You have mastered this topic when you can:

1) define or describe **INTERMOLECULAR FORCES**.
2) define or describe **VAN DER WAALS FORCES**: **DIPOLE-DIPOLE FORCES** & **LONDON DISPERSION FORCES**.
3) define or describe **HYDROGEN BONDS**.

INTERMOLECULAR FORCES

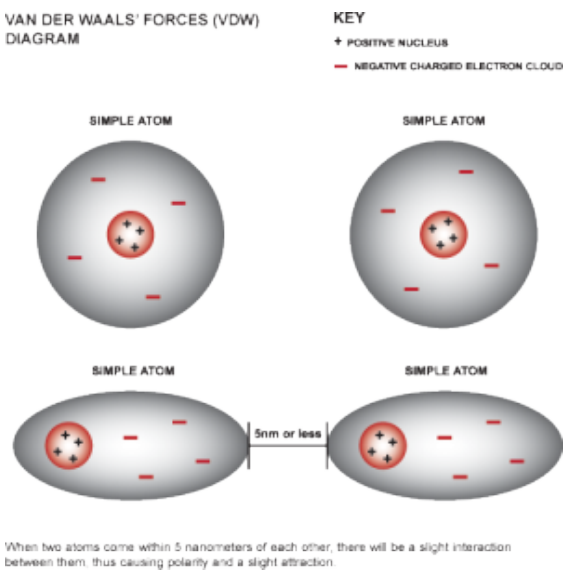
I) ***INTERMOLECULAR FORCES*** _____.

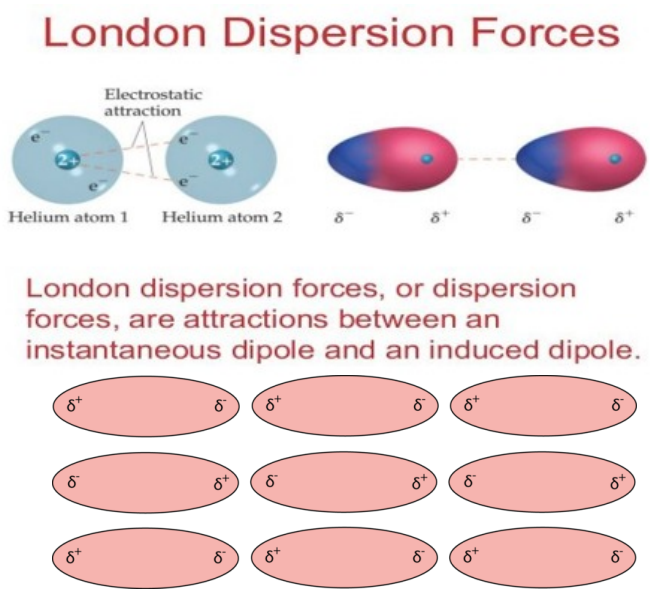
There are two kinds of ***intermolecular forces***: **VAN DER WAALS** forces & **HYDROGEN BONDS**.

A) Johannes ***van der Waals*** suggested that small forces between molecules determine their state at SATP. These forces are known as **VAN DER WAALS FORCES**. There are two kinds of ***van der Waals forces***: **LONDON DISPERSION FORCES** and **DIPOLE-DIPOLE FORCES**.

1) ***LONDON DISPERSION FORCES*** _____.

It is an attraction between all particles due to the movement of electrons within the atom or the molecule. The movement of electrons eventually creates an area of concentration of electrons on one side of the atom or molecule. This creates a temporary separation of charge called an instantaneous dipole. This instantaneous dipole causes a separation of charge in the adjacent particles. These created particles are called induced dipoles. The instantaneous and induced dipoles are weakly attracted to each other or to a dipole the atoms or molecule beside it causing the particles to be attracted to each other.





a) ***London dispersion forces*** can also be thought of as "gravity" between molecules. The force of gravity is dependent on an object's mass (amount of material): the greater the mass the greater the object's gravity; the smaller the mass the smaller the object's gravity. The earth is approximately six times more massive than the moon making its gravity is approximately six times greater.

i) Since the mass of a single molecule is so incredibly small, its ***London dispersion force***, its "molecular gravity", is incredibly small, this means ***London dispersion forces*** **are the** ***weakest forces of attraction between molecules***.

2) ***DIPOLE-DIPOLE FORCES*** _____

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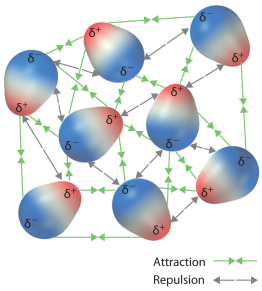
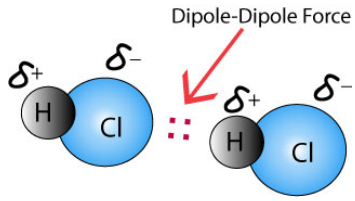
Since attraction between opposite charges is involved in ***dipole-dipole forces***, they are considerably stronger than ***London dispersion forces***.





B) **HYDROGEN BONDS**: ***A HYDROGEN BOND***_____

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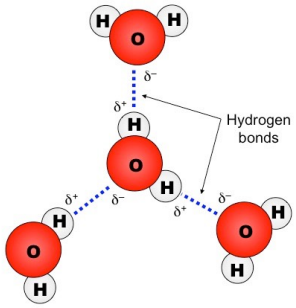
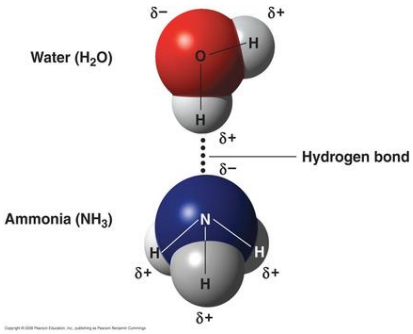
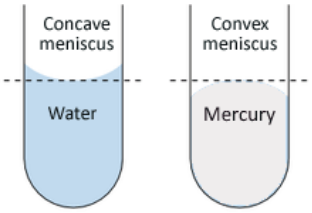
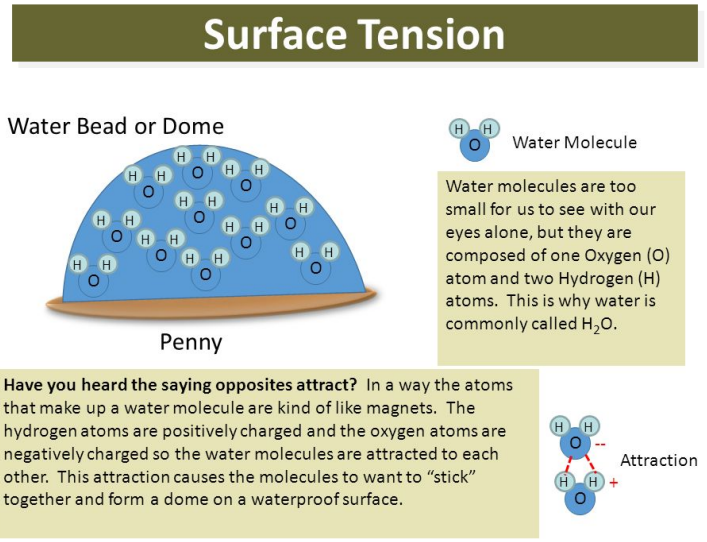


H—F ····· H—F ····· H—F



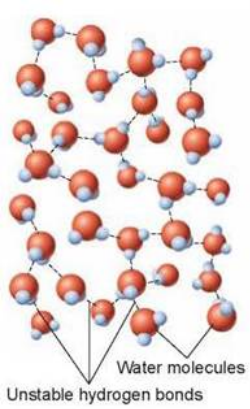
1) When hydrogen and oxygen bond together they form the polar molecule H_2O. Each hydrogen atom is "slightly positive" while the oxygen is "slightly negative". This means the hydrogen of one water molecule is strongly ***attracted*** to the oxygen of another water molecule. The ***attraction*** between water molecules makes them very sticky resulting in the characteristic high surface tension and the meniscus formed when wat



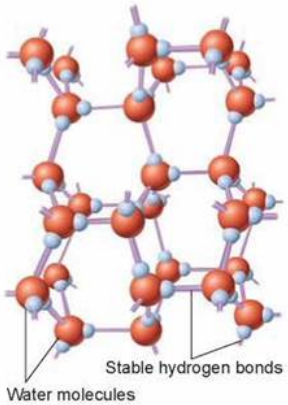


a) Because ***hydrogen bonds*** are so strong, water has a relatively high boiling point of 100°C.

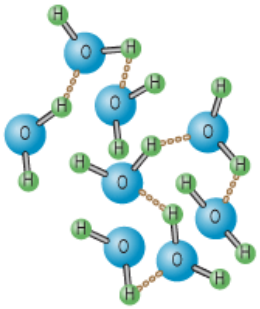
b) Water expands when it freezes. Because water is polar it contains positively and negatively charged ends and the laws of ***attraction*** and ***repulsion*** require water molecules in the solid phase must align themselves as follows: +-+-+-+-+-+-+- which creates spaces between the water molecules. This results in 10 g of $H_2O_{(s)}$, solid water (ice), having a larger volume than 10 g of $H_2O_{(l)}$, liquid water, thus water expands when frozen. Since there are spaces empty spaces between the water molecules, $H_2O_{(s)}$ will float on $H_2O_{(l)}$ and thus acts like an insulating layer against the cold thus protecting aquatic life from freezing to death.



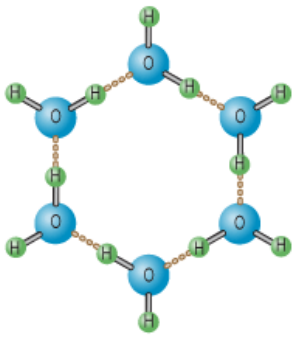
(a) Liquid water



(b) Ice



Structure of molecules in water



Structure of molecules in ice

C) **Required Practice 1:** Answer these questions. **{Answers are on page 3.}**

1. Define or describe intermolecular force.
2. State the types of van der Waals forces and describe their differences.
3. State the types of intermolecular forces from weakest to strongest.
4. How are dipole-dipole forces similar to hydrogen bonds?
5. How are dipole-dipole forces different from hydrogen bonds?

A) The three ***intermolecular forces*** (***London dispersion forces***, ***dipole-dipole forces*** and ***hydrogen bonds***) are used to explain the physical properties of molecular compounds and to predict the state of substances at SATP.

1) ***Non-polar molecules*** are attracted to each other by ***London dispersion forces*** only. As a result, ***non-polar molecules*** are ***weakly attracted*** to each other. This means that ***non-polar molecules*** tend to be gasses, liquids or soft, flexible waxy solids at SATP. This also means that very little ***heat energy*** is required to change their state from solid to liquid to gas thus they tend to have relatively low melting and boiling points.

2) ***Polar molecules*** are attracted to each other by ***dipole-dipole forces.*** The difference in electronegativity between the atoms within the molecule determines the strength of the polar bond. The stronger the polarity of the bond the stronger the ***attraction*** the molecule has to other polar molecules. This means ***polar molecules*** tend to be liquids or solids at SATP. This also means that a large amount of ***heat energy*** is required to change their state of a polar molecule from solid to liquid to gas thus they tend to have moderately high melting and boiling points.

3) ***Polar molecules*** containing H – F, H – O or H – N bonds are attracted to each other by ***hydrogen bonds***. As a result, they are ***strongly attracted*** to each other. This means that ***polar molecules*** containing H – F, H – O or H – N bonds tend to be liquids or solids at SATP. This also means that a large amount of ***heat energy*** is required to change their state from solid to liquid to gas, thus they tend to have relatively high melting and boiling points.

B) **Required Practice 2:** Answer these questions. **{Answers are on page 3.}**

1. Which type of van der Waals forces exists between all molecules?
2. State the type of intermolecular force(s) between these molecules.
   a. Non-polar molecules.
   b. Molecules containing H – F and H – O.
   c. An highly polar molecule that is liquid at SATP.
   d. A moderately polar molecule that is liquid at SATP.
   e. Molecules within a soft waxy solid at SATP.

ANSWERS TO THE REQUIRED PRACTICE

Required Practice 1 from page 3

1. The force of attraction between molecules. **2.** London dispersion forces are the force of attraction experienced by all matter (molecular gravity). Dipole – dipole forces are the forces of attraction between weakly or moderately polar molecules. **3.** London dispersion forces, dipole – dipole forces, hydrogen bonding. **4.** Both dipole – dipole forces and hydrogen bonding involve polar bonds. **5.** Dipole – dipole forces involve weakly or moderately polar molecules whereas hydrogen bonding involves highly polar molecules containing H – O, H – F or H – N bonds.

Required Practice 2 from page 3

1. London dispersion forces exist between all molecules. **2a.** London dispersion forces. **2b.** Hydrogen bonding. **2c.** Hydrogen bonding. **2d.** dipole – dipole forces. **2e.** dipole – dipole forces.
