34. NAMING SCHEME FOR HADRONS

34.1. Introduction

We introduced in the 1986 edition [1] a new naming scheme for the hadrons. Changes from older terminology affected mainly the heavier mesons made of the light (u, d, and s) quarks. Otherwise, the only important change to known hadrons was that the $F^{\pm}$ became the $D_s^{\pm}$. None of the lightest pseudoscalar or vector mesons changed names, nor did the $c\overline{c}$ or $b\overline{b}$ mesons (we do, however, now use χ_c for the $c\overline{c}$ χ states), nor did any of the established baryons. The Summary Tables give both the new and old names whenever a change occurred.

We follow custom and use spectroscopic names such as $\Upsilon(1S)$ as the primary name for most of those ψ, Υ, and χ states whose spectroscopic identity is known. We use the form $\Upsilon(9460)$ as an alternative, and as the primary name when the spectroscopic identity is not known.

34.2. "Neutral-flavor" mesons ($S = C = B = T = 0$)

Table 34.1 shows the names for mesons having the strangeness and all heavy-flavor quantum numbers equal to zero. The scheme is designed for all mesons, whether ordinary or exotic. (This isn't quite true: We haven't proposed names for mesons whose charge Q, strangeness S, or other *additive* quantum numbers can't be matched by a $q\overline{q}$ state. For example, we have no name for a meson with $Q = 2$, or for one with $Q = -1$ and $S = +1$.)

Table 34.1: Symbols for mesons with the strangeness and all heavy-flavor quantum numbers equal to zero.

	$J^{PC} =$	$\left\{\begin{array}{l} 0^{-+} \\ 2^{-+} \\ \vdots \end{array}\right.$	1^{+-} 3^{+-} $\vdots$	1^{--} 2^{--} $\vdots$	0^{++} 1^{++} $\vdots$
$q\overline{q}$ content	$^{2S+1}L_J =$	$^1(L\,\text{even})_J$	$^1(L\,\text{odd})_J$	$^3(L\,\text{even})_J$	$^3(L\,\text{odd})_J$
$u\overline{d}, u\overline{u} - d\overline{d}, d\overline{u}$ $(I = 1)$		π	b	ρ	a
$d\overline{d} + u\overline{u}$ and/or $s\overline{s}$ $(I = 0)$		η, η'	h, h'	ω, ϕ	f, f'
$c\overline{c}$		η_c	h_c	$\psi^\dagger$	χ_c
$b\overline{b}$		η_b	h_b	Υ	χ_b
$t\overline{t}$		η_t	h_t	θ	χ_t

†The J/ψ remains the J/ψ.

First, we assign names to those states with quantum numbers compatible with being $q\overline{q}$ states. The rows of the Table give the possible $q\overline{q}$ content. The columns give the possible parity/charge-conjugation states,

$PC = -+,\ +-,\ --$, and $++$;

these combinations correspond one-to-one with the angular-momentum state $^{2S+1}L_J$ of the $q\overline{q}$ system being

$^1(L \text{ even})_J$, $^1(L \text{ odd})_J$, $^3(L \text{ even})_J$, or $^3(L \text{ odd})_J$.

Here S, L, and J are the spin, orbital, and total angular momenta of the $q\overline{q}$ system. The quantum numbers are related by

$$P = (-1)^{L+1},\ C = (-1)^{L+S}, \text{ and } G \text{ parity } = (-1)^{L+S+I},$$

where of course the C quantum number is only relevant to neutral mesons.

The entries in the Table give the meson names. The spin J is added as a subscript except for pseudoscalar and vector mesons, and the mass is added in parentheses for mesons that decay strongly. However, for the lightest meson resonances, we sometimes omit the mass, as in ρ for $\rho(770)$, ϕ for $\phi(1020)$, *etc.*

Measurements of the mass, quark content (where relevant), and quantum numbers I, J, P, and C (or G) of a meson thus fix its symbol. Conversely, these properties may be inferred unambiguously from the symbol.

If the main symbol cannot be assigned because the quantum numbers are unknown, X is used. Sometimes it is not known whether a meson is mainly the isospin-0 mix of $u\overline{u}$ and $d\overline{d}$ or is mainly $s\overline{s}$. A prime (or pair ω, ϕ) may be used to distinguish two such mixing states.

Names are assigned for $t\overline{t}$ mesons, although the top quark is evidently so heavy that it is expected to decay too rapidly for bound states to form.

Gluonium states or other mesons that are not $q\overline{q}$ states are, if the quantum numbers are *not* exotic, to be named just as are the $q\overline{q}$ mesons. Such states will probably be difficult to distinguish from $q\overline{q}$ states and will likely mix with them, and we make no attempt to distinguish those "mostly gluonium" from those "mostly $q\overline{q}$."

An "exotic" meson with J^{PC} quantum numbers that a $q\overline{q}$ system cannot have, namely $J^{PC} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+}, \cdots$, would use the same symbol as does an ordinary meson with all the same quantum numbers as the exotic meson except for the C parity. Then a caret or "hat" is added; for example, an isospin-1 0^{--} meson would be a $\widehat{\pi}$, an isospin-0 1^{-+} meson would be an $\widehat{\omega}$.

The results of all this are as follows. Established mesons whose names changed slightly in 1986 are:

Old name	New name	Old name	New name
$H(1190)$	$h_1(1170)$	$A_2(1320)$	$a_2(1320)$
$B(1235)$	$b_1(1235)$	$f'(1525)$	$f_2'(1525)$
$A_1(1270)$	$a_1(1260)$	$\omega(1670)$	$\omega_3(1670)$
$f(1270)$	$f_2(1270)$		

Established mesons whose names changed completely are:

Old name	New name	Old name	New name
$S(975)$	$f_0(980)$	$g(1690)$	$\rho_3(1690)$
$\delta(980)$	$a_0(980)$	$\theta(1690)$	$f_J(1710)$
$D(1285)$	$f_1(1285)$	$X(1850)$	$\phi_3(1850)$
$\epsilon(1200)$	$f_0(1300)$	$g_T(2010)$	$f_2(2010)$
$E(1420)$	$f_1(1420)$	$h(2030)$	$f_4(2050)$
$\iota(1440)$	$\eta(1440)$	$g'_T(2300)$	$f_2(2300)$
$D(1530)$	$f_1(1510)$	$g''_T(2340)$	$f_2(2340)$
$A_3(1680)$	$\pi_2(1670)$		

The old $S(975)$, $D(1285)$, $\epsilon(1200)$, $E(1420)$, $D(1530)$, $\theta(1690)$, $g_T(2010)$, $h(2030)$, $g'_T(2300)$, and $g''_T(2340)$ all became f mesons; the new scheme revealed that they are all $PC = ++$, $^3(L \text{ odd})_J$ states.

34.3. Mesons with nonzero S, C, B, and/or T

Since the strangeness or a heavy flavor of these mesons is nonzero, none of them are eigenstates of charge conjugation, and in each of them one of the quarks is heavier than the other. The rules are:

1. The main symbol is an upper-case italic letter indicating the heavier quark as follows:

   $$s \to \overline{K} \qquad c \to D \qquad b \to \overline{B} \qquad t \to T\ .$$

   We use the convention that *the flavor and the charge of a quark have the same sign.* Thus the strangeness of the s quark is negative, the charm of the c quark is positive, and the bottom of the b quark is negative. In addition, I_3 of the u and d quarks are positive and negative, respectively. The effect of this convention is as follows: *Any flavor carried by a charged meson has the same sign as its charge.* Thus the K^+, D^+, and B^+ have positive strangeness, charm, and bottom, respectively, and all have positive I_3. The D_s^+ has positive charm *and* strangeness. Furthermore, the $\Delta(\text{flavor}) = \Delta Q$ rule, best known for the kaons, applies to every flavor.
2. If the lighter quark is not a u or a d quark, its identity is given by a subscript. The D_s^+ is an example.
3. If the spin-parity is in the "normal" series, $J^P = 0^+, 1^-, 2^+, \cdots$, a superscript "*" is added.
4. The spin is added as a subscript except for pseudoscalar or vector mesons.

Thus the pseudoscalar and vector K, K^*, D, D^*, and B mesons did not change names. Established mesons whose names did change were:

Old name	New name	Old name	New name
$Q_1(1280)$	$K_1(1270)$	$L(1770)$	$K_2(1770)$
$Q_2(1400)$	$K_1(1400)$	$K^*(1780)$	$K_3^*(1780)$
$\kappa(1350)$	$K_0^*(1430)$	$K^*(2060)$	$K_4^*(2045)$
$K^*(1430)$	$K_2^*(1430)$	F	D_s

Most notably, the F (the $c\overline{s}$ state) became the D_s.

34.4. Baryons

The symbols N, Δ, Λ, Σ, Ξ, and Ω used for more than 30 years for the baryons made of light quarks (u, d, and s quarks) tell the isospin and quark content, and the same information is conveyed by the symbols now used for the baryons containing one or more heavy quarks (c, b, and t quarks). The rules are:

1. Baryons with *three* u and/or d quarks are N's (isospin 1/2) or Δ's (isospin 3/2).
2. Baryons with *two* u and/or d quarks are Λ's (isospin 0) or Σ's (isospin 1). If the third quark is a c, b, or t quark, its identity is given by a subscript.
3. Baryons with *one* u or d quark are Ξ's (isospin 1/2). One or two subscripts are used if one or both of the remaining quarks are heavy: thus Ξ_c, Ξ_{cc}, Ξ_b, *etc.*
4. Baryons with *no* u or d quarks are Ω's (isospin 0), and subscripts indicate any heavy-quark content.

In short, the number of u plus d quarks together with the isospin determine the main symbol, and subscripts indicate any content of heavy quarks. A Σ always has isospin 1, an Ω always has isospin 0, *etc.*

Reference:

1. Particle Data Group: M. Aguilar-Benitez *et al.,* Phys. Lett. **170B** (1986).