TUTORIAL-8

PHYSICS-II

SHUBHAM GARG
9919103057
BATCH: F2

1. Define the terms:

(a) Ionization Energy-

The electron can be completely freed from the influence of the nucleus by supplying sufficient energy and the minimum energy needed for this is called Ionization energy.

(b) Electron Affinity-

It is defined as the energy that is given out when an electron is added to an atom to form a negative ion.

(c) Lattice Energy-

The lattice energy is that energy evolved when a crystal is formed from individual ions, rather than from individual atoms.

(d) Cohesive Energy-

The cohesive energy of an ionic crystal is the energy that would be liberated by the formation of the crystal from individual neutral atoms. It is usually expressed in eV/atom, or eV/molecule or in kJ/kmol.

2. (a) Hydrogen Bonds

Hydrogen Bonds are relatively weak bonds and do not involve the sharing or transfer of electrons. The bond between each oxygen and hydrogen atom is a polar covalent bonds, which involves the unequal sharing of electrons.

(b) Electronegativity is used to determine a bond to be ionic.

3. (a) Pure covalent bonds can only be formed by the interaction of singly occupied orbitals and the maximum number of bonds is given by the number of existing singly occupied orbitals. With bond formation, molecular orbital formation, the bonding capability is saturated. In covalent bond formation, charge distribution is axial between the reaction partners(σ bond) or lateral between the partners (π bonds) the bonding is directional

(b) Ionic bonds are the result of charge transfer which results in the formation of ions with opposite charge. The electric force fields associated with the ions are non-directional and therefore the bonding capability is not saturated by the close proximity of oppositely charged species.

4. Given: $u(r) = -\alpha/r^4 + \beta/r^{12}$

for equilibrium $\rightarrow$ $\left.\frac{du}{dr}\right|_{r=r_0} = 0$

$$\Rightarrow r_0 = \left(\frac{3\beta}{\alpha}\right)^{1/8}$$

for stable bonding, the energy released will be

$$u(r_0) = -\frac{\alpha}{\left[\left(\frac{3\beta}{\alpha}\right)^{1/8}\right]^4} + \frac{\beta}{\left[\left(\frac{3\beta}{\alpha}\right)^{1/8}\right]^{12}}$$

$$= \frac{-\alpha^{3/2}}{(3\beta)^{1/2}} + \frac{\beta\alpha^{3/2}}{(3\beta)^{3/2}}$$

$$= \frac{-\alpha^{3/2}3\beta + \beta\alpha^{3/2}}{(3\beta)^{3/2}}$$

$$= \left(\frac{\alpha}{3\beta}\right)^{3/2} \times (-2\beta)$$

$$= -\left(\frac{4\alpha^3}{27\beta}\right)^{1/2}$$

5. Given: $u(r) = -A/r^2 + B/r^{10}$

for Equilibrium $\left.\frac{du}{dr}\right|_{r=r_0} = 0$

which results $A = 5B r_0^{-8}$ ---- (1)

Dissociation Energy is given by -

$u(r_0) = -A/r_0^2 + B/r_0^{10}$

Using (1) $\rightarrow$

$u(r_0) = -\frac{4}{5}\frac{A}{r_0^2}$ ----- (2)

as $u(r_0) = -8.0\,eV$, on solving (2) for A $\rightarrow$.

$A = 7.84 \times 10^{-19}\ eV.m^2$

$B = 5.90 \times 10^{-96}\ eV.m^{10}$ (from equation (1))

$f = \frac{du}{dr} = -\frac{2A}{r^3} + \frac{10B}{r^{11}}$ ----- (3)

In order to dissociate the molecule $\rightarrow$

$\left.\frac{df}{dr}\right|_{r=r_0} = 0 \Rightarrow r_0 = \left(\frac{110B}{6A}\right)^{1/8}$

$\boxed{r_0 = 3.25\ \mathring{A}}$ ----- (4)

and force required $\rightarrow$

$P(r_0) = 9.53 \times 10^{-9}\,N$

$= \boxed{9.53\,nN}$

6. The potential energy of a pair of Hydrogen atom is $\rightarrow$

$U = -\frac{e}{4\pi\varepsilon_0 r_0}\ eV$ or $U = -\frac{e^2}{4\pi\varepsilon_0 r_0}\ J$

$= -\frac{1.6\times10^{-19} \times 9\times10^{9}}{5.1\times10^{-10}} = \boxed{-2.82\,eV}$

Now, energy required to transfer an e^- from anion to cation is

$E_r = \Delta U + U$

$= I.P - E.A + U$

$= 13.595 - 0.754 + (-2.82)$

$\boxed{E = 10.021\,eV}$

7. The attractive force between the two ions is coulomb i.e.

$$F = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r_0^2}$$

$$= \frac{9\times10^9 \times (1.6\times10^{-19})^2}{\{(1.67+1.95)\times10^{-10}\}^2}$$

$$= \frac{9\times1.6\times10^{9-38-20}}{(3.62)^2}$$

$$= 1.76\times10^{-9} \text{ Coulomb}$$

$$\boxed{F = 1.76nC}$$

8. $u(r) = -a/r^m + b/r^n$

$u(r)\Big|_{r=r_0} = \text{minimum} = -a/r_0^m + b/r_0^n$

$$\left[\frac{du}{dr}\right]_{r=r_0} = 0 = \frac{ma}{r_0^{m+1}} - \frac{nb}{r_0^{n+1}}$$

$$\Rightarrow b = (a r_0^{n-m})(m/n)$$

So $u(r) = -a/r^m + b/r^n$

$$= -a/r^m + \frac{a r_0^{n-m}}{r^n} \cdot \frac{m}{n}$$

(b) P.E. at $r = r_0$ which is minimum

$$U_{min} = -\frac{a}{r_0^m}\left[1 - \frac{m}{n} \cdot \frac{r_0^{n-m}}{r_0^{n-m}}\right]$$

$$= -\frac{a}{r_0^m}\left[1 - \frac{m}{n}\right]$$

(a) $$\left[\frac{du}{dr}\right]_{r=r_0} = \frac{ma}{r_0^{m+1}} - \frac{nb}{r_0^{n+1}} = 0$$

$$\Rightarrow r_0^n = r_0^m\left[\left(\frac{b}{a}\right)\left(\frac{n}{m}\right)\right]$$

$$\Rightarrow \frac{r_0^n}{r_0^m} = \left(\frac{b}{a}\right)\left(\frac{n}{m}\right)$$

$$\boxed{r_0 = \left[\left(\frac{b}{a}\right)\left(\frac{n}{m}\right)\right]^{1/n-m}}$$

$$\left[\frac{d^2u}{dr^2}\right]_{r=r_0} = -\frac{am(m+1)}{r_0^{m+2}} + \frac{bn(n+1)}{r_0^{n+2}} > 0$$

$$\Rightarrow \quad bn(n+1) > am(m+1) r_0^{n-m}$$

$$bn(n+1) > am(m+1)\left(\frac{b}{a}\right)\left[\frac{n}{m}\right]$$

$$(n+1) > (m+1)$$

$$\boxed{n > m}$$

Hence proved.

(c) $u(r) = -a/r^m + b/r^n$, $m=1, n=8$

$\Rightarrow u(r) = -a/r + b/r^8$

molecule will break at critical distance r_c

$$\left[\frac{dF}{dr}\right]_{r=r_c} = 0 \quad ; \quad F = -\frac{\partial u}{dr} = -\frac{a}{r^2} + \frac{8b}{r^9} \quad \text{—(1)}$$

$$\therefore \left[\frac{\partial F}{\partial r}\right]_{r_c} = \frac{2a}{r^3} - \frac{72b}{r^{10}} = 0 \Rightarrow r_c = \left[\frac{36b}{a}\right]^{1/7}$$

$F(r)$ will be min when $\frac{d^2F}{dr^2}$ is +ve

so from equation (1) $\rightarrow$

$$\frac{d^2F}{dr^2} = +ve = \frac{6a}{r^4} - \frac{720b}{r^{10}}$$

$$F_{min} = a/r^2 - 8b/r^9$$

$$= a\left(\frac{a}{36b}\right)^{2/7} - 8b\left(\frac{a}{36b}\right)^{9/7}$$

$$= \frac{a^{9/7}}{(36b)^{2/7}}\left(1 - \frac{8}{36}\right)$$

$$\boxed{F_{min} = \left(\frac{7}{9}\right)\frac{(a)^{9/7}}{(36b)^{2/7}}}$$