HEAT AND TEMPERATURE

Heat is a type of ENERGY. When absorbed by a substance, heat causes inter-particle bonds to weaken and break which leads to a change of state (solid to liquid for example).

Heat causing a phase change is NOT sufficient to cause an increase in temperature.

Heat also causes an increase of kinetic energy (motion, friction) of the particles in a substance. This WILL cause an increase in TEMPERATURE. Temperature is NOT energy, only a measure of KINETIC ENERGY

The reason why there is no change in temperature at a phase change is because the substance is using the heat only to change the way the particles interact ("stick together"). There is no increase in the particle motion and hence no rise in temperature.

THERMAL ENERGY is one type of INTERNAL ENERGY possessed by an object. It is the KINETIC ENERGY component of the object's internal energy.

When thermal energy is transferred from a hot to a cold body, the term HEAT is used to describe the transferred energy. The hot body will decrease in temperature and hence in thermal energy. The cold body will increase in temperature and hence in thermal energy.

Temperature Scales: The K scale is the absolute temperature scale. The lowest K temperature, 0 K, is absolute zero, the temperature at which an object possesses no thermal energy.

The Celsius scale is based upon the melting point and boiling point of water at 1 atm pressure (0, 100^{o} C)

$K = {}^{o}C + 273.13$

UNITS OF HEAT ENERGY

The unit of heat energy we will use in this lesson is called the JOULE (J). Sometimes the CALORIE (cal) is used to express heat energy.

Here's how the Joule and calorie are related:

Joule (J) – 1 joule is the amount of energy that raises the temperature of 1 gram of water by 0.239^{o}C.

calorie (cal) – 1 calorie is the amount of heat required to change the temperature of 1 gram of water by 1^{o}C.

1 cal = 4.184 J

Coefficient of linear expansion: Solids

$$\alpha = \frac{\Delta l}{l_o \Delta T}$$

$$\frac{\Delta l}{l_o} = \alpha \Delta T$$

alpha is the coefficient of thermal expansion, which varies depending upon the composition of the object.

Coefficient of volume expansion: Liquids

$$\beta = \frac{\Delta V}{V_o \Delta T}$$

$$\frac{\Delta V}{V_o} = \beta \Delta T$$

beta is the coefficient of volume expansion, which will again vary depending upon the composition of the object.

These equations tell you that the space an object occupies depends upon temperature. Liquid expansion is always measured in volume. Solid expansion can be expressed in area and volume ratios; the coefficient of area expansion is 2x the linear coefficient and the coefficient of volume expansion is 3x the linear coefficient.

COEFFICIENT OF LINEAR EXPANSION FOR SOLIDS

Material	Coefficient ($\frac{\Delta l}{l^0C}$)	Temperature (^{0}C)
Aluminum	23.8×10^{-6}	20-100
Brass	19.3×10^{-6}	0-100
Copper	16.8×10^{-6}	25-100
Glass, tube	8.33×10^{-6}	0-100
Crown	8.97×10^{-6}	20-300
Pyrex	3.3×10^{-6}	20-300
Gold	14.3×10^{-6}	16-100
Ice	50.7×10^{-6}	-10-0
Iron, soft	12.10×10^{-6}	40
Steel	10.5×10^{-6}	0-100
Invar (nickel steel)	0.9×10^{-6}	20
Lead	29.40×10^{-6}	18-100
Magnesium	26.08×10^{-6}	18-100
Platinum	8.99×10^{-6}	40
Rubber, hard	80×10^{-6}	20-60
Quartz, fused	0.546×10^{-6}	0-800
Silver	18.8×10^{-6}	20
Tin	26.92×10^{-6}	18-100
Zinc	26.28×10^{-6}	10-100

COEFFICIENT OF VOLUME EXPANSION (LIQUIDS)

LIQUID	COEFFICENT $\frac{\Delta V}{V^0C}$
Acetone	14.87 x 10-4
Alcohol, ethyl	11.2×10^{-4}
Benzene	12.37×10^{-4}
Carbon disulfide	12.18×10^{-4}
Carbon Tetrachloride	12.36×10^{-4}
Chloroform	12.73×10^{-4}
Ether	16.56×10^{-4}
Gasoline	10.8×10^{-4}
Glycerol	5.05×10^{-4}
Mercury	1.82×10^{-4}
Petroleum	9.55×10^{-4}
Turpentine	9.73×10^{-4}
Water	2.07×10^{-4}

GASES

IDEAL GASES have the same coefficient of volume expansion and it is constant at all temperatures.

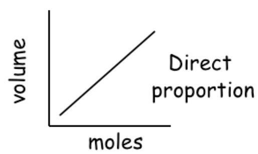
Number of Particles vs Volume

When **pressure** and **temperature** are constant…

V ⇧ when **n** ⇧

AVOGADRO'S LAW

$$\frac{V}{n} = \text{constant}$$



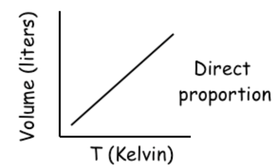
Volume vs Temperature

When **pressure** and **moles** are constant…

V ⇧ when **T** ⇧

Charles' LAW

$$\frac{V}{T} = \text{constant}$$



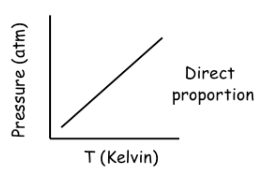
Pressure vs Temperature

When **VOLUME** and **moles** are constant…

P ⇧ when **T** ⇧

Gay-Lussac's LAW

$$\frac{P}{T} = \text{constant}$$



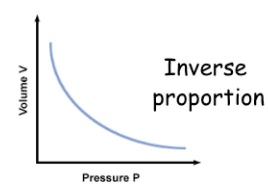
Pressure vs Volume

When **temperature** and **moles** are constant…

P ⇧ when **V** ⇩

Boyle's LAW

$$PV = \text{constant}$$



ideal gas law: $PV = nRT$

STP, 0° C and 1 atmosphere pressure

HEAT CAPACITY AND SPECIFIC HEAT

What is HEAT CAPACITY AND SPECIFIC HEAT AND HOW ARE THEY RELATED?

The HEAT CAPACITY is the amount of heat required to raise the temperature of an object or substance 1^{o}C. IT IS DEPENDENT UPON THE MASS OF THE OBJECT.

The SPECIFIC HEAT is similar but defined for a specific amount of mass. It is the amount of heat required to raise 1 GRAM of a substance 1^{o}C.

THINK OF THE SPECIFIC HEAT PROPERTY LIKE THIS: IT TELLS YOU HOW MUCH HEAT A SUBSTANCE CAN ABSORB BEFORE YOU SEE ITS TEMPERATURE GO UP.

UNITS OF SPECIFIC HEAT: J/g^{o}C

Think about this: If the value for the specific heat of a substance is low, what does that say about the nature of the substance? What if it is high?

Substances with HIGH SPECIFIC HEAT are "stubborn" (for lack of a better word) about ABSORBING enough heat to make their particles "wiggle" faster (KE increase). These substances ARE POOR CONDUCTORS OF HEAT.

Substances with LOW SPECIFIC HEAT don't require as much energy to increase the KE of the particles.
These substances absorb heat energy EASILY and are GOOD CONDUCTORS OF HEAT.

WATER HAS A RELATIVELY HIGH SPECIFIC HEAT. To get water to increase its temperature, the molecules have to be able to move faster and to accomplish this hydrogen bonding between them must be broken first. HEAT absorbed by water must break these intermolecular forces BEFORE the water temperature can increase.

METALS HAVE LOW SPECIFIC HEAT VALUES. Metals are dense, with lots of particles packed into a small volume. This enables them to absorb and CONDUCT (transfer) heat throughout their structure (atom to atom) readily. They DON'T STORE heat well but CONDUCT it (transfer it) very well.

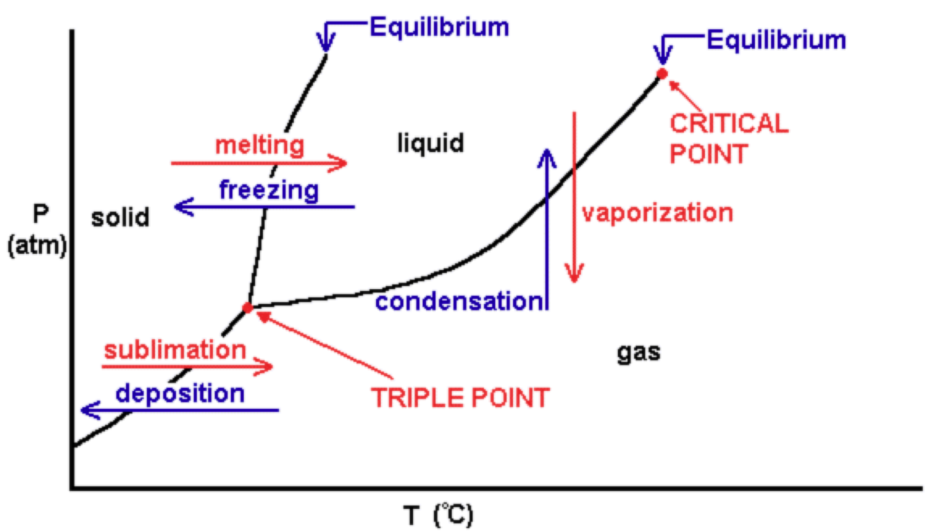
Changes in Phase

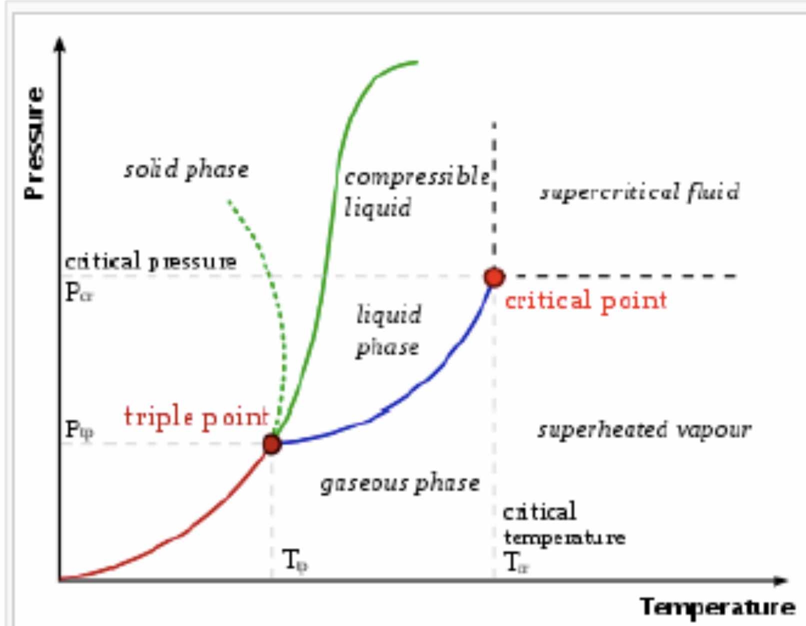
Changes in phase are dependent upon pressure and temperature

The NORMAL melting and boiling point of a substance is the temperature at which the phases are in equilibrium at 1 atmosphere.

The CRITICAL POINT on a phase diagram is the temperature and pressure point beyond which the gas and liquid phases are not distinct.

The TRIPLE POINT on a phase diagram is the point at which the three phases co-exist.





A typical phase diagram. The dotted green line gives the anomalous behaviour of water

HOW SPECIFIC HEAT IS RELATED TO HEAT exchange

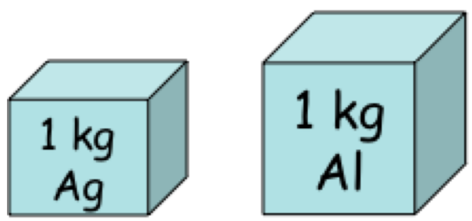
Mathematically, specific heat is related to the absorbed or released heat with the following equation:

$$Q = mC_p\,\Delta T$$

Q is the heat absorbed in J (usually)
m is the mass of the object in grams (g)
C_p is the specific heat in J/g°C
ΔT is the change in temperature before and after Q is exchanged

The SMALLER the specific heat value, the LARGER the temperature increase when comparing materials of the same mass

CONSIDER:



The two metal blocks have the same mass. Ag has a lower specific heat than Al. Which one will experience the greatest rise in temperature if the SAME number of joules of heat are applied?

Does this help: $\Delta T = \dfrac{Q}{m\,c}$

LAW OF HEAT EXCHANGE: when heat is transferred from a hot to a cold body, the amount of heat received by the cold body = the amount of heat lost by the hot body.

HEAT LOST = HEAT GAINED $\quad Q_{lost} = (mCp\,\Delta T)_{hot} = (mC_p\Delta T)_{cold} = Q_{gain}$

CHANGES IN STATE

WHAT HAPPENS WHEN A SUBSTANCE CHANGES STATE? ENERGY MUST BE EXCHANGED WITH THE SURROUNDINGS.

THE SUBSTANCE MUST EITHER LOSE OR GAIN HEAT, DEPENDING ON THE DIRECTION OF THE PHASE CHANGE.

A SIMPLE WAY TO REMEMBER WHETHER HEAT IS LOST OR GAINED IS TO CONSIDER HOW CONDENSED (HOW CLOSE THE PARTICLES ARE TO EACH OTHER) THE PHASE IS AFTER THE CHANGE OF STATE.

TO GO FROM A MORE CONDENSED TO A LESS CONDENSED PHASE REQUIRES A GAIN OF HEAT BY THE SUBSTANCE (ENDOTHERMIC).

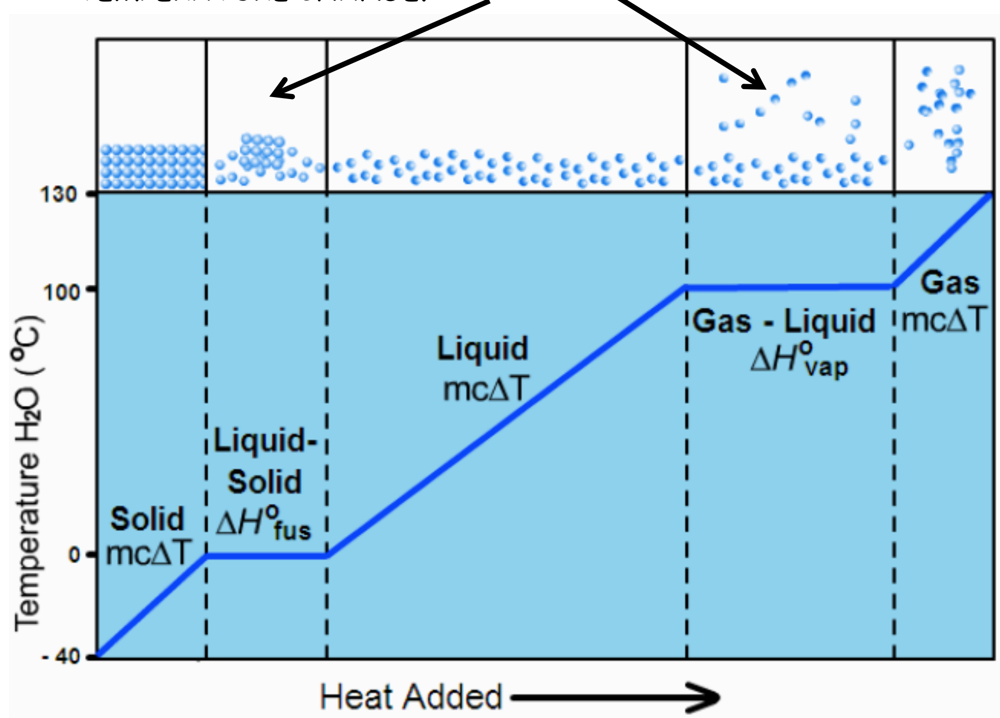
TO GO FROM A LESS CONDENSED TO A MORE CONDENSED PHASE REQUIRES THAT THE SUBSTANCE GIVE UP OR LOSE HEAT (EXOTHERMIC).

A CHANGE IN STATE IS A PHYSICAL CHANGE.

Heat of fusion: the amount of heat required to change a unit mass of a solid into a liquid without a change in temperature. This is at the normal melting point.

Heat of vaporization: the amount of heat required to change a unit mass of a liquid into a gas without a change in temperature. This is at the normal boiling point.

DURING THE PHASE CHANGE, HEAT IS BEING ABSORBED BUT THE TEMPERATURE DOES NOT CHANGE BECAUSE THE HEAT IS USED TO "UNHINGE" THE INTERPARTICLE FORCES. THERE IS NO CHANGE IN THE KINETIC ENERGY OF THE PARTICLES AND THEREFORE NO TEMPERATURE CHANGE.



HEAT CONSTANTS

Material	Specific heat $(cal/g^0C$	Melting Point (^0C)	Boiling Point (^0C)	Heat of Fusion (cal/g)	Heat of Vaporization (cal/g)
Alcohol	0.581	-115	78.5	24.9	204
Aluminum	0.217	660.2	2467	94	2520
Ammonia,l	1.047	-77.7	-33.35	108.1	327.1
Ammonia, g	0.525				
Brass(40%Zn)	0.0917	900			
Copper	0.0924	1083	2595	49	1150
Glass, crown	0.161				
Iron	0.1075	1535	3000	7.89	1600
Lead	0.0305	327.5	1744	5.47	207
Mercury	0.0333	-38.87	356.58	2.82	70.613
Platinum	0.0317	1769	3827	27.2	
Silver	0.0562	960.8	2212	26.0	565
Tin	0.0543	232	2270	14.4	520
Tungsten	0.0322	3410	5927	43	
Water	1.00		100		538.2
Ice	0.530			79.71	
Steam	0.481				
Zinc	0.0822	419.4	907	23.0	420