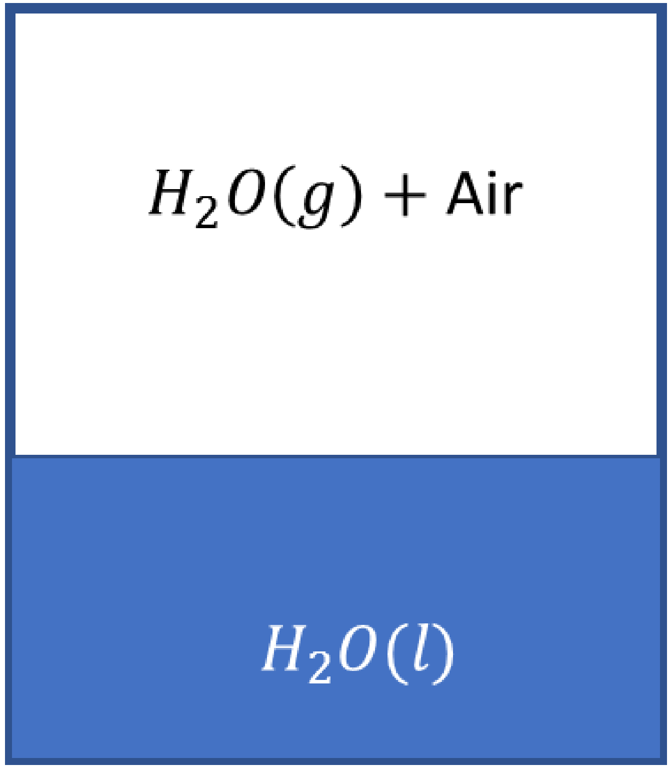
Learning Activities

Week 4

Question 1

(a) A system consists of liquid water in equilibrium with a gaseous mixture of air and water vapor. How many phases are present? Does the system consist of a pure substance? Explain.



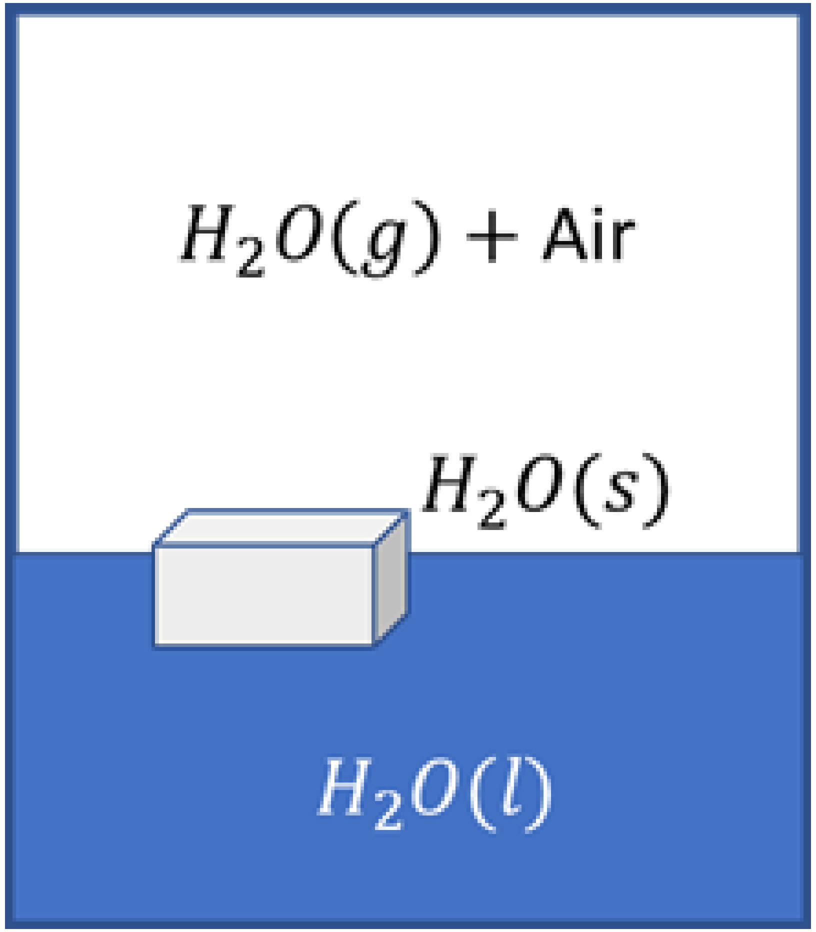
Answer 1

- The system described consists of liquid water in equilibrium with a gaseous mixture of air and water vapor. In this scenario, **there are two distinct phases present**: the liquid phase (liquid water) and the gas phase (mixture of air and water vapor).
- A pure substance in thermodynamics is defined as a substance that has a uniform and invariable chemical composition throughout. It can exist in different phases, but the chemical composition must be the same.
- In the case of the system mentioned, **it does not consist of a pure substance** because the gaseous phase is a mixture of **two different components**: air (which is itself a mixture of gases like nitrogen, oxygen, argon, etc.) and water vapor.
- While water in liquid and vapor phases would be considered a pure substance, the presence of air changes the chemical composition between the liquid and gas phases, hence it is not a pure substance system.
- This system can undergo various processes without losing its identity as a non-pure substance. For example, if some of the water vapor condenses into the liquid phase or if some of the liquid water evaporates into the vapor phase, the system still contains the same **two components (air and water) in two different phases**.

Question 2

(b) Repeat for a system consisting of ice and liquid water in equilibrium with a gaseous mixture of air and water vapor.

How many phases are present? Does the system consist of a pure substance? Explain.



Answer 2

- For a system consisting of ice and liquid water in equilibrium with a gaseous mixture of air and water vapor, there are **three phases present**: The solid phase (ice), the liquid phase (liquid water), and the gas phase (gaseous mixture of air and water vapor).
- The system does **not consist of a pure substance**. A pure substance is defined as a material with a uniform and unchanging composition.
- In the case of the given system, while the ice and liquid water could be considered a pure substance (both being H_2O), the inclusion of air in the mixture introduces other components.
- This means that there are multiple chemical substances present, thus **the system as a whole is not a pure substance**. The presence of air in the gas phase alters the chemical composition between the solid, liquid, and gas phases, preventing the system from being classified as a pure substance.

Question 3

- Atomic and molecular weights of some common substances are listed in the Table. Using data from the appropriate table, determine the mass, in kg, of 10 kmol of each of the following: air, H_2O, Cu, SO_2.
- Air is a mixture of gases, primarily nitrogen (N_2) and oxygen (O_2), along with small amounts of other gases. For most engineering calculations, air is considered as a mixture of 78% nitrogen and 21% oxygen by volume.

Atom	Atomic Mass (g/mol)
N (Nitrogen)	14.007
O (Oxygen)	15.999
H (Hydrogen)	1.008
Cu (Copper)	63.546
S (Sulfur)	32.065

Answer 3

- Air (average): 28.97 g/mol (Note: This is an approximation for dry air which is primarily a mixture of N_2 and O_2), H_2O: 18.015 g/mol, Cu: 63.546 g/mol and SO_2: 64.063 g/mol
- To convert the molecular masses to kilograms per kilomole, we use the fact that 1 g/mol is equivalent to 1 kg/kmol. So the mass of 10 kmol of each substance would be: Air: (28.97 kg/kmol)10 kmol = 289.7 kg, H2O: (18.015 kg/kmol)10 kmol = 180.15 kg, Cu: (63.546 kg/kmol)10 kmol = 635.46 kg SO_2 : (64.063 kg/kmol)10 kmol = 640.63 kg
- These calculations assume that the given molecular or atomic masses are correct and that "air" is treated as a single compound for this calculation, which in practice would usually mean considering dry air.

Question 4

Two temperature measurements are taken with a thermometer marked with the Celsius scale. Show that the difference between the two readings would be the same if the temperatures were converted to the Kelvin scale.

$$T_2(\circ C) - T_1(\circ C) = [T_2(\circ C) + 273.15] - [T_1(\circ C) + 273.15] = T_2(K) - T_1(K)$$

Question 5

A gas initially at P_1 = 1 bar and occupying a volume of 1 liter is compressed within a piston-cylinder assembly to a final pressure P_2 = 4 bar.

If the relationship between pressure and volume during the compression is PV = constant, determine the volume, in liters, at final pressure.

Answer 5

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

If the process is isothermic (PV = constant), then $T_1 = T_2$

$$\frac{P_1 V_1}{P_2} = V_2$$

V_2 = (1/4) L

Question 6

- The following table lists temperatures and specific volumes of water vapor at two pressures:

p = 1.0 MPa		p = 1.5 Mpa	
T (°C)	v (m^3/kg)	T (°C)	v (m^3/kg)
200	0.2060	200	0.1325
240	0.2275	240	0.1483
280	0.2480	280	0.1627

- Suppose ideal gas behavior.

- Using the data provided here, estimate:
- (a) the specific volume at T = 240 ºC, p = 1.25 MPa, in m^3/kg.
- (b) the temperature at p = 1.5 MPa, v = 0.1555 m^3/kg, in ºC.
- (c) the specific volume at T = 220 ºC, p = 1.4 MPa, in m^3/kg.