13.E: Intermolecular Forces (Exercises)

13.1: Intermolecular Interactions

Q13.1a

List all the intermolecular interactions that take place in each of the follow kings of molecules: CCl_3F, CCl_2F_2, $CClF_3$, and CF_4.

Q13.1b

Determine what type of intermolecular forces exist in the following molecules: LiF, MgF_2, H_2O, and HF.

S13.1b

- H_2O: London Force, Dipole-Dipole interaction, Hydrogen bonds.
- HF: Dipole-Dipole intermolecular forces, Hydrogen bonds.
- MgF_2 and LiF: strong ionic attraction.

Q13.2a

Arrange the follow species in order of decreasing melting points: CsBr, KI, KCL, MgF2.

Q13.2b

Which has the highest boiling point $I_{2,}$ $Br_{2,}$ and Cl_2. Explain why?

S13.2b

The atomic weigh of Iodine = 127, Bromine = 80, and Chlorine = 35.5. The weigh is proportion to the London dispersion force, and the higher molecular weigh, the larger the force. Thus, I_2 has a highest boiling point.

Q13.3

1-Propanol C_3H_7OH and methoxyethane CH_3O C_2H_5 have the same molecular weigh. Which has the higher boiling point?

S13.3

The 1-Propanol can form London Force, Dipole- Dipole, and H- bonding due to the H bonded to O atom of OH group, whereas the methoxyethane can not form the H-bonding. Therefore, the 1-Propanol has higher intermolecular attractive force and thus a higher boiling point.

Q13.3

Why do the lightest compounds such as NH3, H2O, and HF have the highest boiling points?

Q13.4a

What kind of attractive interaction exists between atoms and between nonpolar molecules?

Q13.4b

Why nature gas CH_4 is a good choice to storage tank in winter?

S13.4b

It's about boiling point. The methane has the boiling point at -161 °C, making it to be a good choice for winter season.

Q13.4

Explain why methane (CH_$_{4\backslash)}$ is used as the primary heating gas in Alaska during wintertime instead of the more commonly used butant or propane gases use in the lower 48 states.

S13.4

Methane (CH_4) remains gas because its boiling point is about -160°C. Other gases, such as propane or butane, would liquefy under freezing condition. Therefore, methane is more likely to be used during wintertime at Alaska

Q13.5

Define types of intermolecular forces and give example for each.

S13.5

There are 3 types of intermolecular force: London Dispersion, Dipole-Dipole (Example: Two $NaCl$) and Ion-Dipole (Example: Mg^{+} and HCl)

- Dipole- Dipole occurs between polar molecules
- Ion- Dipole occurs between an ion and polar molecules
- London Dispersion occurs between the nonpolar molecules.

Q13.6

How does the intermolecular determine the boiling point?

S13.6

The weakest intermolecular, the lowest boiling point.

Q13.7a

What is their dipole-dipole interaction of wo HCl molecules are co-linear head-to tail.

Given: The dipole moment of HF is 1.86 D. The dipole moment of HCl is 1.05 D. The distance between the two is 1.78

H^{+}-F^{-} - - - - H^{+}-Cl^{-}

S13.7a

$$V = -\frac{2\mu_A \mu_B}{4\pi\varepsilon_0 r^3} \tag{13.E.1}$$

$$V = -\frac{2(1.05)(1.86)}{4\pi(8.854187817 \cdot 10^{-12})(1.78)^3} \tag{13.E.2}$$

13.2: The Ionic Bond

Q13.7b

Calculate an ion-ion interaction energy between K^{+} and Cl^{-} at a distance of 600 pm.

S13.7b

The ion-ion interaction energy is given by Coulomb's law.

$$V = \frac{q_1 q_2}{4\pi\epsilon_o r} \tag{13.E.3}$$

$$V = \frac{-(1.602 \times 10^{-19}\ \cancel{C})(1.602 \times 10^{-19}\ \cancel{C})}{4\pi(8.853 \times 10^{-12}\ \cancel{C^2} \cdot N^{-1} \cdot m^{\cancel{-2}})(6 \times 10^{-10}\ \cancel{m})} = -3.84 \times 10^{-19}\ J \tag{13.E.4}$$

Q13.7

Calculate an ion-dipole interaction energy between K^{+} and HCl at a distance of 600 pm. HCl has a dipole moment of 1.08 D.

S13.7

$$\mu = 1.08\ \cancel{D} \times \frac{3.3356 \times 10^{30}\ C \cdot m}{1\ \cancel{D}} = 3.6 \times 10^{-30}\ C \cdot m \tag{13.E.5}$$

$$V = \frac{-q\ \mu}{4\pi\epsilon_o r^2} = \frac{-(1.602 \times 10^{-19}\ \cancel{C})(3.6 \times 10^{-30}\ \cancel{C} \cdot \cancel{m})}{4\pi(8.853 \times 10^{-12}\ \cancel{C^2} \cdot N^{-1} \cdot m^{\cancel{-2}})(6 \times 10^{-10}\ \cancel{m})^2} = -1.44 \times 10^{-20}\ J \tag{13.E.6}$$

As expected this is appreciably smaller in energy than covalent bonds (e..g, HCl has a bond enthalpy of $7.0 \times 10^{-19}\ J$).

13.3: Types of Intermolecular Forces

Q13.8a

Rank the interactions from weakest to strongest:

a. H_2O - - OH_2
b. Li^+ - - F^-
c. Li^+ - - OH_2

S13.8a

a. ion-ion interaction: Li^+ - - F^-
b. ion-dipole interaction: Li^+ - - OH_2
c. dipole-dipole interaction: H_2O - - OH_2

Q13.8b

A low concentration electrolytic solution behaves non-ideally while a high concentration of the same solution behaves ideally. Explain this phenomenon in terms of forces, noting that Coulomb forces depend on $1/r^2$ while van der Waals forces depend on $1/r^7$. Which of these forces are low concentration electrolytic solutions likely to follow? High concentration?

S13.8b

The interatomic distances in a low concentration electrolytic solution are greater than those in a high concentration solution. They follow van der Waals forces and thus behave less ideally. High concentration electrolytic solutions follow Coulomb forces.

Q13.9a

Calculate the ion-dipole interaction between H_2O and Li^+. You are given the dipole moment of H_2O is 1.82 D. The distance between these two is 2 Å.

S13.9a

$$V = -\frac{q\mu}{4\pi\varepsilon_0 r^2} \tag{13.E.7}$$

$$= \frac{1.82D \cdot (\frac{3.3356\cdot 10^{-30} Cm)}{1D}}{4\pi(8.85\cdot 10^{-12})(2\cdot 10^{-10}m)^2} = 1.36\ kJ/mol \tag{13.E.8}$$

Q13.9b

Calculate the potential energy of interaction between a Cl^- ion situated 120 pm away from an H_2O molecule with a dipole moment of 1.85 D.

S13.9b

$$\mu = 1.85\ \cancel{D} \times \frac{3.3356\times 10^{30}\ C\cdot m}{1\ \cancel{D}} = 6.18\times 10^{-30}\ C\cdot m \tag{13.E.9}$$

$$r = 1.2\times 10^{-10}\ m \tag{13.E.10}$$

$$V = \frac{q\mu}{4\pi\varepsilon_o r^2} = \frac{(-1.602\times 10^{-19}\ C)(6.18\times 10^{-30}\ C\cdot m)}{4\pi(8.851\times 10^{-12}\ C^{-2}N^{-1}m^{-2})(1.2\times 10^{-10}\ m)^2} \tag{13.E.11}$$

Q13.10

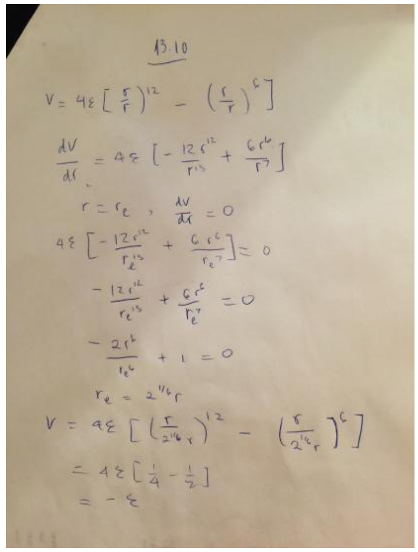
Do you expect a greater dipole-dipole interaction between two molecules that are antiparallel or between two molecules that are co-linear head-to-tail?

S13.10

You expect a stronger interaction when the two are co-linear head-to tail. This can be seen by looking at the formula or in the images of the two.

Q13.10

Express the equilibrium distance r_e in term ð and show V = - €



13.10

$$V = 4\varepsilon\left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6}\right]$$

$$\frac{dV}{dr} = 4\varepsilon\left[-\frac{12\sigma^{12}}{r^{13}} + \frac{6\sigma^{6}}{r^{7}}\right]$$

$$r = r_e, \quad \frac{dV}{dr} = 0$$

$$4\varepsilon\left[-\frac{12\sigma^{12}}{r_e^{13}} + \frac{6\sigma^{6}}{r_e^{7}}\right] = 0$$

$$-\frac{12\sigma^{12}}{r_e^{13}} + \frac{6\sigma^{6}}{r_e^{7}} = 0$$

$$-\frac{2\sigma^{6}}{r_e^{6}} + 1 = 0$$

$$r_e = 2^{1/6}\sigma$$

$$V = 4\varepsilon\left[\left(\frac{\sigma}{2^{1/6}\sigma}\right)^{12} - \left(\frac{\sigma}{2^{1/6}\sigma}\right)^{6}\right]$$

$$= 4\varepsilon\left[\frac{1}{4} - \frac{1}{2}\right]$$

$$= -\varepsilon$$

Q13.12

a. Determine Vander Waals radius of Argon.
b. Use this radius to find fraction of volume by 2 mole of argon at room temperature at 1 atm.

S13.12

a. r= σ/2 = 3.40 A^0 /2 = 1.70 A^0

b. Volume of 2 mole of Ar

4/3 πr^3 ((6.022 x 10^23)/(2 mol))= 4/3 π (1.70 x 10^(-10) m)^3 ((6.022 x 10^23)/(2 mol))

= 6.19 x 10-6 L mol-1

V/n=RT/P= ((0.08206 L atm K^(-1) mol^(-1) (298.2 K))/1atm

= 24.5 L mol-1

The fraction of this volume occupied by 2 mole of Ar

(1.239 x 10^-2 L mol^{-1})/ 24.47 L mol^{-1} = 2.5 x10 $^{-7}$

Q13.15

a) What is the original of polarity in a molecule?

b) Is CO_2 polar? Explain.

Q13.16

Of the following compound, which one(s) is/are soluble?

a. CH_4
b. NCl_3
c. C_6H6
d. $CO(NH_2)_2$

Q13.17

What makes a compound soluble in water? Explain using examples.

Q13.18

Explain why does water have a high specific heat.

Q13.20

The energy of a hydrogen bond for each base pair in DNA is 15 kJ/mol. Two complimentary strands has 50 base pairs each. What is the ratio of the 2 different strands to hydrogen double helix in a solution given a temperature of 300 K.

S13.20

First calculate the ratio of the two different strands for just one pair.

$$e^{\Delta E/RT} = exp[(15 \times 10^3\ J/mol)/(8.314\ J/K*mol)(300\ K) = 2.4 \times 10^{-3} \tag{13.E.12}$$

Since there are 50 base pairs, we need to multiply by 50 to account for all the base pairs.

exp[100X(15X10^3 J/mol)/(8.314 J/K*mol)(300K) = 0

Q13.24

Consider two pure liquids. One has strong intermolecular interactions, and the other has relatively weak intermolecular interactions. For the following properties, indicate which of the liquids you would expect to have a higher value (answer with "strong" or "weak").

a. viscosity
b. vapor pressure
c. freezing point
d. surface tension

S13.24

a. Strong. Higher viscosity results from stronger interactions between the liquid molecules.
b. Weak. The liquid with weaker bonds takes less energy to turn into vapor, so it will exert a higher vapor pressure.
c. Strong. The freezing point is the same as the melting point; it takes more energy to melt a solid with stronger intermolecular interactions.
d. Strong. Surface tension is a result of intermolecular interactions. The stronger these interactions, the greater the surface tension.

Q13.25

Fun fact: if the DNA in a single human cell were stretched out (but still in its familiar double helix conformation), it would be approximately 2 meters long. The distance, along the helix, between nucleotides is 3.4 Å.

a. Estimate the number of basepairs in the haploid human genome, from the 2 meter fun fact.
b. The human body contains about 100 trillion cells. About a quarter of these are erythrocytes (red blood cells) and contain no genomic DNA. Use the average molar mass for a basepair, 650 grams per mole, to estimate how much of a human's mass is human genomic DNA.
c. At its closest, Pluto is 4.28 billion km from Earth. Do you have enough DNA to reach Pluto?

Hint: Humans are diploid.

S13.25

(a)

$$ 2\ m/cell \times \dfrac{bp}{3.4\ Å} \times \dfrac{10^{10}\ Å}{m} \times \dfrac{cell}{2\ haploid\ genomes} = 3 \times 10^{9} \dfrac{bp}{haploid\ genome} \]

Three billion basepairs.

(b) 75 trillion of the human cells in your body have genomic DNA.

$$ 75 \times 10^{20}\ cells \times \dfrac{haploid\ genomes}{cell} \times \dfrac{3 \times 10^9\ bp}{haploid\ genome} \times \dfrac{mol}{6.022 \times 10^{23}} \times 650 \dfrac{g}{mol\ bp} = 200\ g \]

That's about half a pound.

(c)

$$\dfrac{2\ m}{cell} \times 75 \times 10^{12}\ cells \times \dfrac{km}{1000\ m} = 2 \times 10^{11}\ km$$

Yes, you have way more DNA than you need to stretch it from Earth to Pluto.

13.4: Hydrogen Bonding

13.5: The Structure and Properties of Water

13.6: Hydrophobic Interaction