Masses and radiative M1 transitions of heavy-light open-flavour mesons

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Introduction

In addition to the exclusive decays like semileptonic, leptonic, hadronic as well as rare decays, the radiative transitions of mesonic systems with light-heavy quark-antiquark combinations (D, D^*, D_s, D_s^*, B, B^*, B_s and B_s^*) are of much interest as they provide insight to the interactions and QCD dynamics. While most of these exclusive decays are easier to probe experimentally, the physics of these decays are difficult to formulate because of their non-perturbative nature. Much rigorous field theoretical formulation is required to theoretically compute the transitions which requires high computational capability, so phenomenological approach is normally preferred.

We have successfully used extended relativistic harmonic confinement model (ERHM)for computation of hadronic masses, exclusive decay rates as well as radiative transitions of heavy quakonia [1–4]. The same set of parameters is used in the present study to test it for the heavy-light mesonic sector. Due to the unavailability of most of the experimental results for these systems, we have compared our results with other available phenomenological models.

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The masses and M1 transition rates

We use the spectroscopic parameters of ERHM having coulomb plus harmonic form of potential and confined one gluon exchange operator instead of free gluon propagator used in most of the potential models [1–4]. The parameters are $m_q = 82$ MeV/c^2; where $q = u = d$, $m_s = 358$ MeV/c^2, $m_c = 1428$ MeV/c^2 and $m_b = 4637$ MeV/c^2. The mass spectrum of D, D^*, D_s, D_s^*, B, B^*, B_s and B_s^* predicted by our model have been utilized for the present computations along with other theoretical predictions. The wave functions used in ERHM with single center size parameter are used for the computation of transition widths.

M1 transition rates are normally weaker than E1 rates, but they are of more interest as they may allow access to spin-singlet states that are very difficult to produce otherwise. They are also important in understanding inclusive quark molecular transitions. It is also interesting that the known M1 rates show serious disagreement between theory and experiment when it comes to potential models. This is in part due to the fact that M1 transitions between different spatial multiplets are nonzero only due to small relativistic corrections to a vanishing lowest-order M1 matrix element [5].

The M1 transition width between two S-wave states is given by [6]

$$\Gamma_{n^3S_1 \to n'^1S_0\gamma} = \frac{4}{3}\alpha\langle e_Q\rangle^2 \frac{k_\gamma^3}{m^2}|I|^2 \qquad (1)$$

TABLE I: Masses of heavy-light mesons in MeV

System	Present	PDG [7]	[8]	[9]
$D(1S)$	1815	1869	1869	1869
$D(2S)$	2653	2420	–	2633
$D^*(1S)$	1934	2007	2011	2010
$D^*(2S)$	2690	2460	–	2721
$D_s(1S)$	2009	1969	1967	1967
$D_s(2S)$	2778	2536	–	–
$D_s^*(1S)$	2110	2317	2110	2107
$D_s^*(2S)$	2814	–	–	–
$B(1S)$	5094	5279	5270	5279
$B(2S)$	6192	5721	–	5876
$B^*(1S)$	5265	5325	5329	5324
$B^*(2S)$	6235	–	–	5974
$B_s(1S)$	5375	5366	5378	5362
$B_s(2S)$	6264	5840	–	5974
$B_s^*(1S)$	5409	5415	5440	5407
$B_s^*(2S)$	6299	–	–	6862

TABLE II: Radiative M1 transitions of s-wave heavy-light mesons (keV)

State			PDG			
Initial	Final	Present	[7]	[9]	[10]	[11]
$1D^*$	$1D$	25.2(115)	< 800	32	20.0	20.81
$2D^*$	$2D$	0.82(38)	–	–		(138)
$1D_s^*$	$1D_s$	2.0(98)	< 4500	0.2	0.18	0.1
$2D_s^*$	$2D_s$	0.02(36)	–	–	–	(136)
$1B^*$	$1B$	9.14(168)	–	–	0.40	0.42
$2B^*$	$2B$	0.59(43)		–	–	(46)
$1B_s^*$	$1B_s$	0.02(34)	–	–	0.07	0.09
$2B_s^*$	$2B_s$	0.07(35)	–	–	–	(47)

Where

$$I = \int_0^\infty r^2 dr R_{n'0}(r) R_{n0}(r) j_0(\frac{k_\gamma r}{2})$$

and the effective charge is given by [12]

$$\langle e_Q \rangle = \frac{m_q e_Q + m_Q e_{\bar{q}}}{m_Q + m_q}$$

with $m_Q/\bar{q}$ and $e_Q/\bar{q}$ are masses and modulus of fractional electronic charges on the heavy/light quark/antiquark respectively.

Results and Conclusion

The photon energies depend on the model in most cases as we have assumed theoretical masses for unknown states. For the low-energy favored M1 transitions, the photon energies are found to be nearly the same as the mass splittings. The wide variation in predicted hyperfine splittings leads to considerable uncertainty in predicted rates for these transitions. The computed masses and magnetic radiative transition rates are tabulated along with other theoretical predictions and available experimental values in Tables I and II. The values in the parentheses are energy of the photon in MeV. The transition widths obtained by all the potential models are well off with compared to experimental data, however, almost all of them are found to be within same range and order.

References

[1] P.C. Vinodkumar, J.N. Pandya, V.M. Bannur and S.B. Khadkikar, Eur. Phys. Jnl. **A 4** (1999)

[2] J.N. Pandya and P.C. Vinodkumar, Pramana J. Phys. **57(4)**, 821 (2001)

[3] A.K. Rai, J.N. Pandya and P C Vinodkumar,J. Phys. **G 31**, 1453-1464 (2005)

[4] A.K. Rai, J.N. Pandya and P.C. Vinodkumar, Eur. Phys. Jnl. **A 38**,77 (2008)

[5] T. Barnes, S.Godfrey and E.S.Swanson, Phys. Rev. **D 72**, 054026 (2005)

[6] N. Brambilla, Y. Jia, and A. Vairo, Phys. Rev. **D 73**, 054005 (2006)

[7] C. Amsler et al. (Particle Data Group), Phys. Lett. **B 667**, 1 (2008) and 2009 partial update for the 2010 edition

[8] T. Matsuki, T. Morii, K. Sudoh, Prog. Theor. Phys. **117**, 1077 (2007)

[9] A. M. Badalian, B. L. G. Bakker, Y. A. Simonov, Phys. Rev. **D 72**, 116001 (2007)

[10] H. M. Choi, Phys. Rev. **D 75**, 073016 (2007)

[11] S. N. Jena, P. Panda, K. P. Sahu, J. Phys. G: Nucl. & Part. **27**, 1519 (2001)

[12] S. Godfrey, Phys. Rev. **D 72**, 054029 (2005)