## ENV 407 - Atmospheric Processes: from Clouds to Global Scales

## Worksheet – Moist processes in the atmosphere

1. The enthalpy of a water cloud is

$$dH = \left(m_d c_{pd} + \cancel{m_v c_{pv}} + \cancel{m_l c_l}\right) dT + L_{lv}\, dn_v$$

where the subscripts d, v, and l refer to dry air, water vapor and liquid water, respectively. Which terms in the parentheses are usually neglected and why?

$m_v c_{pv}$, $m_\ell c_\ell$ because Their contribution to H is low (small v, l)

2. During the isobaric cooling of unsaturated air, the relative humidity $\mathcal{H}$ (increases, decreases, remains the same).

3. During the isobaric cooling of saturated air, the relative humidity $\mathcal{H}$ (increases, decreases, remains the same).

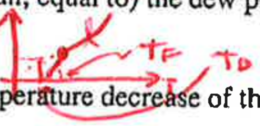
$\mathcal{H} = 1$ when saturated.

4. As the dew point depression decreases, $\mathcal{H}$ (increases, decreases, remains the same)

$T - T_D \downarrow \Rightarrow T$ becomes closer to $T_D$, i.e. closer to saturation (higher humidity)

5. The frost point temperature is (greater than, less than, equal to) the dew point temperature

from phase diag.:




6. During the isobaric cooling of saturated air the temperature decrease of the air is proportional to the cooling (true, false)

7. During reversible condensation (i.e. no water falls out), which of the following is true

a) $dw_l < -dw_s$

b) $dw_l = -dw_s$

c) $dw_l > -dw_s$

$W_v = W_s$ when saturated (condensation happens)

So $W_t = \text{const} \Rightarrow W_v + W_\ell = \text{const} \Rightarrow dW_\ell = -dW_v = -dw_s$

8. The wet bulb temperature is (greater, less) the (physical) temperature

9. The wet bulb temperature is (greater, less) than the dew point temperature.

10. What is the temperature of a rain drop falling through an unsaturated layer

a) T, the temperature of the air

b) $T_w$, wet bulb temperature

c) $T_d$, dew point temperature

d) none of the above

For a pressure of 1000 hPa, determine the following. You may use the attached $e_s$ table.

Given:

11. $w_s = 5\ \text{g kg}^{-1}$, find $T$

$$W_s = \varepsilon \frac{P_s}{P} = 0.62 \frac{P_s}{1000} \Rightarrow P_s = \frac{W_s}{0.62} 1000 \ (\text{hPa}) = \frac{0.005}{0.62} 1000 = 8.065 \ \text{hPa}$$

kg/kg

$T \simeq 4°C$

12. $T = 25°C$, find $w_s$

$P_s$ @ 25°C (hPa)

$$w_s = \varepsilon \frac{P_s}{P} = 0.62 \frac{31.68}{1000} = 0.0196 \text{ kg/kg} = 19.6 \text{ g/kg}$$

13. $T = 30°C$ and $w = 15$ g/kg, find $\mathcal{H}$

$$\mathcal{H} = \frac{w_v}{w_s} = \frac{15 \times 10^{-3} \text{ kg/kg}}{w_s} =$$

$$\boxed{w_s(30°C) = \varepsilon \frac{P_s(30°C)}{P} = 0.62 \frac{42.42}{1000} = 26.3 \times 10^{-3} \text{ kg/kg}}$$

$$= \frac{15}{26.3} = 0.57 \text{ or } 57\%$$

14. $T = 20°C$ and $T_D = 15$, find $\mathcal{H}$

$$\mathcal{H} = \frac{P_v}{P_s} = \frac{P_s(T_D)}{P_s(20°C)} = \frac{17.042}{23.371} = 0.729 \text{ or } 72.9\%$$

15. $T = 15°C$ and $\mathcal{H} = 0.8$, find $T_D$

$$\mathcal{H} = 0.8 = \frac{P_v}{P_s} \Rightarrow P_v = 0.8 P_s(15°C) = 0.8 \times 17.042 = 13.634 \text{ hPa}$$

from table

So $T_D$ is when $13.634 \equiv P_s \Rightarrow T_D \simeq 11.5°C$

16. $w = 20$ g/kg, find $T_D$

$$w = \varepsilon \frac{P_v}{P} \Rightarrow P_v = \frac{w_v}{\varepsilon} P = \frac{20 \times 10^{-3}}{0.62} \times 10^3 = 32.25 \text{ hPa}$$

then $T_D$ (from table) $= 25.5°C$

17. $T_F = -10°C$, find $T_D$

Saturation vapor pressure over ice @ −10°C

$T_F = -10°C \Rightarrow P_v = 2.597$ hPa, So from tables, That $P_v$ corresponds to saturated vapor over liquid at −11.5°C

So $T_D = -11.5°C$.

## Appendix D | Saturation Pressures over Pure Liquid Water and Pure Ice as a Function of Temperature

liquid ice

| T (°C) | $P_v^*$ (hPa) | $P_{v,i}^*$ (hPa) | T | $P_v^*$ | $P_{v,i}^*$ | T | $P_v^*$ | T | $P_v^*$ |
|---|---|---|---|---|---|---|---|---|---|
| -50 | 0.0635 | 0.0393 | -24 | 0.8826 | 0.6983 | 1 | 6.565 | 26 | 33.606 |
| -49 | 0.0712 | 0.0445 | -23 | 0.9647 | 0.7708 | 2 | 7.054 | 27 | 35.646 |
| -48 | 0.0797 | 0.0502 | -22 | 1.0536 | 0.8501 | 3 | 7.574 | 28 | 37.793 |
| -47 | 0.0892 | 0.0567 | -21 | 1.1498 | 0.9366 | 4 | 8.128 | 29 | 40.052 |
| -46 | 0.0996 | 0.0639 | -20 | 1.2538 | 1.032 | 5 | 8.718 | 30 | 42.427 |
| -45 | 0.1111 | 0.0720 | -19 | 1.3661 | 1.135 | 6 | 9.345 | 31 | 44.924 |
| -44 | 0.1230 | 0.0810 | -18 | 1.4874 | 1.248 | 7 | 10.012 | 32 | 47.548 |
| -43 | 0.1379 | 0.0910 | -17 | 1.6183 | 1.371 | 8 | 10.720 | 33 | 50.303 |
| -42 | 0.1533 | 0.1021 | -16 | 1.7594 | 1.505 | 9 | 11.473 | 34 | 53.197 |
| -41 | 0.1704 | 0.1145 | -15 | 1.9114 | 1.651 | 10 | 12.271 | 35 | 56.233 |
| -40 | 0.1891 | 0.1283 | -14 | 2.0751 | 1.810 | 11 | 13.118 | 36 | 59.418 |
| -39 | 0.2097 | 0.1436 | -13 | 2.2512 | 1.983 | 12 | 14.016 | 37 | 62.759 |
| -38 | 0.2322 | 0.1606 | -12 | 2.4405 | 2.171 | 13 | 14.967 | 38 | 66.260 |
| -37 | 0.2570 | 0.1794 | -11 | 2.6438 | 2.375 | 14 | 15.975 | 39 | 69.930 |



| T (°C) | $P_v^*$ (hPa) | $P_{v,i}^*$ (hPa) | T | $P_v^*$ | $P_{v,i}^*$ | T | $P_v^*$ | T | $P_v^*$ |
|---|---|---|---|---|---|---|---|---|---|
| -36 | 0.2841 | 0.2002 | -10 | 2.8622 | 2.597 | 15 | 17.042 | 40 | 73.773 |
| -35 | 0.3138 | 0.2232 | -9 | 3.0965 | 2.837 | 16 | 18.171 | 41 | 77.798 |
| -34 | 0.3463 | 0.2487 | -8 | 3.3478 | 3.097 | 17 | 19.365 | 42 | 82.011 |
| -33 | 0.3817 | 0.2768 | -7 | 3.6171 | 3.379 | 18 | 20.628 | 43 | 86.419 |
| -32 | 0.4204 | 0.3078 | -6 | 3.9055 | 3.684 | 19 | 21.962 | 44 | 91.029 |
| -31 | 0.4627 | 0.3420 | -5 | 4.2142 | 4.014 | 20 | 23.371 | 45 | 95.850 |
| -30 | 0.5087 | 0.3797 | -4 | 4.5444 | 4.371 | 21 | 24.858 | 46 | 100.89 |
| -29 | 0.5588 | 0.4212 | -3 | 4.8974 | 4.756 | 22 | 26.428 | 47 | 106.15 |
| -28 | 0.6133 | 0.4668 | -2 | 5.2745 | 5.173 | 23 | 28.083 | 48 | 111.65 |
| -27 | 0.6726 | 0.5169 | -1 | 5.6772 | 5.622 | 24 | 29.829 | 49 | 117.40 |
| -26 | 0.7369 | 0.5719 | 0 | 6.1070 | 6.106 | 25 | 31.668 | 50 | 123.39 |
| -25 | 0.8068 | 0.6322 | | | | | | | |