TABLE 1.2 **A summary of the the main types of electrostatic interactions found in proteins.** Van der Waals interactions are also described here because of their electrostatic nature. q is the full charge (in electron charges), μ is the dipole moment (in Debye), r_{ij} is the distance between the charges (in Å), and ε_r is the relative dielectric constant of the medium. The θ angles in the second and third equations are defined in Figure 1.15b. To obtain the energy in kcal/mol, the following prefactors should be used: **332** for the first equation, **69.1** for the second equation, and **14.4** for the third equation.

Interaction	Example	Potential energy	Distance dependence	Typical distance (Å)	Typical strength in vacuum [*a] (kcal/mol)
Charge-charge (ionic)	Salt bridge	$U = \frac{q_i q_j}{\varepsilon_r r_{ij}}$	$1/r$	< 4 (salt bridge)	~80
Charge-fixed dipole	Hydrogen bond	$U = \frac{q_i \mu_j (\cos\theta)}{\varepsilon_r r_{ij}^2}$	$1/r^2$	2.8–3.0 [*b]	0–7 [*c]
Fixed dipole – fixed dipole	Hydrogen bond	$U = \frac{\mu_i \mu_j (2\cos\theta_i \cos\theta_j - \sin\theta_i \sin\theta_j)}{\varepsilon_r r_{ij}^3}$	$1/r^3$		
Induced dipole – induced dipole	Van-der Waals interactions	$U = \frac{A_{ij}}{r_{ij}^{12}} - \frac{B_{ij}}{r_{ij}^6}$	$1/r^6$ (attractive) $1/r^{12}$ (repulsive)	3.5 [*d]	0.1–0.5 [*e]

[*a] In proteins, the strength of these interactions is difficult to determine, and different values have been suggested by different studies (e.g., [136]; see Chapter 4 for details).

[*b] [133]. In the case of hydrogen bonds, if the bond is described as donor-hydrogen-acceptor (D–H···A), the reported values correspond to the D···A distance. The corresponding H···A distance is typically 2 Å [134].

[*c] [166–168].

[*d] [169].

[*e] [167,170].