SI Chemistry - Full Discipline Demo

Melting Points

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Chemistry - Full Discipline Demo
Course	SI Chemistry - Full Discipline Demo
Instructor	Sales SI Demo

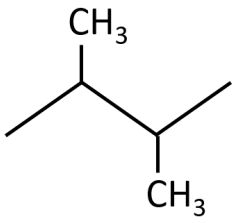
Test Your Knowledge

Label the hexane and hexane derivatives formed through a chemical reaction as having the lowest, intermediate, or highest melting point.

Highest

Intermediate

Lowest



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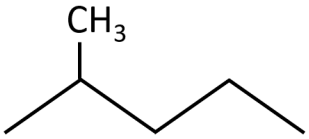

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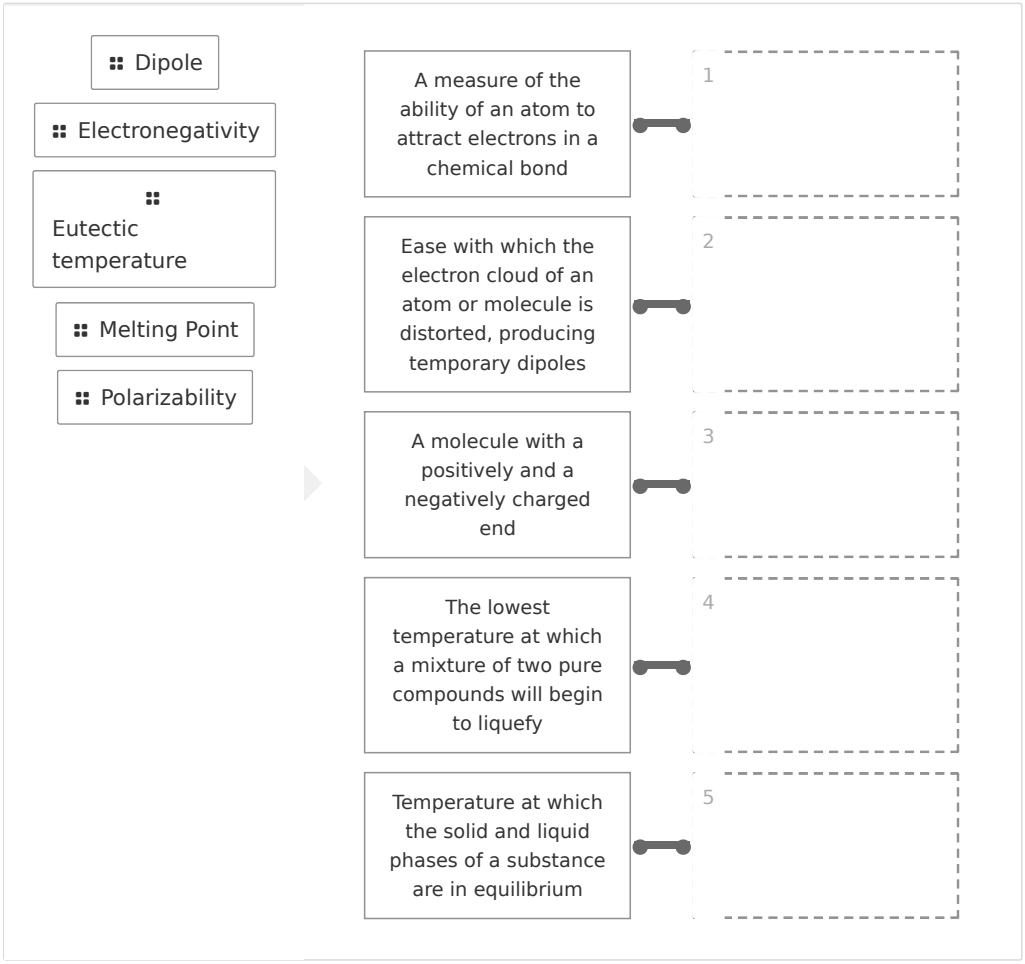
Correct answers:

1 Intermediate 2 Highest 3 Lowest

Match each term with the best description.

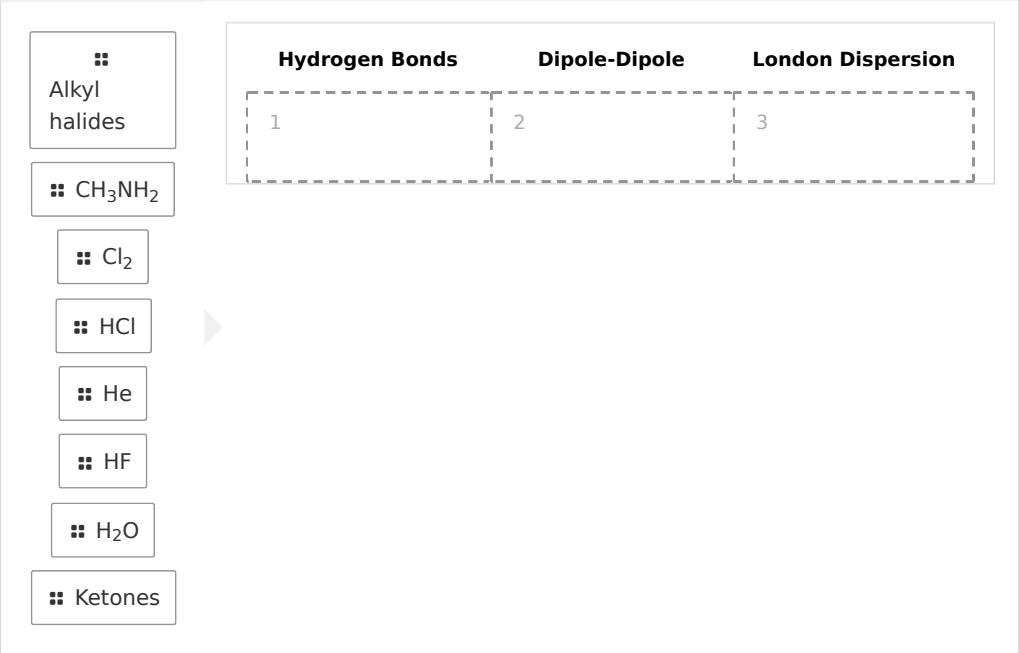


Correct answers:

1 Electronegativity 2 Polarizability 3 Dipole

4 Eutectic temperature 5 Melting Point

Categorize the compounds as being held together by hydrogen bonds, dipole-dipole interactions, or London dispersion forces.



Correct answers:

1 H_2O HF CH_3NH_2

2 Alkyl halides Ketones HCl

3 Cl_2 He

Exploration

As the strength of intermolecular forces increase, the amount of energy required to disrupt the forces increases.

- True ✔
- False

London dispersion forces are permanent dipole moments because the movement of electrons is continuously changing.

- True
- False ✔

Dipole-dipole forces are present in all molecular liquids and solids, but are of lower significance if other intermolecular forces are present.

- True
- False ✔

When comparing similarly sized molecules, _____ are the strongest intermolecular forces.

- dipole-dipole forces
- hydrogen bonds ✔
- London dispersion forces

High melting points indicate weak intermolecular forces.

- True
- False ✔

Molecules that are _____ are able to pack tightly together, maximizing the interactions between molecules.

- compact
- rigid
- symmetrical
- All of the above ✔

A pure substance will have a melting range of _____.

- 5°C
- less than 1°C ✔
- 3°C
- greater then 10°C

The eutectic temperature is the lowest temperature at which a mixture of two compounds will completely liquefy.

- True
- False ✔

Exercise 1

Data Table 1: Properties of Tetracosane and 1-Tetradecanol
(SAMPLE ANSWER BELOW)

Chemical	Chemical Formula	Molecular Mass (g/mol)	Shape (i.e. symmetry, branching, etc.)
Tetracosane	$C_{24}H_{50}$	338.66	$Long\ straight\ chain,\ not\ rigid\ (21\ freely\ rotating\ bond$
1-tetradecanol	$C_{14}H_{30}O$	214.39	$Long\ straight\ chain,\ not\ rigid\ (12\ freely\ rotating\ bond$

Data Table 2: Properties Influencing Melting Points
(SAMPLE ANSWER BELOW)

Property	Description	Comparison
Size	Larger molecules have higher melting points due to a larger surface area. Larger molecules also have increased polarizability.	Tetracosane would have a higher melting point because it is much larger than 1-tetradecanol with a greater molecular mass, and greater polarizability making the London dispersion forces stronger.
Shape	Rigid, compact, and symmetrical molecules fit tightly into a crystal lattice which maximizes the intermolecular forces.	Both tetracosane and 1-tetradecanol are long, straight chain symmetrical molecules with no branching, but have some freely rotating bonds. 1- tetradecanol has less symmetry than tetracosane due to the OH bond. Tetracosane would have a higher melting point due to the slight lack of symmetry of 1-tetradecanol.
Polarity	Polar molecules have stronger dipole-dipole forces. The more polar a molecule is the higher the melting point.	1-tetradecanol is slightly polar, whereas tetracosane is nonpolar. 1- tetradecanol would have a higher melting point since polar molecules have stronger dipole-dipole forces.
Intermolecular Forces	When comparing similarly sized molecules, London dispersion forces are the weakest intermolecular forces, followed by dipole-dipole forces which can be weak to intermediate in strength, and	Tetracosane molecules are held together by London dispersion forces and 1-tetradecanol has the potential for some hydrogen bonding due to the OH bond. 1-tetradecanol would have a higher melting point due to the stronger hydrogen bonding.

	hydrogen bonding which is the strongest of the intermolecular forces.	

Panel 1: Melting Point Prediction
(SAMPLE ANSWER BELOW)

Student predictions will vary, but should demonstrate comprehension of the properties affecting melting points and application of the properties combined since tetracosane and 1-tetradecanol are not similarly
sized molecules. 1-tetradecanol is slightly polar and has hydrogen bonding, but since tetracosane is a much larger molecule with a larger surface area it has stronger polarizability which should result in a higher melting point than 1-tetradecanol.

Exercise 2

Using molecular structure, explain why tetracosane has a higher melting point than 1-tetradecanol despite the fact that solid tetracosane is held together solely by London forces and 1-tetradecanol has the potential for hydrogen bonding.

These compounds have different molecular weights and structures; however, they are good chemicals to use for determining the melting point as a demonstration of symmetry and surface area. Tetracosane is a long-chain hydrocarbon with a much larger surface area than 1-tetradecanol increasing its polarizability. Additionally, although 1-tetradecanol is an alcohol with hydrogen bonding, which is a stronger intermolecular force than London dispersion
forces, the symmetry of tetracosane as a long-chain hydrocarbon with no branching or substituents maximizes the interactions. This yields a higher melting point.

Compare the sharp melting point of a pure compound versus the melting range of a mixture. Use the data in Data Table 3 and Data Table 4 to support your answer.

The sharp melting point of a pure substance is a temperature range of less than 1.0°C beginning when the substance first begins to liquefy and ending when it is completely liquefied. The melting range of a mixture is a broader range of temperature change between when the substance first begins to liquefy to when it is completely liquefied. Both the tetracosane and 1-tetradecanol have a sharp melting point, whereas when the two compounds are combined the mixture has a melting range initially below the melting point of 1-tetradecanol. The mixture's melting point increases depending on the percent composition of tetracosane to 1-tetradecanol in the particular sample. HOL results included a melting range of 36.0-43.0°C.

Explain the effect percent composition of a mixture has on its melting point. Then:

a. Interpreting your results based on the assumed eutectic point of composition of a 50/50 mixture, state the percent composition of your Trial 1 mixture sample. Support your answer using the graph in Photo 1.

b. Based on the graph in Photo 1, what would the approximate percent composition be of a mixture of tetracosane and 1-tetradecanol if the upper level of the melting point was 37°C?

Percent composition affects the melting point because if two pure compounds melt at different temperatures, the sample will melt at a broad range according to whichever compound is the most prevalent in the sample.
a. HOL results indicated the sample contained a greater percent composition of tetracosane than 1-tetradecanol as the melting point range extended over a broad temperature range from 36.0°C to 47.0°C, exceeding the melting point of 1-tetradecanol. Based on the results of the Trial 1 mixture and graph, the results produced by HOL contained approximately 65% tetracosane to 35% 1-tetradecanol. Regardless of the percent composition of the student's sample, they should relate to their data that the eutectic temperature of the mixture of tetracosane and 1-tetradecanol was below that of 1-tetradecanol. Then, depending on percent composition, the melting range increased to just below that of 1-tetradecanol or tetracosane. Students should state an approximate percent composition that corresponds with the plotted upper melting point of the mixture according to the graph.
b. Based on the graph in Photo 1, at an upper limit melting point of 37.0°C for a mixture of tetracosane and 1-tetradecanol, the approximate percent composition is 40% tetracosane and 60% 1-tetradecanol.

Why is it necessary to use fresh room temperature water for each trial, instead of simply placing the crystallized sample back into the hot water bath? Why is it necessary to use a fresh sample to determine melting point instead of using the original sample that was already melted?

If the water is near or above the melting point of the compound at the beginning of the trial, the temperature at which the sample melts cannot be accurately measured. A fresh sample must be used to record an accurate melting point as the melting process causes the substance to collapse and the crystal arrangement to become disorderly, which can lead to depressed or inaccurate melting point measurements.

How would the rate of heating a sample influence the recorded melting points? Would your recorded melting point be too high or too low with a faster rate of heating? What would be the probable effect on the melting point range? Is the chemical identity of a substance altered when it melts? Describe any possible sources of error for this exercise.

Heating too quickly will give a higher temperature reading than the true reading since the thermometer will “overrun” the true melting point. The range would be broader. No, the chemical identity is not altered because melting is a physical change.
The sources of error from this experiment include an inaccuracy of the thermometers used based on estimating between the lines on the thermometer to the nearest 0.1°C, thermometers not being properly calibrated, or the temperature displayed on the thermometer not being true to the actual water temperature. Other sources of error include the addition of too much chemical to the capillary tube. If there was more than 1-2 mm of powder in the capillary tube then the melting point range would have been broader than what it actually is. Another source of error would be from not packing the powder in the capillary tube enough or the powder not being finely ground enough. Each of these things would cause air pockets in the sample leading to slow heat transfer.

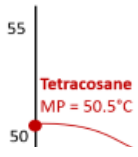
Data Table 3: Melting Points of Tetracosane, 1-tetradecanol, and the Mixture
(SAMPLE ANSWER BELOW)

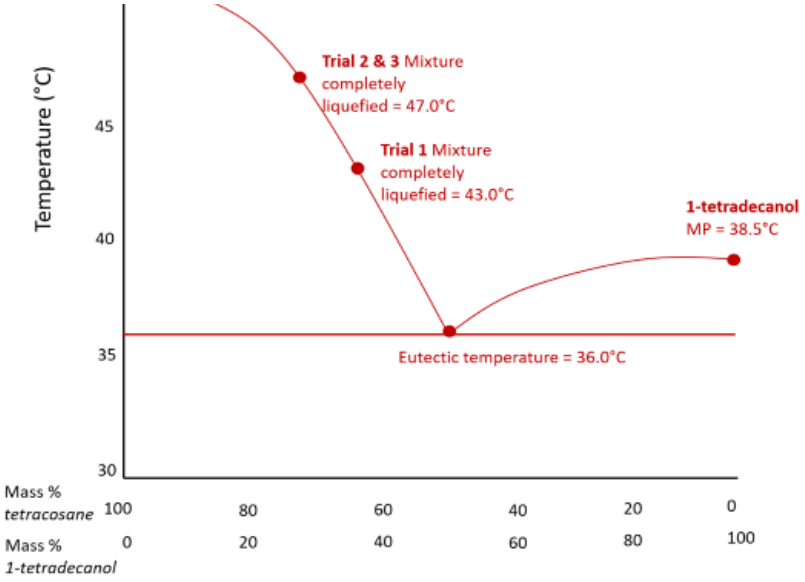
	Melting Point of Tetracosane (°C)	Melting Point of 1-Tetradecanol (°C)	Meltin
Trial 1	50.0-51.0	38.0-39.0	36.0-4
Trial 2	50.0-51.0	38.0	36.0-4
Trial 3	50.0-51.0	39.0	36.0-4
Average of the 3 Trials	50.5	38.5	

Data Table 4: Hypothesis, Results, and Conclusions of the Melting Point of a Mixture
(SAMPLE ANSWER BELOW)

Hypothesis	If the eutectic temperature is lower than the lowest melting point of the pure compounds in the mixture, then the eutectic temperature of the mixture of tetracosane and 1-tetradecanol will be lower than 38.5°C.
Eutectic Temperature	36.0°C
Conclusions	The hypothesis was supported based on the mixture beginning to liquefy at 36°C, which is a lower temperature than the melting point of 1-tetradecanol at 38.5°C.

Photo 1: Graph of Results
(SAMPLE ANSWER BELOW)





Competency Review

The higher the melting point, the _____ the intermolecular forces.

- stronger ✔
- weaker
- average

_____ are the only type of intermolecular force to attract non-polar molecules.

- Dipole-dipole forces
- Ion-ion forces
- Hydrogen bonds
- London dispersion forces ✔

The tendency of a molecule to form a temporary dipole is known as the _____.

- electronegativity
- polarizability ✔
- dispersion rate
- None of the above

Hydrogen bonds have an increasing strength of attraction with _____ electronegativity.

- increasing ✔
- decreasing
- None of the above

Electronegativity measures the ability of an atom to repel electrons in a chemical bond.

- True
- False ✔

As the magnitude of partial charges increases in polar molecules, _____ will increase in strength.

- dipole-dipole forces ✔
- hydrogen bonds
- London dispersion forces

Aromatic rings containing an alkyl group have a _____ melting point than an aromatic ring with no substituents.

- higher
- lower ✔

If Chemical A has a melting point of 73°C and Chemical M has a melting point of 63°C, then the beginning point of the melting range of the mixture of Chemical A and Chemical M will be _____.

- above 73°C
- in between 63°C and 73°C
- below 63°C ✔

The polarity of 1-tetradecanol is more dominant than the molecular weight of tetracosane yielding a lower melting point for 1-tetradecanol.

- True
- False ✔

To accurately determine the melting point of a chemical, _____ of chemical should be included in the capillary tube.

- 3-5 mm
- 1-2 cm
- 1-2 mm ✔
- 1 cm

The melting point range of a chemical is the temperature range during which the chemical _____.

- begins to melt
- is completely melted
- begins to melt and is completely melted ✔
- None of the above

Compound A has a melting point of 18.7°C, Compound B has a melting point of 7.2°C. When the compounds are mixed together the eutectic temperature will be _____.

- above 18.7°C
- above 7.2°C
- below 7.2°C ✔
- between 7.2°C and 18.7°C

Extension Questions

Different crystalline forms of the same pure substance which have different arrangements and/or molecular conformations are known as polymorphs.Polymorphs of a compound can have different melting points due to the different arrangement of molecules creating a dissimilar crystal lattice. Typically, these polymorphs of a compound will have their own distinct melting points, solubilities, densities, dissolution rates and other physical properties.
Use the internet to research the melting points of the polymorphs of chocolate (cocoa butter). Write a brief synopsis of each polymorph of chocolate including its melting point and how it becomes a polymorph.

(SAMPLE ANSWER BELOW)

There are over six polymorphs of chocolate. Polymorph I has a melting point of 17.3°C and is produced when melting chocolate is rapidly cooled. Polymorph II has a melting point of 23.4°C and is produced by cooling melted chocolate at a rate of 2°C per minute. Polymorph III has a melting point of 25.5°C and is formed from the crystallization of the melted chocolate at 5-10°C. Polymorph IV has a melting point of 27°C and is a product of storing Polymorph III at 16-21°C. Polymorph V has a melting point of 33.8°C and is produced when chocolate is cooling and then slightly reheated and mixed causing a slow crystallization of the melt. Polymorph VI has a melting point of 36.3°C and is produced when Polymorph V is at room temperature for several months.

Michele has three samples of a mixture of pure benzoic acid and pure acetanilide and needs to determine the percent composition of each sample. List the steps that Michele would go through in order to determine the percent composition using the melting point.

(SAMPLE ANSWER BELOW)

Michele first needs to look up the known melting point of both benzoic acid (122.4°C) and acetanilide (114.3°C). Next, Michele should conduct a melting point experiment of each sample to determine the melting point range. Once the melting point range has been determined, she can plot the known melting points of benzoic acid and acetanilide, as well as the melting point range of each mixture sample including the eutectic temperature on the provided graph. After plotting the melting points Michele can analyze the melting point range from the eutectic temperature to the upper limits of the melting point range of each sample to determine if it follows that of benzoic acid or acetanilide and compare the results to the percent composition scale. Finally, Michele can draw the melting point curves for benzoic acid and acetanilide by connecting the melting point data points to a theoretical 50/50 percent composition eutectic temperature.