CHP#07

DENSITY AND TEMPERATURE

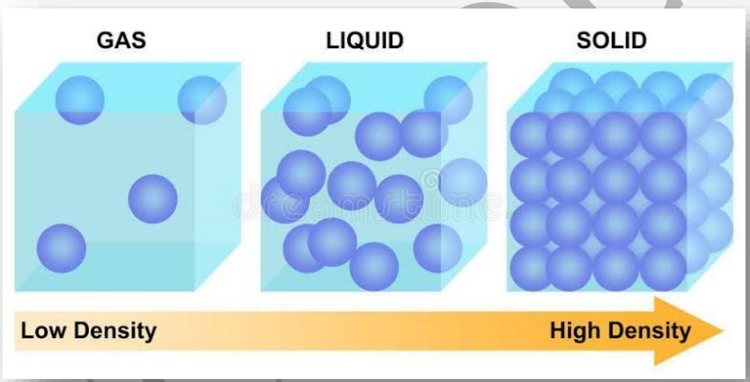
Q#01: Define density? Why are solids denser than liquids, and liquids denser than gases?

Ans:

Density:

Density is the measure of mass per unit volume of a substance.

The substance which has more closely packed atoms, has more matter in a fix volume. Therefore, it is dense substance. Solids like metals; rocks etc. are denser materials because they have closely packed atoms in the given volume. Substances in which atoms are far from each other, they have small amount of matter in a fix volume, so they are less dense. It is the reason why liquids and gases have less density than solids. In general density of solids is greater than liquids and density of liquids greater than gases.



Mathematically:

Density = Mass/Volume

$$\rho = \frac{m}{v}$$

Where

ρ is density.

M is mass.

V is volume.

Its SI unit is kilogram per cubic meter (Kg/m^3). Smaller unit to measure density is gram per cubic centimeter (g/cm^3). Density of liquids is usually measured in gram per millimeters (g/ml). It is scalar quantity.

Q#02: Describe methods to determine densities of regular and irregular shaped solids, liquids and gases.

Regular Shaped Solids:

Measurement:

- Measure the dimensions (length, width, height) of the solid using a ruler or caliper.
- Calculate the volume (V) using the appropriate formula (V = L × W × h) for a rectangular solid.
- Measure the mass (m) of the solid using a balance.

Calculation:

Calculate the density (ρ) using the formula $\rho = m/v$

Irregular Shaped Solids:

Measurement:

- Use a graduated cylinder partly filled with water. Note the initial water level.
- Carefully submerge the irregular solid in the water; the water level will rise.
- Record the new water level.
- The volume of the solid can be found from the difference in water levels.
- Measure the mass (m) of the solid using a balance.

Calculation:

Calculate the density using the formula($\rho = m/v$) , where (v) is the volume of the solid obtained from the water displacement.

Liquids:

Measurement:

- Use a graduated cylinder to measure the volume (V) of the liquid.
- Measure the mass (m) of an empty container and then again with the liquid using a balance.
- Subtract the mass of the empty container from the mass of the container with the liquid to find the mass of the liquid.

Calculation:

Calculate the density using the formula **($\rho = m/v$).**

Gases:

Measurement:

- Determine the volume (V) of the gas using a gas syringe or by filling a container of known volume.
- Measure the mass (m) of the gas by weighing the container with the gas inside.
- Subtract the mass of the container alone to find the mass of the gas.

Calculation:

Calculate the density using the formula ($\rho = m/v$).

Q#03: Distinguish between solids, liquids and gases.

Ans: Solids, liquids, and gases are the three primary states of matter, each with distinct characteristics:

Solids:

Shape and Volume: Solids have a definite shape and a fixed volume.

Particle Arrangement: Particles in solids are tightly packed in a regular, orderly arrangement.

Movement: Particles vibrate in place but do not move freely.

Compressibility: Solids are not easily compressible due to the close packing of particles.

Density: High density.

Examples: Ice, wood, metal.

Liquids:

Shape and Volume: Liquids have a definite volume but take the shape of their container.

Particle Arrangement: Particles are close together but not in a fixed arrangement.

Movement: Particles can move past each other, allowing liquids to flow.

Compressibility: Liquids are slightly compressible, but much less so than gases.

Density: Medium density.

Examples: Water, oil**,** alcohol**.**

Gases:

Shape and Volume: Gases have neither a definite shape nor a fixed volume. They expand to fill their container.

Particle Arrangement: Particles are far apart and randomly arranged.

Movement: Particles move freely and rapidly in all directions.

Compressibility: Gases are highly compressible due to the large amount of space between particles.

Density: Low density.

Examples: Oxygen, carbon dioxide, nitrogen.

The primary differences among these states are based on the arrangement and movement of their particles, which in turn affect their shape, volume, and compressibility.

Q#04: Does there exist a fourth state of matter? What is that and how it is formed?

Ans: Yes, there is a fourth state of matter called plasma. Plasma forms when a gas is heated to a very high temperature or exposed to a strong electrical or magnetic field. This energy causes the gas atoms to lose electrons, creating a mix of positively charged ions and free electrons.

Characteristics of Plasma:

Ionized Gas: Plasma is made up of charged particles, unlike a regular gas which is made of neutral atoms.

Conducts Electricity: Because it has free-moving charged particles, plasma can conduct electricity.

Responsive to Magnetic Fields: Plasma can be influenced by magnetic fields due to its charged particles.

Emits Light: Plasmas often glow and emit light, as seen in neon signs and lightning.

Formation of plasma:

Heating a Gas: Heating a gas continuously increases the kinetic energy of gas molecules, due to which attractive forces between molecules keep on decreasing. The molecules and atoms start colliding with each other and walls powerfully. Due to it electrons of atoms are removed and atoms become positive, turning the gas into plasma.

Example: The Sun is made of plasma because it is extremely hot.

Strong Electromagnetic Field: Applying a strong electrical or magnetic field can also ionize the gas and create plasma.

Example: Neon signs use electricity to ionize the gas inside them, making them glow.

Examples of Plasma:

Natural Plasmas: The Sun, stars, lightning, and the Northern and Southern Lights.

Man-made Plasmas: Fluorescent lights, neon signs, plasma TV screens, and plasma cutters.

Plasma is actually the most common state of matter in the universe because stars and much of space are made of it.

Q#05: How is the motion of particles related to the temperature of a substance and how is temperature related to the internal energy of a substance?

Ans: The motion of particles in a substance is directly related to its temperature. Here's how:

1. Kinetic Energy and Temperature: Temperature is a measure of the average kinetic energy of the particles in a substance. As the temperature increases, the average kinetic energy of the particles increases. This means that the particles move faster.

2. States of Matter:

Solids: particles are closely packed together and can only vibrate in place. As temperature increases, these vibrations become more energetic.

Liquids: particles have more freedom to move around compared to solids. With increasing temperature, the movement of these particles becomes more rapid.

Gases: particles are far apart and move freely. As the temperature rises, the speed of the gas particles increases significantly.

3. Thermal Expansion: When particles move faster due to an increase in temperature, they tend to take up more space. This is why most substances expand when heated.

4. Phase Changes: When a substance is heated to its melting point, the energy provided is used to overcome the forces holding the particles in a solid structure, leading to melting. When heated to its boiling point, the energy allows particles to break free from the liquid phase into the gas phase.

In summary, the temperature of a substance is a direct indicator of the kinetic energy and thus the motion of its particles. Higher temperatures correspond to greater particle motion and energy.

Temperature related to internal energy of substance:

Temperature is directly related to the internal energy of a substance. Internal energy includes both the kinetic and potential energy of the molecules. In gases, internal energy is mainly kinetic energy, which is proportional to temperature. In solids and liquids, internal energy includes both kinetic and potential energy. As temperature increases, the kinetic energy of molecules increases, raising the internal energy.

Q. What is Absolute Zero?

Ans. Absolute zero is the lowest possible temperature of a substance at which its particles have least kinetic energy. Its value is zero kelvin on kelvin scale, -273˚C on Celsius scales and -459.

Q#06: Describe two different physical properties that vary with temperature and explain how these properties can be used to measure temperature.

Ans:

<u>**Variation of volume and pressure**</u>:

Gas thermometers measure temperature by observing how gases behave when heated or cooled. There are two types: constant volume and constant pressure thermometers.

Constant Volume Thermometer: In this thermometer, the gas volume remains constant (Gay-Lussac's law). When the thermometer bulb is heated, the gas inside gains more kinetic energy. This makes the gas particles move faster and collide more frequently with each other and the container walls, causing an increase in pressure. This change in pressure indicates a change in temperature.

Constant Pressure Thermometer: Here, the pressure of the gas is kept constant (Charle's law). When the emperature rises, the gas inside the thermometer expands, pushing against a piston or exerting pressure on a fixed volume. The change in volume of the gas is then used to measure the temperature.

Both types of gas thermometers use these principles to accurately measure temperature based on the properties of gases under different conditions of pressure and volume.

Variation in color of crystals:

Liquid crystals are those materials that change colour with a change in temperature. Liquid crystals are packed inside a plastic strip. Liquid crystals are substances that change colour with a change in temperature. In these thermometers, a liquid crystal material is sealed in a plastic strip or patch. We touch it with the body whose temperature is to be measured. When its temperature changes, it also changes colour. By matching the colour to a temperature scale, we can determine the temperature of a body. These thermometers are often used as fever thermometers and for aquariums and baby bottles.

Resistance thermometer or thermistors:

It can measure temperature due to change in its resistance (change in opposition to flow of current through it) due to variation of its temperature.

Bimetallic strip thermometers:

It can measure temperature by variation in volume expansion of Thermocouple: It can measure temperature due to change in its emf produced due to variation in its temperature.

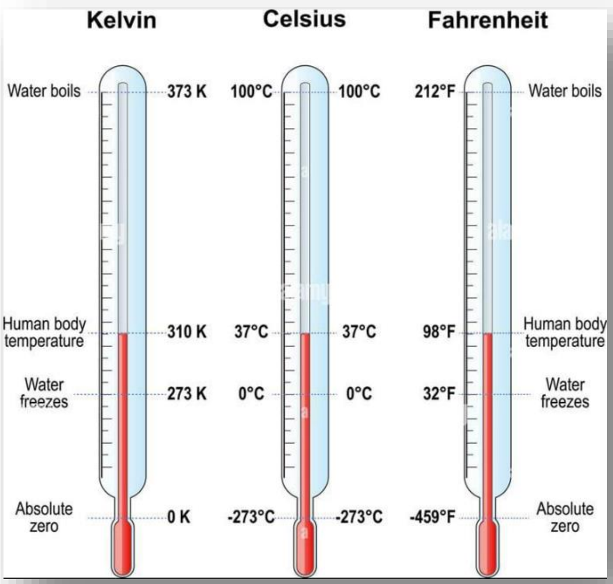
Q#07: What is lower and upper fixed points? Discuss different scales of temperature.

Ans:

Lower and upper fixed points:

A thermometer has a scale on its stem. This scale has two fixed points. The lower fixed point is marked to show the position of liquid in the thermometer when it is placed in ice. Similarly, upper fixed point is marked to show the position of liquid in the thermometer when it is placed in steam at standard pressure above boiling water.

Celsius (°C):



Introduction: The Celsius scale, also known as the centigrade scale, is commonly used worldwide, especially for everyday temperature measurements. It is defined by the freezing point of water at 0°C and the boiling point of water at 100°C at standard atmospheric pressure.

Usage: Widely used in most countries for weather forecasts, cooking, and scientific purposes.

Fahrenheit (°F):

Introduction: The Fahrenheit scale is primarily used in the United States and a few other countries. It sets the freezing point of water at 32°F and the boiling point at 212°F.

Usage: Commonly used for weather forecasts, household temperature measurements, and industrial applications.

Kelvin (K):

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Introduction: The Kelvin scale is the SI unit for temperature and is used mainly in scientific contexts. It is an absolute scale with its zero point at absolute zero, the theoretical lowest possible temperature where molecular motion stops. The freezing and boiling points of water are 273.15 K and 373.

Usage: The Kelvin scale is used primarily in scientific fields like physics and chemistry. It measures absolute temperature starting from absolute zero (-273.15°C). Kelvin is essential in thermodynamics, scientific research, and describing color temperature in lighting.

Q#08: Discuss the conversion of temperature from one scale to another.

Ans.

From Celsius to kelvin scale:

The temperature T on kelvin scale can be obtained by adding 273 in the temperature C on Celsius scale. Thus

$$T (k) = 273 + C$$

From kelvin to Celsius scale:

The temperature on Celsius scale can be found by subtracting 273 from temperature in kelvin scale. Thus

$$C = T (K) - 273$$

From Celsius to Fahrenheit scale:

Since 100 divisions on Celsius scale are equal to 180 divisions on Fahrenheit scale. Therefore, each division on Celsius scale is equal to 1.8 divisions on Fahrenheit scale. Moreover, 0°C corresponds to 32° F.

$$F = 1.8C + 32$$

Here F is the temperature on Fahrenheit scale and C is the temperature on Celsius scale.

Q#09. Calculate the temperature at which Fahrenheit and Celsius scales have same value.

Ans. We can solve this problem by solving for *x*:

°C = 5/9 * (°F - 32)
x = 5/9 * (x - 32)
x = (5/9)x - 17.778
1x - (5/9)x = -17.778
0.444x = -17.778
x = -40 degrees Celsius or Fahrenheit

Q#10: How do the sensitivity, range, and linearity of a thermometer impact its accuracy and suitability for different applications?

Ans: The sensitivity, range, and linearity of a thermometer are crucial factors that impact its accuracy and suitability for different applications. Here's a detailed explanation of how each factor plays a role:

Sensitivity:

Definition: Sensitivity refers to the ability of a thermometer to detect small changes in temperature. It is often expressed as the smallest temperature change that the thermometer can reliably detect.

Impact on Accuracy: High sensitivity means the thermometer can detect even minute changes in temperature, which is essential for applications requiring precise temperature control, such as in scientific research or certain industrial processes.

Suitability for Applications: High-sensitivity thermometers are ideal for laboratory experiments, medical diagnostics, and any application where small temperature fluctuations are significant. Conversely, low-sensitivity thermometers may suffice for general weather monitoring or household use.

Range:

Definition: The range of a thermometer is the span of temperatures over which it can accurately measure. This is typically specified by the minimum and maximum temperatures the device can record.

Impact on Accuracy: A thermometer needs to cover the expected temperature range of the application without sacrificing accuracy. A thermometer with a limited range might not be suitable for environments where temperatures fall outside its specified limits, leading to inaccurate readings or even damage to the thermometer.

Suitability for Applications: Different applications require different ranges. For example, industrial processes might need thermometers with ranges from extremely low (cryogenic) to very high (furnace temperatures). Medical thermometers, on the other hand, need a range that covers typical human body temperatures, while weather monitoring systems require a range that covers expected atmospheric temperatures.

Linearity:

Definition: Linearity refers to the degree to which the output of the thermometer is directly proportional to the temperature across its entire range. A linear thermometer will have a consistent and predictable response over its range.

Impact on Accuracy: Non-linear thermometers may provide accurate readings at certain points but can be inaccurate at others. Linearity ensures that the thermometer provides a consistent and reliable response throughout its range, which simplifies calibration and improves overall accuracy.

Suitability for Applications: Linearity is especially important in scientific and industrial applications where precise temperature measurements are critical. For less critical applications, slight non-linearity might be acceptable, provided the thermometer is calibrated accordingly and the non-linear behavior is well understood.

Q#11: What are the main components of a glass thermometer and thermocouple thermometer.

Ans:

Main Components of a Glass Thermometer:

Bulb: The reservoir at the bottom of the thermometer, usually filled with mercury or alcohol, which expands or contracts with temperature changes.

Capillary Tube: A narrow tube connected to the bulb through which the liquid expands or contracts. The liquid level in this tube indicates the temperature.

Scale: Markings on the glass tube or adjacent to it, calibrated to indicate temperature readings corresponding to the liquid level.

Glass Enclosure: The outer protective casing made of glass, which allows for clear visibility of the liquid level and protects the internal components.

Main Components of a Thermocouple Thermometer:

Thermocouple Junction: The point where two dissimilar metals (typically copper and constantan, or other combinations) are joined. This junction generates a voltage (thermoelectric EMF) that varies with temperature.

Lead Wires: Wires made of the same materials as the thermocouple metals, used to connect the thermocouple junction to the measuring instrument.

Reference Junction: A second junction maintained at a known temperature (often at 0°C or ambient temperature) to provide a reference point for the temperature difference measurement.

Measuring Instrument: Typically, a voltmeter or a digital thermometer that interprets the voltage generated by the thermocouple junction to provide a temperature reading.

Protective Sheath: An outer casing (often metal or ceramic) that protects the thermocouple junction and lead wires from environmental damage and contamination.

Q#12: Analyze how the structure of a liquid in glass thermometer can be modified to improve its performance. Give detail answer.

Ans: To make a liquid-in-glass thermometer work better, you can make a few changes:

Smaller Tube: Use a narrower tube where the liquid expands. This makes the thermometer more sensitive to temperature changes.

Consistent Tube Size: Keep the tube diameter the same throughout its length to ensure the thermometer reacts consistently to temperature changes.

High-Quality Glass: Use good-quality glass that doesn't expand much when heated, like borosilicate glass. This helps keep temperature readings accurate.

Tube Length: Choose the right length for the tube based on the temperature range you need to measure. Longer tubes can measure wider ranges, but shorter ones are more sensitive.

Liquid Choice: Pick the right liquid for the temperature range you're measuring. Mercury works well for higher temperatures, while alcohol-based liquids are good for lower ones.

Bulb Shape: Design the bulb where the liquid is housed carefully to improve how quickly and accurately the thermometer responds to temperature changes.

Accurate Calibration: Make sure the thermometer is calibrated correctly so it gives accurate temperature readings.

Protective Cover: Put a cover around the thermometer to keep it safe from damage and help it last longer.

These changes will help your thermometer give more precise temperature readings for different uses.

Conceptual Questions

Q#01: Two liquids A and B, have densities 1 g/mL and 1.2 g/mL respectively. When both liquids are poured into a container, one liquid floats on top of the other. Which liquid is on top, and why?

Ans: When liquids A and B, with densities of 1 g/mL and 1.2 g/mL respectively, are mixed in a container, liquid A floats on top of liquid B. This happens because liquid A has a lower density than liquid B. In liquids, less dense substances float on top of denser ones due to buoyancy.

Q#02: Write a method to find the volume and density of a human body?

Ans: To find the volume of a human body, submerge it in water to measure the displaced volume. Calculate the body's density by dividing its mass (measured on a scale) by its volume.

Q#03: How is plasma the fourth state of matter? Give a reason.

Ans: Plasma is the fourth state of matter because it is essentially a "soup" of free atoms and electrons, whereas the other three forms of normal matter (solids, liquids, and gases) consist of atoms with tightly associated electrons.

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Q#04: Why water is not used in liquid in glass thermometer.

Ans: Water cannot expand as much as mercury expands for a small rise in temperature. Water is not used in liquid-in-glass thermometers due to its limited temperature range (0°C to 100°C), which doesn't cover the broader range of temperatures thermometers often need to measure accurately. Water is not opaque and shining. Water sticks to the sides of the glass tube, so water is not used in thermometer.

Q#05: Can we increase internal energy of a substance without increasing its temperature?

Ans: Yes, it is possible to add heat to a substance without changing its temperature during the phase transition. Phase transition is the process in which a substance changes its physical state, such as from solid to liquid, liquid to gas, or vice versa, while the temperature remains constant.

Q#06: Why are fixed point scales required for thermometers? What difficulties are there when setting fixed points for thermometer scales?

Ans: Fixed point scales are important for thermometers because they set clear reference temperatures, like the freezing and boiling points of water, to make sure measurements are accurate and can be compared. It can be tricky to choose these points and make sure they stay stable over time and in different places. Getting everyone to agree on which points to use and making sure thermometers can measure them accurately are also challenges.

Q#07: Mercury is replaced with alcohol in liquid in glass thermometers. Discuss the possible change in sensitivity and range of thermometer?

Ans: Replacing mercury with alcohol in thermometers reduces sensitivity slightly and limits the temperature range to -115°C to 78°C, compared to mercury's broader range of -39°C to 357°C. Alcohol thermometers are safer but may be less accurate in stable conditions than mercury thermometers.

Q#08: Why-273.15°C temperature is called absolute zero? Can we achieve this temperature?

Ans: Absolute zero, at -273.15°C, is the lowest possible temperature where particle motion theoretically stops. Achieving it is extremely challenging and has not been done yet due to the laws of thermodynamics.

Q#09: Can we increase the sensitivity of a liquid-in-glass thermometer without changing its range?

Ans: To increase the sensitivity of a liquid-in-glass thermometer without changing its range, you can:

1. Use a smaller bulb.

2. Choose a liquid with a higher thermal expansion coefficient.

3. Use a thinner or longer capillary tube.

These adjustments make the thermometer react more sensitively to temperature changes while still measuring the same range of temperatures.

Q#10: Why are liquids denser than gases?

Ans: The molecules of a liquid are packed relatively close together. Consequently, liquids are much denser than gases.

Q#11: Density of material changes with the temperature. Can you explain why?

Ans: Heating a substance causes molecule to speed up and spread slightly further apart, occupying a larger volume that results in a decrease in density. Cooling a substance causes molecule to slow down and get slightly closer together, occupying a smaller volume that results in an increase in density.

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Assignment Questions:

1. An iceberg floats in seawater with only one-tenth of its volume above the surface. If the density of seawater is 1.025 g/cm³, calculate the density of the iceberg. (30.9225 g/cm³)

2. A solid cube of an unknown metal has a mass of 50 grams. When it is completely submerged in a liquid with a density of 0.8 g/cm³, the cube displaces a volume of liquid weighing 40 grams. Determine the density of the metal cube.(density of water = 1 g/cm³).(1 g/cm³)

3. A mixture consists of two liquids, A and B, with densities of 1.2 g/cm³ and 0.9 g/cm³ respectively. When 100 cm³ of liquid A is mixed with 150 cm³ of liquid B, the mixture has a density of 1.02 g/cm³. Justify the density of mixture to be 1.02 g/cm³.(1.02 g/cm³)

4. A container is filled with a mixture of solid iron balls and glycerin. The mass of the iron balls is 500 grams, and the mass of glycerin is 200 grams. The volume of the iron balls is 62.5 cm³, and the volume of the container with the mixture is 250 cm³. Calculate the density of the mixture. (Density of iron = 7.87 g/cm³, Density of glycerin = 1.26 g/cm³).(Density of iron = 8 g/cm³, Density of glycerin = 1.06 g/cm³).

5. Temperature of water in a beaker is 50°C. What is its value in Fahrenheit scale? (122 °F)

6. Normal human body temperature is 98.6°F. Convert it into Celsius scale and Kelvin scale. (37 °C, 310K)

7. Liquid oxygen freezes at -218.4°C and boils at -183.0°C. Express these temperatures on Fahrenheit scale

(-297 °F, -361.4 °F)