Freezing Point

Through various experiments, students will investigate the properties of water and find out what changes it from one state to another

Grade Level: 4th Grade

Phenomena:
How does water's chemical structure change from a liquid to solid?

Objectives:
- Students will state the temperature at which water freezes in both Fahrenheit and Celsius
- Students will explain why ice is less dense than water
- Students will evaluate environmental implications related to the density of ice.

Materials:
- Ice 4-5 pieces per student
- Frozen bottle or jug of water
- Clear plastic cups
- Activity sheet (page 7)

Time Considerations:
- Preparations: 20-25 min
- Activity 1: 5-7 min
- Activity 2: 5-7 min
- Activity 3: 10 min
- Activity 4: 15 min
- Activity 5: 10 min
- Activity 6: 10 min

Related Activities:
- Let it Snow! Let it Melt!

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Next Generation Science Standards

4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

Science and Engineering Practices (SEP):
Asking questions and defining problems.
Analyzing and interpreting data.

Disciplinary Core Ideas:
4-LS1 From Molecules to Organisms: Structures and Processes

Cross Cutting Concepts:
Energy and matter.
Stability and change.

Excellence in Environmental Education Guidelines

Strand 2.1— the Earth as a Physical System.

- **B) Changes in matter—** Learners are able to identify basic characteristics of and changes in matter. Describe objects in terms of the materials they are made of and their observable properties. Identify the effects of factors such as heating, cooling, and moisture on the properties of materials and how quickly change happens. For example, describe the change of water from solid to liquid to gas in the environment.

Background

Ice plays an important role in our everyday lives, especially during the long winter months in northern Nevada. We use it in our drinks, it forms on sidewalks, allows us to skate on lakes and can ruin our fruit. Understanding the properties of ice allows us to better understand how it can affect our daily lives.

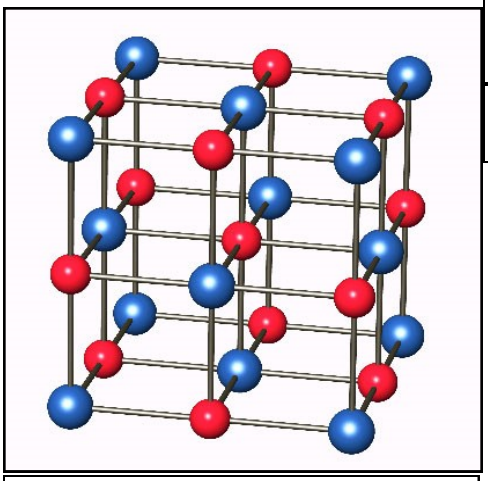
Like all substances, water can exist as a solid, liquid, or gas. Ice is the solid form of water while the term water vapor is used to describe its gaseous state. Water is unique because it can be observed as a solid, liquid, and gas within a relatively small temperature range. (0-100 °C)

When water cools to 0ºC (32ºF) It begins to solidify. This process is called freezing, so the temperature at which something changes from a liquid to a solid is called the freezing point. When ice warms up to 0ºC and begins to melt that temperature is called the melting point.

When many substances freeze the molecules pack together,

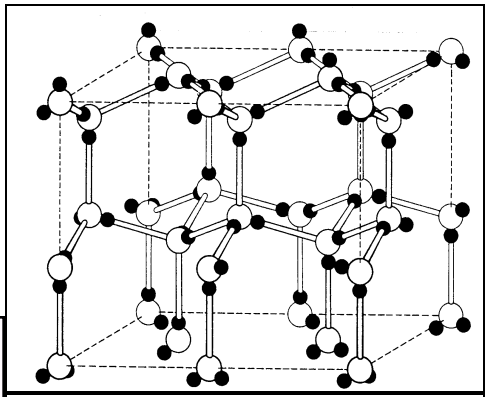
reducing the amount of empty space and making the solid form more dense than the liquid form. However, the shape of water molecules causes ice crystals to have more empty space than liquid water.

Water molecules consist of two hydrogen atoms bonded to a single oxygen atom. Due to electronic forces, the molecule is bent at an angle of 104.5º. It is this angle which allows for the expansion of ice. When water exists in the liquid form, the molecules are free to move around and bump together. When the freezing point of a substance is reached, molecules begin to form bonds with each other creating solid crystals. In water, a hydrogen bond forms between the hydrogen of one molecule and the oxygen of another. Since the molecules are bent, the forming of these bonds creates open space in the crystal causing the water to expand as molecules become fixed in place.



Atoms in a salt crystal are closely packed

A simple visual representation of this can be done using your fingers. Hold your thumb and forefinger into an 'L' shape, roughly modeling the water molecule and the angle. The tip of your thumb and finger are the hydrogen atoms while the skin between them represents the oxygen.



The structure of an ice crystal has more open space than a salt crystal.

In liquid water, the molecules are free to slide past each other. To model this, place the web between your thumb and forefinger nearly together and twist or slide your hands. In water, the molecules move close together like this, yet do not actually join together. This is due to the hydrogen bonds constantly being created and destroyed.

To model ice, connect your thumb or forefinger to the web of your other hand. With your hands connected this way, they take up much more space just like the molecules in ice.

Since water expands when it freezes, the density is affected. Density is the amount of space taken up by a set number of molecules. Density can be calculated using density =mass ÷ volume (or stuff ÷ space). When water freezes it takes up more space but no 'stuff' is added. This causes ice to have a lower density than liquid water so ice floats.

This reduced density has a profound effect on the environment. As water in lakes and ponds freeze, it floats to the surface and creates a layer of ice that insulates the rest of the pond. This prevents the pond from freezing solid and allows fish to swim around underneath.

Freezing the water contained in fruit can have drastic consequences. Plant cells are filled with liquid, but have a fixed volume. When the water in cells freezes it expands and breaks open the cells destroying the fruit. To prevent this from happening, farmers will spray their fruit with water in an extreme cold so the outside freezes. This creates an insulation so the temperature of the fruit will not fall below 32 degrees, even if the outside temperature keeps decreasing.

Since more than half of the human body is water, our cells can be damaged by the cold too. When human cells are damaged by freezing it is called frostbite and severe cases might require amputation to prevent infection.

Ice also is a huge factor in weathering and the deterioration

of roads. When snowmelt or runoff freezes on a roadway or in a rock, the water that is trapped in the cracks will expand, causing more cracking to occur. This process is called ice wedging.

Prior to the lesson, freeze a sealed plastic bottle or milk jug filled with water.

Preparation

Gather all lesson materials.

Introduction:

Begin the lesson by holding up a jug of water that has been frozen solid. Ask the students what they notice about the jug. (the sides are bulging or broken)

Doing the Activity

Ask the students why they think the sides of the jug are bulging. (Do not give answer, allow students just to brainstorm ideas). Explain that today we are going to learn about some unique properties of ice that explain what happened to the jug.

Activity 1: Ice brainstorm

Ask students to list some things they already know about ice. The following questions may be used to help guide discussion:

What is ice? *(the solid form of water)*

What are the other forms water can take? (*Liquid water, solid ice, gaseous water vapor)*

Where do we find ice in the world? *(glaciers, icecaps, arctic, Antarctica, your freezer, etc)*

What is the process by which water turns into a solid? *(freezing)*

At what temperature does this occur? *(32º For 0º C)*

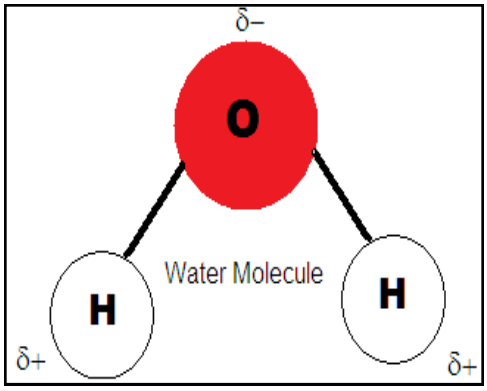
This temperature is called the **freezing point**, because it is the point at which liquid water turns into solid ice.

Activity 2: What is Water?

Before we can take a closer look at what happens when water freezes, we must understand water a bit more.

Ask the class what water is. (Water molecules, H_2O, hydrogen and oxygen)

Write H_2O on the board and ask



what it means. What does the 'H' stand for? The 'O'? What about the '2'? (2 hydrogen atoms and one oxygen atom) These are the parts of every water molecule.

Draw the molecule on the board, making sure you mark the angle.

Ask the students to hold up their thumb and forefinger in an 'L' shape. The tips of their thumb and finger represent the hydrogen and the web of skin between them represents the oxygen. The angle is about the same as a water molecule.

Demonstrate how the water molecules are arranged by interlocking your two 'molecules'.

In any liquid, the molecules move freely and bump into each other. (move your "molecules")

At the freezing point, the molecules slow down and bind together. In water, each hydrogen bonds with an oxygen. (stick one thumb to the web of your other hand)

Show the difference between ice and water a few times with your hands, having the students follow along. But don't mention that the ice has expanded.

Activity 3: What is Ice?

(NOTE: This activity builds off of the December mineral/crystal lesson for fourth grade).

Ask the students how many of them think ice is a mineral.

Ask the students what all minerals have in common and write these characteristics on the board:

- Non-living (inorganic)
- Naturally occurring

- Definite crystalline structure
- Definite chemical composition

With the students, compare each property to the properties of ice. (ice has all four properties)

Ask the students if water is a mineral and examine the list again. (no, liquid water doesn't have a crystalline structure)

Activity 4: Ice and Water Exploration

Tell the students that we are going to examine and compare ice and water.

Hand out one work sheet to each group (pg. 7) and let them take a minute to look it over.

Ask the students to write three characteristics of ice, water, or both. Each group should predict whether the ice will float and circle their hypothesis on the worksheet.

Discuss the results by having a student from each group tell you a similarity or difference between ice and water.

Ask the students whether they think the ice will sink or float and why.

Pass out cups of water and ice to groups.

Have students put their ice in the water. Did it float? Does it seem strange that a solid would float? What do other solids do when we place them in water? Why does ice float?

Activity 5: Why Ice Floats or Density

Ask the students why the ice is floating. (it is NOT lighter, it is **less dense** than the water)

Ask the students to hold up their hands showing the water molecule model, and transition from water to ice. Does anyone notice what is happening? (The ice is expanding, as it arranges itself in a crystalline structure). It is this expansion that makes the ice float.

Icebergs are huge pieces of ice that float in the ocean.

Ask students to stand up in a group and model water molecules with their bodies by putting their hands in the air and forming a V with their arms.

Their hands will be the hydrogen and their head is the oxygen.

Tell the students that the temperature is dropping to the freezing point and have them bond by placing one hand gently on a classmate's head without moving their arms.

Ask students to look at the amount of space their "ice" takes up. By placing their hand on a classmate's head, the students should have to spread out.

Emphasize that no "water" was added, but you are now taking up more space. What does that mean about the density? (it decreased/the ice is less dense)

Water expands as it freezes, so ice has a lower density and floats in water.

Other ways to describe density are:

- 7 people in a small car is dense, but only two in the same car is less dense.
- Oil in salad dressing is less dense than the water and floats on top.
- A suitcase that you need to sit on to zip is dense
- A golf ball is more dense than a ping pong ball
- Draw two equal size circles, one with many dots, the other with just a few. The circle with more dots is more dense.
- Examine density mathematically by using the

formula D=M/V. A smaller fraction means a smaller density.

Activity 6: Natural Implications

(This section can be optional, depending on time. It is interesting to show how this expanding ice can affect the real world).

Effect on fruit: Fruit can be severely affected by freezing. Has any one ever put an apple in the freezer? What do you think will happen to the apple when it thaws out? It will be mushy! This is because the cells that give the apple structure broke open when they froze. This is the same thing that occurs with frost bite

Bodies of water: imagine that ice did not float, now picture a pond that is freezing, how will that pond freeze? All the way through. Since ice floats, it allows aquatic organisms to

Oranges are very susceptible to ice damage due to their high water content.

swim freely under the ice. This is important to sustained life on earth.

Conclusion

Ask questions about water and its importance to life on earth:

- Why is water important to life?
- Is ice a mineral?
- Why does ice float?
- How does this affect our daily lives?

Assessment

Assess the students on their activity sheets, observations, and contributions to class discussion.

Extensions

Let students design and conduct their own experiment on ice. Have them write their hypothesis, materials, procedure, results, and conclusions.

Give students materials to create their own crystalline structure. After you have gone over the structure of ice, students should be able to build their own model.

Compare the density of other substances using a small clear container to layer liquids such as water, corn syrup, vegetable oil, rubbing alcohol etc.

- Compare the density of solids by placing them in a large container of water. (an old fish tank works well) Objects that are more dense than water usually sink while those that are less dense float.
- Determine whether sugar or aspartame is more dense by placing cans of Coke and Diet Coke in a large container of water.
- Calculate the density of objects in the classroom:
  - Fill a beaker, graduated cylinder, or measuring cup part way with water and note the volume.
  - Weigh the object
  - Place the object in the water and note what the new volume
  - The change in volume is volume of the object, so you can use D=M/V to calculate the density.

Vocabulary

Ice– Frozen Water

Freeze- Conversion from a liquid to a solid by losing heat. Water freezes at 0 degrees Celsius.

Melt- Conversion from a solid to liquid state due to the addition of heat

Inorganic- made of non-living materials that do not come from plants or animals

Crystal Structure- The spatial arrangement of atoms in crystals and most metals.

Freezing point- The temperature at which a liquid becomes a solid (The freezing point of water is 32 degrees Fahrenheit or 0 degrees Celsius).

Density- Mass of a unit volume of a substance. D=M/V

Sources

- Best, B. *Lessons for Cryonics from Metallurgy and Ceramics.* Ice crystal picture. Retrieved from http://www.benbest.com/cryonics/lessons.html.
- Frost damaged orange. Image retrieved from http://www.flickr.com/photos/23085117@N00/2641375916
- Iceberg photo. Retrieved from http://hyperphysics.phy-astr.gsu.edu/hbase/Chemical/chempic/iceberg.jpg
- Salt crystal Image retrieved from http://www.hull.ac.uk/chemistry/intro_inorganic/Chap5-2NaCl.htm

The *FREEZING* Point!

Frozen Explosion!

What caused the jug to bulge?

Ice	Ice and Water	Water

Water & Ice Experiments! **Prediction:** Will the ice float in the water? **YES NO**

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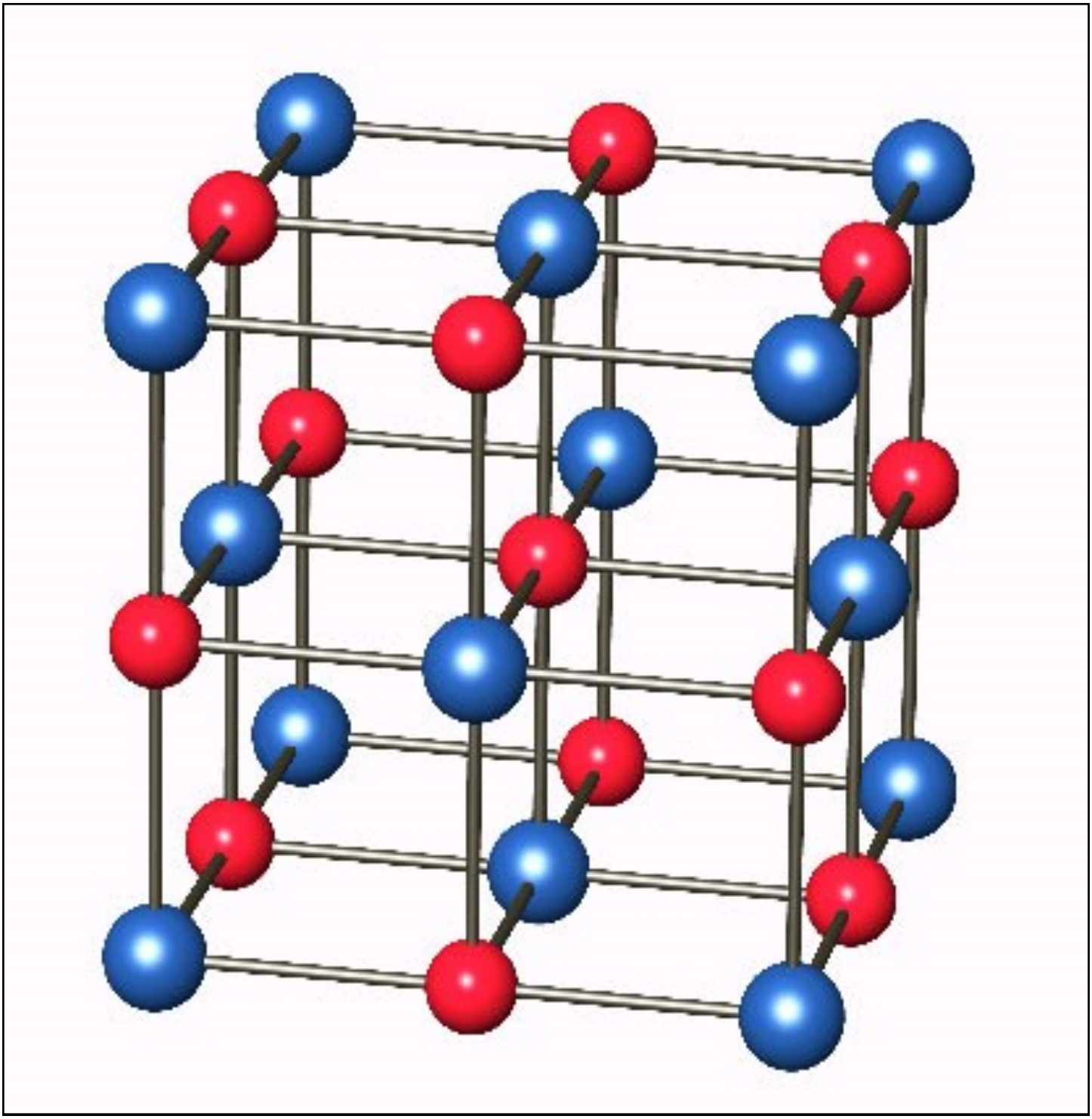

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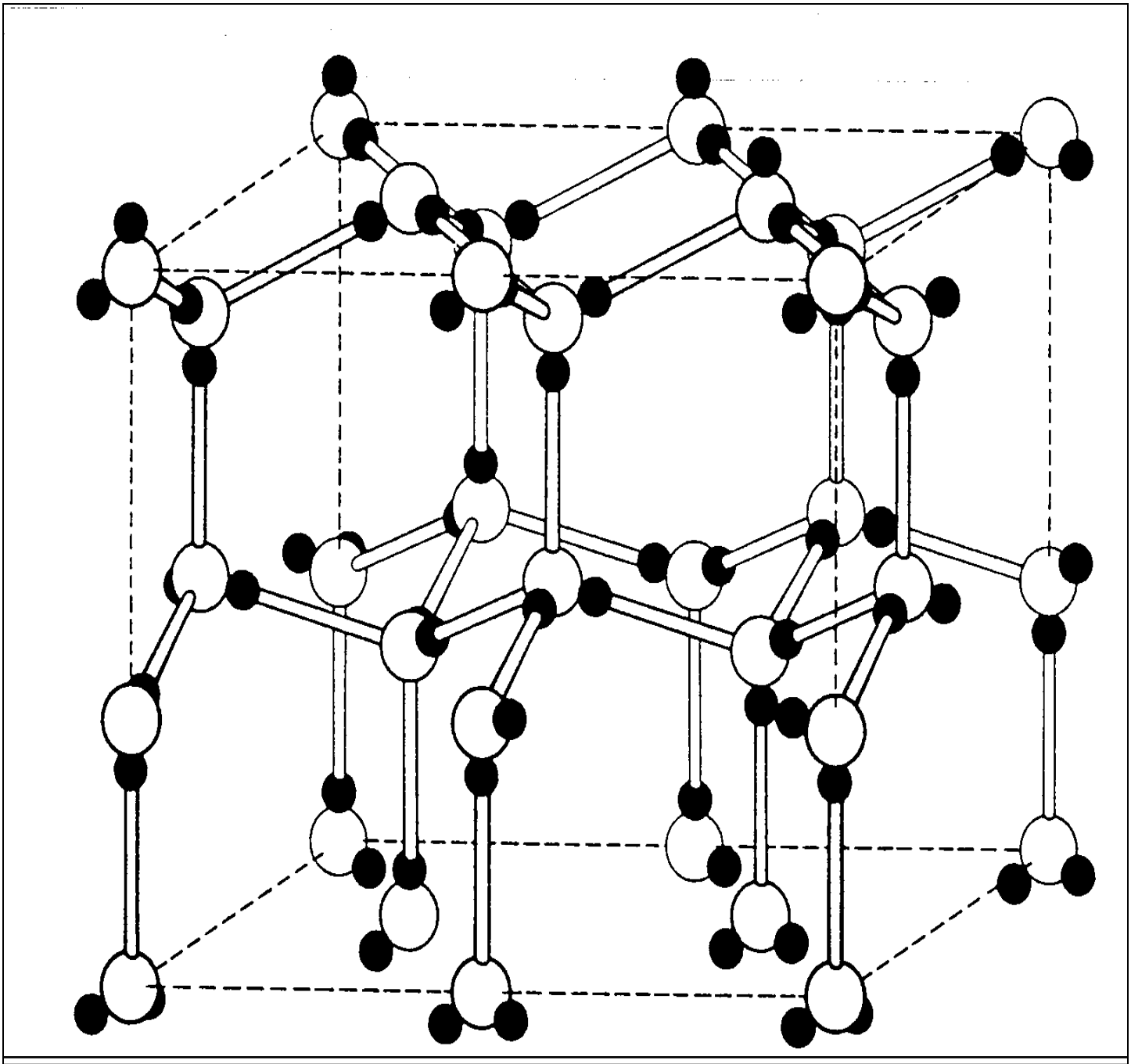

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