GENERAL CHEMISTRY C1404

Spring 2003

Thermodynamics • Electrochemistry • Kinetics

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Some Course Information

- Homework assigned at start of each chapter
- Lecture notes posted on web one day after lecture
- Office Hours: MT 12:30-1:30

THERMODYNAMICS

THERMO (HEAT) and DYNAMICS (MOTION)

ENERGY

HEAT

WORK

TEMPERATURE

POWER

THERMODYNAMICS

THERMO (HEAT) and DYNAMICS (MOTION)

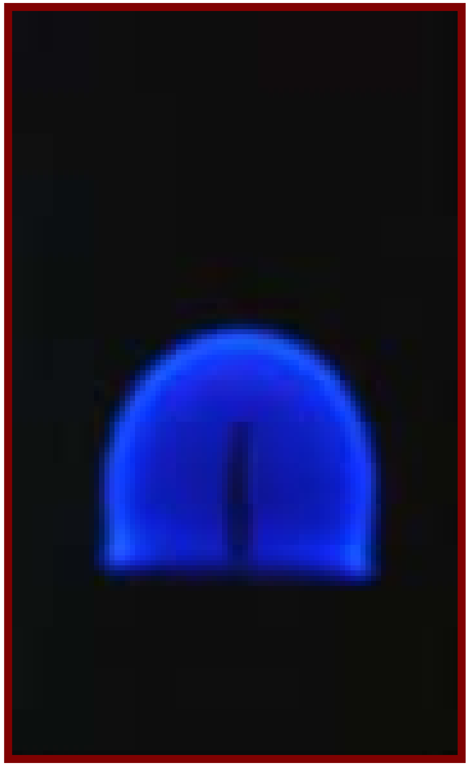
THERMODYNAMICS

THERMO (HEAT) and DYNAMICS (MOTION)

WIND TURBINE POWER GENERATION

THERMODYNAMICS

THERMO (HEAT) and DYNAMICS (MOTION)



ENERGY

SYMBOLS & WORDS IN
GOLD
ARE IMPORTANT

ENERGY

E = T + V

ENERGY IS CONSERVED

KINETIC

- DUE TO MOTION OF ATOMS, MOLECULES, OR OBJECTS
- T = 1/2 mv2 FOR TRANSLATIONAL MOTION
- MAGNITUDE DEPENDS ON VELOCITY

POTENTIAL

- DUE TO A FORCE BETWEEN ATOMS, MOLECULES, OR OBJECTS
- MAGNETIC, GRAVITATIONAL, ELECTROSTATIC
- MAGNITUDE DEPENDS ON RELATIVE POSITION

ENERGY

ENERGY APPEARS IN MANY FORMS

MOTION

LIGHT

SOUND

WAVES AND TIDES

WIND

ELECTRICITY

FOODS AND FUELS

"HEAT"

ENERGY

ENERGY APPEARS IN MANY FORMS

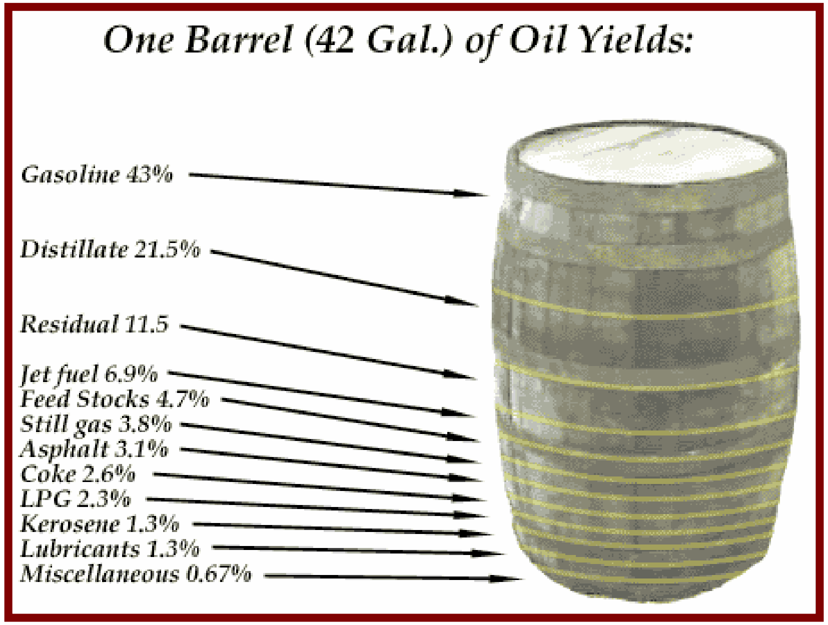
MOTION

"HEAT"

LIGHT

SOUND

ENERGY SOURCES



BARREL OF OIL = 5.8×10^6 Btu
WORLD CONSUMPTION =
7.6×10^7 barrel day^{-1}

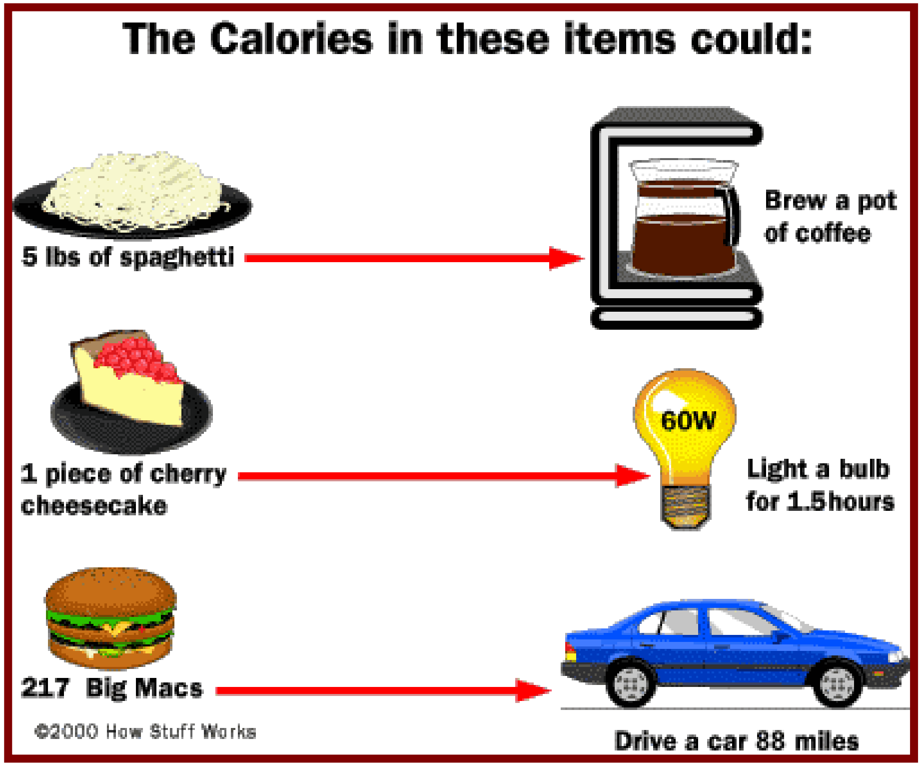
1 Btu = 252 cal
1 Calorie = 1.00 kcal

1 BARREL OF OIL =
5.2×10^3 SNICKERS BARS

SNICKERS CANDY BAR = 280 Calories
WORLD CONSUMPTION UNKNOWN

ENERGY SOURCES

THE ENERGY IN FOOD IS SUBSTANTIAL



ENERGY

ENERGY CALCULATIONS

HOW MUCH ENERGY DOES IT TAKE TO WALK UP THE STEPS FROM COLLEGE WALK TO LOW LIBRARY ASSUMING THE ONLY ENERGY NEEDED IS THAT TO INCREASE THE GRAVITATIONAL POTENTIAL ENERGY OF YOUR BODY, $\Delta V = m \times g \times \Delta h$? NOTE: $g = 9.8\ m\ s^{-2}$.

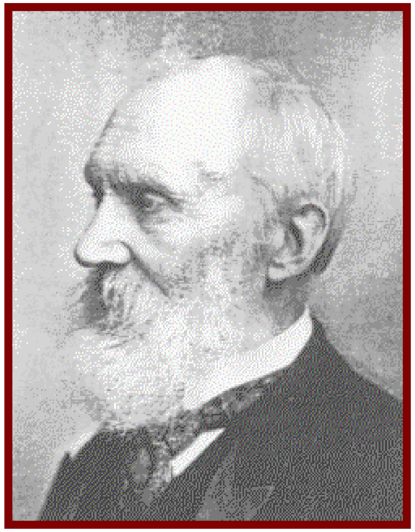
HOW MANY TIMES DO YOU HAVE TO MAKE THIS CLIMB TO "WORK OFF" ONE SNICKERS BAR?

ANSWERS TOMORROW.

THERMODYNAMICS

THERMO (HEAT) and DYNAMICS (WORK)

STEAM ENGINE



WILLIAM THOMSON
BARON KELVIN OF LARGS

THERMODYNAMICS

THERMO (HEAT) and DYNAMICS (WORK)

"SCIENCE OWES MORE TO THE STEAM ENGINE THAN THE STEAM ENGINE OWES TO SCIENCE." ANON.

THERMODYNAMICS

THERMO (HEAT) and DYNAMICS (WORK)

- WORK = w = FORCE OPPOSED x DISTANCE MOVED

PV WORK: $w = P \times \Delta V = (\text{Force/Area}) \times (\text{Area} \times \Delta l)$
WORK AGAINST GRAVITY: $w = m \times g \times \Delta h$

WORK DONE BY SOMETHING DECREASES ITS ENERGY.
WORK DONE ON SOMETHING INCREASES ITS ENERGY.

- POWER = WORK PER UNIT OF TIME

THERMODYNAMICS

THERMO (HEAT) and DYNAMICS (WORK)

- BUT WHAT IS HEAT?
- HOW DO WE MEASURE IT?
- HEAT IS RELATED TO TEMPERATURE.
- HOW DO WE MEASURE THAT?

THERMODYNAMICS

THERMO (HEAT) and DYNAMICS (WORK)

- TEMPERATURE IS MEASURED WITH A THERMOMETER.
- WHAT IS A THERMOMETER?
- WHAT DOES A THERMOMETER MEASURE?

TEMPERATURE AND EQUILIBRIUM

TEMPERATURE IS MEASURED WITH A THERMOMETER

- A THERMOMETER DETERMINES WHETHER TWO OBJECTS ARE IN THERMAL EQUILIBRIUM.
- A THERMOMETER MEASURES SOME PHYSICAL PROPERTY THAT DEPENDS ON TEMPERATURE.

MEASURING TEMPERATURE

TEMPERATURE IS MEASURED WITH A THERMOMETER

- A THERMOMETER NEEDS A SCALE.
- SCALES WE USE: CENTIGRADE, FAHRENHEIT, KELVIN.
- CENTIGRADE AND FAHRENHEIT SCALES DEFINED BY BOILING POINT (100C OR 212F) AND FREEZING POINT OF WATER (0C OR 32F) OF WATER.
- KELVIN SCALE DEFINED BY IDEAL GAS LAW (PV = nRT) AND HAS AN ABSOLUTE ZERO.

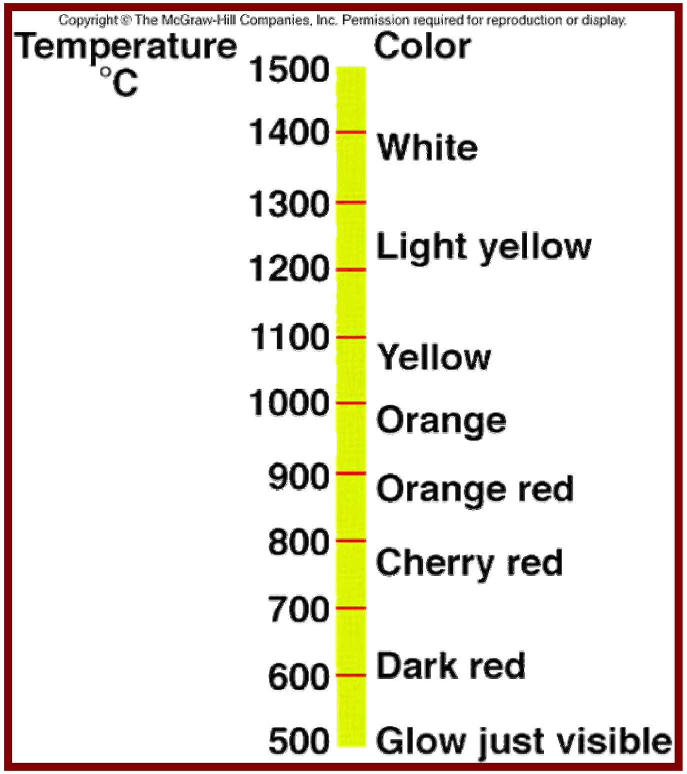
EXAMPLES OF THERMOMETERS

- AN ORDINARY LIQUID THERMOMETER MEASURES THE EXPANSION/CONTRACTION OF A LIQUID.
- A THERMOCOUPLE MEASURES THE TEMPERATURE-DEPENDENT ELECTRICAL POTENTIAL OF THE CONTACT BETWEEN TWO DIFFERENT METALS.
- LIQUID CRYSTALS HAVE A COLOR THAT CHANGES WITH TEMPERATURE.
- A PYROMETER MEASURES BLACKBODY RADIATION.

EXAMPLES OF THERMOMETERS

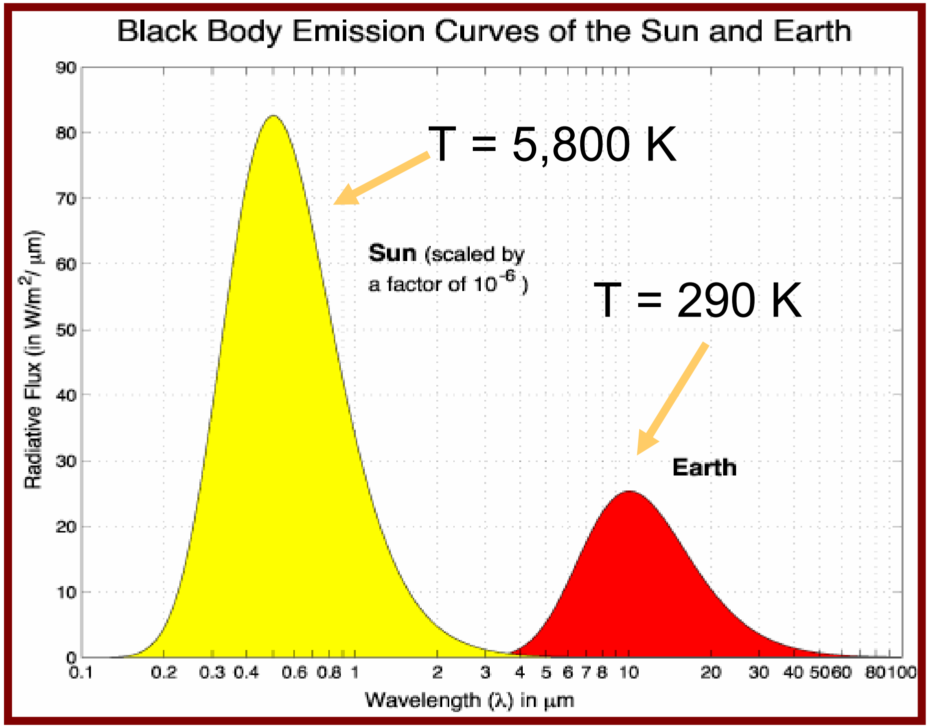
A PYROMETER MEASURES BLACKBODY RADIATION

- ALL BODIES RADIATE LIGHT DUE TO THEIR THERMAL ENERGY.
- THE COLOR AND THE INTENSITY OF THE LIGHT REVEAL THE TEMPERATURE.



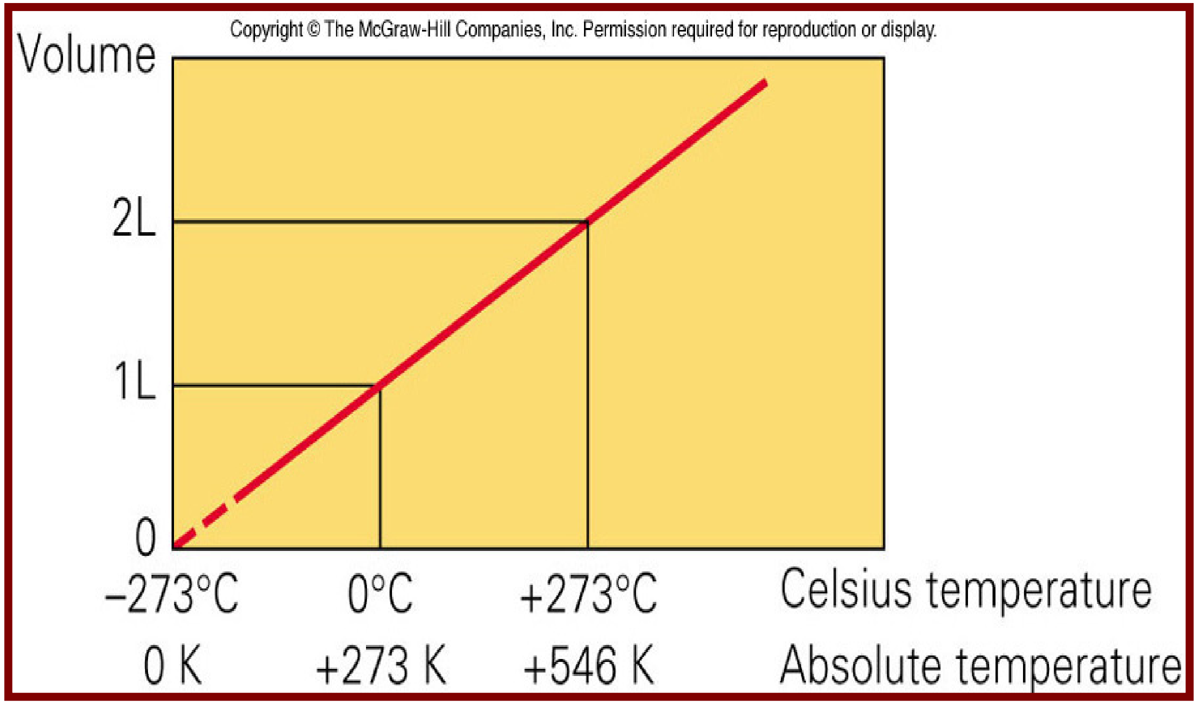
EXAMPLES OF THERMOMETERS

BLACK BODY RADIATION IS TEMPERATURE DEPENDENT



EXAMPLES OF THERMOMETERS

IDEAL GAS THERMOMETER



PV = nRT so V = (nR/P)T

HEAT VERSUS TEMPERATURE

TEMPERATURE CHANGES ARE USED TO QUANTITATIVELY DEFINE HEAT

PROCEDURE

1. TWO OBJECTS ARE INITIALLY NOT AT THE SAME TEMPERATURE.
2. WE BRING THEM INTO CONTACT WITH ONE ANOTHER.
3. WHEN THEY HAVE REACHED EQUILIBRIUM WE MEASURE THE TEMPERATURE.
4. WE REPEAT THIS PROCEDURE FOR OBJECTS OF MANY DIFFERENT MATERIALS.

HEAT VERSUS TEMPERATURE

TEMPERATURE CHANGES ARE USED
TO QUANTITATIVELY DEFINE HEAT

RESULTS

THE TEMPERATURE <u>CHANGE</u> FOR <u>EACH</u> OBJECT DEPENDS ON THE MASS AND THE IDENTITY OF <u>BOTH</u> OBJECTS.

$$m_1 \times c_{s,1} \times \Delta T_1 = - m_2 \times c_{s,2} \times \Delta T_2$$

NEGATIVE SIGN BECAUSE ΔT_1 and ΔT_2 ARE OF OPPOSITE SIGN

$\Delta T_1 = T_{equil} - T_{1,initial}$ $\Delta T_2 = T_{equil} - T_{2,\ initial}$

ONE OF THESE HAS TO BE NEGATIVE

HEAT VERSUS TEMPERATURE

TEMPERATURE CHANGES ARE USED
TO QUANTITATIVELY DEFINE HEAT

THE TEMPERATURE CHANGE FOR EACH OBJECT DEPENDS ON THE MASS AND THE IDENTITY OF BOTH OBJECTS.

$$m_1 \times c_{s,1} \times \Delta T_1 = - m_2 \times c_{s,2} \times \Delta T_2$$

mass

c_s IS THE SPECIFIC HEAT
(UNITS ARE Joule g^{-1} K^{-1})

HEAT VERSUS TEMPERATURE

HEAT IS THE FLOW OF ENERGY
FROM ONE OBJECT TO ANOTHER

HEAT IS GIVEN THE SYMBOL q AND IS DEFINED BY:

$$q = m_1 \times c_{s,1} \times \Delta T_1$$

<u>and</u>

$$q = m_2 \times c_{s,2} \times \Delta T_2$$

NOW ΔT_1 and ΔT_2 HAVE OPPOSITE SIGN, WHILE THE MASSES AND SPECIFIC HEATS ARE POSITIVE.
SO, IT SEEMS WE HAVE A PROBLEM WITH THE SIGN OF q.
THIS WILL BE EXPLAINED IN A MOMENT.

MOLAR HEAT CAPACITY

ANOTHER WAY TO WRITE THIS IS:

- $n_1 \times C_{P,1} \times \Delta T_1 = - n_2 \times C_{P,2} \times \Delta T_2$

# of moles

$C_P = c_s \times \rho$

ρ IS THE MOLAR DENSITY
(UNITS ARE g^{-1} $mole^{-1}$)

C_P IS THE MOLAR HEAT CAPACITY AT CONSTANT PRESSURE
(UNITS ARE Joule $mole^{-1}$ K^{-1})

HEAT CAPACITY CALCULATIONS

HOW MANY SNICKERS BARS PROVIDE ENOUGH ENERGY TO HEAT THE WATER IN A COMMON HOUSEHOLD WATER HEATER (40 GALLONS) FROM 55 FAHRENHEIT TO 130 FAHRENHEIT?

TAKE A GUESS AS TO HOW MANY CUBIC FEET (AT STP) OF NATURAL GAS (MOSTLY METHANE) WOULD HAVE TO BE BURNED TO DO THE SAME THING?

ANSWERS TOMORROW.