

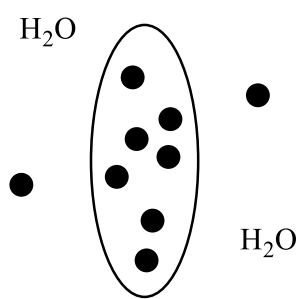
CHEM1405: Worksheet 6: Osmotic Pressure and Acids and Bases

Model 1: The origin of osmotic pressure

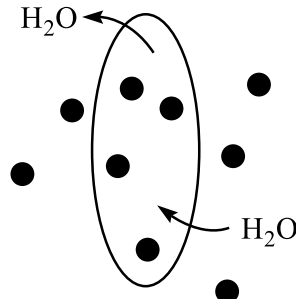
The cell membrane is a semi-permeable barrier to the passage of many (but not all) molecules and ions. Water can diffuse through it but many charged and large molecules cannot.

To maximise entropy, the concentration of the solutions on either side of a membrane tend to equalise. If the membrane is impermeable to the *solute*, only the *solvent* (water) can flow across the membrane to achieve this.

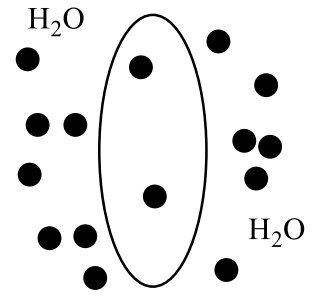
The schemes below show 3 cells with solute particles shown as black dots. The first picture represents a cell which has *higher* levels of solute relative to the medium it is in. The second represents a cell which has the *same* levels of solute as the medium. The third represents a cell which has *lower* levels of solute than the medium.



(i) Hypotonic medium



(ii) Isotonic medium



(iii) Hypertonic medium

Critical thinking questions

- In an isotonic medium, water flows in and out at the same rate. Draw arrows on the other two pictures to indicate the direction in which water flows.
- Describe what you think will happen to the size of the cell in each of the mediums.
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- Animal cells do not have cell walls. Using your answer to Q2, describe what might occur if pure water is accidentally injected into a blood vessel.
- Animals continually expend energy by pumping Na^+ ions out of their cells. By considering the effect this has on the solute concentration in the cell, suggest why this action is vital for the health of the cell.
 - In some blood disorders, such as sphero- and ellipto- cytosis, the membrane of the red blood cells is so permeable to Na^+ ions that these ions diffuse into the cell more rapidly than the pump can cope with. What effect will this have on the flow of water and hence on the shape of the cell? (*Hint*: consider the names of these disorders.)

Model 2: Osmotic pressure

The pressure that must be applied to the solution to stop the processes described in Model 3 is called the *osmotic pressure*, π . For dilute solutions, it is given by:

$$\pi = cRT \quad \text{where } R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$$

c is the concentration of *all* impermeable species in solution. As salts dissociate into ions in solution, the concentrations of all of the ions must be added together.

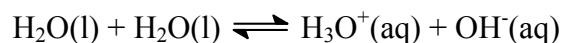
Critical thinking questions

- If 0.35 mol of NaCl and 0.15 mol of KCl are added to 1.00 L of water, calculate:
 - $[\text{Na}^+(\text{aq})]$
 - $[\text{K}^+(\text{aq})]$
 - $[\text{Cl}^-(\text{aq})]$
- What is the overall concentration of ions in this solution?
- Calculate the osmotic pressure for this solution at 298 K. (*Hint*: if you use the concentration from Q2 in mol L^{-1} then you will calculate the pressure in kPa. Note that 0.1 MPa \sim 1 atm.)
- Explain why the osmotic pressure depends on the concentration of particles but not their identity. (*Hint*: re-read Model 3 on the origin of osmotic pressure).
- Suppose a compartment separated from an extracellular medium by a semipermeable membrane. The membrane allows movement of water but not solute particles. For each of the initial compositions shown below, does the compartment (a) swell, (b) stay the same size or (c) shrink?

	compartment	medium			
(i)	0.1 M sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$)	0.1 M glucose ($\text{C}_6\text{H}_{12}\text{O}_6$)	(a)	(b)	(c)
(ii)	0.1 M sucrose	0.05 M sucrose	(a)	(b)	(c)
(iii)	0.10 M sucrose	0.05 M NaCl	(a)	(b)	(c)
(iv)	0.10 M sucrose	0.050 M MgCl_2	(a)	(b)	(c)

Model 3: pH

Water is able to act as both an acid and a base and it is possible for water to react with itself in an acid-base reaction called the *autoprotolysis* or *autoionization* of water:



The equilibrium constant for this reaction $K_w = [\text{H}_3\text{O}^+(\text{aq})][\text{OH}^-(\text{aq})]$. At 25 °C, $K_w = 1.0 \times 10^{-14}$. Several definitions have proven to be useful:

$$\text{pH} = -\log_{10}[\text{H}_3\text{O}^+(\text{aq})], \quad \text{pOH} = -\log_{10}[\text{OH}^-(\text{aq})] \quad \text{p}K_w = -\log_{10}K_w$$

Critical thinking questions

1. During the course of a titration, a student measures the pH several times. What is $[\text{H}_3\text{O}^+(\text{aq})]$ for each pH value below? (Actually calculate $[\text{H}_3\text{O}^+(\text{aq})]$ – do *not* leave in the form 10^x).

pH	0.50	1.50	2.50	3.50	4.50	5.50	5.75
$[\text{H}_3\text{O}^+(\text{aq})]$							

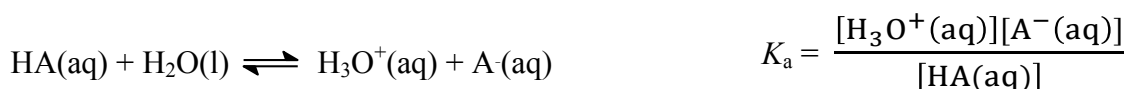
2. What is the effect of the number to the left and to the right of the decimal point in the pH on $[\text{H}_3\text{O}^+(\text{aq})]$?

Model 4: Strong and Weak Acids

A **strong acid** is one that is essentially 100% dissociated in water: if 1.0 mole of the acid is added to enough water to make a 1.0 L solution, the solution will have $[\text{H}_3\text{O}^+(\text{aq})] = 1.0 \text{ M}$ and will be $\text{pH} = 0.00$

A **weak acid** is one that is *significantly* less than 100% dissociated in water: if 1.0 mole of the acid is added to enough water to make a 1.0 L solution, the solution will have $[\text{H}_3\text{O}^+(\text{aq})] < 1.0 \text{ M}$ and will be $\text{pH} > 0$.

When an acid HA is placed in water, $\text{H}_3\text{O}^+(\text{aq})$ ions are produced according to the reaction:



Critical thinking questions

1. What are the *major* species present in a solution of a strong acid like HCl?
2. What are the *major* species present in a solution of a weak acid like CH_3COOH ?
3. Under what pH conditions would $\text{CH}_3\text{COO}^-(\text{aq})$ be the *dominant* species in a solution of CH_3COOH ?
4. What are the *major* species present in a solution of a weak base like CH_3NH_2 ?
5. Under what pH conditions would $\text{CH}_3\text{NH}_3^+(\text{aq})$ be the *dominant* species?

7. The extent of ionization of a drug helps determine how it is distributed in the body because ions are less likely to cross cell membranes than uncharged molecules. Are the two drugs below likely to be absorbed in (i) the acid environment of the stomach or (ii) the basic environment of the intestine?

