Senior High School

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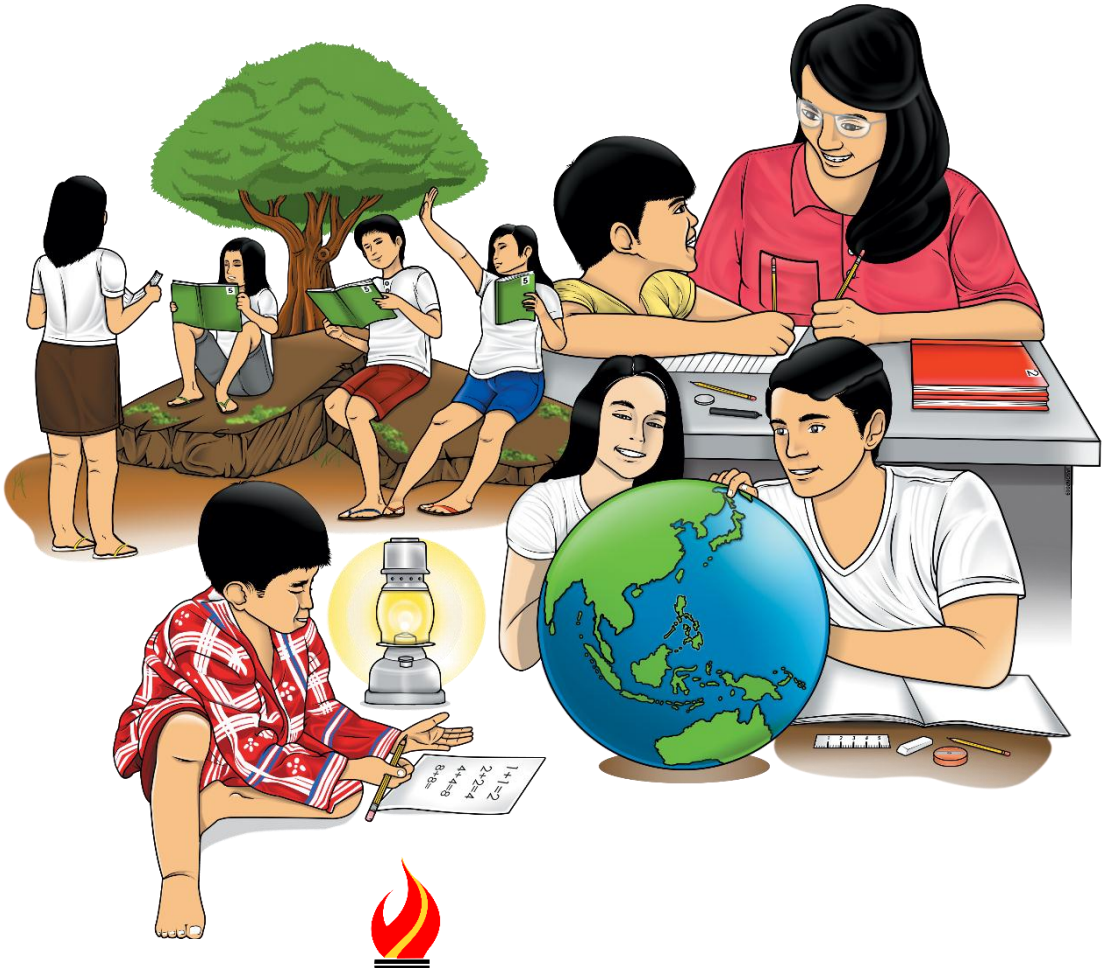
Physical Science

Quarter 1 – Module 5:
General Types of Intermolecular Forces



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Introductory Message

This Self-Learning Module (SLM) is prepared so that you, our dear learners, can continue your studies and learn while at home. Activities, questions, directions, exercises, and discussions are carefully stated for you to understand each lesson.

Each SLM is composed of different parts. Each part shall guide you step-by-step as you discover and understand the lesson prepared for you.

Pre-tests are provided to measure your prior knowledge on lessons in each SLM. This will tell you if you need to proceed on completing this module or if you need to ask your facilitator or your teacher's assistance for better understanding of the lesson. At the end of each module, you need to answer the post-test to self-check your learning. Answer keys are provided for each activity and test. We trust that you will be honest in using these.

In addition to the material in the main text, Notes to the Teacher are also provided to our facilitators and parents for strategies and reminders on how they can best help you on your home-based learning.

Please use this module with care. Do not put unnecessary marks on any part of this SLM. Use a separate sheet of paper in answering the exercises and tests. And read the instructions carefully before performing each task.

If you have any questions in using this SLM or any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator.

Thank you.

What I Need to Know

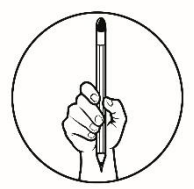
This module was designed and written with you in mind. It is here to help you master the *General Types of Intermolecular Force*s. The scope of this module permits it to be used in different learning situations. The language used recognizes the varied vocabulary level of students. The lessons are arranged to follow the standard sequence of the course. But the order in which you read them can be changed to correspond with the textbook you are now using.

The module is divided into two lessons, namely:

- Lesson 1 – Intermolecular forces in Substances
- Lesson 2 – Intermolecular forces present between and among substances

After going through this module, you are expected to:

1. describe the types of intermolecular forces present in substances, and
2. identify the types of intermolecular forces existing between and among substances.



What I Know

Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

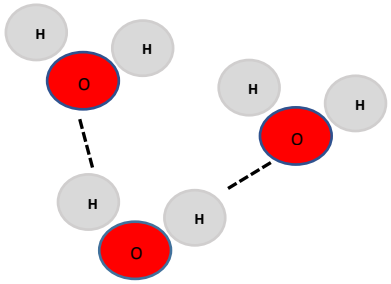
1. Which forces of attraction or repulsion are responsible for the bulk properties of different substances?
   a. covalent
   b. intermolecular
   c. intramolecular
   d. ionic

2. Ion-dipole forces exist among certain species of substances. Which among the pairs of substances exhibit this type of interaction?
   a. bromide (Br^-) and benzene (C_6H_6)
   b. chloride (Cl^-) and methane (CH_4)
   c. potassium ion (K^+) and water (H_2O)
   d. sodium ion (Na^+) and carbon tetrachloride (CCl_4)

3. Why do larger atoms experience increased polarizability than smaller atoms?
   a. The electrons are loosely held in smaller atoms so electron distribution is easier to distort.
   b. The electrons are tightly held in smaller atoms so electron distribution is easier to distort.
   c. The electrons are loosely held in larger atoms so electron distribution is easier to distort.
   d. The electrons are tightly held in larger atoms so electron distribution is easier to distort.

4. How is instantaneous dipole best described?
   a. It arises from the high polarization of the atoms or molecules.
   b. It is a permanent dipole induced by polar molecules to ions.
   c. It is the strongest attractive force between and among molecules.
   d. It results to the formation of temporary dipoles induced to atoms or molecules.

5. The figure below shows H-bonding among polar water molecules. What is unique about this type of interaction?



a. H-bonding arises from the interaction between hydrogen (H) and the transition metals.
b. It exists when the less electronegative O binds with the more electronegative H.
c. It occurs when a H-atom in a polar bond interacts with a more electronegative atom such as O, N, or F of another polar molecule.
d. It happens when a H-atom in a nonpolar bond interacts with a more electronegative atom such as O, N, or F.

6. Which among the following is the reason why ion-dipole interaction is the strongest among the intermolecular forces?
a. The net charge of the dipole is balanced by the charge of the ion.
b. The oppositely charged end of the dipole is oriented closest to the ion.
c. The magnitude of the ion is equal to the dipole moment of the polar molecule.
d. The dipole moment of the polar molecule is directed towards the more electronegative end.

7. Which is true about the interaction of substances that exhibit dipole-dipole attractive forces?
a. The dipoles form crystal lattice that makes the interaction strong.
b. The positive (+) end of one dipole aligns to the negative (-) end of another dipole.
c. The positive (+) end of one dipole orients itself to the positive (+) end of another dipole.
d. The dipole moment of one dipole is directed towards the more electronegative part of the molecules.

8. Why are dispersion forces always present among all kinds of substances?
a. Polarization is high when charged ends are present in molecules.
b. The electron distributions present in nonpolar molecules are polarized by nearby atoms or ions.
c. There are ions which cause the distortion of electron distributions present in polar molecules.
d. There are electron distributions that are distorted by the force exerted by an ion or polar molecule that is placed near an atom or a nonpolar molecule.

9. London dispersion forces are a function of the molar mass of substances. What happens to the dispersion forces of the molecules as the molar mass increases?
   a. They are increased.
   b. They are decreased.
   c. They remain the same.
   d. They cannot be measured.

10. Heat of hydration is the result of favourable interaction between the cations and anions of an ionic compound with water. What is the nature of this attraction?
   a. H-bonding
   b. ion-dipole forces
   c. dispersion forces
   d. dipole-dipole interaction

11. Which is true about dipole moment?
   I. It arises from the similarities in the electronegativity values of elements.
   II. It is the shift of electron density from one atom to a more electronegative atom.
   III. It occurs between two ions in an ionic bond or between atoms in a covalent bond.
   IV. The larger the difference in electronegativity between elements, the smaller the dipole moment is.
   a. I & II b. III & IV c. II & III d. I & IV

12. The strength of ion-dipole interaction depends on the ions present. Which is true about this interaction with ions of the same magnitude?
   a. Cations interact more strongly than anions because their charges are less concentrated.
   b. Cations interact more strongly than anions because their charges are less concentrated.
   c. Cations interact more strongly than anions because their charges are more concentrated.
   d. Anions interact more strongly than cations because their charges are more concentrated.

13. At any certain time the shift in the position of the electrons in an atom will likely create temporary positive and negative poles. Which among the following is this kind of dipole?
   a. dipole forces
   b. dipole moment
   c. dispersion forces
   d. instantaneous dipole

14. Which forces of attraction are present between the substances I_2 and NO_3^-?
    a. London dispersion forces
    b. H-bonding and ion-induced dipole interaction
    c. Van der Waals interaction and dipole-dipole interaction
    d. London dispersion forces and ion-induced dipole interaction

15. Which of the following species is capable of hydrogen-bonding among themselves?
    a. ethane (C_2H_6)
    b. acetic acid (CH_3COOH)
    c. beryllium hydride (BeH_2)
    d. potassium fluoride (KF)

Lesson 1 Types of Intermolecular Forces

Atoms in molecules and ionic substances are attracted to each other either by sharing or complete transfer of electrons. These attractions keep the molecules and their identities intact.

But, say, how do molecules or substances stay together and exhibit properties that are unique to them? This is known as bulk properties.

These are properties due to many atoms, ions or molecules acting together. The properties of matter are observed when the atoms or molecules behave as one.

These properties are specific for different materials at the macroscopic level as seen by the naked eye.In this lesson, you will learn how the different forces of attraction known as intermolecular forces keep substances together. You will also be able to identify the intermolecular forces present between and among substances, thus their bulk properties can be predicted.

What's In

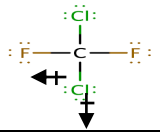
This simple activity will help you recall what you understood about Lewis electron dot structure (LEDS) and polarity of molecules. The polarity of substances will guide you in identifying the intermolecular forces present between and among molecules.

Notes to the Teacher

1. This module will help the students understand the concepts of intermolecular forces (IMF).
2. Allow the students to answer each part thoroughly, either individually or in pairs.
3. Let the students check the answers to each part. Have a short discussion of the concepts involved after checking.
4. The students will then move to the next part of the module. They will have the feedback and discussion after every part.
5. Inputs can be given in addition to the discussion in this module.
6. Kindly entertain questions for further discussions.

Directions:

1. Use a clean sheet of paper to answer this part.
2. Copy the table and fill it up with the correct information.
3. Show the direction of the dipole moment for each molecule.
4. An example is given to guide you in this activity.

Substance	LEDS	Shape	Polarity
1. CCl_2F_2		Tetrahedral	Polar
2. N_2			
3. CH_4			
4. H_2O			
5. CO			

Polarity of molecules based on the LEDS

What's New

Activity 1: Description of Intermolecular Forces

The following activity introduces you to various types of intermolecular forces (IMF) existing between and among different kinds of substances. By analyzing the presented diagrams, you can deduce what IMF are involved in each set.

Directions: Using the illustrations below, describe what happens in each of the attractions between substances by completing each sentence with the correct words from the box. Tell what kind of attractive forces keep the substances together.

partially negative	positive	negative
cation	dipole	temporary
attracted		
Kind of interaction:	H-bonding	dipole-dipole
	ion-induced dipole	ion-dipole
	dipole-induced dipole	

1. This attraction happens between polar molecules. The charges align so that the _____ pole of one molecule is attracted to the _____ end of the other molecule. Kind of interaction: _____

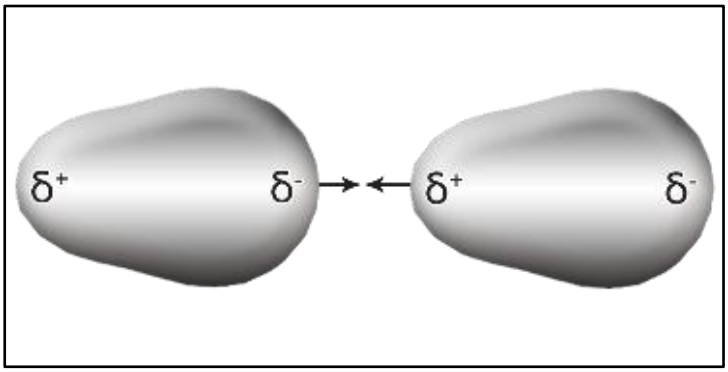


Figure 1.1

2. The _____ sodium ion is attracted to the partially _____ end of water molecules. Kind of attraction: _____

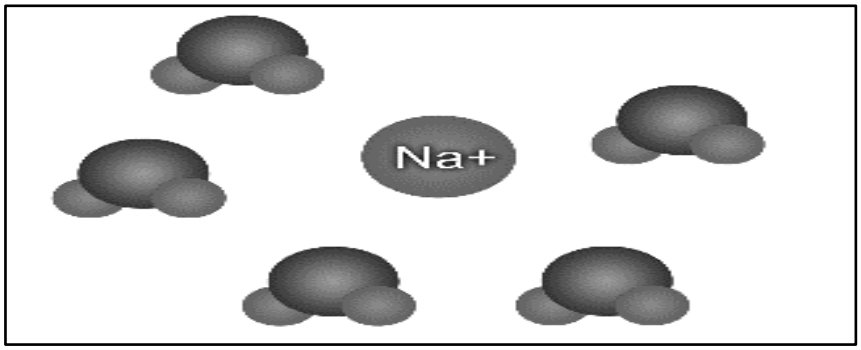


Figure 1.2

3. A _____ ion or _____ approaches a neutral nonpolar substance. This results to a distortion of the substance and leads to the development of positive and negative poles. Kind of attraction: _____

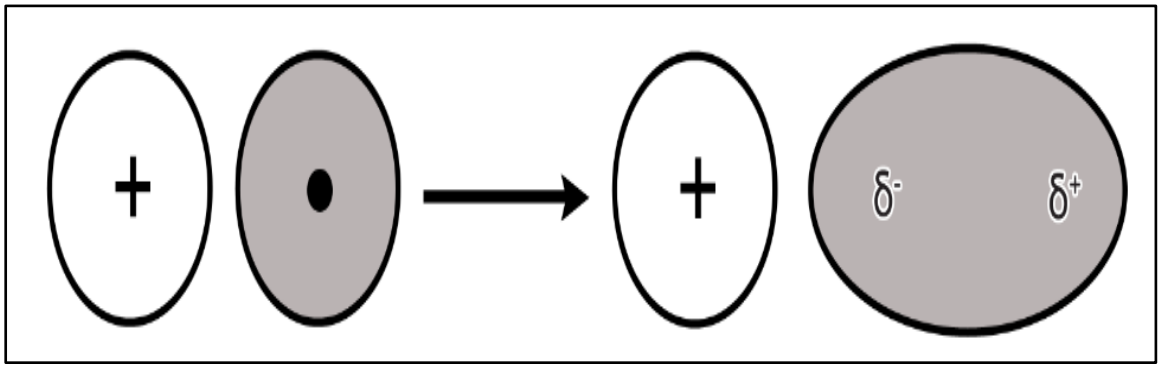


Figure 1.3

4. A permanent _____ approaches a neutral nonpolar substance resulting to a _____ dipole. Kind of attraction: _____

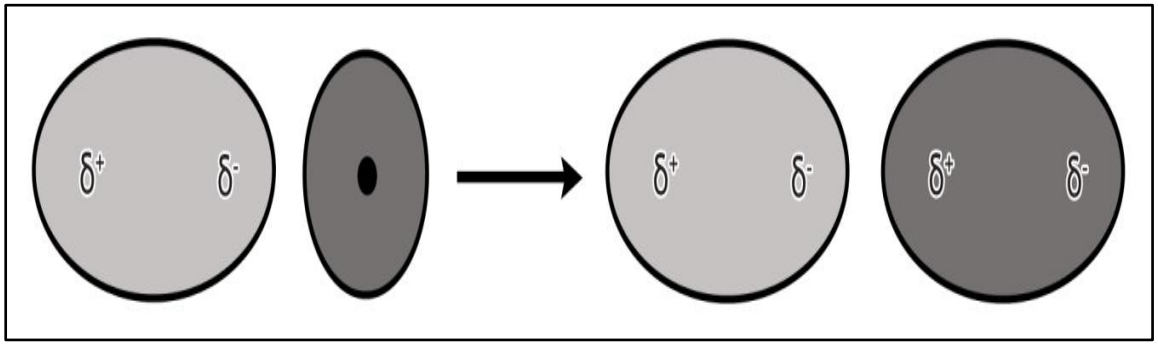


Figure 1.4

5. The partially- _____ oxygen of one water molecule is _____ to the partially- _____ hydrogen of the other water molecule.

Kind of attraction: _____

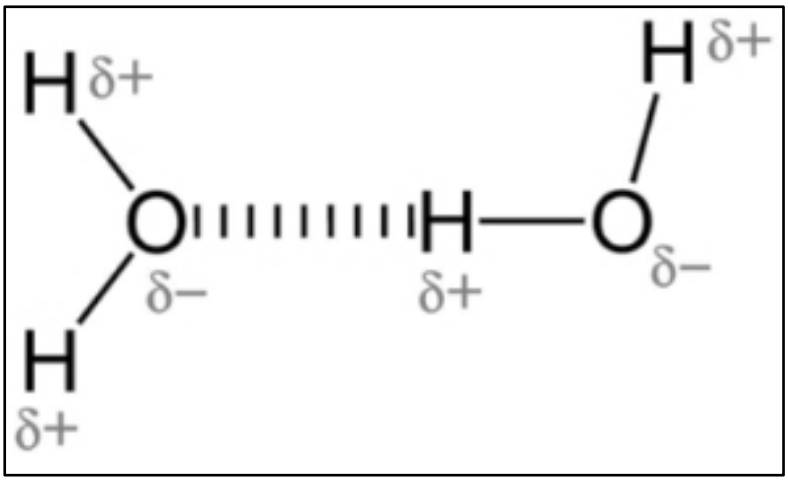


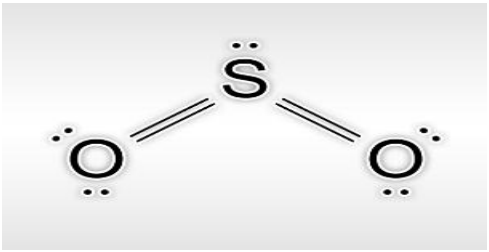
Figure 1.5

Activity 2. Intermolecular Forces Among Substances

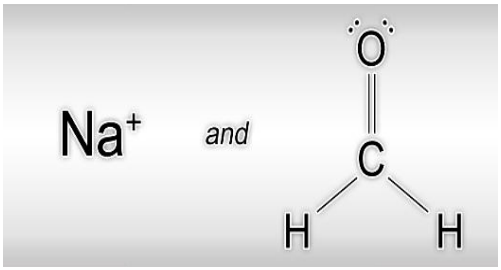
Directions: Use the words inside the box to identify the intermolecular forces (IMF) present among the following species. You can use the choices more than once if applicable.

H-bonding	dipole-dipole
ion-induced dipole	ion-dipole
dipole-induced dipole	

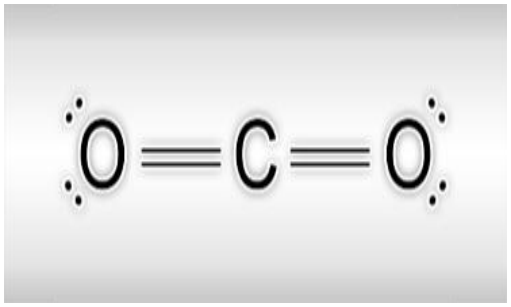
a. Sulfur dioxide (SO_2) and another SO_2



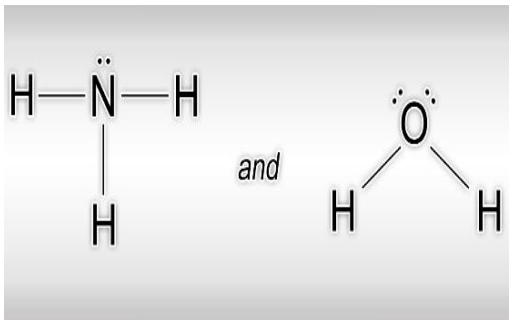
b. Sodium ion (Na^+) and Formaldehyde (CH_2O)



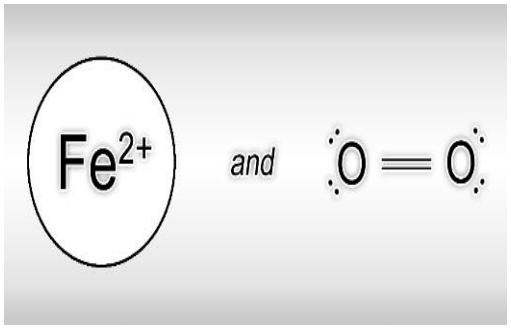
c. Carbon dioxide (CO_2) with another CO_2



d. Ammonia (NH_3 and H_2O)



e. Fe^{2+} and O_2

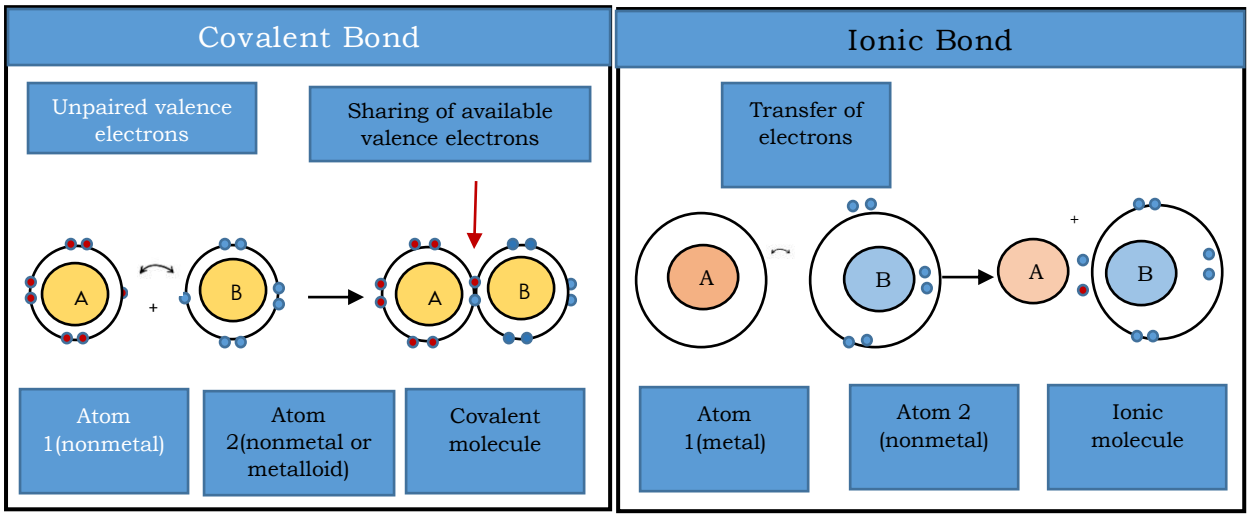


What is It

This section gives a brief and thorough discussion of the concepts of intermolecular forces. The different types of attractions are described in Activity 1 such that they can be easily identified between and among substances in Activity 2.

Description of Intermolecular Forces

Atoms are held together in molecules by strong intramolecular forces, like covalent and ionic bonds. Below are figures that show these types of intramolecular forces.



On the other hand, other forms of attractive forces are present to keep these molecules together giving rise to the different states of matter, which, then exhibit their own bulk properties such as boiling, melting, and freezing points, and viscosity among others.

There are three general types of intermolecular forces (IMF), namely, van der Waals forces, ion-dipole interaction, and H-bonding.

Van der Waals forces, after the Dutch chemist Johannes van der Waals (1837-1923) consist of dipole-dipole interaction, dipole-induced dipole interaction, and dispersion forces. Dipole-dipole attraction is present among polar molecules. Through constant movement, the charges of the molecules align in such a way that the positive (+) end of one molecule is attracted to the negative (-) end of the other molecule. This happens due to the shift of electron density towards the more electronegative element in the molecule resulting in (+) and (-) ends. The measure of this electron shift is known as dipole moment, represented by a crossed ar:

Dipole-induced dipole interaction, just like the dipole-dipole forces, depends on the presence of polar molecules. The other molecule needs not to be a polar one.

The partial charges present in the dipole cause the polarization or distortion of the electron distribution of the other molecule. This gives rise to regions of partial (+) and (-) poles. This induced dipole will then be attracted to the original polar molecules, resulting to dipole-induced dipole attraction.

Dispersion forces (London dispersion forces), were named after the German physicist Fritz London (1900-1954). The electron cloud of a neutral substance can be normally distributed around the nucleus. At any given time, the electron distribution may be uneven resulting in an instantaneous dipole. This temporary

dipole will then influence the neighbouring atoms through attractive and repulsive forces.

Eventually, the substances will gain instantaneous dipoles, too. The attraction between opposite charges will happen among the species present. These are true for ion-induced dipole and induced dipole-induced dipole interactions.

Ion-dipole interaction results from the attraction between either a cation (+) or an anion (-) with permanent polar molecules. The ions will be attracted to the opposite charges present in the dipole resulting to this type of attraction.

H-bonding is a special type of dipole-dipole interaction between the H-atoms in a polar bond. It requires that the H-atoms in the molecules be bonded with more electronegative atoms such as O, N, or F to form H-bonds with other molecules.

All interacting substances exhibit the presence of London dispersion forces in addition to other forces of attraction among them.

These can be summarized in the following table.

Intermolecular Forces (IMF)	Description
1. van der Waals Forces	Happens when electron density shifts toward the more electronegative atom
a. dipole-dipole	Present among polar molecules; the positive (+) end of one molecule aligns to the negative (-) end of the other molecule
b. dipole-induced dipole	Between polar and nonpolar molecules; the partial charges of the dipole cause the polarization or distortion of the electron distribution of the nonpolar molecule
c. dispersion forces	The electron distribution of the molecules is distorted by continuous movement of electrons in the atoms resulting to instantaneous dipole
2. Ion-dipole interaction	Attraction between either a cation or an anion with permanent polar molecules
3. H-bonding	Attraction between H-atoms bonded to more electronegative atoms such as O, N, or F in a polar molecule and the atoms O, N, or F

Intermolecular forces (IMF) existing among species

Polar substances exhibit *dipole-dipole* interaction due to the presence of (+) and (-) ends of the molecules. In the exercise above, sulphur dioxide (SO_2) has polar ends that will participate in the dipole-dipole forces of attraction.

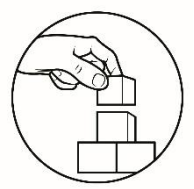
With the presence of an ion (cation or anion), the charged ends of polar molecules will be attracted to the dipole. This is true in the case of Na+ and formaldehyde. The positive (+) sodium ion will be attracted to the partially-negative oxygen in formaldehyde, resulting to an *ion-dipole* interaction.

For the third example, CO_2 is a nonpolar substance. It is a linear molecule and the electron shift at the right of C is balanced by the electron shift to the left. This produces no net shift in electron density so no net charged is produced. For nonpolar molecules, only *dispersion forces* are present.

In both NH_3 and H_2O, the hydrogen atoms are bonded to more electronegative atoms, nitrogen and oxygen, respectively. This permits them to form H-bonds with other molecules with the same condition. Thus, H-bond is present between NH_3 and H_2O.

Ion-induced dipole forces of attraction are present among Fe^{2+} ions together with oxygen molecules. The charge in iron will distort the electron distribution in O_2 resulting in temporary poles in oxygen. The oppositely-charged particles, Fe^{2+} and partially-negative end of O_2 will then be attracted to form the above-mentioned force of attraction.

In all of the examples above, London dispersion forces are also present.



What's More

Activity 1.1 Match Me Up

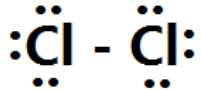
Match Column A with column B. Choose the letters of the correct answer and write it on your answer sheet.

Column A	Column B
1. Attractive forces between polar molecule	a. hydration
2. Electrostatic attraction between an ion and a polar molecule	b. ion-induced dipole
3. Favorable interaction between the ions of an ionic compound and water	c. H-bonding
4. Distortion of the electron distribution of an atom or molecule brought about by an ion or a polar molecule	d. polarizability
5. Dispersion of charges when an ion approaches a molecule	e. dipole-dipole
6. Happens when a H-atom bonded to electronegative atoms, such as O, N, F approaches a nearby electronegative atom	f. dipole-induced dipole
7. Dispersion of charges when a dipole approaches a nonpolar molecule	g. ion-dipole
8. The ease with which electron distribution is distorted	h. dipole
9. Substance with positive and negative ends	i. cations
10. Positively-charged ions	j. dispersion forces
	k. anions

Activity 2.1 Which I Am?

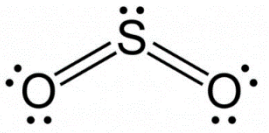
Identify the intermolecular forces present in the following species.

1. Chlorine gas (Cl_2)

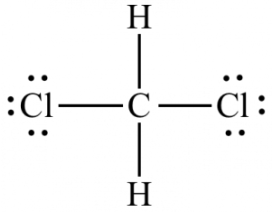


2. Carbon monoxide (CO)

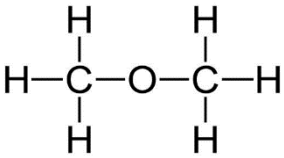
3. Sulfur dioxide (SO_2)



4. Dichloromethane (CH_2Cl_2)

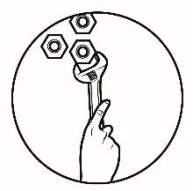


5. Dimethyl ether (CH_3-O-CH_3)



What I Have Learned

1. What remarkable learning experiences did you get after going through the different activities in this module?
2. What common observations about various substances do you have at home and around you that can be explained by intermolecular forces?



What I Can Do

Knowledge of concepts is not enough for a learning experience to be meaningful. We should also understand how the concepts we learned on intermolecular forces can be applied to real life situation to get the most out of what we learned. You can try this task to help you realize the advantage of fully understanding intermolecular concepts.

Create a poster on proper handling of substances like alcohol, acetone, and hair sprays, even gasoline. Integrate the concepts of intermolecular forces (IMF) that you learned in this module to explain why substances at home should be given careful attention. Also indicate in the poster what macroscopic (bulk) properties are observed with various substances.

Assessment

Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. What is true about intermolecular forces?
   a. They are strong bonds that form between atoms of molecules.
   b. Substances can form more than one but one will predominate.
   c. They are weaker than the intramolecular forces between atoms.
   d. There is a vague relationship between intermolecular forces and bulk properties.

2. When will ion-dipole interaction most likely to happen?
   a. If repulsion between a dipole and another dipole exists
   b. If there is an attraction between an ion and a polar molecule
   c. When a repulsion between a polar with a nonpolar molecule occurs
   d. When there is an attraction between a polar with another polar molecule

3. Why are dispersion forces high in molecules with a great number of electrons?
   a. The electron distribution of big molecules is easily polarized.
   b. The nucleus in the molecules has greater effective shielding effect.
   c. The electrons move freely around the nucleus resulting to a greater energy
   d. The electrons in the molecules can easily jump from one orbital to another.

4. What are considered van der Waals forces of attraction?
   a. dipole-dipole; dipole-induced dipole; London dispersion forces
   b. dipole-induced dipole; ion-induced dipole; London dispersion forces
   c. ion-induced dipole; dipole-dipole; London dispersion forces
   d. London dispersion forces; ion-induced dipole; dipole-induced dipole

5. What is the distinguishing characteristic of London dispersion forces?
   a. The electron cloud of the atoms is evenly distributed around the nucleus.
   b. There is permanent (-) and (+) ends that participate in electrostatic attractions.
   c. There is an instantaneous dipole that influences neighbouring substances to gain dipoles.
   d. The atoms of two neighbouring molecules participate in give and take of electrons.

6. How does dipole-dipole interaction happen?
    a. Polar molecules shift electron density that gives rise to neutral substances.
    b. The electron distribution in the polar molecules is distorted that results to (-) and (+) poles.
    c. Polarization of big nonpolar molecules brings about the formation of permanent (+) and (-) charges.
    d. The (-) and (+) ends of one polar molecule align themselves to the (+)and (-) ends of another polar molecule and attract each other.

7. What is the role of cation during ion-dipole interactions?
    a. It causes repulsion of charges among the molecules.
    b. It distorts the electron distribution in the dipole.
    c. It is attracted to the (-) ion of the permanent dipole.
    d. It hastens formation of (+) ions that are attracted to the permanent dipole.

8. Which condition permits H-bonding to form?
    a. If there is an unshared pair of electrons in the central atom
    b. If the interacting substances have central atoms with O, N, F as attached atoms
    c. When the substances involved are polar and have molecules with H-atoms attached to O, N, F
    d. When the substances involved are polar and have molecules with C-atoms attached to O, N, F

9. Which ions will result to higher ion-dipole interactions?
    a. anions
    b. cations
    c. divalent
    d. monatomic

What Intermolecular forces are present in the following species?

10) CH_4

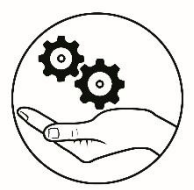
11) CH_3COOH

12) O_3

13) N_2

14) NH_3

15) PCl_5



Additional Activities

This part will test whether you fully understand what intermolecular forces are present between and among species.

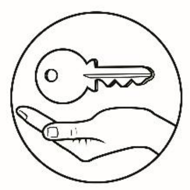
Optional: Watch Intermolecular Forces Magic Trick

https://www.youtube.com/watch?v=ODnqtf3aAvw

Write a short reflection (3-5 sentences) of what you see and understand about the video.

Grading Rubric: Poster Project on Handling Substances based on Existing Intermolecular Forces

Criteria	0	1	2	3	4
Title	No title on the project	Partial/incomplete project	Title is present but capitalized and spelled incorrectly	Title is correctly written in neat, attractive letters	Title is correct, neat, creative, and colorful
Facts	No facts on the poster	Only 1 fact is written on the poster or facts are incorrect	2-3 facts are written and are partially incorrect	4 facts are written and are correct	5 facts are written and are correct
Illustrations	No illustration on the poster	1 illustration related to the topic is indicated on the poster	2 illustrations related to the topic are present on the poster	3 neat, clear illustration related to the topic are present	4 neat, clear, creative illustrations related to the topic are present
Color	No vivid color is presented	A very limited amount of color is present	Poster has a fair amount of color	Poster uses neatly colored elements	Poster uses neat, clear, creative coloring
Appearance/ Aesthetics	Poster lacks neatness and is poorly organized	Poster lacks neatness and is mostly disorganized	Poster is somewhat organized and neat	Poster is organized, neat, and clear	Poster is very organized with neat, clear, easy-to read lettering
Timeliness	Submitted 3 or more days late of the due date	Submitted 1-2 day late of due date	Submitted on due date	Submitted 1-2 days ahead of time	Submitted 3 days ahead of time
TOTAL					



Answer Key

What I Know

1. B
2. C
3. C
4. D
5. C
6. B
7. B
8. D
9. A
10. D
11. C
12. C
13. D
14. D
15. B

What's More

Act. 1.1 Match Me Up

1. E
2. G
3. A
4. J
5. B
6. C
7. F
8. D
9. H
10. I

Act. 2.1 Which I Am

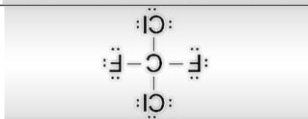
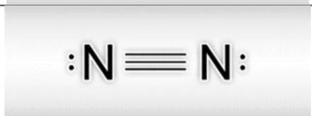
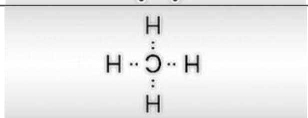
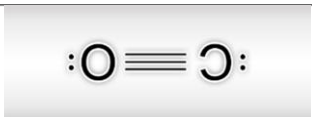
1. LDF
2. LDF, dipole-dipole
3. LDF, dipole-dipole
4. LDF, dipole-dipole
5. LDF, dipole-dipole

Assessment

1. C
2. B
3. A
4. A
5. C
6. D
7. C
8. C
9. B
10. London Dispersion forces
11. London dispersion forces; dipole-dipole; H-bonding
12. London dispersion forces; dipole-dipole
13. London dispersion forces
14. London dispersion forces; dipole-dipole; H-bonding
15. London dispersion

What's In

Polarity of molecules based on the LEDS

Substance	LEDS	Shape	Polarity
1. CCl_2F_2 (Freon-12)		Tetrahedral	Polar
2. N_2 (Nitrogen gas)		Linear	Nonpolar
3. CH_4 (Methane)		Tetrahedral	Nonpolar
4. H_2O (Water)		Bent	Nonpolar
5. CO (Carbon monoxide)		Linear	Polar

What's New

Act.1 Description of Intermolecular Forces

1. partially negative, positive ; Kind of interaction: dipole-dipole
2. positive, negative ; Kind of interaction : ion-dipole
3. positive, cation ; Kind of intersection; ion-induced dipole
4. dipole, temporary; Kind of interaction: dipole-induced dipole
5. negative, attracted, positive ; Kind of interaction: H-bonding

Act. 2 Intermolecular Forces Among Substances

1. London dispersion forces, dipole-dipole
2. London dispersion forces, ion-dipole
3. London dispersion forces
4. London dispersion forces, dipole-dipole, H-bonding
5. London dispersion forces, ion-induced dipole

What Have I Learned

1. The general types of intermolecular forces are van der Waals forces, ion-dipole interaction, and H-bonding.

   2a) van der Waals forces are interactions between molecules that can be either repulsive or attractive depending on the distance of the molecules.

   a1) Dipole-dipole intraction depends on the presence of (+) and (-) charges that align themselves so that the (+) will be attracted to the (-) poles of the molecules.

   a2) Dipole-induced dipole interaction depends on the presence of a dipole that causes the polarization of the electron distribution resulting to temporary dipoles.

   a3) Dispersion forces result from the distortion of the electron distribution or polarization of the molecules.

2. a. London dispersion forces, dipole-dipole
   b. London dispersion forces
   c. London dispersion forces, dipole-dipole interaction, H-bonding
   d. London dispersion forces
   e. London dispersion forces

Additional Activities

Answers will vary.

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