04 Mar 24 Reflective Writing Assignment

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Reflective Writing Assignment due Tues Mar 24

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Consider the same set up we used for showing thermal equilibrium: a coffee mug with a second smaller container inside. Let there be 20 mL of hot water in the inner container, and 100 mL of cold water outside. Thermometers are used to monitor the temperatures in each.

Part A

Write a description using a molecular-level perspective about the initial conditions for this system and what happens over time until things no longer change. Indicate your estimate for the ending condition. The story must describe exactly how the system gets from starting condition to end condition. [This question requires recalling what we did and talked about in class.]

Part B

Look at the second attachment, which shows an illustration of the way atoms are bonded together in metals, and the way in which atoms are bonded together in a material like glass or sand. Generally, metals conduct heat much more quickly than materials like silica (or glass). Suggest an explanation for why metals conduct heat more quickly. [This question requires extending the idea in Part A and connecting that idea to an idea that we talked about early in the semester.]
Reflective Writing Assignment

**Part A:**

In this scenario, there is a coffee mug with 100 mL of cold water, and inside the coffee mug, there is a smaller container filled with 20 mL of hot water. Thermometers are used to monitor the temperature in each. Here is how the water gets to thermal equilibrium. In the smaller container of warm water, the water molecules are going to be moving faster because they have a higher average kinetic energy than the cold water molecules. The collisions between the warm water molecules are also going to be more forceful than the collisions between the cold water molecules. There is a container separating the hot water from the cold water. The molecules in this solid container will be vibrating about a fixed position.

For the kinetic energy in the hot water molecules to transfer to the cold water molecules, it has to go through the middle container. The fast moving hot water molecules will begin to collide with the fixed, vibrating molecules of the solid container. By doing this, the hot water molecules will transfer their kinetic energy to the molecules in the container. The molecules in the container will receive the kinetic energy from the hot water molecules, and they will begin to vibrate faster. The molecules in the container will begin to vibrate faster and collide with one another. So far, the kinetic energy has transferred from the hot water molecules into the molecules in the container, and at this point we would see the temperature of the hot water begin to fall, because the average kinetic energy is falling.

The kinetic energy will transfer through the container until the energy reaches the molecules on the outer edge of the container. These molecules in the container will be moving faster than the cold water molecules, so when the cold water molecules collide with the molecules in the container, the cold water molecules will begin to receive kinetic energy. At last, the cold water molecules will begin to move faster, and they will begin to have more forceful collisions. As the cold water molecules receive energy, the temperature of the cold water will begin to increase.

We see the flow of kinetic energy from the hot water, through the container, into the cold water. As the hot water loses kinetic energy, its temperature drops, and as the cold water receives kinetic energy, its temperature increases. When both waters are the same temperature (have the same level of kinetic energy), this transfer of heat will cease to happen. The body with less energy will always receive kinetic energy from the body with more energy. When the energy levels between the molecules are equal, there will be no more receiving or giving of kinetic energy.

Now, this scenario doesn't give specific initial temperatures, but because there is more cold water than there is hot water, the ending temperature will be a lot closer to the initial cold water temperature than the initial hot water temperature. When there is more cold water than hot water, there are more cold water molecules drawing kinetic energy from a smaller number of hot water molecules. Because of this, the temperature for thermal equilibrium will be much closer to the initial temperature for the cold water. If there is more hot water molecules than cold water molecules, there will be less cold water molecules drawing energy from the hot water molecules, so the thermal equilibrium will be closer to the hot water temperature. I repeat; for this scenario, my estimate for the ending condition is that the final temperature will be closer to the initial cold water temperature.
Part B:

Based on the attachment that depicts the way that atoms are bounded together in metals in glass, it appears that metal conducts heat better than glass because of their respective electron arrangements. In metals, the electrons are not stuck to the individual atoms. The electrons are free to roam among the atoms. My belief is that both the atoms and the electrons can receive thermal energy. As we know, the atoms in a solid don’t float freely, but rather they vibrate in a fixed position. In metals, the conduction of heat will take place in the vibrating of the atoms. On top of vibration and collisions between particles, the electrons have energy too, and they are allowed to float freely and transfer energy between the atoms, which will make the conduction process happen faster.

Now let’s take a look at how glass is made up. The electrons in glass aren’t allowed to float freely. The electrons are shared exclusively between two atoms. The electrons cannot move from the positions they are in. Glass is a poorer conductor of heat than metal because glass has a smaller number of free-floating electrons. If the electrons aren’t moving freely like they are in metal, they won’t transfer kinetic energy between the atoms, so it will take longer for glass to conduct heat. Essentially, there are two ways of transferring heat. The first way is what we have mainly discussed during the semester. Energy is transferred through the particles colliding and interacting. This happens in both glass and metal. The second way of transferring heat is through the free electrons. Because metal has these free electrons and glass doesn’t, metal will conduct heat faster than glass does. In glass, the energy has to overcome the bonds between the atoms and the electrons for the glass to conduct heat. In metal, there are no bonds between the atoms and the electrons.
Part A:
The initial conditions of the molecules in the 20mL of hot water will be moving at a faster speed and be more spread out than the molecules of the 100mL of cold water. The hot water has more heat energy than the cold water. This is why the molecules will be moving at a faster rate and be further apart from each other. The molecules of the hot water will decrease speed and the molecules of the cold water will increase speed as the system goes from starting to ending conditions. Over time, heat energy is going to be transferred in the system. Heat energy will be lost from the hot water and gained by the cold water. This transfer of thermal energy will continue until a thermal equilibrium is reached. Thermal equilibrium is the zeroth law of thermodynamics. This means that a transfer of heat will continue between the hot and cold water until they reach the same temperature. When the initial hot and cold water are at the same temperature, they have reached a thermal equilibrium and there will be no more heat transfer between them. When this happens, the molecules in both the initial hot water and cold water will both be moving at the same speed. The initial hot water molecules will be moving slower and will be closer together than in the beginning of the experiment. The molecules of the cold water will be moving faster at the end and further apart from each other than they were in the beginning of the experiment.

Part B:
Metals are better at conducting heat than other materials such as glass. Looking at the attachment, you can see that the atoms in a metal are bonded together in a different way than those of a glass. Metallic bonds have close packing. This packing of the atoms is also ordered and symmetrical which makes metals good conductors of heat. The atoms in a substance like glass are not packed in a very symmetrical form. Symmetry in the packing of atoms is one reason why metals are better at conducting heat than glass. Another reason is because the electrons in metals are weakly bound to the metal atoms. Since these electrons can move around and are not stuck to one atom in the metal, they will carry kinetic energy across the entire metal. The electrons in glass can’t move from their location. These electrons are stuck between the two atoms that share them. Packing, better symmetry, and the freedom of electrons to move around are all factors that make metals better conductors of heat than glass.
Reflective Writing Assignment

PART A:

Initially in this system, the inner container has many “hot” molecules, moving very quickly and colliding with each other and the inside of the container, where as the outside container has many “cold” molecules that are not moving quickly, and not colliding to any large extent. When the smaller container of “hot” water is placed inside the larger “cold” container, immediately a change begins to occur, similar to a domino effect. The “hot” molecules are colliding rapidly, and they are making contact with the molecules of the innermost part of the inner container. As those collisions occur, the kinetic energy is transferred from the “hot” molecule to the solid molecule of the inner container. As this happens, the molecules of the innermost of the inner container begin colliding with each other, then colliding with molecules in the middle of the inner container, and eventually with the outermost molecules of the inner container. This entire time, energy is being moved from the initial point of the liquid in the inner container, to and through the solid of the inner container. Once the outermost molecules of the inner container have this transferred kinetic energy, they collide with the “cold” molecules they are in direct contact with in the larger cold solution. These collisions continue to occur between the inner container and the “cold” molecules until all of the “cold” molecules have been reached, and eventually the inner portion of the outer container is reached by this domino effect. The kinetic energy from the formerly “cold” molecules, which are now warmer because of the addition of kinetic energy, collide with and through the outer container as well. The kinetic energy is moved from the inside out, similar to a rippling effect. This ripple will continue until homeostasis is reached, and the molecules (both formerly “hot” and “cold”) are not uneven in energy levels, at which point the temperatures of the two solutions, after a period of time (time depends on the initial temperature) will reach thermal equilibrium and be at equivalent temperatures.

PART B:

This question regards the same phenomena as the test question about the dishwasher safe containers. As seen in the pictures, the metal has a much more simple, consistent structure than the glass or sand. The shape of the molecule of metal is a shape that is easily “stacked” in an orderly fashion, with many of them being able to be in a small amount of space together. This is important because the glass or sand does not have that quality, and its molecular shape does not allow for many molecules to be together in close proximity to each other. When conducting heat, the closer the molecules are to each other, the easier and faster the heat will transfer, thus making metal a better conductor of heat. In terms of how this phenomena relates to earlier in the semester, I am not exactly sure which aspect we are referring to, but I know from more recent information we learned, especially that day in the computer lab, that the way in which molecules are arranged greatly affects what they are capable of and how much energy it takes to do so. Since metal conducts heat easily, it is not only faster, but I would think it would take less energy to transfer, than glass where the energy to go the distance between the molecules is greater, making more time and energy wasted and expended.
Consider the same set up we used for showing thermal equilibrium: a coffee mug with a second smaller container inside. Let there be 20 mL of hot water in the inner container, and 100 mL of cold water outside. Thermometers are used to monitor the temperatures in each.

Part A

Write a description using a molecular-level perspective about the initial conditions for this system and what happens over time until things no longer change. Indicate your estimate for the ending condition. The story must describe exactly how the system gets from starting condition to end condition. [This question requires recalling what we did and talked about in class.]

In the initial conditions of the experiment, there is a small container with 20mL of hot water that has just been placed inside a coffee mug that holds 100mL of cold water. The hot water has molecules of H2O that are moving quickly, and bouncing off of the walls of the small container it is comprised in. The state of the matter is liquid. It has an increased level of kinetic and thermal energy compared to the large container. The temperature reading from the thermometer will be higher than that of the cold water. The cold water has molecules of H2O that are moving moderately fast (but still slower than hot water), and are tapping off of the walls of the large container is it comprised in. The state of the matter is liquid. It has a decreased level
of kinetic and thermal energy compared to the hot water. The temperature reading from the thermometer will be lower than that of the hot water.

In the middle of the experiment, the two substances are going to attempt to reach thermal equilibrium. Thermal equilibrium is best defined as the point at which all parts in a system are the same temperature. In other words, the thermometers measuring the temperature of the two cups will eventually read the same temperature. During the process of trying to attain thermal equilibrium, energy must be transferred. According to the law of conservation of energy, energy cannot be created or destroyed. Instead, it is only transferred from one thing to another. This happens in the described experiment. Thermal and kinetic energy is transferred from the hot water to the cold water. This occurs through the wall of the small container. The molecules with higher energy, otherwise known as the molecules in the hot water, bang against the molecules of the small container they are comprised in. The molecules in the hot water have higher energy because energy increases with heat and temperature. This collision of the high energy molecules and the molecules of the container causes an energy transfer, since it is known that energy cannot be created or destroyed. This energy transfer through the molecules of the small container and continues on further to the lower energy molecules. The lower energy molecules are the ones that are in the cold water. The energy of the high energy molecules hitting against the small container travels through the molecules in the wall of the small container to enter the larger container. When this happens, thermal energy is passed, causing the temperature in the cold water to increase. The transfer of energy also causes the temperature of the hot water to decrease, because the hot water has lost some energy and the cold water has gained some energy from the transfer. If the thermometer recordings are compared, the probe in the cold water will slowly increase, and the one in the hot water will slowly decrease. This is showing the process of attaining
thermal equilibrium. It has not been reached yet, but the range between the two temperatures is diminishing as they both attempt to reach the same temperature.

In the ending conditions of the experiment, thermal equilibrium is attained in the system. This means that the temperatures in the cold and hot water will stop fluctuating, and the probes will reflect the same numerical value. This will be demonstrated by looking at and recording the temperatures on the two thermometers. The equilibrium being reached in the system indicates that the energy transfer from the hot to the cold water has ceased. It has stopped because the temperatures are the same in each cup, as is the amount of energy. Therefore, the molecules are moving at the same pace, and they have the same amount of energy in both cups. Even though the molecules may still be banging off of the wall of the smaller container, energy is no longer transferred because it is unnecessary.

Part B

Look at the second attachment, which shows an illustration of the way atoms are bonded together in metals, and the way in which atoms are bonded together in a material like glass or sand. Generally, metals conduct heat much more quickly than materials like silica (or glass). Suggest an explanation for why metals conduct heat more quickly. [This question requires extending the idea in Part A and connecting that idea to an idea that we talked about early in the semester.]

As has been mentioned in lecture, metal is a good conductor of heat, whereas glass is considered to be a weak conductor. This is because metal atoms have free electrons that are on the outer shell of the atom, which glass does not have. These “free” outer electrons are known as
valence electrons, and they are not necessarily attached and “stuck” to any one atom or covalent bond, hence being called “free”. This free electron allows for easier heat transfer because it is not “stuck” as the electrons of glass are. The bond with the outer electron in metals is weak. This weak bond allows energy to be transferred very easily to and from the electron, since it is not attached to a second atom. This easy transfer of energy repeats throughout the entire surface of the metal, from one electron to another, allowing it to travel throughout the entire surface of the metal. In other words, this is how energy and heat is easily transferred throughout metals, and why metals are considered such good conductors of heat.

This structure including an outer electron differs from glass. In glass, the electrons in the atom are covalently bonded. Covalent bonds are very strong and rigid. This is because in order to be considered a covalent bond, the two atoms must share a singular electron pair in order for each atom to be stable. This sharing of electrons means the attraction between the two atoms is very strong and hard to be broken. Covalent bonds are so strong that they do not allow the electrons to move around. Without the free electrons moving as they are in a metal substance, heat is not as easily transferred and conducted in glass. This is because the electrons cannot move throughout the metal substance. In a metal substance, the free electrons are so weakly bonded that they can easily transfer the energy from the hot end of a brick of metal to a cool end due to their fluidity, and allow the heat to be conducted throughout the whole piece of metal and to other objects. In glass, the electrons are stuck in place, meaning that the heat does not “move” or conduct through the piece of glass as efficiently. In other words, in glass, the energy does not transfer as easily due to the electrons being “tied up” by being shared between two atoms instead of being free. This leads to inefficiency in heat and energy transfer (also known as conduction), which is is what allows metal to be a better conductor of heat than glass is.
Reflective Assignment

Part A:

The experiment which involves a smaller container submerged in another larger container which is filled with water helps to demonstrate the law of thermal equilibrium. The inner container contains a smaller quantity of hot water, while there is a larger quantity of cold water in the outer container (mug). On the molecular level there are molecules which compose each of the substances whether it be the cold water, hot water, or the containers. Hot water contains a lot of energy or kinetic energy which can be seen by the fast pace of the water’s molecules. Hot water is composed of molecules which are moving rapidly and colliding with one another frequently. The inner container which holds the hot water is composed of molecules just like any other substance. Before the hot water was added to the inner container the molecules were moving relatively slowly assuming the container was being stored at room temperature. Once the hot water was added it began to transfer heat energy to the container until they both reached the same temperature, law of thermal equilibrium. The cold water’s molecules are moving slowly as we visualized using the Phet simulation earlier in the semester. Therefore when the cold water was added to the mug, assuming the mug was at room temperature, heat is drawn from the mug until the cold water and the mug are at the same temperature. Once the inner container is submerged in the outer container the same process occurs between the cold water and the inner...
container. The process I have just described would occur if each container was allotted the time to reach a thermal equilibrium with the substance it is holding. The same process would occur if the inner and outer containers came into contact quickly. The hot water transfers energy to the container it is being held in, the inner container transfers heat to the cold water, and then the “cold” water transfers heat to the mug. On the molecular level this involves the rapidly moving molecules colliding with the molecules of the container. As the water’s molecules continue to hit the container’s molecules they begin to move quicker and quicker. With each collision the molecules will move faster. As the container’s molecules begin to increase speed they will begin to accelerate the cold water’s molecules. This can be described as molecules colliding with one another causing them to “spin”. With each collision the molecule of the colder substance spins faster and faster. The molecule which initially collides with the “warmer” molecule will begin to speed up and collide with molecules in the same substance causing them to accelerate also. As these molecules increase speed they will begin to have greater collisions with the colder substance, cold water, causing them to increase speed as well. The transfer of heat energy can be seen by the increase in speed of the particles. This sequence can be compared to a chain reaction. The increase in speed and the occurrence of several collisions between molecules illustrates the transfer of energy from one substance to another. This transfer of energy is the transfer of “heat” from one substance to the other. As the speed of the substance’s molecules increase its kinetic energy is increasing also. Therefore the average kinetic energy of the substance is increasing likewise, which is the same as the temperature of the substance increasing. The ending result would be the molecules of each substance moving at the same rate and containing the same amount of energy as one another. Therefore each substance would have the same temperature.
Overall, from the molecular perspective several things occur as the substances gradually migrate towards thermal equilibrium. This experiment deals with four substances: hot water, an inner container, cold water, and an outer container. Each of these substances is composed of many molecules moving at a speed determined by their amount of kinetic energy or temperature as discussed previously. When these substances come into contact they try to achieve thermal equilibrium. For these purposes I will assume that initially the cold water and the mug are at the same temperature and the inner container is placed in the water of the mug and then filled with hot water. The inner container is cooler than the hot water therefore heat will transfer from the hot water to the inner container. The inner container has molecules which are moving about slowly. The hot water’s fast paced molecules, because of its high amount of kinetic energy, will begin to continuously “bump” into or collide with the molecules of the inner container. These collisions will cause the inner container’s molecules to move faster or “spin” at a faster rate. The molecules of the inner container will all start to increase “speed”. These molecules are also in contact with the molecules of the cold water. Therefore simultaneously as the hot water molecules are colliding with the inner container, the outside molecules of the inner container are also colliding with the cold water. Therefore the cold water molecules will start to speed up and will start to cause “harder” collisions with the molecules of the mug. The mugs molecules will now begin to move faster and faster as well as the collisions occur. As you can see there is a chain of events beginning where the heat is starting to be transferred from. The heat transfer comes from the collision of molecules causing the cold molecules to speed up and the hot molecules to slow down. Since there is such a large volume of cold water the hot water will decrease a lot more than the cold water will increase. This is because the cold water molecules have very little kinetic and heat energy, therefore the hot water molecules will transfer a lot of
energy in order to speed up the large volume of cold water molecules. In the end, when thermal
equilibrium is achieved all four components will be at the same temperature. The final
temperature will be closer to the initial temperature of the cold water than to the initial
temperature of the hot water because the cold water has a much greater volume. The hot water is
transferring a lot of energy in order to increase the kinetic energy of the substance in contact with
it. Since the large volume of cold water will draw a lot of the heat from the inner container, that
container will also draw heat from the hot water. Overall, thermal equilibrium is achieved by fast
pace molecules, hot, speeding up the slower molecules, cold. The amount of change is
determined by how much of each substance is present. At the final point there will be no further
changes, all of the molecules will be moving at the same speed and will be at the same
temperature.

Part B:

Through personal experience and from examples in this course I can make the conclusion
that metals conduct heat much quicker than silica or glass. This is the result of the way the
molecules of each substance are bonded and also because of their ability or restraint to move. As
seen from the provided diagrams of metallic bonding and silica the metal seems to have much
closer bonds along with freer mobility of those molecules. The silica is bonded in a way which
always holds certain atoms in groups because of the way they are bonded. In both cases the
molecules will increase motion has heat or energy is transferred to them. This will be in the form
of motion in a certain area or through vibration. In the case of metallic bonds parts of the
molecules will be able to move around allowing heat to be transferred in that way as well. In the
case of the silica, the atoms of the molecule are unable to move because of the strong bonds,
therefore the conduction and transfer of heat is that much slower. The diagrams represent a
molecule of each substance. As seen by the diagram the weak bond to the outer electrons allows them to move about freely. This is the motion that I previously referred to. As the electrons gain energy and increase motion they move about increasing the conduction and transfer of the heat energy. In contrast to the silica atom, the strong bonds between each atom prevent any additional “free” motion from occurring. The free electron of the metallic bond acts as a “tool” to disperse the heat. Therefore the transferred energy accelerates these electrons which conducts heat energy quickly making metal a faster conductor of heat than silica or glass. The motion of the electrons helps to distribute the energy throughout the molecule, whereas the silica or glass conducts heat solely through vibrations or small movements. I can personally visualize this conduction of heat as the electrons in the metallic bonds moving throughout each molecule “dispersing or depositing” heat throughout it. “Metallic bonds have weak bonds to the outer electron allowing it to move in this manner.” This free motion allows the heat to transfer more quickly through the molecule whereas the glass or silica isn’t able to have free motion of its electrons preventing a quick conduction or transfer of heat energy. This question also relates back to part A in the sense that when heat energy is transferred to metals the outer, free electrons can be easily moved allowing the heat to be quickly conducted. When heat is transferred to the glass the bonds prevent acceleration of the atoms which prevents heat from being conducted quickly. The movement of the free electrons in the metallic bonds helps accelerate the atoms quickly which increase the kinetic energy and heat energy much quicker than that of the fixed atoms in the glass.

Glass and silica also have much more complex structures as can be seen from the attached diagrams. Therefore more energy is required to move these heavier atoms. We discussed this aspect earlier in the course using the formula for kinetic energy \( \text{Ke}=\frac{1}{2}mv^2 \). It
is much easier and takes less energy, to move lighter atoms which could also be seen from the Phet simulation. Therefore if the metal atoms can be moved more easily they will conduct heat much quicker than heavier more complex, fixed structures of glass or silica. The glass and silica also has stronger bonds therefore it takes more time and heat (energy) to move its molecules. Since this motion takes more time to achieve, glass won’t conduct heat as quickly as metals will. Another aspect which allows metals to conduct heat quicker is the distance between the atoms of the molecules. The atoms of the metal are close together allowing heat to transfer quickly, while the atoms of the glass are more spread out causing slower conduction of heat since each atom has to travel more before a collision occurs. The weaker bonds of the metals allow movement to be achieved with less energy. This energy is in the form of heat therefore metals will “absorb” or conduct heat much easier and quicker. As a result of the “free” electron and the light atoms with a simple structure the metallic molecules are able to conduct heat much more quickly than the glass molecules.
Works Cited

Attached Molecular Diagrams
J31

Chem: Fire and Ice

03/24/15

Part A:

At the molecular level the 20 mL of hot water consists of particles that move rather freely, the polar attractions of intermolecular bonds are weak and the molecules move rapidly about. The cold water, begins in a state where the attractions and bonds are more evident and the density of the water is greater. The molecules in the cold water move about relatively freely but a bit more slowly and in a slightly more structured manner than those in the hot water. The energy in the each contained section of water is equal to the number of particles multiplied by the amount of kinetic energy, which is found in the form of temperature. As one container is placed inside the other, temperatures begin to change. Molecules in the hot water collide with their container, transferring kinetic energy to the molecules in the container which then transfers the energy to the cold molecules colliding on the opposite side of the container. As molecules continue this collision process, kinetic energy is lost by the hot water and gained by the cold – a change made evident by the dropping temperature of the hot water and rising temperature of the cold water. The collision process will continue endlessly, but the inner and outer container temperatures will eventually meet as the energy is transferred and becomes relatively evenly distributed throughout all the particles. The final temperature will be significantly closer to the temperature of the cooler water, because as the energy is transferred and averaged between particles the total energy in the system must remain the same. Seeing as the number of particles does not change and there are many more cold particles than hot, the average is brought down considerably by the abundance of cool particles in the outer container.

Part B

Experiments using metal and using glass as a container between hot and cold water showed that metal conducted heat faster. Water reached a temperature equilibrium more quickly when metal was used as the separation material. Metals conduct heat more quickly because of their free electrons. The electrons travel freely in metals allowing energy to be quickly transferred. In the structured bonding of a glass material the energy of heat would have to be transferred in a rather specific way from atom to
atom. However, the unbounded electrons can receive heat from any atom and release it to any other atom.

When experimenting with liquids we found that when warm and cold water are directly mixed an equilibrium temperature is more rapidly obtained than when the two substances are placed in contact yet separated by another container. The example of metal and glass is very different, however a similarity does exist. Because electrons in metals act as free agents, when warmth is applied it is similar to the direct mixing. The electrons can carry the heat throughout the whole substance transferring the energy to any random atom in close proximity. The glass is more similar to the experiment in which separation occurred. Just as the container, which acted as separation, regulated the manner in which heat was transferred, so do the bonds in glass. The container forced the transfer of heat to first transfer into the container’s molecules before moving to the cold molecules. The bonds between the glass atoms and electrons provide for a structure in which energy can only be transferred in a limited number of directions. An electron can only pass energy from one atom to another, thus the movement of the heat energy is slowed through the strict bonding of glass molecules.
Part A:

In this experiment there is an inner container filled with 20 mL of hot water, which resides inside a container filled with 100 mL of cold water. The molecules of water from the inner container will interact with the water molecules in the outer container and over time the hot and cold water will reach thermal equilibrium. Heat energy naturally flows from higher temperatures to lower temperatures, which results in the hot water becoming cooler and the cold water becoming warmer. Energy is able to be transferred between molecules when they collide and interact. Molecules in the liquid phase are slightly spread out and experience some movement. The difference between cold water molecules and hot water molecules is that the hot water molecules have more energy. This means that the hot water molecules are moving more rapidly than the cold water molecules, which allows for more collisions and interactions between molecules and between molecules and the container. The motion of the molecules creates kinetic energy. When the molecules collide against the inner container they transfer energy to the container. Once the cold molecules in the outer container collide against the inner container the energy will be transferred to the cold molecules. The hot water molecules inside the inner container will lose some kinetic energy to the cold water molecules in the outer container. The thermometer inside the inner container will show the gradual decrease in temperatures and the thermometer inside the outer container will show the gradual increase in temperature. When thermal equilibrium is reached the temperatures will remain constant. These collisions do not result in a total loss of energy, only a transfer. Therefore, the amount of energy remains the same throughout the experiment. Thermal equilibrium will be reached when the hot and cold molecules have the same average kinetic energy.

Part B:

Metals conduct heat more quickly because of their molecular structure. For example, a non-metal atom is formed by a number of covalent bonds, which exclusively share electrons. This means that the electrons cannot move freely. Particle collision of the electrons is not possible in non-metals and the transfer of heat is only possible through vibration of the atoms. In a metal the electrons in the outer shell of the atom are weakly bonded, which allows the electrons to move freely throughout the metal. The individual metal atoms come together in a group
and reside in a cloud of communal electrons. Particle collision, through the collisions of the free electrons, and vibration, through the bonds of the metal atoms, are possible in a metal. Metals can conduct heat more quickly because the free electrons can collide and interact along with the vibration of the atoms. Whereas, non-metals do not have free electrons and so they do not conduct heat as quickly as metals. In Part A an inner container was filled with hot water and placed in an outer container filled with cold water. If the inner container had been a metal can it would have quickly became warm. As the hot water molecules collided against the metal can the transfer of heat would occur between the vibration of the hot water atoms, the vibration of the metal atoms, and also the particle collisions of the free electrons. The metal can would intake the energy more quickly and in turn could transfer the energy to the cold water molecules more quickly too. It would take less time for the molecules inside the metal can and the water molecules inside the outer container to reach thermal equilibrium.
A. This system starts with two different volumes of liquid at two different temperatures. The 20 mL inner container has 20 mL of water at say 50 degrees Celsius. This temperature indicates that the average kinetic energy of these 20 mL of water is 50 degrees Celsius. However, this experiment pertains more to the total kinetic energy of the system. 20 mL of water contains a fixed number of molecules, and the individual speed of each molecule results in a total kinetic energy of these 20 mL. Likewise, the 100 mL of water that is maybe 5 degrees Celsius has a much lower average kinetic energy, but its total kinetic energy is even lower than that of the 20 mL because there are more molecules moving at a higher speed. When the smaller container is placed in the larger one, the molecules of the inner container will collide with the molecules of the container they are in, speeding them up, and these molecules will then collide with the molecules of the water on the outside, which will speed them up. Their temperatures will change quickly at first, and then more slowly, and the inner cup will experience a much greater temperature change than the outer cup. This is because the total energy of the system is constant, and the inner cup only has so much energy to transfer to the numerous molecules of the outer cup. In theory the system will eventually reach thermal equilibrium, probably around 12.5 degrees Celsius. This is because each molecule in the small cup must transfer a large amount of its energy to a number of molecules in the big
cup in order to speed up the many molecules in the big cup to a speed equal to that of the small cup. So, the unequal volumes of liquid result in unequal changes in temperature, because the total energy of each individual cup is different, but the total energy of the system remains the same as it reaches an equilibrium.

B. Metals conduct heat more quickly because of their molecular structure. The dissociated electrons combined with the tightly packed metal ions are what allow this to occur. Since the nuclei of the metal molecules are very close together, their vibration and motion occurs very close to the next nuclei, resulting in easier, quicker collisions. This close proximity allows the metal to conduct heat because if one metal ion begins vibrating more rapidly, it will collide with the next very quickly, transferring this energy quickly through the metal. Furthermore, the electrons themselves are moving and can experience changes in kinetic energy, so if these free electrons are moving fast they can transfer their energy to other electrons very quickly, because they are free to move about the metal. This also results in the quick conduction of heat. The glass or quartz molecules on the other hand, have a very rigid structure which spaces out the molecules. Since the shape is rigid and has more space between molecules, the vibrations of one molecule will take longer to influence the vibrations of the next, because they are farther apart. This distance between the molecules results in a slower conduction of heat. Their electrons are also localized, so they can only move between the molecules that are covalently bonded. This means that their range of motion is more limited than that of the metal, and therefore heat cannot be transferred as quickly.
Reflection Assignment

A. Write a description using a molecular-level perspective about the initial conditions for this system and what happens over time until things no longer change. Indicate your estimate for the ending condition. The story must describe exactly how the system gets from starting condition to end condition. [This question requires recalling what we did and talked about in class.]

The initial system contains a coffee mug filled with 100 mL of cold water. Since we are dealing with water, a liquid, the molecules will be arranged in a random formation. In a cold substance, a limited amount of heat, also known as thermal energy, can be found. This lack of energy results in a cold temperature, and causes the molecules to stay closer together and move slower.

Within the same initial system, a separate container houses 20 mL of hot water. The molecules in the hot water will also take on a random arrangement because it is in the liquid phase. Since the temperature is hot, however, the molecules will remain slightly further apart compared to the cold water molecules. The motion of the hot water molecules will be faster because more heat energy is present in the system.

Once the smaller container of hot water is inserted into the coffee mug of cold water, heat will be transferred immediately from the hot temperature object to the cold temperature object. Unlike straight mixing the two volumes of water, the heat transfer must overcome the internal container barrier; in order for the hot water to heat up, the container holding the hot water will also need to heat up. Since the molecules of the hot water are moving relatively fast, the particles will collide with the molecules of the container holding the hot water. These interactions will transfer energy from the hot water to the container and result in an increase in the temperature of the container and a decrease in the temperature of the hot water.

On the external side of the hot water container sits a volume of cold water. As the molecules of the container are increasing their speed and temperature from the energy they gained from the hot water, they are transferring the energy to the cold water. This transfer causes the container temperature to decrease and the cold water temperature to increase. Throughout time, heat energy will flow from the hot water to the internal container. Once the internal container receives enough heat to become warmer than the temperature of the cold water, heat will transfer from the container to the cold water. This process of heat transfer will occur until the entire system, both the hot and cold water, reach the same temperature, known as thermal equilibrium. At this point, all of the molecules will be moving at the same speed and the temperature will be much closer to the initial cold water temperature because the system required five times as much cold water than hot water. For example, if the 20 mL of cold water’s initial temperature was 40°C and the 80 mL of hot water’s initial temperature was 0°C, I would expect the water to reach equilibrium around 8°C.
B. Look at the second attachment, which shows an illustration of the way atoms are bonded together in metals, and the way in which atoms are bonded together in a material like glass or sand. Generally, metals conduct heat much more quickly than materials like silica (or glass). Suggest an explanation for why metals conduct heat more quickly. [This question requires extending the idea in Part A and connecting that idea to an idea that we talked about early in the semester.]

After examining the bonding models of metals compared to the bonding structure of a substance similar to glass, it was evident that the major difference between the two deals with the strength of the bonds between the atoms and the outer electrons. In metallic substances, electrons float freely across the metal due to their extremely weak bonds. Having these loose electrons allows metals to conduct heat more quickly than other materials.

When a nonmetallic substance, such as glass, absorbs heat energy, the particles vibrate from side to side. The motion of the molecules is limited to a back and forth vibration pattern because it is in the solid state, which is characterized by a regular and rigid molecular arrangement with slight molecular movement. The heat is transferred from one molecule to the next when two vibrating particles interact. With restricted movement among the molecules, the heat takes a longer period of time to be transferred from one side of the substance to the other.

In the situation of a metallic substance absorbing heat, the same vibration process takes place. This process, however, contains one additionally element, which speeds up the process. Metallic substances have free electrons, which are no longer attached to the atom because the bond is so weak. These loose electrons absorb heat and freely float throughout the metal, colliding with more molecules and at a faster pace. These free electrons increase the speed of heat transfer because their movement is not restricted, thus they can carry the energy throughout the entire metal.
Reflective Writing Assignment due Tues Mar 24

Please submit this assignment electronically by an email attachment of a Word document. This allows me to comment in your document and send it back to you.

I can’t keep you from consulting other sources, but you may find it more valuable for your understanding to try to respond using only the course materials and notes.

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Consider the same set up we used for showing thermal equilibrium: a coffee mug with a second smaller container inside. Let there be 20 mL of hot water in the inner container, and 100 mL of cold water outside. Thermometers are used to monitor the temperatures in each.

Part A

Write a description using a molecular-level perspective about the initial conditions for this system and what happens over time until things no longer change. Indicate your estimate for the ending condition. The story must describe exactly how the system gets from starting condition to end condition. [This question requires recalling what we did and talked about in class.]

Part B

Look at the second attachment, which shows an illustration of the way atoms are bonded together in metals, and the way in which atoms are bonded together in a material like glass or sand. Generally, metals conduct heat much more quickly than materials like silica (or glass). Suggest an explanation for why metals conduct heat more quickly. [This question requires extending the idea in Part A and connecting that idea to an idea that we talked about early in the semester.]
Covalent bonding in Quartz, which has similarities to glass.

The lines between atoms indicate that electrons are shared exclusively between those two atoms. The electrons can't move from those locations.
Consider the same set up we used for showing thermal equilibrium: a coffee mug with a second smaller container inside. Let there be 20 mL of hot water in the inner container, and 100 mL of cold water outside. Thermometers are used to monitor the temperatures in each.

Part A

**Write a description using a molecular-level perspective about the initial conditions for this system and what happens over time until things no longer change. Indicate your estimate for the ending condition. The story must describe exactly how the system gets from starting condition to end condition. [This question requires recalling what we did and talked about in class.]**

Initially, each cup has a different temperature and volume – specifically 20mL of hot water in one container and 100 mL of cold water in the other container. On a molecular level, the molecules in the hot water container contain more kinetic energy and move at a faster rate than those of the cold water. When the 20mL hot water container is placed inside the 100mL of cold water, energy transfer begins to occur. Energy is able to be transferred through the container from the hot water to the cold water and vice versa (this speed of this depends on the material of the container due to several factors including molecular form and conductivity) which starts the process of the two containers reaching the same temperature. This is called thermal equilibrium, which states that two objects come to intermediate temperature when combined. This is also known as the “zero-th law of thermodynamics.” The resulting temperature, which would be the same in both containers, would be an average of the two temperatures in proportion to the volume. The air temperature will also have an effect on the temperature change, due to the water’s exposure to air. It will gradually cool the hot water and warm the cold water as this whole process occurs.

Part B

**Look at the second attachment, which shows an illustration of the way atoms are bonded together in metals, and the way in which atoms are bonded together in a material like glass or sand. Generally, metals conduct heat much more quickly than materials like silica (or glass). Suggest an explanation for why metals conduct heat more quickly. [This question requires extending the idea in Part A and connecting that idea to an idea that we talked about early in the semester.]**

Metals conduct heat more quickly mainly due to the delocalized electrons. As opposed to glass, where each electron stays in a fixed position in relation to their atoms, metal electrons can drift away and throughout the molecular structure, creating a system of communal electrons for the metal atoms. Since these electrons move more freely and come in contact with others much more often than those of glass, the transfer of kinetic energy happens at a much faster rate.
In the initial setup, there are fast moving liquid molecules and separated surrounding slow moving liquid molecules by a layer of solid, slowly vibrating molecules. As time moves on, the faster moving molecules on the inside collide with the molecules on the inner edge of the solid barrier. The molecules on the inner edge of the solid begin to vibrate faster and bump into other solid molecules until this added vibration reaches molecules on the outer edge of the solid structure. When slow moving liquid molecules on the outside collide with the faster vibrating solid molecules on the outside edge of the barrier, their speed increases. This process continues until more and more of the outer liquid molecules are moving at a faster pace, having been heated up by the molecules on the inside. As the inner liquid molecules collide with the solid barrier, they give some of their energy to the solid molecules. Over time, more and more of the inner liquid molecules are moving slower, having decreased in temperature.

Based on the law of thermal equilibrium and the fact that the experiment began with more cold water than warm water, you would expect the final temperature of both the inside and the outside water to be somewhere in between the two original temperatures, somewhere closer in proximity to the initial cold water temperature.
Part B

Metals are much better conductors of heat than materials like glass and sand. This is because in a solid metal structure, electrons are very delocalized, being evenly shared and constantly moving throughout the entire solid. Sand and glass on the other hand are very limited in the sharing of electrons. Electrons from a particular atom tend to only delocalize to two or three of the surrounding atoms, having much less interaction than when electrons are shared throughout the whole solid, as is the case with metals. In part A, heat transfer is visualized as a process of collisions that carry vibrational energy from one side of the solid barrier to the other. In the case of the metals, the atoms are much more interconnected, energy-wise, making it easier for the vibrational motion to travel quickly through the metal. In the case of something like glass, this motion would travel slowly through the solid, as each atom in the structure is relatively independent of the rest of the atoms in the structure and it is much less interconnected.
Reflective Writing Assignment

Part A

The hot water in the inner container has a higher temperature and its molecules’ have more energy. For this reason, the hot molecules are moving faster than the cold molecules. When the hot water container is placed in the coffee mug with cold water, the heat energy can be transferred from the hot molecules to the colder molecules.

The speed of this transfer depends on material of the inner container. If it is made of an insulated plastic like the coffee mug, then it would take a very long time for the heat energy to travel from the inner container to the cold water. If the inner container is an aluminum can, the heat energy will transfer much faster, because aluminum is a conductor of heat. Regardless, this set up will cause the heat to transfer much more slowly than if the two volumes of water were directly combined in one container.

As the heat energy leaves the inner container, the molecules of the 20mL water begin to slow down. Conversely, the heat energy transfers to the 100mL water and those molecules speed up a bit. The temperature of the inner container decreases and the temperature of the outer container increases. Because there are more molecules in the outer coffee mug, the energy from the inner container must be more widely spread about the molecules. Energy is not created not destroyed in this experiment; it is only transferred. This conservation of energy causes the two volumes to move towards a thermal equilibrium that is closer to the original temperature of the
100mL of water in the mug. There isn’t enough heat energy in the smaller container to spread about the molecules to reach a thermal equilibrium that is directly in the middle of the two starting temperatures.

**Part B**

Electrons are charged particles that can transfer energy and heat between molecules. Metals have ‘electron clouds’ around their molecules. Electrons in metals do not have strong bonds to the metal molecules which gives them the freedom to spread out among the metal or cluster together in one spot. This freedom of movement makes metals more conductive of heat. The electrons can gather in one area of a metal and use teamwork to transfer heat energy strongly and quickly.

Materials like silica or glass have molecules that are attached by covalent bonds. These bonds mean that the atoms’ electrons are not easily shared with other atoms. The electrons are only for the two atoms that are bonded together. Heat energy cannot be transferred as strongly as those of metals because the electrons do not have the same freedom and cannot work together for a quicker transfer of energy.
Reflective Writing Assignment

Part A.

We start with 20 mL of hot water in the inner container and 100 mL of cold water outside. Inside the can the water molecules are moving quickly and outside the can the molecules are moving slowly in comparison. The hot water molecules movement causes the molecules right outside of the can to start moving faster (due to collisions), then those molecules collide with other molecules and they start moving more. In other words it is like a rippling effect and the molecules start moving faster and faster initiated from the hot water molecules in the can. This is how kinetic energy and ultimately heat is transferred from the hot water to the cold water. Once all the molecules are moving at the same speed the heat has been transferred and all the water should be the same temperature. Since there was a lot more cold water than hot water the final average speed of the molecules and overall temperature will be lower and much closer to the temperature (and speed) of the cold water.

Part B.

The reason metals conduct heat much more quickly than glass or sand is because of the way its atoms are bonded and “put” together. The bonds in the metals are weaker than the bonds in the glass. The atoms in metals are also very uniform and close together while the atoms in the glass or sand aren’t very uniformly structured and have varying distance between them.
Therefore the heat can be more easily transferred in the atoms of the metals because they are closer together and can move more freely. The collisions will happen faster and the atoms will all be moving at the same speed in less time than it would take the atoms in the glass. The quicker the molecules can move the same speed in the metal the faster they can transfer the kinetic energy or heat to other substances. Getting all the molecules to be moving the same speed takes a longer time in glass, so it takes longer to transfer heat to another substance. Hence metals are better conductors than glass.
Reflective Writing Assignment due Tues Mar 24

Consider the same set up we used for showing thermal equilibrium: a coffee mug with a second smaller container inside. Let there be 20 mL of hot water in the inner container, and 100 mL of cold water outside. Thermometers are used to monitor the temperatures in each.

A) Write a description using a molecular-level perspective about the initial conditions for this system and what happens over time until things no longer change. Indicate your estimate for the ending condition. The story must describe exactly how the system gets from starting condition to end condition. [This question requires recalling what we did and talked about in class.]

The hot water molecules in the inner container will be moving quickly. The molecules of the cold water in the outer container will be moving slowly. Both will be hitting the inner cup, which serves as a physical boundary between them. As the hot molecules hit the cup, they will transfer kinetic energy across the cup to the molecules on the other side. This causes the hot molecules to slow down and cool off. The cold molecules, on the other hand, will pick up this transferred energy, move more quickly, and heat up. Eventually the molecules on either side of the cup will be moving at the same average speed, and the temperature of the water will be the same in both inner and outer cups. However, because there is more cold water than hot water, the end temperature will be colder than the average between the two original temperatures.

B) Look at the second attachment, which shows an illustration of the way atoms are bonded together in metals, and the way in which atoms are bonded together in a material like glass or sand. Generally, metals conduct heat much more quickly than materials like silica (or glass). Suggest an explanation for why metals conduct heat more quickly. [This question requires extending the idea in Part A and connecting that idea to an idea that we talked about early in the semester.]

The electrons in metal are weakly bound and able to move around the entire piece of metal, whereas the electrons in glass are tightly bound and cannot move between atoms. In the simulations, we have seen molecules in a solid vibrate more quickly as they heat up. In a material like glass, where the electrons cannot move around, this vibrating could only transfer heat in a limited fashion. With metal, the electrons are able to actually move around, so they are able to interact with and pass energy to more molecules in a shorter span of time.
Consider the same set up we used for showing thermal equilibrium: a coffee mug with a second smaller container inside. Let there be 20 mL of hot water in the inner container, and 100 mL of cold water outside. Thermometers are used to monitor the temperatures in each.

Part A

Write a description using a molecular-level perspective about the initial conditions for this system and what happens over time until things no longer change. Indicate your estimate for the ending condition. The story must describe exactly how the system gets from starting condition to end condition. [This question requires recalling what we did and talked about in class.]

Answer:

At the beginning of this experiment the contents of both the mug and the inner container are in the liquid phase. This means that there is some structure to the molecules, but they are not as rigidly organized as in a solid. However, in the inner container the molecules are moving faster than in the outer container. This is because the water in the inner container is hotter. This gives the molecules more energy and allows them to move faster. While these liquids may not be directly mixing, there is a transfer of energy between them. The final ending temperature in both containers is dependent on the initial temperatures of the liquids and the volumes of each. Because there is more cold water than hot water the final temperature will be closer to that of the cold water than the hot water. The respective temperature increase and decrease will be proportional to the amount of each liquid in relation to the whole. For example, if there were 100mL of 5°C water and 20mL of 40°C water, the final temperature would be approximately 10.8°C.
This temperature change/energy transfer can be described on a molecular level. The water molecules with more energy (the “hot” water) hit the walls of their container. This container is also made up of molecules, so the water molecules are essentially hitting other molecules. An energy transfer occurs because the liquid water molecules have more energy than the molecules of the solid container. As the water molecules continue to hit the container, energy moves from molecule to molecule within the container. These molecules then begin to hit the “cold” water molecules on the other side of the container. An energy transfer occurs just as it did before. This continues until the amount of energy is the same in both volumes of water. Because the volume of cold water is greater than the volume of hot water, more energy is needed to increase the energy of all of the “cold” water molecules. This is why the final temperature is closer to that of the initial cold temperature.

Part B

Look at the second attachment, which shows an illustration of the way atoms are bonded together in metals, and the way in which atoms are bonded together in a material like glass or sand. Generally, metals conduct heat much more quickly than materials like silica (or glass). Suggest an explanation for why metals conduct heat more quickly. [This question requires extending the idea in Part A and connecting that idea to an idea that we talked about early in the semester.]

Answer:

In metals, negatively charged electrons are able to move much more freely among the positively charged metal atoms. When “hotter” molecules (or those with more energy) bump into the metal, the energy is transferred to the atoms that are hit. This causes the metal atom to have more energy and vibrate faster. Because the electrons do not exist between specific atoms, the atoms are much closer together. When one atom gains more energy, it transfers energy to the atoms closest to it. This continues until energy is transferred throughout the metal. In substances such as glass, there are covalent bonds between atoms. The electrons are shared exclusively between two atoms. These atoms are not as close together as those of a metal, making it more difficult to transfer energy.
More energy is needed for an individual atom to have enough energy to hit a nearby atom and cause an energy transfer. For this reason, metals conduct heat much more quickly than substances such as glass.
Consider the same set up we used for showing thermal equilibrium: a coffee mug with a second smaller container inside. Let there be 20 mL of hot water in the inner container, and 100 mL of cold water outside. Thermometers are used to monitor the temperatures in each.

Part A

Write a description using a molecular-level perspective about the initial conditions for this system and what happens over time until things no longer change. Indicate your estimate for the ending condition. The story must describe exactly how the system gets from starting condition to end condition. [This question requires recalling what we did and talked about in class.]

The molecules in the 20 mL of hot water are in disorder because heat is present. The molecules are vibrating and colliding with one another because of the kinetic energy in the container. The molecules in the 100 mL of cold water are more structured than the those of the hot water, but are still vibrating and colliding with one another because the water is not frozen into solid ice. There is more heat present in the can than in the mug.

When the can of hot water is placed into the mug of cold water, the heat that is present in the can will rapidly begin to transfer through the metal can (a conductor) and into the cold water in the mug, weakening the bonds between the molecules of the cold water and encouraging them to vibrate and move around. As time goes on, this heat transfer will continue at a slower pace than the initial transfer. The hot water molecules will lose heat energy and the cold water molecules will receive heat energy.

When the 20 mL container of hot water comes in contact with the 100 mL container of cold water, no energy will be lost in the transfer of heat. Instead, heat will be transferred from the can to the mug until the water in both containers comes to a thermal equilibrium, or the estimated average temperature of the two containers. This thermal equilibrium is a point relative to the two volumes where the temperatures of each container meet.
Part B

Look at the second attachment, which shows an illustration of the way atoms are bonded together in metals, and the way in which atoms are bonded together in a material like glass or sand. Generally, metals conduct heat much more quickly than materials like silica (or glass). Suggest an explanation for why metals conduct heat more quickly. [This question requires extending the idea in Part A and connecting that idea to an idea that we talked about early in the semester.]

Both substances conduct heat in the same manner as any substance conducts heat (as I described in Part A); the substance is heated, the atoms absorb this heat energy, the molecules begin to vibrate, move, and collide with one another, and pass energy from molecule to molecule. However, as shown in the attached illustration, metallic bonding has a special quality that conducts heat more quickly than glass does. This special quality comes in the form of the outer electron that is very weakly bound to the atoms; they are “free” electrons. These free electrons are able to move across the entire metal. Because of this ability, when metal is heated, the free electrons also transfer heat in addition to the basic process of heat transfer that all substances undergo. The can used in Part A was metal meaning the transfer of heat was aided by the free electrons present in the can.
Consider the same set up we used for showing thermal equilibrium: a coffee mug with a second smaller container inside. Let there be 20 mL of hot water in the inner container, and 100 mL of cold water outside. Thermometers are used to monitor the temperatures in each.

Part A

Write a description using a molecular-level perspective about the initial conditions for this system and what happens over time until things no longer change. Indicate your estimate for the ending condition. The story must describe exactly how the system gets from starting condition to end condition. [This question requires recalling what we did and talked about in class.]

From the description of the setup, it is clear that there is more cold water than there is hot. During our classroom experiments, it was found that when there is more water of a particular temperature, in this case cold, the ending temperature would favor a thermal equilibrium of the water with the greater quantity. So basically, because there is more cold water, the ending temperature will be leaning towards the colder side, instead of just splitting the average temperatures of the two liquids. This is because the warm water molecules are moving very quickly. They are bouncing against the walls of the container and making the molecules within the container speed up. These molecules then hit the other side of the container, and give some of their energy to the cold molecules. This ripple effect is passing thermal energy from the warm water, through the container, and into the cold water. When the cold-water molecules begin to feel the effects of
this ripple, they move faster and generate more heat because of the energy that they received. This is a concept we have been working with for a while. As molecules gain speed, the amount of heat increases. This would result in the temperature to increase slightly. However, as stated before, the cold-water temperature would not fully rise to the temperature of the warm water because there is simply too much cold water for the warm water to impact. However, they do reach thermal equilibrium eventually. This means that the temperatures of the inner and outer containers are the same, and their respective molecules are acting similarly.

Part B

Look at the second attachment, which shows an illustration of the way atoms are bonded together in metals, and the way in which atoms are bonded together in a material like glass or sand. Generally, metals conduct heat much more quickly than materials like silica (or glass). Suggest an explanation for why metals conduct heat more quickly. [This question requires extending the idea in Part A and connecting that idea to an idea that we talked about early in the semester.]

Metals conduct heat more quickly than materials such as glass and silica because of their weekly bounded electrons. The electrons of a metal are free to roam, while those of glass are stuck to the molecules. When a piece of metal is heated, the molecules begin to vibrate and take in some of the heat. The electrons also receive heat and move around the substance. This allows the heating process to speed up. They have absorbed this heat, and can go around and act as thermal transmitters to other parts of the substance, if you will. Meanwhile, when a piece of glass is heated up, their electrons are stuck. They simply absorb their heat as a unit and cannot really interact with the surrounding molecules in the way that metal does. They still vibrate quickly, but there are no travelling electrons that can move to transfer their heat to the other molecules. I’m having difficulty relating it to something we did earlier in the year, but I am reminded of the
balloon exercise. When the balloon was rubbed against the hair, there was friction and electrons were exchanged. This exchange made the water more attracted to the balloon because of their opposite charges. So when electrons are able to move, the substances they are moving within become better conductors of electricity, and possibly heat as well... This can also simply relate to the basic idea we have been working with. When there is an increase in movement within a molecular structure, temperature increases because there is a lot of kinetic energy. Because more than just the molecules are moving (now electrons are involved as well), temperature will increase at a greater rate because there is more movement, more chaos, more collisions, and a lot of thermal energy.
Reflective Writing Assignment

Part A

Initially, the molecules of the hot water are moving quickly, and the molecules of the cold water are moving slowly. Gradually, thermal energy transfers from the hot water to the container holding it, increasing the heat and the speed of the container’s molecules. Then thermal energy transfers from the container to the cold water surrounding it, causing the cold water molecules to move more quickly and gain heat while losing cold. As the molecules of the hot water transfer thermal energy to their surroundings, they simultaneously lose heat, and stop moving as quickly as they were before, due to the decrease in thermal energy. My group started to come up with an equation to estimate the equilibrium, but in general, because there is a higher volume of cold water than hot water, the temperature of the cold water will have increased only slightly, whereas the temperature of the hot water will have decreased significantly by the end of the heat transfer.

Part B

The electrons in metals can move around more freely than the electrons in glass or sand can, since they are so weakly bound to the atoms. The electrons in substances like glass or sand, on the other hand, cannot move from their positions and are fixed rigidly. Since the electrons in metals can move so freely, when they are affected by an increase in thermal energy, they will be able to move around much more quickly, conducting heat in the metal. Molecular movement in glass/sand is much more restricted, so when thermal energy increases, it will take longer for the molecules to conduct heat, and they will most likely not be able to conduct as much heat as metals can.
Part A:

The liquids being used are at an uneven ratio so the inner, smaller portion size, will be influenced more by the outer temperature. At the beginning they will each be complete opposites, one hot and one cold, and only be affected by the room temperature until they begin to interact with one another. Both will influence one another until they reach an equilibrium temperature and the energy between the two objects is even. The hotter water is 1/5 the amount of the cold water and will lose heat at a faster rate because it is trying to warm up a larger amount of cold particles, compared to the cold particles having to cool down less. There is a barrier, the cup holding the second liquid, that is between the heat transfer. Depending on the material of this cup the amount of time needed to reach a thermal equilibrium will differ. Due to air pockets in Styrofoam that material would cause the heat transfer to take longer than a material such as plastic or metal because it is able to keep its original temperature longer, but on average it would probably take between 8 and 12 minutes. During the process the cold water molecules are gaining energy and the hot water molecules are losing energy to reach a speed between that will be equivalent to their temperature change.

Part B:

Metals conduct heat more quickly than other materials such as glass because their outer electrons have a weak bond so they will be influenced to gain energy more easily and conduct heat through the rest of the object. Glass seems to have stronger bonds and it shows that the electrons have specific bonds to certain atoms showing that there is a stronger bond formed within this structure. This would explain why when metal was used during the above experiment in class the heat transfer did not take all that long compared to other materials. When materials have molecules that have weaker bonds the transfer of heat and ability for heat to change that objects state are much easier/take less time. When the bond is weaker less heat is needed to influence those molecules to gain heat/loosen or break their bond. This would explain why metal can conduct heat more easily, because its molecules are influenced more by their surroundings than other materials are.
Part A

With 20 mL of hot water in the inner container and 100 mL of cold water in the outer container, the predicted end temperature of both water would be closer to the cold water’s temperature because there is more cold water. The movement and interactions of the water molecules can explain this phenomenon. The hot water molecules have more kinetic energy than the cold-water molecules and when they interact, even through the glass container, the hot water molecules transfer some of their kinetic energy. This transfer of kinetic energy in turn increases the speed of the cold water molecules. The transfer of kinetic energy continues until all the molecules have equal energy, or at equilibrium.

Part B

Metals may conduct heat more quickly than a material such as glass because the molecules of metals are organized in a clear pattern. This helps transfer the kinetic energy (heat). On the contrary materials like silica appear to be in a more random formation.