Racah notation and Paschen notation [1]

They're notations for describing states of singly excited atoms, especially rare gas atoms. Racah notation is basically a combination of *LS* or Russell-Saunder coupling and J_1L_2 coupling. *LS* coupling is for a parent ion and J_1L_2 coupling is for an coupling of the parent ion and the excited electron. The parent ion is an unexcited part of the atom. For example, in Ar atom excited from a ground state …$3p^6$ to an excited state …$3p^54p$ in electronic configuration, $3p^5$ is for the parent ion while *4p* is for the excited electron.

In Racah notation, states of excited atoms are denoted as $\left(^{(2S_1+1)}L_{1_{J_1}}\right)nl[K]^o_J$. Quantities with a subscript 1 are for the parent ion, *n* and *l* are principal and orbital quantum numbers for the excited electron, *K* and *J* are quantum numbers for $\vec{K} = \vec{J_1} + \vec{l}$ and $\vec{J} = \vec{K} + \vec{s}$ where $\vec{l}$ and $\vec{s}$ are orbital angular momentum and spin for the excited electron respectively. "*o*" represents a parity of excited atom. For rare gas atom, usual excited states are Np^5nl where *N = 2, 3, 4, 5, 6* for Ne, Ar, Kr, Xe, Rn in order. So the parent ion can only be $^2P_{1/2}$ or $^2P_{3/2}$, so the notation can be shortened as $nl[K]^o_J$ or $nl'[K]^o_J$ where nl means the parent ion is in $^2P_{3/2}$ while nl' is for the parent ion in $^2P_{1/2}$ state.

Paschen notation is somewhat weird notation; it is an old notation made to attempt to fit an emission spectrum of Ne to a hydrogen-like theory. It has rather a simple structure to indicate energy levels of excited atom. the energy levels are denoted as $\boldsymbol{n'l_{\#}}$. *l* is just an orbital quantum number of the excited electron. *n'l* is written in a way that *1s* for (*n = N + 1, l = 0*), *2p* for (*n = N + 1, l = 1*), *2s* for (*n = N + 2, l = 0*), *3p* for (*n = N + 2, l = 1*), *3s* for (*n = N + 3, l = 0*), and etc. Rules of writing *n'l* from the lowest electronic configuration of the excited electron are: (1) *l* is written first, (2) *n'* starts with *1* and the relation of *l = n' - 1, n' - 2, ... , 0* (like a relation between *n* and *l*) is kept, (3) *n'* is written in order (ex: *n' = 3* must be written after *n' = 2*). (4) *n'* must not be repeated for same *l* (example: for *l = 0*, next *n'l* from *1s* is *2s*). *n'l* is an attempt to describe electronic configuration of the excited electron in a way of describing electronic configuration of hydrogen atom. # is an additional number denoted to each energy level of given *n'l* (there can be multiple energy levels of given electronic configuration, denoted by Term symbol). # denotes each level in order, for example, *# = 10* is for a lower energy level than *# = 9* level and *# = 1* is for the highest level in a given *n'l*.

Example of Paschen notation [2]

Electronic configuration of Neon	*n'l* in Paschen notation	Electronic configuration of Argon	*n'l* in Paschen notation
$1s^2 2s^2 2p^6$	Ground state	$[Ne]3s^2 3p^6$	Ground state
$1s^2 2s^2 2p^5 3s^1$	1s	$[Ne]3s^2 3p^5 4s^1$	1s
$1s^2 2s^2 2p^5 3p^1$	2p	$[Ne]3s^2 3p^5 4p^1$	2p
$1s^2 2s^2 2p^5 4s^1$	2s	$[Ne]3s^2 3p^5 5s^1$	2s
$1s^2 2s^2 2p^5 4p^1$	3p	$[Ne]3s^2 3p^5 5p^1$	3p
$1s^2 2s^2 2p^5 5s^1$	3s	$[Ne]3s^2 3p^5 6s^1$	3s

Reference

1. https://www.physics.utoronto.ca/~phy326/hene/HeNeAppendices.pdf
2. https://web.archive.org/web/20120618234059/http://technology.niagarac.on.ca/lasers/Chapter3.html