Senior High School

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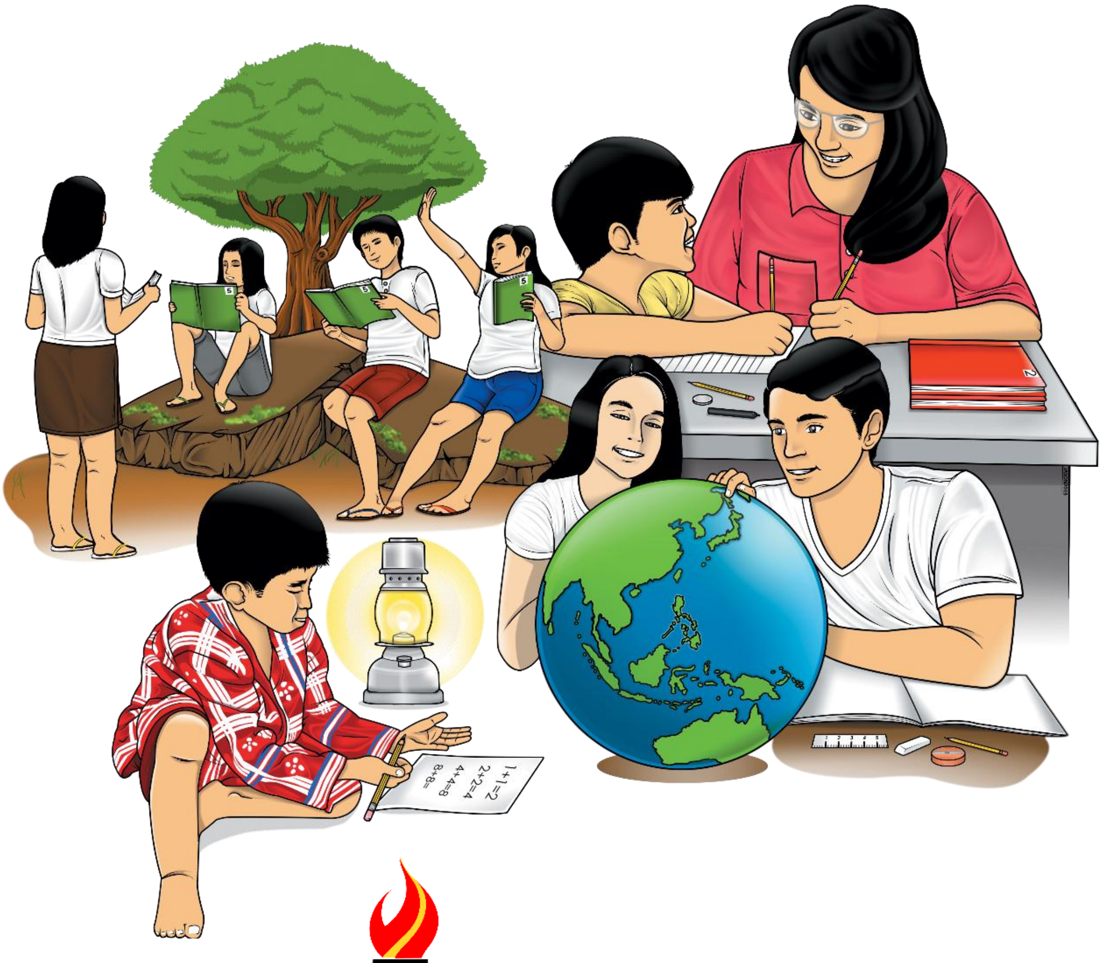
Physical Science
Quarter 1 – Module 6:
Effects of Intermolecular Forces on Properties of Substances



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Secretary: Leonor Magtolis Briones
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Development Team of the Module

Writers: Valeria Amor C. Rosita, Bayani T. Vicencio, Valeria Amor C. Rosita

Editors: Priscilla D. Domino, Gertrudes L. Malabanan

Reviewers: Rogelio D. Canuel, Elmer C. Bobis, Gertrudes L. Malabanan, Ronaldo V. Ramilo, Dennis B. Masangcay, Glory R. Perez, Cirilo M. Bathan Jr.

Illustrator: Geselle A. Teaňo

Layout Artist: Elsie R. Reyes

Management Team: Francis Cesar B. Bringas
Job S. Zape, Jr.
Ramonito Elumbaring
Reicon C. Condes
Elaine T. Balaogan
Fe M. Ong-ongowan
Rogelio F. Opulencia
Rhina O. Ilagan
Edna U. Mendoza
Ronaldo V. Ramilo

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Department of Education – Region 4A CALABARZON

Office Address: Gate 2 Karangalan Village, Brgy. San Isidro, Cainta, Rizal
Telefax: 02-8682-5773/8684-4914/8647-7487
E-mail Address: lrmd.calabarzon@deped.gov.ph

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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.

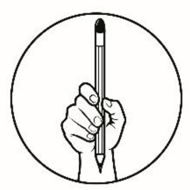
Thank you.

What I Need to Know

This module was designed and written with you in mind. It is here to help you master the *Effects of Intermolecular Forces on the Properties of Substances*. The scope of this module permits it to be used in different learning situations. The language used recognizes the varied vocabulary levels 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.

After going through this module, you are expected to:

1. Identify the intermolecular forces present in each of the given substances.
2. Compare the strengths of intermolecular forces in pairs of substances.
3. Predict which among the given substances will exhibit higher boiling, melting, and freezing points, viscosity, surface tension, and solubilities.
4. Explain the effects of intermolecular forces on the properties of substances.



What I Know

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

1. Liquids can form spherical elastic film to minimize surface area. What intermolecular forces are responsible for the formation of this film in water?
   a. dipole-induced dipole
   b. H-bonding
   c. ion-induced dipole
   d. London dispersion forces

2. Which among the following is the amount of energy required to stretch or increase the surface of a liquid by a unit area (ex., 1 cm^2)?
   a. heat of vaporization
   b. specific heat
   c. surface tension
   d. vapour pressure

3. How is the ability of water molecules to move against gravity referred to?
   a. capillary action
   b. surface tension
   c. temperature
   d. viscosity

4. Substances like heavy syrup and molasses flow slower than water. How is the ability of these substances to resist flow called?
   a. capillary action
   b. pressure
   c. surface tension
   d. viscosity

5. What is the term that pertains to the pressure exerted by the vapor from the evaporation of a liquid or solid above a sample of the liquid or solid in a closed container?
   a. boiling point
   b. capillary action
   c. surface tension
   d. vapour pressure

6. What is true about liquids with strong intermolecular forces?
   a. Vapour pressure is low.
   b. Vapour pressure is high.
   c. Viscosity tends to be high.
   d. Viscosity is immeasurable.

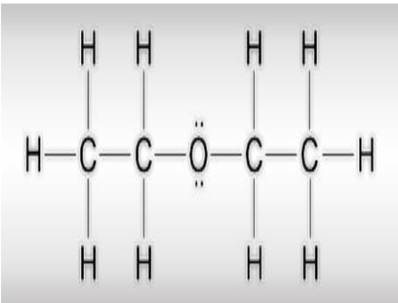
7. What happens when the vapour pressure of a liquid becomes equal to the atmospheric pressure?
   a. The liquid will boil.
   b. The vapour will condense.
   c. Melting of the solid form will start.
   d. There will be freezing of the liquid.

8. Using the chart on the vapour pressure of the four substances, which among them has the lowest boiling point?

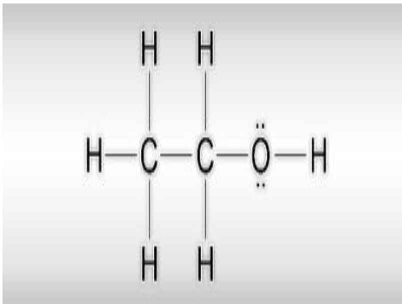
Substance	Vapour Pressure @ 25^{0}C, atm
Diethyl ether $(C_2H_5)_2O$	0.7
Bromine (Br_2)	0.3
Ethyl alcohol (C_2H_5OH)	0.08
Water (H_2O)	0.03

   a. water
   b. bromine
   c. ethyl alcohol
   d. diethyl ether

9. Based on the LEDS below, which has a lower boiling point and what accounts for the difference based on the intermolecular forces present in each species?



Diethyl ether



Ethyl alcohol

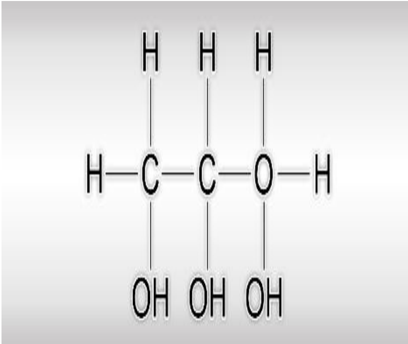
a. Ethyl alcohol has a lower boiling point due to the dispersion forces present among the molecules.
b. Ethyl alcohol has a higher boiling point because of the predominant H-bonding present among the molecules.
c. Diethyl ether has a lower boiling point due to dipole-dipole interaction.
d. Diethyl ether has a higher boiling point because it is capable of forming H-bond.

10. The atmospheric pressure on top of a mountain is lower than at sea level. As a consequence, what will happen to the cooking time of an egg on top of the mountain?
    a. The egg will cook faster since the boiling temperature will be lower.
    b. The egg will cook at a shorter time since the boiling temperature will be higher.
    c. The egg will cook at a longer time due to a lower boiling temperature.
    d. The egg will cook at a shorter time due to higher boiling temperature.

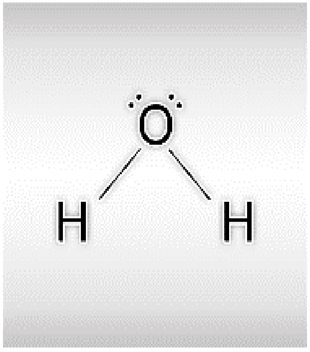
11. Sodium chloride is completely soluble in water. What is responsible for its solubility in water?
    a. Na^+ and Cl^- ions are favorable sites for H-bonding to form.
    b. The ions in NaCl participate in ion-induced dipole attractions with water.
    c. The presence of charged ends in NaCl enables dipole-dipole interaction with water.
    d. London dispersion forces in NaCl predominate leading to strong dipole interactions with water.

12. Xenon has a greater atomic weight than neon. Xe has 131.3 amu while Ne has 20.2 amu. The boiling points are 166.1K and 27.3K, respectively. How do intermolecular forces account for the difference?
    a. Dipole- dipole interaction is greater in Xe than Ne so more energy is needed to break the bonds.
    b. H-bonding is greater for substances with higher atomic weight so greater energy is needed to change Xe to vapour.
    c. Atomic weight increases the chance of lesser dispersion forces so greater energy is needed to separate Xe atoms to change to vapour
    d. London dispersion forces are greater in substances with heavier atomic weight so greater energy is needed to separate the atoms of Xe than Ne.

13. Which is more viscous between glycerol and water based on their LEDS and intermolecular forces?



Glycerol



Water

a. Glycerol because it has more OH^- groups that form London dispersion forces among the molecules.
b. Glycerol because it has more OH^- groups that form H-bonding among the molecules.
c. Glycerol because it has less OH^- groups that form London dispersion forces among the molecules.
d. Glycerol because it has less OH^- groups that form H-bonding forces among the molecules.

14. When does vapour pressure equilibrium happen?
a. When the vapour pressure is equal to atmospheric pressure.
b. When evaporation occurs at the same time with condensation.
c. When the rate of vaporization is equal to the rate of condensation.
d. When the amount of vapour inside the container is equal to the amount of the liquid.

15. Which is **TRUE** of vapour pressure?
a. It is affected by the surface area of the liquid or solid.
b. Vapour pressure is higher when the temperature of the molecule is low.
c. Molecules with high molar heat of vaporization have low vapour pressure.
d. When vapour pressure is lower than atmospheric pressure, boiling occurs.

Lesson 1 Effects of Intermolecular Forces on the Properties of Substances

The properties of matter can be seen from either the microscopic or macroscopic level. The microscopic level includes the atoms, molecules, and ions, which we cannot see. The macroscopic level shows how the bulk properties are exhibited by matter. These properties include surface tension, viscosity, boiling, melting, and freezing points, and solubility. Intermolecular forces play a very important role to determine how substances behave at the macroscopic level or visible state.

In this lesson, you will learn how the different forces of attraction bring about the bulk properties exhibited by substances. This lesson will help you understand why a certain substance behaves differently from other substances.

What's In

This simple activity will help you recall what you understood about the types of intermolecular forces present in each substance.

Notes to the Teacher

1. This module will help the students remember the concepts of intermolecular forces (IMF) and the forces of attraction present among species.
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.

Table 1
Intermolecular Forces Present in Substances

Substance	LEDS	Shape	Polarity	Intermolecular Forces Present
1) Methyl alcohol (CH_3OH)				
2) Ozone (O_3)				
3) Methylamine (CH_3NH_2)				
4) Iodine (I_2)				
5) Hydrogen fluoride (HF)				

What's New

Activity 1: Factors affecting the strength of intermolecular forces among molecules

There are several factors that affect the strength of intermolecular forces in substances, thus, resulting to properties that are unique to each.

Directions: Refer to the pairs of substances in the table. Write the predominant intermolecular forces (IMF) exiting in each. Compare the properties of each substance in the pair based on the predominant IMF. An example is given below to guide you in this activity.

Table 2
Comparative Properties of Substances Based on Predominant Intermolecular Forces

Pair of Substances	Predominant Intermolecular Forces in Each Substance	Comparative Properties		
		Strength of Intermolecular Forces (Weaker/ Stronger)	Boiling Point (Higher/ Lower)	Melting Point (Higher/ Lower)
1. a. Sodium chloride (NaCl)	Dipole-dipole	Stronger	Higher	Higher
b. Methane (CH_4)	London dispersion forces	Weaker	Lower	Lower
2. a. Carbon tetrachloride (CCl_4)				
b. Trichloromethane or chloroform ($CHCl_3$)				
3. a. Ammonia (NH_3)				
b. Methyl fluoride (CH_3F)				
4. a. Phosphorus pentachloride (PCl_5)				
b. Phosphorus pentabromide (PBr_5)				
5. a. Pentane (C_5H_{12})				
b. isopentane (C_5H_{12})				
6. a. Fluorine (F_2)				
b. Bromine (Br_2)				

Activity 2: Intermolecular Forces and Physical Properties of Matter

Refer to the chart below on physical properties of matter. Answer the questions and relate the intermolecular forces present among the substances to explain the exhibited properties.

Table 3

Physical Properties of Substances Based on Size of Molecules and Intermolecular Forces

Substance	Predominant Intermolecular Forces	Molar Mass, g/mol	Relative Strength of Intermolecular Forces	Melting Point, K	Boiling Point, K
Fluorine (F_2)	London Dispersion Forces	38	Weakest	53	85
Bromine (Br_2)	London Dispersion Forces	160	Stronger	266	332
Astatine (At_2)	London Dispersion Forces	420	Strongest	575	610

1. Which substance has the highest melting and boiling points?
2. How does the strength of the intermolecular forces present in each substance compare to each other?
3. How does the strength of the intermolecular forces relate to the boiling and melting points of the substances?

What is It

This section gives brief and thorough explanation on how intermolecular forces affect the bulk properties of matter, namely surface tension, viscosity, boiling, melting, and freezing points, and solubility. These properties are observed when atoms, molecules, or ions act together as one. These are behaviors of substances that can be seen by the naked eye and are unique for each.

Activity 1: Factors affecting the strength of intermolecular forces among molecules

The properties of substances as viewed on the macroscopic level can be explained by the types of intermolecular forces present between and among substances. These bulk properties can be predicted through an analysis of the interplay of intermolecular forces in each substance.

The chart below tells us of the relative strengths of intermolecular forces. The given information can be used to guide you when relating the intermolecular forces (IMF) to the properties of substances.

Figure 1

Relative Strengths of Intermolecular Forces

Ion-dipole	Strongest
H-bonding	↑
Dipole-dipole	
Dipole-induced dipole	
London dispersion forces	Weakest

Properties of substances affected by intermolecular forces

- **Surface Tension**

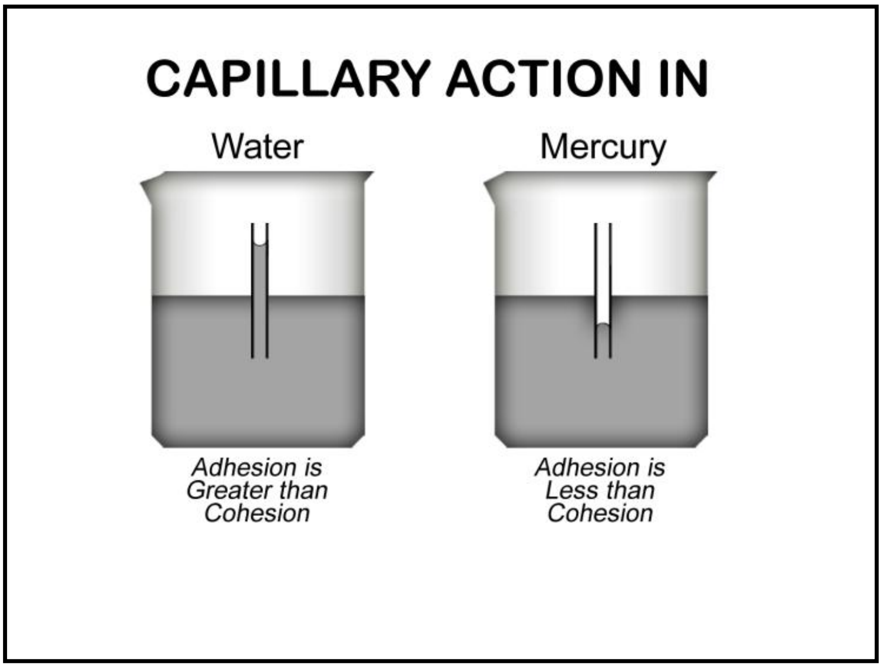
This is the amount of energy required to stretch the surface area of liquids (e.g., 1 cm^2). Liquids with high intermolecular forces tend to have high surface tensions. When water is dropped on a waxy surface, it tends to form a round bead to minimize the surface area that it occupies.

An example of surface tension is capillary action. It is the ability of liquid molecules to move against gravity. The forces bringing about capillary action are cohesion (intermolecular attraction between like molecules) and adhesion (an attraction between unlike molecules.

Water molecules exhibit cohesion while the attraction between water and the sides of the glass tube is adhesion. If adhesion is stronger than cohesion, the liquid is pulled upward.

If cohesion is greater than adhesion, there is a depression or lowering, resulting to a lower height of the liquid in the capillary tube.

Figure 2
Capillary Action



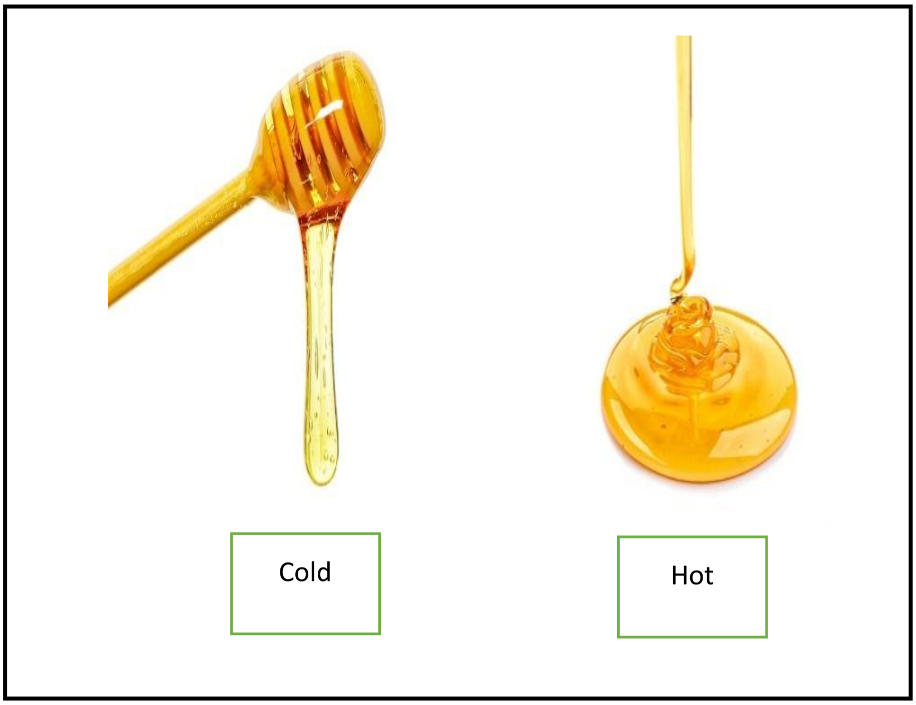
The stronger the intermolecular forces possessed by molecules, the higher is the surface tension of the substance.

- **Viscosity**

This is a measure of a liquid's resistance to flow. The greater the viscosity of a liquid, the more slowly it flows. The viscosity of substances decreases with high temperatures; thus, syrup flows faster when hot.

Figure 3

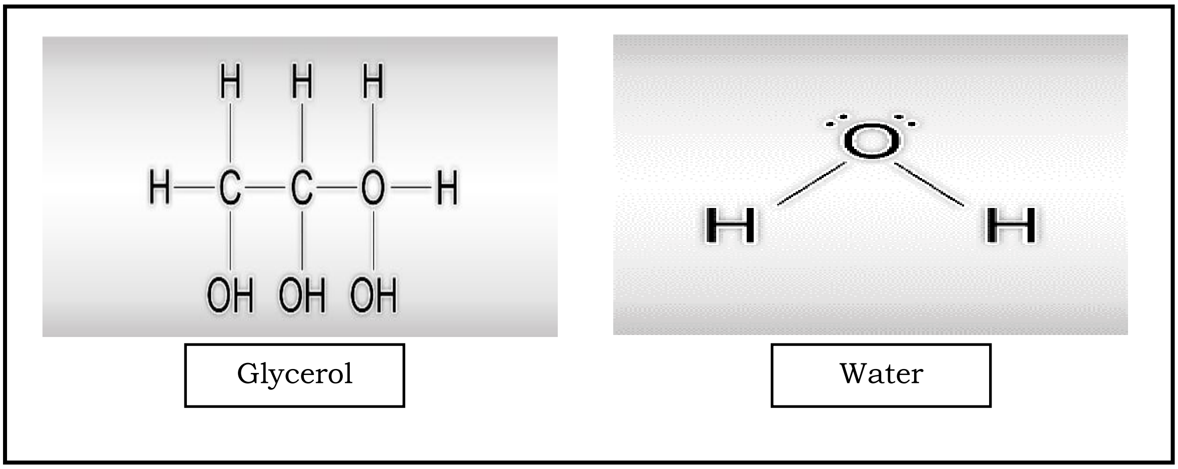
Viscosity of Honey at Different Temperatures



The strength of intermolecular forces affects the ease with which substances flow. Liquids that have high intermolecular forces are highly viscous. The presence of strong H-bonds in some liquids makes these substances highly viscous. The LEDS of glycerol below shows three (3) OH^- groups that can participate in H-bonding whereas water has only one OH^- group to form H-bonding. Glycerol is more viscous than water.

Figure 4

Strength of Intermolecular Forces and Viscosity of Substances

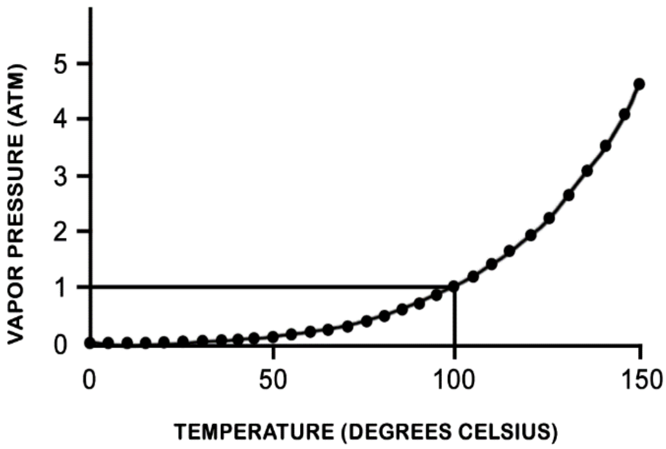


- **Boiling Point and Melting Point**

Boiling point depends on the equilibrium vapour pressure exerted by the liquid or solid above the liquid or the solid. This means that the rate of vaporization is equal to the rate of condensation of the substance in a closed container. Vaporization is the change of a solid or liquid substance to the gaseous phase. On the other hand, condensation is the change of gas to liquid. Vapour pressure also varies with temperature. The graph below shows the effect of temperature on the vapour pressure of water.

Figure 5

Temperature-Water Vapor Relationship

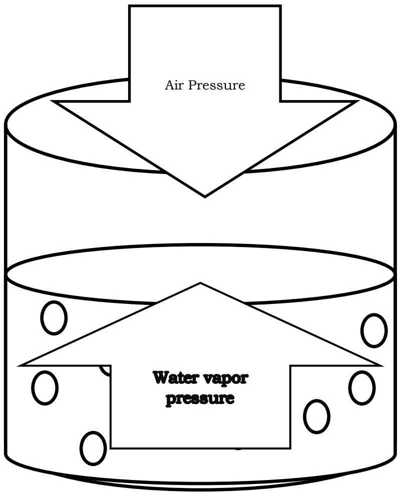


Source: https://www.chem.purdue.edu/gchelp/liquids/vpress.html

At 100°C, the vapour pressure is equal to the atmospheric pressure of 1.00 atm. Boiling occurs at this point, where the vapour pressure of water is equal to the pressure of the atmosphere.

Figure 6

Pressure-Boiling Point Relationship



The vapor pressure also varies at different altitudes. It is higher at sea level, like in Batangas City, than in Baguio City. Boiling, thus, is higher in Batangas City than in Baguio City.

There are substances that boil at a lower temperature and some at a higher temperature. These temperatures depend on the vapour pressure exerted by the liquids or solids. Vapour pressure, on the other hand, depends on the intermolecular forces present in the substances. When the intermolecular forces are strong, the vapour pressure is low.

As a consequence, boiling will occur at a higher temperature because more energy is needed to break the intermolecular bonds for the substance to change into vapour. Water, for example, exhibits strong H-bonds such that vaporization needs more energy to change the liquid to vapour.

London dispersion forces predominate in methane, CH_4. These are the weakest forces of attraction among molecules. It needs a little energy to break the bonds such that methane changes to vapour easily. As a consequence, more vapour are released in which vapour pressure will eventually equal to atmospheric pressure. Boiling then will occur. This explains why water has a higher boiling point than methane.

This is also true for acetone. Acetone is a polar molecule so dipole-dipole forces hold the molecules together. Dipole-dipole forces are stronger than London dispersion forces, so, it needs more energy to break the bonds in acetone than in methane. As a consequence, methane boils at a lower temperature than acetone.

This condition is also true for melting point. The ease with which bond breaks affects the melting points of substances. The greater intermolecular forces there are among molecules the higher is their melting point.

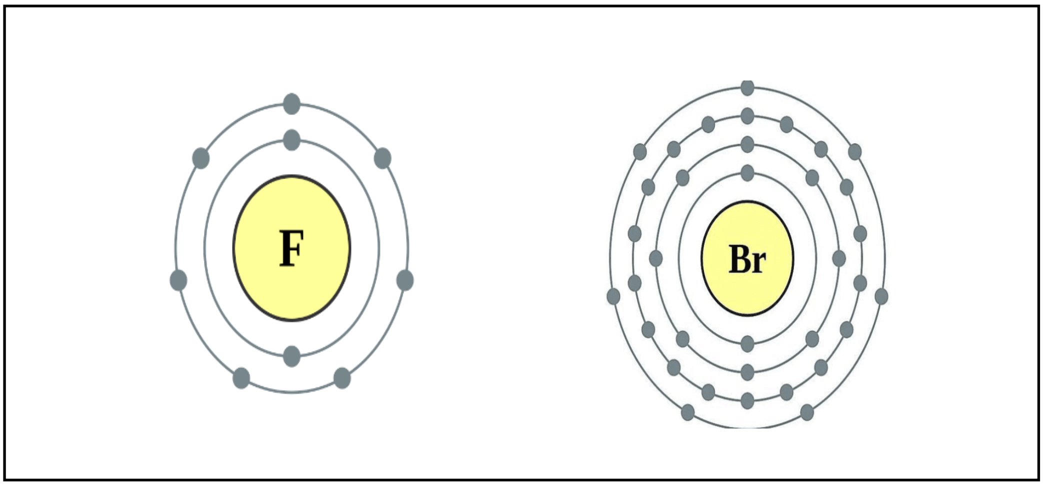
The strength of dispersion forces also depends on the size of the substance or the number of electrons in the substances. The ease with which the electron distribution is distorted explains the amount of dispersion forces that a substance exhibits. The distortion of the electron distribution is known as polarizability.

The greater the polarizability of the electron distribution, the greater are the dispersion forces. When the dispersion forces are high, the boiling and melting points are also high.

Br_2 and F_2 are both diatomic gases. They are also both nonpolar, but Br_2 is a bigger molecule than F_2. The polarizability of Br_2 is greater than F_2, so it has greater dispersion forces. This explains why Br_2 has a higher boiling point than F_2. Greater amount of energy is needed to overcome the big dispersion forces in Br_2 than in F_2.

Figure 6

Electron Distribution of F_2 and Br_2



- **Solubility**

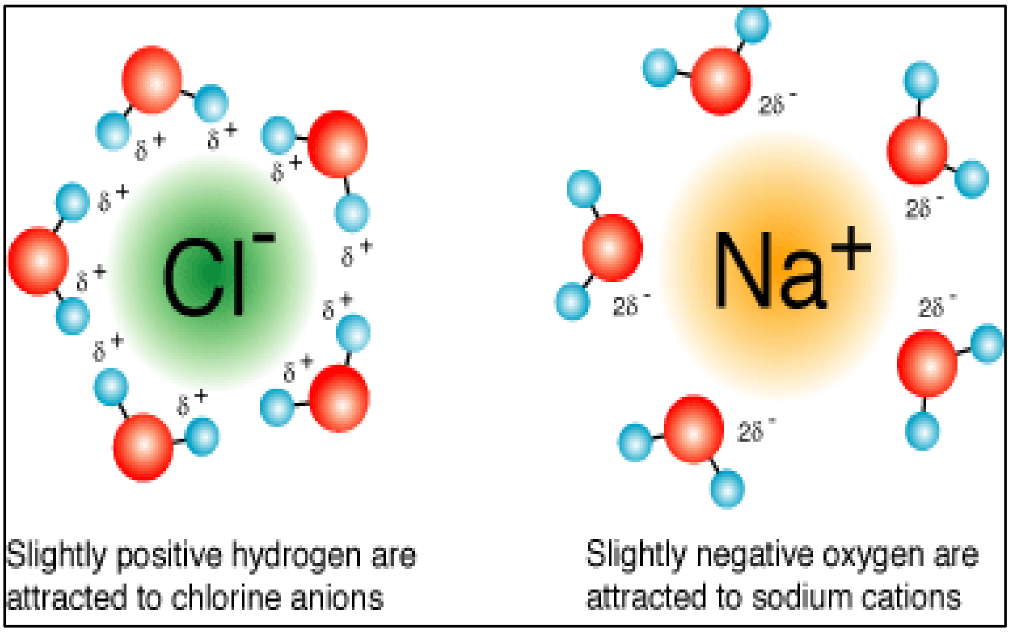
Solubility is the ability of a substance (solid, liquid, or gas) to dissolve in a given substance (solid, liquid, or gas). The amount of any substance dissolved in a solvent (the substance that dissolves another substance) depends on the types of interaction among molecules, pressure, and temperature.

The rule “Like dissolves like” applies to solubility. This means that the kind of substances being dissolved should exhibit the same properties or should be compatible for them to form solutions. The polarity of molecules is an important factor for substances to dissolve in certain molecules. Highly polar molecules will dissolve substances that have dipoles. The negatively-charged particles will be attracted to the positively-charged particles of the involved substances. This attraction will subsist in the solutions.

Water is considered as a universal solvent because of its ability to dissolve almost everything. Water is highly polar and has the ability to form H-bonds with polar substances.

Figure 7

Dissolution of Polar NaCl in Polar H_2O Molecules



Nonpolar substances, on the other hand, will also dissolve nonpolar substances. Intermolecular forces, such as dispersion forces, will prevail to maintain the dissolution of substances.

To predict the behaviour of substances, several considerations should be taken.

First, the polarity of substances should be determined together with the predominant intermolecular forces present in the substances. For example, consider NaCl (sodium chloride) and CH_4 (methane). NaCl is a dipole while methane is nonpolar. Dipole-dipole interaction is predominant in NaCl while dispersion forces are present among methane molecules.

Since dipole-dipole forces are stronger than dispersion forces, NaCl will have higher boiling and melting points. It is also highly soluble in water due to ion-dipole interaction that will prevail. Methane is not soluble in water because there are no poles that will participate in the dissolution process with water.

Between CCl_4 (carbon tetrachloride) and $CHCl_3$ (trichloromethane), trichloromethane has a higher boiling and melting points than carbon tetrachloride. It is also slightly soluble in water. Trichloromethane is a polar molecule while carbon tetrachloride is a nonpolar molecule. The dipole-dipole interaction in $CHCl_3$ is stronger than the dispersion forces in CCl_4. Again, the boiling and melting points are higher in $CHCl_3$ than in CCl_4. Hence, since $CHCl_3$ is polar, then it is soluble in water.

Ammonia (NH_3) and methyl fluoride (CH_3F) are both polar but the ability of NH_3 to form H-bonds qualifies it for higher boiling and melting points than CH_3F. At the same time, H-bonding also enables NH_3 to be more soluble in water than CH_3F.

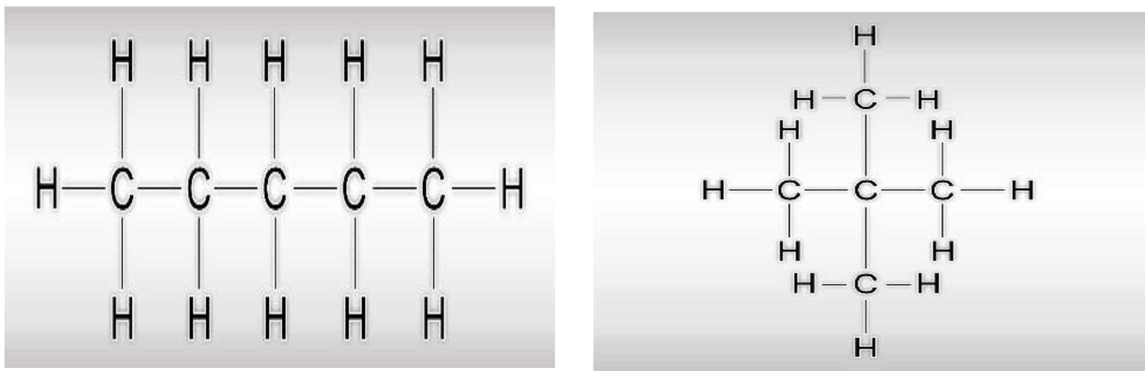
Phosphorus pentachloride (PCL_5) and phosphorus pentabromide (PBr_5) have the same molecular shape and polarity. What matters here is the size of the molecule when comparing the properties of these substances. Bromine contains more electrons than chlorine. This makes PBr_5 bigger and heavier. In this case, dispersion forces are greater in PBr_5 so it has higher boiling and melting points than PCL_5. Since these two substances are both nonpolar, then they are not soluble in water.

Pentane (C_5H_{12}) and isopentane (C_5H_{12}) both contain the same number of C and H atoms in the formula. However, their molecular structures are different. Below are the LEDS of the two substances.

Pentane has an extended structure while isopentane has a compact structure. Extended structures have more opportunities for interactions than compact structures. Extended molecules have stronger intermolecular forces than the compact structures. As such, the boiling point of pentane is higher than that of isopentane. It is also true for their melting points. Both molecules are nonpolar so they are not soluble in water.

Figure 8

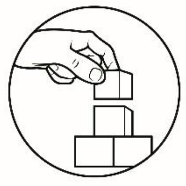
Comparative Properties of Molecules with Extended and Compact Structures



Pentane

Isopentane

The nature of intermolecular forces present in molecules is a good gauge to predict properties of substances.

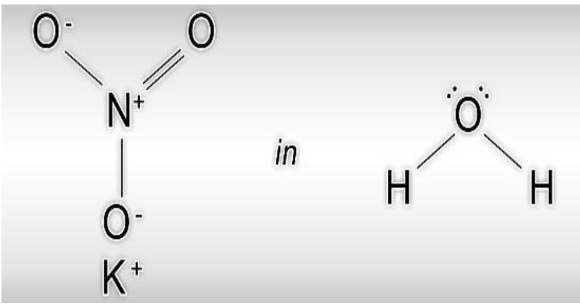


What's More

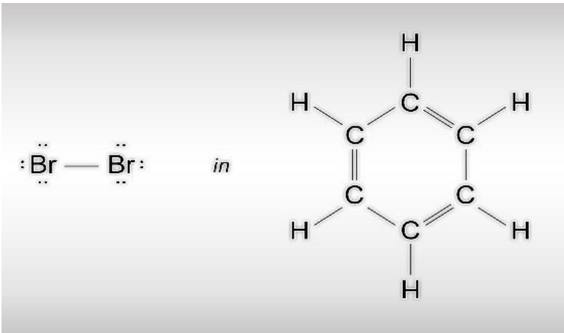
Activity 1.1 Solute-solvent interactions

1. Identify the principal type of solute-solvent interaction responsible for forming the following solutions:

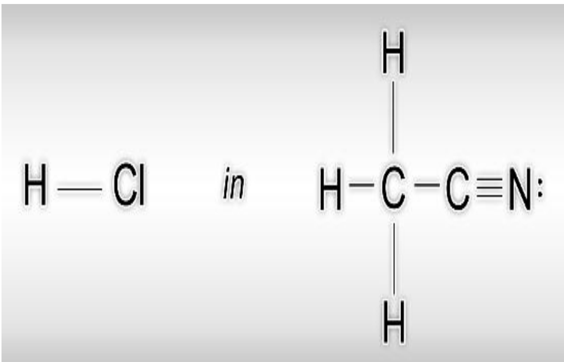
   a. Potassium nitrate (KNO_3) in H_2O



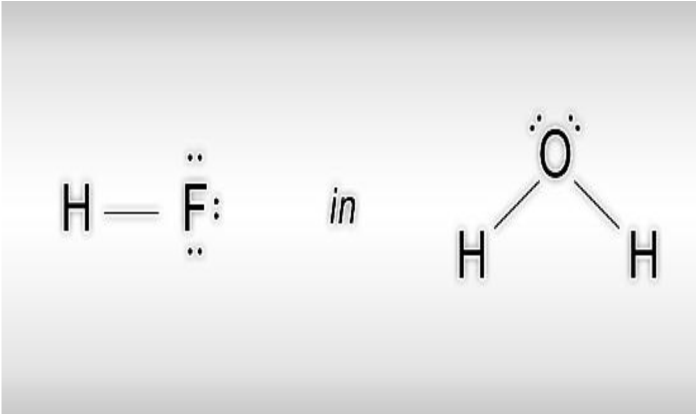
   b. Bromine (Br_2) in benzene (C_6H_6)



   c. Hydrochloric acid (HCl) in acetonitrile (CH_3CN)



d. Hydrogen fluoride (HF) in H_2O

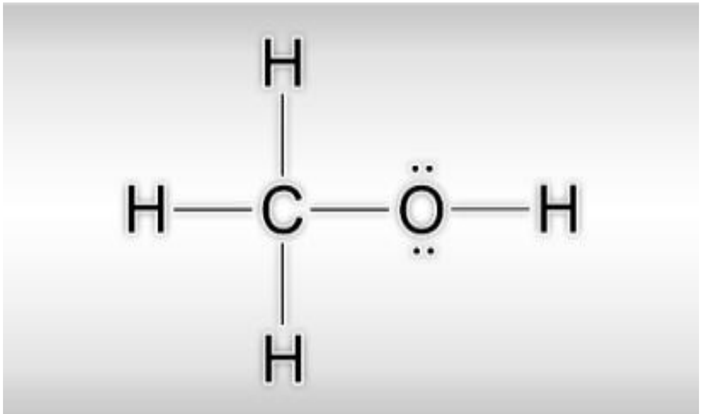


2. Which pair/s of substances will make a solution with each other? Which pair/s of substances will make a solution with each other? Write soluble or insoluble.

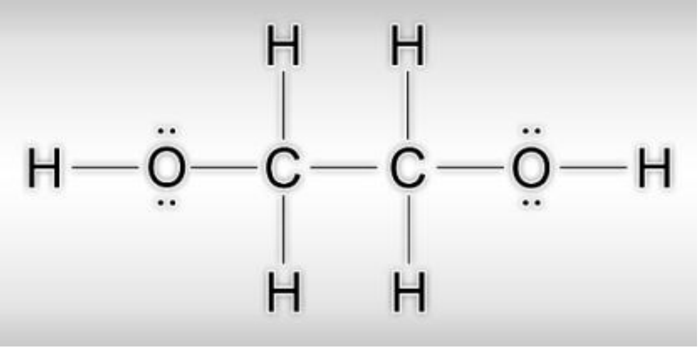
a. CH_3NH_2 and H_2O
b. CH_3-CH_3 and CH_3OH
c. SO_2 and CH_4
d. $MgCl_2$ and H_2O
e. CH_2 = CH_2 and CH_4

3. Arrange the following substances in the order of increasing boiling points by writing their corresponding letters.

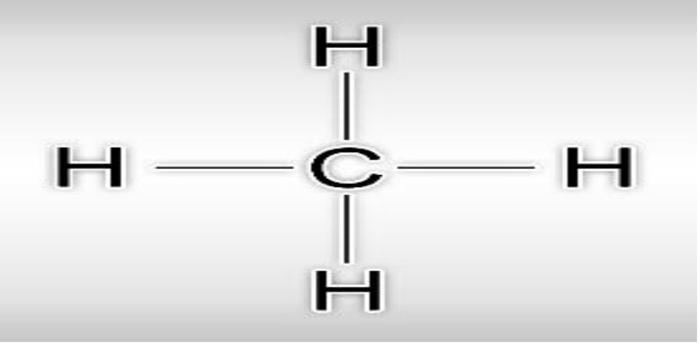
a. Ethanol



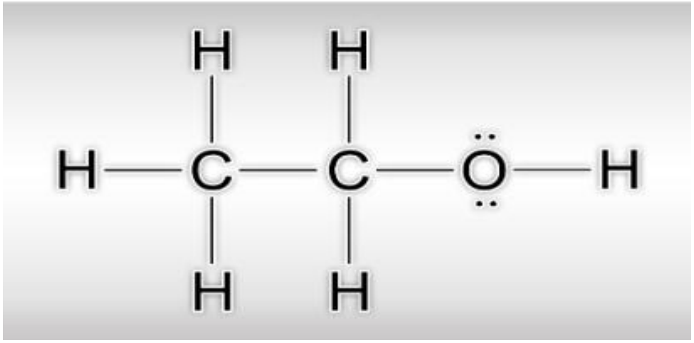
b. Ethane



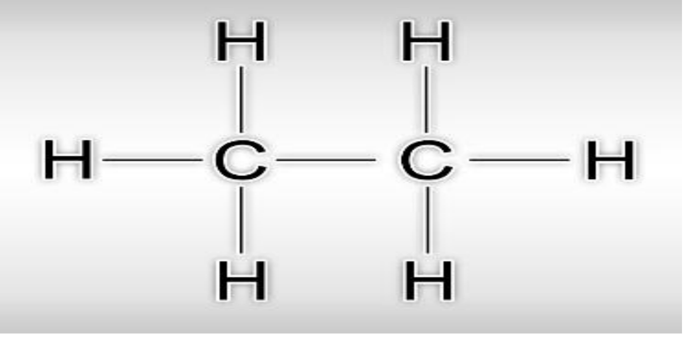
c. Ethylene glycol



d. Methane

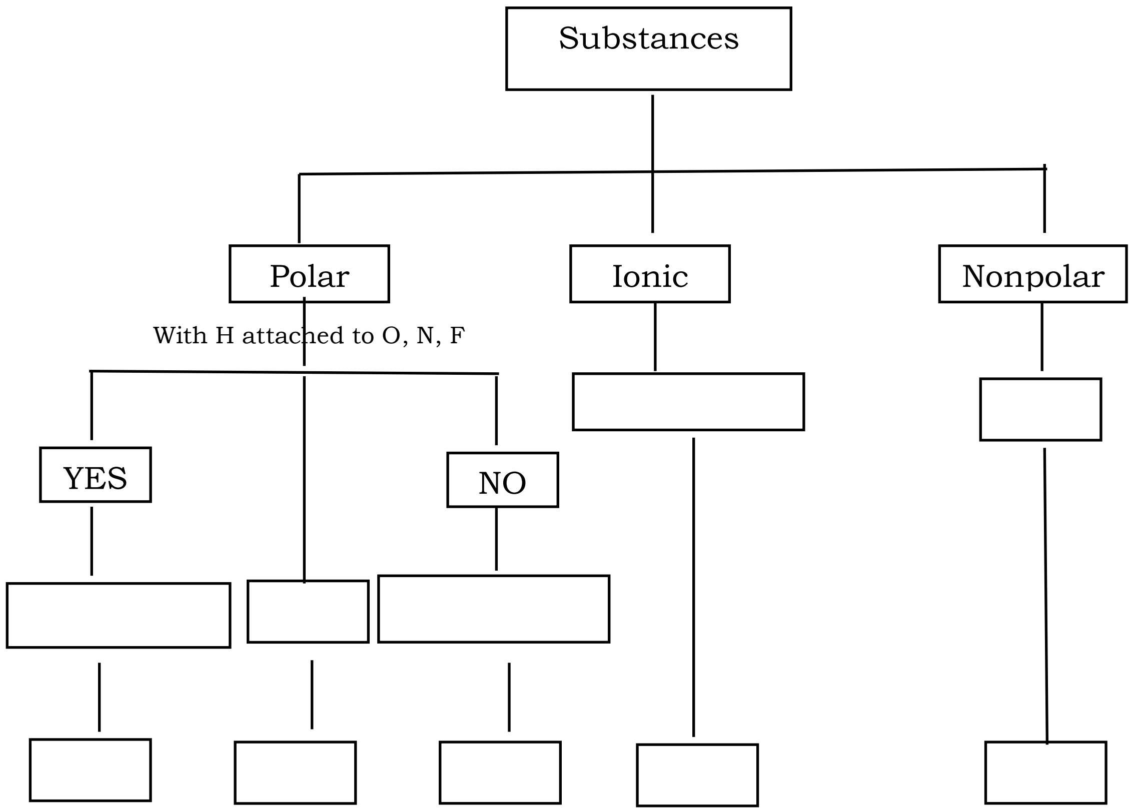


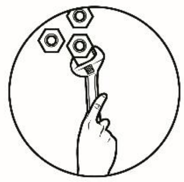
e. Methanol



What I Have Learned

Complete the concept map with the types and effects of intermolecular forces on the physical properties of matter. Write in the last boxes if the boiling and melting points and viscosity will be either high or low.





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 situations to get the most out of what we learned. Let us look at this simple situation that will help us realize the advantage of fully understanding intermolecular concepts.

Situation:

You are asked by your mother to cook pork nilaga. You have only an ordinary casserole to use for cooking. She even reminds you to save energy because we are in a state of pandemic due to COVID -19. Saving resources nowadays is a must because we are not sure of the world's economy. As a student of Physical Science and with your knowledge of properties of matter in relation to intermolecular forces, how are you going to perform your task in such a way that energy is not wasted?

Assessment

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

1. What properties of matter that we see in the macroscopic level are influenced by intermolecular forces?
   a. bulk
   b. covalent
   c. individual
   d. ionic

2. Which intermolecular forces depend on the polarizability of molecules?
   a. dipole-dipole
   b. hydrogen bonding
   c. ion-dipole
   d. London dispersion forces

3. Cohesive forces bring about capillary action. What do these forces do to molecules?
   a. They pull molecules towards gravity.
   b. They draw the same kind of molecules together.
   c. They trigger interactions among polar molecules.
   d. They hasten attractions among different molecules.
4. What will result when adhesion is stronger than cohesion? The liquid is pulled
   a. upward and results to concave meniscus.
   b. downward and results to convex meniscus.
   c. upward and becomes higher than the surrounding liquid.
   d. downward and becomes higher than the surrounding liquid.

5. Which of the following statements is **TRUE** about viscosity of substances?

   a. Viscosity of substances increases as the temperature increases.
   b. The least viscous substance flows the slowest among the substances.
   c. Molecules that form H-bonds have higher viscosities than those with London dispersion forces.
   d. Substances with London dispersion forces exhibit greater viscosity than those with ion-dipole interactions.

6. What is expected of the boiling point when intermolecular forces are high? It will be
   a. dependent on the kinds of atoms.
   b. dependent on the number of atoms.
   c. high.
   d. low.

7. Water is a polar molecule that is capable of forming H-bonds.
   What is expected to be its vapour pressure?
   a. It is low since weak intermolecular forces are present.
   b. The polar ends hinder the breaking of bonds, thus, less water vapour is produced.
   c. Vapour pressure is high since a great amount of energy is needed to break the H-bond.
   d. Vapour pressure is low since it is hard to break the H-bond among the molecules and escape as vapour.

8. Which intermolecular forces allow for easy escape of molecule to the vapour phase?

   a. dipole-dipole interaction
   b. H-bonding
   c. ion-dipole forces
   d. London dispersion forces

9. The vapour pressure on top of the mountain is low. What will happen to the cooking time of an egg up there?

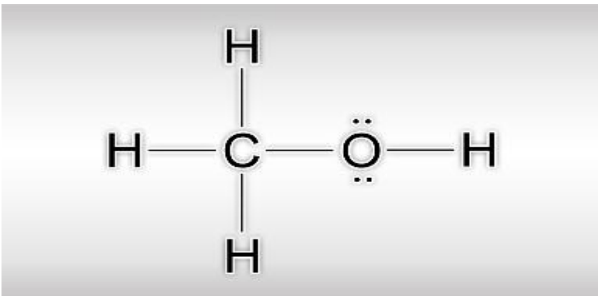
a. The cooking time will be longer since the temperature of the water is higher.
b. The cooking time will be shorter since the temperature of the water is higher.
c. The cooking time will be longer since the temperature of the water is lower.
d. The cooking time will be shorter since the temperature of the water is lower.

10. Why will methane, CH_4, not dissolve in water?

a. It is due to greater molar mass of H_2O than CH_4.
b. Both possess the same intermolecular forces.
c. They have different kinds of atoms in their structure.
d. The two substances have different intermolecular forces between them.

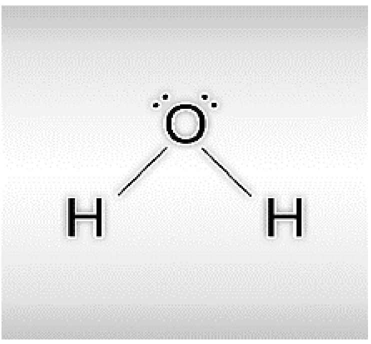
11. Which among the following substances has lower viscosity than methyl alcohol?

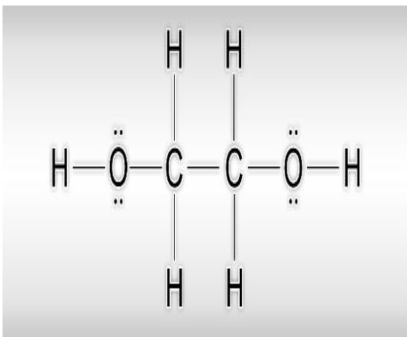
Methyl alcohol



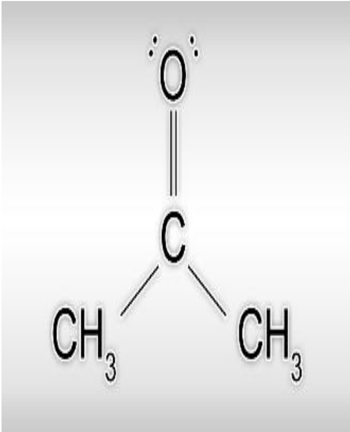
a. Water, H_2O

b. Ethylene glycol, $C_2H_6O_2$

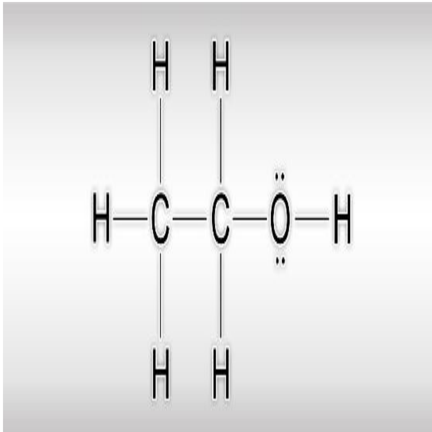




c. acetone, C_3H_6O



d. ethyl alcohol, C_2H_5OH



12. Arrange in increasing boiling points.

I. Carbon dioxide (CO_2) II. Water (H_2O)
III. Oxygen gas (O_2) IV. Glucose ($C_6H_{12}O_6$)

a. I, II, III, IV
b. III, I, II, IV
c. III, II, I, IV
d. II, I, IV, III

Identify the predominant intermolecular forces present between each pair of molecules.

13. Water (H_2O) and acetic acid (CH_3COOH)

14. Carbon dioxide (CO_2) and methane (CH_4)

15. Potassium iodide (KI) and Water (H_2O)

Additional Activities

This part will test whether you fully understand the influences of intermolecular forces present between and among species to the bulk properties of substances. You can answer this by recalling the strategies discussed earlier in this module. Remember also that the predominant intermolecular forces are the determinants of what the bulk properties of substances will be.

You can try this self-learning activity on cooking eggs with three different substances namely water, vinegar, and cooking oil.

1. Twenty (20.0) mL each of water, vinegar, and cooking oil will be measured and used to cook uniform-sized eggs.

2. Each of the substances will be placed in a uniform cold pan. (Note: You can do this one at a time.)

3. The heat will be turned on and wait for the substances to boil.

4. Uniformed-sized eggs will be placed in the boiling substances. The eggs are already done when the egg whites and yolks are thoroughly cooked.

5. The time that the substances start to boil and cook the eggs will be recorded in the following data table.

Substance	Boiling Time, min.	Cooking Time, min.
1. Water		
2. Vinegar		
3. Cooking Oil		

Guide Questions:

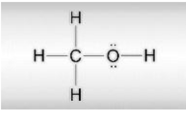
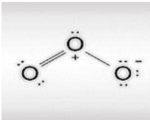
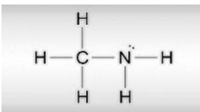
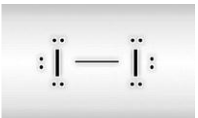
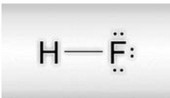
1. Based on the boiling time, which substance do you think has the strongest intermolecular forces? Which has the weakest intermolecular forces?

2. Which among the substances will have the highest boiling point, based on the predominant existing intermolecular forces?

3. How do you relate the cooking time of the eggs to the boiling temperature of each substance?

4. How do you relate the boiling temperature and the strength of intermolecular forces existing in the above substances?

Answer Key

Substance	EDS	Shape	Polarity	Intermolecular Forces Present
1. CH_3OH (Methyl alcohol)		Tetrahedral, bent	Polar	H-bonding, London dispersion forces, dipole-dipole interaction
2. O_3 (Ozone)		Bent	Polar	London dispersion forces, dipole-dipole interaction
3. CH_3NH_2 (Methyl amine)		Tetrahedral, bent	Polar	H-bonding, London dispersion forces, dipole-dipole interaction
4. I_2 (Iodine)		Linear	Nonpolar	London dispersion forces
5. HF		Linear	Polar	H-bonding, London dispersion forces, dipole-dipole interaction

What I Know

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

What's More

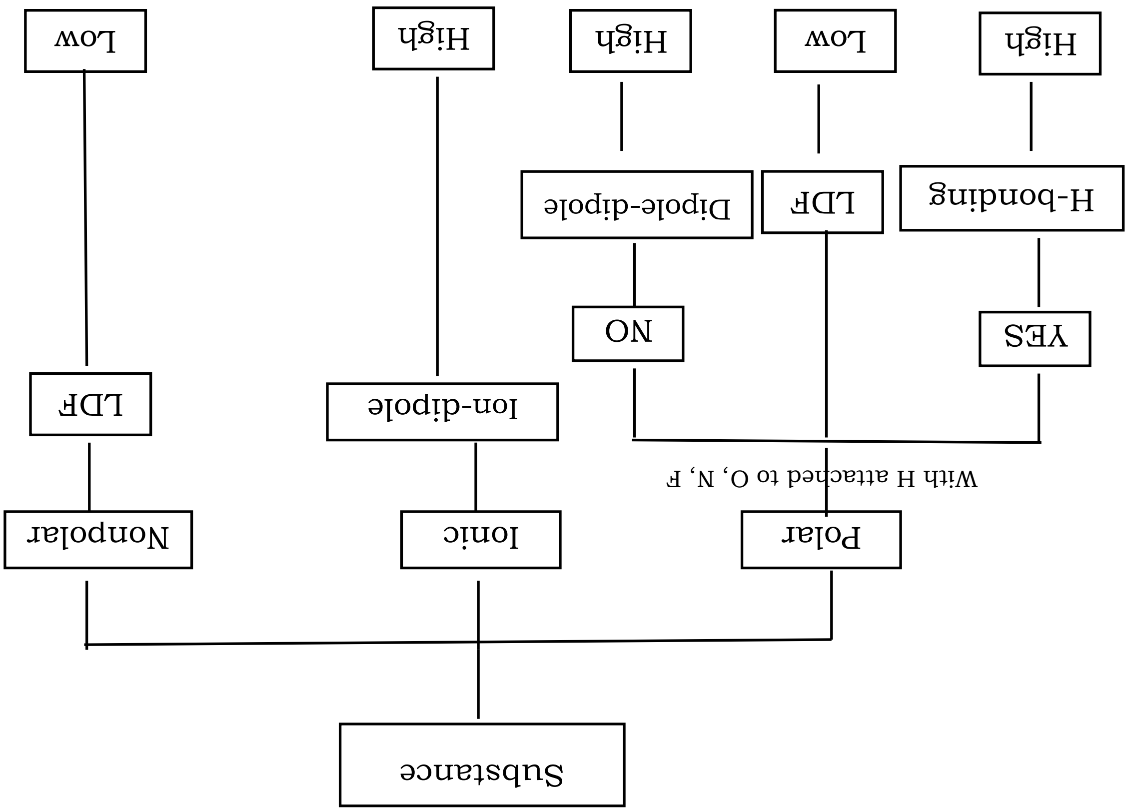
1. a) ion-dipole
   b) London dispersion forces
   c) dipole-dipole
   d) H-bonding
2. a) Soluble
   b) Insoluble
   c) Insoluble
   d) Soluble
   e) Soluble
3. d, b, e, a, c

Assessment

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

Pair of Substances	Predominant Intermolecular Forces in Each Substance	Comparative Properties		
		Strength of Intermolecular Forces (Weaker/ Stronger)	Boiling Point (Higher/ Lower)	Melting Point (Higher/ Lower)
1. a. Sodium chloride (NaCl)	Dipole-dipole	Stronger	Higher	Higher
b. Methane (CH_4)	London dispersion forces	Weaker	Lower	Lower
2. a. Carbon tetrachloride (CCl_4)	London dispersion forces	Weaker	Lower	Lower
b. Trichloromethane or chloroform ($CHCl_3$)	Dipole-dipole	Stronger	Higher	Higher
3. a. Ammonia (NH_3)	H-bonding	Stronger	Higher	Higher
b. Methyl fluoride (CH_3F)	Dipole-dipole	Weaker	Lower	Lower
4. a. Phosphorus pentachloride (PCl_5)	London dispersion forces	Weaker	Lower	Lower
b. Phosphorus pentabromide (PBr_5)	London dispersion forces	Stronger	Higher	Higher
5. a. Pentane (C_5H_{12})	London dispersion forces	Stronger	Higher	Higher
b. isopentane (C_5H_{12})	London dispersion forces	Weaker	Lower	Lower
6. a. Fluorine (F_2)	London dispersion forces	Weaker		
b. Bromine (Br_2)	London dispersion forces	Stronger		

What I Have Learned



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For inquiries or feedback, please write or call:

Department of Education - Bureau of Learning Resources (DepEd-BLR)

Ground Floor, Bonifacio Bldg., DepEd Complex
Meralco Avenue, Pasig City, Philippines 1600

Telefax: (632) 8634-1072; 8634-1054; 8631-4985

Email Address: blr.lrqad@deped.gov.ph * blr.lrpd@deped.gov.ph