Astro 301/ Fall 2006

(50405)

Introduction to Astronomy

http://www.as.utexas.edu/~sj/a301-fa06

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Lecture 11: Tu Oct 10

North Korean nuclear test on Mon Oct 9 2006

North Korea claims to have conducted nuclear test on an atomic fission bomb on Oct 9,2006

See today's lecture on energy released by nuclear fission

Recent and Upcoming topics in class

Energy

-- Energy and Luminosity

-- Forms of Energy.

-- Principle of Conservation of Energy

-- Equivalence of Mass and Energy or $E=mc^2$

-- What fraction f of the stored energy do different processes

Chemical reactions
Nuclear fusion
Nuclear Fission
Accretion of matter onto a black hole

-- Atomic Nuclear Fission Bomb dropped on Hiroshima and Nagasaki
North Korean nuclear test on October 9, 2006

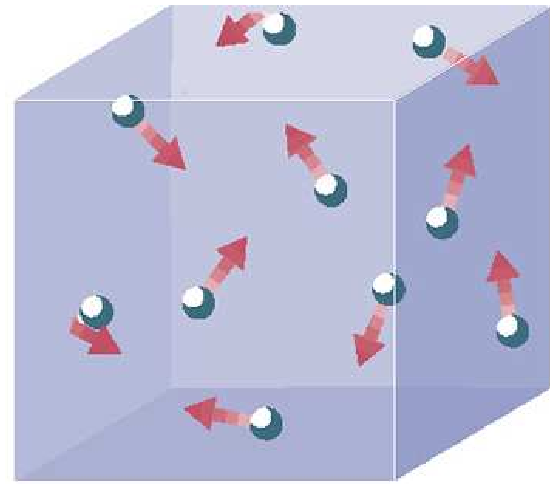
-- How much energy is released during nuclear fusion ? The missing mass problem

Energy and Work

Table 4.1 Energy Comparisons

Item	*Energy (joules)*
Average daytime solar energy striking Earth, per m^2 per second	1.3×10^3
Energy released by metabolism of one average candy bar	1×10^6
Energy needed for 1 hour of walking (adult)	1×10^6
Kinetic energy of average car traveling at 60 mi/hr	1×10^6
Daily energy needs of average adult	1×10^7
Energy released by burning 1 liter of oil	1.2×10^7
Energy released by fission of 1 kg of uranium-235	5.6×10^{13}
Energy released by fusion of hydrogen in 1 liter of water	7×10^{13}
Energy released by 1-megaton H-bomb	5×10^{15}
Energy released by major earthquake (magnitude 8.0)	2.5×10^{16}
Annual U.S. energy consumption	10^{20}
Annual energy generation of Sun	10^{34}
Energy released by supernova (explosion of a star)	10^{44}–10^{46}

Forms of Energy

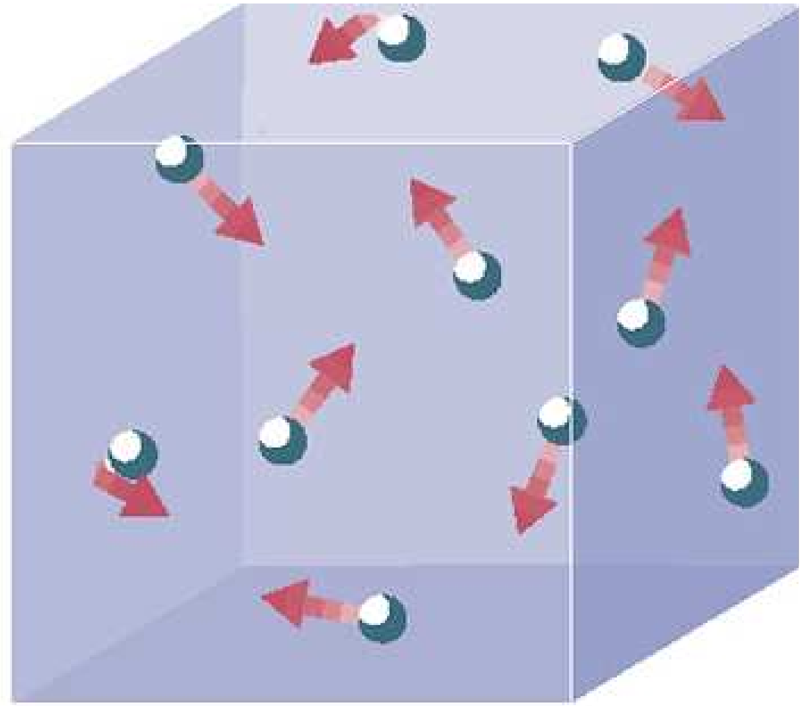


See in-class notes

Radiative energy (light)
Sound energy
Kinetic energy
Thermal Energy

Temperature affect the motion of atoms

A macroscopic body (e.g, a hot kettle, a star, your hand) contains atoms that are moving randomly

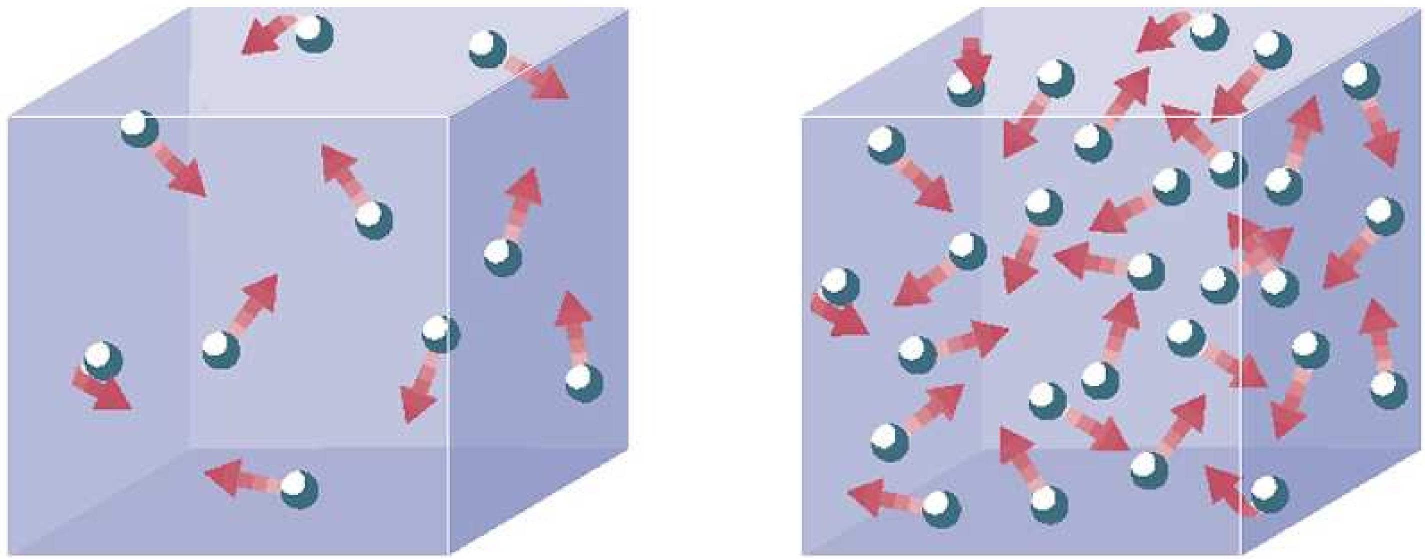


The temperature of a body determines the random speed at which its atoms move

High temperature à high speed à large thermal energy

Low temperature à low speed à low thermal energy

Thermal Energy



Thermal Energy of each particle depends on temperature T

Total thermal energy of 2 blocks of matter having same volume is larger for block having more particles à higher density

The Kelvin, Celsius and Fareneit temperature scales

Celsius temperature = Kelvin temperature - 273°

Celsius temperature = (Farenheit temperature - 32) /1.8

ºK	Example	Speed of Atoms
0	Absolute zero	Atoms at rest
273	Water freezes	
373	Water boils	500 meters/sec
1800	Iron melts	
3000	Iron vaporizes	
5800	Sun’s surface	7 km/sec

What fraction f of the stored energy do different processes extract?

Einstein's equivalence principle

Energy **stored in** Mass M is given by $E= Mc^2$

1) Chemical reactions extract energy

$E = f \ Mc^2$ where $f = 10^{-9}$

2) Nuclear fission of Uranium or Plu extract energy

$E = f \ Mc^2$ where $f < 10^{-3}$

à Uranium bomb on Hiroshima, Plutonium bomb on Nagasaki

3) Nuclear fusion of a mass M of H into He extract energy

$E = f \ Mc^2$ where $f = 0.007$

à Hydrogen bomb in 1952

4) Infall of mass M on the accretion disk of a black hole releases

$E = f \ Mc^2$ where $f = 0.1$

Atomic nuclear fission bomb dropped on Hiroshima

Nuclear fission of Uranium or Plu extract energy $E = f \ Mc^2$ where $f < 10^{-3}$

Aug 6, 1945: Hiroshima hit by an atomic fission bomb made of Uranium. Mass of Uranium was a few kg of which 1 g was entirely converted to energy

Energy released equivalent to detonating 15,000 tons (33 million pounds) of TNT

Atomic Nuclear Fission Bomb dropped on Nagasaki

The atomic bomb mushroom cloud seen from an American aircraft

The atomic bomb mushroom cloud over Nagasaki on August 9, 1945

Atomic Fission Bomb: Nagasaki

Nagasaki 2 days before the atomic bombing

Nagasaki 3 days after the atomic bombing

Atomic Fission Bomb: Nagasaki

DAMAGE CAUSED BY THE ATOMIC BOMB EXPLOSION

* Levelled Area...................6.7 million square meters

* Damaged Houses:

Completely Burned ------11,574

Completely Destroyed-----1,326

Badly Damaged------------5,509

Total-------------------18,409

* Casualties

Killed------73,884

Injured-----74,909

Total------148,793

(Large numbers of people died in the following years from the effects of radioactive poisoning.)

North Korean nuclear test on Mon Oct 9 2006

North Korea claims to have conducted nuclear test on an atomic fission bomb on Oct 9,2006

Energy released is thought to be equivalent to detonating 550 tons of TNT

How much energy is released during nuclear fusion ?
(The missing mass problem)

1. Energy released during nuclear fusion is related to the missing mass or mass difference between starting and end products: **See in class notes**

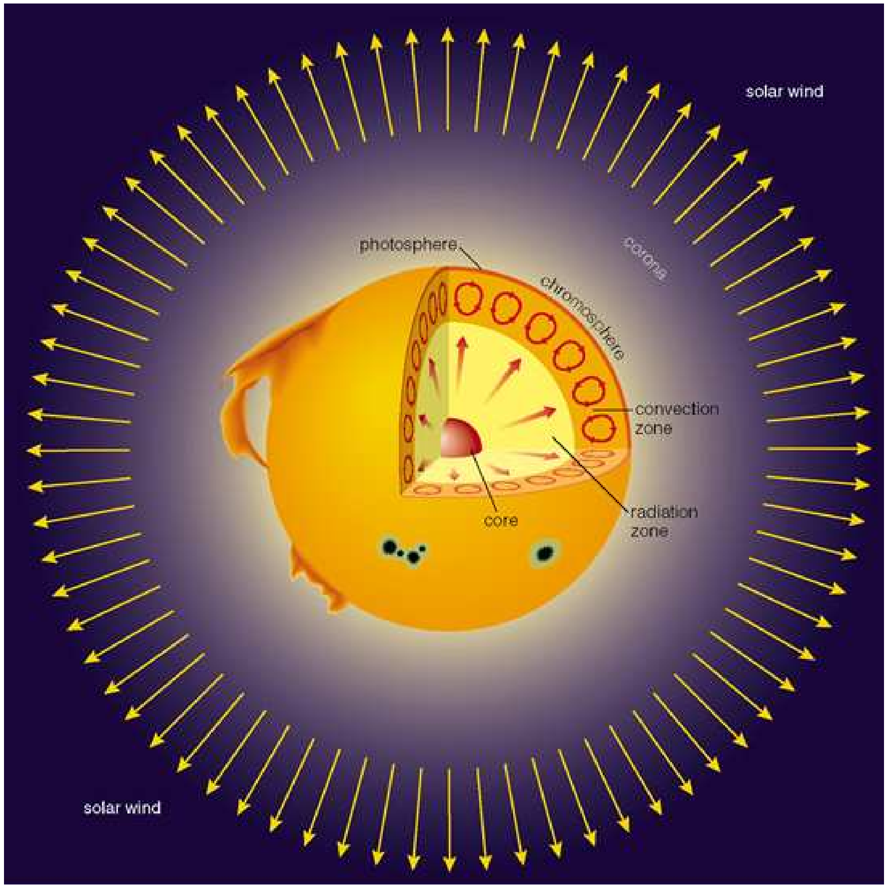
   Fusion energy E = (iniitial mass – end mass) c^2

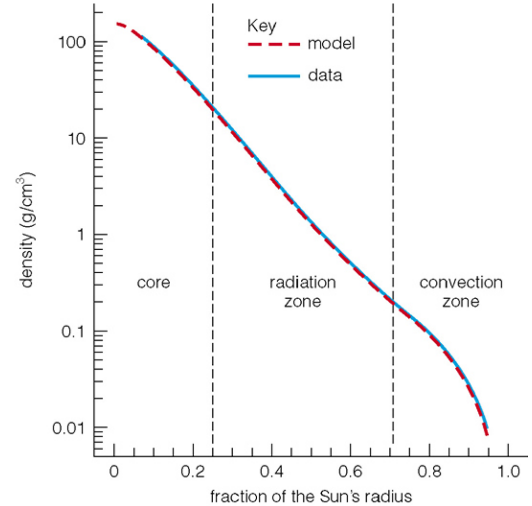
2. Where does this relationship come from ? It can be derived very simply from the principle of conservation of energy : **See in class notes**

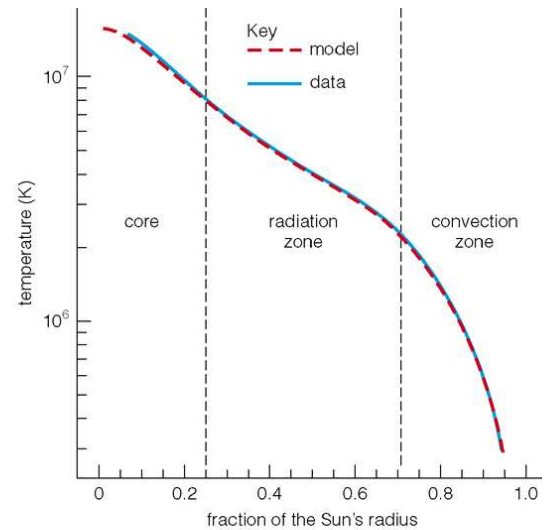
3. We stated earlier that the nuclear fusion of a mass M of H into He extracts energy E = f Mc^2 where f = 0.007

   Where does the number 0.007 comes from ? We can derive it from the first principles in (1) above:: **See in class notes**

The Sun is powered by nuclear fusion of H into He in its core







- Nuclear fusion occurs in core where temp and pressure are very high.
  T drops from 1.5 x 10^7 K in the core down to 5800 K at the surface or photosphere
- The energy released is transported from core to the photosphere where it is released as light and heat.