Entropy

*How does the organization of atoms and molecules affect chemical states?*

**Model I: The Deck of Cards analogy**

Imagine a brand new deck of cards sitting by itself in a large room. The deck has never been used, except that it has been removed from its box. It has not been shuffled, but is still in the factory shipped order, which is:

Hearts, Clubs, Diamonds, Spades  
Ace to King within each suit

Definition: The *state* of a deck of cards refers to the order of cards within the deck. We will call the factory order an *ordered state*, that is, the cards from each suit are all together and in order from ace to king.

**Questions**

1. In card games, what is the purpose of shuffling the deck before playing?
2. In a randomly shuffled deck of cards
3. Are there a large number or small number of ordered states?
4. Are there a large number or small number of disordered states?
5. After shuffling, is the observed order (or *state*) more likely to be an ordered state, or a disordered state?
6. Form this into a generalization – why does the order of cards in a shuffled deck always come out disordered? Use a complete sentence.
7. Are you more or less likely to have ordered states in a blackjack dealers “shoe” – a device that can contain six or more decks of cards, all shuffled together?

**Information**

**Entropy** (abbreviated “S”) is a measure of the number of states a system can have. However, because the more states a system can have means that it is more like to be found in a disordered state, we often just say that entropy is a measure of disorder. (Notice that entropy is related to *disorder,* not order).

If a change occurs which leads to a more disordered system, the change in entropy (ΔS) is positive. If the system becomes more ordered, the ΔS is negative.

**Questions**

1. Which of these has the highest entropy: an ordered deck or a shuffled deck?
2. Rank the following from least to greatest entropy.
3. Legos scattered on the floor, legos mixed together in a bucket, legos assembled together
4. A bag of marbles, the same marbles spilled on a floor, the same marbles sitting in a straight line, the same marbles in a straight line organized by color
5. If a person spills a bag of marbles, if this a positive or negative change in entropy (ΔS)?
6. If a person organizes a desk, is this a positive or a negative ΔS (change in entropy) for the desk?

**Model II: Predicting the Sign of ΔS**

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| --- | --- | --- |
| Solid water | Liquid water | Gaseous Water |

**Questions**

1. Draw in representations for the solid, liquid and gaseous water.
2. What do you know about how molecules of H2O can move in a solid versus a liquid versus a gas?
3. In which state of matter, solid, liquid, or gas can the molecules have the most numbers of possible positions and speeds, in other words, which phase can water have the most chemical states?
4. In terms of entropy, write the phases of matter in proper order from most to least entropic.

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1. In the transition from liquid to gas, is the system increasing or decreasing in entropy? Is this a positive or a negative change?
2. In the transition from solid to liquid, is the system increasing or decreasing in entropy? Is this a positive or a negative change?
3. Is sublimation (solid to gas) a positive or negative change in entropy?
4. If you increase the temperature of a solid, does its entropy increase, decrease or remain the same? Justify your answer in terms of the definition of chemical state given above.
5. If you have a reaction that changes one mole of gas into two moles of gas, will the entropy of the system increase, decrease or remain the same? Justify your answer in terms of the definition of chemical state given above.

**Exercises**

1. Fill in the chart below:

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| --- | --- | --- |
| **Change** | **Sign of ΔS** | **Sign of ΔH** |
| Evaporation |  |  |
| Condensation |  |  |
| Sublimation (solid to gas) |  |  |
| Deposition (gas to solid) |  |  |
| Melting |  |  |
| Freezing |  |  |
| Decomposition to atoms |  |  |
| Formation of a compound from atoms |  |  |

1. A hot piece of metal is dropped into a cool glass of water. What is the sign of ΔS for the metal? What is the sign of ΔS for the water?
2. Determine for each of the following reactions if ΔS is positive, negative, or approximately zero.
3. CaCO3 (s) → CaO (s) + O2 (g)
4. 2 NO2 (g) → N2O4 (g)
5. Fe2O3 (s) + 3 CO (g) → 2 Fe (s) + 3 CO2 (g)
6. CF4 (g) + 2 Br2 (l) → CBr4 (l) + 2 F2 (g)
7. KClO4 (s) → KCl (s) + 2 O2 (g)
8. 6 CO2 (g) + 6 H2O (l) → C6H12O6 (s) + 6 O2(g)
9. 2 H2O2 (l) → 2H2O (l) + O2 (g)
10. NaCl (s) + H2O (l) → Na+ (aq) + Cl– (aq)   
     (Solid sodium chloride dissolves in water)