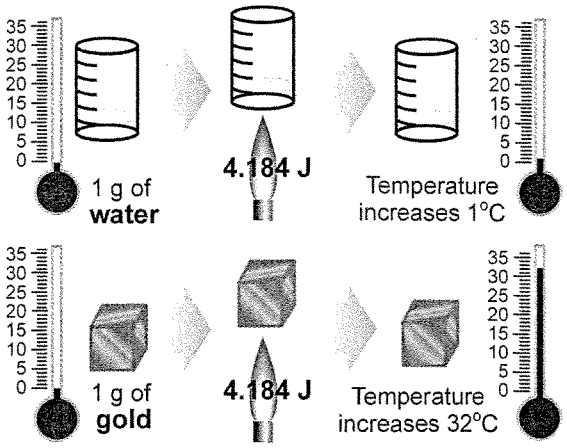
Specific heat

Differences in materials

The same amount of heat causes a different change in temperature in different materials. For example, it takes 4.184 joules of heat energy to raise the temperature of one gram of water by one degree Celsius. If you add the same quantity of heat to one gram of gold, the temperature goes up by 32.4°C! The different temperature rise happens because different materials have different abilities to store thermal energy.



Specific heat

The **specific heat** in J/g°C is the quantity of energy it takes to raise the temperature of one gram of a material by one degree Celsius. Water is an important example; the specific heat of water is 4.184 J/g°C. It takes 4.184 joules to raise the temperature of one gram of water by one degree Celsius. The specific heat of gold is 0.129 J/g°C. It only takes 0.129 J to raise the temperature of 1 gram of gold by 1°C. The specific heat of water is 32 times higher than it is for gold.

TABLE 3.1. Specific heat of some common substances

Material	Specific heat (J/g°C)	Material	Specific heat (J/g°C)
Air at 1 atm	1.006	Oil	1.900
Water	4.184	Concrete	0.880
Aluminum	0.900	Glass	0.800
Steel	0.470	Gold	0.129
Silver	0.235	Wood	2.500

The heat equation

The heat equation is used to calculate how much energy (E) it takes to make a temperature change ($T_2 - T_1$) in a mass (m) of material with specific heat (c_p).

Heat equation

Energy (J) $E = mc_p(T_2 - T_1)$

Mass (g); Temperature change (°C); Specific heat (J/g°C)

Chemistry terms

specific heat - the quantity of energy, measured in J/g°C, it takes per gram to raise the temperature one degree Celsius.

Why specific heat varies

Different substances have different specific heats

Substances have a wide range of specific heats. Pure metals, like gold, tend to have a low specific heat. Molecular substances, like water and oil, tend to have a higher specific heat. Specific heat varies for many reasons.

Molecular substances can absorb energy in ways that don't increase temperature, such as internal motion of the atoms within a molecule. This is because bonds between atoms are not rigid rods, like the diagrams show. Rather, bonds are like flexible springs that can bend and stretch. Typically, only the motion of whole molecules affects temperature. The motion of atoms within a molecule, however, may not affect temperature. When energy is absorbed in ways other than motion of the whole molecule, temperature goes up less and the specific heat increases.

Stronger forces between molecules mean it takes more energy to cause a single molecule to move a given amount. This makes the specific heat higher. In general, strong bonds between molecules raise the specific heat because they limit thermal motion of individual molecules (or atoms).

Why specific heat varies

Materials with heavy atoms or molecules have low specific heat compared with materials with lighter atoms. This is because temperature measures the energy per atom. Heavy atoms mean fewer atoms per kilogram. Energy that is divided between fewer atoms means more energy per atom, and therefore more temperature change. Silver's specific heat is 235 J/kg°C and aluminum's specific heat is 900 J/kg°C. One gram of silver has fewer atoms than a gram of aluminum because silver atoms are heavier than aluminum atoms. When heat is added, each atom of silver gets more energy than each atom of aluminum because there are fewer silver atoms in a gram. Since the energy per atom is greater, the temperature increase in the silver is also greater.

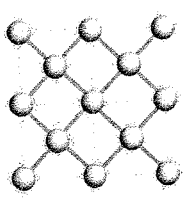
Why is the specific heat of aluminum almost 4 times greater than the specific heat of silver?

1 gram

Silver

Specific heat: **235** J/kg°C

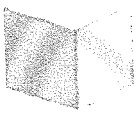
Heavier atoms, mean **fewer** atoms per gram.



Energy is spread over **fewer** atoms

More energy per atom

Higher temperature gain per joule (lower specific heat)

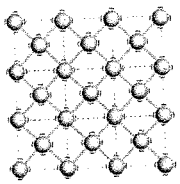


1 gram

Aluminum

Specific heat: **900** J/kg°C

Lighter atoms, mean **more** atoms per gram.



Energy is spread over **more** atoms

Less energy per atom

Lower temperature gain per joule (higher specific heat)