**Honors Chemistry II Unit 8 Tentative Agenda** Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Thermodynamics

| **Date** | **Agenda** |
| --- | --- |
| Wednesday 12/18 | * Chapter 5 Notes
* Homework
	+ Read Chapter 5, 8.2 (again), 8.8 (again), 13.1, 19.3-19.7
	+ Mastering Problems 1-10
 |
| Thursday 12/19 | * 13.1 and Chapter 19 Notes
* Boltzman Bucks Activity
* Hint of the day: Review stoichiometry. There will be 5 multiple choice questions on the test about stoichiometry.
* Homework
	+ Mastering Problems 11-20
 |
| Friday 12/20 | * Continue Chapter 19 Notes
* Hint of the day: Review bonding. There will be 10 multiple choice questions on the test about bonding.
* Homework
	+ Prelab for at least Lab #13.
	+ Mastering Problems 21-30
 |
| Monday 1/6 | * Finish Notes
* Review/Mastering
* Hint of the day: **Know what enthalpy of formation and bond dissociation energy are and how they are similar and different.**
* Homework
	+ Prelab for Lab #12
	+ Mastering Problems 31-40
 |
| Tuesday 1/7 | * Labs:
	+ Flinn Lab #13: Enthalpy of Reaction & Hess’s Law
	+ Flinn Inquiry #12: Designing a Hand Warmer
* Homework
	+ Mastering Problems 41-50
 |
| Wednesday 1/8 | * Labs:
	+ Flinn Lab #13: Enthalpy of Reaction & Hess’s Law
	+ Flinn Inquiry #12: Designing a Hand Warmer
* Homework
	+ Mastering Problems 51-60
 |
| Thursday 1/9 | * Labs:
	+ Flinn Lab #13: Enthalpy of Reaction & Hess’s Law
	+ Flinn Inquiry #12: Designing a Hand Warmer
* Homework
	+ Mastering Problems 61-100
 |
| Friday 1/10 | * Unit 8 Quiz
* Turn in Labs
* Mastering/Catch up day
* Homework
	+ Mastering Problems 101-116, Mastering Due @ 11:59PM
	+ Study for test
 |
| Monday 1/13 | * Unit 8 Test
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**LO 3.11 The student is able to interpret observations regarding macroscopic energy changes associated with a reaction or process to generate a relevant symbolic and/or graphical representation of the energy changes. [See SP 1.5, 4.4]**

Essential knowledge 3.C.2: Net changes in energy for a chemical reaction can be endothermic or exothermic.

a. Macroscopic observations of energy changes when chemicals react are made possible by measuring temperature changes.

b. These observations should be placed within the context of the language of exothermic and endothermic change.

c. The ability to translate observations made at the macroscopic level in the laboratory to a conceptual framework is aided by a graphical depiction of the process called an energy diagram, which provides a visual representation of the exothermic or endothermic nature of a reaction.

d. It is important to be able to use an understanding of energy changes in chemical reactions to identify the role of endothermic and exothermic reactions in real-world processes.

**LO 5.1 The student is able to create or use graphical representations in order to connect the dependence of potential energy to the distance between atoms and factors, such as bond order (for covalent interactions) and polarity (for intermolecular interactions), which influence the interaction strength. [See SP 1.1, 1.4, 7.2, connects to Big Idea 2]**

All changes in matter involve some form of energy change. Thus, the availability or disposition of energy plays a role in virtually all observed chemical processes. Thermodynamics provides a number of tools for understanding this key role, particularly the conservation of energy, including energy transfer in the forms of heat and work. Chemical bonding is central to chemistry, so one key concept associated with energy is that the breaking of a chemical bond inherently requires an energy input, and because bond formation is the reverse process, it will release energy. One key determinant of chemical transformations is the change in potential energy that results from changes in electrostatic forces. In addition to the transfer of energy, the thermodynamic concept of entropy is an important component in determining the direction of chemical or physical change.

Enduring understanding 5.A: Two systems with different temperatures that are in thermal contact will exchange energy.

The quantity of thermal energy transferred from one system to another is called heat.

The particles in chemical systems are continually undergoing random motion. The temperature of a system is a direct measure of the average kinetic energy associated with this random motion. When chemical systems that have different temperatures are placed in thermal contact, kinetic energy is transferred from the hotter object to the cooler object until the temperatures become equal. This transfer of kinetic energy is referred to in this course as heat transfer. An understanding of heat as the transfer of energy between a system at higher temperature and a system at lower temperature is fundamental. Many practical applications exist, such as weather prediction, design of heating and cooling systems, and regulation of the rates of chemical reactions.

Essential knowledge 5.A.1: Temperature is a measure of the average kinetic energy of atoms and molecules.

a. All of the molecules in a sample are in motion.

b. The Kelvin temperature of a sample of matter is proportional to the average kinetic energy of the particles in the sample. When the average kinetic energy of the particles in the sample doubles, the Kelvin temperature is doubled. As the temperature approaches 0 K (zero Kelvin), the average kinetic energy of a system approaches a minimum near zero.

c. The Maxwell-Boltzmann distribution shows that the distribution of kinetic energies becomes greater (more disperse) as temperature increases.

**LO 5.3 The student can generate explanations or make predictions about the transfer of thermal energy between systems based on this transfer being due to a kinetic energy transfer between systems arising from molecular collisions. [See SP 7.1]**

Essential knowledge 5.A.2: The process of kinetic energy transfer at the particulate scale is referred to in this course as heat transfer, and the spontaneous direction of the transfer is always from a hot to a cold body.

a. On average, molecules in the warmer body have more kinetic energy than the molecules in the cooler body.

b. Collisions of molecules that are in thermal contact transfer energy.

c. Scientists describe this process as “energy is transferred as heat.”

d. Eventually, thermal equilibrium is reached as the molecular collisions continue.

The average kinetic energy of both substances is the same at thermal equilibrium.

e. Heat is not a substance, i.e., it makes no sense to say that an object contains a certain amount of heat. Rather, “heat exchange” or “transfer of energy as heat” refers to the process in which energy is transferred from a hot to a cold body in thermal contact.

f. The transfer of a given amount of thermal energy will not produce the same temperature change in equal masses of matter with differing specific heat capacities.

**LO 5.4 The student is able to use conservation of energy to relate the magnitudes of the energy changes occurring in two or more interacting systems, including identification of the systems, the type (heat versus work), or the direction of energy flow. [See SP 1.4, 2.2, connects to 5.B.1, 5.B.2]**

**LO 5.5 The student is able to use conservation of energy to relate the magnitudes of the energy changes when two nonreacting substances are mixed or brought into contact with one another. [See SP 2.2, connects to 5.B.1, 5.B.2]**

Enduring understanding 5.B: Energy is neither created nor destroyed, but only transformed from one form to another. The conservation of energy plays an important role in reasoning about the transfer of energy in chemical systems. A molecular system has energy that is a function of its current state. The energy of a system changes when the state of the system changes; for instance, when the temperature of the system changes, when a substance melts or boils, or when a chemical reaction occurs, the energy changes. Conservation of energy implies that any change in the energy of a system must be balanced by the transfer of energy either into or out of the system. This energy transfer can take the form of either heat transfer or work. Work includes all forms of energy transfer other than heat transfer. Examples of mechanical work include the expansion of a gas against a piston in engines. The change in energy associated with a chemical process is an important aspect of such processes characterizing, for instance, the amount of energy that can be obtained from a fuel system. Because the change in energy associated with a given process is proportional to the amount of substance undergoing that process, this change is best described on a per mole (or per gram) basis, as in heat capacities (for heating/cooling), enthalpies of fusion or vaporization (for physical transformations), and enthalpies of reaction (for chemical transformations). Calorimetry provides a convenient means to measure changes in energy, and thus is used experimentally to determine heat capacities or enthalpies of physical and chemical transformations.

Essential knowledge 5.B.1: Energy is transferred between systems either through heat transfer or through one system doing work on the other system.

a. Heating a cold body with a hot body is a form of energy transfer between two systems. The transfer of thermal energy is an important concept in thermodynamics.

b. An additional form of energy transfer is through work. Work is described by other scientific frameworks, such as Newtonian Mechanics or electromagnetism.

c. In this course, calculations involving work are limited to that associated with changes in volume of a gas. An example of the transfer of energy between systems through work is the expansion of gas in a steam engine or car piston. Reasoning about this energy transfer can be based on molecular collisions with the piston: The gas is doing work on the piston, and energy is transferred from the gas to the piston.

Essential knowledge 5.B.2: When two systems are in contact with each other and are otherwise isolated, the energy that comes out of one system is equal to the energy that goes into the other system. The combined energy of the two systems remains fixed. Energy transfer can occur through either heat exchange or work.

a. When energy is transferred from system 1 to system 2, the energy transferred from system 1 is equal in magnitude to the energy transferred to system 2.

b. If a system transfers energy to another system, its energy must decrease. Likewise, if energy is transferred into a system, its energy must increase.

**LO 5.6 The student is able to use calculations or estimations to relate energy changes associated with heating/cooling a substance to the heat capacity, relate energy changes associated with a phase transition to the enthalpy of fusion/vaporization, relate energy changes associated with a chemical reaction to the enthalpy of the reaction, and relate energy changes to P∆V work. [See SP 2.2, 2.3]**

Essential knowledge 5.B.3: Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions.

a. Heating a system increases the energy of the system, while cooling a system decreases the energy. A liter of water at 50°C has more energy than a liter of water at 25°C.

b. The amount of energy needed to heat one gram of a substance by 1°C is the specific heat capacity of that substance.

c. Energy must be transferred to a system to cause it to melt (or boil). The energy of the system therefore increases as the system undergoes a solid-liquid (or liquid- gas) phase transition. Likewise, a system gives off energy when it freezes (or condenses). The energy of the system decreases as the system undergoes a liquid- solid (or gas-liquid) phase transition.

d. The amount of energy needed to vaporize one mole of a pure substance is the molar enthalpy of vaporization, and the energy released in condensation has an equal magnitude. The molar enthalpy of fusion is the energy absorbed when one mole of a pure solid melts or changes from the solid to liquid state and the energy released when the liquid solidifies has an equal magnitude.

e. When a chemical reaction occurs, the energy of the system decreases (exothermic reaction), increases (endothermic reaction), or remains the same. For exothermic reactions, the energy lost by the reacting molecules (system) is gained by the surroundings. The energy is transferred to the surroundings by either heat or work. Likewise, for endothermic reactions, the system gains energy from the surroundings by heat transfer or work done on the system.

f. The enthalpy change of reaction gives the amount of energy released (for negative values) or absorbed (for positive values) by a chemical reaction at constant pressure.

**LO 5.7 The student is able to design and/or interpret the results of an experiment in which calorimetry is used to determine the change in enthalpy of a chemical process (heating/cooling, phase transition, or chemical reaction) at constant pressure. [See SP 4.2, 5.1, 6.4]**

Essential knowledge 5.B.4: Calorimetry is an experimental technique that is used to determine the heat exchanged/transferred in a chemical system.

a. The experimental setup for calorimetry is the following: A chemical system is put in thermal contact with a heat bath. The heat bath is a substance, such as water, whose heat capacity has been well established by previous experiments. A process is initiated in the chemical system (heating/cooling, phase transition, or chemical reaction), and the change in temperature of the heat bath is determined.

b. Because the heat capacity of the heat bath is known, the observed change in temperature can be used to determine the amount of energy exchanged between the system and the heat bath.

c. The energy exchanged between the system and the heat bath is equal in magnitude to the change in energy of the system. If the heat bath increased in temperature, its energy increased, and the energy of the system decreased by this amount. If the heat bath decreased in temperature, and therefore energy, the energy of the system increased by this amount.

d. Because calorimetry measures the change in energy of a system, it can be used to determine the heat associated with each of the processes listed in 5.B.3. In this manner, calorimetry may be used to determine heat capacities, enthalpies of vaporization, enthalpies of fusion, and enthalpies of reactions. Only constant pressure calorimetry is required in the course.

**LO 5.8 The student is able to draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the breaking and formation of chemical bonds. [See SP 2.3, 7.1, 7.2]**

Enduring understanding 5.C: Breaking bonds requires energy, and making bonds releases energy.

Chemical bonds arise from attractive interactions between negatively charged electrons and the positively charged nuclei of the atoms that make up the bond. As electrons approach a positive charge, the potential energy of a system is lowered. Therefore, having electrons shared between atoms results in the system being in a lower energy state, which can only happen if energy is somehow released. Thus, making chemical bonds releases energy. The converse is true for the opposing process. In order to break a chemical bond, energy must be put into the system to overcome the attractive interaction between the shared electrons and the nuclei of the bonded atoms. When considering chemical reactions, however, it is important to recognize that in most cases both bond breaking and bond formation occurs. The overall energy change is determinable from looking at all the energy inputs (to break bonds) and the energy outputs (from the formation of bonds). There are several ways to calculate energy changes for reactions, including traditionally used methods involving enthalpy of formation. One compelling conceptual model for this calculation is to use average bond energies or enthalpies to determine the energy change of a reaction. Many practical examples of chemistry take place in solvents (often water); thus, the determination of overall changes in energy for a reaction must include consideration of any solvent interactions with reactants and products. Energy may appear in different forms, such as potential energy or kinetic energy. In chemical systems, the stored energy is called chemical energy, and the energy of motion (translational, rotational, or vibrational) is called thermal energy. Chemical energy is the potential energy associated with chemical systems. The amount of chemical energy in a system changes when the chemicals are allowed to react. The energy transferred to or from the surroundings when a chemical system undergoes a reaction is often in the form of thermal energy.

Essential knowledge 5.C.1: Potential energy is associated with a particular geometric arrangement of atoms or ions and the electrostatic interactions between them.

a. The attraction between the electrons of one atom and the protons of another explains the tendency for the atoms to approach one another. The repulsion between the nuclei (or core electrons) explains why the atoms repel one another at close distance. The distance at which the energy of interaction is minimized is called the bond length, and the atoms vibrate about this minimum energy position.

b. A graph of energy versus the distance between atoms can be plotted and interpreted. Using this graph, it is possible to identify bond length and bond energy.

c. Conceptually, bond making and bond breaking are opposing processes that have the same magnitude of energy associated with them. Thus, convention becomes important, so we define the bond energy as the energy required to break a bond.

d. Because chemical bonding arises from electrostatic interaction between electrons and nuclei, larger charges tend to lead to larger strengths of interaction. Thus, triple bonds are stronger than double or single bonds because they share more pairs of electrons.

e. Stronger bonds tend to be shorter bonds.

Essential knowledge 5.C.2: The net energy change during a reaction is the sum of the energy required to break the bonds in the reactant molecules and the energy released in forming the bonds of the product molecules. The net change in energy may be positive for endothermic reactions where energy is required, or negative for exothermic reactions where energy is released.

a. During a chemical reaction, bonds are broken and/or formed, and these events change the potential energy of the reaction system.

b. The average energy required to break all of the bonds in the reactant molecules can be estimated by adding up the average bond energies or bond enthalpies for all the bonds in the reactant molecules. Likewise, the average energy released in forming the bonds in the products can be estimated. If the energy released is greater than the energy required, then the reaction is exothermic. If the energy required is greater than the energy released, then the reaction is endothermic.

c. For an exothermic reaction, the products are at a lower potential energy compared with the reactants. For an endothermic reaction, the products are at a higher potential energy than the reactants.

d. In an isolated system, energy is conserved. Thus, if the potential energy of the products is lower than that of the reactants, then the kinetic energy of the products must be higher. For an exothermic reaction, the products are at a higher kinetic energy. This means that they are at a higher temperature. Likewise, for an endothermic reaction, the products are at a lower kinetic energy and, thus, at a lower temperature.

e. Because the products of a reaction are at a higher or lower temperature than their surroundings, the products of the reaction move toward thermal equilibrium with the surroundings. Thermal energy is transferred to the surroundings from the hot products in an exothermic reaction. Thermal energy is transferred from the surroundings to the cold products in an endothermic reaction.

f. Although the concept of “state functions” is not required for the course, students should understand these Hess’s law ideas: When a reaction is reversed, the sign of the enthalpy of the reaction is changed; when two (or more) reactions are summed to obtain an overall reaction, the enthalpies of reaction are summed to obtain the net enthalpy of reaction.

g. Tables of standard enthalpies of formation can be used to calculate the standard enthalpy of reactions. Uses should go beyond algorithmic calculations and include, for instance, the use of such tables to compare related reactions, such as extraction of elemental metals from metal oxides.

**LO 5.12 The student is able to use representations and models to predict the sign and relative magnitude of the entropy change associated with chemical or physical processes. [See SP 1.4]**

Enduring understanding 5.E: Chemical or physical processes are driven by a decrease in enthalpy or an increase in entropy, or both. One of the most powerful applications of thermodynamic principles is the ability to determine whether a process corresponding to a physical or chemical change will lie toward the reactant or product side when the process reaches a steady equilibrium state. The standard change in Gibbs free energy, ΔG° = ΔH° – TΔS°, is used to make this determination. If ΔG° < 0, then products are favored at equilibrium, and the forward process is considered to be “thermodynamically favored.” Conversely, if ΔG° > 0, then reactants are favored at equilibrium, and the reverse process is considered to be “thermodynamically favored.” Both the enthalpy change (ΔH°) and the entropy change (ΔS°) are closely related to the structure and nature of the components of the system; for this reason, it is often possible to make qualitative determinations concerning the sign (and magnitude) of ΔG° without explicit calculation. Enthalpy changes are closely related to the relative bond energies (and relative strengths of intermolecular interactions) of the reactants and products; entropy changes are generally related to the states of the components and the number of individual particles present. In this way, the Gibbs free energy provides a framework based on molecular structure and intermolecular interactions for understanding why some chemical reactions are observed to proceed to near completion, while others reach equilibrium with almost no products being formed. Some processes that are not thermodynamically favored (for example, the recharging of a battery) can be driven to occur through the application of energy from an external source — in this case, an electrical current. Importantly, in biochemical systems, some reactions that oppose the thermodynamically favored direction are driven by coupled reactions. Thus, a cell can use energy to create order (a direction that is not thermodynamically favored) via coupling with thermodynamically favored reactions. For example, many biochemical syntheses are coupled to the reaction in which ATP is converted to ADP + phosphate. In some cases, processes that are thermodynamically favored are not observed to occur because of some kinetic constraint; quite often there is a high activation energy to overcome in order for the process to proceed. Thus, although Gibbs free energy can be used to determine which direction of a chemical process is thermodynamically favored, it provides no information about the rate of the process, or the nature of the process on the microscopic scale.

Essential knowledge 5.E.1: Entropy is a measure of the dispersal of matter and energy.

a. Entropy may be understood in qualitative terms rather than formal statistical terms. Although this is not the most rigorous approach to entropy, the use of qualitative reasoning emphasizes that the goal is for students to be able to make predictions about the direction of entropy change, ΔS°, for many typical chemical and physical processes.

b. Entropy increases when matter is dispersed. The phase change from solid to liquid, or from liquid to gas, results in a dispersal of matter in the sense that the individual particles become more free to move, and generally occupy a larger volume. Another way in which entropy increases in this context is when the number of individual particles increases when a chemical reaction precedes whose stoichiometry results in a larger number of product species than reacting species. Also, for a gas, the entropy increases when there is an increase in volume (at constant temperature), and the gas molecules are able to move within a larger space.

c. Entropy increases when energy is dispersed. From KMT, we know that the distribution of kinetic energy among the particles of a gas broadens as the temperature increases. This is an increase in the dispersal of energy, as the total kinetic energy of the system becomes spread more broadly among all of the gas molecules. Thus, as temperature increases, the entropy increases.

**LO 5.13 The student is able to predict whether or not a physical or chemical process is thermodynamically favored by determination of (either quantitatively or qualitatively) the signs of both ΔH° and ΔS°, and calculation or estimation of ΔG° when needed. [See SP 2.2, 2.3, 6.4, connects to 5.E.3]**

Essential knowledge 5.E.2: Some physical or chemical processes involve both a decrease in the internal energy of the components (ΔH° < 0) under consideration and an increase in the entropy of those components (ΔS° > 0). These processes are necessarily “thermodynamically favored” (ΔG° < 0).

a. For the purposes of thermodynamic analysis in this course, the enthalpy and the internal energy will not be distinguished.

b. The phrase “thermodynamically favored” means that products are favored at equilibrium (K > 1).

c. Historically, the term “spontaneous” has been used to describe processes for which ΔG° < 0. The phrase “thermodynamically favored” is used here to avoid misunderstanding and confusion that can occur because of the common connotation of the term “spontaneous,” which students may believe means “immediately” or “without cause.”

d. For many processes, students will be able to determine, either quantitatively or qualitatively, the signs of both ΔH° and ΔS° for a physical or chemical process. In those cases where ΔH° < 0 and ΔS° > 0, there is no need to calculate ΔG° in order to determine that the process is thermodynamically favored.

e. As noted below in 5.E.5, the fact that a process is thermodynamically favored does not mean that it will proceed at a measurable rate.

f. Any process in which both ΔH° > 0 and ΔS° < 0 are not thermodynamically favored, (ΔG° > 0) and the process must favor reactants at equilibrium (K < 1). Because the signs of ΔS° and ΔH° reverse when a chemical or physical process is reversed, this must be the case.

**LO 5.14 The student is able to determine whether a chemical or physical process is thermodynamically favorable by calculating the change in standard Gibbs free energy. [See SP 2.2, connects to 5.E.2]**

Essential knowledge 5.E.3: If a chemical or physical process is not driven by both entropy and enthalpy changes, then the Gibbs free energy change can be used to determine whether the process is thermodynamically favored.

a. Some exothermic reactions involve decreases in entropy.

b. When ΔG° > 0, the process is not thermodynamically favorable. When ΔG° < 0, the process is thermodynamically favorable.

c. In some reactions, it is necessary to consider both enthalpy and entropy to determine if a reaction will be thermodynamically favorable. The freezing of water and the dissolution of sodium nitrate in water provide good examples of such situations.

**Mastering Chemistry Assignment Breakdown**

| [**#**](http://session.masteringchemistry.com/myct/yui-dt0-href-ordinal) | [**TITLEShow Descriptions**](http://session.masteringchemistry.com/myct/yui-dt0-href-title) | **DIFFICULTY** | **MEDIAN TIME** |
| --- | --- | --- | --- |
| [**This Course**](http://session.masteringchemistry.com/myct/yui-dt0-href-courseDifficulty) | [**System**](http://session.masteringchemistry.com/myct/yui-dt0-href-systemDifficulty) | [**This Course**](http://session.masteringchemistry.com/myct/yui-dt0-href-formattedCourseTime) | [**System**](http://session.masteringchemistry.com/myct/yui-dt0-href-formattedSystemTime) |
| 1 | [Problem 5.17](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917429) | -- | 1 | -- | 2m |
| 2 | [Problem 5.21](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917468) | -- | 1 | -- | 1m |
| 3 | [Give It Some Thought: 5.1](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917470) | -- | 1 | -- | 1m |
| 4 | [Go Figure 5.2](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917432) | -- | 1 | -- | <1m |
| 5 | [Go Figure 5.3](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917743) | -- | 1 | -- | 1m |
| 6 | [Go Figure 5.4](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917457) | -- | 1 | -- | <1m |
| 7 | [Problem 5.22](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917745) | -- | 1 | -- | 1m |
| 8 | [Problem 5.15](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917459) | -- | 1 | -- | 7m |
| 9 | [Problem 5.26](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917435) | -- | 1 | -- | 2m |
| 10 | [Give It Some Thought: 5.3](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917751) | -- | 1 | -- | 1m |
| 11 | [Go Figure 5.7](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917472) | -- | 1 | -- | 1m |
| 12 | [Go Figure 5.6](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917436) | -- | 2 | -- | 2m |
| 13 | [Problem 5.3](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917473) | -- | 1 | -- | 1m |
| 14 | [Problem 5.4](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917765) | -- | 1 | -- | 3m |
| 15 | [Problem 5.6](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917474) | -- | 2 | -- | 6m |
| 16 | [Problem 5.7](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917758) | -- | 1 | -- | 2m |
| 17 | [Problem 5.27](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917782) | -- | 1 | -- | 8m |
| 18 | [Chapter 5 Question 5 - Multiple Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917783) | -- | 1 | -- | 1m |
| 19 | [Chapter 5 Reading Quiz Question 3](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917477) | -- | 1 | -- | 1m |
| 20 | [Chapter 5 Question 7 - Multiple Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917478) | -- | 2 | -- | 1m |
| 21 | [Chapter 5 Question 8 - Multiple Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917775) | -- | 1 | -- | 1m |
| 22 | [Chapter 5 Question 9 - Multiple Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917802) | -- | 2 | -- | 1m |
| 23 | [Chapter 5 Question 10 - Multiple Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917479) | -- | 2 | -- | 1m |
| 24 | [PV Work](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31918735) | -- | 2 | -- | 4m |
| 25 | [Give It Some Thought: 5.7](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917809) | -- | 2 | -- | 2m |
| 26 | [Go Figure 5.10](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31917810) | -- | 1 | -- | 1m |
| 27 | [Problem 5.8](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31918743) | -- | 1 | -- | 1m |
| 28 | [Chapter 5 Question 16 - Multiple Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920576) | -- | 1 | -- | <1m |
| 29 | [Chapter 5 Question 15 - Multiple Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31919756) | -- | 1 | -- | <1m |
| 30 | [Give It Some Thought: 5.6](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920043) | -- | 1 | -- | 1m |
| 31 | [Problem 5.39](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920047) | -- | 1 | -- | 6m |
| 32 | [Problem 5.41](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920048) | -- | 3 | -- | 6m |
| 33 | [Give It Some Thought: 5.8](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920050) | -- | 1 | -- | 1m |
| 34 | [Chapter 5 Question 17 - Bimodal](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920602) | -- | 3 | -- | 2m |
| 35 | [Chapter 5 Question 18 - Bimodal](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920051) | -- | 2 | -- | 2m |
| 36 | [Heat Capacity](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920053) | -- | 2 | -- | 14m |
| 37 | [Using the Law of Conservation of Energy](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920054) | -- | 3 | -- | 11m |
| 38 | [Coffee Cup Calorimetry](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920056) | -- | 5 | -- | 6m |
| 39 | [Specific Heat](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920057) | -- | 3 | -- | 12m |
| 40 | [± Calorimetry](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920058) | -- | 5 | -- | 19m |
| 41 | [± Enthalpy of a Phase Change](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920622) | -- | 5 | -- | 24m |
| 42 | [± Heat of Solution](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920589) | -- | 4 | -- | 12m |
| 43 | [Problem 5.53](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920623) | -- | 1 | -- | 3m |
| 44 | [Problem 5.59](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920060) | -- | 2 | -- | 8m |
| 45 | [Problem 5.52](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920624) | -- | 1 | -- | 5m |
| 46 | [Chapter 5 Question 27 - Multiple Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920625) | -- | 1 | -- | 1m |
| 47 | [Procedure for Using Hess's Law](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920061) | -- | 1 | -- | 5m |
| 48 | [Apply Hess's Law](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920626) | -- | 3 | -- | 11m |
| 49 | [Interactive Activity—Applications of Hess’s Law](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920642) | -- | 2 | -- | 9m |
| 50 | [Problem 5.64](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920631) | -- | 2 | -- | 4m |
| 51 | [Problem 5.63](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920633) | -- | 1 | -- | 2m |
| 52 | [Chapter 5 Question 39 - Bimodal](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920610) | -- | 2 | -- | 2m |
| 53 | [Chapter 5 Question 40 - Bimodal](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920611) | -- | 2 | -- | 1m |
| 54 | [Chemical Energy](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920597) | -- | 3 | -- | 10m |
| 55 | [Standard Enthalpy of Reaction](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920648) | -- | 3 | -- | 5m |
| 56 | [Formation Reactions](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920601) | -- | 4 | -- | 9m |
| 57 | [Standard Enthalpy of Formation Reaction](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920692) | -- | 4 | -- | 7m |
| 58 | [± Enthalpy](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920727) | -- | 3 | -- | 9m |
| 59 | [Problem 5.76](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920733) | -- | 3 | -- | 5m |
| 60 | [Go Figure 5.22](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920714) | -- | 1 | -- | 1m |
| 61 | [Problem 5.67](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920736) | -- | 1 | -- | 2m |
| 62 | [Problem 5.10](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920773) | -- | 2 | -- | 12m |
| 63 | [Thermodynamics and Redox](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920782) | -- | 2 | -- | 20m |
| 64 | [Solution Formation](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31921354) | -- | 2 | -- | 3m |
| 65 | [± Energetics of Solution Formation](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31921503) | -- | 1 | -- | 6m |
| 66 | [Problem 13.17](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31921504) | -- | 1 | -- | 1m |
| 67 | [Go Figure 13.4](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31921486) | -- | 1 | -- | 1m |
| 68 | [Chapter 13 Question 1 - Bimodal](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31921487) | -- | 1 | -- | 1m |
| 69 | [Chapter 13 Question 1 - Multiple-Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31921488) | -- | 2 | -- | 1m |
| 70 | [Chapter 13 Question 7 - Multiple-Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920755) | -- | 2 | -- | 2m |
| 71 | [Problem 19.1](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31920757) | -- | 1 | -- | 2m |
| 72 | [Problem 19.2](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31921508) | -- | 1 | -- | 3m |
| 73 | [Problem 19.3](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31921510) | -- | 1 | -- | 5m |
| 74 | [Problem 19.8](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922098) | -- | 1 | -- | 2m |
| 75 | [Problem 19.9](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922267) | -- | 2 | -- | 4m |
| 76 | [Problem 19.15](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922665) | -- | 1 | -- | 2m |
| 77 | [Give It Some Thought: 19.1](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922658) | -- | 1 | -- | <1m |
| 78 | [Give It Some Thought: 19.2](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922270) | -- | 1 | -- | <1m |
| 79 | [Go Figure 19.1](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922659) | -- | 1 | -- | <1m |
| 80 | [Chapter 19 Question 3 - Multiple-Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922666) | -- | 1 | -- | 1m |
| 81 | [Chapter 19 Question 1 - True/False](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922660) | -- | 1 | -- | <1m |
| 82 | [Chapter 19 Question 2 - True/False](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922289) | -- | 1 | -- | <1m |
| 83 | [Problem 19.36](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922300) | -- | 2 | -- | 4m |
| 84 | [Chapter 19 Question 4 - True/False](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922891) | -- | 1 | -- | <1m |
| 85 | [Chapter 19 Question 15 - Multiple-Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923324) | -- | 1 | -- | 1m |
| 86 | [Give It Some Thought: 19.8](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922841) | -- | 1 | -- | 1m |
| 87 | [Problem 19.48](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923327) | -- | 1 | -- | <1m |
| 88 | [Standard Free Energy of Formation](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31922896) | -- | 2 | -- | 8m |
| 89 | [± Gibbs Free Energy: Temperature Dependence](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923407) | -- | 2 | -- | 9m |
| 90 | [Give It Some Thought: 19.9](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923411) | -- | 1 | -- | 1m |
| 91 | [Give It Some Thought: 19.10](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923424) | -- | 1 | -- | <1m |
| 92 | [Go Figure 19.16](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923397) | -- | 1 | -- | <1m |
| 93 | [Chapter 19 Reading Quiz Question 7](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923455) | -- | 1 | -- | 2m |
| 94 | [Chapter 19 Question 21 - Bimodal](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923461) | -- | 1 | -- | 1m |
| 95 | [Chapter 19 Question 31 - Bimodal](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923399) | -- | 1 | -- | 1m |
| 96 | [Chapter 19 Question 8 - Algorithmic](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923434) | -- | 3 | -- | 3m |
| 97 | [± Gibbs Free Energy: Spontaneity](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923514) | -- | 3 | -- | 7m |
| 98 | [± Enthalpy, Entropy, and Spontaneity](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923495) | -- | 2 | -- | 6m |
| 99 | [Pause and Predict Video Quiz: The Balance Between Enthalpy and Entropy](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923496) | -- | 2 | -- | 4m |
| 100 | [Problem 19.61](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923518) | -- | 1 | -- | 10m |
| 101 | [Problem 19.71](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923498) | -- | 1 | -- | 7m |
| 102 | [Problem 19.65](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923543) | -- | 2 | -- | 3m |
| 103 | [Problem 19.66](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923480) | -- | 1 | -- | 6m |
| 104 | [Problem 19.70](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923525) | -- | 3 | -- | 5m |
| 105 | [Chapter 19 Reading Quiz Question 9](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923481) | -- | 1 | -- | 1m |
| 106 | [Chapter 19 Reading Quiz Question 8](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923583) | -- | 2 | -- | 1m |
| 107 | [Chapter 19 Question 11 - Algorithmic](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923549) | -- | 2 | -- | 1m |
| 108 | [A Molecular View of Thermodynamics](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923559) | -- | 3 | -- | 7m |
| 109 | [± Coupled Reactions](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923630) | -- | 3 | -- | 11m |
| 110 | [± Gibbs Free Energy and Equilibrium](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923876) | -- | 3 | -- | 20m |
| 111 | [± Gibbs Free Energy: Equilibrium Constant](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923878) | -- | 3 | -- | 15m |
| 112 | [± Isomerization of Glucose to Fructose](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923687) | -- | 2 | -- | 5m |
| 113 | [Chapter 19 Question 46 - Bimodal](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923880) | -- | 2 | -- | 4m |
| 114 | [Chapter 19 Question 44 - Multiple-Choice](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923690) | -- | 1 | -- | <1m |
| 115 | [Chapter 19 Question 15 - Algorithmic](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923714) | -- | 2 | -- | 1m |
| 116 | [Chapter 19 Question 16 - Algorithmic](http://session.masteringchemistry.com/myct/itemView?showStatsForCourse=1110976&view=solution&showStats=1&assignmentProblemID=31923888) | -- | 1 | -- | 2m |
| **Average:** |  | **Total:** |
| **--** | **1.7** | **-- 489 minutes** |