PHAS1228 – Thermal Physics

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Course web pages: http://www.cmmp.ucl.ac.uk/~als/

The course consists of **30 lectures** covering main course material, and **6 hours of other activities**,
2 problem solving classes and **4 homeworks**.
Assessment is based on an unseen written examination (85%) and four sets of homework: (15%)

SOME OF THE KEY CONCEPTS:

- **Atomistic theory** of matter, internal energy and heat

- **Energy conservation** laws

- Relation between **heat and work**

- **Entropy**

1228 THERMAL PHYSICS

THERMODYNAMICS

- Internal energy – heat – work
- Phenomenological
- Describes heat engines

KINETIC THEORY

- Ideal gas model
- Derivation of equation of state
- Statistical description of gases

ATOMIC AND MOLECULAR

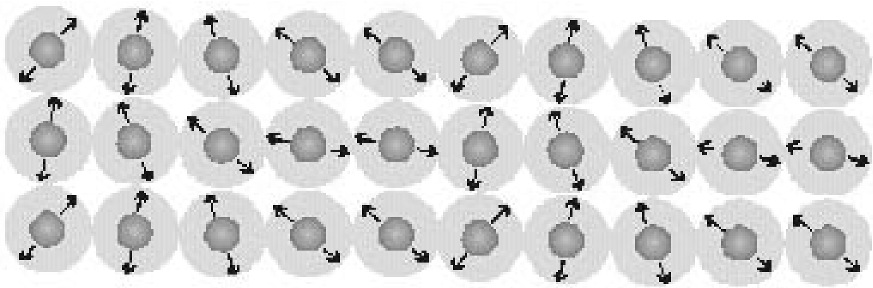
- Concepts of quantum theory
- Degrees of freedom
- Mechanisms of energy transfer

THERMODYNAMICS

Is about **equilibrium** properties

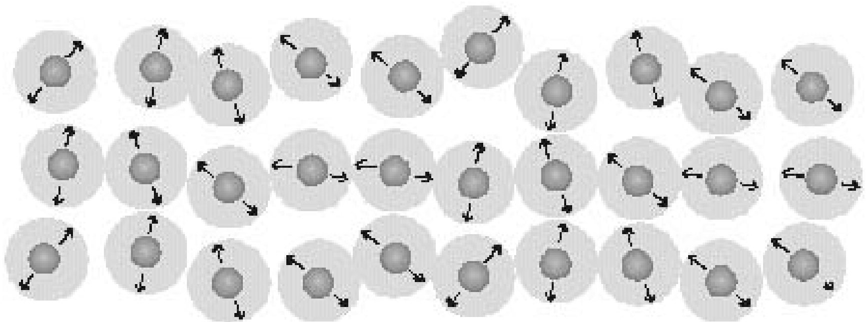
Is very successful in explaining the bulk properties of **matter** and the correlation between these properties and the mechanics of atoms and molecules

Matter - gases, liquids, solids and plasma



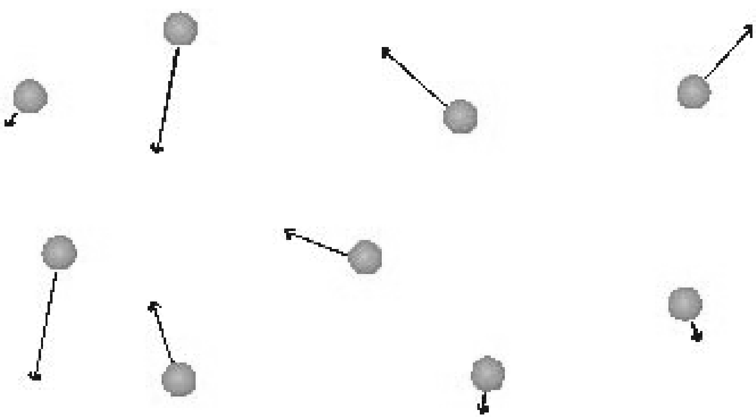
SOLIDS

The particles **vibrate around fixed positions**.
They are close together and so attract each other strongly. This is why solids maintain their shape.



LIQUIDS

The particles are still relatively close together but now have **enough energy to "change places" with each other**. This is why liquids can **flow**.



GASES

Average distance between particles typically **10 times greater** than in solids and liquids. The particles now move **freely at random**, occupying all the space available to them.

We start with gasses and apply a **model** = “Ideal Gas”

Other models: uncompressible liquid; ideal crystal

Another general model we will use is that of **system** and **surroundings**

System at **equilibrium** can be described by a number of **thermodynamic variables** that are ***independent of the history of the system*****.**

Such variables are called **state variables** or **state functions** depending on the context.

We can describe a system by a set of ***independent state variables*** and we can express other variables (*state functions*) through this set of independent variables.

For example, we can describe ideal gas by P and T and use V = RT/P to define V.

For different applications we can choose **different sets of independent variables** that are the most convenient.

THERMODYNAMICS

- **Describes processes that involve changes in temperature, transformation of energy, relationships between heat and work.**

- **Used as a science, and engineering tool, that is necessary for describing the performance of propulsion systems, power generation systems, refrigerators, fluid flow, combustion, ...**

- **Is based on generalization of extensive empirical evidence (however most thermodynamic principles and can be derived from kinetic theory)**

KINETIC THEORY

- **Describes processes that involve changes in temperature of ideal and real gas using simple models of particles and their interaction, and classical mechanics**

- **Used to derive the phenomenological equations of state of ideal gas and explain on statistical level the distribution of speeds of gas particles and heat capacity of gases**

ATOMIC AND MOLECULAR THEORY

- Introduces some fundamental concepts of quantum theory of atoms, the nature of chemical bonding between atoms and structure of solids

- Used to introduce the ideas of degrees of freedom of atomic and molecular motion and their relation to heat capacity

- Provides simple explanations to energy transfer mechanisms, thermal expansion of solids

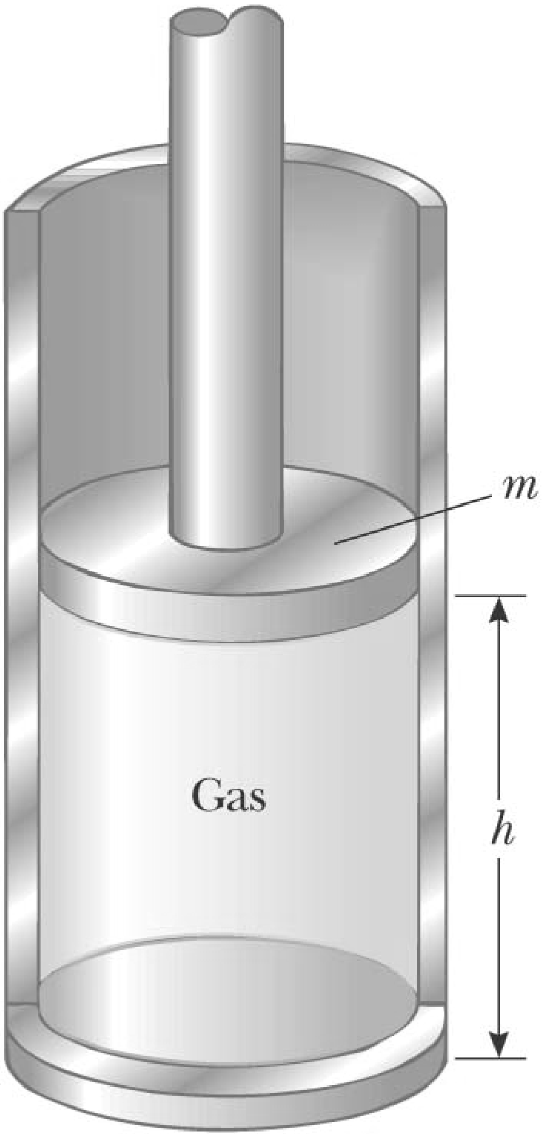
Three Laws of Thermodynamics (paraphrased):

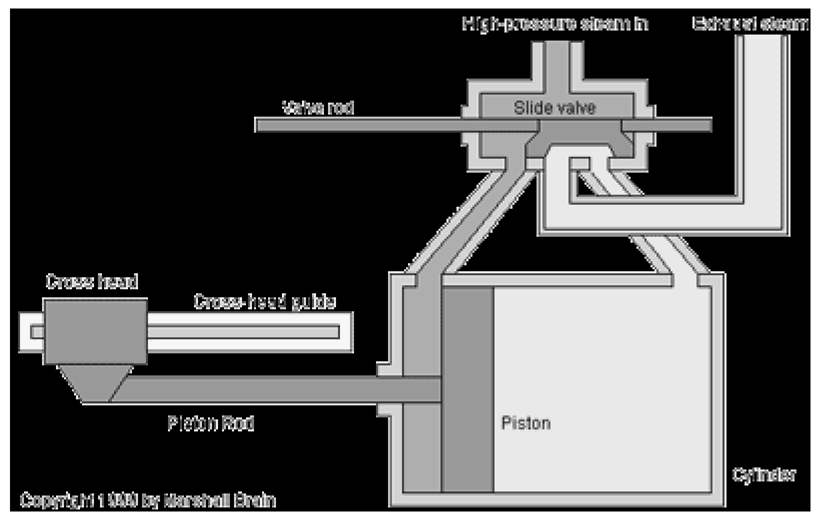
First Law: You can't get anything without working for it

Second Law: The most you can accomplish by work is
to break even.

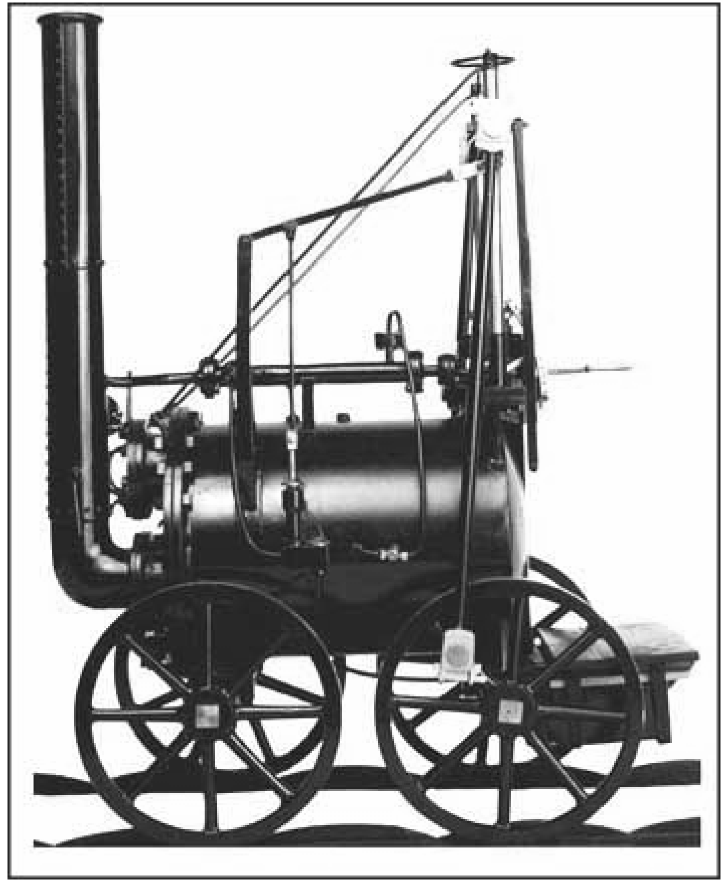
Third Law: You can't break even.

THERMODYNAMICS



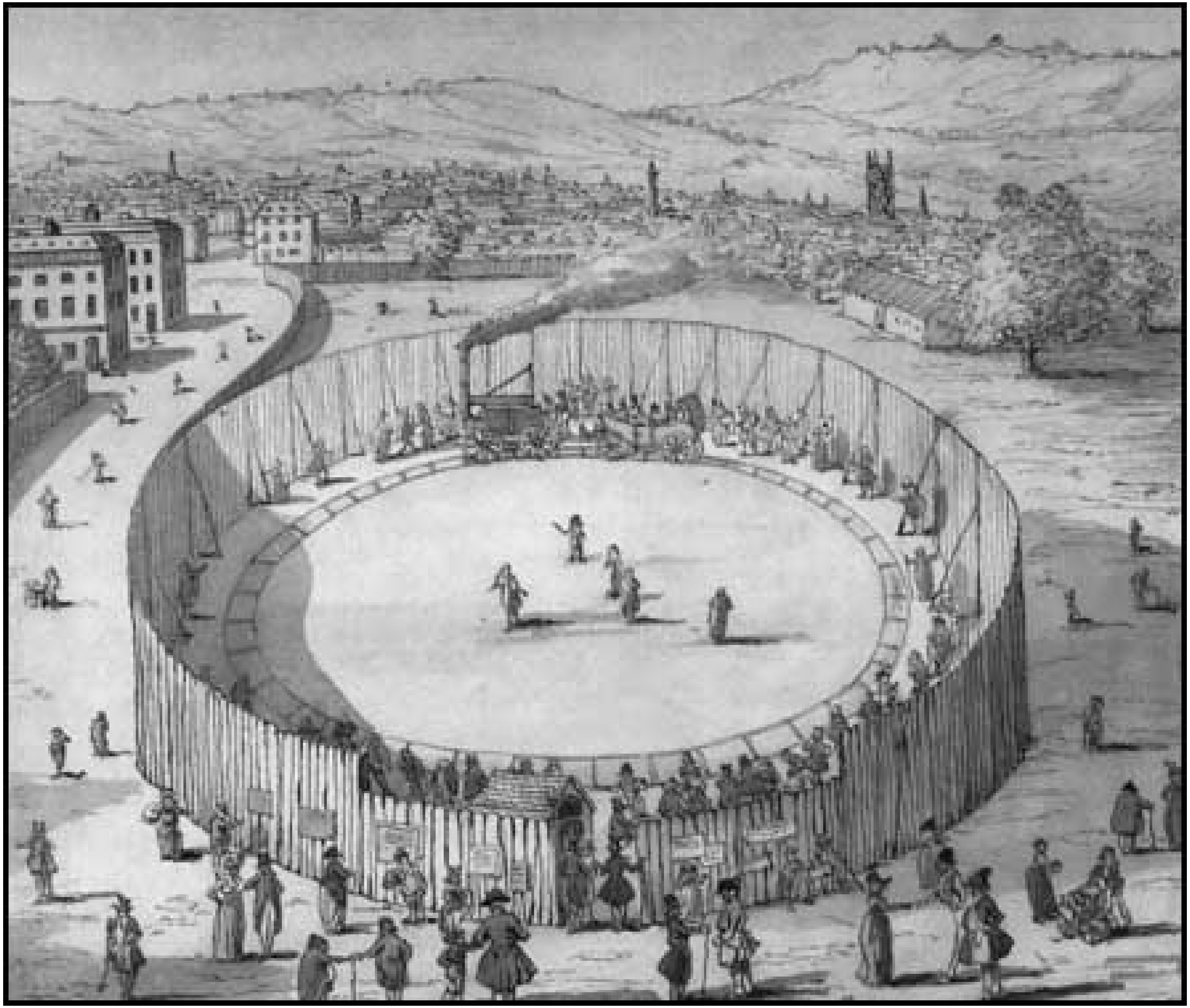


Richard Trevithick



In February 1804, Trevithick produced the world's first steam engine to run successfully on rails. The locomotive, with its single vertical cylinder, 8 foot flywheel and long piston-rod, managed to haul ten tons of iron, seventy passengers and five wagons from the ironworks at Penydarren to the Merthyr-Cardiff Canal.

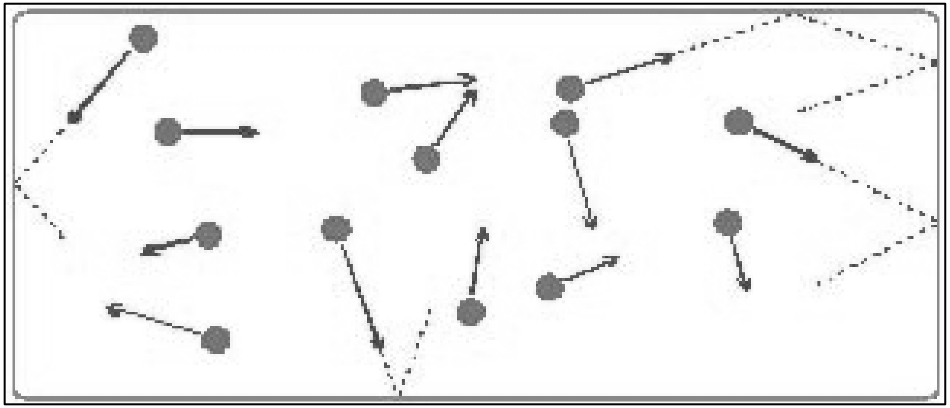
In the summer of 1808 Trevithick erected a circular railway or steam circus in Euston Square in London.

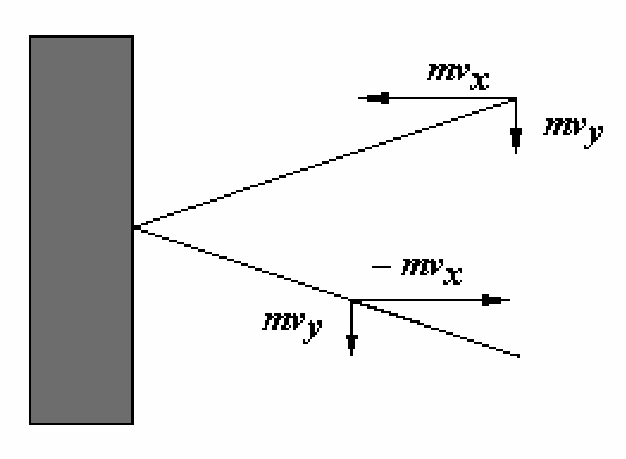


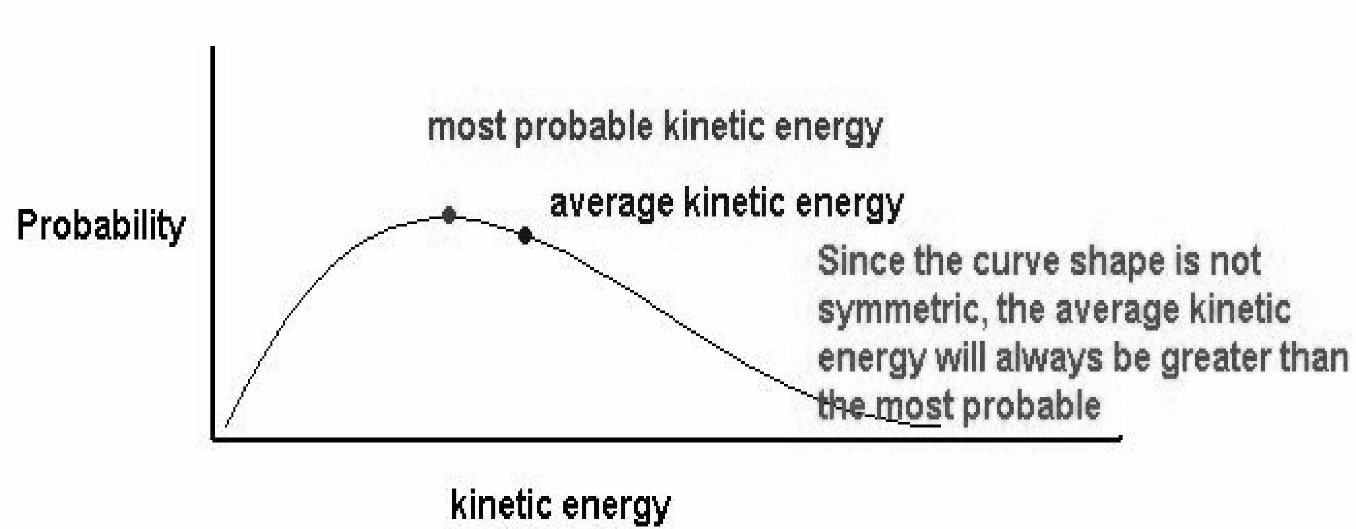
THERMODYNAMICS

A **calorimeter** is a device that helps scientists measure the energy of a particle. This triangular section is layered with sheets of **lead and plastic**. The lead is heavy and dense, so the particles have a hard time going through it. Scientists can tell how much energy a particle had by seeing how much lead it took to stop it.

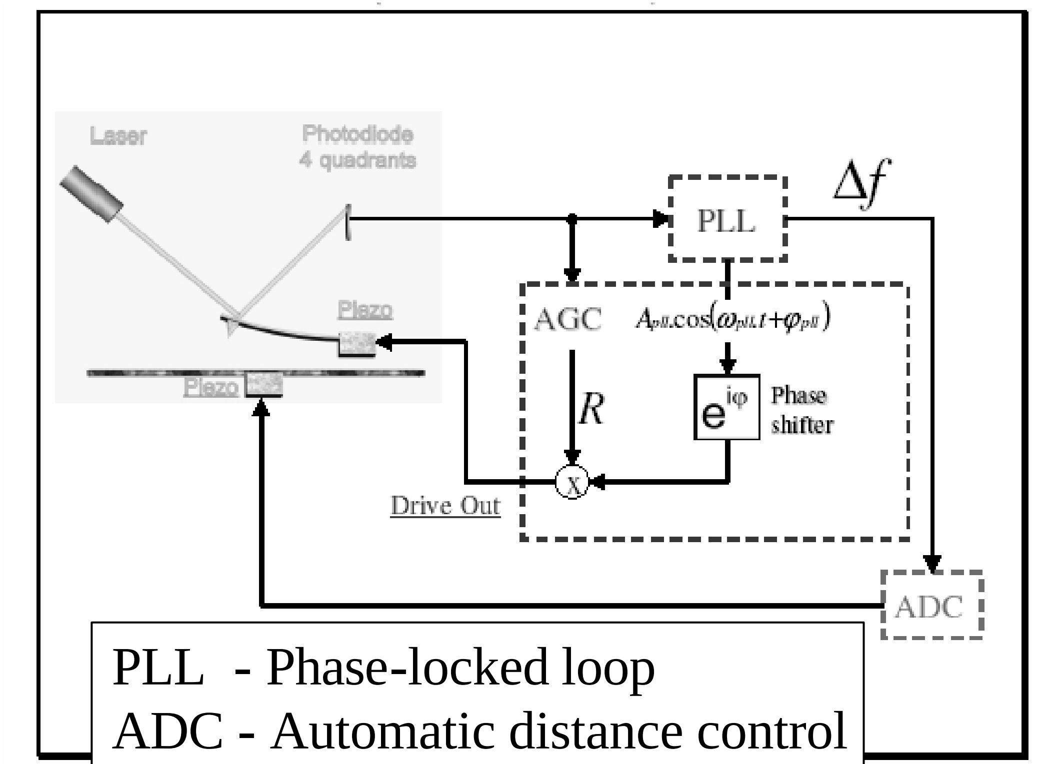
KINETIC THEORY

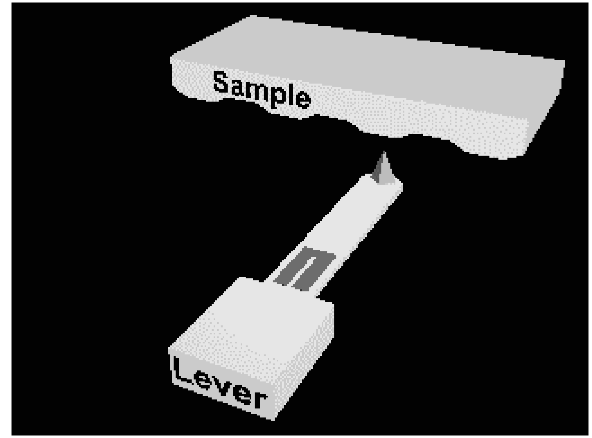






Schematic description of NC-AFM



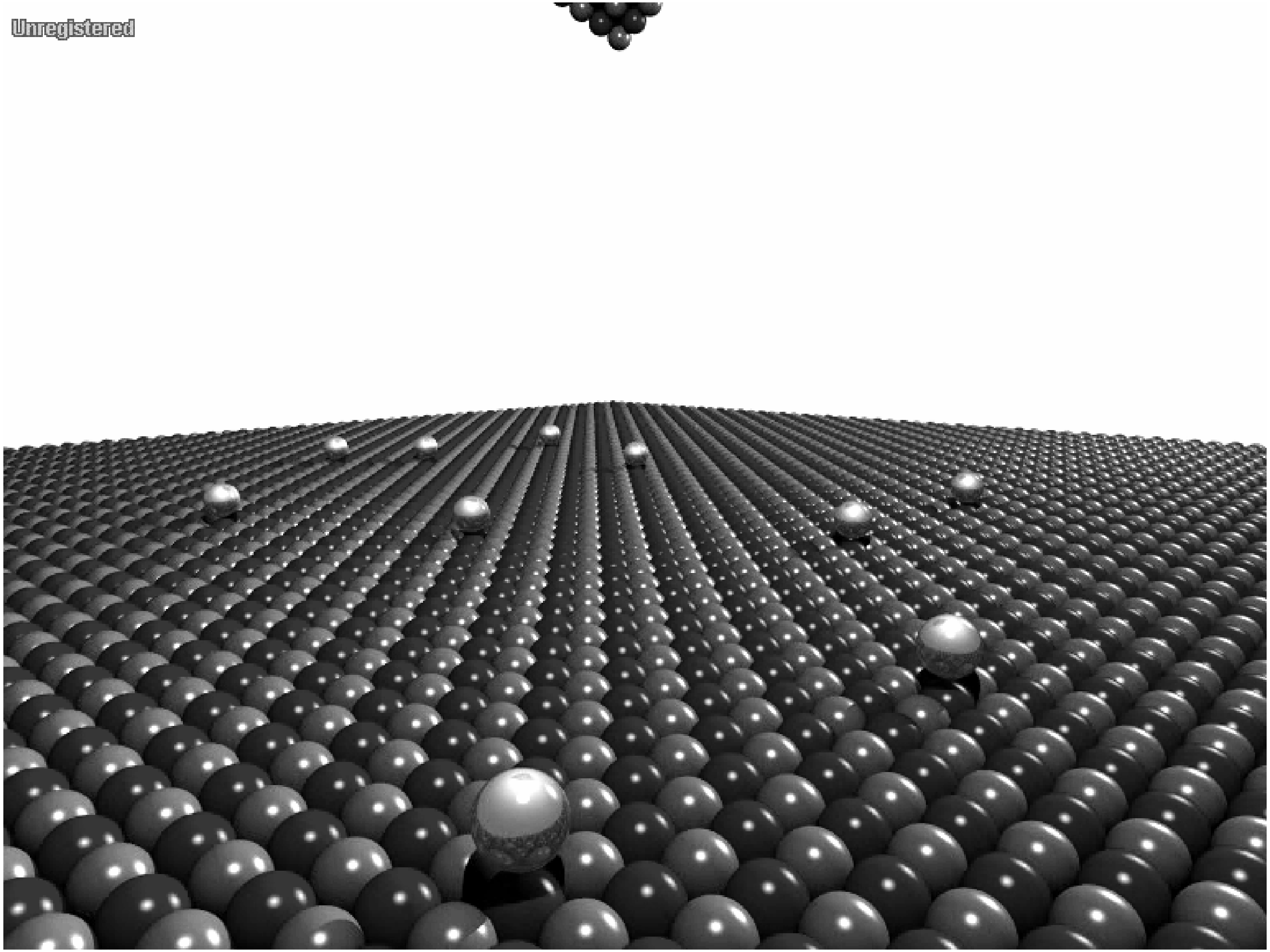


PLL - Phase-locked loop
ADC - Automatic distance control
AGC - Automatic gain control

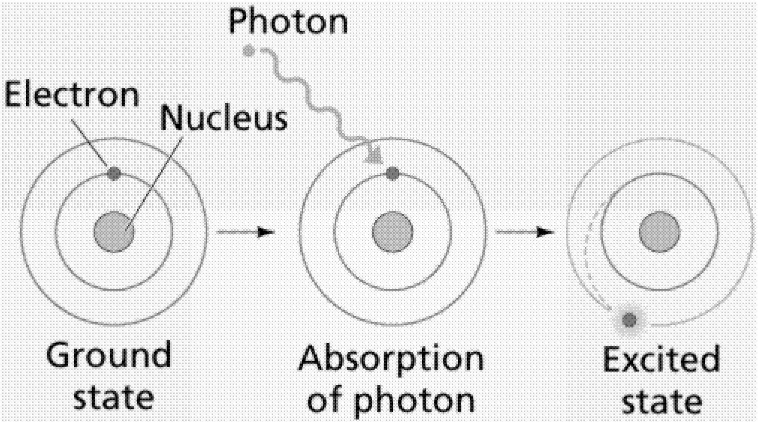
$$m.\ddot{z}(t) = -\frac{m.\omega_0}{Q}.\dot{z}(t) - k z(t) + R.A_{pll}.\sin(\omega_{pll}.t+\varphi) + F_{int}(z(t),\dot{z}(t),D(t))$$

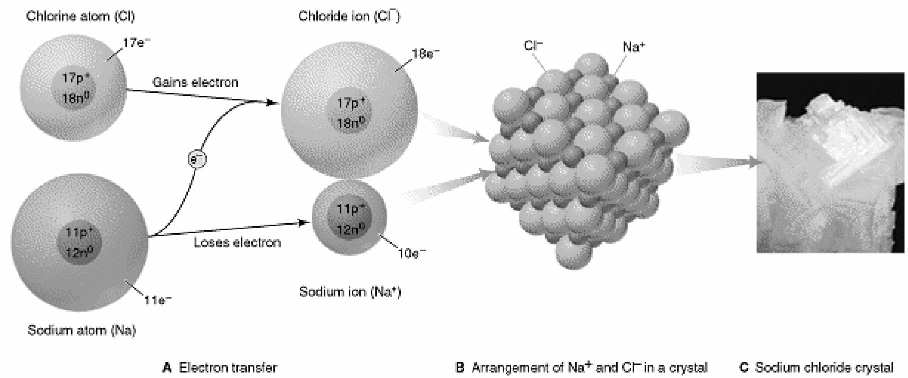
R. Garcia and R. Perez, Surf. Sci. Rep. 47, 197 (2002)

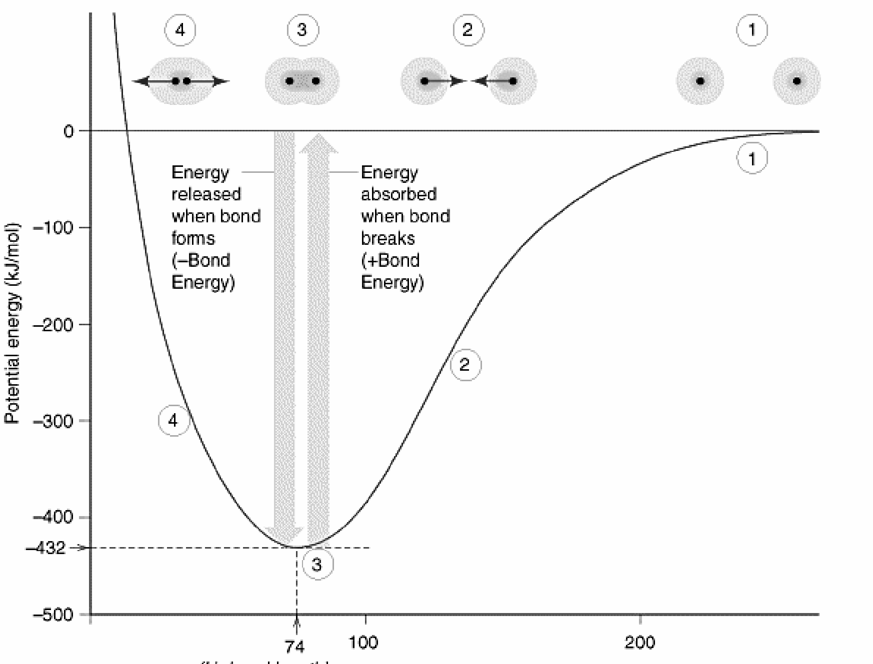
Manipulating Pd on MgO (001): Surface landscape



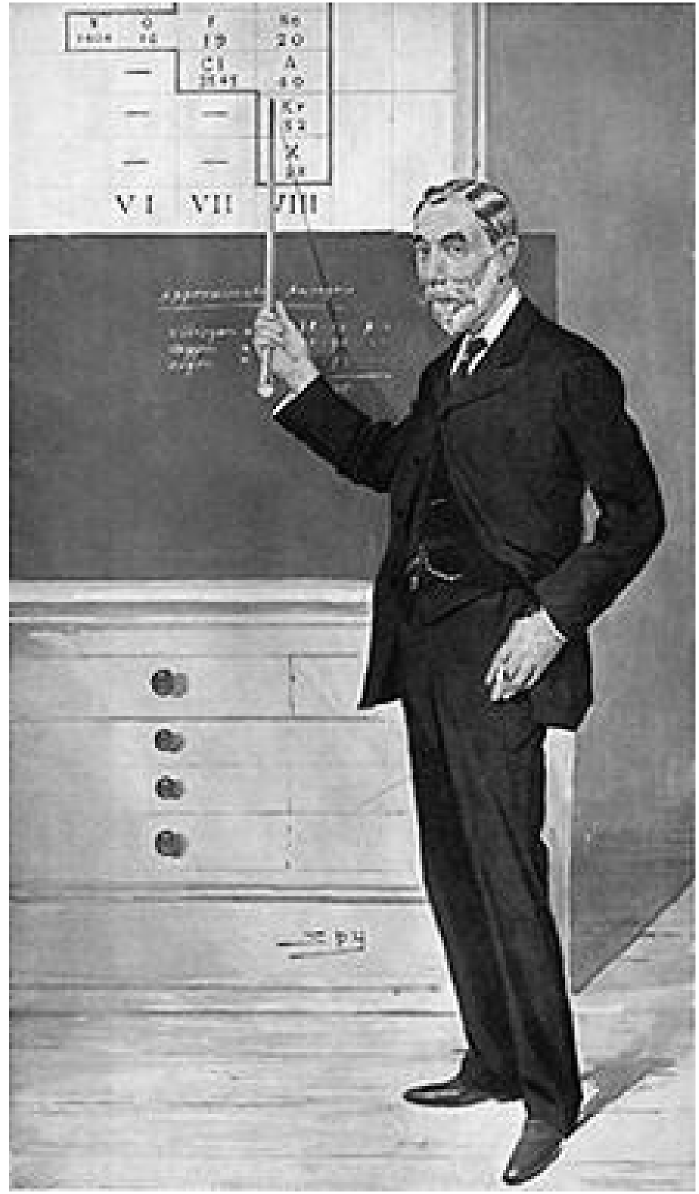
ATOMIC AND MOLECULAR THEORY







Sir William Ramsey
Nobel Price 1904



In 1887 Ramsay became professor of general chemistry at University College London, where he remained until his retirement in 1913.

Neon (Ne)

•The word “Neon” stems from the Greek word “neos” meaning “new.”

•It is an inert, odorless gas found in the atmosphere and within rocks making up the Earth’s crust.

•We process on average 88,000 pounds of liquid air to yield about 1 pound of Neon; hence its qualification as a rare gas.

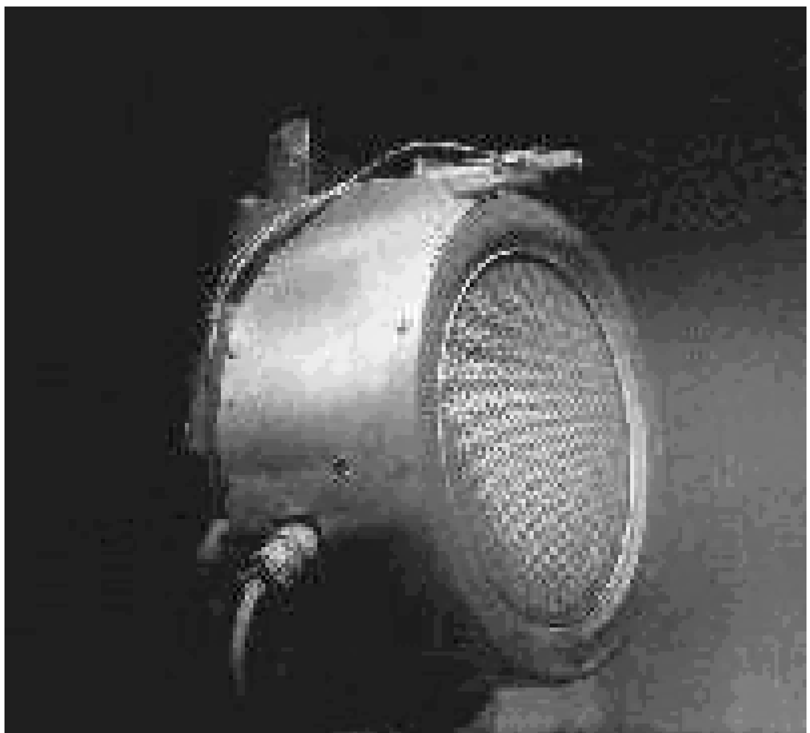
•Of all the rare gases, its light is the most intense at common electrical voltages and currents, and is the most recognized by name.

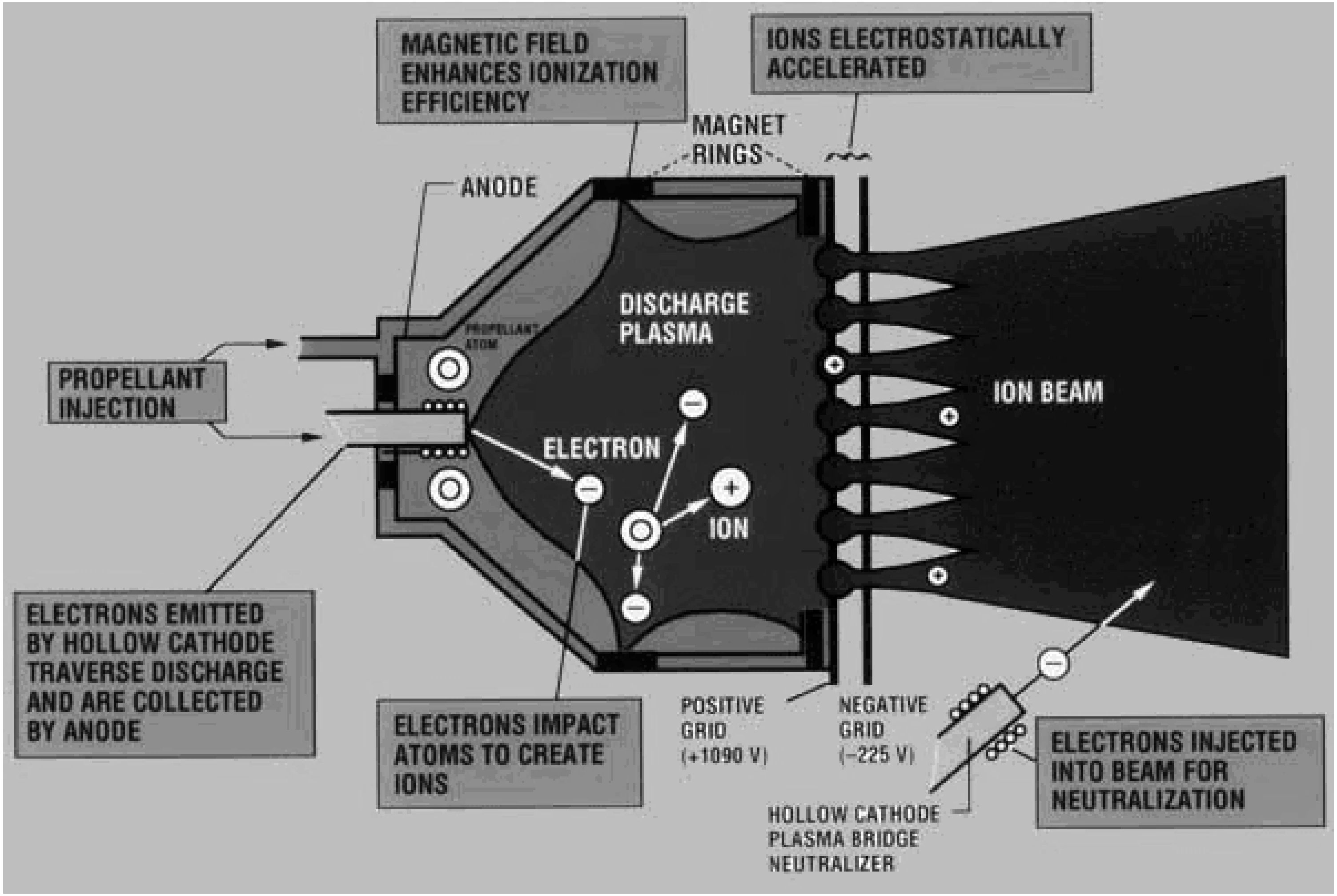
•We know it is used in advertising to make brilliant red-orange Neon signs. But it’s also used to make several kinds of lasers, as a refrigerant in cooling systems, and in television cathode ray tubes.

ION ENGINE

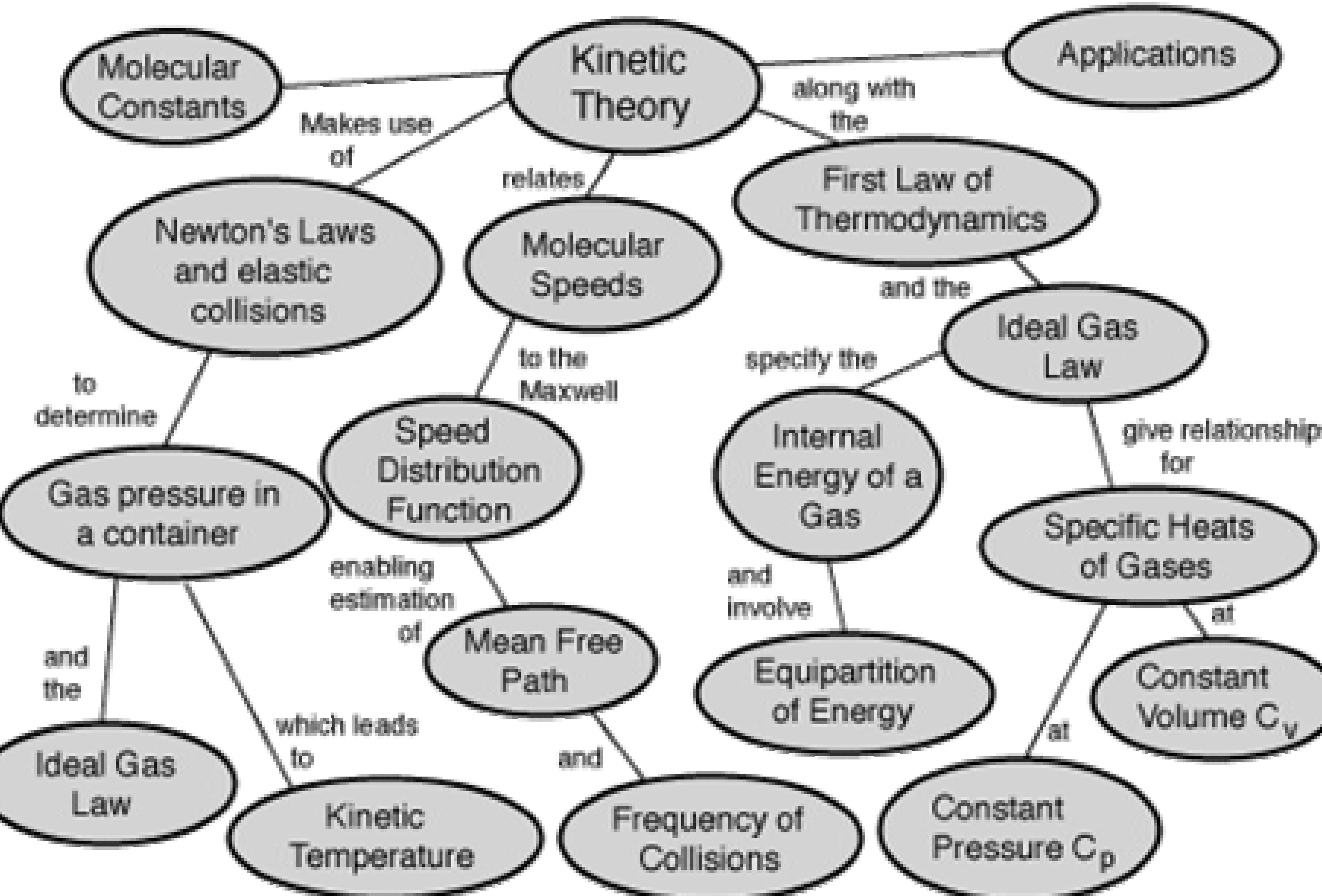
http://www.grc.nasa.gov/WWW/PAO/html/ipsworks.htm

- Ion propulsion is a technology that involves ionizing a gas to propel a craft.
- The gas xenon (which is like neon or helium, but heavier) is given an electrical charge, or ionized.
- It is then electrically accelerated to a speed of about 30 km/second. When xenon ions are emitted at such high speed as exhaust from a spacecraft, they push the spacecraft in the opposite direction.

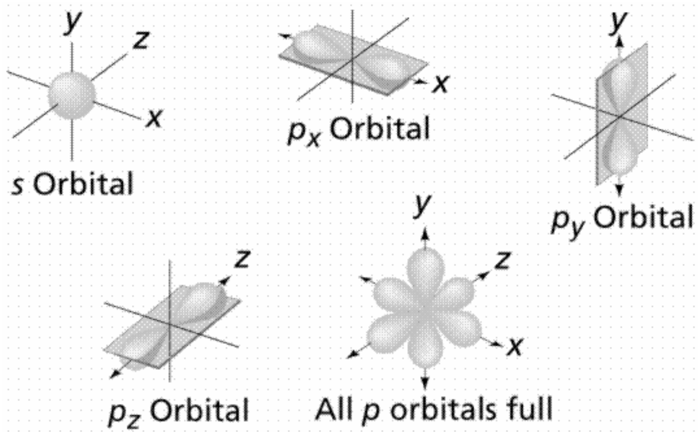




MAGNETIC FIELD ENHANCES IONIZATION EFFICIENCY
IONS ELECTROSTATICALLY ACCELERATED
MAGNET RINGS
ANODE
PROPELLANT ATOM
DISCHARGE PLASMA
PROPELLANT INJECTION
ELECTRON
ION
ION BEAM
ELECTRONS EMITTED BY HOLLOW CATHODE TRAVERSE DISCHARGE AND ARE COLLECTED BY ANODE
ELECTRONS IMPACT ATOMS TO CREATE IONS
POSITIVE GRID (+1090 V)
NEGATIVE GRID (−225 V)
ELECTRONS INJECTED INTO BEAM FOR NEUTRALIZATION
HOLLOW CATHODE PLASMA BRIDGE NEUTRALIZER


Molecular Constants
Kinetic Theory
Applications
Makes use of
relates
along with the
First Law of Thermodynamics
Newton's Laws and elastic collisions
Molecular Speeds
and the
Ideal Gas Law
to the Maxwell
specify the
to determine
Speed Distribution Function
Internal Energy of a Gas
give relationship for
Gas pressure in a container
Specific Heats of Gases
enabling estimation of
and involve
at
Mean Free Path
and the
Equipartition of Energy
Constant Volume C_v
which leads to
at
and
Ideal Gas Law
Kinetic Temperature
Frequency of Collisions
Constant Pressure C_p

ATOMIC AND MOLECULAR THEORY



BUCKINGHAM & UTTING

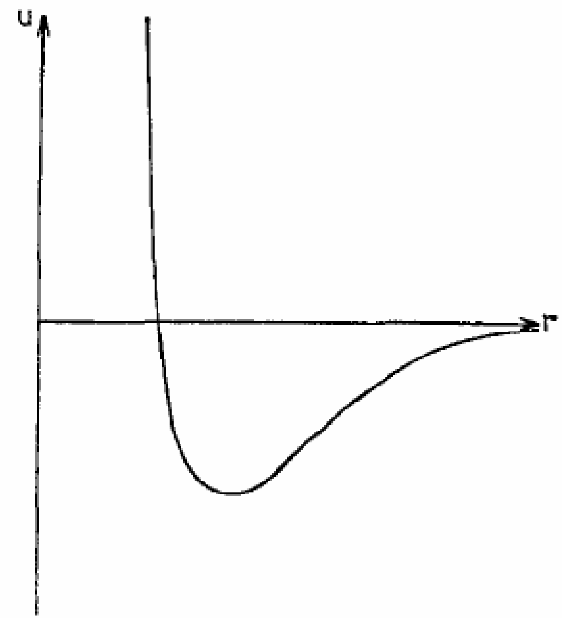


FIGURE 1. The variation of the interaction energy u with separation r.