

**Self-Evaluation Before and After Facilitating Session.Topic:
Pure Substance - Part 2**

| Please use the following codes and please mark your selection. 1=- Strongly Disagree: 2=Disagree 3 = Unsure/Undecided 4=Agree 5 = Strongly Agree | | Pre | Post |
|--|---|-----|------|
| 1. | I have read the chapter before coming to the discussion session today. | 4.3 | 4.6 |
| 2. | I am able to state that a <u>system</u> is simply a space or mass that I choose to study. | 4.3 | 4.6 |
| 3. | I am aware that a process has taken place whenever there are changes in the system's properties such as changes in T, P, E, V or the mass, m. | 4.1 | 4.6 |
| 4. | I realize that intensive properties can easily be obtained by considering the system to have a mass of 1 kg. Hence, to obtain an intensive property, I will just divide all of the size-dependent extensive properties by the mass of the system. Examples are the specific internal energy, $u = U/m$, the specific total energy, $e = E/m$, the specific volume, $v = V/m$, the specific kinetic energy, $ke = KE/m$, the specific potential energy, $pe = PE/m$, and many more. <i>Notice that the intensive properties are represented by using lower case alphabets and the term "specific" is used to mean "for a unit mass (mass of 1 kg) of the system".</i> | 3.9 | 4.6 |
| 5. | I am aware that the common system involved in thermodynamics are the <u>pure substances</u> ; substances that have homogeneous chemical composition throughout. Examples include water, refrigerants used for cooling, nitrogen, helium, air in gaseous phase, a two-phase such as ice-water mixture and water-vapor mixture. Oil-water mixture is not a pure substance since the two substances do not mix homogeneously. | 4.3 | 4.7 |
| 6. | I realize that water can exist in the solid phase (ice), the liquid phase and the gaseous phase (vapor). | 4.3 | 4.7 |
| 7. | I realize that the solid-liquid mixture (ice-water mixture) and the liquid-gaseous mixture (water-vapor mixture) respectively can coexist in real life as exhibited by iced-tea (ice-water mixture at its melting point) that I always drink or the water that is boiling (liquid-vapor mixture at its boiling point). | 4.1 | 4.5 |
| 8. | I can sketch a temperature versus specific volume graph (T - v) for the phase change process of the ice that I had placed on the stove in my kitchen. Given a pressure of 101 kPa or atmospheric pressure, water begins to melt (ice changing to liquid) at 0°C and begins to boil (liquid begin to vaporize) at 100°C. The boiling temperature is known as the <u>saturation (boiling) temperature at 101 kPa</u> and is normally represented by $T = T_{sat@101kPa}$. | 3.8 | 4.4 |
| 9. | I know that the state at the start of boiling (phase change) is called the <u>saturated liquid (liquid ready to vaporize)</u> phase. The state at the end of boiling is called the <u>saturated vapor (vapor ready to condense)</u> phase and in between the two states where liquid and vapor coexist, it is called the <u>saturated liquid-vapor mixture or simply wet-mix phase</u> . The state where the temperature is below the boiling point is known as <u>compressed liquid (liquid not ready to vaporize)</u> phase while the state where the temperature is higher than the boiling point is referred to as <u>superheated vapor phase (vapor not ready to condense)</u> . | 4.0 | 4.6 |
| 10. | I am aware that the specific volume at the start of boiling (liquid starts to vaporize) <i>increases with an increase in pressure</i> while the specific volume at the <i>end of boiling (all the liquid turns into vapor) decreases with an increase in pressure</i> . The subscript <i>f</i> and subscript <i>g</i> is used to designate properties at the saturated liquid state and the saturated vapor respectively. For example, v_f and v_g are the specific volume for the saturated liquid and saturated | 4.0 | 4.4 |

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| | vapor respectively. Note that the phase change occur at the constant boiling (saturation) temperature. These values can be found in a <u>property table</u> such as given in Appendix A-5 in my Thermodynamics textbook. | | |
| 11. | I realize that as the pressure increases, the horizontal line connecting the saturated liquid and saturated vapor points gets shorter and eventually vanishes. The point where the line vanishes and the saturated liquid and saturated vapor point merges is called the <u>critical point</u> . This point has a pressure of $P_{cr} = 22.09 \text{ MPa}$ ($1 \text{ MPa} = 1000 \text{ kPa}$), a temperature of $T_{cr} = 374.14^\circ\text{C}$, and a specific volume of $v_{cr} = 0.003155 \text{ m}^3/\text{kg}$. Beyond this point there is no wet-mix phase, only the superheated vapor phase. | 3.9 | 4.4 |
| 12. | I realize that by drawing a line to connect the saturated liquid points and a line to connect the saturated vapor points through the critical point, for pressure lines at and below the critical pressure, I will see a dome being formed. States to the left of the saturated liquid line but below the critical temperature is compressed liquid, those within the line (underneath the dome) is wet-mix and the phase to the right of the saturated vapor line and also above the critical temperature is the superheated vapor phase. The $T - v$ diagram containing the saturated liquid and saturated vapor lines and the pressure lines is known as a property diagram. | 4.0 | 4.6 |
| 13. | I know that values for the saturation temperatures, saturated liquid volume, v_f and saturated vapor volume, v_g for any pure substances at any given pressure can be obtained from tables such as table A1 through A13 in the Yunus & Cengel Thermodynamics textbook. | 3.9 | 4.4 |
| 14. | Using table A-5 (saturated water-pressure table), for example, I found that water at a pressure of $P = 50 \text{ kPa}$ starts to boil at 81.33°C ($T_{\text{sat}@50 \text{ kPa}} = 81.33^\circ\text{C}$). The volume for the saturated liquid state is $v_f = 0.001030 \text{ m}^3/\text{kg}$ and the volume when all the water has turned into vapor (saturated vapor phase) is $v_g = 3.240 \text{ m}^3/\text{kg}$. Hence, if I had 1 kg of water at a temperature of 25°C , the water is in <u>compressed liquid phase</u> (since the given temperature, $T < T_{\text{sat}@50 \text{ kPa}}$) which means that its volume can be estimated to be $v = v_f@25^\circ\text{C}$ (read the temperature table A-4, $v_f@25^\circ\text{C}$) . It will start boiling if I can increase the temperature to the saturation temperature, 81.33°C . At this temperature, further addition of energy will force the water to begin vaporizing. The energy required to change 1 kg of water at its boiling point completely into vapor is called <u>specific latent heat of vaporization</u> . On the contrary, if the water temperature is given as 100°C , then the water is <u>superheated vapor because this temperature is bigger than the saturation (boiling) temperature at 50 kPa</u> ($T > T_{\text{sat}@50 \text{ kPa}}$). If this was the case, then the other properties for water at the given T and P , can be obtained by reading table A-6 (superheated water table). | 3.3 | 4.1 |
| 15. | I can sketch a pressure versus specific volume diagram ($P - v$) for the phase change process of water at room temperature $T = 25^\circ\text{C}$ and a room pressure of $P = 101 \text{ kPa}$. If the temperature remains constant, water in a container will start to boil at the <u>saturation (boiling) pressure</u> , $P_{\text{sat}@25^\circ\text{C}} = 3.169 \text{ kPa}$. Since the room pressure $P > P_{\text{sat}@25^\circ\text{C}}$, ($101 \text{ kPa} > 3.169 \text{ kPa}$), hence at room temperature and pressure, water is in a compressed liquid phase . Hence, to vaporize it, the pressure needs to be reduced to the boiling or saturation pressure. When the pressure is reduced lower than 3.169 kPa (sat.pressure), the water will be in the superheated vapor phase. | 3.3 | 4.2 |

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| 16. | The state at the end of boiling is called the <u>saturated vapor (vapor ready to condense)</u> phase and in between the two states where liquid and vapor coexist, it is called the <u>saturated liquid-vapor mixture or simply wet-mix phase</u> . The state where the <u>pressure is higher than the boiling point</u> is known as <u>compressed liquid (liquid not ready to vaporize)</u> phase while the state where the <u>pressure is lower than the boiling point</u> is referred to as <u>superheated vapor phase (vapor not ready to condense)</u> . | 3.8 | 4.4 |
| 17. | I am aware that the specific volume at the start of boiling (liquid starts to vaporize) increases with an increase in temperature while the specific volume at the end of boiling (all the liquid turns into vapor) decreases with an increase in temperature. | 3.8 | 4.3 |
| 18. | I realize that as the temperature increases, the horizontal line connecting the saturated liquid and saturated vapor gets shorter and eventually vanishes. The point where the line vanishes and the saturated liquid and saturated vapor point merges is called the <u>critical point</u> . This point has a pressure of $P_{cr} = 22.09$ MPa (1MPa = 1000 kPa), a temperature of $T_{cr} = 374.14^\circ\text{C}$, and a specific volume of $v_{cr} = 0.003155$ m ³ /kg. Beyond this point there is no wet-mix phase, only the superheated vapor phase. | 4.0 | 4.4 |
| 19. | I realize that by drawing a line to connect the saturated liquid points and a line to connect the saturated vapor points through the critical point, for temperature lines at and below the critical temperature, I will see a dome being formed. States to the left of the saturated liquid line but below the critical pressure is compressed liquid, those within the line (underneath the dome) is wet-mix and the phase to the right of the saturated vapor line and also above the critical pressure is the superheated vapor phase. The P - v diagram containing the saturated liquid and saturated vapor lines and the pressure lines is known as a property diagram. | 4.0 | 4.3 |
| 20. | I know that values for the saturation pressures, saturated liquid volume, v_f and saturated vapor volume, v_g for any pure substances at any given pressure can be obtained from tables such as table A1 through A13 in the Yunus & Cengel Thermodynamics textbook. | 3.9 | 4.5 |
| 21. | Using table A-4 (saturated water-temperature table), for example, I found that water at a temperature of $T = 50^\circ\text{C}$ starts to boil at 12.349 kPa ($P_{sat@50^\circ\text{C}} = 12.349$ kPa). The volume for the saturated liquid state is $v_f = 0.001012$ m ³ /kg and the volume when all the water has turned into vapor (saturated vapor phase) is $v_g = 12.03$ m ³ /kg. Hence, if I had 1 kg of water at $T = 50^\circ\text{C}$ and a pressure of $P = 50$ kPa, the water is in <u>compressed liquid phase</u> (since the given pressure, $P > P_{sat@50^\circ\text{C}}$) which means that its volume can be estimated to be $v = v_{f@50^\circ\text{C}}$ (read the temperature table A-4, $v_{f@50^\circ\text{C}}$) . It will start boiling if I can reduce the pressure to the saturation pressure, 12.349 kPa. At this pressure, water will vaporize. Further reduction in pressure will convert the wet-mix phase to superheated vapor. On the contrary, if the water pressure is given as 5 kPa and $T = 50^\circ\text{C}$, then the water is <u>superheated vapor because its pressure is smaller than the saturation pressure at 50°C ($P < P_{sat@50^\circ\text{C}}$)</u> . If this was the case, then the other properties for water at the given T and P, can be obtained by reading table A-6 (superheated water table). | 3.5 | 4.3 |
| 22. | I am aware that if I have determined the phase of a system as <u>compressed liquid</u> , than the specific properties such | 3.2 | 4.3 |

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| | as v , u , and h can be approximated to be $v_{f@T}$, $u_{f@T}$, and $h_{f@T}$. Hence, I need to refer to the <u>temperature table</u> to obtain the properties or values of v , u , and h . | | |
| 23. | I realize that if I have determined that the phase of my system as <u>superheated vapor</u> , than the specific properties such as v , u and h are $v_{@T,P}$, $u_{@T,P}$, and $h_{@T,P}$. Hence, I need to refer to the <u>superheated water or superheated refrigerant 134a table</u> to obtain the properties v , u and h . If the values cannot be read from the table directly but lies between two values, then I can approximate it to be between the two values or I can perform the interpolation technique to obtain the exact value. | 3.2 | 4.2 |
| 24. | I am able to define the term <u>quality</u> in the wet-mix phase as the ratio of the vapor mass to the system's total mass or mathematically represented as Quality, $x = (\text{mass of vapor} / \text{mass of system}) = \frac{m_g}{m} = \frac{m_g}{m_f + m_g}$. The more vapor in the wet mix phase, the higher the quality. The <u>highest value is one (saturated vapor)</u> if all the liquid has vaporized, hence $m_f = 0$ and $m_g = 1$, thus making $x = 1$. <u>The lowest value is zero (saturated liquid)</u> since at this state, $m_g = 0$, ($m_f = 1$) hence $x = 0$. Values of x along the saturated liquid line and saturated vapor line on the property diagrams are 0 and 1 respectively. In the wet-mix phase, $0 < x < 1$, and <u>quality is not defined in any other phases</u> . | 3.4 | 4.0 |
| 25. | I realize that for a wet-mix phase, the temperature for any given pressure or the pressure for any given temperature, are the saturation temperature and saturation pressure respectively. I also realize that properties such as v , u and h must have values lower than that of the saturated vapor value but higher than the saturated liquid value. If I use the symbol y to represent properties such as v , u or h , then $y_f < y < y_g$ in the wet mix phase. | 3.5 | 4.3 |
| 26. | I can derive the average value of y in the wet-mix phase by doing the following. Consider a tank of total volume V containing a mixture of liquid (mass is m_f) and vapor (mass is m_g) of total mass, m , I can write $V = V_f + V_g$. Replacing the total volume by the specific volume, $m v_{avg} = m_f v_f + m_g v_g$. Dividing both sides by the total mass, m , then $v_{avg} = \frac{m_f v_f + m_g v_g}{m} = \frac{m_f}{m} v_f + \frac{m_g}{m} v_g$. Realize that $m = m_f + m_g$, hence by replacing m_f by $m - m_g$, and recalling that $x = \frac{m_g}{m}$, then $v_{avg} = \left(\frac{m - m_g}{m}\right) v_f + \frac{m_g}{m} v_g = \left(\frac{m}{m} - \frac{m_g}{m}\right) v_f + x v_g$ Canceling the masses and replacing the mass ratios with the quality, then, $v_{avg} = (1 - x) v_f + x v_g = v_f - x v_f + x v_g = v_f + x(v_g - v_f) = v_f + x v_{fg}$ The expression $x v_{fg}$ is often written in place of $x(v_g - v_f)$. In the wet-mix phase, it is understood that the property y is an average value, hence $y = y_f + x(y_g - y_f) = y_f + x y_{fg}$ and this expression is ONLY VALID while the system is <u>boiling</u> . At the <u>saturated liquid and saturated vapor line, $y = y_f$ and y_g respectively since $x = 0$ and $x = 1$</u> | 3.2 | 4.2 |

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| | respectively. Note that the term y_{fg} means $y_g - y_f$. | | |
| 27. | I am able to read the property table in the textbook such as table A-4 and A-5 to determine the saturation pressures, $P_{sat@T}$, or temperatures, $T_{sat@P}$, the saturated liquid properties, y_f , the saturated vapor properties, y_g and the property, y , (superheated vapor in table A-6 or compressed liquid phase) for any pressure or temperature that I know. In addition, I can determine the phase of the system once I have 2 independent intensive properties (such as T , v , or T , P) and to mark the phase of the system on a $T - v$ or $P - v$ diagram with respect to the saturation lines (the dome) that I have sketched. | 3.5 | 4.4 |
| 28. | I am able to determine the phase of a system if I know the state of the system. For example if the temperature of refrigerant-134a in a tank is 0°C , and the quality of the system is 0.2000, then the <u>phase is wet-mix since the quality is $0 < x < 1$</u> . Then the system's pressure must be the saturation (boiling) pressure since the system is in a wet-mix phase (boiling). The other properties are determined by using the expression $y = y_f + xy_{fg}$. The volume, $v = v_f + xv_{fg} = 0.014552 \text{ m}^3/\text{kg}$ (use values from table A-11), will be used as one of the property to determine the final state of the system since a <u>rigid tank means no change in volume</u> (and hence the specific volume since the mass remains constant for closed systems). Thus if the system's temperature is increased to 20°C , then the phase for the final state ($T = 20^\circ\text{C}$, $v = 0.014552 \text{ m}^3/\text{kg}$) is determined by comparing $v = 0.014552 \text{ m}^3/\text{kg}$ to the saturated liquid volume, v_f , and the saturated vapor volume, v_g , at $T = 20^\circ\text{C}$. Since $v_f < v < v_g$, at $T = 20^\circ\text{C}$ (read Table A-11), then the final state is still wet-mix phase. Hence the pressure is the saturation (boiling) pressure at 20°C ($P = P_{sat@20^\circ\text{C}}$). Before other properties such as u and h can be determined using the expression $y = y_f + xy_{fg}$, the quality for this final phase must be calculated. Note that v_f and v_g which are used must be the values read at $T = 20^\circ\text{C}$. It can be shown that the quality is $x = \left[\frac{v - v_f}{v_g - v_f} \right]_{@20^\circ\text{C}} = 0.3926$. It can be shown that if the initial state had a quality of 0.8, then the final state when the temperature is increased to, 20°C will be superheated vapor since $v > v_g$. Hence use table A-13 to determine u and h . | 3.2 | 4.3 |
| 29. | I know that when my system is not water and refrigerant-134a but is a gas such as air, nitrogen or carbon dioxide, I need to determine if these real gases behave like ideal gases. | 3.4 | 4.1 |
| 30. | I am aware that the properties of ideal gases are related by the <u>ideal gas equation of state</u> . The need to know this relation is significant since not all property tables such as A-4, A-5 and A-6 can be made available for all known pure substances. | 3.8 | 4.3 |
| 31. | I can write the ideal gas equation of state as $Pv = RT$ where R is the <u>gas constant</u> in units of $\text{kJ}/\text{kg}\cdot\text{K}$, and T is the <u>absolute temperature</u> for the gas measured in units of Kelvin. | 3.9 | 4.3 |
| 32. | I realize that I can also rewrite the ideal gas equation in terms of the total volume , V , and the mass of the gas , | 3.5 | 4.1 |

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| | <p><i>m</i>. Since the total volume is $V = m v$ and by replacing the specific volume, $v = \frac{V}{m}$, the ideal gas equation is $\frac{PV}{m} = RT$ or $PV = mRT$. Note that the units are kilojoule on both sides where $1 \text{ kJ} = 1 \text{ kPa m}^3$. The expression can also be written in term of the number of kilomoles of the gas. The mass of the gas, $m = MN$ where M is the molar mass in units of kg/kmol and N is the number of kilomoles in units of kmol. Writing the gas constant, R in terms of the universal gas constant $R_u = \frac{R}{M} = 8.314 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}}$, then the ideal gas equation is $PV = \frac{MNR_u T}{M}$ which is $PV = NR_u T$.</p> | | |
| 33. | <p>I know that in order for real gases to behave like ideal gases, the gas must have <u>low density</u> (low mass to volume ratio). In other words, the pressure must be much lower than the critical pressure ($P \ll P_{cr}$) and the temperature must be higher than the critical temperature ($T \gg T_{cr}$). If these 2 conditions are met, then the real gases can be treated as ideal gases since its density is low and the gas molecules are very far apart from each other. Hence it obeys the ideal gas equation of state : $PV = NR_u T$ or $PV = mRT$ or $Pv = RT$. Note that T is the absolute temperature measured in Kelvin. The typical values of R, T_{cr} and P_{cr} for some gases can be read from Table A-1 in the appendix of Cengel & Yunus Thermodynamics textbook.</p> | 3.3 | 4.0 |