Senior High School

Department of Education
National Capital Region
SCHOOLS DIVISION OFFICE
MARIKINA CITY

Physical Science

First Quarter - Module 3

General Types of Intermolecular Forces

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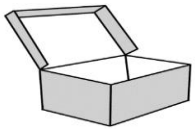

What I Need to Know

This module was designed and written with you in mind. It is here to help you master the general types of intermolecular forces of attraction and explain its effects on the properties of substances. The scope of this module permits it to be used in many different learning situations. The language used recognizes the diverse vocabulary level of students. The lessons are arranged to follow the standard sequence of the course.

Learning Competencies

- **Describe the general types of intermolecular forces. (S11/12PSIIIc-d-17)**
- **Explain the effect of intermolecular forces on the properties of substances. (S11/12PS-IIId-e-19)**

Specifically, at the end of this lesson, you are expected to

- differentiate the general types of intermolecular forces of attraction;
- give examples of each type of intermolecular force; and
- discuss how the intermolecular forces affect the properties of substances and cite specific examples of these.

What I Know

Read the question carefully and encircle the letter of the correct answer.

1. Which among the following is an intermolecular force of attraction?
   A. Covalent bond
   B. Hydrogen bond
   C. Ionic bond
   D. Metallic bond

2. What type of IMFA is present between polar molecules?
   A. Dipole-dipole force
   B. Ion-dipole force
   C. London dispersion force
   D. Metallic bond

3. What IMFA exists between two nonpolar molecules?
   A. Dipole-dipole force
   B. Hydrogen bond
   C. Ion-dipole force
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4. Which sequence of IMFA is correctly arranged by increasing force of attraction?
   A. Dipole-dipole → London dispersion → ion-dipole →hydrogen bond
   B. Hydrogen bond → ion-dipole → London dispersion → dipole-dipole
   C. Ion-dipole → hydrogen bond → dipole-dipole → London dispersion
   D. London dispersion → dipole-dipole → hydrogen bond → ion-dipole

5. What type of IMFA exists between iron II (Fe^{2+}) and oxygen gas in the blood?
   A. Dipole-dipole interaction
   B. hydrogen bond interaction
   C. ion-dipole interaction
   D. London dispersion interaction

6. Which compounds can form a dipole-dipole interaction?
   A. Ammonia (NH^3) dissolved in water
   B. Table salt (NaCl) dissolved in water
   C. Carbon dioxide (CO_2) dissolved in water
   D. Potassium iodide (KI) dissolved in water

7. Which is **TRUE** about nitrogen gas (N_2)?
   A. It is polar and has a permanent dipole.
   B. It is non-polar and has a permanent dipole.
   C. It is polar and may have a momentary dipole.
   D. It is non-polar and may have a momentary dipole.

8. If the given compounds are in their respective containers, which among them can produce hydrogen bond when interacting with one another?
   A. CH_4 B. HCl C. H_2O D. NaCl

9. Based on their viscosity, which has the strongest IMF?
   A. Cooking oil
   B. Ketchup
   C. Mayonnaise
   D. Water

For items 10 – 11. There are four types of liquids with the following boiling points:

Bottle 1	–	25.0°C
Bottle 2	–	40.0°C
Bottle 3	–	75.0°C
Bottle 4	–	100.0°C

10. Which bottle has the strongest IMFA?
    A. Bottle 1
    B. Bottle 2
    C. Bottle 3
    D. Bottle 4
11. If placed in the same condition, which liquid would have the highest vapor pressure?
    A. Bottle 1
    B. Bottle 2
    C. Bottle 3
    D. Bottle 4

12. Which property of water is exhibited by the absorption and distribution of water by plants?
    A. Boiling point
    B. Capillary action
    C. Surface tension
    D. Vapor pressure

13. Water striders and Jesus Christ lizards are two organisms that can walk on water. Which property of liquid makes them capable of doing this?
    A. Capillary action
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    D. Viscosity

14. Which property of liquid is described as the amount of gas in equilibrium with the liquid and solid phases?
    A. Boiling point
    B. Melting point
    C. Vapor pressure
    D. Viscosity

15. Which among these properties decreases when IMFA increases?
    A. Capillary action
    B. Surface tension
    C. Vapor pressure
    D. Viscosity

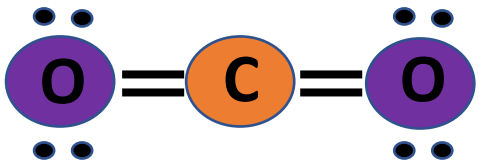
Lesson General Types of Intermolecular Forces

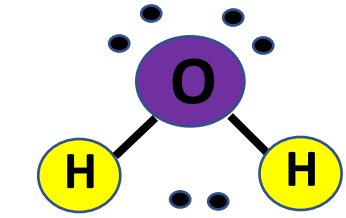
What's In

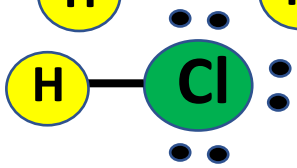
In the previous module, you have learned about the difference between polar and nonpolar covalent compounds.

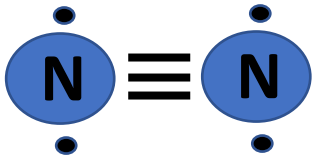
Activity 1

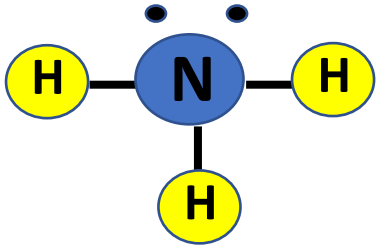
Below are structures of some molecules. Analyze each given molecule and classify it as polar or nonpolar. Then, write a brief justification for your answer.

1. 

2. 

3. 

4. 

5. 

Your skills in drawing the Lewis structure of molecules and ideas about its polarity are very substantial for you to deeply understand the next lesson.

What's New

Here are some of the important terms used throughout this module.

- **Intramolecular forces of attraction** are the forces of attraction within molecules.
- **Intermolecular forces of attraction (IMFA)** are the forces of attraction between neighboring molecules.
- **Dipole moment** happens when there is a separation of charges due to difference in the electronegativity.
- **Induced dipole moment** is a temporary dipole created due to distortion in the electron cloud of an atom or a molecule.

As of this moment, you already knew that compounds and molecules are formed from the bonding of atoms. The bonding is formed as a result of an attractive force known as **intramolecular forces of attraction**. This includes ionic bond, covalent bond, and metallic bonding. Some examples of molecules are water (H_2O), carbon dioxide (CO_2), and glucose ($C_6H_{12}O_6$).

Think of three (3) more examples of molecules.

But why do molecules attract one another?

For you to easily visualize it, get a glass of water (H_2O) and put one teaspoon of table salt (NaCl) in it. Then, stir it up for one minute. Observe what will happen. After dissolving the salt in water, what do you think happened to the sodium (Na) and chlorine (Cl) compositions of the table salt (sodium chloride)?

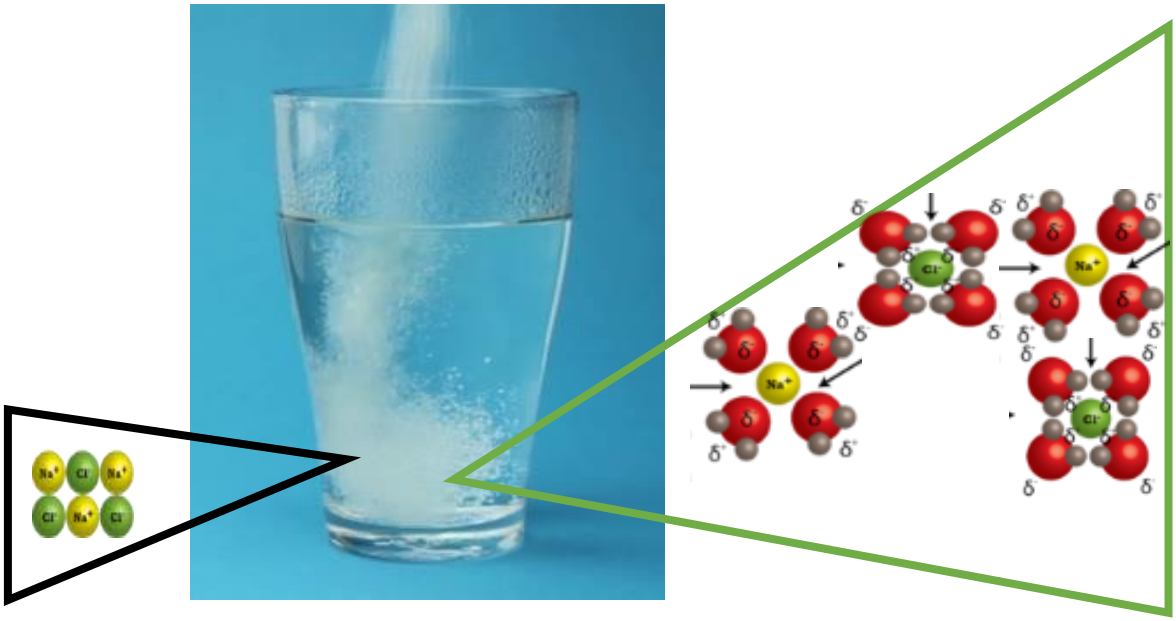


Figure 1. At molecular level view of sodium chloride dissolved in water.
Source: *"Universal Solvent." Digital Image. mHarned 8B. Accessed August 8, 2020. https://mharned8b.wixsite.com/schmidt/universal-solvent*

The illustration above shows what happened at molecular level when you are dissolving salt in water.

What Is It

The important concepts to understand from the example are:

1. Sodium chloride is an ionic compound. It is composed of a **cation (Na^+)** and an **anion (Cl^-)**.

2. Water (H_2O) is a polar molecule. It means it has uneven distributions of electrons; oxygen atom is ***partially negative*** (**δ−**) while hydrogen atoms are ***partially positive*** (**δ+**). This happens because of the difference in their electronegativities.

3. When sodium chloride is dissolved in water, its cation which is Na^+ attracts the partially negative side of the water, which is the oxygen atom. While its anion which is Cl^- attracts the partially positive side of

water which are the hydrogen atoms. This leads to their separation which is called **dissociation.**

4. This attraction between and are examples of intermolecular `force of attraction.

Here are the different types of Intermolecular forces of attraction, **and** some of their examples.

MAJOR TYPES OF IMFA

1. Ion-Dipole Interaction

Ion-dipole interaction happens when an ion comes across a polar molecule. The best example of this type of interaction is the simple experiment you conducted wherein you dissolved table salt in water.

The ions (Na^+ and Cl^-) interacted with water molecules that are polar (having partially negative and partially positive sides) leading to its dissociation.

2. Dipole-Dipole Interaction

Dipole-dipole interaction is happening between two polar molecules interacting to one another. An example of this is when you have a bottle of ammonia (NH_3).

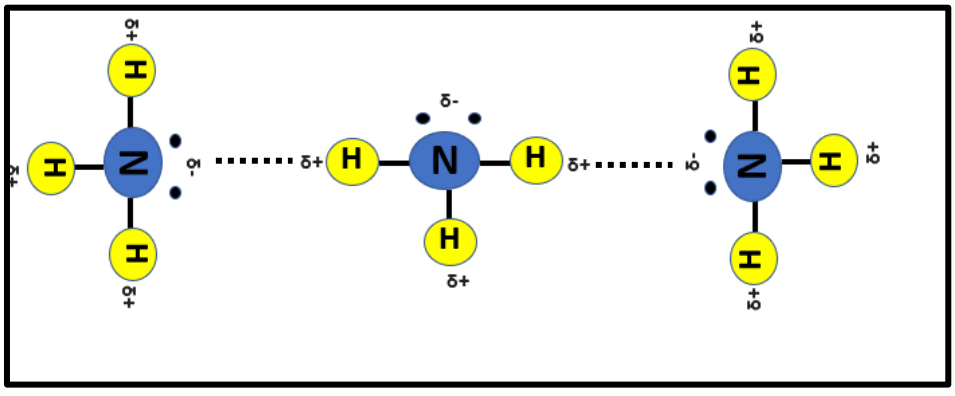


Figure 2. Interaction of ammonia (NH_3) molecules

A molecule of ammonia is a polar molecule. It means it has uneven sharing of electrons leading to the formation of partially positive side which is hydrogen and partially negative side which is nitrogen.

When they interact with one another inside the bottle, H (δ+) is attracted with N (δ-) of the neighboring NH_3 molecule and vice versa. This interaction is an example of dipole-dipole, which is represented by broken lines as shown in Figure 2.

2.1. Hydrogen bond

The interaction of NH_3 – NH_3 molecules in Figure 2 is also an example of one special type of dipole-dipole interaction is called the **hydrogen bond**. It is true to cases wherein H is interacting with highly electronegative elements such as nitrogen (N), oxygen (O), and fluorine (F).

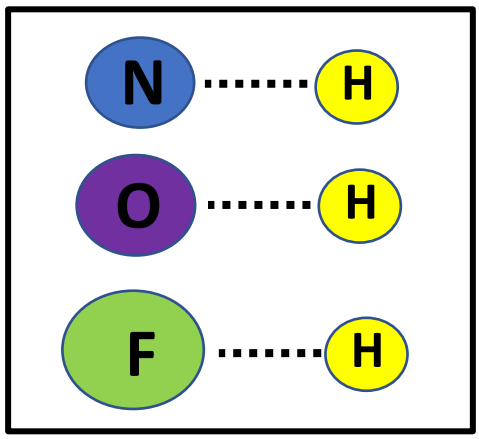


Figure 3. Molecules forming H-bond

3. London Dispersion Interaction

This type of IMFA is exhibited by interactions happening among **non-polar molecules** and **noble gases**.

When there is a distortion in the electron clouds of atoms or molecules creating the so-called **induced dipole**. This is a temporary shift of electrons causing one end of an atom or molecule becomes more positive than the other.

Example of this is interaction between oxygen gas (O_2) and nitrogen gas (N_3) in a container. These two molecules are both nonpolar.

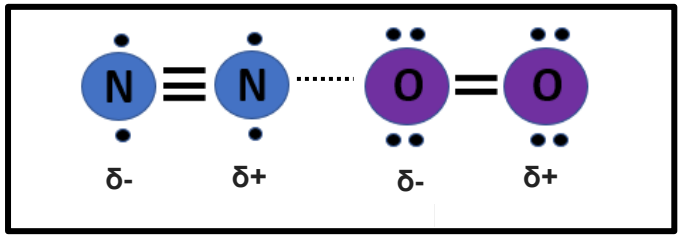


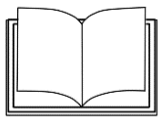
Figure 4. Molecules of nitrogen gas interacting with oxygen gas exhibiting London dispersion.

ORDER OF STRENGTH OF IMFA

You must bear in mind that the strength of the intermolecular forces of attraction varies depending on its type. The arrangement below shows the order of their strength.

ion-dipole > H-bond > dipole-dipole > London dispersion

NOTE: The attractive forces increase with increasing molar mass and size of the molecule.



What's More

Intermolecular force of attraction between the molecules of a substance affects its physical properties. Some of the physical properties are:

A. Viscosity

On a movable, smooth surface, pour same amount of water, ketchup, oil, and mayonnaise. Then, slowly put it on a slanting position and observe which among the liquid reach the ground first.

All these samples are liquid. But why do they not flow in the same rate? It is because they vary in terms of viscosity. **Viscosity** is the resisting ability of a liquid to flow. From the activity, the liquid that reached the ground first is described as less viscous and the one that moved very slowly and reached the ground last is the most viscous.

More viscous substances have stronger intermolecular forces.

As the IMFA gets stronger, the viscosity of a substance increases.

B. Surface tension

Waking up in a very cold morning, have you seen droplets of water on surfaces of leaves or vehicles? Or do you observe these droplets formed on the surface of a cold bottle or a pitcher full of ice? How come water is formed into round droplets?

Figure 5. Water droplets on leaves showing surface tension.

Source: *"Lotus leaf with water drop." Digital Image. Ninithi. Accessed August 8, 2020. https://ninithi.wordpress.com/2015/07/30/how-lotus-leaf-make-water-droplet-dance-on-its-surface/*

This phenomenon is due the physical property called surface tension. Surface tension is the ability of a liquid surface to be stretched forming an elastic sheet or membrane.

Aside from the spherical shape of water droplets, this property explains how some insects or animals can walk on water.

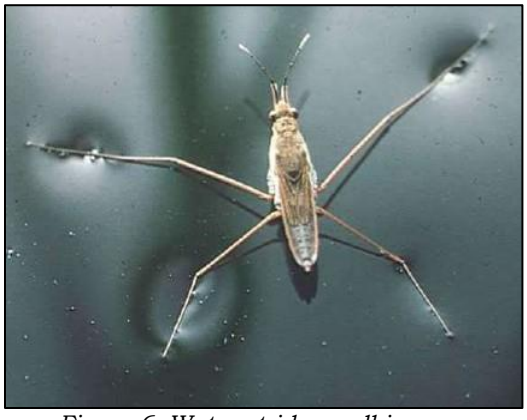


Figure 6. Water strider walking on the water.

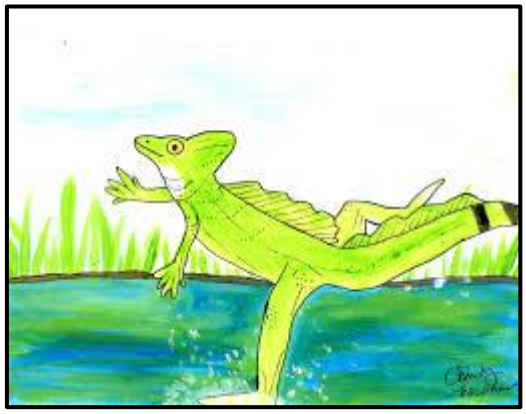


Figure 7. Jesus Christ lizard running on water.

Sources:

(1) "Water springer." Digital Image. Springer link. Accessed August 8, 2020. https://link.springer.com/chapter/10.1007/978-3-319-63607-8_1

(2) "The Jesus Christ lizard." Digital Image. Blueridge. Accessed August 8, 2020. https://blueridgechristiannews.com/2019/09/17/the-jesus-christ-lizard/

Surface tension is also determined by the IMFA between the molecules of the given substance like in this case, molecules of water.

As the IMFA gets stronger, the surface tension of a substance increases.

C. Capillarity action/ Capillarity

When you throw an object upward, you can infer that it will go down. It is because of gravity. If everything is pulled by gravity, haven't you ever wondered how do trees sip water from the ground and distribute it to all its parts including those on top?

This phenomenon is called **capillary action or capillarity**. This is described as the rise or fall of a liquid in a narrow tubes or absorbent material.

For the capillary action to take place, it involves to two types of forces: the cohesive force (cohesion) and the adhesive force (adhesion).

- **Cohesion** is an attractive force between same substances in which they are sticking together. Example of this is a water molecule interacting with another water molecule.
- **Adhesion** is an attractive force between different substances wherein they are clinging to one another. Example of this is a water molecule interacting with the surface of the tube.

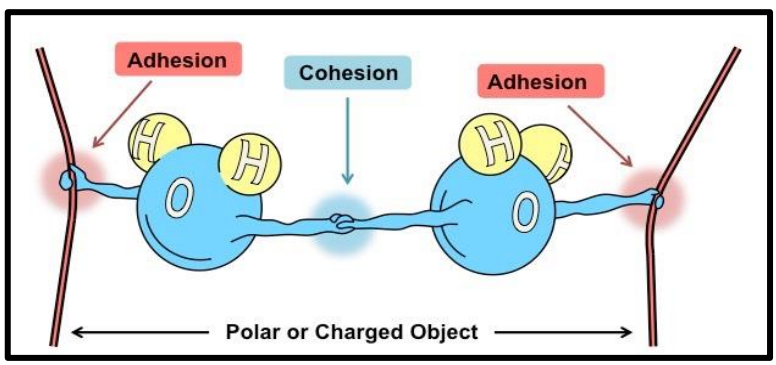


Figure 8. Visual representations of cohesion and adhesion.
Source: *"Capillary Rise." Digital Image. Toppr. Accessed August 8, 2020. https://www.toppr.com/content/story/amp/problems-on-capillary-rise-25049/*

As these two forces combined together, the water from the ground that is absorbed by plant's roots is capable of climbing to the stem going up to different leaves, fruits, or flowers growing on the top of it. This is how plants are capable of sipping their water and cultivate.

The strength of attraction present in the cohesion and adhesion defining how strong the capillary action of a substance is determined by the IMFA they have.

As the IMFA gets stronger, the capillarity action increases.

Vapor pressure

Many people enjoy hot beverages in the morning, such as coffee or hot chocolate. In to prepare this, you have to boil water in the kettle. However, before you can understand boiling, you must first understand the concept of vapor pressure

Vapor pressure is the tendency of a substance to turn into vapor (gaseous) state when its rate of evaporation is equal to its rate of condensation in a closed container.

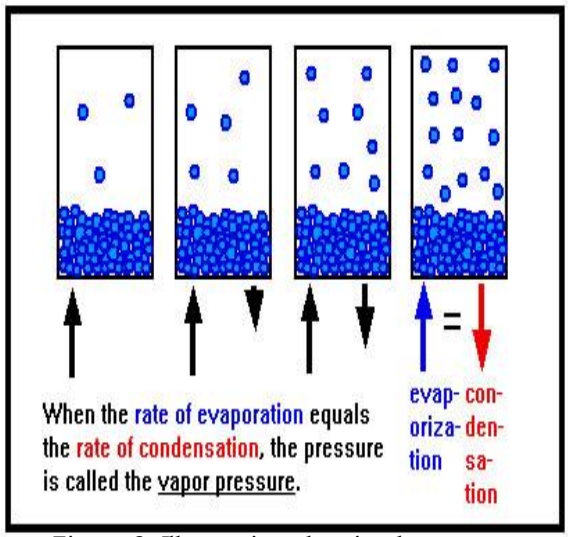


Figure 9. Illustration showing how vapor pressure is attained.
Source: *"Vapor Pressure." Digital Image. Cengage Learning. Accessed August 8, 2020. https://slideplayer.com/slide/16413391/*

Evaporation is the turning of liquid into gas while **condensation** is the process where gas turns into liquid. To attain **vapor pressure**, the rates of these two processes must be equal or reaching equilibrium.

If the IMFA of a substance is strong, the molecules of a substance are difficult to break or separate, thus, slowing down the attainment of vapor pressure. With this, they have an inverse relationship.

As the IMFA gets stronger, the vapor pressure of a substance decreases.

D. Boiling point and Melting point

Boiling point is the temperature at which the atmospheric pressure (outside) is equal to the vapor pressure (inside) of a gas in a

closed container. Water boils at 100.0°C which is very high. It implies that the IMFA existing among water molecules is strong.

Melting point is the temperature at which a solid substance melts. Ice has melting point of 0°C, which is still relatively high as compared to solid oxygen (-218.4°C), methane (-182°C), and carbon dioxide (-78.5°C). This indicates that IMF of solid water is stronger.

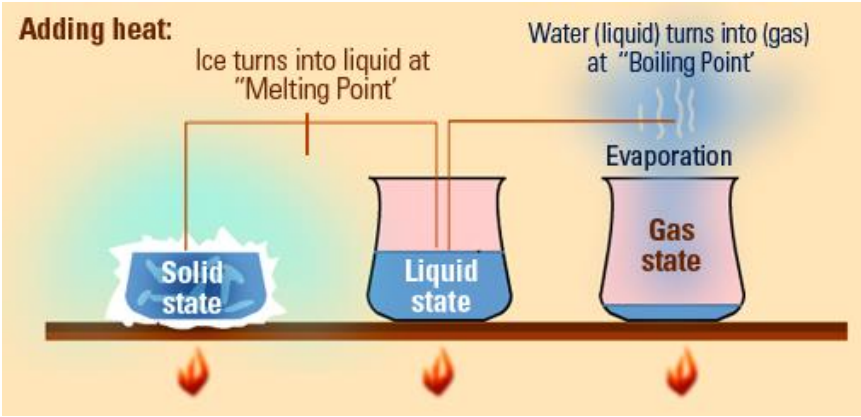


Figure 10. Illustration showing the difference between melting point and boiling point.
Source: *"Melting point and boiling point." Digital Image. eSchool Today. Accessed August 8, 2020. https://www.flickr.com/photos/ 21728850@N02/ 12089681666/*

As the IMFA gets stronger, the boiling point and melting point of a substance increases.

Activity 2

Write **TRUE** if the statement is correct and **FALSE** if it is wrong. Write your answer on a separate sheet of paper.

1. As the IMFA increases, the surface tension increases.
2. As the IMFA decreases, the capillarity increases.
3. As the IMFA gets stronger, the vapor pressure decreases.
4. As the IMFA gets stronger, the melting point decreases.
5. As the IMFA stronger, the viscosity increases.
6. IMFA has an inverse relationship with surface tension.
7. IMFA has an inverse relationship with vapor pressure.

What I Have Learned

Activity 3

Complete the table below by filling each blank with the appropriate term or concept from the box of choices provided.

Types of IMFA	Relative Strength	Interacting molecules
Ion-dipole interaction	_____	_____
Hydrogen bonding	_____	_____
Dipole-dipole interaction	_____	_____
London dispersion interaction	_____	_____

Choices:

weakest	strong	weak
polar molecules	nonpolar molecules and noble gases	ions and polar molecules
polar molecules with partially positive H		medium

What I Can Do

Activity 4

Do the following tasks in connection with the listed substances.

A. Draw the molecular structure of the given compound.
B. Classify the compound as polar or nonpolar.
C. Identify the type of the intermolecular forces of attraction of the substances.
D. Rank them according to their relative strength (1 as the strongest, and so).

Substance	(A) Lewis Structure	(B) Polarity	(C) IMFA	(D) Rank
Bromine gas (Br_2)				
Hydrogen fluoride (HF)				
Hydrogen sulfide (H_2S)				
Methane (CH_4)				
Methanol (CH_3OH)				

Posttest

Read the question carefully and encircle the letter of the correct answer.

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   B. Hydrogen bond → ion-dipole → London dispersion → dipole-dipole
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    A. Capillary action
    B. Melting point
    C. Surface tension
    D. Viscosity

Additional Activities

Identify the most probable intermolecular force of attraction in the following:

1. KCl —— KCl _____
2. NH_3 —— NH_3 _____
3. Na_2S —— Na_2S _____
4. HF —— HF _____
5. MgS —— MgS _____
6. CH_3OH —— CH_3OH _____
7. H_2 —— H_2 _____
8. CuO —— CuO _____
9. SbH_3 —— SbH_3 _____
10. CO_2 —— CO_2 _____

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(3) The Commision on Higher Education. 2020. *Teaching Guide for Senior High School: Physical Science.* Quezon City, August 8.

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