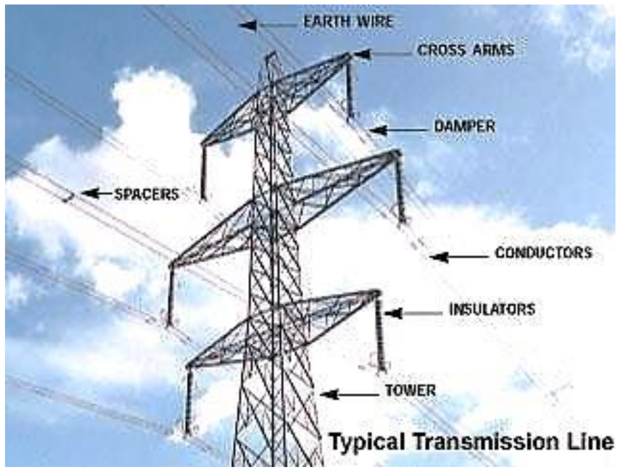
Note: These questions will be discussed in the tutorial sessions on September 12.

Question 1:

Electrical utility companies must transport electricity from the power generation plant to consumers. As shown below, one of the common transmission methods is to use aboveground wires suspended between structural support towers. The towers and transmission wire are often fabricated from metals, but the "spacers" between the transmission lines and the towers are usually made from ionic solids. Explain the choice of materials for these three applications.



Solution:

To minimize the power loss associated with the resistance of the transmission lines, it is necessary to select a material with a high electrical conductivity. Thus, metals rather than ionic compounds are used for this application. The structural support material is selected for its mechanical rather than its electrical properties. It would be unwise to fabricate these towers from a brittle material, since the structure may experience high loads from many sources including gusts of wind and possible collisions with motor vehicles. In addition, because of their high ductility, metals are more easily formed into large and complex shapes. Finally, we must consider the purpose of the "spacers." If the metal transmission lines are in close proximity to the metal support structure, the possibility of a short circuit that will electrify the entire structure exists. Therefore, the wires must be insulated from the support structure by using a high–electrical-resistance ionic solid as the "spacer."

Question 2:

Calculate the force of attraction between a K^+ and an O^{2-} ion the centers of which are separated by a distance of 1.5 nm.

Solution

The attractive force between two ions FA is just the derivative with respect to the interatomic separation of the attractive energy expression, Equation 2.8, which is just

$$F_A = \frac{dE_A}{dr} = \frac{d\left(-\frac{A}{r}\right)}{dr} = \frac{A}{r^2}$$

The constant A in this expression is defined in footnote 3. Since the valences of the K^+ and O^{2-} ions (Z_1 and Z_2) are +1 and -2, respectively, $Z_1 = 1$ and $Z_2 = 2$, then

$$F_A = \frac{(Z_1 e)(Z_2 e)}{4\pi\varepsilon_0 r^2}$$

$$= \frac{(1)(2)(1.602 \times 10^{-19} \text{ C})^2}{(4)(\pi)(8.85 \times 10^{-12} \text{ F/m})(1.5 \times 10^{-9} \text{ m})^2}$$

$$= 2.05 \times 10^{-10} \text{ N}$$

Question 3:

For each of the following compounds, state whether the bonding is essentially metallic, covalent, ionic, van der Waals, or hydrogen:

(a) Ni, (b) ZrO_2, (c) graphite, (d) solid Kr, (e) Si, (f) BN, (g) SiC, (h) Fe_2O_3, (i) MgO, (j) W, (k) H_2O within the molecules, (l) H_2O between the molecules.

If ionic and covalent bonds are involved in the bonding of any of the compounds listed, calculate the percentage ionic character in the compound.

Solution

(a) Ni:	Nickel bonding is primarily metallic.
(b) ZrO_2:	From Pauling's equation, the Zr–O bond is 73.4% ionic and 26.6% covalent, where x_A and x_B are the electronegativities of zirconium and oxygen, respectively.
(c) Graphite:	The bonding is covalent within the layers and secondary between the layers.
(d) Solid Kr:	The bonding represents van der Waals due to fluctuating dipoles.
(e) Si:	Silicon bonding is covalent.
(f) BN:	The B–N bond, from Pauling's equation (2-10), is 26.1% ionic and 73.9% covalent.
(g) SiC:	From Eq. (2-10), the Si–C bond is 11% ionic and 89% covalent.
(h) Fe_2O_3:	From Eq. (2-10), the Fe-O bond is 55.5% ionic and 44.5% covalent.
(i) MgO:	From Eq. (2-10), the Mg-O bond is 70.2% ionic and 29.8% covalent.
(j) W:	Tungsten bonding primarily consists of metallic bonding with some covalent character.
(k) H_2O within the molecules:	The H–O bond is 38.7% ionic and 61.3% covalent.
(l) H_2O between the molecules:	Hydrogen bonding exists between H_2O molecules.

Question 4:

Calculate the number of atoms in one ton of iron.

Solution:

Atomic weight of iron is 55.85 g/mol, thus:

1 ton Fe = 1,000 kg Fe = 1,000,000 g / (55.85 f/mol) = 17905.1 moles of Fe

Each mole contains 6.02 x 10^{23} atoms, therefore:

1 tonne of Fe has 17905.1 x (6.02 x 10^{23}) = 1.078 x 1028 atoms/tonne

Question 5:

The interaction energy between Na^+ and Cl^- ions in the NaCl crystal can be written as:

$$E(r) = -\frac{4.03 \times 10^{-28}}{r} + \frac{6.97 \times 10^{-96}}{r^8}$$

Where the energy is given in joules per ion pair, and the interionic separation *r* is in meters. Calculate the binding energy and the equilibrium separation between the Na^+ and Cl^- ions. Also estimate the elastic modulus Y of NaCl given that:

$$Y = \frac{1}{6r_0}\left[\frac{d^2E}{dr^2}\right]_{r=r_0}$$

Solution:

$$@\ equilibrium: \left.\frac{dE(r)}{dr}\right]_{@r_0} = 0 \Rightarrow\ 4.03 \times 10^{-28} r_0^{-2} - 8 \times 6.97 \times 10^{-96} r_0^{-9} = 0 \xrightarrow{yields} r_0 = 2.81 \times 10^{-10}$$

$$E(r_0) = -\frac{4.03 \times 10^{-28}}{2.81 \times 10^{-10}} + \frac{6.97 \times 10^{-96}}{(2.81 \times 10^{-10})^8} = 1.255 \times 10^{-18} \frac{J}{ion\ pair}$$

$$Y = \frac{1}{6r_0}\left[\frac{d^2E}{dr^2}\right]_{r=r_0} = \frac{1}{6r_0}[-2(4.03 \times 10^{-28}) r_0{}^{-3} + (-8)(-9)(6.97 \times 10^{-96}) r_0^{-10}]$$

$$Y = \frac{1}{6 \times 2.81 \times 10^{-10}}[-2(4.03 \times 10^{-28})(2.81 \times 10^{-10})^{-3} + (-8)(-9)(6.97 \times 10^{-96})(2.81 \times 10^{-10})^{-10}]$$

$$Y = 7.543 \times 10^{10}\ Pa = 75.43\ GPa$$