Classification of Processes in Plasma Physics

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April 2024: Version 2.5 adds process codes for species transport in materials.

March 2022: Version 2.4 adds process code COM.

December 2021: Version 2.3 adds process codes HAI, HAR, HTE, HDN, PRD.

November 2021: Version 2.2 adds process codes HDE, HDI, HMI, HMT.

December 2020: Version 2.1 fixes mistaken duplicate codes (HAS and SVS).

April 2020: This work is an update of version 1.2 of the document "Classification of Processes" [1] produced as an outcome of the Technical Meeting on Standards and Software Tools for Atomic and Molecular Databases held at IAEA Headquarters in Vienna from 27 – 29 November 2019 [2].

Notes
The classification codes are three-letter abbreviations, the first letter indicating the general group of processes to which a process belongs (e.g. E for electron-heavy particle interactions). In the examples, A, B and C refer to an arbitrary atom and n an arbitrary integer greater than 1.

These tables are available online at https://amdis.iaea.org/databases/processes. Comments and corrections can be addressed to the lead author at ch.hill@iaea.org.

[1] D. Humbert, Yu. Ralchenko, P. Krstic, R. E. H. Clark, "Classification of Processes", Version 1.2, IAEA Publication October 2003; https://amdis.iaea.org/media/miscellaneous-publications/plasma-processes-classification-v1.2.pdf.

[2] C. Hill, Summary Report of a Technical Meeting on the Development of Software Programs and Database Tools for Modelling Edge Plasma Processes in Fusion Devices, IAEA Publication INDC(NDS)-0805, December 2019; https://www-nds.iaea.org/publications/indc/indc-nds-0805/. Online meeting details available at https://amdis.iaea.org/meetings/software-tools/.

Electron-Heavy Particle Interactions

EAE	Auger Electron Ejection	Electron-impact induced Auger electron ejection	$e^- + A \rightarrow A^{**+} + 2e^-$; $A^{**+} \rightarrow A^{*2+} + e^-$
EAS	Angular Scattering	Differential electron-scattering cross sections, usually as a function of energy and angle.	
EBS	Bremsstrahlung	The emission of electromagnetic radiation by a charged particle as it is decelerated through Coulomb interactions with other charges; "free-free" radiation in the context of plasma physics.	$e^- + A \rightarrow e^- + A + h\nu$
EDA	Dissociative Attachment	Dissociative attachment	$e^- + AB \rightarrow A + B^-$
EDC	Dielectronic Capture	Dielectronic capture	$e^- + A^+ \rightarrow A^{**}$
EDE	Dissociative Excitation	Electron-impact dissociative excitation	$e^- + AB \rightarrow A^* + B + e^-$
EDI	Dissociative Ionization	Electron-impact dissociative ionization	$e^- + AB \rightarrow A^+ + B + 2e^-$
EDP	Depolarization, Change of Polarization	Electron-impact change of polarization, including depolarization	
EDR	Dissociative Recombination	Electron-impact dissociative recombination	$e^- + AB^+ \rightarrow A + B$
EDS	Dissociation	Electron-impact dissociation	$e^- + AB \rightarrow A + B + e^-$
EDT	Electron Detachment	Electron-impact detachment	$e^- + A^- \rightarrow A + 2e^-$
EDX	De-excitation	Generic inelastic collisional processes in which a scattered electron gains energy from the target particle.	$e^- + A^* \rightarrow e^- + A$
EEL	Elastic Scattering	Scattering of an electron with no change in energy.	$e^- + A \rightarrow e^- + A$
EEX	Excitation	Electron-impact excitation	$e^- + A \rightarrow e^- + A^*$
EEX	Change of Excitation	Electron-impact change of excitation. *Deprecated: Use EEX: Excitation or EDX: De-excitation instead.*	$e^- + A^* \rightarrow e^- + A^{**}$
EFL	Fluorescence (Optical Emission)	Total optical emission following electron-impact events	
EGN	General	General electron-impact processes that do not fall into any more specific category.	
EHT	Transport	Transport cross sections: momentum, viscosity and higher-order.	
EIN	Ionization	Electron impact ionization	$e^- + A \rightarrow A^+ + 2e^-$

EIP	Ion-Pair Formation	Electron-impact induced formation of a (positive, negative) ion pair	$e^- + AB^+ \rightarrow A^+ + B^-$
ELB	Line Broadening, Shapes and Shifts	Data relating to the line shapes and positions of radiative transitions	
EMI	Multiple Ionization	Electron-impact ionization to a charge state greater than +1	$e^- + A \rightarrow A^{n+} + (n+1)e^-$
EMT	Momentum Transfer	Electron impact momentum transfer	
ENI	Negative Ion Formation	Electron-impact formation of negative ion (attachment)	$e^- + A \rightarrow A^-$
ERC	Recombination	Electron-impact recombination	$e^- + A^{n+} \rightarrow A^{(n-1)+}$
ERD	Dielectronic Recombination	Electron-impact dielectronic recombination	$e^- + A^+ \rightarrow A^{**} \rightarrow A^* + h\nu$
ERO	Electron-Ion-Other Recombination	Electron-ion recombination involving a third body other than an electron	$e^- + A^+ + B \rightarrow A + B$
ERR	Radiative Recombination	Electron-impact recombination with radiative emission	$e^- + A^+ \rightarrow A + h\nu$
ERT	Three-Body Recombination	Electron-impact three-body recombination	$e^- + e^- + A^+ \rightarrow A + e^-$
ERV	Rovibrational Excitation	Electron-impact rovibrational excitation	$e^- + AB \rightarrow e^- + AB$ $(v=*; \ J=*)$
ESF	Spin-Flip	Electron-impact change of spin state	$e^- + {}^{[S]}A \rightarrow e^- + {}^{[S']}A$
ETS	Total Scattering	Total electron scattering cross sections	
EUP	Unknown Products	Electron-impact collision with unknown products. *Deprecated: use EGN (General) instead.*	
EXE	Electronic Excitation	Electron-impact electronic excitation	$e^- + AB \rightarrow e^- + AB^*$
EXR	Rotational Excitation	Electron-impact rotational excitation	$e^- + AB \rightarrow e^- + AB$ $(J=*)$
EXV	Vibrational Excitation	Electron-impact vibrational excitation	$e^- + AB \rightarrow e^- + AB$ $(v=*)$

Photon-Particle and Field-Particle Interactions

PAD	Scattering	Photon scattering (angular diffusion)	
PAE	Auger Electron Ejection	Photon-induced Auger electron ejection	$A + h\nu \rightarrow A^{**+} + e^-;$ $A^{**+} \rightarrow A^{*2+} + e^-$
PCS	Compton Scattering	Inelastic scattering of a photon by a charged particle that decreases the photon energy.	
PDP	Depolarization, Change of Polarization	Photon-induced change of polarization, including depolarization	

PDS	Photodissociation	Photodissociation of a molecule	$h\nu + AB \rightarrow A + B$
PDT	Photodetachment	Absorption of a photon inducing the removal of an electron from an anion to form a neutral species.	$h\nu + A^- \rightarrow A + e^-$
PEA	Effective Absorption, Total Diffusion	Effective Absorption, Total Diffusion of photons	
PED	Elastic Diffusion	Photon elastic diffusion processes (Thomson scattering, Rayleigh scattering)	
PES	Elastic Scattering	Scattering of a photon with no change in energy.	$h\nu + A \rightarrow h\nu + A$
PEX	Photoexcitation	Photon absorption leading to excitation	$h\nu + A \rightarrow A^*$
PFF	Inverse Bremsstrahlung	Acceleration of a charged particle by a photon absorption process mediated by an electron-particle Coulomb interaction; "free-free absorption" in the context of plasma physics.	$e^- + A + h\nu \rightarrow A + e^-$
PFL	Fluorescence	Fluorescence	$A^* \rightarrow A + h\nu$
PGF	General Electromagnetic Field	Miscellaneous effects induced by an electromagnetic field	
PGN	General	General photon-particle interaction processes which do not fall into any more specific category	
PIN	Photoionization	Photon-induced ionization	$h\nu + A \rightarrow A^+ + e^-$
PIP	Ion-Pair Formation	Photon-induced formation of a (positive, negative) ion pair	$AB + h\nu \rightarrow A^+ + B^-$
PMA	Multiphoton Excitation	Absorption of more than one photon, leaving to excited and/or charged products	$nh\nu + A \rightarrow A^+/A^*/A^{*+}$
PNL	Non-Linear Effects	Non-linear radiative effects	
PRD	Radiative Decay	Radiative decay (not necessarily fluorescence)	$A^* \rightarrow A + h\nu$
PRV	Rovibrational Excitation	Photon-induced rovibrational excitation	$BC + h\nu \rightarrow BC\ (v=*; J=*)$
PSE	Stark Effect	Spectral line-splitting caused by an external electric field	
PTA	True Absorption	True Absorption of a photon	
PTF	Interaction with Time-Varying Fields	General interactions with time-varying fields	
PTS	Total Absorption, Total Scattering	Total photon absorption or scattering cross sections.	
PXE	Electronic Excitation	Photon-induced electronic excitation	$BC + h\nu \rightarrow BC^*$

PXR	Rotational Excitation	Photon-induced rotational excitation	$BC + h\nu \rightarrow BC\ (J=*)$
PXV	Vibrational Excitation	Photon-induced vibrational excitation	$BC + h\nu \rightarrow BC\ (v=*)$
PZE	Zeeman Effect	Spectral line-splitting caused by a static magnetic field	

Heavy Particle-Heavy Particle Interactions

HAC	Association	Heavy-particle collision leading to association (i.e. bond formation)	$A + B \rightarrow AB$
HAI	Associative Ionization	Heavy particle impact associative ionization	$A + B \rightarrow AB^+ + e^-$
HAR	Radiative Association	Heavy particle impact radiative ionization	$A + B \rightarrow AB + h\nu$
HAS	Angular Scattering	Heavy-particle differential scattering cross sections, usually as a function of energy and angle.	
HAT	Attenuation	Attenuation	
HCX	Charge Transfer	Heavy-particle impact leading to charge-transfer.	$A^+ + B \rightarrow A + B^+$; $A^- + B \rightarrow A + B^-$
HDC	Dissociative Charge Transfer	Heavy-particle dissociative charge transfer	$A^+ + BC \rightarrow A + B^+ + C$
HDE	Dissociative Excitation	Heavy particle impact dissociative excitation	$A + BC \rightarrow A^* + B + C$; $A + BC \rightarrow A + B + C^*$
HDI	Dissociative Ionization	Heavy particle impact dissociative ionization	$A + BC \rightarrow A^+ + B + C$; $A + BC \rightarrow A + B^+ + C$
HDN	Dissociative Neutralization	Heavy particle impact dissociative neutralisation	$AB^- + C^+ \rightarrow A + B + C$
HDS	Dissociation	Heavy-particle impact leading to dissociation (bond-breaking)	$A + BC \rightarrow A + B + C$
HDT	Detachment	Heavy-particle collisions leading to electronic detachment.	$A + B^- \rightarrow A + B + e^-$
HDX	De-excitation	Heavy-particle impact leading to de-excitation (decrease of total internal energy).	$A^* + B \rightarrow A + B$
HEL	Inelastic Energy Losses	Heavy-particle collisions leading to inelastic energy loss.	
HES	Elastic Scattering	Scattering of heavy particles with no change in energy.	$A + B \rightarrow A + B$
HET	Energy Transfer	Heavy-particle collisions with energy transfer between the particles.	

HEX	Excitation	Heavy-particle impact leading to excitation (increase of total internal energy).	A + B → A* + B
HFL	Fluorescence	Heavy particle collisional excitation followed by radiative decay.	A + B → A* + B; A* → A + hν
HGN	General	General heavy-particle collisional processes which do not fall into any more specific category	
HHT	Transport	Heavy particle transport cross sections: momentum, viscosity and higher-order.	
HIN	Ionization	Heavy-particle collisions leading to ionization	A + B → A + B$^+$ + e$^-$
HIP	Interaction Potentials	Interaction potentials between heavy particles.	
HIR	Interchange Reactions	Heavy-particle interchange reactions	A + BC → AB + C
HLB	Line Broadening, Shapes and Shifts	Data relating to line shapes and positions determined by heavy-particle collisions.	
HMI	Multiple Ionization	Heavy particle impact ionization with a charge state change greater than +1	A + B → A^{n+} + (n+1)e$^-$ + B
HMN	Mutual Ion-Ion Neutralization	Neutralization of heavy-particle ions.	A$^+$ + B$^-$ → A + B
HMT	Momentum Transfer	Heavy particle momentum transfer	
HPN	Penning Ionization	Ionization through collision of an internally-excited heavy-particle with another heavy particle.	A* + B → A + B$^+$ + e$^-$
HRC	Recombination	Heavy-particle collisions with recombination	
HRV	Rovibrational Excitation	Heavy particle impact rovibrational excitation	A + BC → A + BC (v=*; J=*)
HST	Electron-Stripping	Ionization of the projectile in a heavy-particle collision.	A + B → A$^+$ + B + e$^-$
HTE	Electron Transfer	Heavy-particle electron transfer	A$^-$ + B → A + B$^-$
HTI	Transfer Ionization	Transfer of an electron from an atom to an ion, followed by further ionization.	A + B$^+$ → A^{2+} + B + e$^-$
HTS	Total Scattering	Total heavy particle scattering cross sections	
HUP	Unknown Products	Heavy-particle collisions/reactions with unknown products. *Deprecated*	A + B → ?
HXE	Electronic Excitation	Heavy particle impact electronic excitation	A + BC → A + BC*
HXF	Fine-Level Excitation	Heavy particle impact fine-level excitation	A + B → A + B (J=*)
HXH	Hyperfine Excitation	Heavy particle impact hyperfine-level excitation	e$^-$ + AB → e$^-$ + AB (F=*)

HXR	Rotational Excitation	Heavy particle impact rotational excitation	A + BC → A + BC ($J=*$)
HXT	Excitation Transfer	Transfer of internal excitation in a heavy-particle collision.	A* + B → A + B*
HXV	Vibrational Excitation	Heavy particle impact vibrational excitation	A + BC → A + BC ($v=*$)

Structure and Spectra

SAD	Autodetachment	Autodetachment in atoms and molecules
SAI	Autoionization	Autoionization processes in atoms and molecules.
SDP	Dynamic Polarizability	Dynamic polarizability of atoms and molecules
SDS	Autodissociation	Autodissociation in atoms and molecules
SEW	Energy Levels and Wavelengths	Energy levels and transition frequencies / wavelengths of atoms and molecules.
SFT	Forbidden Transitions	Forbidden transitions in atoms and molecules
SGN	General	General spectral processes and structural properties that do not fall into any more specific category
SHF	Hyperfine Structure	Hyperfine structure of atoms and molecules
SIA	Interatomic Potentials	Interatomic Potentials as they relate to the spectral or structural properties of atoms or molecules.
SIE	Isoelectronic sequences	Isoelectronic sequences of atoms
SIP	Ionization Potentials	Ionization potentials of atoms and molecules.
SIR	Infrared Spectra	Infrared spectra of atoms and molecules
SLS	Line Broadening, Shapes and Shifts	Data relating to line shapes and positions with a focus on spectroscopy or atomic/molecular structure.
SMM	Magnetic Moments	Magnetic moments (dipolar, quadrupolar, etc.) of atoms and molecules.
SPM	Polarizabilities, Electric Moments	Polarizabilities and electric moments (dipolar, quadrupolar, etc.) of atoms and molecules.
SQE	QED Effects	QED effects in atoms and molecules
SRA	Raman spectroscopy	Raman spectroscopy of atoms and molecules.
SRP	Relaxation Processes	Relaxation processes in atoms and molecules.
SRS	Rotational Spectra	Rotational spectra of molecules
SRY	Rydberg States	Rydberg states of atoms and molecules.
SSM	Potential Curves and Structure of Molecules	Potential energy curves/surfaces and molecular structure data.
STP	Transition Probabilities and Oscillator Strengths	Transition probabilities (Einstein A-factors), oscillator strengths and line intensities of radiative transitions in atoms and molecules.

SUV	UV/VUV/XUV Spectra	UV spectra of atoms and molecules from ~10 nm (extreme ultraviolet) to ~400 nm (near ultraviolet).
SVS	Visible Spectra	Visible spectra of atoms and molecules
SVB	Vibrational Spectra	Vibrational spectra of molecules
SXR	X-Ray Spectra	X-Ray spectra of atoms and molecules

Particle-Matter Interactions

MAC	Accomodation	Accomodation
MAD	Adsorption	Adsorption on a surface
MBS	Backscattering	Backscattering from a surface
MCP	Charge State Population	Charge state population of condensed materials.
MCR	Chemical Reactions	Chemical reactions at a surface
MCS	Chemical Sputtering	Chemical sputtering of surfaces.
MDE	Desorption	Desorption from a surface.
MDF	Diffusion	Diffusion of particles through a material
MDP	Deposition	Deposition on a surface.
MEL	Energy Loss and Stopping Power	Energy loss and stopping power of materials with respect to a flux of particles.
MEP	Excited State Population	Excited state population of condensed materials.
MER	Erosion	Erosion of a surface (over a longer timescale than sputtering)
MGN	General	General particle-matter interaction processes that do not fall into any more specific category.
MIR	Particle-Impact Induced Radiation	Radiation induced by particle impact on surfaces.
MMS	Multiple Scattering	Multiple scattering of particles within a material.
MNE	Neutralization, Ionization, Dissociation	Neutralization, ionization or dissociation at a surface.
MPE	Photoelectric Ejection of Electrons	Ejection of electrons due to incoming radiation (the photoelectric effect).
MPM	Permeation	Permeation of particles through a material
MPR	Particle Range	Data relating to the particle transmission through a material.
MPS	Physical Sputtering	Physical sputtering of surfaces
MRC	Recombination	Molecular recombination processes at a surface
MRE	Reemission	Re-emission of accommodated particles at a surface
MRF	Reflection	Reflection of particles from a surface.
MRH	Reflection of Heavy Particles from Surfaces	Reflection of heavy particles from surfaces

MRL	Reflection of Electrons from Surfaces	Reflection of electrons from surfaces
MRS	Radiation-Enhanced Sublimation	Radiation-enhanced sublimation of solids.
MSD	Surface Damage	Surface damage of a surface due to impinging particles over a short timescale.
MSE	Secondary Electron Emission	Secondary electron emission from a surface.
MSI	Surface Interactions	Interactions at surfaces.
MSL	Solubility	Solubility of a species in a given material
MSP	Sputtering	Sputtering of surface material by impinging particles
MTD	Trapping, Detrapping	Trapping and detrapping of accommodated particles in a solid.
MTR	Transmutation	Transmutation of nuclei in solid material by impact of subatomic particles.
MVP	Vapour Formation and Properties	Formation and properties of vapour in front of a surface; in the context of plasma physics, vapour shielding phenomena.

Data Compilations

DEH	Electron-Heavy Particle Interactions	Data compilations concerning electron-heavy particle interactions.
DGN	General	General data compilations that do not fall into any more specific category.
DHH	Heavy Particle-Heavy Particle Interactions	Data compilations concerning heavy particle-heavy particle interactions.
DPF	Photon-Particle and Field-Particle Interactions	Data compilations concerning photon-particle and field-particle interactions.
DPM	Particle-Matter Interactions	Data compilations concerning particle-matter interactions.
DSS	Structure and Spectra	Data compilations concerning atomic and molecular structure and spectra.
DTP	Transport Properties	Data compilations concerning transport properties.

Bibliographic Resources

BEH	Electron-Heavy Particle Interactions	Bibliographic data resources concerning electron-heavy particle interactions.
BGN	General	General bibliographic data resources that do not fall into any more specific category.
BHH	Heavy Particle-Heavy Particle Interactions	Bibliographic data resources concerning heavy particle-heavy particle interactions.

BPF	Photon-Particle and Field-Particle Interactions	Bibliographic data resources concerning photon-particle and field-particle interactions.	
BSS	Structure and Spectra	Bibliographic data resources concerning atomic and molecular structure and spectra.	
BTP	Transport Properties	Bibliographic data resources concerning transport properties.	

Process Flags

COM	Composite Process with Multiple Channels	Process occuring through multiple channels with no uniquely-defined products. For example, the summed cross section of ionization and charge-exchange.	$A + B \rightarrow A^{n+}$