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5.111 Principles of Chemical Science  
Fall 2008

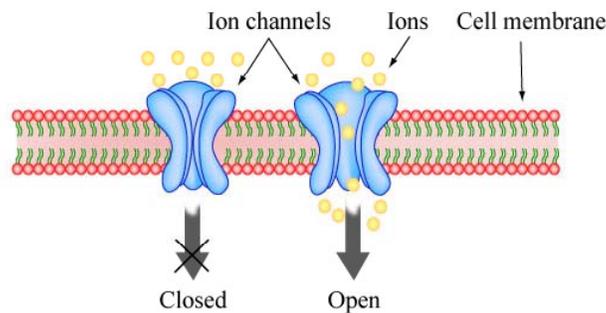
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## Periodic Trends: Atomic Size

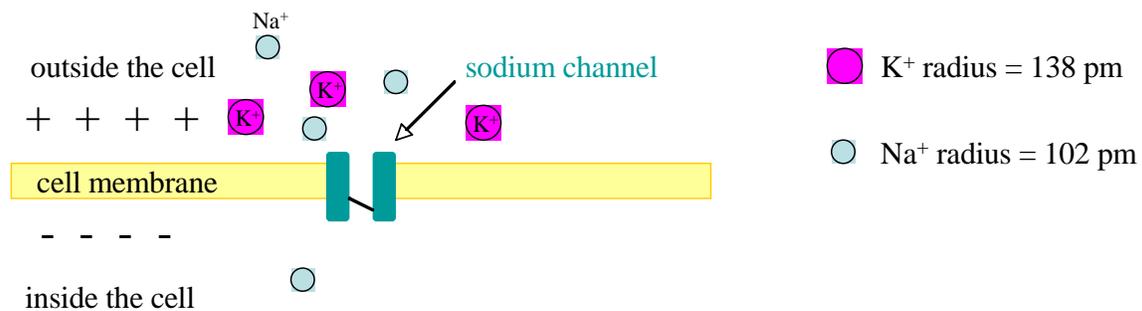
See lecture 9 for an introduction to periodic trends and lecture 10 for a discussion of atomic size.

### Example from page 1 of Lecture 10 notes: The significance of atomic size in the selectivity of ion channels in neurons

Ion channels are protein “gates” that regulate the movement of ions (such as  $\text{Na}^+$  or  $\text{K}^+$ ) across cell membranes. Ion channels can be found in all cell types, but are particularly prevalent in nerve cells (neurons) and muscle cells. Specifically, ion channels underlie the nerve impulses (electrical signals) in neurons. Ion channels help establish and control a voltage gradient in neurons by regulating the influx of sodium ions ( $\text{Na}^+$ ) and potassium ions ( $\text{K}^+$ ).



**Ion channels are SPECIFIC for a certain type of ion.** Thus, sodium ion channels will allow ONLY sodium ions to pass through.



The differences in ionic radius between sodium and potassium ions may seem insignificant:  $1.02 \times 10^{-10}$  for  $\text{Na}^+$  versus  $1.38 \times 10^{-10}$  m for  $\text{K}^+$ .

However, the pore (or opening) in sodium channels is *just* wide enough to accommodate a sodium ion and one associated water molecule. The **pore is too small** for a water-complexed potassium ion!

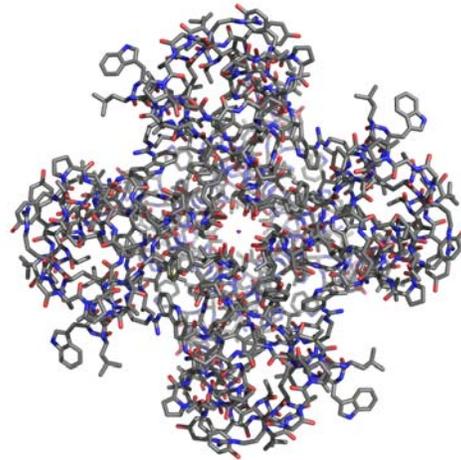
Interestingly, potassium channels also use size for ion selectivity. In potassium channels, the **larger size** of potassium ions enables stabilizing interactions with multiple oxygen atoms (from carbonyl,  $\text{C}=\text{O}$ , groups) within the channel's pore. The stabilizing oxygen atoms are spaced too far apart to simultaneously interact with the smaller sodium ions.

## Crystal structure of an ion channel

Below are two representations of the molecular structure of a **potassium ion channel** looking down the open pore (Protein Data Base (PDB) accession number 1BL8). A  $K^+$  ion passing through the pore is highlighted in purple.



This is a ribbon diagram, showing the protein backbone with the potassium ion as a purple sphere.



This is a stick diagram, showing all of the atoms in both the backbone and side chains of the protein. Carbon atoms are grey, nitrogen atoms are blue, oxygen atoms are red, sulfur atoms are yellow, and potassium ions are purple. The oxygen atoms (each with a partial negative charge) lining the inside of the pore stabilize the positively-charged potassium ions passing through.

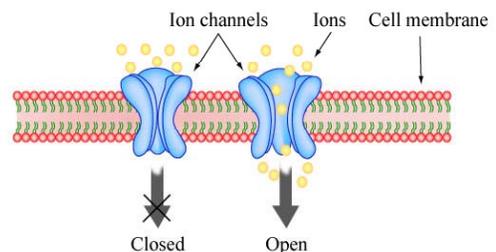
Summery slide as shown in the lecture notes

### *The role of atomic radius in ion channel selectivity :*

#### **Ion channels**

- \* regulate the influx of ions into cells.
- \* enable rapid electrical signaling in neurons.

**Regulation and selectivity are essential.**



Sodium ion channels are selective for  $\text{Na}^+$  in the presence of other ions, including  $\text{K}^+$ . Sodium channels include a tiny pore (~0.4 nm wide) that is *just* wide enough to accommodate a sodium ion and associated water molecule. Too small for potassium!