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Solution:

$$U(r) = \frac{a}{r^n} + \frac{b}{r^s} = -\frac{a}{r^2} + \frac{b}{r^{10}} \tag{1}$$

$$[U(r)]_{r=r_0} = -\frac{a}{r_0^2} + \frac{b}{r_0^{10}} = \text{minimum} \tag{2}$$

Hence,

$$\left[\frac{dU(r)}{dr}\right]_{r=r_0} = 0 = \frac{2a}{r_0^3} - \frac{10b}{r_0^{11}}$$

or

$$\frac{a}{r_0^3} = \frac{5b}{r_0^{11}}$$

$$r_0^8 = \frac{5b}{a} \tag{3}$$

$$r_0^2 = \left[\frac{5b}{a}\right]^{1/4} \tag{4}$$

$$r_0^{10} = \left[\frac{5b}{a}\right]^{5/4} \tag{5}$$

Now the potential energy in the stable configuration, (or) dissociation energy is given by,

$$[U(r)]_{r=r_0} = -\frac{a}{r_0^2} + \frac{b}{r_0^{10}}$$

substituting for r_0^2 and r_0^{10} from equations (4) and (5), we get the equation for minimum energy as,

$$[U(r)]_{r=r_0} = U_{min} = -a\left[\frac{a}{5b}\right]^{1/4} + b\left[\frac{a}{5b}\right]^{5/4}$$

$$= \frac{a^{5/4}}{(5b)^{1/4}}\left[\frac{b}{5b} - 1\right]$$

$$= \frac{a^{5/4}}{(5b)^{1/4}}\left[\frac{1-5}{4}\right]$$

$$U_{min} = -\left[\frac{4}{5}\right]\frac{a^{5/4}}{(5b)^{1/4}}$$

$$= -\frac{4a \cdot a^{1/4}}{5(5b)^{1/4}}$$

or

$$U_{min} = -\left[\frac{4a}{5}\right]\left[\frac{a}{5b}\right]^{1/4} \tag{6}$$

Substituting the value of r_0 from equation (4),

$$\boxed{U_{min} = -(4/5)(a/r_0^2)} \quad \text{Answer}$$

P 2.1 The interaction energy of two particles in the field of each other is given by

$$U(r) = -\frac{a}{r} + \frac{b}{r^5} \quad \text{where } a \text{ and } b \text{ are constants.}$$

(a) Show that the particles form a stable compound for

$$r = r_0 = \left[\frac{5b}{a}\right]^{1/4}$$

(b) Show that in the stable configuration the energy of attraction is 5 times the energy of repulsion.

(c) Show that the potential energy of the two particles in the stable configuration is $-(a/r_0)(8/9)$

2.2 Assume the energy of two particles in the field of each other is given by the function $U(r) = -(a/r) + (b/r^5)$ where a and b are constants and r is the distance between the centres of the particles.

(a) Show that if the particles are pulled apart, the molecule will break as soon as

$$r = \left[\frac{36b}{a}\right]^{1/5} = r_0 (4.5)^{1/5}$$

(b) In the stable configuration the energy of attraction is 8 times the energy of repulsion.

(c) Also show that the minimum force required to break the molecule is equal to

$$\left[\frac{a^{9/5}}{(36b)^{2/5}}\right]\left[1 - \frac{8}{36}\right]$$

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