation and Self-Absorption on the Intensity of the Hg 2537Å Line in Hg+Ar Discharges. T.J. HAMMOND and C.F. GALLO, Xerox Research Laboratories. - In Hg + 5 Torr Ar discharges, curves of the Hg 2537Å intensity vs. current (power) at various constant Hg pressures (from 0.2 to 200 millitorr) have been obtained. The Hg 2537Å intensity initially rises linearly but then tends to bend over and approach an asymptotic limit. It is shown that the non-linear, asymptotic behavior is due to electron de-excitation of the Hg 6^3P_1 state at the higher currents. The variation in Hg 2537Å intensity with Hg pressure can be examined more clearly from a different viewpoint. The Hg 2537Å intensity was measured as a function of Hg pressure at various constant currents (powers). The intensity rises to a peak (which defines an optimum Hg pressure) and then decreases with further increases in Hg pressure due to self-absorption. It is shown that the optimum Hg pressure decreases with increasing current, particularly for small diameter lamps at high powers. These last results are at variance with the literature. Again the behavior is described by the detailed balance between the Hg 6^3P_1 de-excitation rate due to electrons versus the de-excitation rate due to radiation as inhibited by self-absorption.

ED5 *Characteristics of High Pressure Pulsed Gas Discharge, R. L. SCHRIEVER, Lawrence Livermore Laboratory. The dynamic current-voltage characteristics of high pressure double discharge and resistively-loaded pin type gas discharge tubes have been measured. Experiments show that the electrical discharge in each tube is a pulsed, glow discharge. A single description of the discharge applicable to each of these devices is presented. The physics of low pressure dc glow discharges is extended to the high pressure, pulsed case discharge description allows scaling these devices to larger sizes and higher pressures. Significantly, these discharges are found to operate as constant voltage devices. The ratio of electric field to gas pressure (E/p) is found to be approximately constant for a given gas mixture and independent of the external capacitor voltage. Thus it is possible to describe an equivalent circuit for the discharge allowing design of appropriate external circuitry for pulsed, high pressure lasers.

*Work performed under the auspices of the U.S. Atomic Energy Commission.

ED6

Electron Temperature Variations in Deeply Modulated Plasma Columns*. C.J.BURKLEY and M.C.SEXTON, University College,Cork,Ireland --- An 11.5 GHz microwave radiometer was used to monitor electron temperature variations in argon and krypton plasma columns by means of a sampling process involving PIN diode switching. Temperature variations as low as 0.04 db (100^{o}K) were recorded in 0.5A columns current modulated up to 85% with sinusoidal and triangular waveforms.

*Work supported in part by the US Air Force Office of Scientific Research

ED7 Fission Fragment Produced Plasmas

R.A. Walters and R.T. Schneider, University of Florida

Fission fragments are being considered as an excitation source for nuclear pumped lasers. Spectroscopic studies were undertaken to measure plasma properties of fission fragment generated helium and argon plasmas. A plasma source of high luminescence was obtained by inserting a $U_3^{235}O_8$ coated Vycor tube filled with argon into a thermal neutron flux of 3×10^{11} n/sec cm^2. The fission fragment produced plasmas contain ionized and multiple ionized species (He II, Ar II and Ar III). The intensities of the observed lines are linearly dependent on reactor power. Application of an external electric field (no discharge) increases the line intensities up to 10 per cent. This increase is also a linear function of reactor power.

Several of the excited state population densities of argon were found to differ from a Maxwellian distribution. Also transitions not readily observable in a glow discharge in the same device were obtained (He II 4685 and 3203).

SESSION F

Wednesday morning, 18 October

8h30

Room 200

SPECIAL PROGRAM

ON APPLICATIONS OF GASEOUS ELECTRONICS

Chairman: David J. Rose
Massachusetts Institute of Technology
Cambridge, Massachusetts

SESSION G

Wednesday afternoon, 18 October

13h00

Althouse College Cafeteria

GEC BUSINESS MEETING

OVER LUNCH

Chairman: Gordon H. Dunn
Joint Institute for Laboratory Astrophysics
University of Colorado
Boulder, Colorado

SESSION HC

Wednesday afternoon, 18 October

14h00

Room 200

METASTABLES PANEL

Chairman: H. Hotop
Joint Institute for Laboratory Astrophysics
and Freiburg

HC1 Metastable Hydrogen Atom Quenching Collisions.* J.A.Medeiros**,F.W.Byron,Jr., and R.V.Krotkov. Univ. of Mass., Amherst, Mass.
A number of experiments measuring the cross section for collisional quenching of metastable hydrogen atoms, H(2s), at keV energies have been reported in the literature. Systematic differences among the reported measurements have been noted; a series of experiments which tend to support our previously published results will be discussed. New measurements of the quenching cross section for H(2s) collisions with a neon target at impact energies between 1.0 and 30.0 keV will also be presented. The quenching cross section for neon has been found to be very similar to that for a helium target. In addition new calculations of the cross section for quenching at keV energies will also be discussed. The cross section is calculated in the eikonal approximation using a pseudopotential to represent the target atom.

* Research supported by National Science Foundation.
**Present address, University of Western Ontario, London Canada.

HC2
DEEXCITATION OF FAST $He^*(2^1S)$, $He^*(2^3S)$, AND $Ne^*(^3P)$ IN VARIOUS GASES.† J. T. Moseley, J. R. Peterson, D.C. Lorents, and M. Hollstein,‡ Stanford Research Institute, Menlo Park, California 94025

The deexcitation of $He^*(2^1S)$ and $He^*(2^3S)$ by N_2 and Ar has been studied both by an optical technique and by collecting the slow Penning ions formed in the deexcitation. The optical technique allows absolute cross sections to be determined independently for both singlets and triplets over the energy range from 150 to 1600 eV. The slow ion technique was used to determine the total deexcitation cross section for a mixed He^* beam in N_2 and Ar, and for $Ne^*(^3P)$ in Ar, from 50 to 600 eV. The cross sections all lie in the range of 7-20Å^2, and decrease with increasing energy. The results are compared with recent calculations of Olson.[1,2]

* This work was supported by the Office of Naval Research
[1] R. E. Olson, Chem. Phys. Letters 13, 307 (1972).
[2] R. E. Olson, Phys. Rev. (to be published).
‡ Present address: Dornier GmbH, Friedrichshafen (Bodensee), West Germany)

HC3 Quenching Effect of Helium 2 micron Light on a Weak Helium Discharge. A. C. TAM, H. TANG, and W. HAPPER, Columbia U. -- The 2 micron light ($2^1S - 2^1P$) from bright Helium lamps is found to decrease the current of a weak Helium discharge. For small light flux, it is found that the current decrease (for a fixed discharge voltage and ballast) is proportional to the flux of the incident 2 micron light. At a strong enough light flux, the discharge could be stopped altogether. The triplet metastable density is also decreased by the 2 micron light. Since the 2 micron light actually depletes the singlet metastable density, the above quenching effect indicates that (1) singlet-triplet metastable conversion is rapid in a weak Helium discharge, (2) electron-metastable or metastable-metastable collisions give an important contribution to the observed current in a weak Helium discharge. A simple theory of the effect will be presented.

HC4 Excitation Transfer from 2P Atomic States to Molecular States in High Pressure Helium.* P.E. Theiss and G.H.Miley, Univ.of Ill. --Two-body collisional transfer of excitation in high pressure He from 2^3P and 2^1P to $3^3\Sigma$ and $3^1\Sigma$, has been studied via measurements of optical line intensities vs gas pressure(1 to 760Torr). Such transfer was postulated for 2^1P by Stewart et al.(1) to explain vacuum uv continua obtained from proton irradiation of He and is analogous to the Hornbeck-Molnar process. The present work covers 3400 to 9000Å including the cascades into 2P levels and the 6400 and 6594 molecular bands. Excitation was produced in a cylindrical "ion chamber" by a Po210 alpha source. As He_2 is primarily lost by diffusion, the molecular bands observed are attributed to collisional transfer rather than recombination. Studies of the atomic and molecular intensities were also made as a function of an applied radial field [$0 \leq E/P < 25$V/cm-Torr]. The threshold for multiplication of the molecular bands is similar to that for the 2P levels, and the gain follows that of the cascade photons once the voltage reaches a point where higher atomic levels are also excited. Since at high pressure, triplet states have larger populations than singlets, the 6400 band is stronger than the 6594 one.

(1)T.E.Stewart,et al.,JOSA, 60, 290(1970) *Work supported in part by AEC,NSF and Kettering Fnd.

HC5 Velocity Dependence of the Cross Section for the Quenching of $^3P_{0,2}$ Argon in Collisions with Molecular Oxygen.* M. E. GERSH and E. E. MUSCHLITZ, Jr., UNIVERSITY OF FLORIDA. --Measurements of the cross section for the collisional quenching of $^3P_{0,2}$ Ar* by O_2 have been performed with the use of an apparatus that has been described previously.[1] A velocity selected beam of Ar* (of known composition) enters a collision chamber within which a fraction of the beam particles transfer their excitation energy to the target gas. In the velocity range investigated (180-1650 m/sec), the cross section is roughly constant at approximately 40 $Å^2$.

* Supported by the National Science Foundation.

1 S. Y. Tang, A. B. Marcus, and E. E. Muschlitz, Jr., J. Chem. Phys. 56, 566(1972).

HC6 Quenching of Vibrationally-Excited N_2 by N_2O*. M. E. WHITSON, JR., G. R. COOK, and R. J. McNEAL, Aerospace Corp.--We have utilized a vacuum ultraviolet photoionization detection technique to measure the rate coefficient for the transfer of energy from vibrationally-excited nitrogen (N_2^*) to N_2O. The rate coefficient for the transfer reaction (k_1) is obtained from the reduction of the photoion count rate when N_2O is added to a flowing N_2 afterglow. At low N_2 pressures, the effective quenching rate asymptotically approaches k_1, which we find to be $9 \pm 4 \times 10^{-14}$ cm^3 sec^{-1}. At higher N_2 partial pressures, quenching of N_2^* is governed by the loss processes of vibrationally-excited N_2O, including gas phase quenching, wall deactivation, and radiation. Our result for k_1 is lower than the value obtained elsewhere for the rate coefficient of the reverse reaction from studies of quenching of laser-induced N_2O fluorescence by N_2.[1]

*Work done under USAF Contract F04701-72-C-0073

[1]J. T. Yardley, J. Chem. Phys. 49, 2816 (1968).

HC7 Quenching of Vibrationally-Excited N_2 by Atomic Oxygen*. R. J. McNEAL, M. E. WHITSON, JR., and G. R. COOK, Aerospace Corp., --A recently developed[1] photoionization technique for detection of vibrationally-excited nitrogen (N_2^*) has been applied to study of the quenching of N_2^* by O at 300°K in a double discharge-flow experiment. The products of an N_2-He discharge were mixed with the products of an O_2-He discharge, and the reduction in the N_2^* photoion count rate below that observed when the O_2-He discharge was off was analyzed to obtain the quenching rate coefficient, k. The O density was determined by NO_2 titration with the N_2-He discharge off. We find that $k = 3.5 \pm 1.4 \times 10^{-15}$ cm^3 sec^{-1}. The anomalously efficient vibrational relaxation observed in the N_2^* - O system at high temperatures[2] is therefore found to occur at 300°K.

* Work done under USAF Contract F04701-72-C-0073

[1] R. J. McNeal and G. R. Cook, J. Chem. Phys. 56, 1388 (1972).

[2] W. D. Breshears and P. F. Bird, J. Chem. Phys. 48, 4768 (1968).

HC8
CHEMIIONIZATION IN COLLISIONS BETWEEN $He(2^1S)$ AND $He(2^3S)$ AND H-ATOMS.* J. S. Howard, J. P. Riola, R. D. Rundel and R. F. Stebbings, Rice University, Houston, Texas.

Chemiionization in collisions of $He(2^1S)$ and $He(2^3S)$ metastable atoms with atomic hydrogen has been studied at thermal energy using a crossed beams apparatus. Absolute cross-sections have been measured for total ion production and for the production of H^+ and HeH^+ ions for each metastable species. These results will be presented and discussed in the light of other experimental and theoretical information.

* Work supported in part by the Atmospheric Sciences Section, National Science Foundation, NSF Grant GA 27169.

HC9 Associative Ionization in Low Energy Collisions Between Metastable Helium and H and D.* G. D. MAGNUSON and R. H. NEYNABER, Gulf Radiation Technology, San Diego, Calif. -- The exothermic reactions $He^* + H \rightarrow HeH^+ + e$ and $He^* + D \rightarrow HeD^+ + e$ have been studied by a merging-beams technique over a range of interaction energy W from 0.05 to 10 eV. The He^* beam was a composite of $He(2^1S)$ and $He(2^3S)$. Data were obtained by observing signals due to the product ions. For each process the relative effective cross section (i.e., for the composite He^* beam) as a function of W is the same and monotonically decreases with increasing W in good agreement with the theoretical predictions of Miller et al.[1] for associative-ionization collisions of $He(2^3S)$ with H. From the data and the reasonable assumption of a statistical distribution for the states of He^*, the absolute value at W=1 eV for either process, where He^* is $He(2^3S)$, is 2.2×10^{-17} cm^2 with an estimated error of +42% and -31%. Miller et al. obtain a value of 2.5×10^{-17} cm^2.

*The study was supported by the Air Force Office of Scientific Research, Contract No. F44620-70-C-0096.

[1]W.H. Miller, C.A. Slocomb, and H.F. Schaefer III, J. Chem. Phys. 56, 1347 (1972).

HC10 HeH^+ Formation from Low-Energy Collisions of Metastable Helium and Molecular Hydrogen.* R. H. NEYNABER, G. D. MAGNUSON, and J. K. LAYTON, Gulf Radiation Technology, San Diego, Calif. -- The formation of HeH^+ resulting from the interaction of a composite beam of $He(2^1S)$ and $He(2^3S)$ with a beam of H_2 has been studied by a merging-beams technique. The experiment consisted of measuring the lab energy distributions of HeH^+ over a range of interaction energy W from 0.05 to 10 eV. The dominant process for producing HeH^+ is $He^* + H_2 \rightarrow HeH^+ + H + e$. The data indicate that energy can only be conserved by assuming that the electron carries away a substantial portion of the available energy. The two-step model $He^* + H_2 \rightarrow He + H_2^+(v) + e \rightarrow HeH^+ + H + e$ satisfactorily explains the measured lab-energy distributions near W = 0.05 eV but not the results for $W \geq 2$ eV. The distributions indicate that, in the center-of-mass system, most of the HeH^+ is scattered in the direction of the incident He^*. The energies associated with the HeH^+ at the peaks of the distributions are very close to those expected for spectator-stripping.

*The study was supported by the Air Force Office of Scientific Research, Contract No. F44620-70-C-0096.

SESSION KC

Thursday morning, 19 October

8h30

Room 200

LIFETIMES AND SPECTRA

Chairman: S. David Rosner
University of Western Ontario
London, Ontario

KC1 Radiative Lifetimes of the $c^1\Pi$, $A^3\Pi$, and $d^1\Sigma$ States of NH*. R. ANDERSON, Univ. of Missouri-Rolla.--The radiative lifetime of the $c^1\Pi$, $A^3\Pi$, and $d^1\Sigma$ states of NH were measured at five or six different pressures. The $c^1\Pi$ and $A^3\Pi$ states exhibited a pressure dependence. The lifetime of the $c^1\Pi$ state for v'=0 was shorter than measured by Fink and Welge[1] and Smith[2] and the lifetime was longer for v'=0 level of the $A^3\Pi$ state but in close agreement for v'=1. The $d^1\Sigma$ state exhibited two exponential decays at low pressures. The long lived component had a lifetime of 359±8ns and the short lived component had a lifetime of 73±6ns which is in serious disagreement with the results of Smith[2].

*This research was supported by the Office of Naval Research under contract NOOO14-69A-0141-0004.

1. E.Fink and K.H. Welge, Zeut. Naturforoch, 19a, 1193 (1964).
2. W.H.Smith, J.Chem.Phys., 51, 520 (1969).

KC2
RADIATIVE LIFETIMES OF $N_2^+(A^2\Pi_u)$: THE MEINEL BAND SYSTEM.* J. R. Peterson and J. T. Moseley, Stanford Research Institute, Menlo Park, California 94025

The radiative lifetimes of $N_2^+(A^2\Pi_u)$ have been determined for v'=1-8 using an improved version of the time-of-flight apparatus used earlier.[1] The lifetimes decrease from 13.9 ± 1 μsec for v'=1, to 7.3 ± 0.5 μsec for v'=8. Results for v'=2-5 agree well with the recent time-of-flight work of Holland and Maier.[2] An analysis of the data by D. C. Cartwright[3] accurately defines the transition moment and its dependence on internuclear separation. Measurements using pulsed excitation of N_2 have all yielded shorter lifetimes, apparently due to collisional and diffusion effects.

* Work supported by ARPA through the ONR.

[1] M. Hollstein, D. C. Lorents, J. R. Peterson, and J. R. Sheridan, Can. J. Chem. 47, 1858 (1969).
[2] R. F. Holland and W. B. Maier II, J. Chem. Phys. 56, 5229 (1972).
[3] D. C. Cartwright (Aerospace Corp.), private communication.

KC3 Emission from Long-Lived States of N_2^+. Relation to $N_2^+ + N_2 \rightarrow N_3^+ + N$. W. B. MAIER II and R. F. HOLLAND, Los Alamos Scientific Laboratory--Spectra of light emitted from beams of ions produced by electron impact on $^{30}N_2$ and $^{28}N_2$ have been obtained for wavelengths between 3200 and 6000Å. With a spectral resolution of 3Å several hundred peaks are found in the spectra. Many peaks are very near wavelengths expected for $N_2^+ A^2\pi_u \rightarrow X^2\Sigma_g^+$ bands, for A states having quantum vibrational numbers v' as large as 30. Emission bands produced by A → X can be definitely identified for $v' \leq 18$, but the identifications of bands corresponding to $v' > 18$ are less certain. The apparent lifetimes of these emissions are 6-7 μsec. The apparent lifetimes, the populations of the upper states corresponding to $v' \geq 10$, and the electron energy dependences are similar to those found for the N_2^+ states involved in (1) $N_2^+ + N_2 \rightarrow N_3^+ + N$ at low collision velocities. Thus the N_2^+ states involved in reaction (1) may be primarily A states having $v' \lesssim 10$ and not, as previously postulated, the quartet states.

KC4
Relative intensity measurements on the Fox-Duffendack-Barker and Ultraviolet Doublet Band Systems of CO_2

J.C.McCallum and R.W.Nicholls
Centre for Research in Experimental Space Science,
York University, Toronto

The Fox-Duffendack-Barker and Ultraviolet Doublet Band Systems of CO_2 have been stably excited in the hollow cathode of a high voltage discharge through CO_2-O_2. Relative photoelectic intensity measurements were made on the bands of both systems. The measurements agree well with the authors' calculations of realistic Franck-Condon factors for the systems. The intensity measurements also reveal an apparent population inversion in the vibrational levels of the $A^2\Pi$ state of CO_2

* Supported by research grants from the National Research Council of Canada and from the Defence Research Board of Canada

KC5 Electron and Photon Excitation of CF_4. * W. A. BROWN, Lockheed Palo Alto Research Laboratory.--Fluorescence is observed when CF_4 is irradiated by photons of wavelength between 870 and 930Å.[1] The present work includes spectral analysis of the UV induced fluorescence and comparison with the spectrum excited by electrons in the energy range 10 to 200 eV. When CF_4 is excited by 920Å photons, a continuum between 2100 and 3150Å is produced. Excitation with electrons of 14 to 22 eV yields a similar continuum with short wavelength limit of 1850Å. Analysis of the energies of excitation and photon emission leads to the conclusion that the final state produced by these processes consists of ground state CF_3 + F. Electrons of energy above 22 eV produce an additional emission continuum at 1540 - 1700Å.

* Supported by Ames Research Center NASA Contract NAS2-6573 and Lockheed Independent Research Program.

[1] Cook, G. R. and B. K. Ching, J. Chem. Phys. 43, 1794 (1965).

KC6 Measurement of Vibrational Population Distributions in a Hydrogen Plasma, J.A. BURT, York University, Toronto, Ontario.--The vibrational populations of H_2^+ have been measured in a weak plasma by photodissociating H_2^+. Through the use of high pressure the method presents some simplifications over the techniques of Dunn[1]. A quadrupole mass spectrometer samples the ion flow which is crossed by filtered light from a xenon arc lamp. We report the first measurements of the photodissociation of H_3O^+ and O_2^+ in the visible. The technique may be useful for studying vibrational population distributions in lasers. Negative ion photodetachment has also been studied.

[1] Phys. Rev. 5, 1726 (1972)

KC7 Van der Waals Broadening of Neutral Argon.* D.M. CAMM, F.L. CURZON, G.H. COPLEY, S. LEE. Univ. of British Columbia, Canada.--Van der Waals Broadening due to Argon-Argon collisions has been measured using the resonant Faraday effect. This effect occurs for radiation at frequencies close to the absorption lines of magneto active material. Identical argon glow discharges were used for the source and absorber and the results were analysed assuming a Voigt profile. It was found that the broadening scaled with angular momentum in agreement with the simple Van der Waals theory(1) but the magnitude was larger than predicted.

(1) Griem H., 1964, Plasma Spectroscopy, (McGraw-Hill, New York) pp 98-102.

* Work supported by national research council of Canada.

KC8 Determination of Van der Waal's Broadening of FeI Emission Lines Induced by Neutral He.* G.H. COPLEY and D.M. CAMM, Univ. of British Columbia, Vancouver, Canada.--The Van der Waal's broadening coefficients for a number of FeI emission lines in the wavelength range of 3600-5000 Å have been measured at pressures of up to 200 Torr of He in a glow discharge. Accurate lineshape measurements on a small number of lines were carried out with a scanning Fabry-Perot interferometer using "lock-in" detection techniques while slightly less accurate line widths were obtained for a larger number of lines from photographic recording of the Fabry-Perot pattern. The measured coefficients are approximately 50% larger than those predicted by the formulae of Griem.[1] They are, however, in reasonable agreement with the line-broadening calculations of Fullerton and Cowley[2] who have considered the effect of higher order terms in the interaction potential between two neutral atoms.

* Work supported by the National Research Council of Canada.

[1]. Griem, H.R. Plasma Spectroscopy (New York: McGraw-Hill Book Co. 1964)

[2]. Fullerton, W. and Cowley, C.R. Astrophys. J. 165, 643 (1971).

SESSION LC

Thursday morning, 19 October

10h45

Room 200

NEGATIVE IONS

Chairman: T.O. Tiernan
Chemistry Research Laboratory
Wright Patterson Air Force Base, Ohio

LC1 Dye-Laser Photodetachment of OH^- and OD^-.*
H. HOTOP,† T. A. PATTERSON, Joint Institute for Laboratory Astrophysics, and W. C. LINEBERGER,‡ JILA and Dept. of Chemistry, Univ. of Colorado.--Using a tunable dye-laser with 0.5-1 Å bandwidth, we have investigated the photodetachment cross section of OH^- and OD^- ions in the range 7000-6400 Å. A detailed analysis of the observed cross section is made on the basis of the known term values for OH and $OD(X^2\Pi_i)$ and the experimental result[1] that $r_e(OH^-,OD^-)=r_e(OH,OD)$ to within .001 Å. The electron affinities are found as: EA(OH)=(1.826 ± 0.002)eV, EA(OD)=(1.823 ± 0.002)eV, in agreement with Branscomb's number (1.83 ± 0.04)eV, extracted from a low resolution experiment.[2]

[1]R. Celotta and R. A. Bennett (private communication).
[2]L. M. Branscomb, Phys. Rev. 148, 11 (1966).
*Work supported by the Advanced Research Projects Agency.
†On leave from Fakultät für Physik, Universität Freiburg, Germany. Support by the Deutsche Forschungsgemeinschaft is gratefully acknowledged.
‡Alfred P. Sloan Foundation Fellow, 1972-1974.

LC2 Laser Photodetachment Studies of Cu, Ag, Au, and Pt Negative Ions.* H. HOTOP,† R.A. BENNETT, Joint Institute for Laboratory Astrophysics, and W.C. LINEBERGER,‡ JILA and Dept. of Chemistry, Univ. of Colorado.--Photodetachment of Au^- and Pt^- is studied by use of a tunable dye laser of 1-2 Å bandwidth. The threshold behavior of the cross section is that for outgoing p-wave electrons and agrees with Wigner's law over at least 50 meV above threshold. The electron affinities are found as: EA(Au)=(2.3086±0.0007)eV, EA(Pt)=(2.128±0.002)eV. In a different experiment, the energy spectrum of electrons detached from Cu^- and Ag^- ions by an Ar-ion laser beam is measured together with those from O^- and OH^- ions. We obtain EA(Cu)=(1.226±0.010)eV, EA(Ag)=(1.303±0.010)eV. Earlier experimental results (surface ionization)[1] and theoretical calculations (for Cu)[2] differ from our EA's by about 0.5 eV.
[1]E. Ya. Zandberg et al., Sov. Phys.-Tech. Phys. 16, 832 (1971) and references therein.
[2]W. H. E. Schwarz, Chem. Phys. Letters 10, 478 (1971).
*Work supported by the Advanced Research Projects Agency.
†On leave from Fakultät für Physik, Universität Freiburg, Germany. Support by the Deutsche Forschungsgemeinschaft is gratefully acknowledged.
‡Alfred P. Sloan Foundation Fellow, 1972-1974.

LC3 Measurement of the Electron Affinity of NO_2*. C.B. Leffert, W.M. Jackson and E.W. Rothe, Wayne State University--The translational energy dependence of the relative cross section for $Cs + NO_2 \longrightarrow Cs^- + NO_2$ has been measured in the threshold region using crossed molecular beams. Good energy resolution in the center-of-mass is obtained with a time-of-flight technique for the Cs primary beam and by numerical analysis of the remaining c.m. energy spread. The data are well represented by convoluting a c.m. cross section with the experimental energy spreads. The threshold yields the adiabatic electron affinity of NO_2: 2.54 ± 0.05eV. Strictly this electron affinity is a lower limit. The results are consistent with a previous study of this reaction.

*Research sponsored by U.S. Air Force Office of Scientific Research, under Grant AFOSR-69-1799, and by the Army Research Office - Durham.

LC4 Molecular Electron Affinities from Collisional Ionization of Cesium: SF_6 and TeF_6.* R.N. COMPTON, C.D. COOPER,† W.T. DIVVER,‡ and P.W. REINHARDT, Oak Ridge National Laboratory.--The relative cross sections for the production of mass selected negative ions resulting from collisions of Cs with SF_6 and TeF_6 have been studied as a function of the incident cesium atom energy from 0 to 40 eV. Electron affinities (EA) are derived from the threshold for ion-pair production with the results $EA(SF_6) = 0.4 \pm 0.2$ eV and $EA(TeF_6) = 3.4 \pm 0.2$ eV. Maxima in the cross sections for production of SF_6^- and TeF_6^- are observed at ~6 eV and ~5 eV (c.m.), respectively. In both cases the cross sections begin to rise again at ~10 eV (c.m.). These results will be discussed in relation to the electron attachment properties of these molecules.

*Research sponsored by the U.S. Atomic Energy Commission under contract with Union Carbide Corporation.

†Consultant from Dept. of Physics, Univ. of Georgia, Athens, Ga.

‡Graduate student, University of Georgia, Athens, Ga.

LC5 Negative Ion Formation in OCS* J.P.ZIESEL and G.J.SCHULZ Yale U.--Dissociative attachment of low energy electrons to OCS has been studied using a monoenergetic electron beam and mass analysis. The threshold for S^- production from OCS occurs at 0.95 eV and the cross section peaks at 1.35 eV. The threshold value for S^- formation, combined with the known electron affinity[1] of S (2.077 eV) yields the OC-S dissociation energy of $\leq$ 3.1 eV. Comparison of the energy dependence of S^-/OCS with O^-/CO shows that, whereas O^-/CO does have a vertical onset, S^-/OCS does not. A similar situation prevails[2] in CO_2, where the first onset for O^- formation is also non-vertical although the CO_2^- shape resonance exists below the onset for O^- formation, and thus a vertical onset would be expected on a diatomic model. It appears that in these triatomic molecules a small amount of kinetic energy of the fragments is needed for dissociative attachment to become maximized.

*This work was supported in part by DASA through AROD.
[1]W. C. Lineberger and B. W. Woodward, Phys. Rev. Letters 25, 424 (1970).
[2]A. Stamatovic and G. J. Schulz, to be published.

LC6 Temperature Dependence of Electron Attachment at Low Energies for Polyatomic Molecules.* D. SPENCE+ and G. J. SCHULZ, Mason Lab., Yale U.--The cross sections for production of negative ions by attachment of low-energy (< 0.2 eV) electrons to selected polyatomic molecules have been determined for target gas temperature in the range from 300°K to 1200°K. For SF_6, it is found that the total cross section for negative ion production is independent of gas temperature, although Chen & Chantry[1] have shown the relative abundances of different species of negative ions produced from SF_6 to be strongly temperature dependent. In contrast to SF_6, the total cross section for negative ion production in some halogenated hydrocarbons are found to be strongly temperature dependent, with the total cross sections approaching an absolute maximum as the gas temperature is increased.

*Work supported by DASA through AROD and ARPA through ONR.
+Present address: Argonne National Lab., Argonne, Ill.
[1]C. L. Chen and P. J. Chantry. Bull. Am. Phys. Soc. Ser. II, 15, 418 (1970).

LC7 Dissociative Attachment in CO_2.* P.J. CHANTRY Westinghouse Research Laboratories--The production of O^- from CO_2 by dissociative attachment has been studied by electron beam techniques in the range 0-20 eV, with particular emphasis on establishing the reality[1,2] of peaks in the 10-20 eV region. One such peak, at 13 eV, is found to have a cross-section of approximately $6 \times 10^{-21} cm^2$ at room temperature, rising to $2 \times 10^{-20} cm^2$ at 1000^oK. This peak, and the already well-established peaks at ~ 4 eV and ~ 8 eV, have the appropriate[2] first order dependence on pressure. The measured O^- kinetic energy distributions for the ~ 4 eV and ~ 13 eV processes have a prominent peak close to zero energy. The ~ 8 eV process gives a prominent peak at ~ 0.6 eV, in addition to a peak close to zero energy. In all three processes only the high energy tails of the ion energy distributions are sensitive to the particular electron energy used. The general features of the distributions are interpreted in terms of the potential energy surfaces of the respective CO_2^- states.

*Supported in part by ARPA.

1. D.Rapp and D.D.Briglia, J. Chem. Phys. 43 1480 (1965)
2. P.J.Chantry, J. Chem. Phys. 55 1851 (1971).

LC8 Electron Transmission in Atomic Hydrogen* L. SANCHE† and P.D. BURROW Yale U.-- The resonances below the n = 2 level in atomic hydrogen have been studied using the electron transmission method. A trochoidal electron monochromator is used to produce a magnetically collimated electron beam having an energy resolution of 40 meV. Using the technique introduced by Sanche and Schulz,[1] the electron energy in the collision chamber is modulated and the derivative of the transmitted current is detected. Hydrogen atoms are produced by a microwave discharge in a Pyrex tube and effuse through a slit into the collision chamber. The three lowest resonances, ^1S, ^3P, and ^1D, are observed and their energies are in excellent agreement with the most accurate theoretical values. Structure in the total scattering cross section due to excitation of the n = 2 levels at threshold is also observed.

*Supported by the National Science Foundation.
†Present address: Dept. of Nuclear Medicine, C.H.U., U. of Sherbrooke, Sherbrooke, P. Q., Canada.
[1]L. Sanche and G.J. Schulz, Phys.Rev.A 5, 1672 (1972).

SESSION MD

Thursday afternoon, 19 October

14h00

Room 174

AFTERGLOWS 1

Chairman: R. Deloche
Centre d'Etudes Nucleaires
Saclay

MD1 Ambipolar to Free Diffusion: The Temporal Behavior of the Electrons and Ions.* R. A. GERBER and J. B. GERARDO, Sandia Labs.--Simultaneous measurements of the time dependence of the electron number density and the ion wall current in a helium afterglow are reported. The transition from ambipolar to free diffusion is investigated as a function of gas pressure and discharge tube size. The onset of the transition occurs when $\Lambda/\langle \lambda_D \rangle = 86$, where $\langle \lambda_D \rangle$ is the Debye length corresponding to the average electron or ion density, and Λ is the characteristic diffusion length of the vessel. The time dependence of the transition regime was found to depend only on $\Lambda/\langle \lambda_D \rangle$ if times are scaled as tD_+/Λ^2. This latter result is in agreement with high pressure theories which assume mean-free paths short with respect to experimental dimensions. The ion current changed by a factor of $(1.2 \pm 0.5) \times 10^5$ during the transition. The ions diffuse free of space-charge effects when $\Lambda/\langle \lambda_D^i \rangle$ is less than 0.25, where $\langle \lambda_D^i \rangle$ is the Debye length corresponding to the average ion density.

*Work supported by U. S. Atomic Energy Commission.

MD2 Spatial Distributions and Wall Currents for Charged Particles in Ionized Air Containing Water Vapor. F. E. NILES, M. D. KREGEL, and E. L. LORTIE, Ballistic Research Laboratories.--Calculations have been made for the spatial distribution of the concentrations for 59 species and the wall currents of the charged species in ionized air containing either 6 ppm or 0.6 ppm water vapor. The computer code employed a chemistry set consisting of 523 reactions of which 250 are mutual neutralization. Calculations were made for continuous ionization for a duration of 1000 sec and then for the plasma decay for 1 sec. The calculated wall currents as a function of time can be compared directly with the measured wall currents for the principal ions obtained by Hirsh and Eisner.[1] Implications of the agreements and disagreements will be discussed.

[1] M. N. Hirsh and P. N. Eisner, private communication.

MD3 Decay of $Cd(5^3P_1)$ and $Cd(5^1P_1)$-Atom Densities in a Cd-Ne Afterglow.* J.POLMAN and J.E.VAN DER WERF, Philips Research Labs, Eindhoven, Netherlands.--The $Cd(5^3P_1)$ and $Cd(5^1P_1)$-atom density decay in the afterglow of a cylindrical Cd-Ne discharge(R=1.3 cm, p_{Ne}=5 Torr, p_{Cd}=2-20 mTorr)has been measured as a function of current I ($.1 \leq I \leq 1$ A).The $Cd(5^3P_1)$-decay and the final $Cd(5^1P_1)$-decay are governed by inelastic e-Cd collisions, with decay time τ decreasing with increasing I, but τ longer than the effective radiative lifetime.In the early afterglow ($t<5$ μsec) the decay of $Cd(5^1P_1)$ is found to be determined by the trapped 228.8 nm radiation (for p_{Cd}=10 mTorr τ is 3 μsec). The above results agree reasonably with those of calculations with a discharge model,based on a 6-level scheme of Cd. The results of calculations with this model also agree with experimental data[1] on active Cd-Ne and Cd-Ar discharges, apart from the $Cd(5^1P_1)$-densities.

* Submitted by R.Bleekrode

1 R.H.Springer et al., J.Appl.P., 39, 3100(1968).

MD4 Diagnostics of Cesium Plasmas by a Tunable Organic-Dye Laser. D. T. Shaw, State Univ. of N.Y. at Buffalo--A Rhodamine 6G laser tunable in the range of 5700Å to 6100Å is used to selectively excite the 9D-6P 3/2 transitions (5847.5Å and 5845.14Å) and then study the transient decay of 9D 3/2 - 6P 1/2 (5664.02Å). The decay rate is a strong function of the (a) spontaneous transition coefficient, (b) collisional deOexcitation coefficient, (c) electron density, and (d) distribution of bound electronic states. If the transition coefficients (a and b) are known, the decay rate yields information about (c) and (d). The technique was first suggested by Measures[(1)] who showed theoretically the feasibility of the technique based on a 2-level atomic model. Our experimental results show that for quantitative interpretation of the measurements, a 5-level model has to be used (6S,6P,5D,7S,Lamped). The initial experimental results show when the electron density is 10^{12} cm^{-3}, the decay rate is 150 nsec. Two probes are placed inside the discharge tube to measure the electron temperature and density. As long as the laser radiation does not disturb the plasma (n_e and T_e ≈ constant) the responding decay time is a weak function of the electron temperature and the laser input power.

(1) R.M. Measures, J. Appl. Phys. 39, 5232 (1968)

MD5 Gas Temperature and Partial Pressure Dependence of Electron-Ion Kinetics of High Pressure He, Ne, N_2, and He-Ne, He-N_2 Gas Mixtures. W.H. Ellis and G.H. Sanders, U. of Florida.--Pulsed ionization chamber measurements, coupled with nuclear methods of ionization, have shown that the simple gas temperature dependence reported for Ne and N_2 and their mixtures with He at los pressures ($\sim$10 torr), i.e. $\alpha_2(ne)$ = const., $\alpha_2(N_2)$ = const. $T^{-3/2}$, remains valid for total gas pressures of $\sim$1 atm and ionization densities of 10^8-10^{11} cm^{-3}, while He exhibits a complex dependence which rises to a maximum at $\sim$450°K and then drops at a $T^{-9/2}$ dependence above $\sim$600°K. The latter can be explained in terms of the presence of He_3^+ at these pressures. The N_2 partial pressure dependence of α_2 shown by He-N_2 mixtures is flat in the range of 1-10 torr, where the N_4^+ ion has been seen to dominate plasma losses, while above 15 torr, the loss coefficient increases rapidly, indicating an increasing importance for higher condensation products such as N_6^+ to the overall plasma loss.

MD6 Columnar Recombination of Fission Fragment Produced Ionization in 10 atm He and 1 atm Ar-N_2. W.H. ELLIS, U. of Florida--The observation of an enhancement of the second order loss coefficient for fission fragment produced plasmas in 10 atm He and 1 atm Ar-N_2, over that measured for gamma rays and the $^3He(n,p)t$ reaction, is explained in terms of the columnar recombination theory by Wilhelm[1]. The excellent agreement obtained between the experiment and the predictions of theory (within 3-4%) lends considerable support for the validity of the fundamental assumptions of the theory. The fact that Wilhelm's theory for diffusion and recombination of ionization distributed initially in a high density column, involves only the ordinary volume recombination coefficient, and the excellent agreement obtained between theory and experiment, where the initial, local column density is $10^{16} cm^{-3}$, leads to the suggestion that, for high pressure gases, the volume recombination coefficient remains electron density independent even into the range of $10^{16} cm^{-3}$.

[1] H.E. Wilhelm, J. Chem. Phys. 47, 4356(1967).

SESSION ND

Thursday afternoon, 19 October

16h00

Room 174

AFTERGLOWS II

Chairman: Sanborn C. Brown
Massachusetts Institute of Technology
Cambridge, Massachusetts

ND1
Electron energy balance and distribution function in a helium afterglow. W.E. WELLS, P. MONCHICOURT, R. DELOCHE, J. BERLANDE, C.E.A. Saclay (France)
A theoretical model is presented to calculate the electron energy balance and distribution function, in a helium afterglow, taking into account all the electron heating and cooling processes presently known. Much of the electron heating, during the afterglow, is due to the relaxation of very energetic electrons produced by metastable-metastable collisions and metastable superelastic de-excitation. A very precise computation of the energy partition of these non-Maxwellian electrons, between the Maxwellian electron gas and the neutrals, is presented. The electron temperature is calculated under quasi steady state equilibrium condition. The electron energy distribution function is computed for several sets of afterglow conditions. The deviation from a Maxwellian distribution is examined in detail. It is shown that the metastable relaxation governs the electron energy balance and the distribution function, during the afterglow.

ND2
Electron Temperature measurement in a helium afterglow. R. DELOCHE, P. MONCHICOURT, W.E. WELLS, J. BERLANDE, C.E.A. Saclay (France) -
The electron radiation temperature decay has been measured in a helium afterglow, at 10, 20, 40 and 80 Torr, using a very sensitive microwave, X band radiometer. In our experimental conditions, the radiation temperature has been shown to closely approximate the electron temperature. The range of validity of the electron temperature measurements by radiometric technique is indicated. Experimental decay curves of the electron temperature are given as a function of electron density and compared with theoretical curves and other measurements. It is shown that the thermalization of the electrons to the gas temperature, during the afterglow, is very slow with respect to previous assumptions. An elevated electron temperature is observed for electron densities above 10^{11} cm^{-3}. The influence of the discharge conditions on the electron temperature decay curve has been studied.

ND3 The Temperature and Pressure Dependence of the Lifetime of Helium Singlet Metastable Atoms. Sister John C. Hungerman, Marygrove College, Detroit.--The lifetime of helium singlet metastable atoms has been measured as a function of pressure and temperature in a pulsed afterglow in helium. The loss of metastable is by diffusion to the walls of the container with subsequent deactivation, by collision with ground state atoms to form the $A^1\Sigma_u^+$ state of the helium molecule which then radiates to the dissociative ground state, and by two-photon radiation. The observed temperature dependence of the first process agrees well with the theories of Palkina and of Buckingham and Dalgarno. The temperature dependence of the second process yields an activation energy of about 0.025 eV, which, if interpreted as the height of the hump in the $A^1\Sigma_u^+$ curve, agrees well with calculated values. The two-photon decay rate is slightly higher than the theoretical values of Dalgarno and Jacobs.

ND4 Effect of Metastables on Statistical Time Lags in Helium.* B.M. LANCASTER, JR. and K.J. NYGAARD, Univ. of Missouri-Rolla.--Data from an experiment for measuring statistical time lags of an electrical discharge in helium are presented. The apparatus consisted of two pulsed discharge gaps in a cylindrical tube, one of these serving as a source of metastables, the other as a detector. The statistical time lag of the detector gap was measured as a function of time in the afterglow of the source. Under conditions where charged particles are prevented from reaching the detector by an electric field, the change in the statistical time lag of the detector yields the relative metastable atom population as a function of time. The method has been used to determine metastable destruction frequencies, and the results are in close agreement with those obtained by Phelps.

*Supported in part by Aerospace Research Laboratory, Wright-Patterson Air Force Base.

ND5 Study of the Afterglow of an Electron Beam-Excited Discharge in Helium at 2000 Torr.* C. B. Collins, A. J. Cunningham, and B. W. Johnson, U. of Texas at Dallas--A system has been developed for the examination of the afterglows of electron beam-excited discharges at Gigawatt power levels in high pressure inert gases. Preliminary measurements on helium at 2000 Torr have shown the selective development of both the atomic and molecular helium spectra. Transitions from the 4d-complex to the $3p\,^3\Sigma g$ state of He_2 together with the 5875Å atomic line were found to be particularly enhanced. The incoherent peak power density emitted in the 5875Å transition during the afterglow period was of the order of 25 watts/cm^3. A lifetime of the afterglow of 200 nanoseconds was measured and found to be consistent with a recombination origin of the light.

*This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by ONR under Contract N00014-67-A-0310-0007.

ND6 Recombination of Electrons with Diatomic Ions of the Two Isotopes of Helium.* A. WAYNE JOHNSON and J. B. GERARDO, Sandia Labs.--The recombination coefficients (α) for electrons with diatomic ions of the two isotopes of helium are reported. The measurements were made by using the perturbation technique which was previously described by the authors.[1] The plasma is perturbed by application of a pulsed electric field which increases the temperature of the electrons; thus, α is decreased and as a consequence the rate of decay of the electron density is temporarily altered. This perturbation serves to temporarily alter the equilibrium ratio between the electron density and the metastable density. The value of α is determined by observation of the electron-density decay in the wake of the heating pulse. The value of α for $^3He_2^+$ is $(1.23 \times 10^{-8} + 5.04 \times 10^{-10} p)$ $cm^3 sec^{-1}$, compared to that for $^4He_2^+$ which is $(1.15 \times 10^{-8} + 3.86 \times 10^{-10} p)$ $cm^3 sec^{-1}$ where p is the gas pressure in Torr.

*Work supported by the U. S. Atomic Energy Commission.

[1]A. Wayne Johnson and J. B. Gerardo, Phys. Rev. A5, 1410 (1972).

ND7 Does He_3^+ Contribute Significantly to the Total Electronic Recombination in a 300°K Helium Plasma Dominated by He_2^+ Ions? * A. WAYNE JOHNSON and J. B. GERARDO, Sandia Labs.--It was previously proposed[1] that He_3^+ ions could possibly account for a significant fraction of the total electronic-recombination rate in a room-temperature helium plasma dominated by He_2^+ ions. We have investigated this proposal by measuring the electronic-recombination coefficient in helium at gas temperatures slightly different than 300°K by a perturbation technique previously described by the authors.[2] It is concluded that at gas pressure less than 50 Torr and gas temperature near 300°K, electronic recombination occurs primarily with He_2^+.

*Work supported by U. S. Atomic Energy Commission.

[1]M. A. Gusinow, R. A. Gerber and J. B. Gerardo, Phys. Rev. Letters 25, 1248 (1970).

[2]A. Wayne Johnson and J. B. Gerardo, Phys. Rev. A5, 1410 (1972).

ND8 Rate of Ionization by Collisions Between Two Helium Atomic Metastables (2^3S).* A. WAYNE JOHNSON and J. B. GERARDO, Sandia Labs.--In all previous studies of the rate, β, of ionizing collision between pairs of triplet helium atomic metastables, the production of the 2^3S states by dissociative recombination of electrons with He_2^+ ions was ignored. We have used a perturbation technique[1] to temporarily decrease the rate of dissociative recombination and have obtained the value of β from the decay of the metastable density during the perturbation. We have also arrived at the value of β from the measured equilibrium ratio of M/N_e and the quasi-equilibrium relations which result from the coupling process between the density of metastables, M, and the density of electrons, N_e. Both techniques yield $\beta = (4.4 \pm 0.8) \times 10^{-9}$ cm^3 sec^{-1} which is to be compared to the previously accepted value of 2×10^{-9} cm^3 sec^{-1}.

*Work supported by U. S. Atomic Energy Commission.

[1]A. Wayne Johnson and J. B. Gerardo, Phys. Rev. A5, 1410 (1972).

SESSION OC

Friday morning, 20 October

8h30

Room 200

ELECTRON IMPACT EXCITATION

Chairman: Paul Marmet
Universite Laval
Quebec, Quebec

OC1 Excitation of the 3^3P Level of Helium by Electron Impact*. R.J. Anderson, R.H. Hughes and J.H. Tung, University of Arkansas.--The exchange excitation of the 3^3P level of helium by electron impact has been studied by means of time-resolved spectroscopy of the $3^3P \rightarrow 2^3S$ (λ3889Å) transition. The study was carried out for electron energies within the range 40-400eV, at a helium gas pressure of ~4mTorr. Under these conditions the total light intensity of the λ3889Å line was observed to vary linearly with both electron beam current and target gas pressure. Radiative cascade transitions from upper n^3S and n^3D states were observed to contribute about 10% of the total λ3889Å light output at 40eV. This fraction increased to about 50% at 400-eV electron impact energy. Within experimental error, the energy dependence of the 3^3P direct excitation cross section was observed to decrease with increasing energy according to the relation $(\text{Energy})^{-3}$. This result is in agreement with the theoretical calculations of Ochkur and Bratsev[1] which predict a similar dependence above ~50eV.

1. V.I. Ochkur and V.F. Bratsev, Opt. Spectry. (USSR) 19, 274 (1965)

* Work supported by the National Science Foundation

OC2 Electron Excitation of H and H_2.* R.A. MICKISH and R.M. ST.JOHN, Univ. of Oklahoma.--Collision processes of electrons impacting upon H and H_2 have been studied in a crossed beam experiment. A Wood discharge was used for dissociation of the molecules to produce an atom enriched beam. Optical cross-section data was obtained by observation at 90° to the beams by a monochromator and photomultiplier system with an absolute scale set with a tungsten standard lamp. A static system was used for observation of e-H_2 collisions as it permitted direct determination of the molecular number density. Excitation functions measured were for: (a) e-H_2 collisions in the flow system yielding molecular lines, 5 lines with the Wood discharge off and on; (b) e-H_2 collisions in the static system and in the flow system with the Wood discharge off yielding atomic Balmer lines through dissociation and excitation, H_α and H_β; (c) e-(H+H_2) collisions in the flow system with the Wood discharge on yielding Balmer lines, H_α and H_β. Subtraction of (b) type data from (c) type data yielded e-H collision data. Relative excitation functions were obtained in each case from onset to 190 eV and absolute cross sections were obtained for e-H_2 collisions leading to H_α and H_β Balmer lines.

*Work supported by AFOSR, Grant AF-AFOSR 71-2051.

OC3 Measurements of Electron Excitation Cross Sections of the Individual Magnetic Sublevels of the ^2P and ^2D States of Potassium.* JERRY E. SOLOMON, DALE E. KORFF, FRED L. ROESLER, AND CHUN C. LIN, University of Wisconsin.--By means of a high-resolution, high luminosity scanning Fabry-Perot interference spectrometer, all six Zeeman components of the $4^2P_{3/2} \rightarrow 4^2S_{1/2}$ transition of potassium produced by electron-beam excitation have been resolved under a magnetic field of 1.8 kG. At incident energies of 10.5, 16.8, and 23 eV, the relative intensities of the $M_J = 3/2 \rightarrow 1/2$ and $M_J = 1/2 \rightarrow -1/2$ components are respectively 0.94, 0.79, and 0.70 which gives the ratios of the cross section of the $M_L = 0$ state to that of $M_L = 1$ (in the limiting uncoupled case) as 1.064, 0.685, and 0.55. The corresponding theoretical values of this ratio based on a three-state close-coupling calculation are 1.050, 0.825, and 0.725.

*Work supported by the U.S. Air Force Office of Scientific Research and by the Air Force Cambridge Research Laboratories, Office of Aerospace Research.

OC4 ABSOLUTE CROSS SECTIONS FOR ELECTRON IMPACT EXCITATION OF THE H AND K RESONANCE LINES OF Ca^+.** PAUL O. TAYLOR AND GORDON H. DUNN, Joint Institute for Laboratory Astrophysics.

Crossed beams of electrons and Ca^+ have been used to measure absolute cross sections for electron impact excitation of the resonance K and H lines of Ca^+ at 3934 and 3968 Å respectively. Polarization fractions of the light were also measured. Experimental uncertainties in the results range around 10%, expressed at the 98% confidence level and representing quadrature combination of both random and systematic uncertainties. Measurements were made from below threshold at 3.1 eV to 700 eV, and results for both H and K agree above 250 eV with the Coulomb distorted wave calculation of Burgess and Sheorey[1], but lie about 30% below the low energy three state close-coupling calculation of Burke and Moores[2].

** Supported in part by the Controlled Thermonuclear Division of the U. S. Atomic Energy Commission.

1. A. Burgess and B. J. Sheorey, private communication.
2. P. G. Burke and D. L. Moores, J. Phys. B. 1, 575 (1968).

OC5 Simultaneous Excitation and Ionization of Argon by Electron Impact* J. W. McCONKEY and F. G. DONALDSON, Physics Dept., Univ. of Windsor, Ontario, Canada. -- Inner and outer shell ionization of Ar has been studied by observing the vacuum U-V radiation resulting from the excitation of the $3s3p^6\ ^2S$ and $3s^23p^4\ 4s\ ^{2,4}P$ levels of Ar^+. These latter levels are of particular interest being the lower levels involved in the Ar ion laser transitions. Absolute cross-sections are presented from threshold up to 2 keV. A crossed electron-gas beam system was used and freedom from polarization effects was obtained by suitable alignment of the electron beam relative to the optic axis and the monochromator entry slit.

*Work supported by the National Research Council of Canada.

OC6 Excitation of Band Emissions in Nitrogen by Secondary and Primary Electrons. WALTER L. BORST and MAHMOOD IMAMI, Southern Illinois University at Carbondale.--Secondary electrons were produced in N_2 by fast primary electrons ($\sim$1 keV). Resulting band emissions excited in the gas by secondary and primary electrons were monitored for pressures from 10^{-4} to 1 Torr. Secondary and primary electron contributions to the total excitation of a band were separated using a movable optical detector that scanned luminosity profiles in the reaction chamber. Second positive (2PG) bands of N_2 were excited solely by secondary electrons, whereas first negative (1NG) bands were excited by primary and/or secondary electrons depending on the interaction volume viewed. The observed intensities depended sensitively on the energy spectrum of the secondary electrons This fact was used to infer the energy spectrum of the secondary electrons. The intensity ratio 2PG(0,0)/1NG(0,0) as excited solely by slow secondary electrons was found to be about 0.5 over a large range of pressure, primary electron energy, and detector position. The present results were compared with atmospheric measurements of auroral emissions and electron spectra.

OC7 Scattering of Alkali Halides By Low Energy Electrons.* M. G. Fickes, R. C. Slater, and R. C. Stern, Columbia U.-- Laboratory differential cross sections for the scattering of thermal beams of CsCl, KI, and TlF by 0.5 to 15 eV electrons have been measured using the molecular beam recoil technique. A novel kinematic analysis is used to transform an assumed First Born approximation differential cross section out into laboratory coordinates.[1] Comparison with experiment yields apparent total cross sections which are a factor of ? below theory for CsCl and KI, and up to a factor of 3 above theory for TlF. These results indicate that scattering at center of mass angles $> 15^{\circ}$ is not well represented by the Born theory.

*Supported by the National Science Foundation.

[1]R. C. Slater, M. G. Fickes, and R. C. Stern, Phys. Rev. Letters 29, 333 (1972).

SESSION OD

Friday morning, 20 October

8h30

Room 174

AFTERGLOWS III

Chairman: A.K. Chattacharya
G.E. Lighting Research Laboratory
Cleveland, Ohio

OD1 Measurements of Recombination of Electrons with H_3^+ and H_5^+ Ions.* M. T. Leu, Manfred A. Biondi and R. Johnsen, Univ. of Pittsburgh--The electron-ion recombination coefficients for H_3^+ and H_5^+ ions have been determined by means of a microwave afterglow/mass spectrometer apparatus. Measurements of electron density decays in helium-hydrogen mixtures are correlated with the decay of mass-identified ion currents to the wall of the microwave cavity. By working at low partial pressures of hydrogen in the mixture, the ion H_3^+ is made to dominate the ion composition and seen to "track" the electron density decay curves. From recombination controlled electron density decay curves, the values $\alpha(H_3^+) = (2.9 \pm 0.5)$, (2.3 ± 0.3), and $(2.0 \pm 0.3) \times 10^{-7}$ cm^3/s, are obtained at 205, 300, and 450°K, respectively. At higher partial pressures of hydrogen, where H_5^+ is the dominant ion, the value $\alpha(H_5^+) = (3.6 \pm 1.0) \times 10^{-6}$ cm^3/s is obtained at 205°K. The implications of these results concerning ionization levels in the atmospheres of the outer planets and in the interstellar medium are discussed.

*This research has been supported, in part, by NASA (NGR 39-011-137).

OD2 Collision Processes Occurring in Decaying Plasmas Produced in Helium-Hydrogen Mixtures:* G.E. Veatch+ and H.J. Oskam, University of Minnesota, Minneapolis.
The time dependence of the densities of He^+, He_2^+, H^+, H_2^+, H_3^+, HeH^+ and He_2H^+ ions was measured in the afterglow period of plasmas produced in helium containing 0.01, 0.02 and 0.1% hydrogen for total gas pressures varying from 1 to 10 Torr. The rate constant for the ionization of H_2 by $He(2^3S)$ was found to be 5.2×10^{-11} cm sec^{-1}. The studies resulted in the observation, for the first time, of the production of H_2^+ by mutual collisions between metastable hydrogen molecules. The radiative life time of these molecules was measured to be 2.7 ± 0.2 msec. The occurrence of several other collision processes was also established. The mobility of H_3^+ in helium was determined to be $\mu_o = 40 \pm 0.5$ cm^2 (volt sec)$^{-1}$.
*Work supported by the National Science Foundation and the Air Force Cambridge Research Laboratories.
+Present address: Lighting Research Laboratories, General Electric Company, Nela Park, Cleveland.

OD3 Mass Spectrometer Measurements in Helium-Cesium Afterglows.* R.S. BERGMAN and L.M. CHANIN, University of Minnesota. The time dependence of the number density of He^+, He_2^+ and Cs^+ were measured in helium afterglows containing small amounts of cesium. Mass spectrometric techniques using a quadrupole mass spectrometer were used to sample the ions in the pressure range of 1 to 10 Torr of helium. The cesium concentration was varied up to 10^{-4} Torr and the discharge tube temperature was varied between 300°K and 600°K. Analysis of the Cs^+ decay curves indicates that the reduced mobility of Cs^+ in helium is 16.5 ± 1 cm^2/volt-sec. From the He_2^+ decay curves the rate coefficient, K, of the charge exchange reaction, $He_2^+ + Cs \xrightarrow{K} Cs^+ + 2He$, is estimated to be $2.5 \pm 1 \times 10^{-9}$ cm^3/sec. No evidence was found to indicate that He^+ is directly involved in the creation of Cs^+.

*Work supported by Office of Naval Research, Power Branch.

OD4 Nitrogen Afterglow Studies at Various Gas Pressures and Temperatures:* G.N. Hays, C.J. Tracy and H.J. Oskam, University of Minnesota, Minneapolis. Studies of the light emission from a pure N_2 afterglow in the pressure range 60μ to 5 Torr and at temperatures from 85°K to 500°K have resulted in several new observations on volume and wall processes affecting the spectral emission. Comparison of the $N_2(1+)$ emission with that of other N_2 band systems shows population of the $B^3\pi_g$ state by a metastable pooling mechanism as well as by direct energy transfer from the $N_2(A^3\Sigma_u^+)$ state. Measurements of the time dependence of the Lewis-Rayleigh afterglow provided a value for the surface catalytic efficiency (γ) for recombination of atomic nitrogen at the wall. The temperature dependence of γ shows a previously unreported minimum near 140°K and some indication of a relative maximum around 90°K. The dependence of γ on [N] indicates a second order wall process at low temperatures, while a linear process is indicated around room temperature. The pressure dependence of γ cannot be explained by a simple evaporation-condensation model.

*Work supported by the National Science Foundation and the Air Force Cambridge Research Laboratories.

OD5 Investigation of Vibrational Relaxation in Low Pressure N_2 Discharges, O. SAHNI and W. C. JENNINGS, Rensselaer Polytechnic Institute -- A novel technique exploiting electron-molecular vibrational coupling has been used to investigate the temporal behavior of vibrational excitation in the active period of a pulsed low pressure N_2 discharge. The technique involves following the decay of the electron average energy $\overline{U}_e$ in afterglows formed by a variable discharge pulse. The vibrational excitation can be probed provided the quasi-steady state value of $\overline{U}_e \gtrsim 0.5$ eV where vibrational losses dominate over elastic and rotational losses, causing the electrons to be in thermal equilibrium with the N_2 vibrational levels. Since the N_2 afterglow is non-Maxwellian, $\overline{U}_e$ is determined by first calculating the electron velocity distribution function from microwave measurements of the collisional broadening of electron cyclotron emission. Results of this first low pressure study show an overall electron super-elastic de-excitation rate coefficient of 6.7×10^{-9} cm^3/sec and a surface catalytic efficiency of $\approx 10^{-2}$ for deactivation at vycor walls.

OD6 Penning Ionisation by $^5S^0$ Oxygen Atoms. D.R. CLARK, Univ. of London, London, England.-- Experiments conducted with a glow discharge through molecular oxygen at $\sim$1 torr pulsed at 20 ms intervals with a square wave current pulse of $\sim$3 ms reveal that the free electron concentration rises sharply in the first 100 μs of the afterglow. The electron concentration was monitored with a microwave cavity by detecting the difference between the resonant frequency at a known time in the afterglow, and that at the end of the cycle, when there are no free electrons left. An analysis of the electron-decay data, using Bionidi's technique developed for the Helium afterglow, suggests that Penning ionisation is taking place by the reaction of $^5S^0$ oxygen atoms. Further evidence for the existence of this state is provided by emission spectra data from the discharge. The rate-constant for the Penning process is $\sim 1 \times 10^{-10}$ molecule^{-1} cm^3 sec^{-1} and the initial concentration of $^5S^0$ at the start of the afterglow is $\sim 5 \times 10^9$ cm^{-3}.

SESSION PC

Friday morning, 20 October

10h45

Room 200

IONIZATION

Chairman: J.W. McConkey
University of Windsor
Windsor, Ontario

PC1 Photoionization of N_2O by Soft X-Rays. R. G. HIRSCH, R. J. VAN BRUNT, and W. D. WHITEHEAD, Univ. of Va.--The relative abundances of thermal energy ions produced from N_2O following absorption of monoenergetic x-rays at energies of .28, 1.25 and 1.5 keV (corresponding to Kα-lines of C, Mg and Aℓ) were measured using a time-of-flight mass spectrometer. The data indicate that a significant change occurs in the ionization character at energies above the K-absorption edges of the atomic constituents. At the higher energies dissociative ionization becomes dominant with fragment molecular ions providing the major contribution. Below the K-edge, only singly-charged ions are observed with N_2O^+ predominating. The absence of any detectable amount of N_2O^{++} demonstrates that the states of this ion which become populated are unstable with a dissociation lifetime significantly shorter than its estimated flight time of 18 microseconds. The relative abundances obtained have been corrected for possible mass and charge dependent discrimination effects associated with the instrument.

PC2

"Photoelectron" Spectroscopy by Electron Impact-Coincidence Measurements of Scattered & Ejected Electrons in CO.

M.J. van der Wiel & C.E. Brion
Dept. of Chemistry, University of B.C., Vancouver, B.C., Canada

The relative intensities for ionization to the lowest three electronic states of CO^+ have been obtained by detecting forward scattered 3.5 keV electrons in coincidence with electrons ejected at 90°. Data are reported for energy losses of the projectile electron in the range of 18 - 50 eV. A simple relation is derived between our data, photoelectron intensities and the angular anisotropy parameter β. This relation appears to be fulfilled satisfactorily for a (photon) energy of 21.2 eV, for which photoelectron intensities and β are available.

PC3 Excitation of The Triplet States $e^3\Sigma_u^+$ and $d^3\Pi_u$ by Electron Impact on H_2. A. WEINGARTSHOFER and E. M. CLARKE, ST.F.X.U. -- It has been suggested by McGowan, Fineman, Clarke, and Hanson[1] that some of the structure observed in the ionization spectrum of H_2 by electron impact may arise through excitation by electron exchange. We find support for this conjecture in our measurements of energy loss spectra on H_2 carried out at primary energies varying from various electron volts to a few millivolts above the threshold formation of these states and at several scattering angles (10°-130°). We also find that some of the structure observed in transmission experiments using a derivative technique by Golden[2] and more recently by Sanche and Schulz[3] may arise from formation of triplet states, particularly the band "g" reported by Sanche and Schulz.

1) Phys. Rev. 167, 52 (1968)
2) Phys. Rev. Letters 27, 227 (1971)
3) Private communication

PC4 Formation of H_2^+ and D_2^+ by Electron Impact. P.Marmet, E. Bolduc and R. Carbonneau, Laval University.-- A new apparatus giving a greatly improved signal to noise ratio on the ionization efficiency curves of H_2 and D_2 near threshold, combined with the new data processing technique[1] reveals many clear structures. We find that direct ionizing or autoionizing (of an intermediate neutral state) mechanisms cannot explain the relative positions of the structures detected in H_2^+ and D_2^+ when we search for the expected Rydberg or vibrational series. This shows that negative ionic states have to be mainly responsible for the variations of the cross sections observed. Furthermore our structures coincide with the ones reported in transmission experiments by Sanche and Schulz[2] and already attributed to negative ion states. Our conclusion is also in agreement with the results of Stevenson.[3]

[1]E.Bolduc,J.J.Quemener and P.Marmet,Can.J.Phys. 49, 3095 (1971).
[2]L.Sanche, G.Schulz, personal communication.
[3]D.P.Stevenson,J.Amer.Chem.Soc.82, 5961(1960).

PC5 Analysis of Numerous Autoionizing Levels in CO. R. CARBONNEAU, E. BOLDUC and P. MARMET, Laval University. -- We report numerous autoionizing levels clearly detected in the electron impact ionization efficiency curve of CO. The experimental technique used is the same as in the study of the rare gases[1] and of the isoelectronic molecule N_2[2]. The levels observed between 14 and 19 eV belong to series converging to the limits $A^2\Pi$ and $B^2\Sigma$ of CO^+. Although our results show many analogies with the photoexcitation spectrum of CO, a new interpretation is needed. Other structures appear above 20.5 eV involving electronic state lying at higher energy than any previously reported for neutral CO.

[1] P. Marmet, J.J. Quéméner, E. Bolduc, Proc. VIIth Int. Conf. Phys. Coll. At., Amsterdam, p. 1044 (1971).

[2] R. Carbonneau, P. Marmet, Int. J. Mass Spectr. Ion Phys., in press.

PC6 Line Contours of Excited States in Ionization Curves. E. BOLDUC, R. CARBONNEAU and P. MARMET, Laval University. -- Fano equation[1] which describes the cross section in the vicinity of resonance energies has been used[2] to fit structures caused by negative-ion states. We now report a fit on a structure detected[3] on the ionization efficiency curve of Ne attributed to the $2s^2 2p^4 (^3P) 3s^2$ neutral state. The theoretical expression used to perform the fit is

$$\sigma(\varepsilon) = \sigma_A \left[(q^2-1)\,tg^{-1}\varepsilon + q\ell n(\varepsilon^2+1)\right] \qquad (1)$$

where the symbols have the same meaning as in ref. 1. Equation (1) is the integral of Fano equation after a suitable slope has been subtracted.[2,4] It is in excellent agreement with our experimental curve. Other structures also follow equation (1).

[1] U. Fano, Phys. Rev. 124, 1866 (1961).
[2] J.J. Quéméner, C. Paquet and P. Marmet, Phys. Rev. A4, [3] 494 (1971).
[3] E. Bolduc, J.J. Quéméner and P. Marmet, J. Chem. Phys. [4] (sept. 1972).
[4] E. Bolduc, J.J. Quéméner and P. Marmet, Can. J. Phys. 49, 3095 (1971).

PC7 Dissociative Ionization of H_2, N_2, NH_3 and CO_2 by Electron Impact* A. CROWE and J. W. McCONKEY
Physics Dept., Univ. of Windsor, Ont., Canada. -- Dissociative ionization of small molecules has been studied using electrons of up to 300 eV incident energy. Cross-sections were made absolute using previous measurements of total fragment production. The electron gun was rotatable relative to the quadrupole mass spectrometer detector and so angular distributions of the fragment ions were obtained. Interesting anisotropies which were obtained will be discussed. Additional measurements concerned the energies and appearance potentials of the fragment ions.

*Work supported by the National Research Council of Canada.

PC8 Statistical Error in Molecular Cross Section Measurements.* G. C. BALDWIN and K. J. MILLER, RPI, Troy, N.Y. 12181--We consider the design and analysis of experiments for total cross section measurement, in which the data are sets of counts of particles transmitted over a measured path through a gas at a sequence of pressures. The probability that the set of counts corresponds to a particular value of the total cross section is derived. From this, recipes are given for determining the best value and rms error of the cross section; for evaluating the increased errors in the cross section, both random and systematic, caused by random fluctuations in the reading of gas pressure; and for prescribing the parameters of an experiment to achieve maximum precision in a given time of measurement.

*Supported by the U. S. Atomic Energy Commission

SESSION PD

Friday morning, 20 October

10h30

Room 174

TRANSPORT PROPERTIES

Chairman: C.E. Veatch
G.E. Company
Cleveland, Ohio

PD1 Transport Coefficients of Gaseous Ions in an Electric Field*

J. H. Whealton and E. A. Mason, Brown University

Kihara's ion mobility theory has been extended to high fields by using a two-point Pade approximate. By so doing both the high field and low field asymptotic behavior is incorporated if it is known for the ion-neutral potential considered. A comparision with the exact results for electrons considering rigid sphere interaction shows agreement to be within 6% for all values of the electric field. The advantage of this interpolation scheme is that it can deal with non-monotone ion-neutral interaction potentials and is not empirical. Kihara's theory is also extended to ions in mixtures of neutral gases and to the evaluation of the diffusion tensor. The expected field-dependent deviations from Blanc's law and deviations from the generalized Nernst-Townsend-Einstein relation are exhibited in the second iteration. Higher iterations will yield the known zero-field deviations from Blanc's law. A few numerical examples will be presented.

*Work supported in part by the National Aeronautics and Space Administration under Grant No. NGL-40-002-059.

PD2 Mobilities of Uranium and Mercury Ions in Helium.* R. Johnsen and Manfred A. Biondi, Univ. of Pittsburgh. - The mobilities of mass-identified U^+ and Hg^+ ions in helium have been determined in a drift tube-mass spectrometer apparatus. For uranium ions a reduced mobility value $\mu_o=(16.0 \pm 0.5)$ $cm^2/V\text{-sec}$ is obtained at 305°K and a standard gas density of 2.69×10^{19} cm^{-3}. The mobility of mercury ions is $\mu_o = (19.4 \pm 0.5)$ $cm^2/V\text{-sec}$ at 292°K, in agreement with two previous determinations. The effect of fast ion injection in drift mobility measurements is discussed, and a new technique to circumvent these problems is described. The results are compared with existing theories of ion mobilities. While the value for uranium agrees well with the prediction of pure polarization type of interaction between ion and atom, the mobility of mercury ions in helium is substantially larger than the predicted value.

*This research was supported, in part, by the Advanced Research Projects Agency (DA-31-124-ARO-D-440).

PD3 Longitudinal Diffusion Coefficient and Drift Velocity Measurements in H_2O and D_2O.* F. J. DAVIS and D. R. NELSON, Oak Ridge National Laboratory. --There have been no reliable measurements of diffusion and drift velocity in water vapor below an $E/P = 20$ volt cm^{-1} $torr^{-1}$. The longitudinal diffusion coefficient D_L in most gases is usually less than the transverse diffusion coefficient D_T. For H_2O, however, recent theoretical predictions[1] indicate that the longitudinal diffusion coefficient is larger than the transverse. The measurements of D_L and drift velocity w were made using the time-of-flight method described previously.[2] Our experimental values of D_L and w in H_2O compare well with the theoretical values of Lowke and Parker.[1]

*Research sponsored by the U. S. Atomic Energy Commission under contract with Union Carbide Corporation.

[1]J. J. Lowke and J. H. Parker, Phys. Rev. 181, 302 (1969).

[2]E. B. Wagner, F. J. Davis, and G. S. Hurst, J. Chem. Phys. 47, 3138 (1967).

PD4 Longitudinal Diffusion Coefficients of K^+ Ions in Ar, N_2, and CO Gas. E.W.McDaniel, G.M.Thomson, J.H.Schummers, D.R.James, E.Graham and I.R.Gatland, Ga.Inst.of Tech.-- We have measured with a drift tube mass spectrometer the longitudinal diffusion coefficients of K^+ ions in argon, nitrogen and carbon monoxide at 300°K. The measurements were made over a range of E/N extending from thermal values up to 650 Td. Here E is the drift field intensity and N is the gas number density. The low-field data are in excellent agreement with the diffusion coefficients calculated by the Einstein equation from the experimental zero-field mobilities. The experimental diffusion coefficients agree closely with the predictions of a modified version of Wannier's theory up to $E/N = 100$ Td in Ar and up to $E/N = 200$ Td in N_2 and CO. This theory assumes the ion-molecule interaction to consist of only the attractive polarization force, of which a constant mean free time between collisions is a consequence. In our modification, the observable drift velocity replaces the non-observable mean free time.

PD5 Transportphenomena in Neon discharges investigated with ^{20}Na tracers. L.C.J.Baghuis, A.M.W. Duys, H.L. Hagedoorn, J.A. v.d.Heide.Eindhoven University--Radioactive ^{20}Na isotopes are used as tracers to investigate transport phenomena in 50-100 torr Neon discharges with currents between 1-200mA and tube diameters of 5-7 cm. The tracers are produced directly in the positive column during short time intervals by means of the $^{20}Ne(p,n)^{20}Na$ nuclear reaction. The amount of tracers is so small that their influence on the discharge is negligible. The tracer concentration is measured as a function of position and time. As the lifetime of ^{20}Na is 0.45$ the experiment can be repeated every 2 seconds. The tracers can be transported over 60cm or more. Experimental results show that the ambipolar diffusion losses decrease strongly above pressures of 100 torr, where recombination becomes important. In the presence of impurities discharges with currents below 10mA have shown negative ions, containing Na atoms, which probably have a large influence on volume recombination. Measured transport times in the discharge correspond with a mobility of 3 ± 1 cm^2/Vs for Na ions in 760 torr Neon.

PD6 Seeding Effect on the Transport Phenomena and Collisional Processes in an Ionized Argon Gas, CHIH WU,Assoc.Prof.Mech.Eng.Dept.,U.S. Naval Ac.,Annapolis, Md.-- The effect of thernuibuc emission of micron-sized magnesium-oxide and copper-oxide solid particles in an argon ionized gas is undertaken. The study is directed towards the case where local thermodynamic equilibrium conditions do not previal. A microscopic interation model between the solid particles and the ionized gas is proposed to account for interactions among all the components. Transport processes and transport properties of such a mixture are formulated. It is seen that on the one hand, electron concentration in the ionized gas may be increased by emission from the solid particles, but electrical conductivity may still be lowered due to scattering by the charge on the particulate matter. On the other hand, the solid particles, depending on the material, may collect electrons. Experimental verification is conducted on a two dimensional channel with magnesium oxide dispersed in a partially ionized gas of argon to demonstrate the interactions of solid particles in an ionized gas.

PD7 Properties of Plasmas Sustained by a Uniform Source of Ionization. J. J. LOWKE and D. K. DAVIES, Westinghouse Research Labs.-- The number and current density profiles of electrons and positive ions in a gaseous discharge have been calculated for various voltages applied to two planar electrodes separated by ~0.3 cm. The discharge is sustained by a uniform source of ion pairs produced in the gas independent of the applied electric field. The solutions of the one-dimensional steady state continuity equations for electrons and ions have been obtained by two independent methods, account being taken of drift, diffusion, and recombination of the charge carriers, ionization of the gas by electrons, and distortion of the applied field due to space charges. For argon, numerical results for discharges of current density < 0.3 mA/cm^2 are in reasonable agreement with available experimental data and also with analytic expressions derived by considering the cathode sheath region only and neglecting diffusion and ionization by electrons. However for higher current densities ionization by electrons in the cathode sheath becomes important and the simple analytic treatment becomes increasingly inaccurate.

PD8 Ions and High-Pressure, Space-Charge-Limited Electron Current. J. H. INGOLD, General Electric Co. It is known that the presence of ions in a gas diode causes the electron current to be larger than the space-charge-limited value. A new theory which attributes this effect to partial neutralization of negative space-charge near the cathode is presented. It is argued that the increase in electron current occurs because the effective spacing of the diode decreases as the positive ion density increases. In other words, a thin, high-pressure, space-charge sheath develops near the anode. This sheath can be thought of as an effective diode because most of the applied voltage appears across the sheath. A general expression for the current-voltage characteristic, which reduces naturally to the high-pressure space-charge equation of Cobine in the absence of ions, is presented.

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