

Thermochemistry

Questions

- Can you measure thermal energy directly?
Why or why not?
- What CAN we measure changes in?
- How does that allow us to figure out changes
in thermal energy of a system?

Specific heat/heat capacity

- How much energy it takes to change the
temperature of a substance.
- Specific heat – energy required to raise 1 g by
1 °C (or 1 K)
- Molar heat capacity – energy required to raise
1 mol by 1 °C (or 1 K)

Name	Formula	Molar mass (g/mol)	Molar heat capacity (J/mol·°C)	Specific heat (J/g·°C)
water	H ₂ O	18	75.4	4.18
methanol	CH ₃ OH	32	81	2.53
ethanol	CH ₃ CH ₂ OH	48	112	2.44
propanol	CH ₃ CH ₂ CH ₂ OH	60	144	2.39

The molar heat capacity increases with molecular weight. Why?

– more ways to use energy as the number of atoms and bonds increases (in vibrations and rotations).

Why is the sp heat of water so high?

Lots of molecules per gram (low molecular weight of H₂O)
Lots of intermolecular attractions

Substance	Specific Heat (J/g °C)
Aluminum	0.90
Copper	0.39
Ice H ₂ O(s)	2.05
Iron	0.45
Silver	0.24
Steam H ₂ O(g)	2.01
Water H ₂ O (l)	4.19

Add same amount of heat to 10g of each -
which will reach the highest temp?

- H₂O(s)
- H₂O(l)
- Aluminum
- Silver
- One of the other materials in the table

Which will end up at the lowest temp?

Why does water in its different phases

That is: why does it take different amounts of thermal energy to raise the temperature of a fixed amount of solid, liquid or gaseous water?

Why does it take so much energy to raise the temperature of liquid water?


Water and its anomalous properties

- High specific heat
- High melting/boiling point
- Low density of ice
- Low vapor pressure (the pressure exerted by a gas above the liquid at a given temperature)

Liquid water

• The relationship of molecules to each other appears -

• The molecules in the liquid phase are moving -



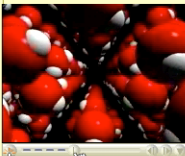
MOVIE DESCRIPTION

The molecules in liquid water are closely packed, but move about from place to place, mainly in clusters. The hydrogen ends of each molecule are attracted to the oxygen ends of adjacent molecules.

Solid water

• Are the molecules moving?

• Between the molecules there is -



MOVIE DESCRIPTION

The molecules in solid water occupy fixed positions in an orderly, closely-packed array. The molecules vibrate around these fixed positions. There are also regular, hexagonal channels throughout the structure.

All these properties are caused by the unique structure of water – with leads to very high intermolecular interactions (which require a lot of energy to overcome)

Question

- What would be the consequences (to life, the universe and everything) if water were a linear molecule?

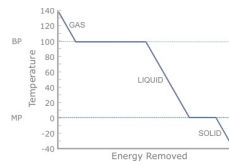
Phase Changes

- What happens when we remove thermal energy from a gas?
- How do we remove thermal energy from a gas?
- What has to happen for molecules to stick together?
- http://phet.colorado.edu/simulations/sims.php?sim=States_of_Matter

Phase Changes and Temperature

- Moving from solid → liquid → gas or Gas → liquid → solid
- What happens to the temperature at a phase change?
- What is the energy being used for?

Phase changes and temperature



2. What happens on the molecular level when thermal energy (heat) is added to boiling water?

- A It increases the speed at which molecules collide. The bonds within the molecules break and cause a release of hydrogen and oxygen gases into the air.
- B. The water molecules will move faster and the attractions between them will be overcome. The temperature of water will not change.
- C. It makes the water molecules move faster and bump into each other; consequently the water temperature will increase in the process.
- D. It increases the movement of water molecules and overcomes the attractions between them. Energy will be released into the environment and new bonds will form to make water vapor.

Questions

- Draw a graph of the change in temperature when equal amounts of thermal energy are added at the same rate to equal masses of water, ethanol and propanol.
- Does each sample reach the same temperature? Why or why not?
- Plot the temperature change vs time as a sample of water vapor moves from a temperature of 110°C to 90°C
- Draw a molecular level picture of what the sample looks like at 110°C and 90°C
- Explain what is happening at each different part of your graph.
