**CHEM 1032 – Spring 2023 - Challenge Question 2 - key**

# Why does humidity feel different in the winter?

A. During the winter, frost tends to form overnight. List the common atmospheric gases and justify why frost is most likely made of water. Suggest what phase transformation(s) could form frost.

- The common atmospheric gases are $N_2$, $O_2$, Ar, $CO_2$, and $H_2O$.
- Since these are all gases, one of them would need change phase in order to become dew/frost. The one with the strongest intermolecular forces would be able to do this most easily because when numerous molecules are attracted to one another they form condensed matter. Based on the molecular structures, all of the molecules except $H_2O$ only have dispersion forces, since $H_2O$ has dispersion, dipole-dipole, and hydrogen bonding it will form condensed matter easiest (i.e. at warmer temperatures than the others).
- For solid water to form it would either need to (1) deposit, turning into a solid directly or (2) condense into liquid water and then freeze into solid water.

B. Explain why the maximum vapor pressures and enthalpies of vaporization are different for the afternoon high temperatures in the winter versus the summer in Philadelphia.

| | Winter High | Summer High |
|---|---|---|
| Temperature | 41 °F | 87 °F |
| Vapor Pressure | 6.5 mmHg | 31.8 mmHg |
| Enthalpy of Vaporization | 44.8 kJ/mol | 43.7 kJ/mol |

- Vapor pressure represents the maximum amount of water that can be held in the gas phase. At high temperatures, molecules have more energy, so they are able to escape the attractions which would hold them together. Whereas at low temperatures, the speed is slower, so intermolecular forces will pull molecules together, causing them to condense. So the maximum amount of water in the air, or the vapor pressure, is much higher in the summer versus the winter.
- Enthalpy of vaporization represents the energy required to transform 1 mole of molecules from liquid into a gas. The enthalpy of vaporization values are more similar to one another than the vapor pressure. This is because at both temperatures, the molecules are being transformed from a liquid to a gas, so a large amount of energy is needed to spread apart the molecules. The reason why the value is slightly smaller at the higher temperature is because the molecules are already moving around faster (Higher T, more KE), thus it takes a little less energy to spread apart he molecules at high temp.

C. Humidity is the percentage of partial pressure of water in air over the total possible water in the air. On the first day of the spring semester the humidity was 72%, but it did not feel humid outside. Calculate the partial pressure of water in air at this time and justify why it did not feel humid. *You may find it helpful to compare the first day of the spring semester to the first day of the fall semester, where the humidity was 89% on the first day of class.*

$$\text{Percentage} = \frac{\text{part}}{\text{whole}} \times 100$$

$$\text{Humidity Percentage} = \frac{\text{partial pressure of } H_2O}{\text{maximum } H_2O \text{ in air}}$$

this is the vapor pressure, which we know varies w/ T

First day of Spring Semester
(January ∴ winter)

$$72\% = \frac{x}{6.5 \text{ mmHg}} \times 100$$

$$x = 4.68 \text{ mmHg}$$

First Day of Fall Semester
(August ∴ Summer)

$$89\% = \frac{x}{31.8 \text{ mmHg}} \times 100$$

$$x = 28.3 \text{ mmHg}$$

Though the % humidity is simillar on both days, the max amount of water is way <u>less</u> in the winter. Therefore the actual amount based on the % is much smaller, 4.68 mmHg vs 28.3 mmHg. The less water in the air the less humid it feels.

D. Much of the humidity in the air comes from vaporization from large bodies of water, like the Schuylkill and Delaware Rivers. Assuming the area of Temple's main campus is $4.1 \times 10^3$ $m^2$ and the height of the campus is 89.1 m (top of Morgan Hall), calculate the energy needed to reach 72% humidity by vaporizing water from the rivers at the winter high temperature. *(For the sake of this exercise, assume ideal gas applies.)*

When we determine energy needed to vaporize we use $\Delta H_{vap}$ (kJ/mol) to see how much energy is needed for a specific amount of moles...

$$\underline{\quad\quad} \text{ moles } H_2O \left| \frac{44.8 \text{ kJ}}{1 \text{ mole } H_2O} \right. = \underline{\quad\quad} \text{ kJ}$$

we need this value!

The question says to assume ideal gas law applies...

$$PV = nRT$$

from Part C
4.68 mmHg → $6.2 \times 10^{-3}$ atm

We're provided with area ($m^2$) and height (m), $m^2 \cdot m = m^3$ (volume)

what we're looking for

0.0821 $\frac{L \cdot atm}{mol \cdot K}$

winter high temp
41°F → 5°C → 278 K

$$3.65 \times 10^5 \text{ m}^3 \left| \frac{100^3 \text{ cm}^3}{1 \text{ m}^3} \right| \frac{1 \text{ mL}}{1 \text{ cm}^3} \left| \frac{1 \text{ L}}{1000 \text{ mL}} \right. = 3.65 \times 10^8 \text{ L}$$

$$(6.2 \times 10^{-3} \text{ atm})(3.65 \times 10^8 \text{ L}) = n \left(0.0821 \frac{L \cdot atm}{mol \cdot K}\right)(278 \text{ K})$$

$$n = 9.92 \times 10^4 \text{ moles } H_2O$$

$$9.92 \times 10^4 \text{ moles} \left| \frac{44.8 \text{ kJ}}{1 \text{ mole}} \right. = 4.44 \times 10^6 \text{ kJ}$$

E. Imagine you are exercising at one of the campus gyms, you work up a sweat and exit the gym area into a hallway. As you may experience, a person who is sweating in a humid area will feel very cold when they go to a non-humid area. If the humidity in the gym is 80% and the humidity in the hallway is 40%, justify why you feel cold *without knowing the temperature of the building*.

- We know that the evaporation of water requires energy, the enthalpy of vaporization is positive, an endothermic value. So as water evaporates energy goes into the water molecules, in the case of sweat the energy is pulled from your skin (heat energy). This is why sweat helps cool us off.
- In the high humidity area, there is a large concentration of water in the air (see Part C), so not much of the water on your skin is able to evaporate. Whereas in the low humidity area there is a low concentration of water in the air, thus more water can evaporate.
- So when moving from high humidity to low humidity you feel cold because the sweat is evaporating quickly, and as it does so is pulling energy from you skin, thus making you feel cold.