

Some Common Misconceptions in AP Chemistry:

Misconception	Correct Thinking
1. Volumes of solutions are additive upon mixing	IMFs can bring particles together, and the total volume before and after mixing can change. Usually an assumption is made: "the volume before and after mixing are the same."
2. The reactant with less mass always limits the rxn.	Moles, not mass, determine the limiting reactant. Thinking in terms of "mole of reaction" can help here.
3. All reactants make products when mixed.	High activation energy, limiting reactant, positive ΔG , or positive ΔH may contribute to slow or negligible conversion to products.
4. Breaking bonds releases energy (as in ATP).	Separating bonded atoms always requires energy. Forming bonds always releases energy. Middle school texts often refer to chemical bonds as "stored energy," and the ATP/ADP phrasing in Biology can support the misconception.
5. All systems/reactions that feel warm are exothermic.	Warmth means that energy flows from an object to the hand. Ice freezing would feel cold, but it is an exothermic process. Define system and surroundings before making claims about endo and exothermic.
6. Heat and temperature are the same.	They are related, but heat is an energy transfer, temperature is a measure of the average kinetic energy of particles. Heat is a quantity and temperature is a degree of hotness. There is a Eureka video on heat and temperature that is available on YouTube, and it explains this well.
7. Radiation is always dangerous.	Radiation exposure is about intensity, energy, and amount. Low energy radiation like IR is not dangerous, but higher energy light such as X-ray or gamma are incredibly harmful. Connecting the energy of light to what it can do to chemical bonds and electrons can illustrate this (IR stretches/vibrates covalent bonds, Visible can promote electrons, UV can ionize some valence electrons, and X-ray can ionize any electron from an atom).
8. The s orbital is closer to the nucleus than the p orbitals in an energy level (and shield the p electrons from the nucleus)	The average radial probability of the s cloud is actually further out than the p clouds. However, the s cloud has greater penetrating ability to the nucleus, so it can get to a state of lower potential energy (hence why s is more likely to be occupied and harder to remove than p electrons). The s electrons do not shield the p electrons, but the inner principal energy levels do shield outer ones.
9. All molecules in a gas at a given temperature have the same velocity.	Temperature measures average kinetic energy. Some particles move faster than others. Maxwell-Boltzmann distribution curves are a good way to show that individual particles of a low temperature sample can move faster than individual particles of a high temperature sample, but the average speed will be higher at higher temps.
10. Particles in gases always move faster than particles in liquids.	Temperature is a bigger factor here than state of matter. Also, o can move slowly in the gas phase. During phase transitions like boiling, the fast moving particles are much more likely to escape into the gas phase, but there can still be slow moving gas particles at any given instant.
11. Rate laws are determined by the coefficients from a balanced net reaction.	Rate laws are determined experimentally. Sometimes rate order will match the coefficient in a net equation, and often it will not. Only for elementary steps (unimolecular, bimolecular collisions) does rate order match the coefficient.
12. Inhibitors slow rxns by raising activation energy.	Inhibitors are often competitors to reactant molecules, decreasing effective concentration, thus slowing rate. They are not "anti-catalysts."
13. A catalyst will make more product.	Catalysts improve efficiency by either by partially breaking bonds on a surface, or by bringing together molecules with the proper orientation, reducing the unsuccessful collisions with incorrect orientation.
14. Stirring increases the energy of collisions by adding kinetic energy.	Stirring can affect surface area exposed if working with a solid reactant, but its effect on temperature is negligible. "What If?" by xkcd did a good write-up on it: https://what-if.xkcd.com/71/

15. When a system reaches equilibrium, all chemical changes stop.	Rates become equal at equilibrium, but products convert to reactants just as reactants continue to convert to products. It is a dynamic process.
16. Systems have a $K=1$ at equilibrium; similarly, all species are at the same concentration when equilibrium is achieved.	It's rare for K to equal 1, and there are many concentrations that can allow for equilibrium. Rates must match, so many sets of concentrations can achieve the equal rates.
17. Catalysts can change equilibrium position.	Catalysts do not "shift" position; they achieve equilibrium faster. While they do reduce activation energy, they reduce it for both forward and reverse reactions.
18. Reactions always go to completion.	Many reactions reach equilibrium, especially in aqueous solutions.
19. The equilibrium constant, K , never changes.	K is dependent on temperature, and for an endothermic reaction, K becomes larger at higher temperature, and vice versa. K can be related to ΔG to determine the effects of temperature on equilibrium position. As temp is changed, the current conditions (Q) no longer match K , so the system will adjust to move towards the new K at the different temperature.
20. Strong and concentrated acids are the same.	Strong = 100% ionized. Concentrated = many moles per Liter.
21. All neutralization reactions produce a neutral solution.	Weak acids titrated with strong bases have $\text{pH} > 7$. Weak bases titrated with strong acids have $\text{pH} < 7$. Weak bases titrated with weak acids (who does this?) would have a pH that will depend on the relative sizes of K_a and K_b for the substances used. Analysis of titration curves can help solidify this point.
22. Only pH values of 1-14 occur.	pH can be negative and can go beyond 14 for highly concentrated strong acids and bases. For these systems, it's just easier to report "10.0 M HCl has $[\text{H}^+] = 10.0\text{M}$ " than to say " $\text{pH} = -1.000$."
23. The endpoint of a titration and the equivalence point are the same.	The endpoint is when the indicator changes color. Ideally, the endpoint and equivalence point should be close, so selecting an indicator within one $\text{p}K_a$ unit of the final pH of the titration is important. However, if a student consistently overtitrates, the endpoint will have more moles of base added than the equivalence point.
24. Exothermic reactions are always thermodynamically favorable; endothermic reactions never are.	ΔG determines favorability, not just ΔH . Enthalpy, entropy, and temperature must all be considered to determine the thermodynamic favorability of a process.
25. A positive ΔG means the reaction does not occur.	Non-favorable reactions are often coupled to other reactions that have larger, negative values of ΔG . For example, recharging a phone battery uses the highly favorable combustion of carbon-based fuels to make electricity that pushes electrons in the non-favored direction. Photosynthesis is not favored, but energy from the sun and energy transfers within the cell allow it to occur.
26. If ΔG is negative, the reaction will occur quickly.	ΔG indicates favorability, not rate. Rate is about kinetic controls. Rusting of iron has a large, negative ΔG , but the process is (thankfully) slow.
27. Water is a good conductor of electricity.	The ions dissolved in water are responsible for its conductivity. Pure water has a resistance of 18 M Ω , which is hugely insulating.
28. Oxidation or reduction can occur in isolation of the other process.	Charge is conserved just like atoms are in chemical reactions. Half-reactions must be balanced to allow an equal electron transfer between these paired processes.
29. Metals want to lose electrons. Nonmetals want to gain them.	Ionization energy is endothermic, the losing of electrons is not favorable for metals. It is true that adding electrons to nonmetals is usually enthalpically favorable. The driving force for ionic compound formation is often the lattice energy. Generally, bringing particles together releases energy and separating particles requires energy (as long as they don't have the same charge).

<p>30. Covalent bonds are broken when substances boil.</p>	<p>At the boiling point, molecules have enough kinetic energy to overcome the IMFs that hold them to adjacent molecules. The covalent bonds inside of the molecule remain intact. Students need to clearly articulate that hydrogen bonding is a force between molecules and avoid vague language like “hydrogen bonds are broken,” which is unclear if the covalent bonds to hydrogen atoms or the hydrogen bonds between molecules are being overcome.</p>
<p>31. Dipole-dipole attractions and hydrogen bonding are stronger than London dispersion forces.</p>	<p>For small molecules like H₂O, it is true that the dipole attractions are stronger than the LDFs among molecules, but if comparing molecules of different size, large molecules often have LDFs that are far greater than dipole-dipole attractions and even H-bonding among smaller molecules. E.g., water boils at 100°C, but oil is still a liquid at this temperature. Oil’s larger, more polarizable electron cloud gives it greater attractions to adjacent molecules than water has to adjacent water molecules.</p>
<p>32. London dispersion forces are stronger because of higher molar mass of molecules.</p>	<p>While molar mass is a convenient number to tabulate to get a concept of the size of a molecule, it is the size and shape of the electron cloud, not the molecule’s mass, that causes changes in LDFs. Sometimes, two molecules with the same molar mass can have very different boiling points, usually due to a greater surface area of the electron cloud allowing for greater polarizability. For example, a molecule with the formula of C₆H₆ could be in a long, zigzag shape, or it could be a flat hexagonal ring (as in benzene). The boiling point on the flat molecule is much higher than that for the zigzag molecule.</p>
<p>33. The entropy of a solution is always greater than of the separated components.</p>	<p>While mixing usually results in more degrees of freedom, and thus a higher entropy, very small ions with high charge density can strongly organize the water molecules around them, so solution formation can have a negative entropy change.</p>
<p>34. Electrons move through the solution or salt bridge in an electrochemical cell.</p>	<p>Charged particles must flow through the salt bridge, but the dissolved ions, not electrons, are responsible for balancing the charge that is flowing through the wire between the two electrodes.</p>
<p>35. Anodes decrease in mass because electrons are being lost from the metal and flowing through the wire.</p>	<p>While electrons do have mass and do move from the anode generally toward the wire, the mass loss is due to soluble cations being formed that float away from the electrode into the surrounding solution. Also, one electron does not make the entire transit from anode to cathode; they bombard the next electron cloud over, pushing electrons on the next atom over in a cascading effect.</p>
<p>36. “Like dissolves like,” so nonpolar molecules don’t dissolve in polar solvents like water. Nonpolar molecules do not attract to polar molecules.</p>	<p>There are attractions between water and oil (LDFs and some very slight dipole-induced dipole attraction). However, the attraction among water molecules is much greater than the energy/entropy payout for mixing with oil. Likewise, oil is much more attracted to molecules of its own type (through very significant LDFs), so they stay with the stronger attraction. This can be altered at high temp, and the TΔS term overcomes the ΔH term, and the interaction becomes thermodynamically favored, hence why steam cleaning removes oily residues. There is a good <i>J Chem Ed</i> article on this topic.</p>