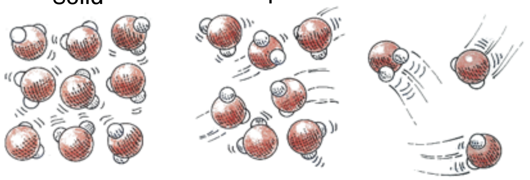
Temperature

Temperature – The measurement of the <u>average</u> kinetic energy of the particles in an object.

Kinetic Molecular Theory – particles of matter are always in motion

Solid Liquid Gas

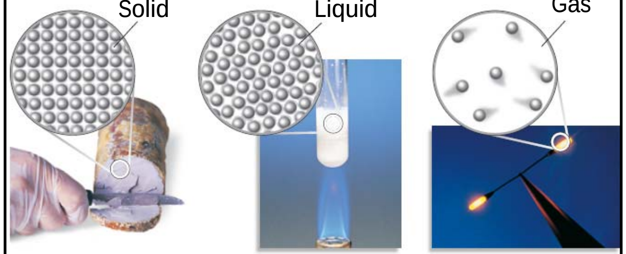


1

Higher Temperature

Faster Particles

Farther Apart



2

Common Temperature Scales

Celsius – related to Centigrade (100 degree)

0°C – water freezes

100°C – water boils

Fahrenheit – used in USA and Belize

32°F – water freezes

212°F – water boils

To make the degree symbol ° type Alt + 0176

3

Absolute Temperature Scales

Kelvin – related to Celsius, starts at "absolute 0" as lowest impossible value to reach.

0K – all motion stops

273.15K – water freezes

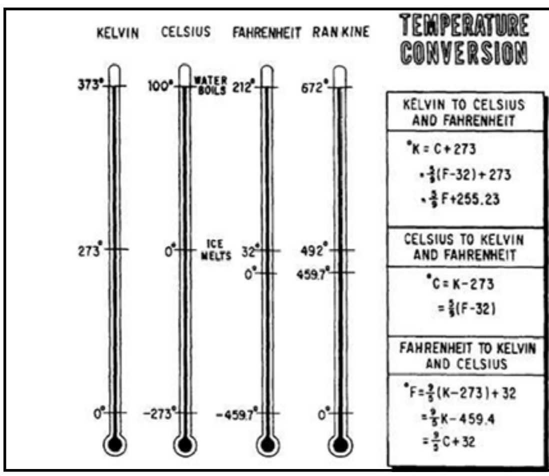
DO NOT USE ° SYMBOL!

Rankine – the "Fahrenheit version of Kelvin"

0°R – Absolute lowest Temp

459.67°R – water freezes

4



5

Temperature Conversion

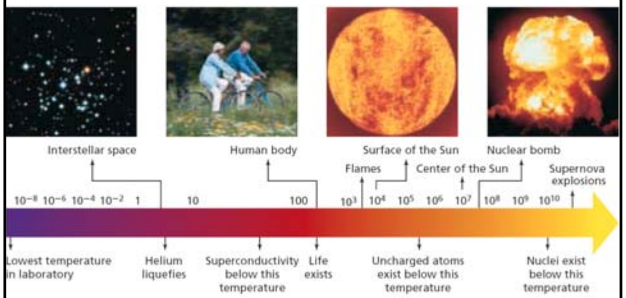
°C to °F $$F = 1.8C + 32$$

°F to °C $$C = \frac{(F - 32)}{1.8}$$

°C to K $$K = C + 273.15$$

6

Relative Temperatures



Temperature (Kelvin)

7

Thermal Energy

- All matter contains thermal energy. This is the total internal energy that results in the temperature of the substance
- A giant iceberg can have more thermal energy than a hot coal even if it is much colder.
- **Heat** is thermal energy in transit. A substance does not contain heat.

8

Heat Energy

- Heat and Temperature are not the same!!
- Cold is the absence of heat, not an energy
  - Same concept as light/dark
- Cold "can't come in", heat flows out
  - Heat flows from High Temp → Low Temp

9

Q = Heat

- Heat can be read in units of Joules (J) or calories.

calorie (cal) – energy to raise 1g of water by 1°C
- 1 calorie = 4.184 Joules

Calorie (kcal) – energy to raise 1kg of water by 1°C. This is used in food measurement and can be called a **kilogram calorie**. (notice this one uses a capitol "C")
- 1 Calorie = 1000 calories
- 1 Calorie = 4.184 kJ

10

Adding Heat

Adding heat to an object will either:

1. Raise the object's temperature
2. Cause a change in state (solid→liquid→gas)
   - This occurs at a constant temperature!

11

Temp and Heat Flow

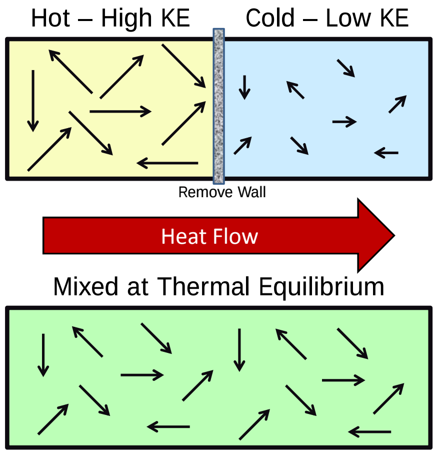
High Temperature → Particles move fast

Low Temperature → Particles move slow

When a hot system meets a cold system…
Hot system transfers heat until even temp.

Thermal Equilibrium – Objects have equal temp, average KE, and energy flow rate

12



13

Heat Transfer

$$Q = m\,C_p\,(T_f - T_o)$$

Q – Heat
m – mass
T – temperature in Kelvin
C_p – specific heat
$\Delta T = (T_f - T_o)$

Way to remember: "m c delta T"

14

Specific Heat

- The amount of energy needed to raise one gram of a substance one degree Celsius.
- Units are [J/kg·K]
- Higher values → "stores" a lot of energy, takes large energy change to heat or cool
- Think of this as the "inertia" of thermal energy

15

Table 12-1

Specific Heat of Common Substances

Material	Specific Heat (J/kg·K)	Material	Specific Heat (J/kg·K)
Aluminum	897	Lead	130
Brass	376	Methanol	2450
Carbon	710	Silver	235
Copper	385	Steam	2020
Glass	840	Water	4180
Ice	2060	Zinc	388
Iron	450		

16

3 Types of Heat Transfer

- Conduction – through matter by "touching"
  - hot metal burns hand
- Convection – through fluid motion (gas/liquid)
  - Fan cools you off (you heat air)
- Radiation – electromagnetic radiation through space, no matter needed
  - Sunlight melts snow

17

Conduction

- Heat travels through solids that conduct heat
- Conductor – a substance that conducts heat very well
  - Copper, iron, gold, diamond, silver, many metals
- Insulator – a substance that conducts heat poorly
  - Wood, Styrofoam, Air, Wool, Concrete

18

Convection

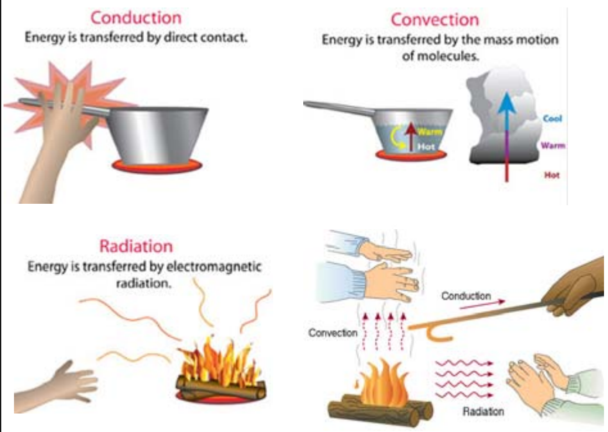
- Convection currents occur due to temperature differences causing density differences.
  - Hot air rises and is replaced by cooler air
  - Warm water rises, cool water sinks
- A faster current will cause faster heat transfer

19

Radiation

- Transfer of electromagnetic radiation
  - This does not use matter to travel (think of light)
  - This is how we get energy from the Sun!
- **All matter** emits radiant energy. The frequency of radiation depends on temperature.
  - Room temperature objects emit infrared radiation.
  - Very hot objects emit visible light

20



21

Phase Changes

Phase changes occur at constant temperature

Heat of Fusion (H_f) – energy required to melt a solid

$$Q = m H_f$$

Heat of Vaporization (H_v) – energy required to vaporize a liquid

$$Q = m H_v$$

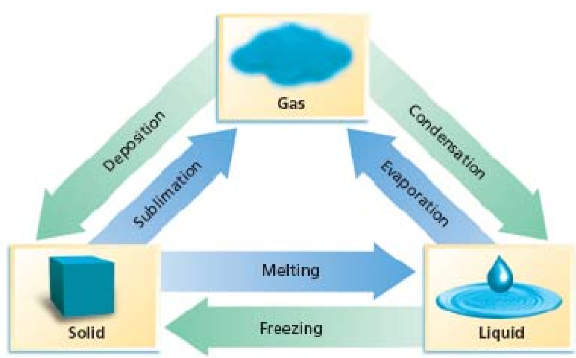
Units are [J/kg]

22

Table 12-2		
Heats of Fusion and Vaporization of Common Substances		
Material	Heat of Fusion H_f (J/kg)	Heat of Vaporization H_v (J/kg)
Copper	2.05×10^5	5.07×10^6
Mercury	1.15×10^4	2.72×10^5
Gold	6.30×10^4	1.64×10^6
Methanol	1.09×10^5	8.78×10^5
Iron	2.66×10^5	6.29×10^6
Silver	1.04×10^5	2.36×10^6
Lead	2.04×10^4	8.64×10^5
Water (ice)	3.34×10^5	2.26×10^6

23

Phase Changes



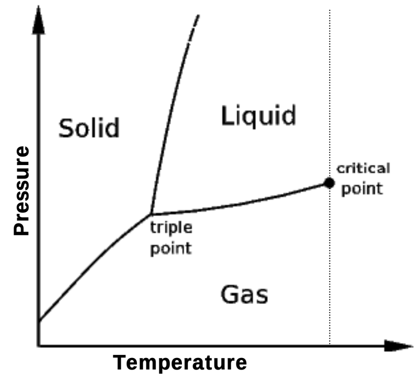
Phase Changes

- Melting — Solid → Liquid
- Freezing — Liquid → Solid
- Evaporation — Liquid → Gas
- Condensation — Gas → Liquid
- Sublimation — Solid → Gas
- Deposition — Gas → Solid

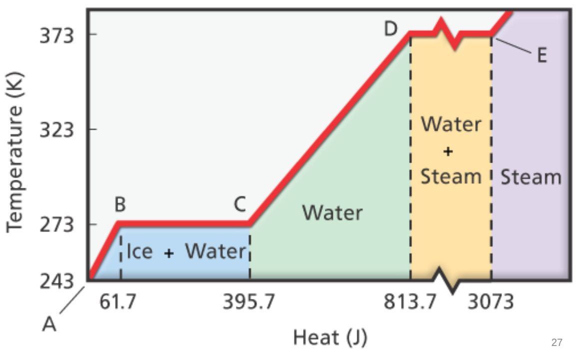
Triple Point – All three states of matter exist at same time

Critical Point – Only gas exists at temperatures past this point

Phase Diagram

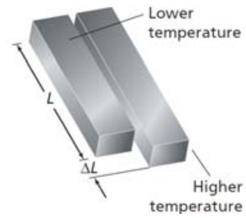


Change of State Graph



Thermal Expansion

- When substances get
  - warmer they expand
  - cooler they contract



- Water is unique
  - Most dense at 4°C
  - Once it is ice it slightly contracts when colder

Thermal Expansion

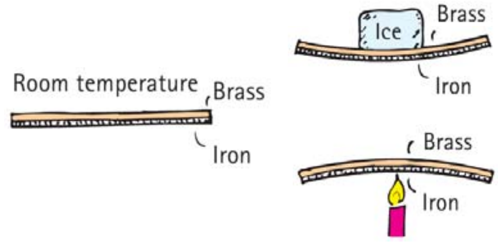
- Each substance has a unique coefficient for thermal expansion.

α (alpha) is used for linear expansion.

β (beta) is used for linear expansion.

Expansion Rates

A bimetallic strip is two metals with different expansion rates attached together. This will curl when heated or cooled.



Coefficients of Thermal Expansion at 20°C		
Material	Coefficient of Linear Expansion, α (°C)$^{-1}$	Coefficient of Volume Expansion, β (°C)$^{-1}$
Solids		
Aluminum	25×10^{-6}	75×10^{-6}
Brass	19×10^{-6}	56×10^{-6}
Concrete	12×10^{-6}	36×10^{-6}
Copper	17×10^{-6}	48×10^{-6}
Glass (soft)	9×10^{-6}	27×10^{-6}
Glass (ovenproof)	3×10^{-6}	9×10^{-6}
Iron, steel	12×10^{-6}	35×10^{-6}
Platinum	9×10^{-6}	27×10^{-6}
Liquids		
Gasoline		950×10^{-6}
Mercury		180×10^{-6}
Methanol		1100×10^{-6}
Water		210×10^{-6}

31

Linear Expansion

The change in length of a material is proportional to the original length and the change in temperature

$$\Delta L = \alpha L_i \Delta T$$

α= coeff of linear expansion

ΔT= change in temperature

ΔL= change in length

L_i = original length

32

Volume Expansion

$$\Delta V = \beta V_i \Delta T$$

β = coeff of volume expansion

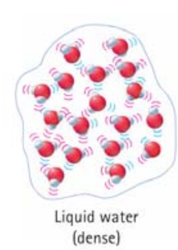
ΔT= change in temperature

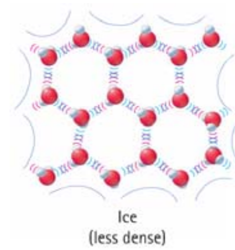
ΔV= change in volume

V_i = original volume

33

Water-Ice Expansion

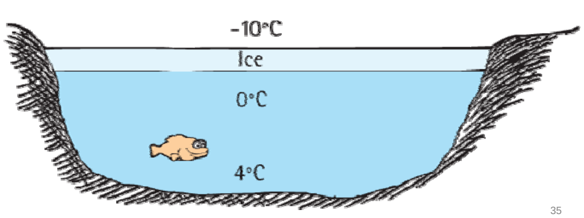




34

Water Density

The most dense water always sinks. Deep lakes and oceans will have a constant temperature of 4°C year round. This makes a safe and consistent habitat for many fish.



35