

April 22, 2002 - BOT311. Test prep questions for water relations.

For these answers assume that 1 atmosphere \approx 1 bar (It is close enough)

1) What are ψ_T , ψ_P , and ψ_S of pure water exposed to 1 atmosphere of pressure?

$$\psi_S = - CRT \quad \text{and since } C = 0, \text{ then } \psi_S = 0 \text{ bars}$$

$$\psi_P = 0 \text{ bars (by definition)}$$

$$\psi_T = \psi_P + \psi_S = 0 \text{ bars}$$

2) What are ψ_T , ψ_P , and ψ_S of pure water exposed to 2 atmospheres of pressure?

$$\psi_S = - CRT \quad \text{and since } C = 0, \text{ then } \psi_S = 0 \text{ bars}$$

$$\psi_P = +1 \text{ bars (Because it is 1 atmosphere above the standard state of water)}$$

$$\psi_T = \psi_P + \psi_S = + 1 \text{ bars}$$

3) What are ψ_T , ψ_P , and ψ_S of pure water exposed to 0 atmospheres of pressure?

$$\psi_S = - CRT \quad \text{and since } C = 0, \text{ then } \psi_S = 0 \text{ bars}$$

$$\psi_P = - 1 \text{ bars (Because it is 1 atmosphere below the standard state of water)}$$

$$\psi_T = \psi_P + \psi_S = - 1 \text{ bars}$$

4) What is the mole fraction of water in pure water?

$$\text{Mole fraction of water} = 55.5 \text{ Moles L}^{-1} / (55.5 \text{ Moles L}^{-1} + 0 \text{ Moles L}^{-1})$$

$$= 55.5 \text{ Moles L}^{-1} / 55.5 \text{ Moles L}^{-1}$$

$$= 1.0 \text{ (No Units)}$$

5) What is the vapor pressure in equilibrium with pure water?

Since it is in equilibrium with pure water, the value will be called e° and you can find it in the table at the appropriate temperature and the units will be in mbars.

If you assume 25 C then the value is

$$e^\circ = 31.72 \text{ mbars}$$

6) What is the vapor density in equilibrium with pure water?

Since it is in equilibrium with pure water, the value will be called VD° (although sometimes there is no “ $^\circ$ ” used for this value, which leads to confusion), and you can find it in the table at the appropriate temperature and the units will be in g m^{-3} .

If you assume 25 C then the value is

$$VD^\circ = 23.05 \text{ g m}^{-3}$$

7) What is the Relative Humidity in equilibrium with pure water?

$$\begin{aligned} \text{RH \%} &= (\text{mole fraction of pure water}) (100) \\ &= (1.0) (100) = 100 \end{aligned}$$

8) What is the ψ_T of the air in equilibrium with pure water?

$$\begin{aligned} \psi_{\text{air}} &= [RT \ln (e/e^\circ)] / V = [(0.08314 \text{ L Bar Mol}^{-1} \text{ K}^{-1}) (298 \text{ K}) \ln (1)] / 0.018 \text{ Mol L}^{-1} \\ &= 0 \end{aligned}$$

Also remember that...

$$e/e^\circ = VD/VD^\circ = \text{RH}/100 = \text{mole fraction of water} = 1.0 \text{ for pure water}$$

But you could have concluded that $\psi_{\text{air}} = 0$ without making any calculations just by knowing that if the air is in equilibrium with pure water at $\psi_T = 0$ bars, then the air must also be at 0 bars.

9) What are ψ_T , ψ_P , and ψ_S of a 0.2 molal solution of glucose exposed to 1 atmosphere of pressure?

$$\psi_P = 0 \text{ (because it is exposed to 1 atmosphere of pressure)}$$

$$\psi_S = - CRT = - (0.2 \text{ mol L}^{-1}) (0.08314 \text{ L Bar Mol}^{-1} \text{ K}^{-1}) (298 \text{ K}) = - 4.96 \text{ Bars}$$

$$\psi_T = \psi_P + \psi_S = (0 \text{ bars}) + (- 4.96 \text{ bars}) = - 4.96 \text{ bars}$$

10) What is the mole fraction of water in a 0.2 molal solution of glucose?

$$\begin{aligned} \text{Mole fraction of water} &= 55.5 \text{ Moles L}^{-1} / (55.5 \text{ Moles L}^{-1} + 0.2 \text{ Moles L}^{-1}) \\ &= 55.5 \text{ Moles L}^{-1} / 55.7 \text{ Moles L}^{-1} \\ &= 0.9964 \text{ (No units)} \end{aligned}$$

11) What is the vapor pressure in equilibrium with a 0.2 molal solution of glucose?

$$e = (0.9964) (e^\circ \text{ mbars})$$

(Where e° is value for vapor pressure in the table at appropriate temperature)

Assuming a temperature of 25 C then...

$$e = (0.9964) (31.72) = 31.606 \text{ mbars}$$

12) What is the vapor density in equilibrium with a 0.2 molal solution of glucose?

$$(0.9964) (VD^{\circ}) \text{ g m}^{-3}$$

(Where VD° is value for vapor density in table at appropriate temperature)

Assuming a temperature of 25 C then...

$$VD = (0.9964) (23.05 \text{ g m}^{-3}) = 22.967 \text{ g m}^{-3}$$

13) What is the Relative Humidity % in equilibrium with a 0.2 molal solution of glucose?

$$RH \% = (\text{mole fraction of water}) (100) = (0.9964) (100)$$

$$= 99.64$$

14) What is the ψ_T of the air in equilibrium with a 0.2 molal solution of glucose?

Since the solution $\psi_T = -4.96$ Bars, then the air also has to be at -4.96 Bars

But if you want to do the calculation (at 25 C), then...

$$\psi_{\text{air}} = [RT \ln (e/e^{\circ})] / V$$

$$= [(0.08314 \text{ L Bar Mol}^{-1} \text{ K}^{-1}) (298 \text{ K}) \ln (31.606 \text{ mbar} / 31.72 \text{ mbar})] / 0.018 \text{ Mol L}^{-1}$$

$$= -0.0893535 \text{ L Bar Mol}^{-1} / 0.018 \text{ Mol L}^{-1}$$

$$= -4.96 \text{ Bars}$$

Also remember that...

$$e/e^{\circ} = VD/VD^{\circ} = RH/100 = \text{mole fraction of water} = 0.9964 \text{ for a 0.2 molal solution}$$

15) What is the ψ_T of the air that is at 27 C and has a Relative Humidity of 75 %?

$$\psi_{\text{air}} = [RT \ln (RH/100)] / V$$

$$= [(0.08314 \text{ L Bar Mol}^{-1} \text{ K}^{-1}) (300 \text{ K}) \ln (0.75)] / 0.018 \text{ Mol L}^{-1}$$

$$= [(29.942 \text{ L Bar Mol}^{-1}) (-0.28768)] / 0.018 \text{ Mol L}^{-1}$$

$$= -0.8.61377 \text{ L Bar Mol}^{-1} / 0.018 \text{ Mol L}^{-1}$$

$$= -478.5 \text{ Bars}$$

$$= -47.85 \text{ Mpa}$$

NOTE: You should be able to go the other way with your calculation. If I give you the value for ψ_{air} , then you should be able to calculate the RH %.

16) Answer question 1 from exam 1 again but using 0.17 molal instead of 0.25 molal sucrose and 0.36 molal instead of 0.45 molal for the potato bulk osmolality.

Question 1 from exam...

A group of students in a plant physiology lab determine that after soaking a piece of potato tissue in a series of sucrose solutions, the potato tissue neither takes up nor loses water when the sucrose solution is 0.25 molal. They also find, using a vapor pressure osmometer, that the potato has a bulk osmolality of 0.45 molal. Assume a temperature of 25 C.

- A) What are the values for total, osmotic (also called solute potential), and pressure potentials for the piece of potato?
 B) What would you predict the pressure potential of the potato to become if you placed that same chunk of potato in pure water and let it equilibrate?
 C) What two important assumptions did you make to arrive at your calculations?

ANSWERS FOR QUESTION 1 FROM EXAM:

$$\begin{aligned} \text{A) } \Psi_{S \text{ potato}} &= - CRT = - (0.36 \text{ Moles L}^{-1}) (0.08314 \text{ L Bar Mol}^{-1} \text{ K}^{-1}) (298 \text{ K}) \\ &= - 8.92 \text{ Bars} \end{aligned}$$

Since the potato slice neither took up nor lost water from the sucrose solution at 0.17 molal, the potato and the sucrose solution must have had the same Ψ_T .

So...we need to calculate the $\Psi_{T \text{ solution}}$

$$\Psi_{P \text{ solution}} = 0 \text{ Bars} \quad (\text{solution was exposed to 1 atmosphere of pressure})$$

Since the sucrose solution contained 0.17 Moles L⁻¹, then...

$$\begin{aligned} \Psi_{S \text{ solution}} &= - CRT = - (0.17 \text{ Moles L}^{-1}) (0.08314 \text{ L Bar Mol}^{-1} \text{ K}^{-1}) (298 \text{ K}) \\ &= - 4.21 \text{ Bars} \end{aligned}$$

Hence, the Ψ_T for the sucrose solution was

$$\begin{aligned} \Psi_{T \text{ solution}} &= \Psi_{P \text{ solution}} + \Psi_{S \text{ solution}} = (0 \text{ Bars}) + (- 4.21 \text{ Bars}) \\ &= - 4.21 \text{ Bars} \end{aligned}$$

Since $\Psi_{T \text{ potato}} = \Psi_{T \text{ solution}}$ then....

$$\Psi_{T \text{ potato}} = - 4.21 \text{ Bars}$$

Now we need to solve for $\Psi_{P \text{ potato}}$

$$\begin{aligned} \Psi_{P \text{ potato}} &= \Psi_{T \text{ potato}} - \Psi_{S \text{ potato}} = (- 4.21 \text{ Bars}) - (- 8.92 \text{ Bars}) \\ &= 4.71 \text{ Bars} \end{aligned}$$

B) The potato would absorb water by osmosis from the pure water surrounding it until the

$$\Psi_{T \text{ potato}} = \Psi_{T \text{ pure water}}$$

and since the $\Psi_{T \text{ pure water}} = 0 \text{ Bars}$ then....

$$\Psi_{T \text{ potato}} = 0 \text{ Bars}$$

Now we need to calculate the $\Psi_{P \text{ potato}}$...

$$\begin{aligned} \Psi_{P \text{ potato}} &= \Psi_{T \text{ potato}} - \Psi_{S \text{ potato}} = (0 \text{ Bars}) - (-8.92 \text{ Bars}) \\ &= 8.92 \text{ Bars} \end{aligned}$$

C) Assumptions are no dilution and no change in volume, otherwise you could not have made your calculations. If the solution concentrations and/or cell volumes in the cells had changed (typically by a small amount), then you could not calculate your answers “exactly” because the small changes in solution concentrations and cell volumes would cause small changes in your results. If you knew the resulting changes volumes and solution concentrations, then you could adjust your calculations for those changes. Otherwise, you HAVE to make the two assumptions.

17) An epiphytic plant with a total leaf water potential of -12 bars experiences a humid atmosphere at 22 C where the Relative Humidity is 99.6 %. Will the plant lose water by transpiration to the air or will the plant actually take up water from the air?

Plant has a $\Psi_T = -12 \text{ Bars}$

if $\Psi_{T \text{ air}} > \Psi_{T \text{ plant}}$ Then water will flow from air to plant

if $\Psi_{T \text{ air}} < \Psi_{T \text{ plant}}$ Then water will flow from plant to air

So, we need to calculate $\Psi_{T \text{ air}}$

$$\begin{aligned} \Psi_{T \text{ air}} &= [RT \ln (RH/100)] / V \\ &= [(0.08314 \text{ L Bar Mol}^{-1} \text{ K}^{-1}) (295 \text{ K}) \ln (0.996)] / 0.018 \text{ Mol L}^{-1} \\ &= -5.46 \text{ Bars} \end{aligned}$$

Since $-5.46 \text{ Bars} > -12 \text{ Bars}$

Then the plant will take up water from the air. In other words, instead of losing water by transpiration, the plant would actually gain water from the environment.

This occurs often in areas of fog such as in cloud forests or other very humid environments. Epiphytes often get much of their water by this phenomenon, they get the rest of their water by direct rain on their little bodies.

18) Plant physiology students grow a tomato plant by hydroponics in a greenhouse. When the hydroponic growth solution is tested in a vapor pressure osmometer, the osmometer reports that the solution is 105 mosmolal (0.105 molal). What do you predict will be the maximum measurable ψ_T of the tomato plant (most likely at pre-dawn), if the water potential is measured with a pressure bomb?

It will be whatever the water potential of the growth solution is (when no transpiration is taking place). Assuming a temperature of 25 C...

$$\psi_{P \text{ solution}} = 0 \text{ (because it is exposed to 1 atmosphere of pressure)}$$

$$\psi_{S \text{ solution}} = - CRT = - (0.105 \text{ mol L}^{-1}) (0.08314 \text{ L Bar Mol}^{-1} \text{ K}^{-1}) (298 \text{ K}) = - 2.60 \text{ bars}$$

$$\psi_T = \psi_P + \psi_S = (0 \text{ bars}) + (- 2.60 \text{ Bars}) = - 2.60 \text{ bars}$$

So...the maximum water potential that the plant could achieve is - 2.60 bars

19) You are making potato chips from scratch. By mistake you drop a thin slice of potato on the floor behind the counter where it stays for the next few years. Assuming that the slice of potato has come into equilibrium with the air around it, what will be the water potential of the “aged” slice of potato when it is in equilibrium with the air in your house at 27 C and a Relative Humidity of 69 %?

It will have the same water potential as the air.

$$\begin{aligned} \psi_{\text{air}} &= [RT \ln (RH/100)] / V = [(0.08314 \text{ L Bar Mol}^{-1} \text{ K}^{-1}) (300 \text{ K}) \ln (0.69)] / 0.018 \text{ Mol L}^{-1} \\ &= - 514.17 \text{ Bars} \end{aligned}$$

The piece of potato would have a $\Psi_T = - 514.17 \text{ Bars}$