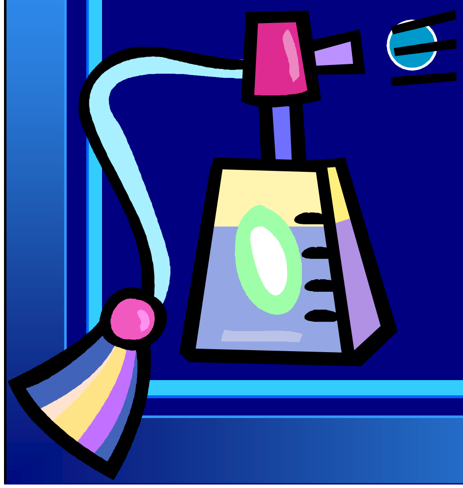
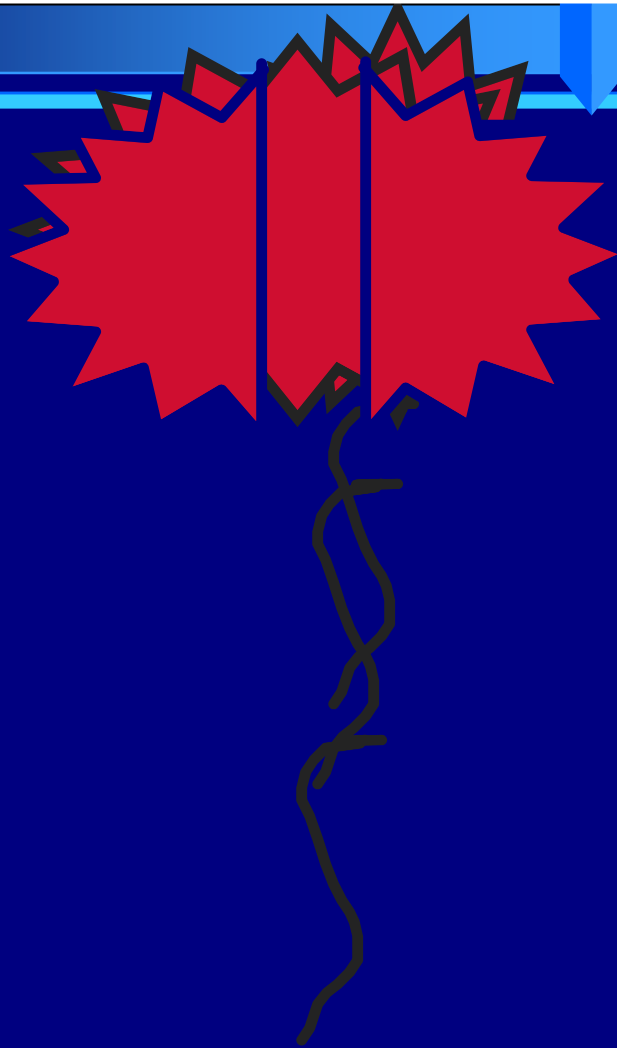
Chapter 13- The States of Matter
13.1- The Nature of Gases

- Gases- indefinite volume and shape, low density.

Kinetic Theory

- Kinetic theory says that molecules are in constant motion.
- Perfume molecules moving across the room are evidence of this.





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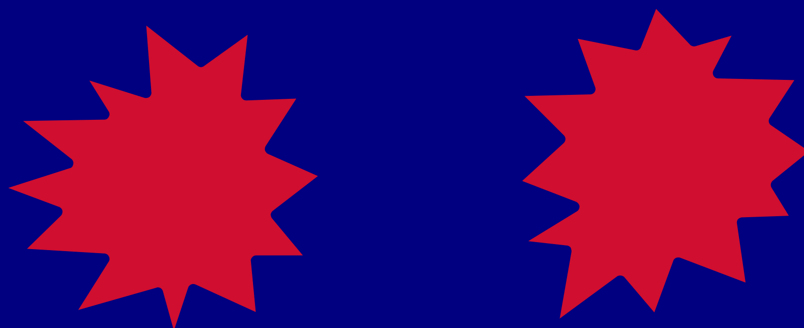
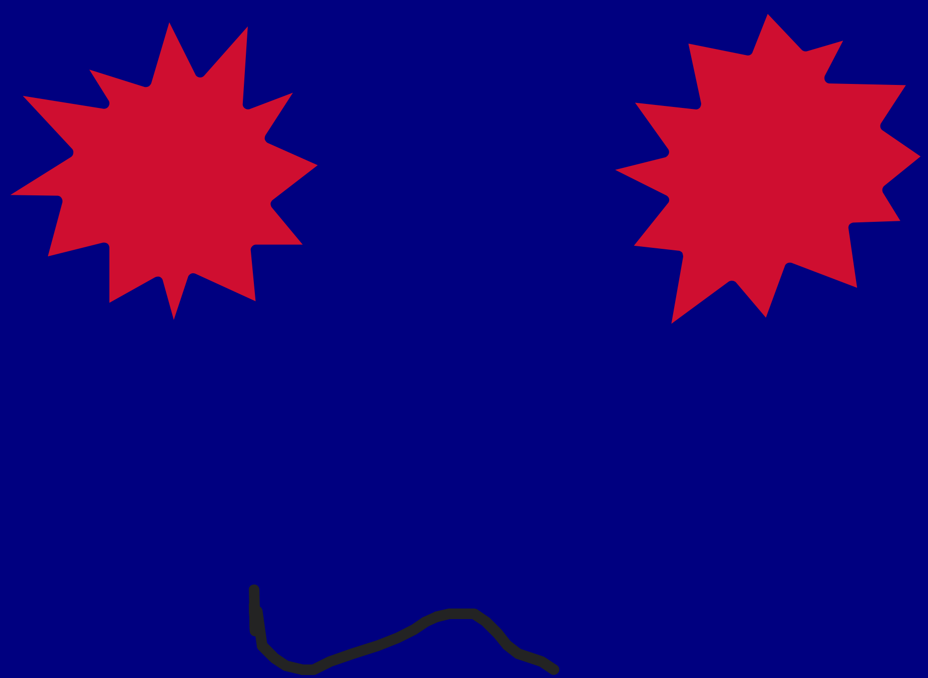


The Kinetic Theory of G

Makes three descriptions of gas p

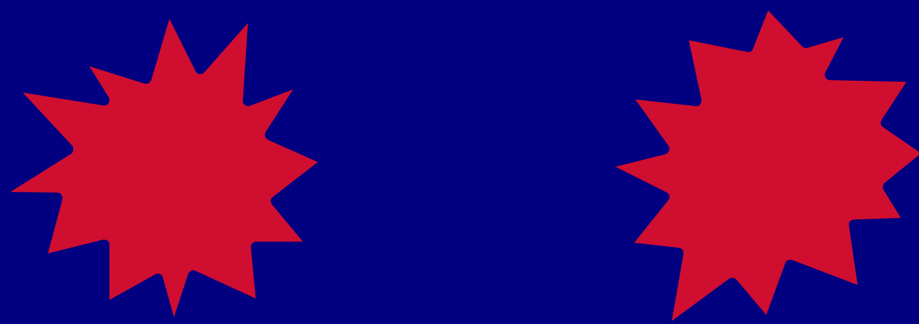
The Kinetic Theory of Gases

Makes three descriptions of gas particles



The Kinetic Theory of Gases

Makes three descriptions of gas particles

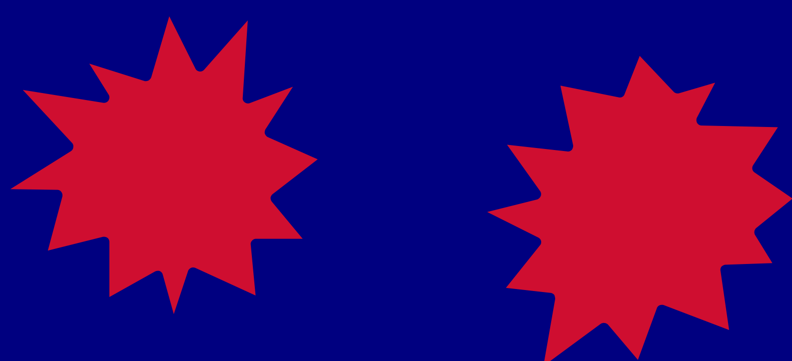


The Kinetic Theory of Gases

Makes three descriptions of gas particles

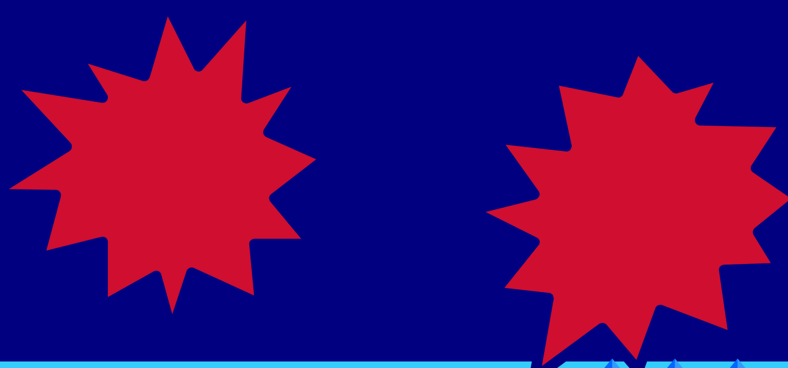
The Kinetic Theory of Gases

Makes three descriptions of gas particles



The Kinetic Theory of Gases

Makes three descriptions of gas particles



The Kinetic Theory of Gases

Makes three descriptions of gas particles

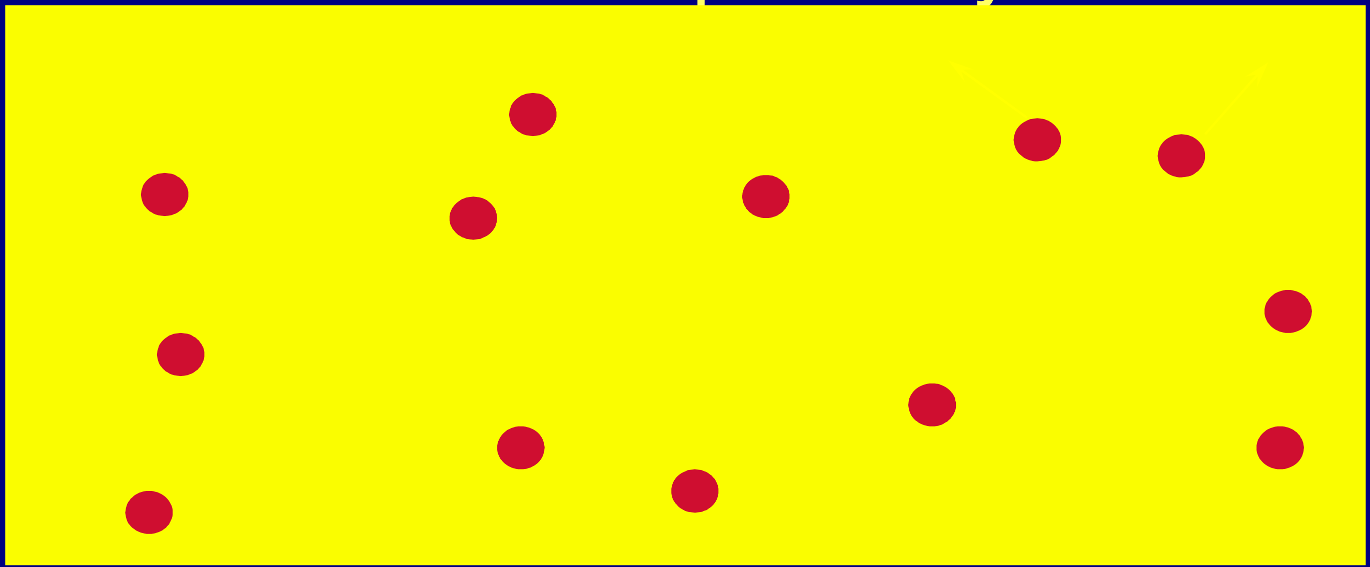
1. A gas is composed of particles

- molecules or atoms
- Considered to be hard spheres far enough apart that we can ignore their volume.
- Between the molecules is empty space.

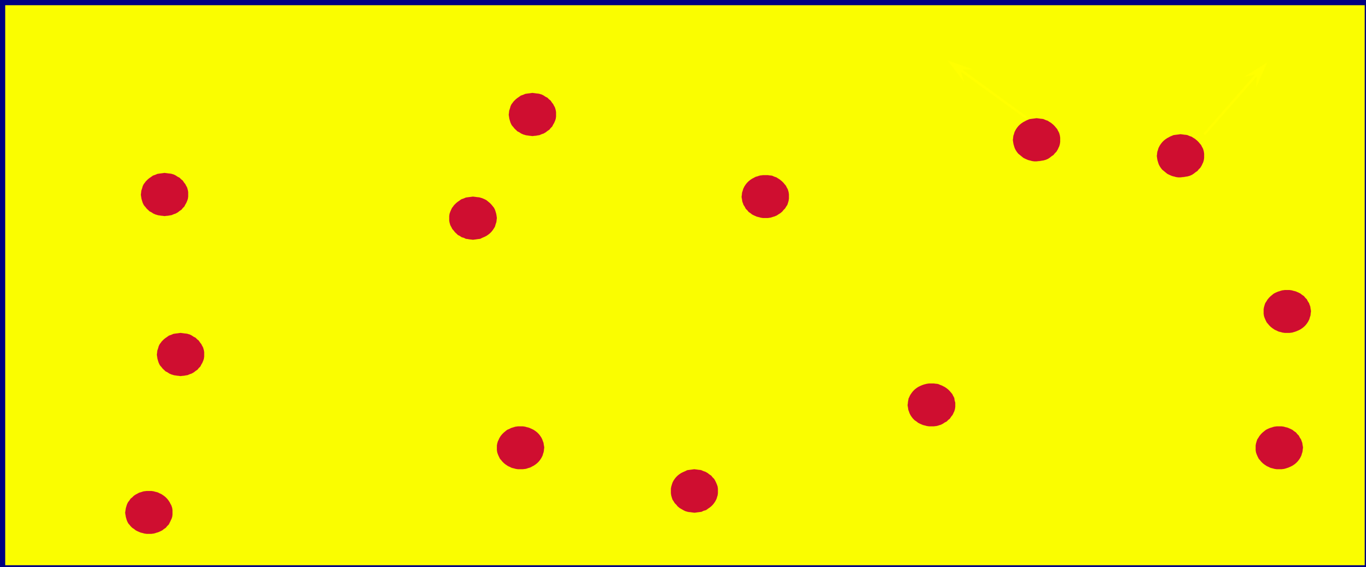
2. The particles are in constant random motion.

- Move in straight lines until they bounce off each other or the walls.

3. All collisions are perfectly elastic

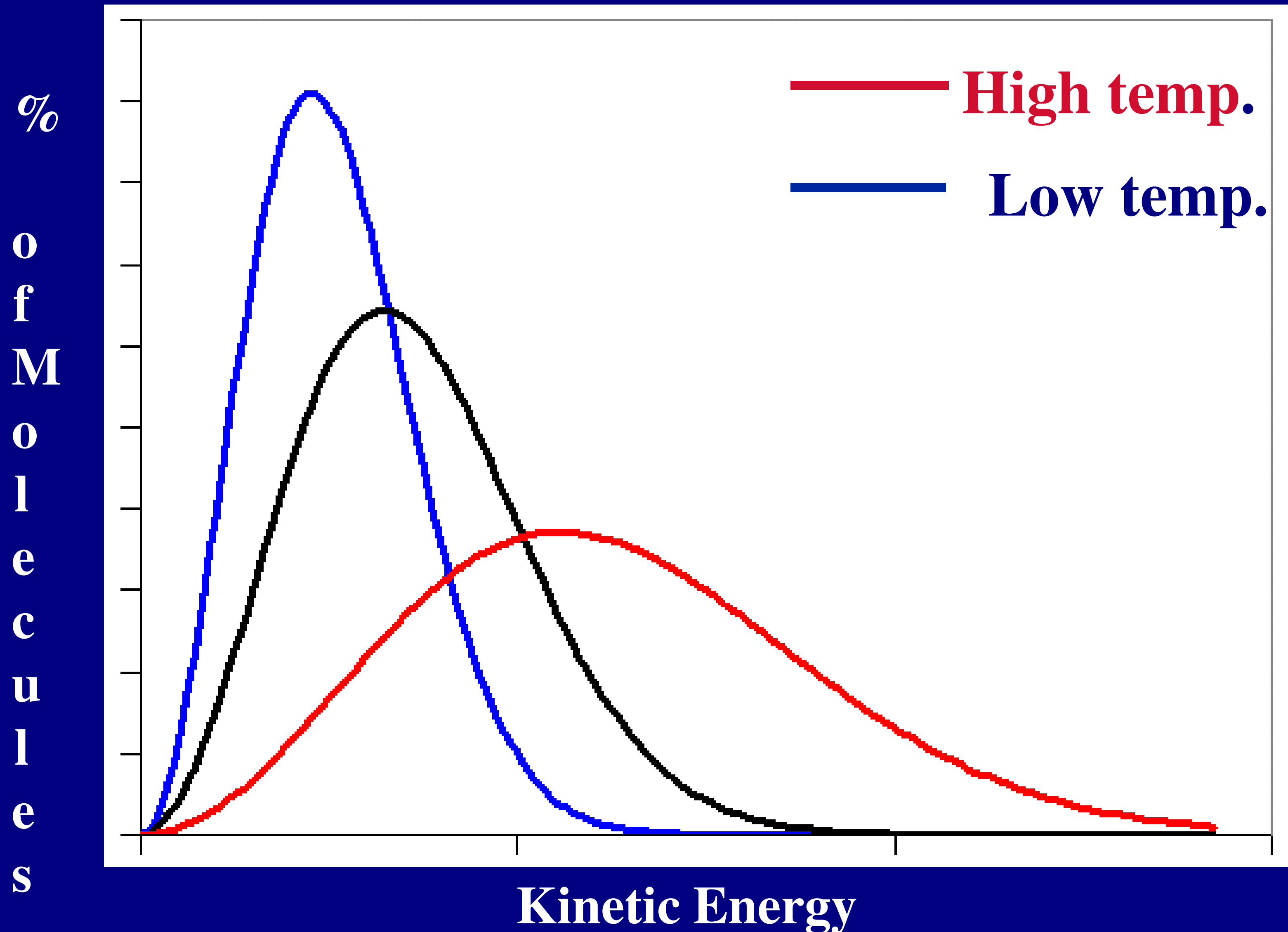


- The Average speed of an oxygen molecule is 1656 km/hr at 20ºC
- The molecules don't travel very far without hitting each other so they move in random directions.

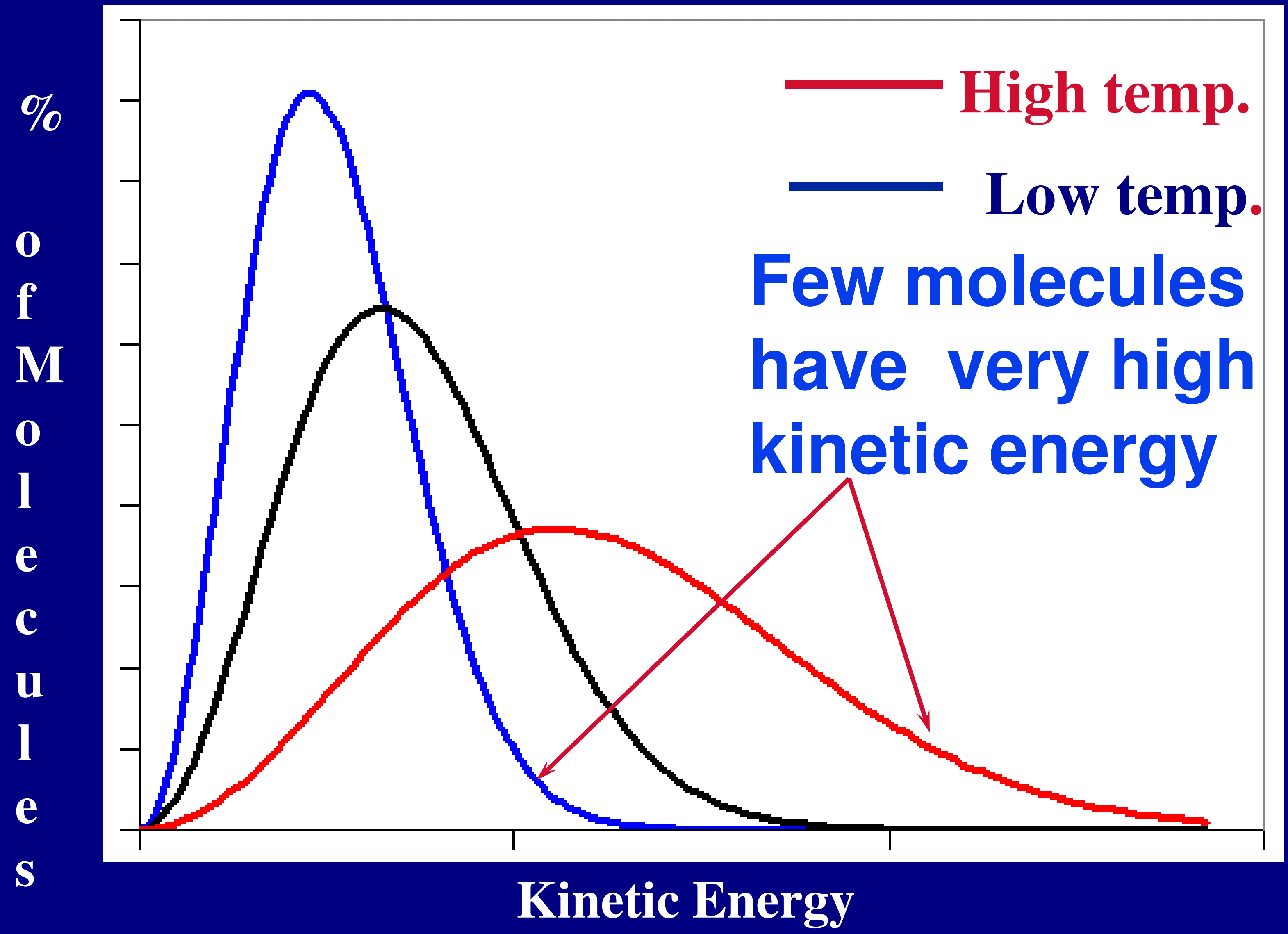


Kinetic Energy and Temperature

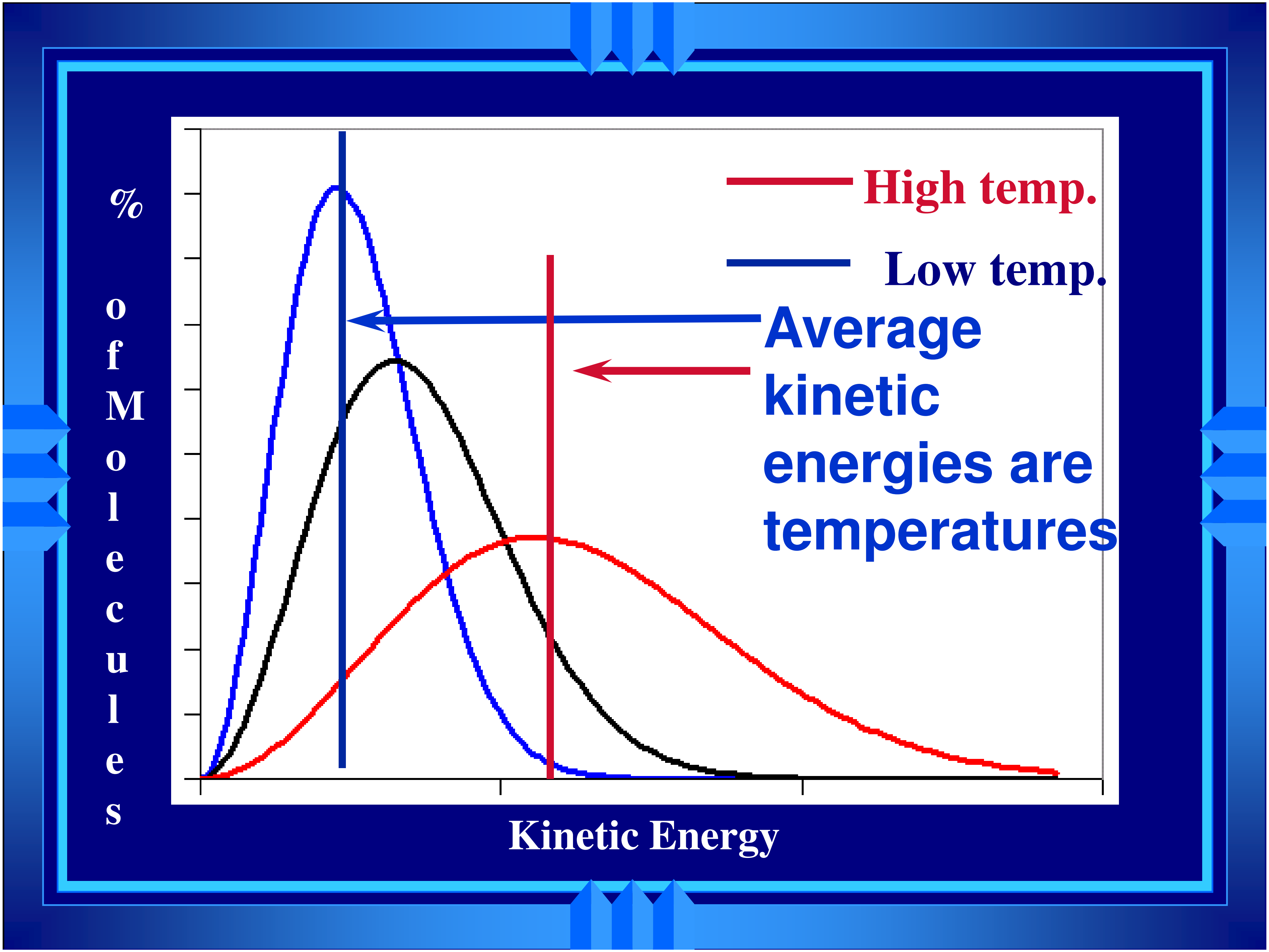
- Temperature is a measure of the Average kinetic energy of the molecules of a substance.
- Higher temperature faster molecules.
- At absolute zero (0 K) all molecular motion would stop.
- **K= Kelvin**
  - 0K = -273.15 ℃
  - 273.15K = 0 ℃
  - 373.15K = 100 ℃



% of Molecules
High temp.
Low temp.
Kinetic Energy



High temp.
Low temp.
Few molecules have very high kinetic energy
% of Molecules
Kinetic Energy



High temp.
Low temp.
Average kinetic energies are temperatures
% of Molecules
Kinetic Energy

Temperature

- The average kinetic energy is directly proportional to the temperature in Kelvin
- If you double the temperature (in Kelvin) you double the average kinetic energy.
- If you change the temperature from 300 K to 600 K the kinetic energy doubles.

Temperature

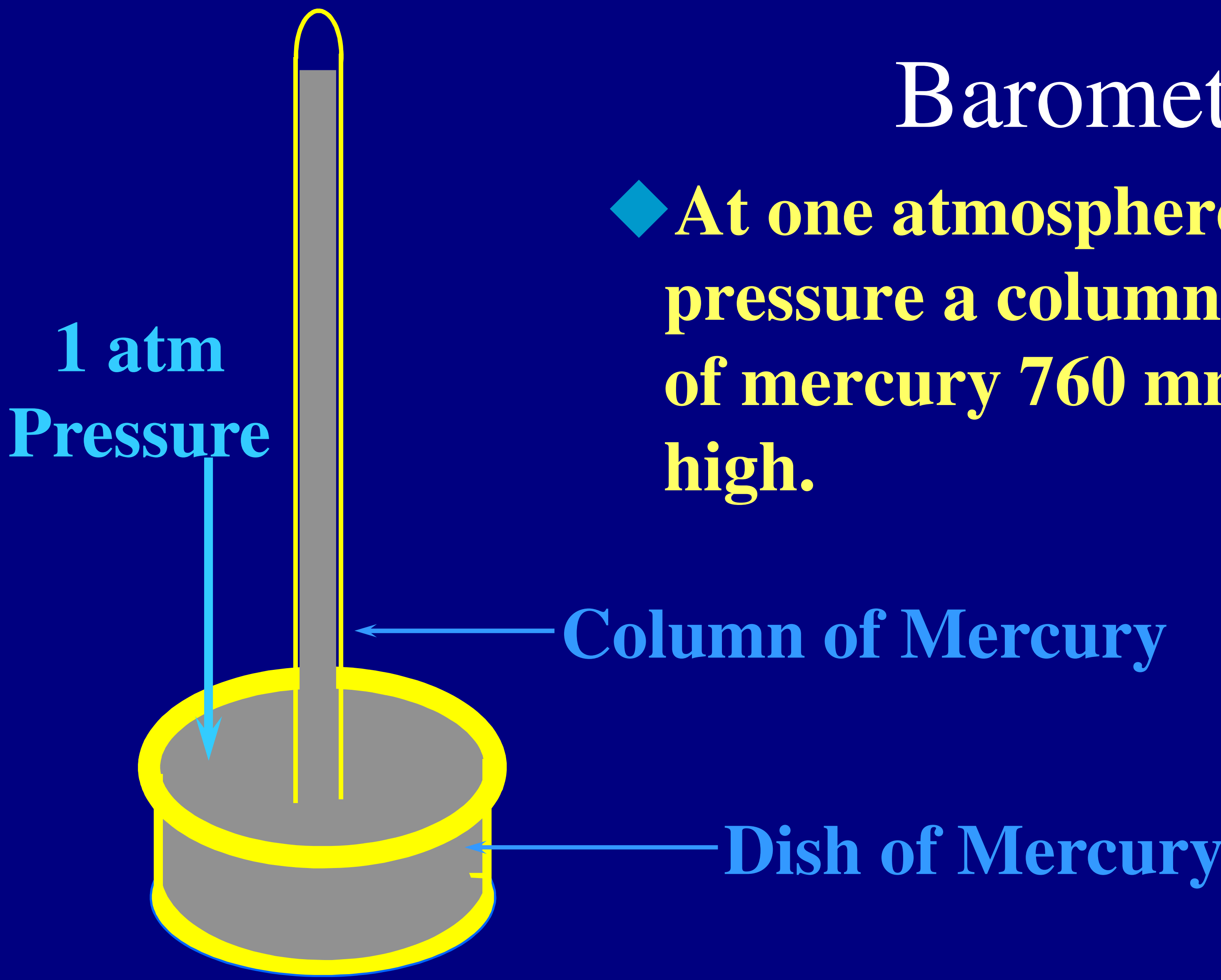
- If you change the temperature from 300ºC to 600ºC the Kinetic energy doesn't double.
- 873 K is not twice 573 K

Pressure

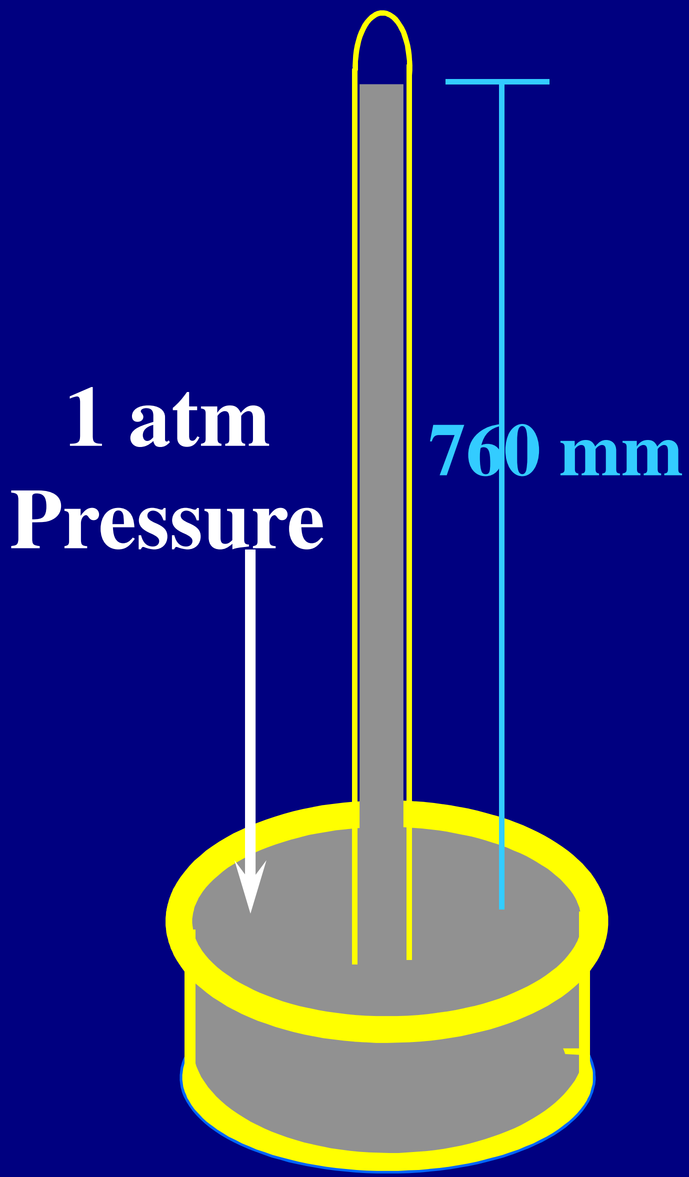
- Pressure is the result of collisions of the molecules with the sides of a container.
- A vacuum is completely empty space - it has no pressure.
- Pressure is measured in units of atmospheres (atm).
- It is measured with a device called a barometer.

Barometer

- At one atmosphere pressure a column of mercury 760 mm high.



Barometer



- At one atmosphere pressure a column of mercury 760 mm high.
- A second unit of pressure is mm Hg
- 1 atm = 760 mm Hg
- Third unit is the Pascal
- 1 atm = 101.3 kPa

Pressure units

- kilopascals – kPa
- 1 atm = 760 mm Hg = 101.3 kPa
- We will learn how to make these conversions later in the semester.

Same KE – different speed

- Mass affects kinetic energy.
- Less mass, less kinetic energy at the same speed
- The smaller particles must have a greater speed to have the same kinetic energy.
- Same temperature, smaller particles move faster

Chapter 13- The States of Matter
13.2- The Nature of Liquids

- Liquids- definite volume, indefinite shape, and high density.

Liquids

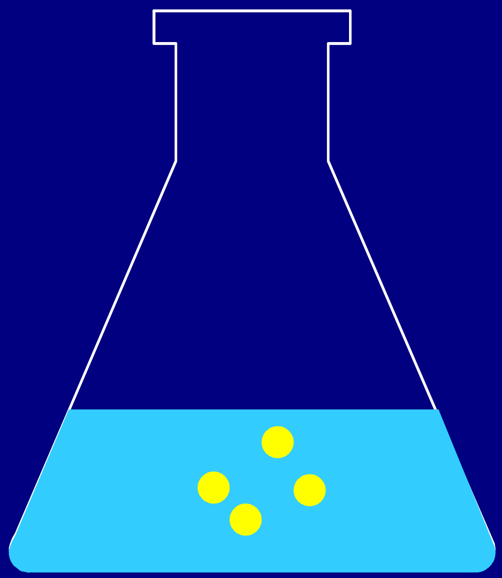
- **Particles are in motion.**
  - Tends to pull them apart
- **Attractive forces between molecules keep them close together.**
- **These are called intermolecular forces.**
  - **Inter = between**
  - **Molecular = molecules**

Breaking intermolecular forces.

- **Vaporization - the change from a liquid to a gas below its boiling point.**
- **Evaporation - vaporization of an uncontained liquid (no lid on the bottle).**

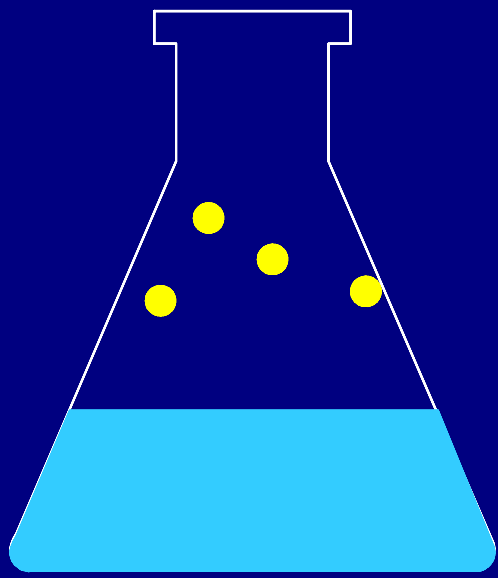
Evaporation

- Molecules at the surface break away and become gas.
- Only those with enough KE escape
- Evaporation is a cooling process.
- It requires energy.



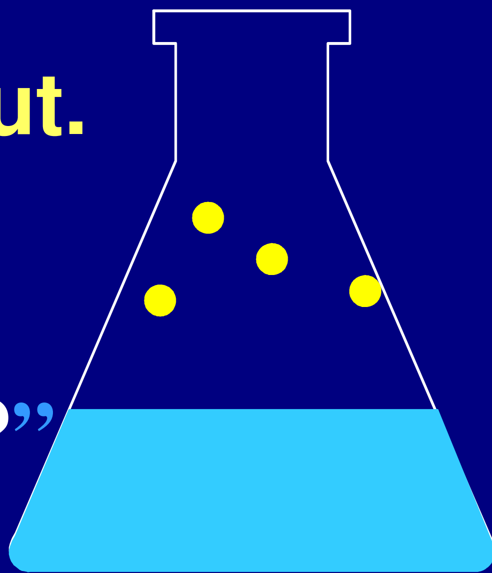
Condensation

- Change from gas to liquid
- Molecules stick together
- Releases energy.



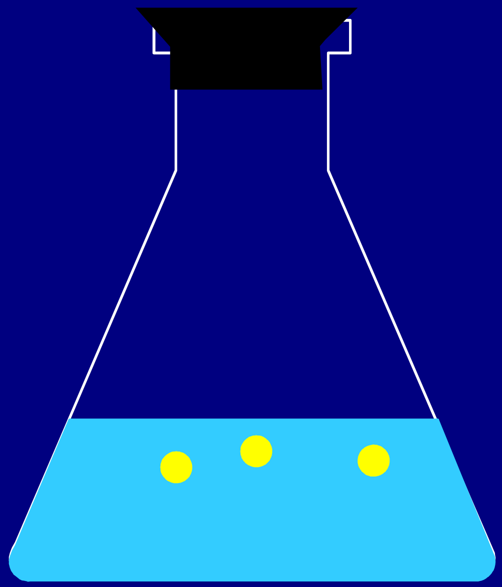
Condensation

- Achieves a dynamic equilibrium with vaporization in a closed system.
- What is a closed system?
- A closed system means matter can't go in or out. (put a cork in it)
- What the heck is a "dynamic equilibrium?"



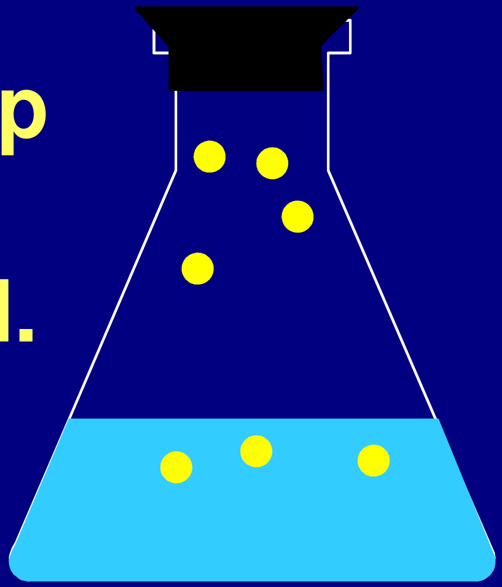
Dynamic equilibrium

- When first sealed the molecules gradually escape the surface of the liquid



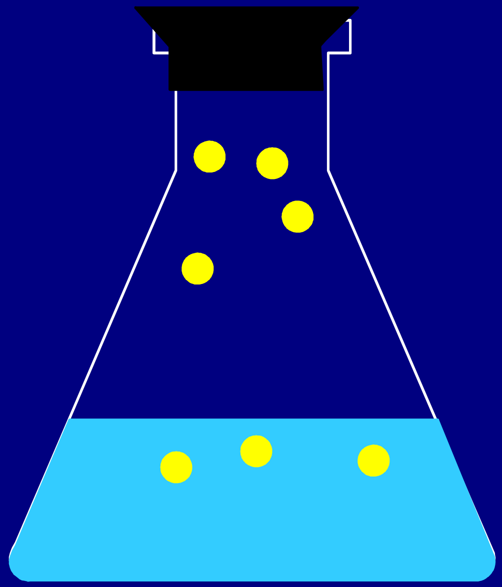
Dynamic equilibrium

- When first sealed the molecules gradually escape the surface of the liquid
- As the molecules build up above the liquid some condense back to a liquid.



Dynamic equilibrium

- As time goes by the rate of vaporization remains constant
- but the rate of condensation increases because there are more molecules to condense.
- Equilibrium is reached when



Dynamic equilibrium

Rate of Vaporization = Rate of Condensation

- **Molecules are constantly changing phase "Dynamic"**
- **The amount of liquid and vapor remains constant "Equilibrium"**

Vapor Pressure

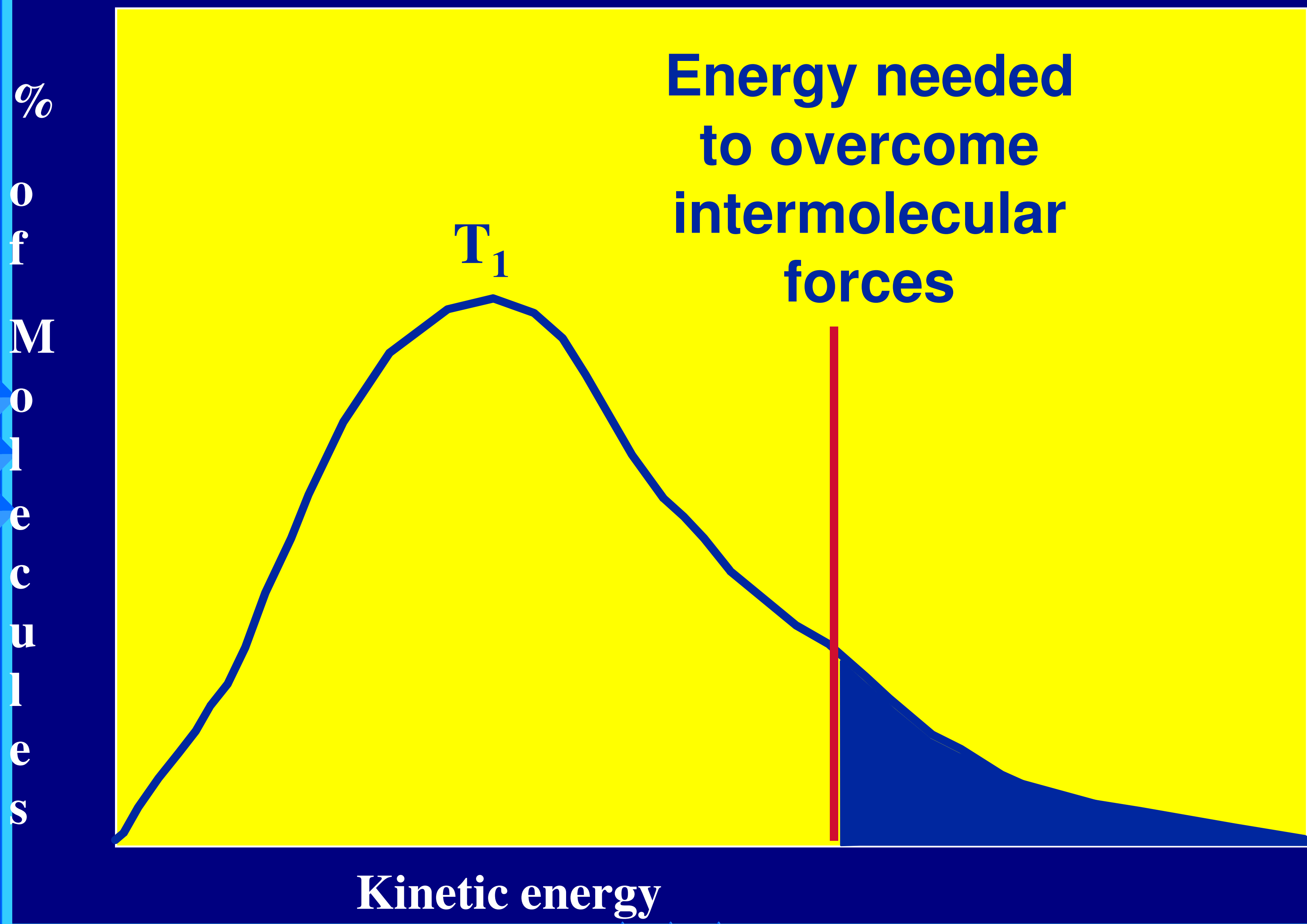
- In a closed container the gas molecules will cause pressure.
- The pressure at equilibrium is called vapor pressure
- Different compounds have different vapor pressures because of different intermolecular forces
- Stronger forces, lower vapor pressure

Vapor Pressure

- At higher temperature there are more gas molecules
- More have the energy to escape
- Higher vapor pressure

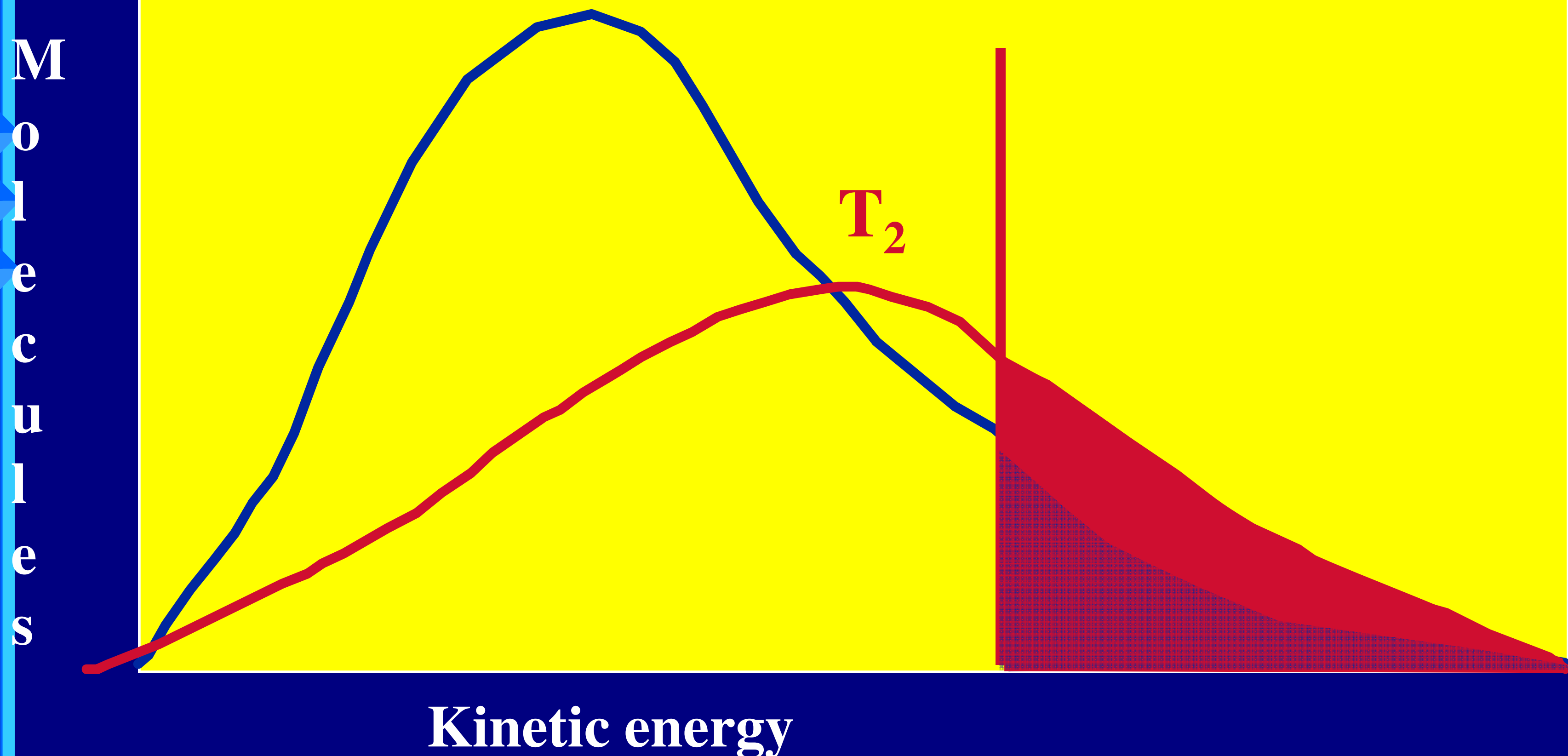
Vaporization

- Vaporization requires heat.
- Energy is required to overcome intermolecular forces
- Absorbing heat cools
- Highest kinetic energy leaves
- Average drops
- Why we sweat.



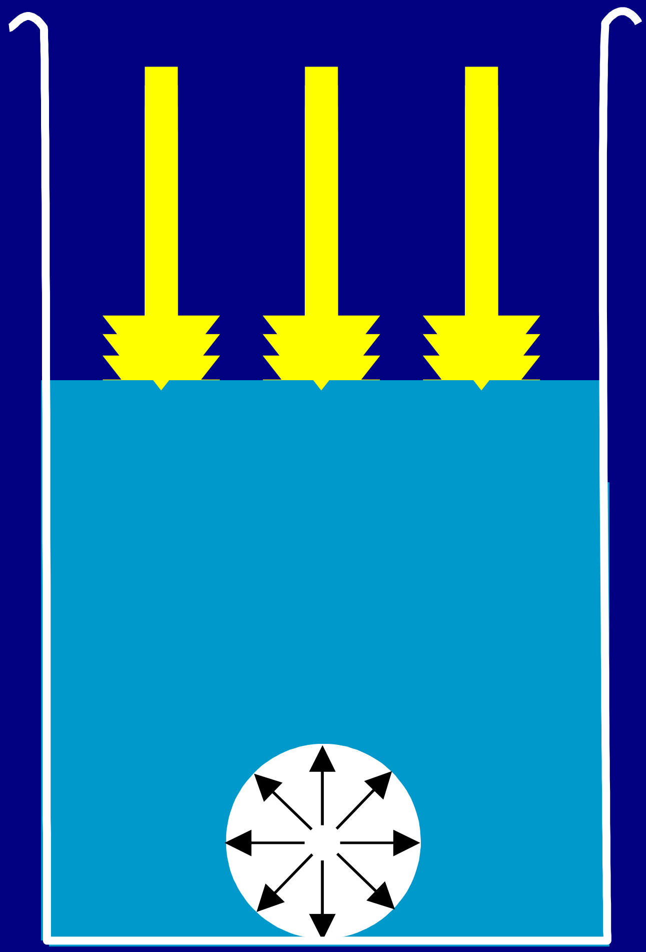
% of Molecules
T1
Energy needed to overcome intermolecular forces
Kinetic energy

- At higher temperature more molecules have enough energy
- Higher vapor pressure.



Boiling

- Making bubbles of gas
- Forces liquid level to rise
- Must push against air pressure on the liquid.



Boiling

- A liquid boils when the vapor pressure = the external pressure
- Temperature is called the boiling point
- **Normal Boiling point** is the temperature a substance boils at 1 atm pressure.
- The temperature of a liquid can never rise above it's boiling point
- Energy goes into breaking forces, not moving faster.

Changing the Boiling Point

- Lower the pressure (going up into the mountains).
- Lower external pressure requires lower vapor pressure.
- Easier to make bubbles
- Lower vapor pressure means lower boiling point.
- Food cooks slower.

Changing the Boiling Point

- Raise the external pressure (Use a pressure cooker)
- Raises the vapor pressure needed.
- Harder to make bubbles
- Raises the boiling point.
- Food cooks faster.

Different Boiling points

- **Different substances boil at different temperatures because they have different intermolecular forces**
  - Weak forces- lower boiling point
- **Different vapor pressures**
  - Low vapor pressure – high boiling point

Chapter 13- The States of Matter
13.3- The Nature of Liquids
13.4 Phase Digrams

- **Solids- definite volume and shape, high density**
- **Solids and Liquids have high densities because their molecules are close together**

Solids

- Intermolecular forces are strong
- Molecules still move!
- Can only vibrate and revolve in place.
- Particles are locked in place - don’t flow.
- Melting point is the temperature where a solid turns into a liquid.
- The melting point is the same as the freezing point.

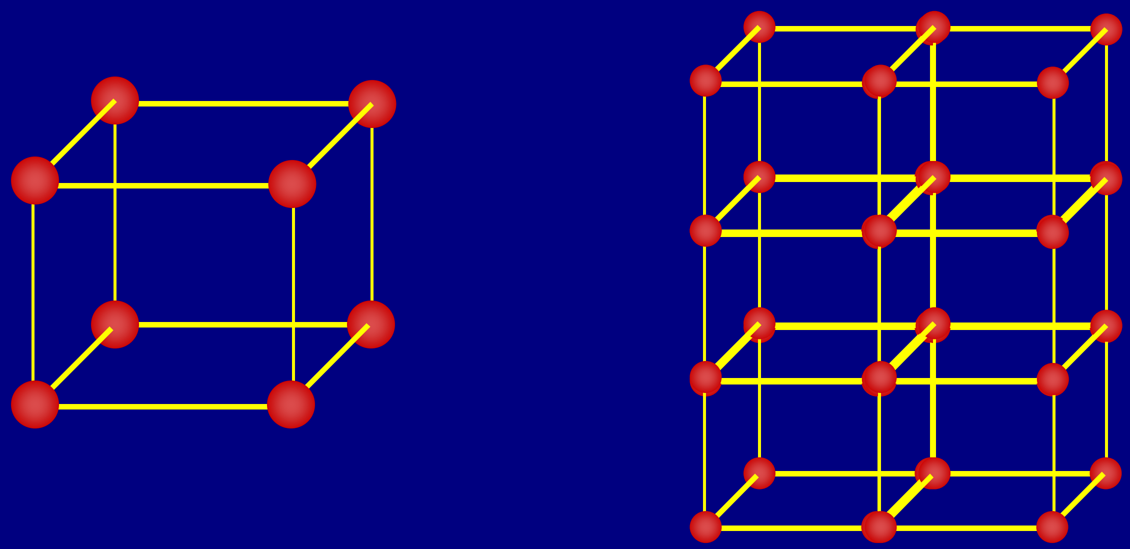
Solids

- When heated, the particles vibrate more rapidly until they shake themselves free of each other.
- As they are heated the temperature doesn’t change.
- The energy goes into breaking bonds, not increasing motion
- Move differently, not faster.

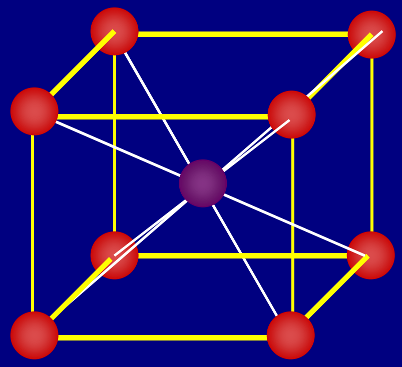
Crystals

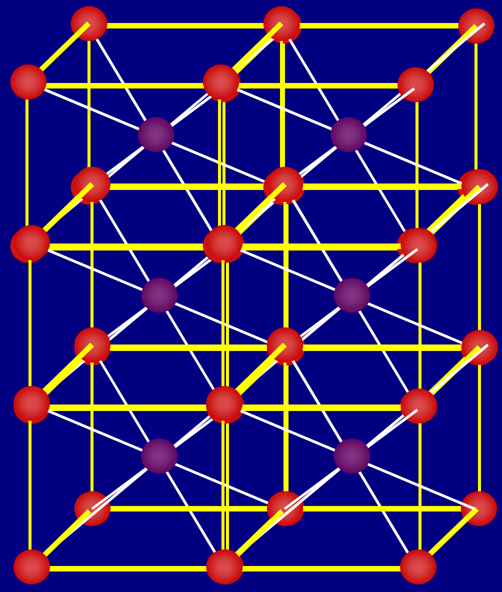
- A regular repeating three dimensional arrangement of atoms in a solid.
- Most solids are crystals.
- Break at certain angles

Cubic

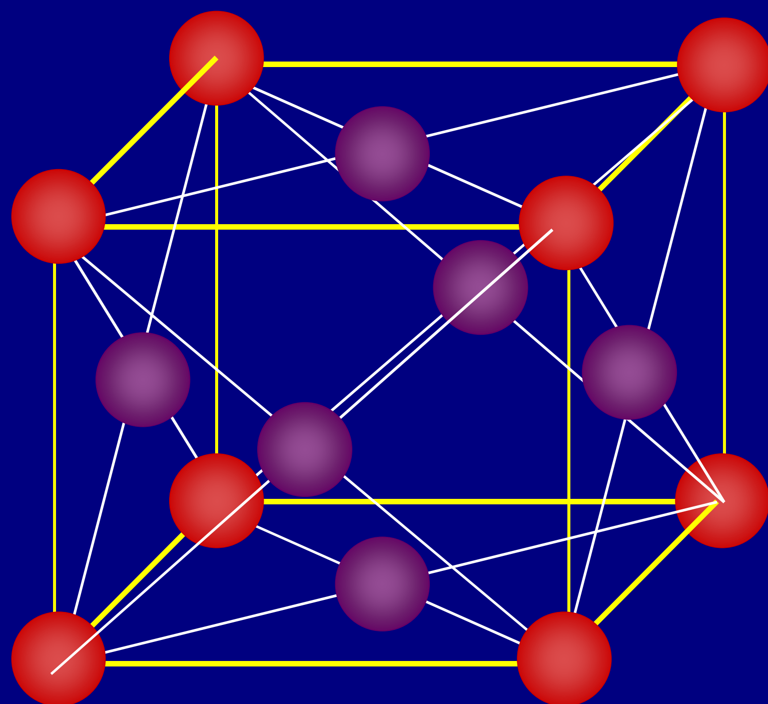


Body-Centered Cubic





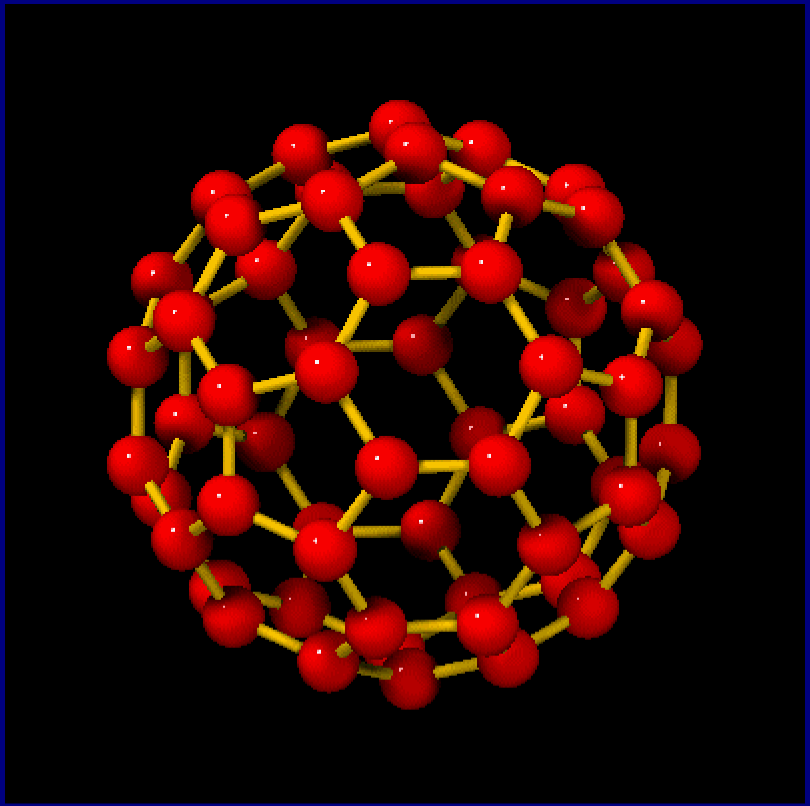
Face-Centered Cubic

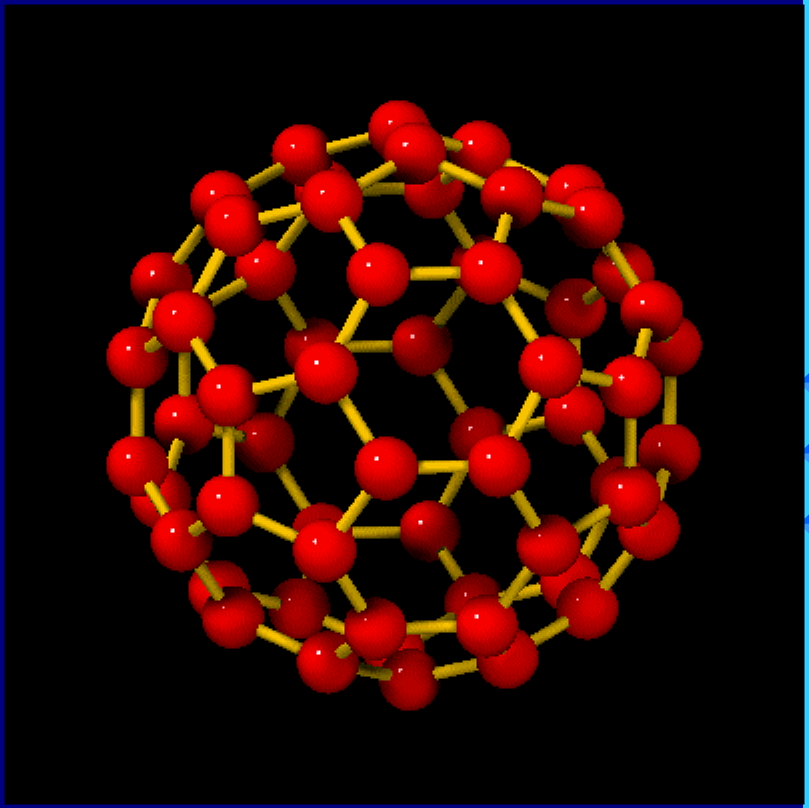


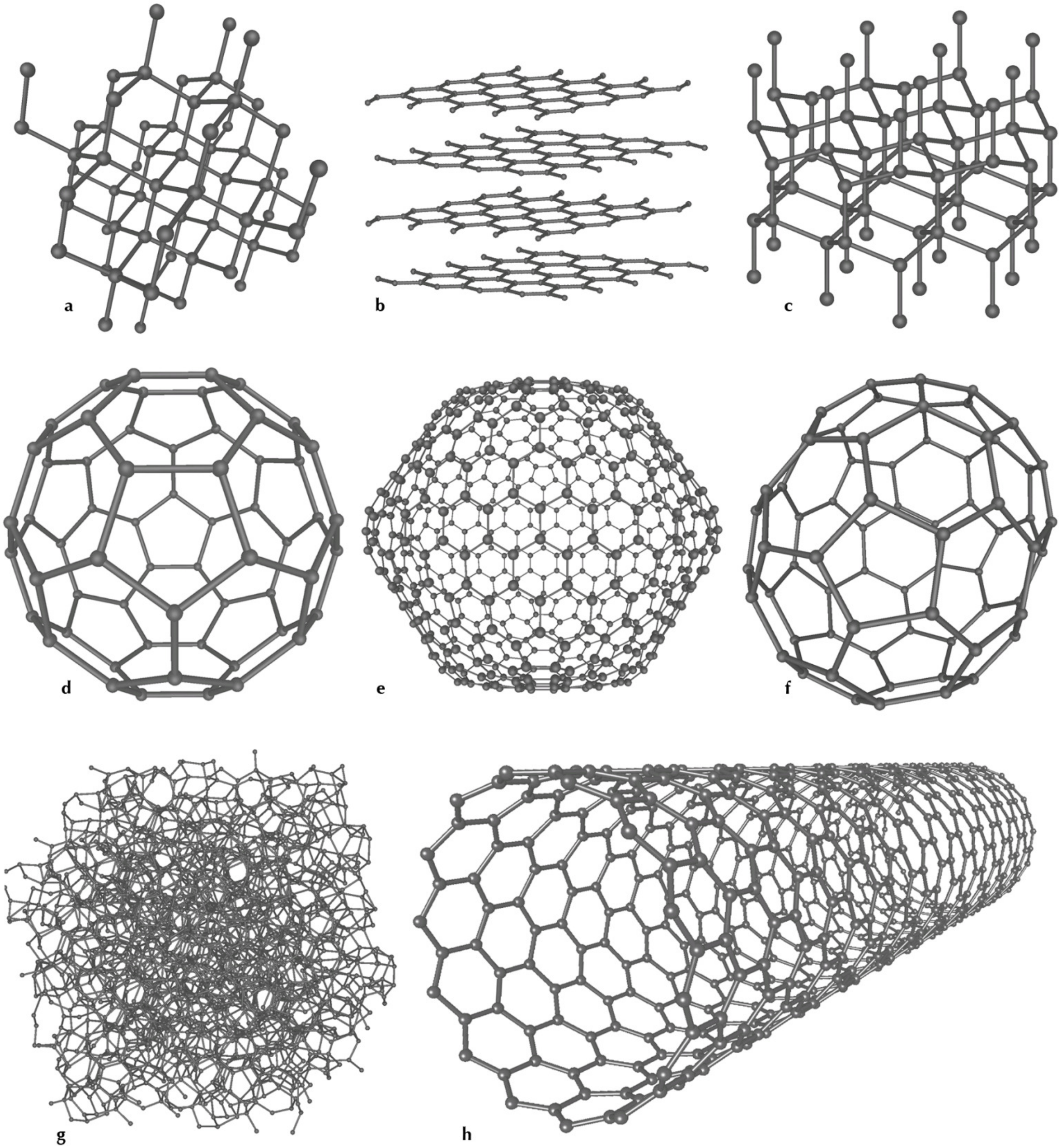
Allotropes

- **When one compound has two or more crystal structures, they are called allotropes.**
- **Graphite, diamond and soot are all carbon**
- **New carbon structures-**
  - Fullerenes- pattern on soccer ball
  - Carbon nanotubes

Fullerenes



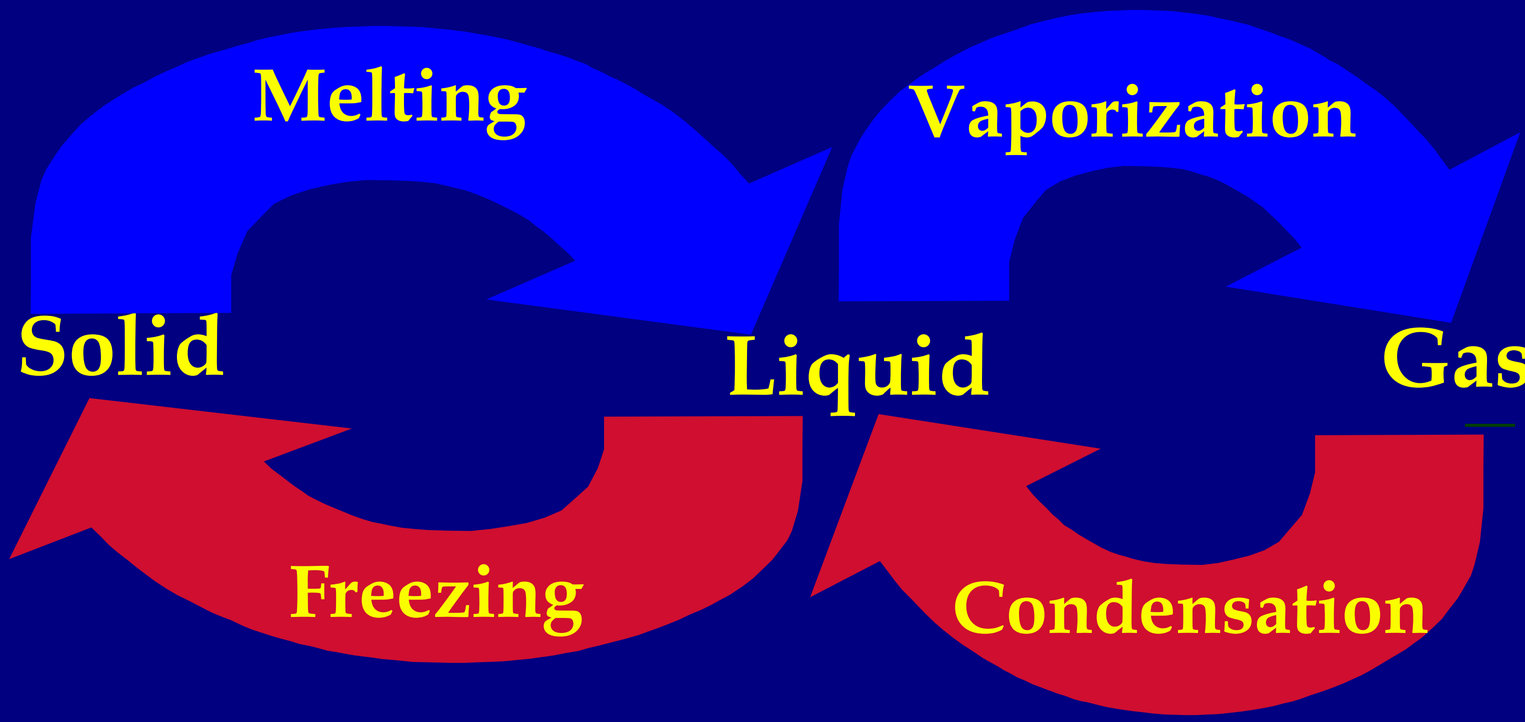


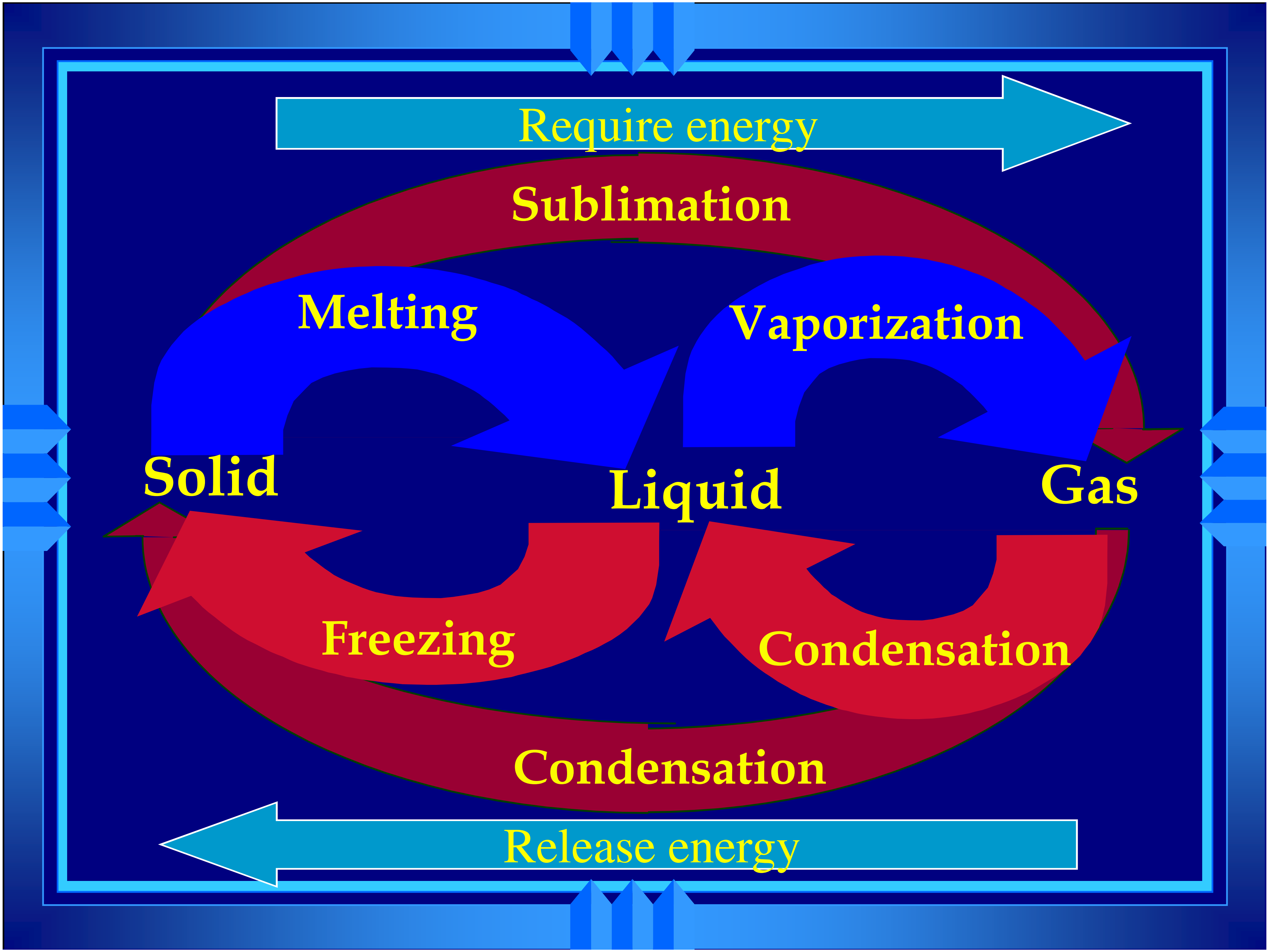

a
b
c
d
e
f
g
h

Amorphous solids

- lack an orderly internal structure.
- Think of them as super-cooled liquids.
- Glasses are one type.
- Rigid but lacking structure
- Do not melt- just gradually get softer.
- Shatter at random angles

Phase Changes





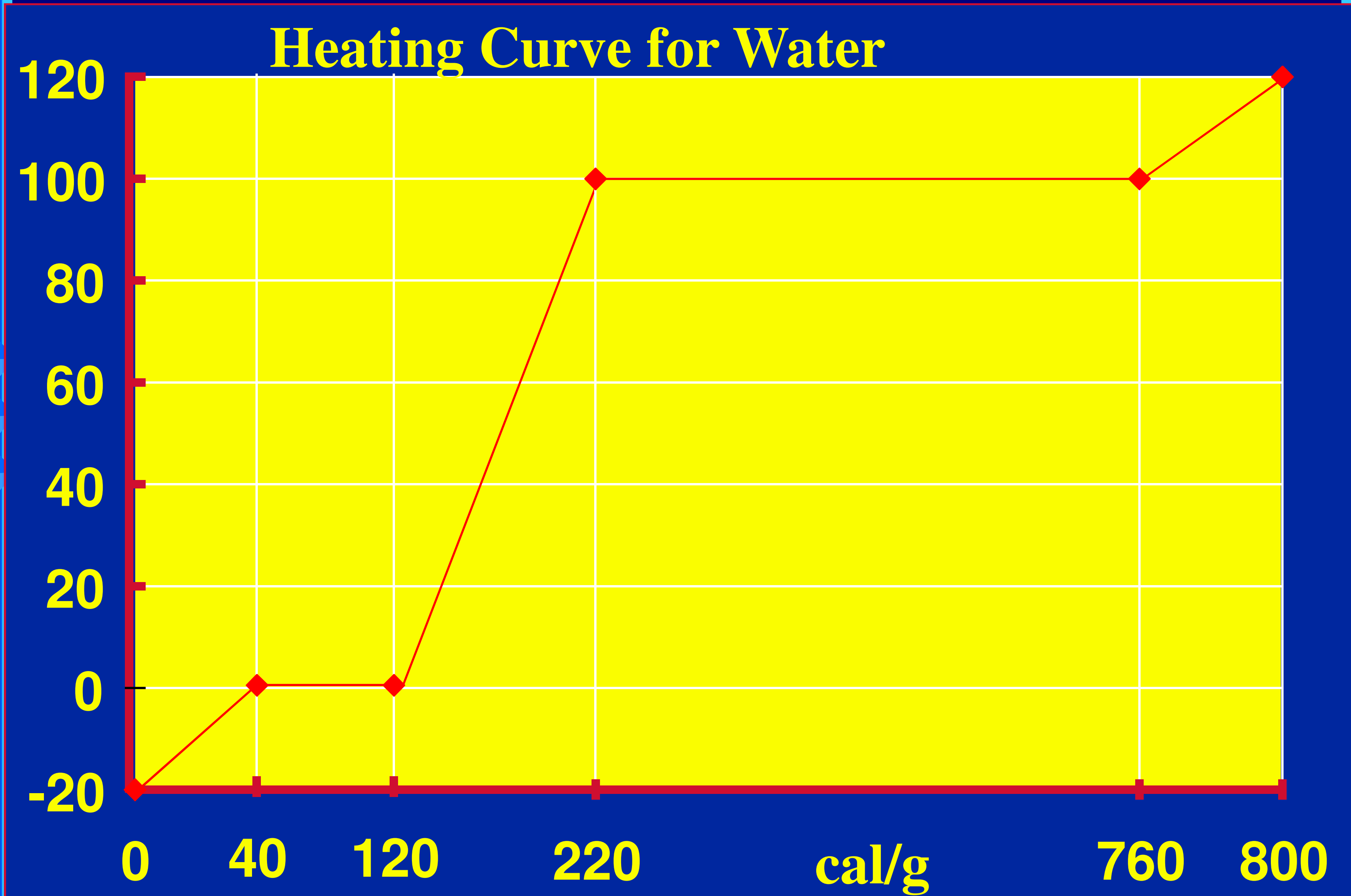
Require energy
Sublimation
Melting
Vaporization
Solid
Liquid
Gas
Freezing
Condensation
Condensation
Release energy

Temperature and Phase Change

- The temperature doesn’t change during a phase change.
- If you have a mixture of ice and water, the temperature is 0ºC
- At 1 atm, boiling water is 100ºC
- You can’t get the temperature higher until it boils

Heating Curve

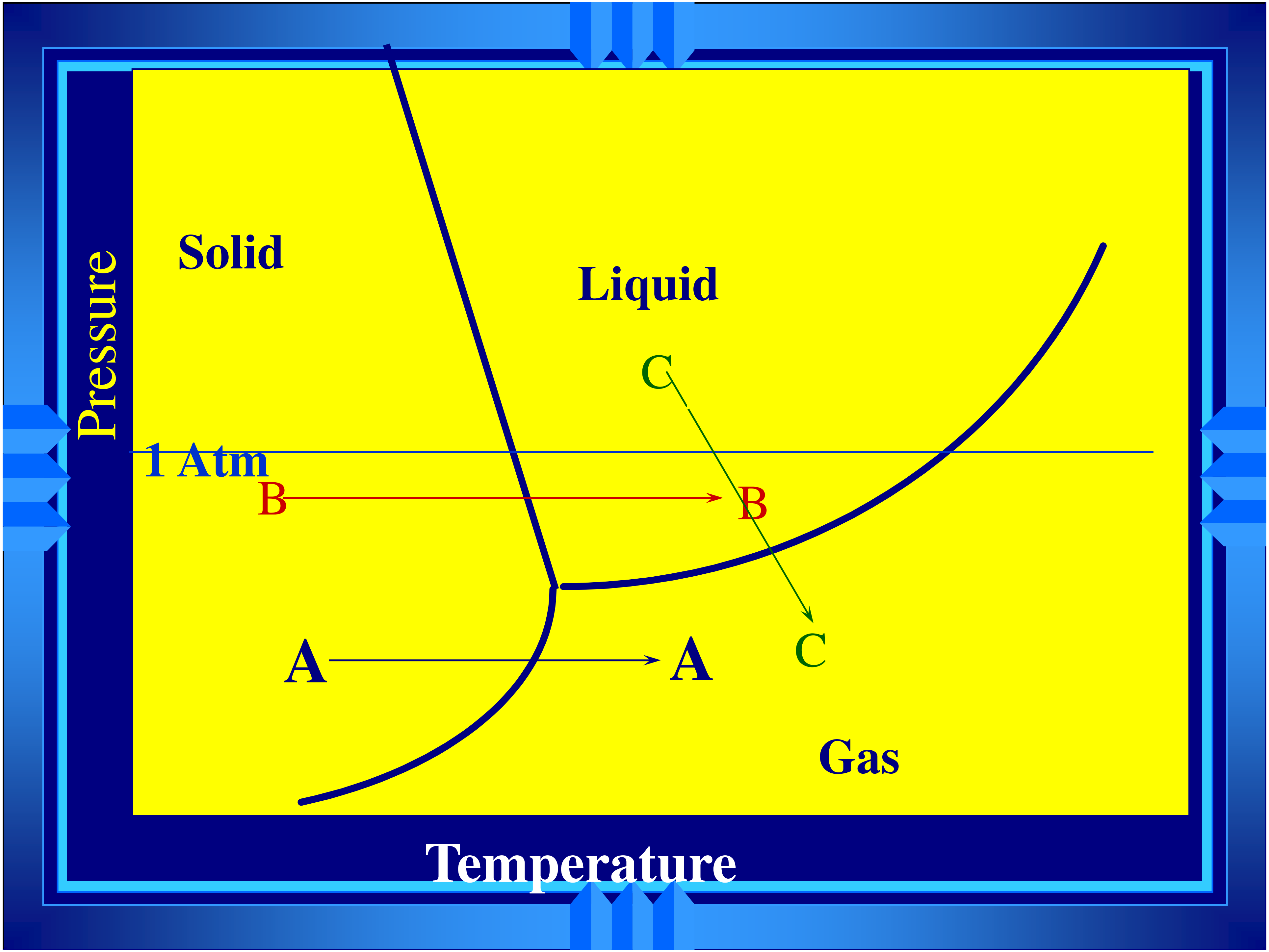
- **A graph of Energy versus temperature.**

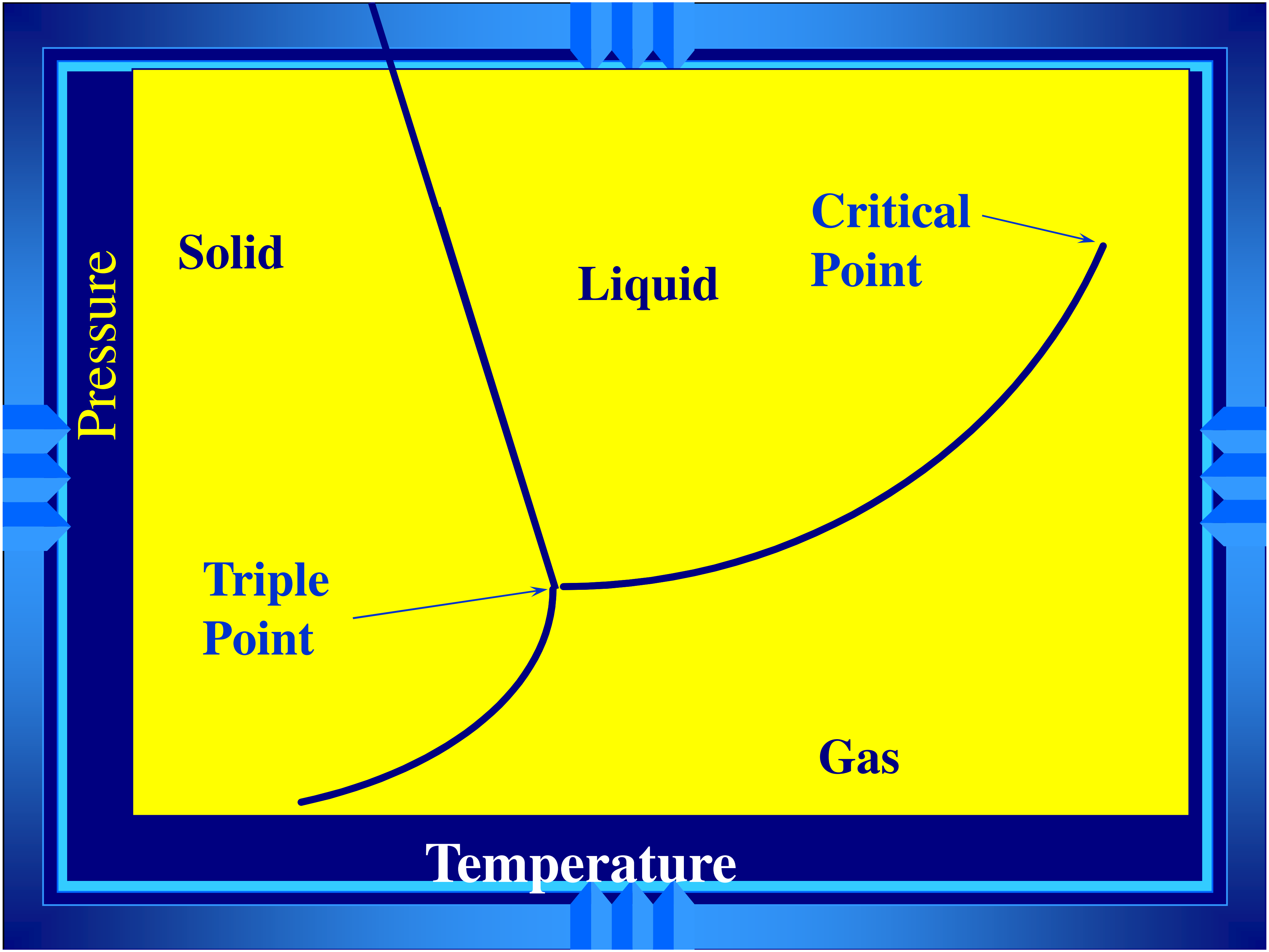


Heating Curve for Water
120
100
80
60
40
20
0
-20
0
40
120
220
cal/g
760
800

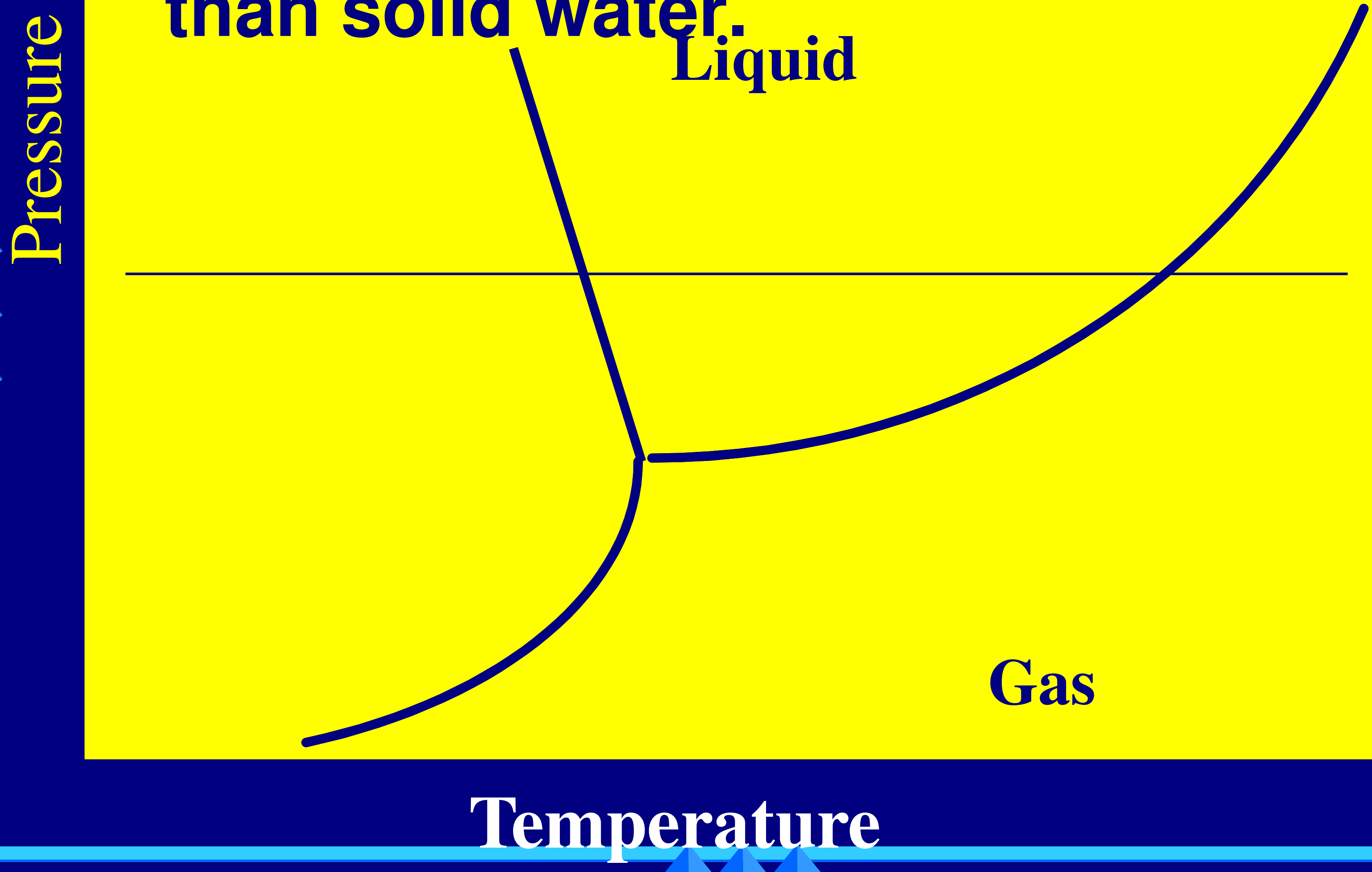
Phase Diagram

- Graph of Pressure versus temperature for a compound.
- Draw lines where the phase changes.


Solid
Liquid
Gas
Pressure
Temperature
1 Atm
A
A
B
B
C
C


Solid
Liquid
Critical Point
Triple Point
Gas
Pressure
Temperature

- This is the phase diagram for water.
- The density of liquid water is higher than solid water.



- This is the phase diagram for CO_2
- The solid is more dense than the liquid
- The solid sublimes at 1 atm.