States of Matter

Department of Chemistry

NC State University

States of Matter

- Solid
- Liquid
- Gas
- Plasma

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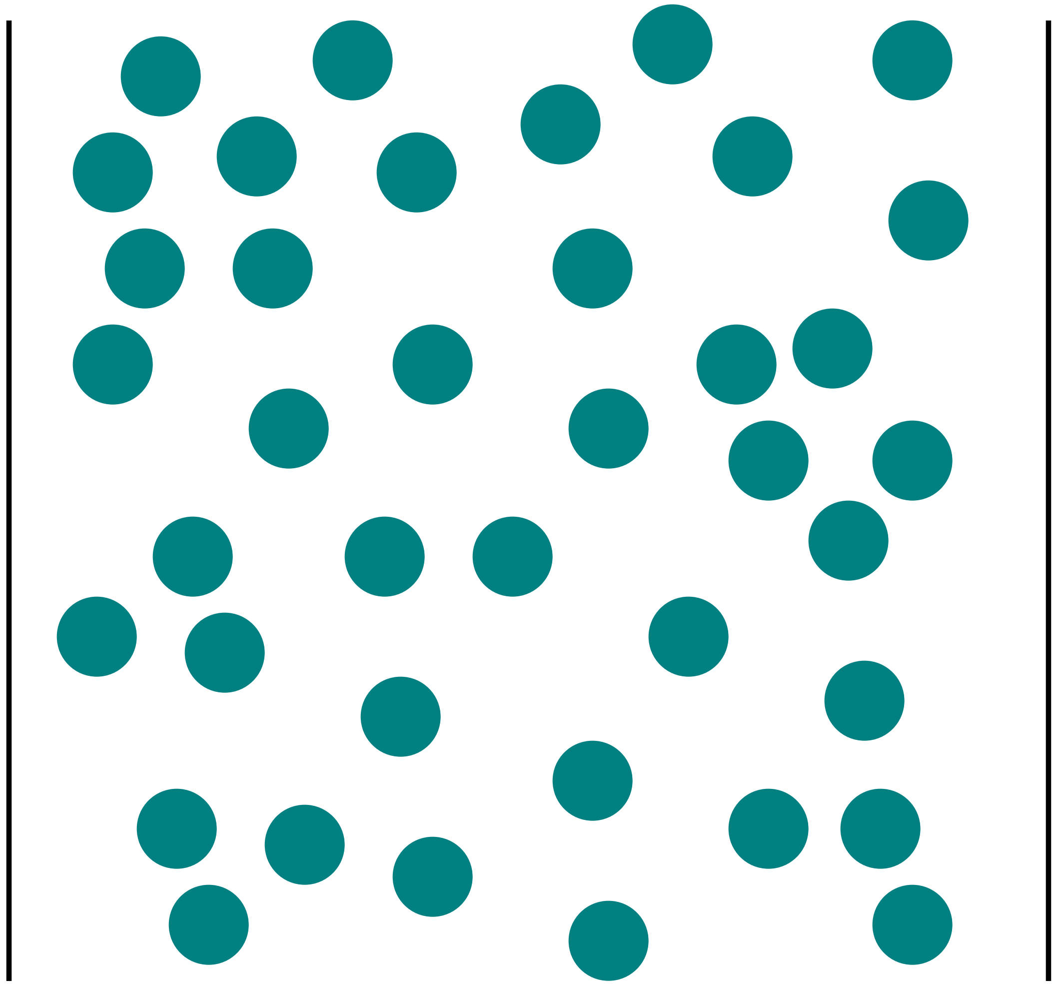
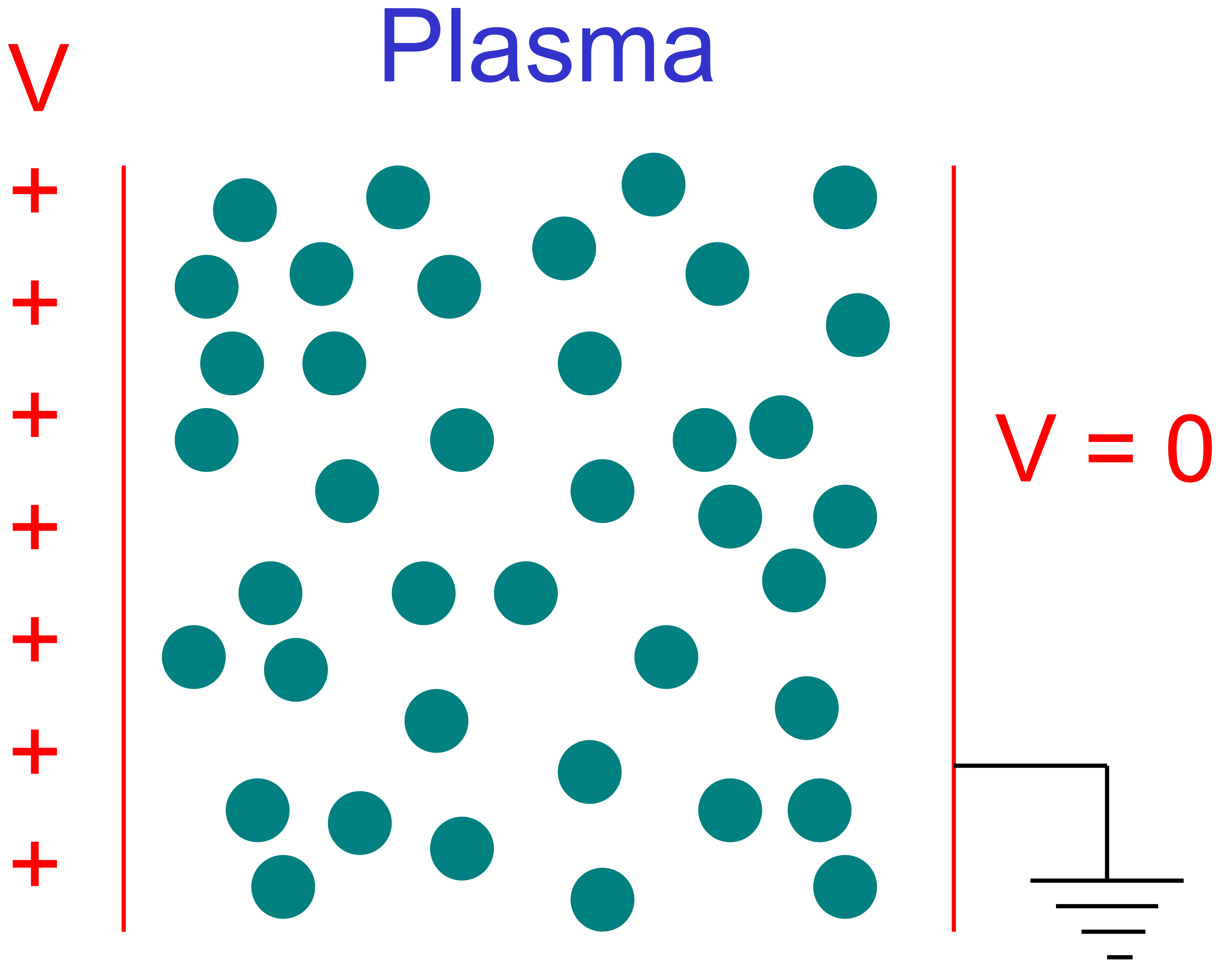
Transitions

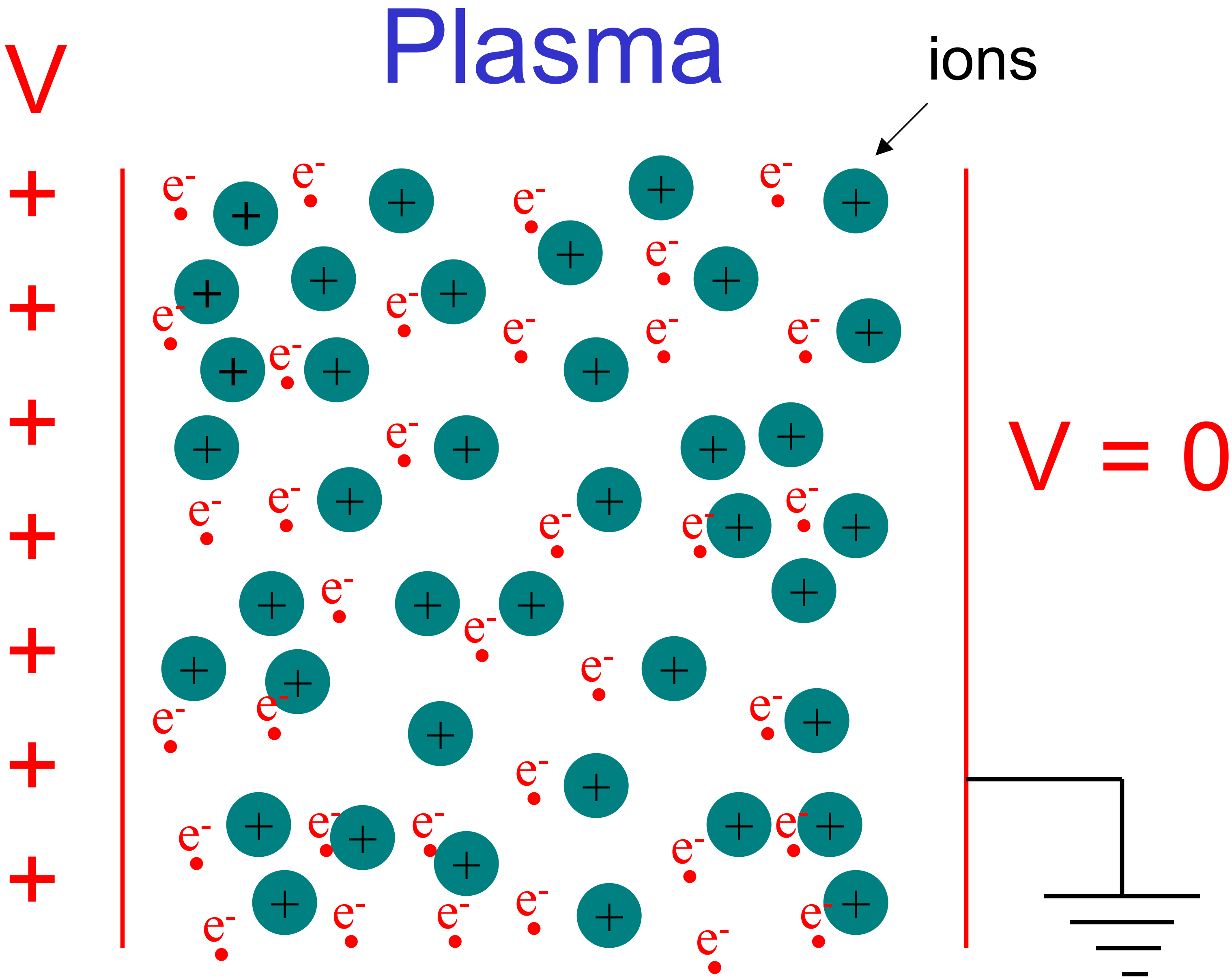
Properties

Gas Phase

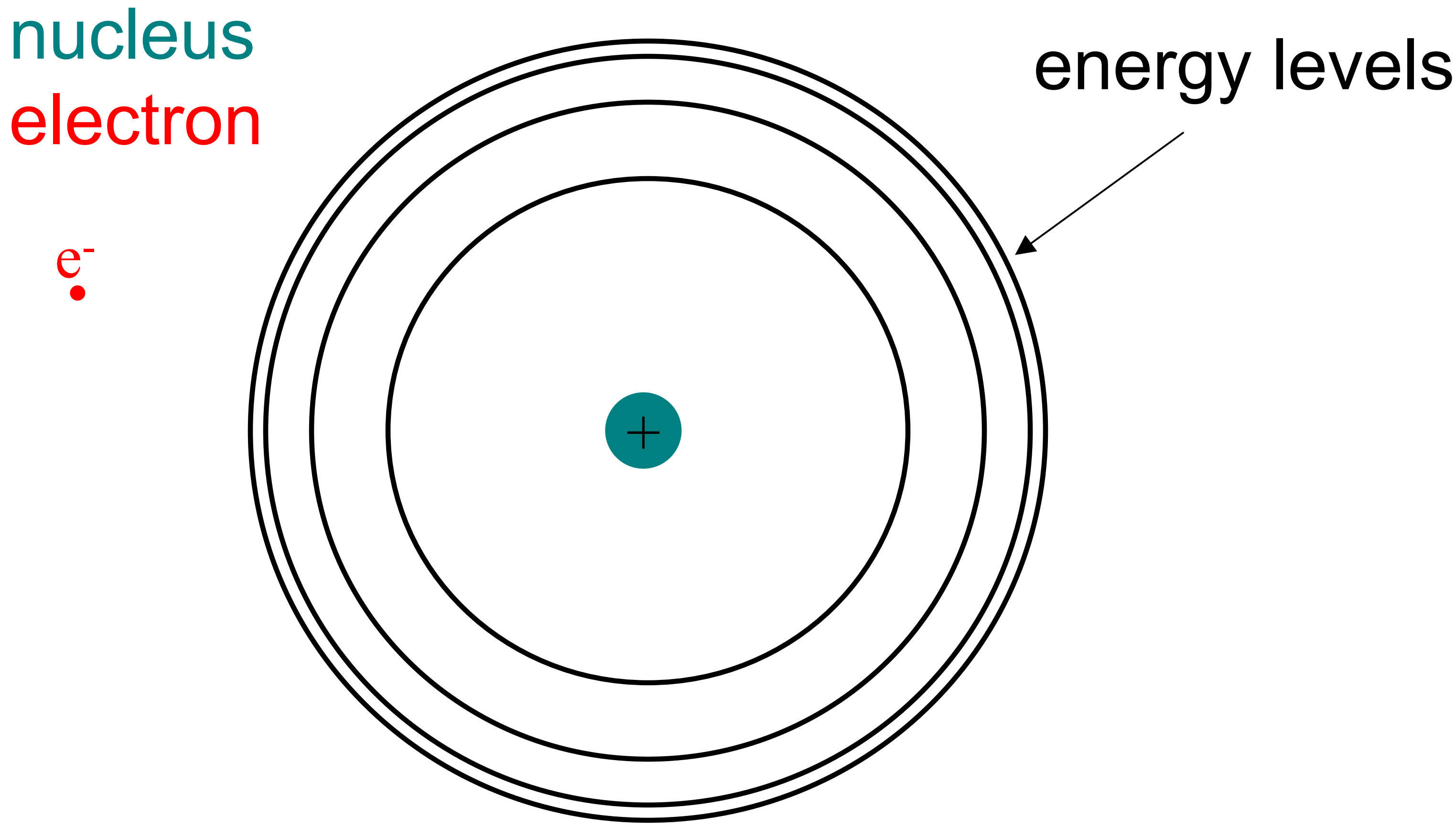




Plasma
V
+
+
+
+
+
+
+
V = 0


Plasma
V
ions
V = 0

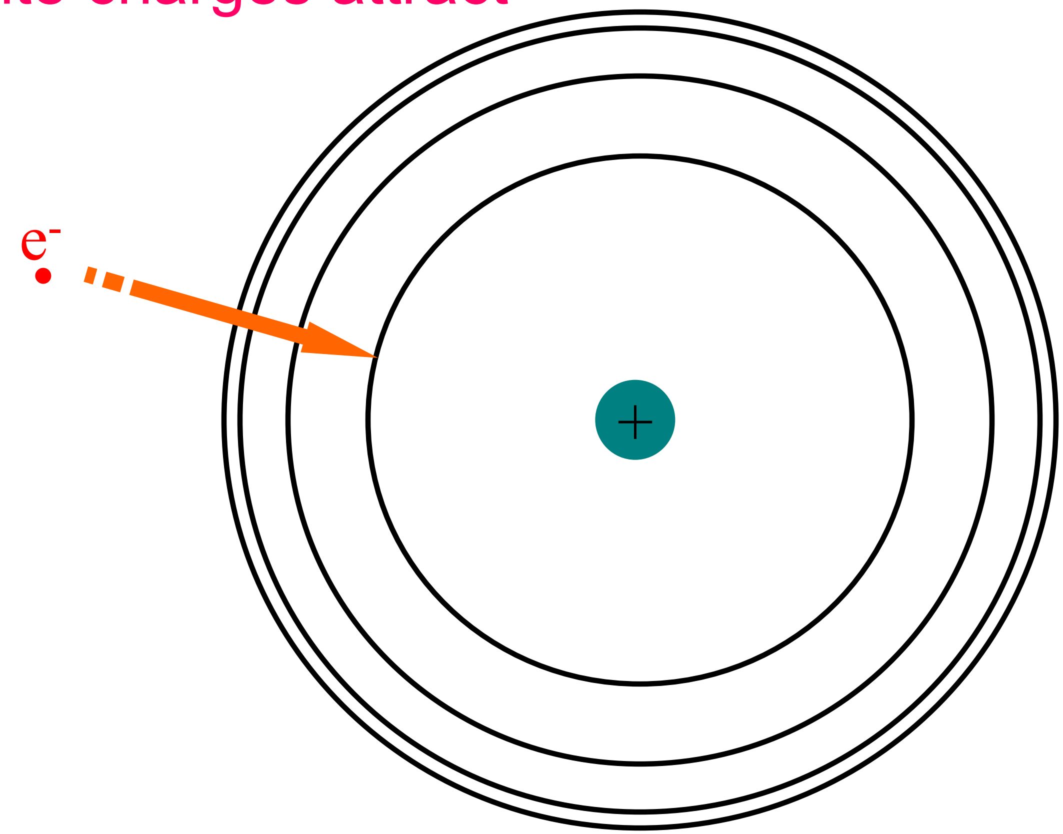
Emission of Light



Example: an atom with energy levels determined by an electrostatic potential

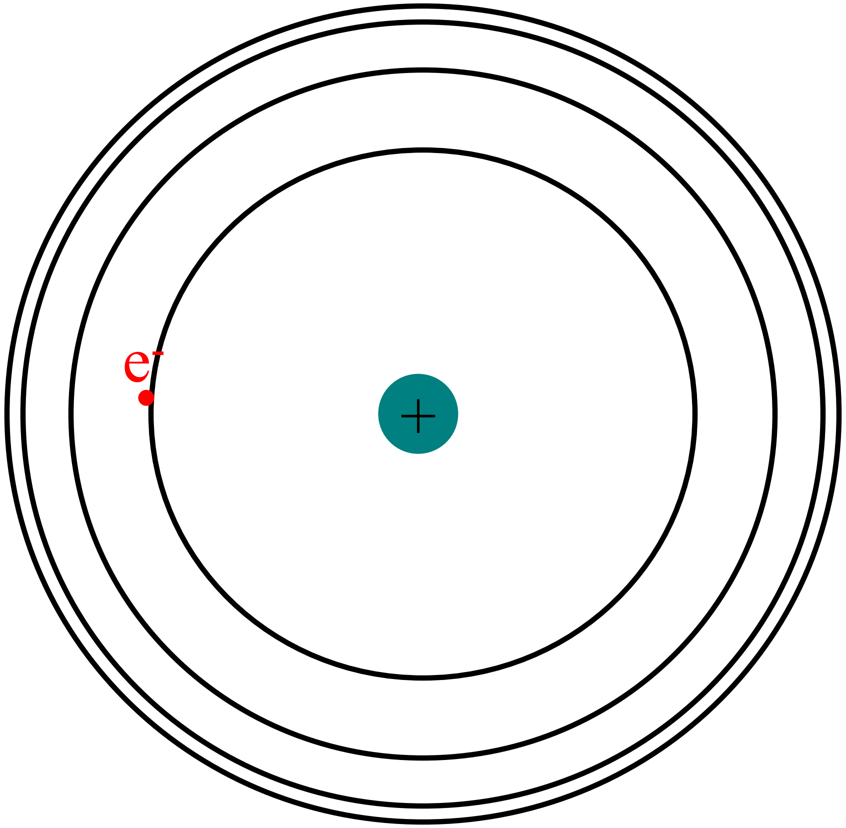
Emission of Light

Opposite charges attract



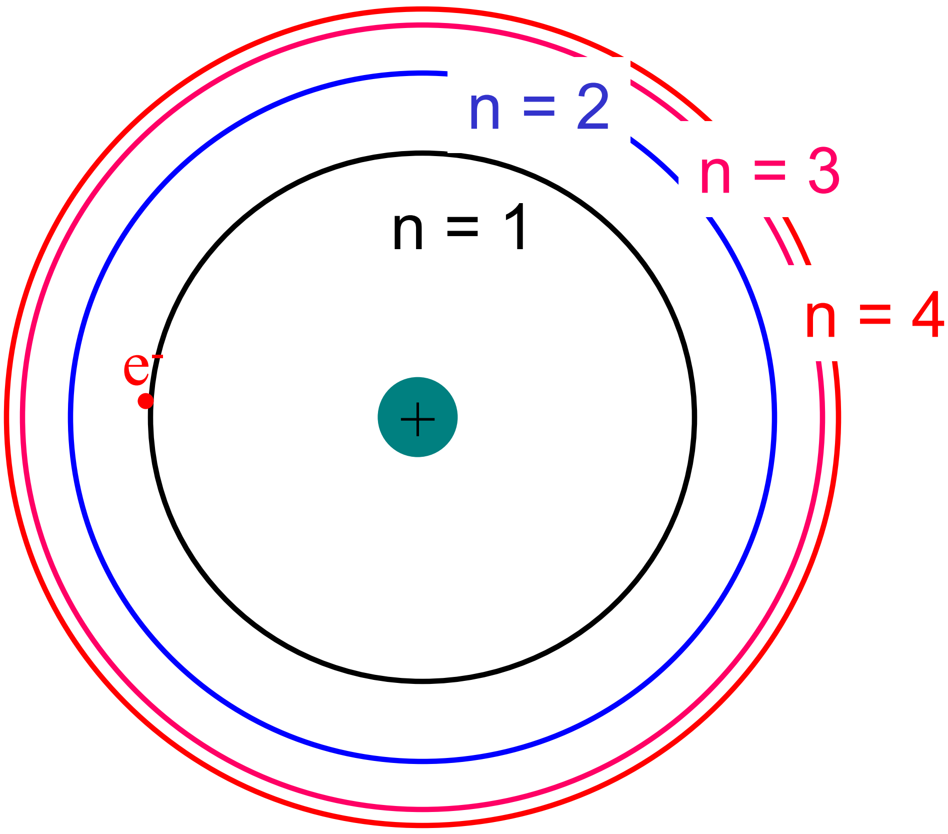
An electron can be excited by an electric discharge.
The electron can return to the atom and emit light.

Emission of Light



The neutral atom is the lowest energy state.

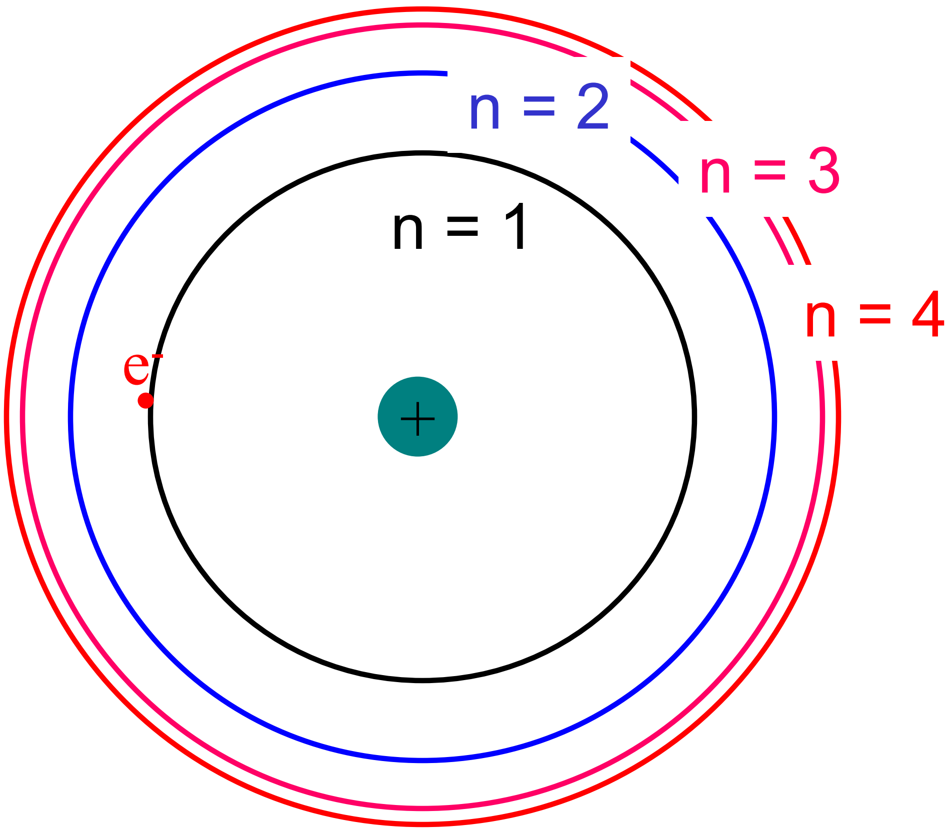
Planetary model of the atom



Energy levels have quantum numbers: $E = -R/n^2$

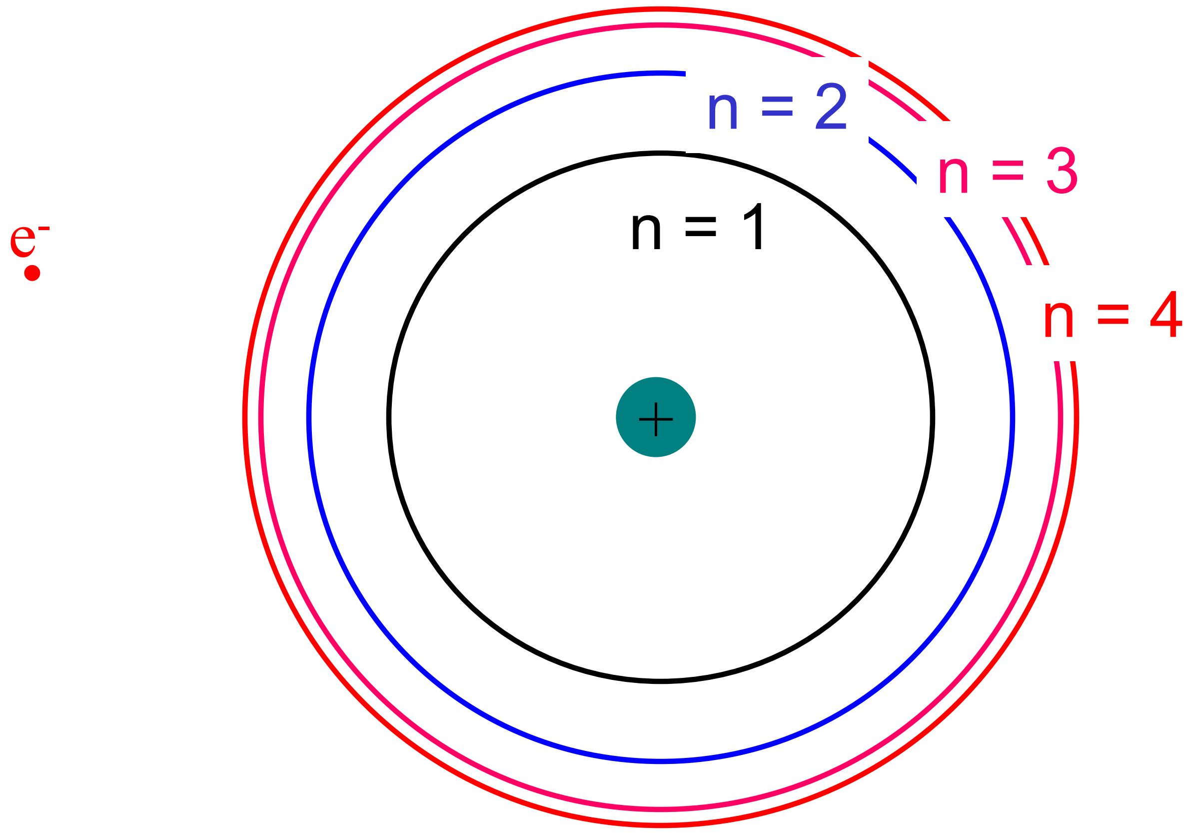
R is a constant called the Rydberg constant.

Planetary model of the atom



The electron is shown in the lowest energy state.
The is the most stable form of the atom.

Electrical energy can make an ion



The is the same moving the electron to a state where n is very big. Energy difference = R.

Properties of a plasma

- It is a conducting gas since there are charge particles (atoms and molecules).

- The plasma is stabilized because like charges repel so the nuclei stay far apart.

- In an electric discharge light is emitted since the atoms and molecules constant return to their lowest energy state.

Application: fluorescent lights

Properties of solids

- Well-defined shape (not compressible)
- They can be conductors (e.g. metals) or insulators
- Density (mass per unit volume)

Transitions of solids

- Solids can melt to form liquids (example: H_2O)
- Solids can sublime to form gases (example: CO_2)
- These transitions require the input of heat energy

Properties of liquids

- Adopt the shape of their container
- They are not compressible (syringe demo)
- Density
- Viscosity (ability to flow)

Transitions of liquids

- Liquids can freeze to form solids (example: H_2O)
  Heat is released!

- Liquids can boil to form gases (example: H_2O)
  Heat must be added!

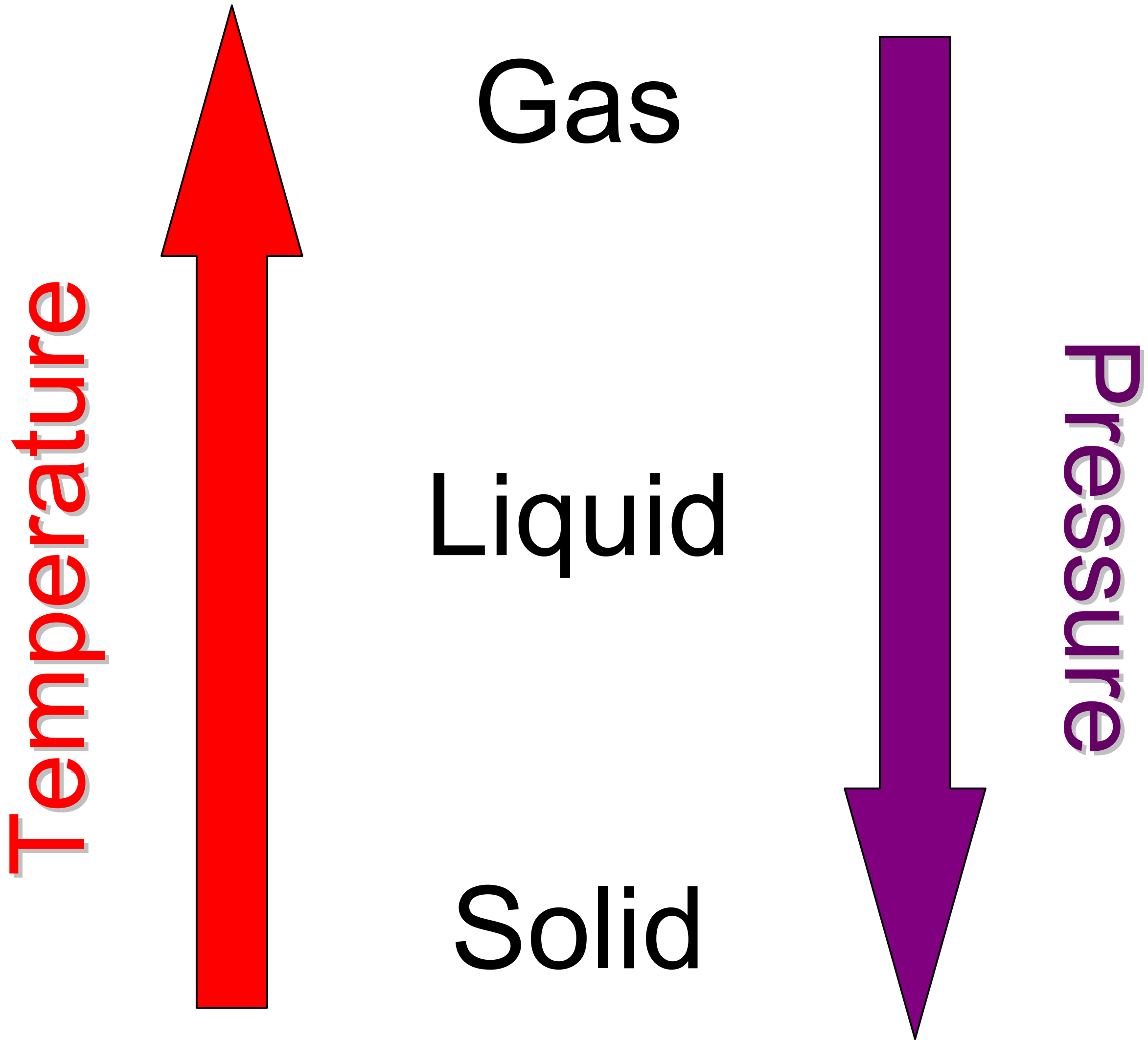
Properties of gases

- Adopt the shape of their container
- They are compressible (syringe demo)
- Density
- Viscosity (ability to flow)

Transitions of gases

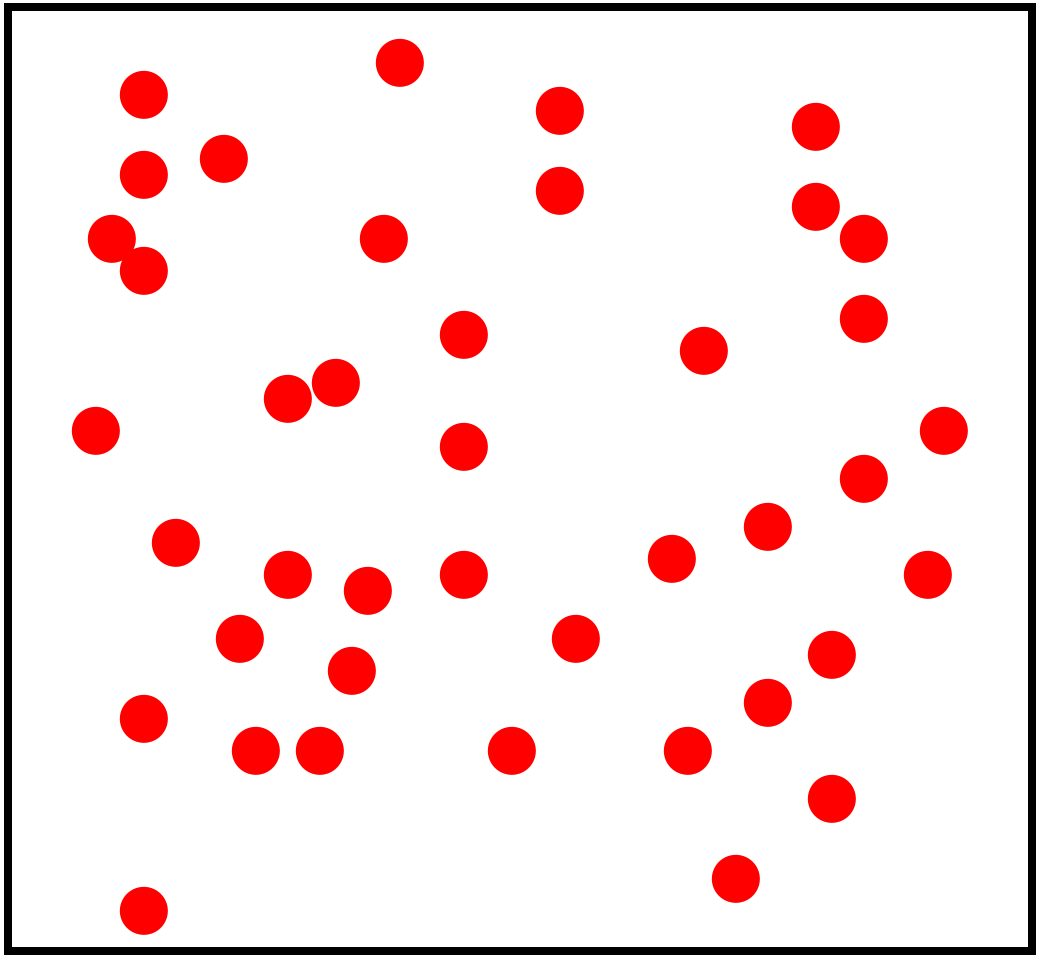
- Gases can condense to form liquids or solids
  Heat is released!

Thermal (heat) energy and pressure determine the state



The Hard Sphere Model

Low density



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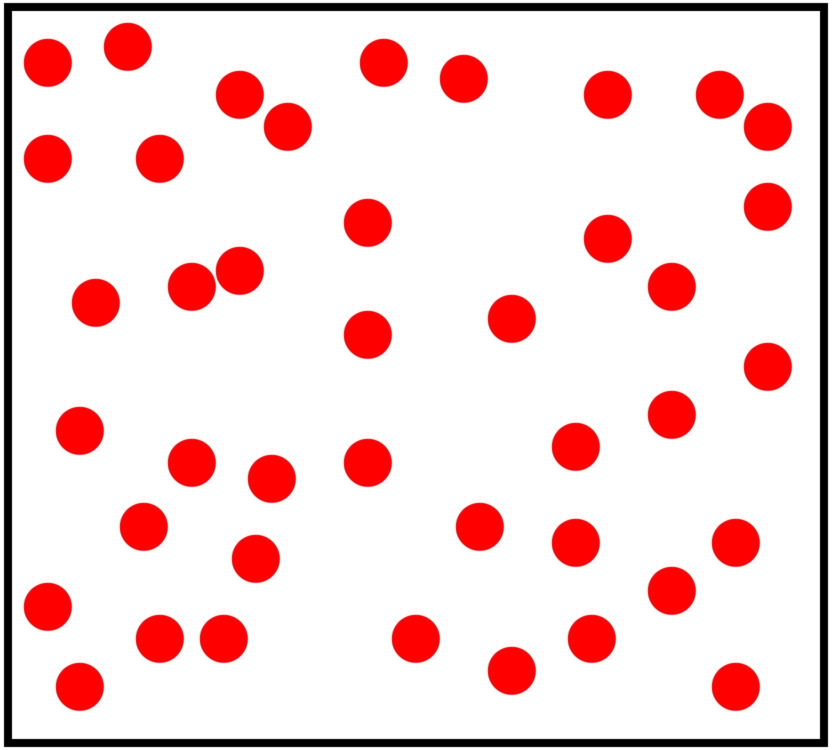

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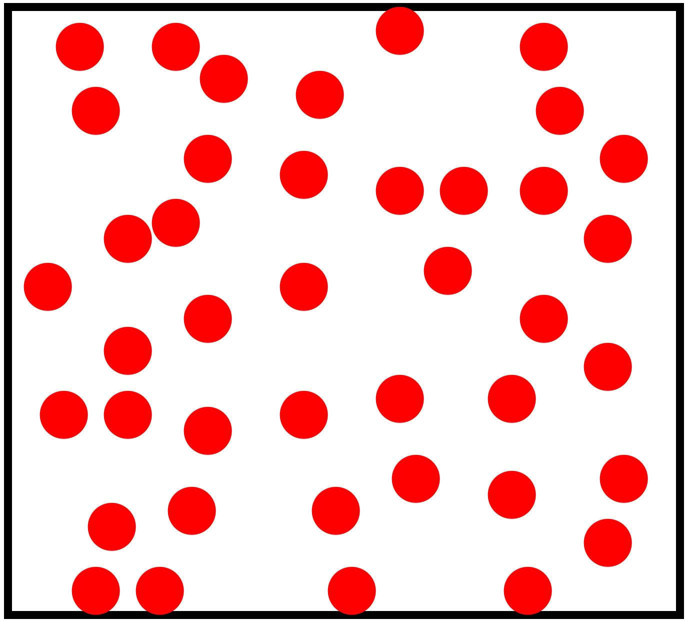

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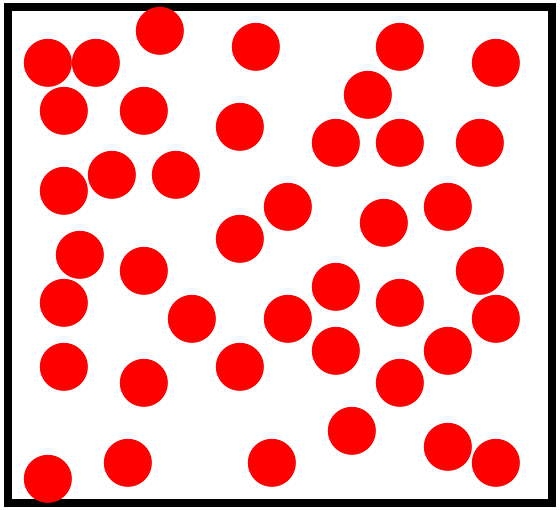
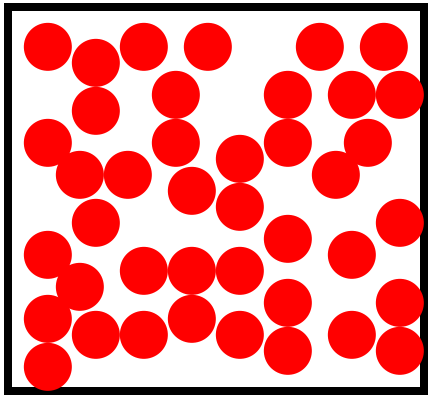


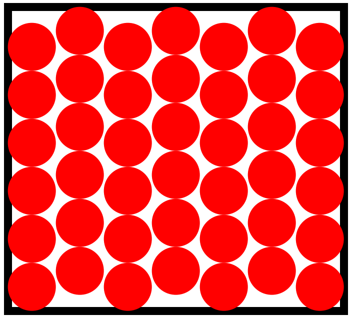
The Hard Sphere Model

At sufficiently high density the gas becomes a liquid.



The Hard Sphere Model

Limiting density: at this density the hard spheres have condensed into a solid. The “gas” cannot be compressed further.



Condensation of Air

Air is a mixture of gases:

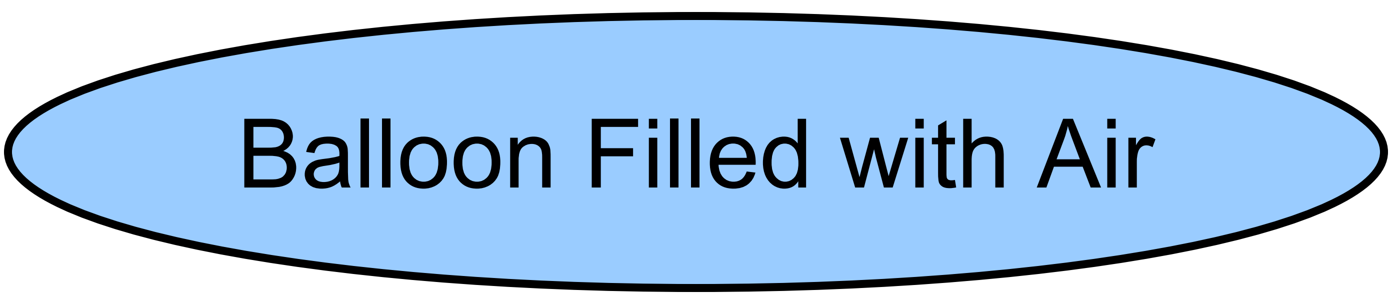
79% Nitrogen (N_2)

20% Oxygen (O_2)

1% Argon (Ar)

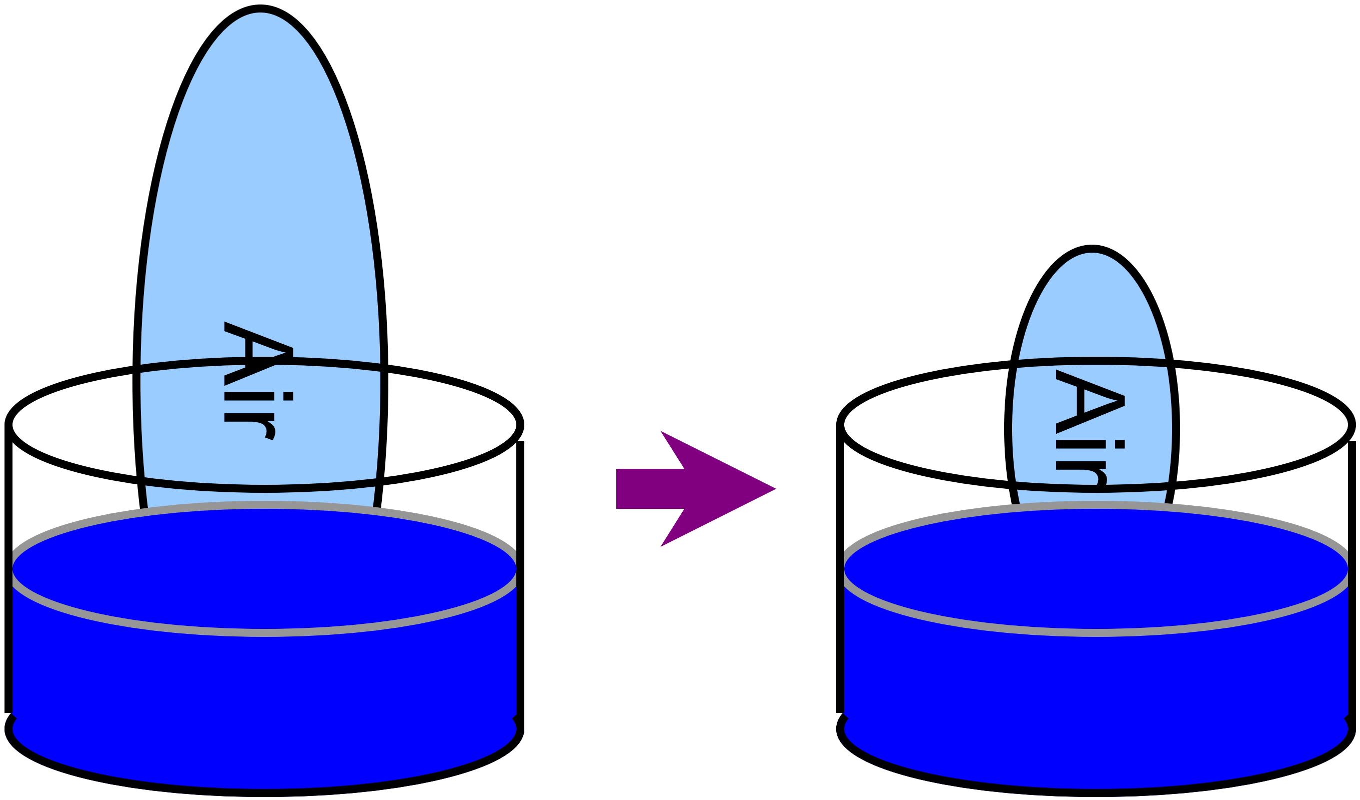
0.036% Carbon dioxide (CO_2)

If these gases are cooled they will condense.



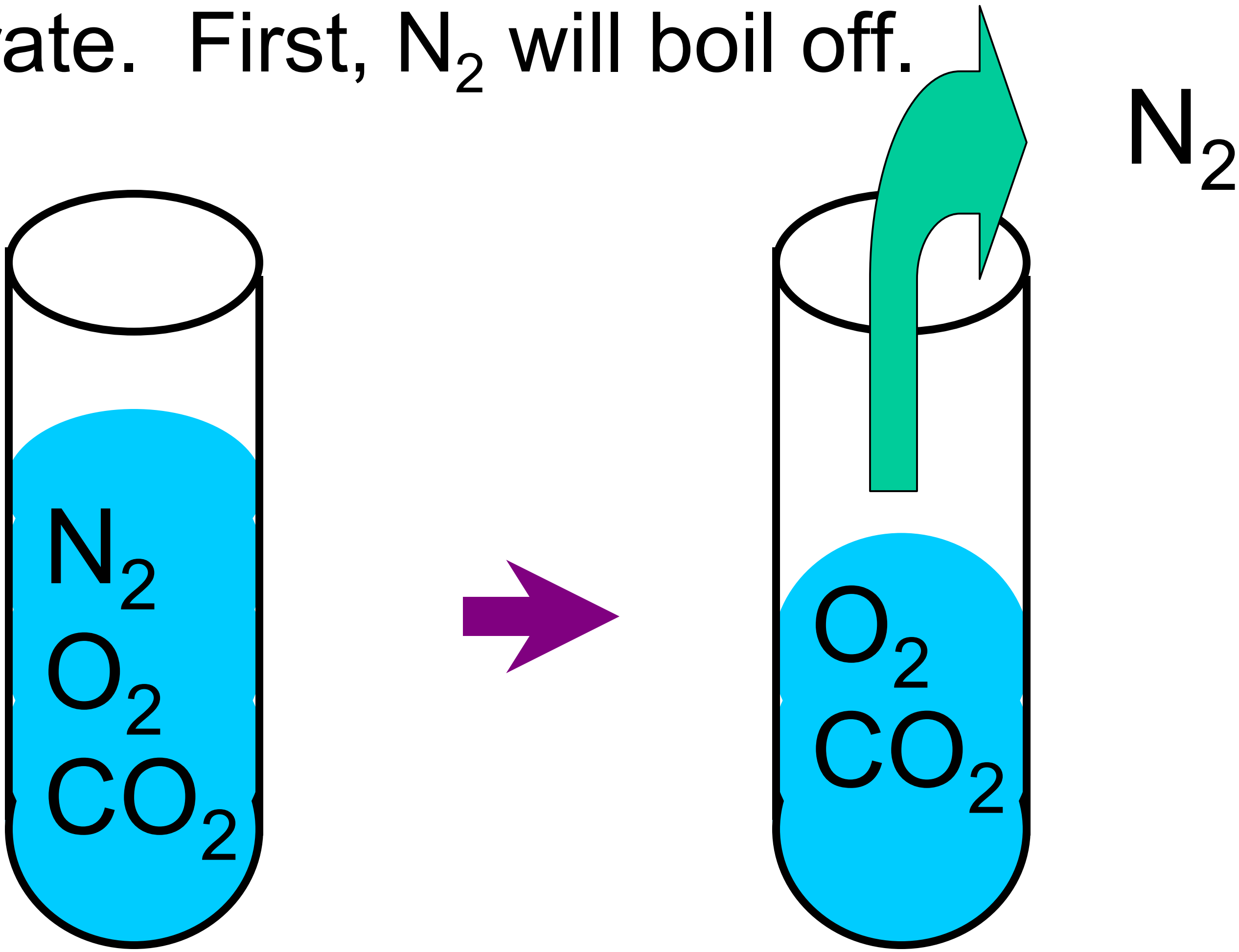
Condensation of Air

We will use liquid nitrogen to condense air. The balloon shrinks because the liquid has a much smaller volume than the gas phase.



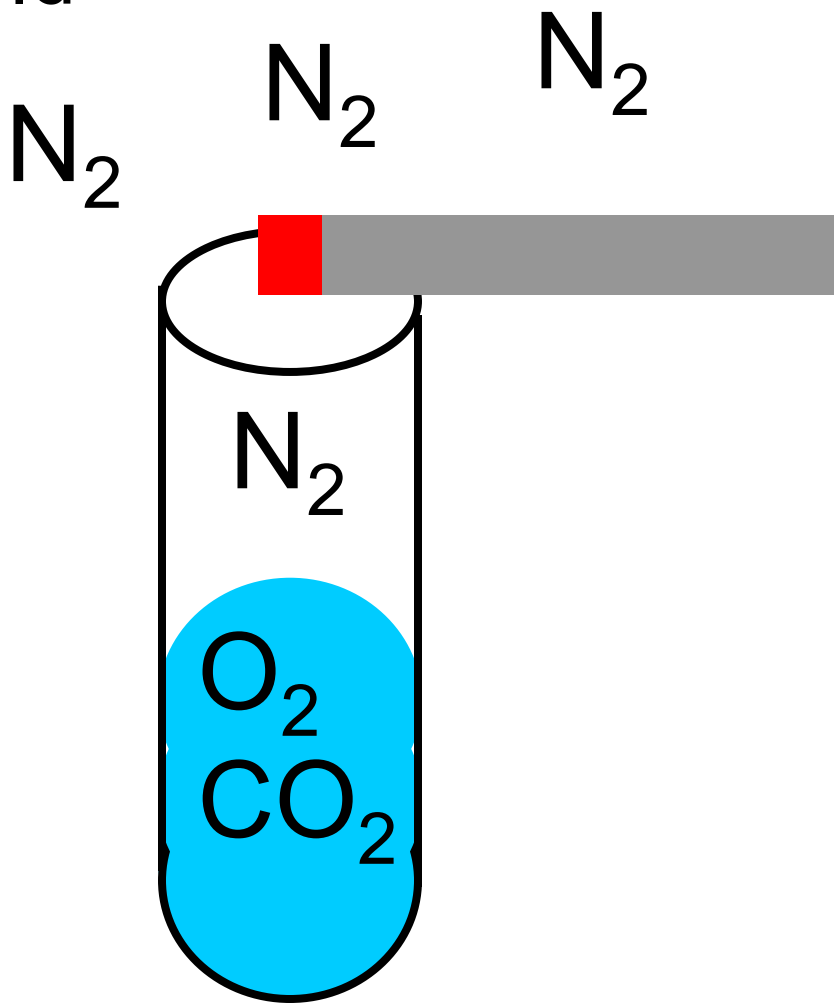
Liquid Air in a Test Tube

Since the air is now a liquid we can keep in A test tube. Now the components of air will evaporate. First, N_2 will boil off.



Properties of Nitrogen

Nitrogen is not a reactive gas. While it is boiling off you can hold a glowing splint over the top of the test tube and it will glow less brightly.



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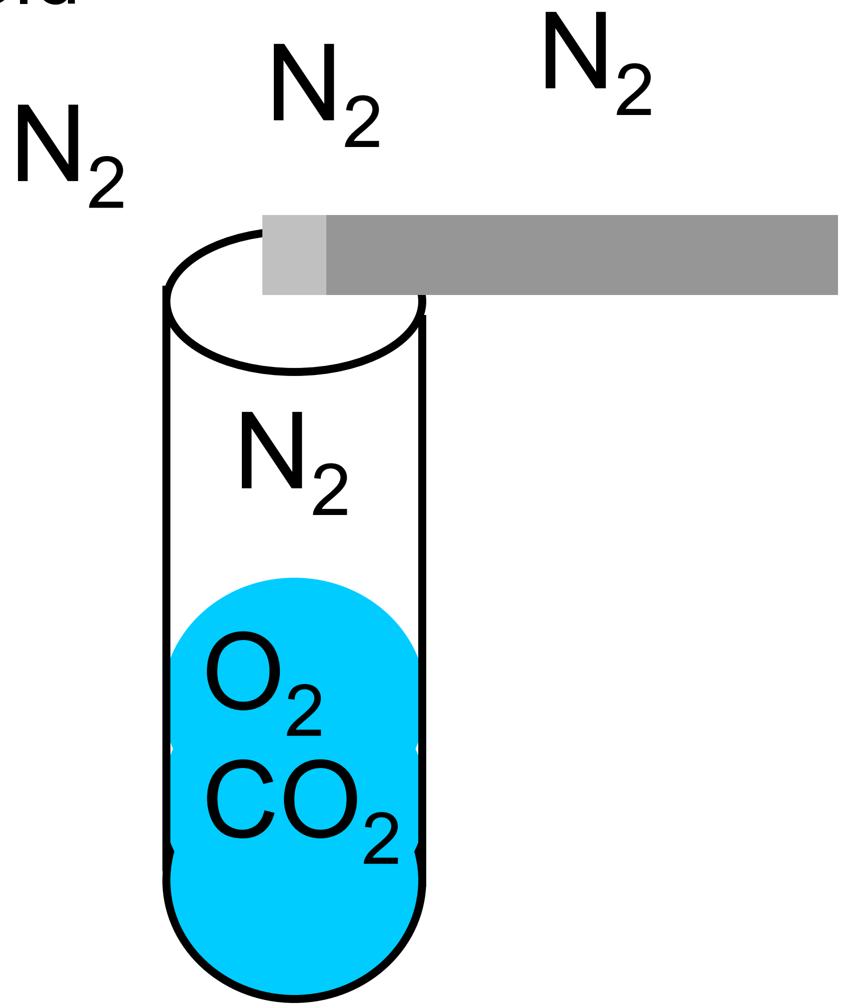
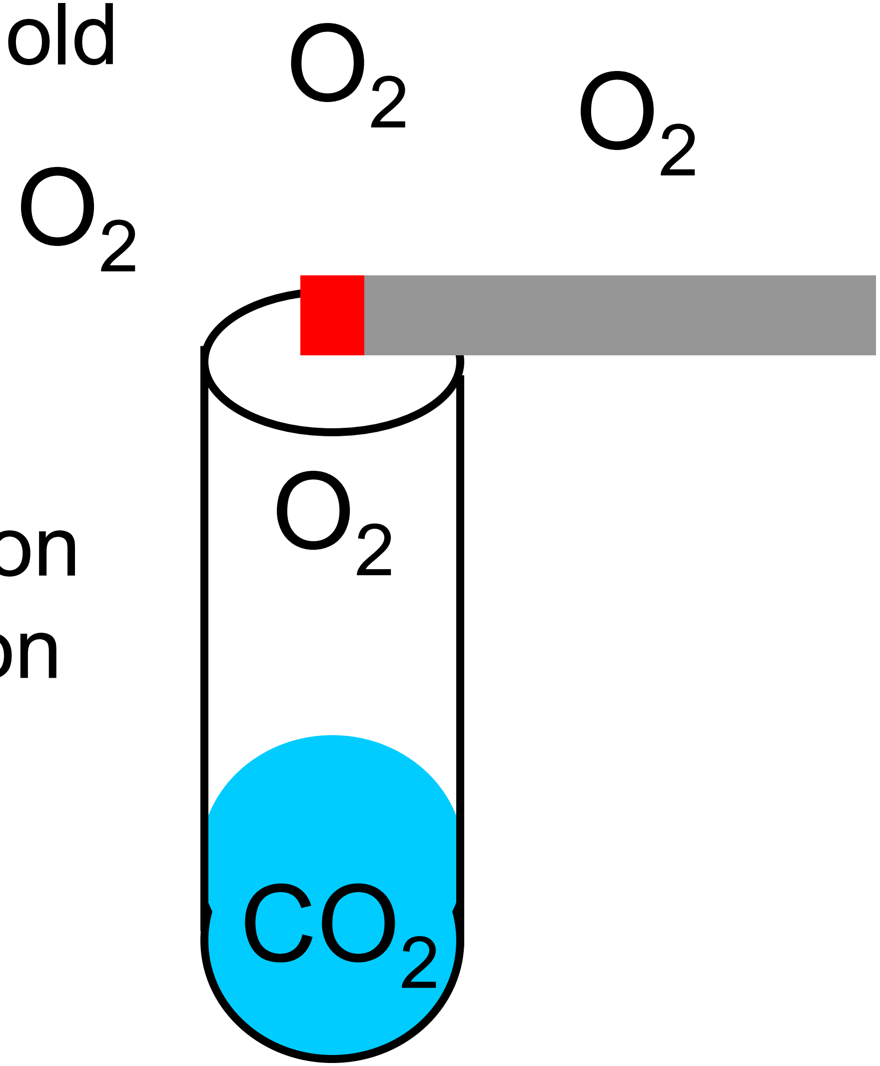


Properties of Oxygen

Oxygen is a reactive gas. While it is boiling off you can hold a glowing splint over the top of the test tube and it will burst into flame. The chemical reaction involving combination with oxygen is called combustion.



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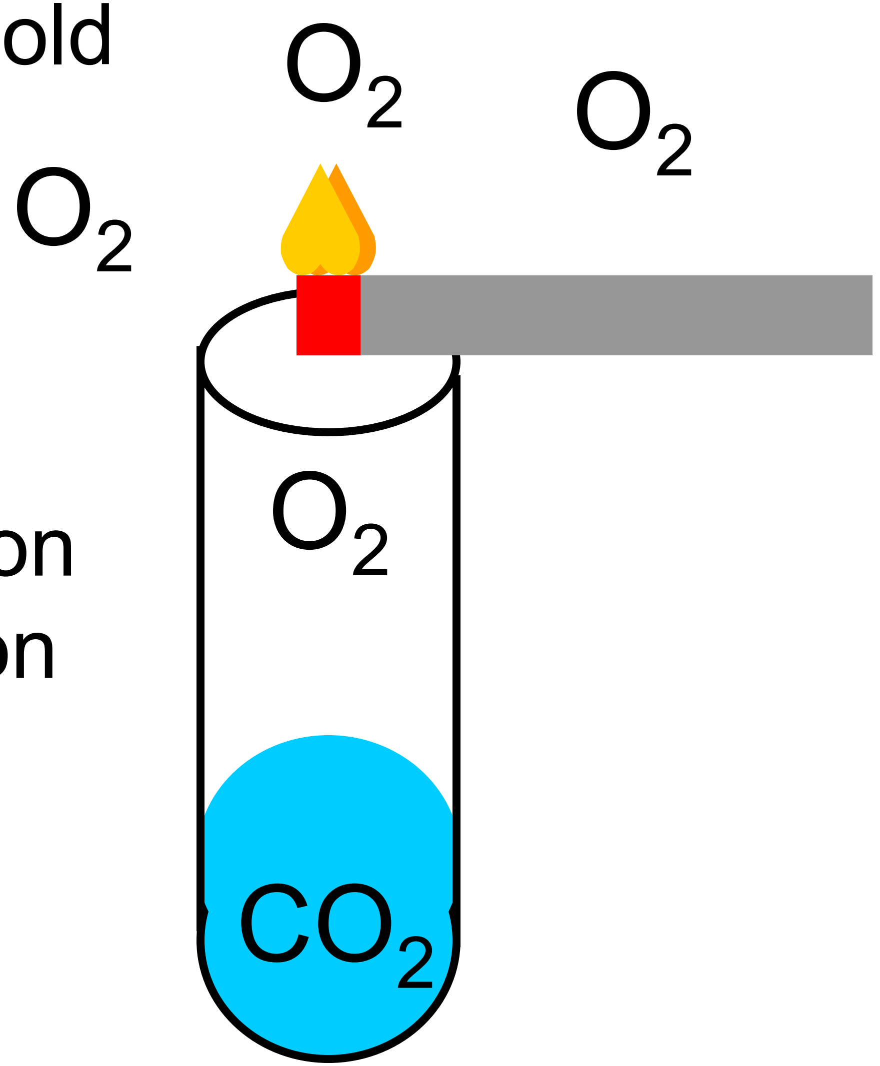
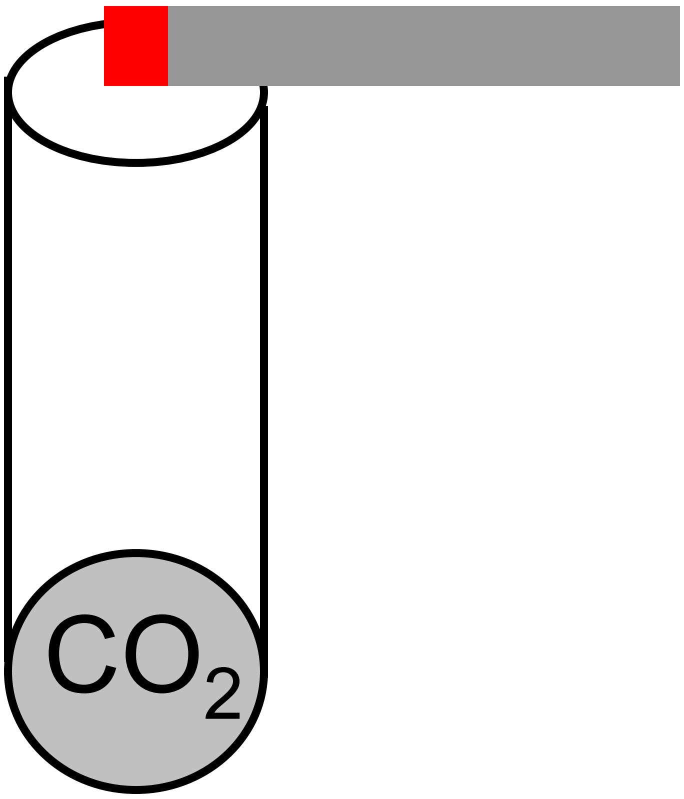


Properties of Carbon Dioxide

Carbon dioxide can exist only as a solid or a gas at atmospheric pressure. CO_2 has a higher vaporization temperature than N_2 or O_2 so it is the last substance to vaporize.

CO_2 can react with water to form an acid, but it will not promote combustion.



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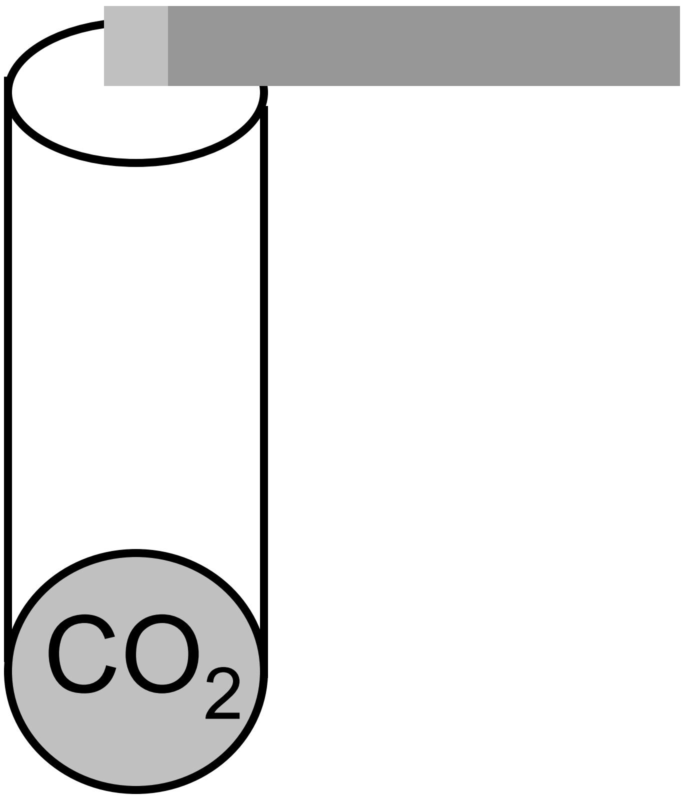
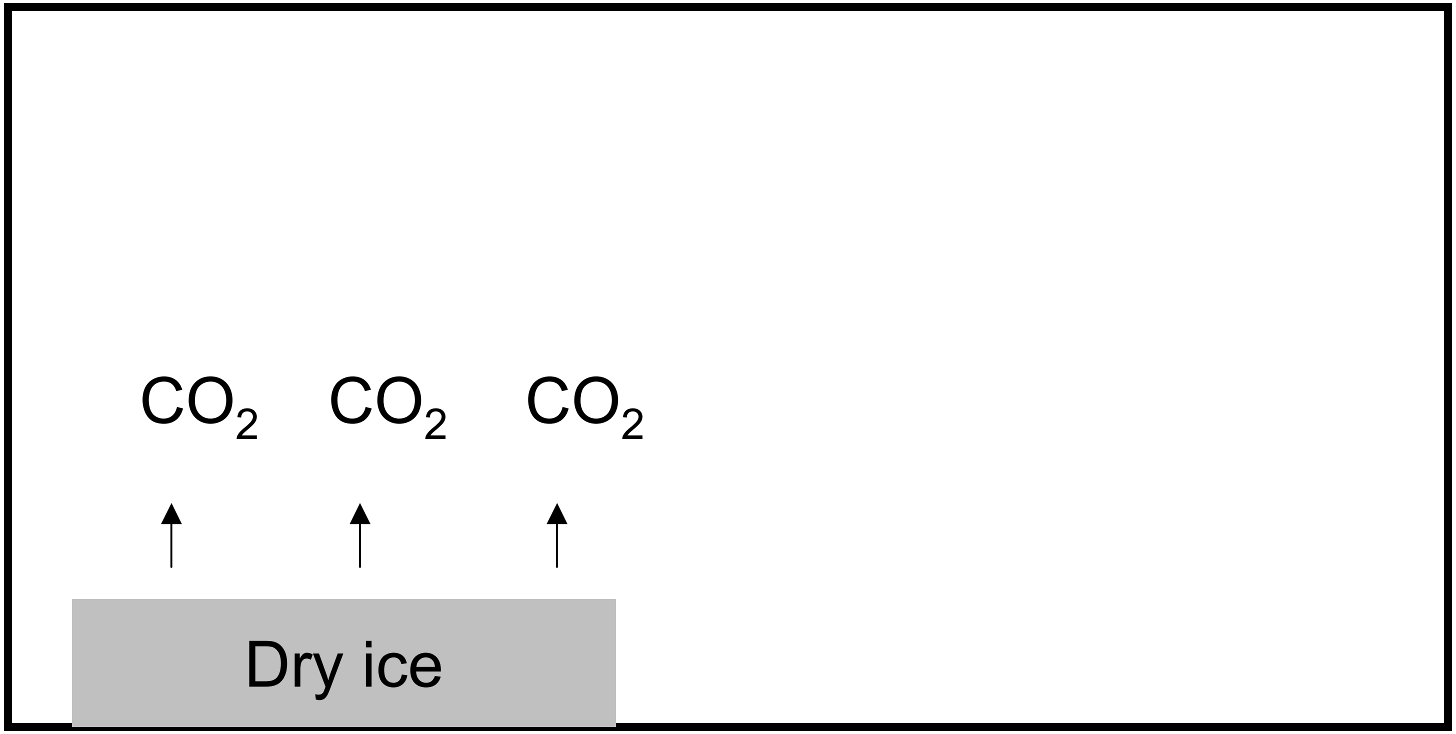


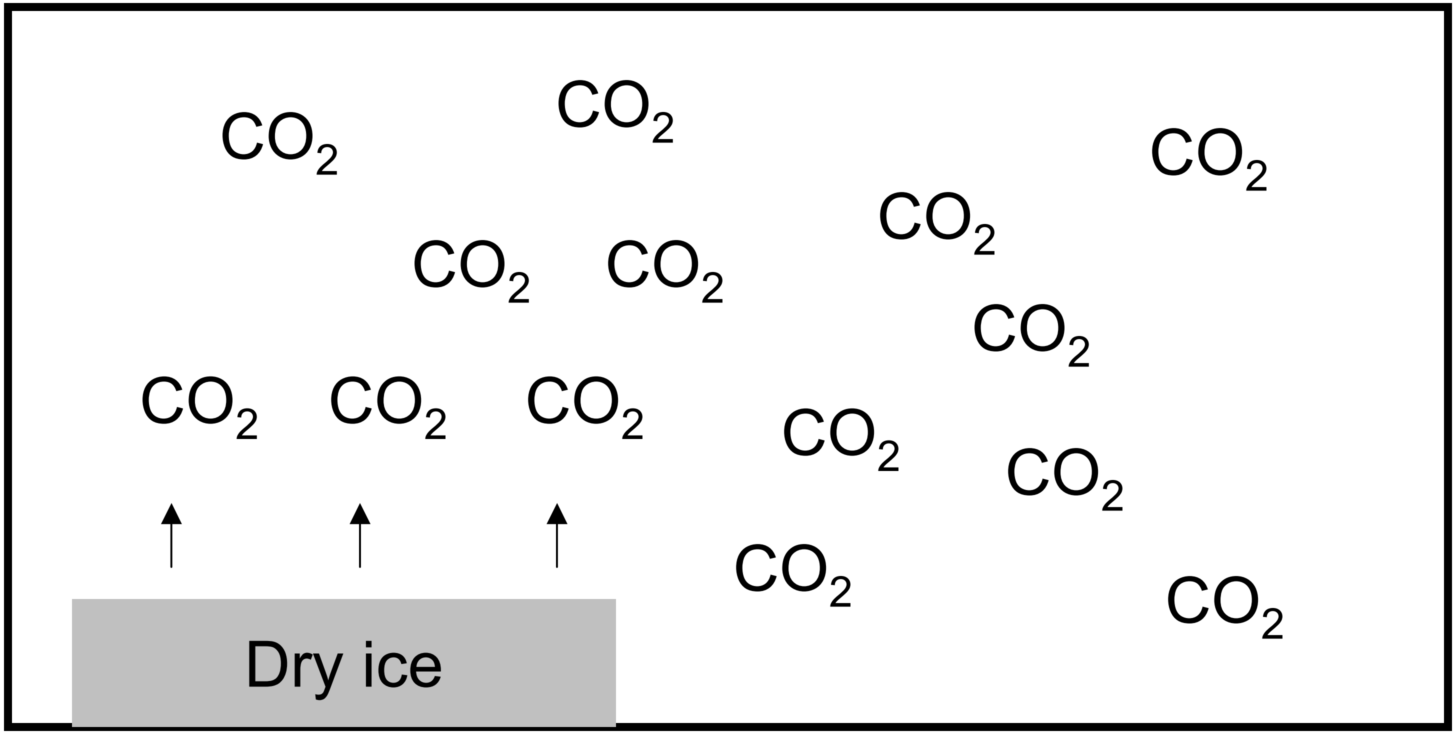
The density of a gas

Add a piece of dry ice to a terrarium.
CO_2 is released by "dry ice" as it sublimes.



The density of a gas

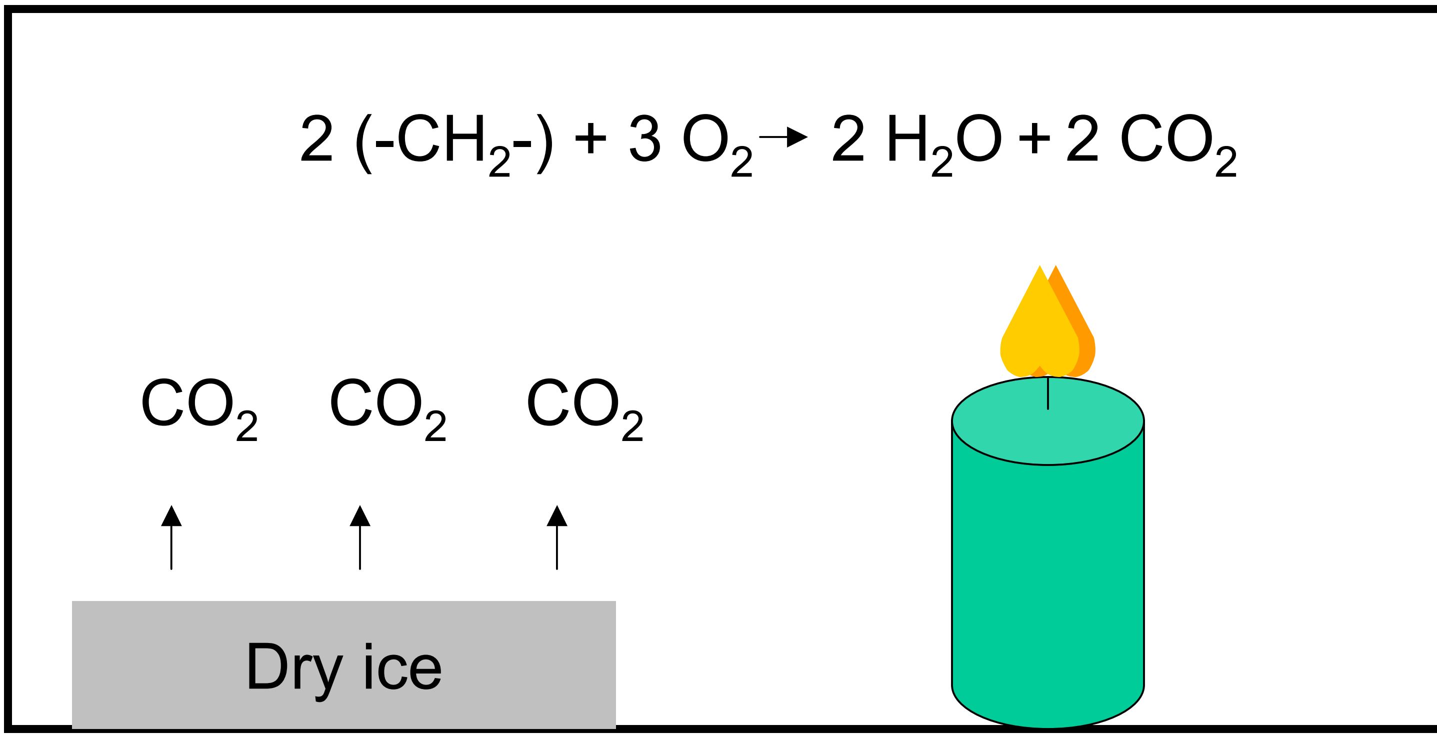
The mass of CO_2 is greater than that of O_2 or N_2
The CO_2 will stay in the terrarium until it fills it and overflows.



The density of a gas

To show this we use a candle. Burning is called combustion and it requires O_2.

$$2\,(\text{-}CH_2\text{-}) + 3\,O_2 \rightarrow 2\,H_2O + 2\,CO_2$$



The density of a gas

As the CO_2 sublimes and fills the terrarium
It displaces the oxygen.

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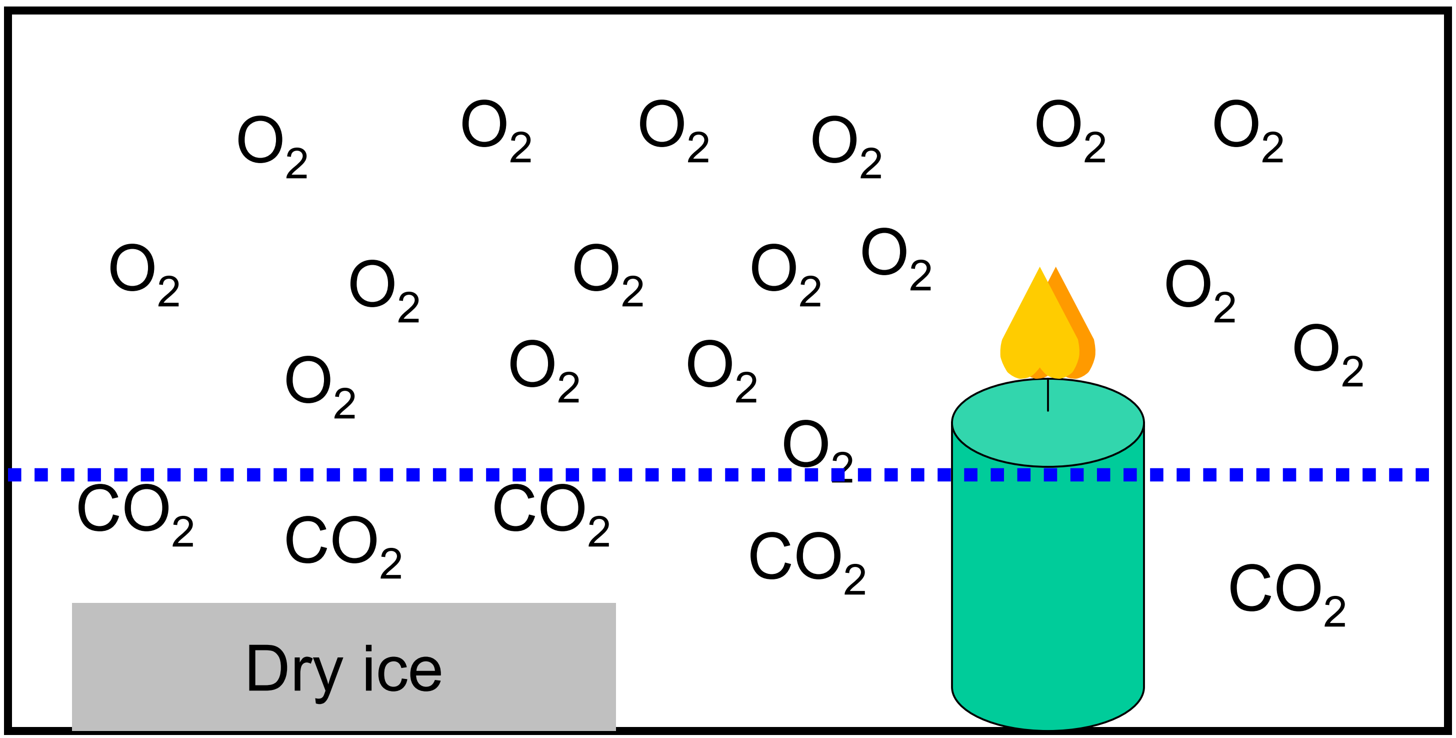
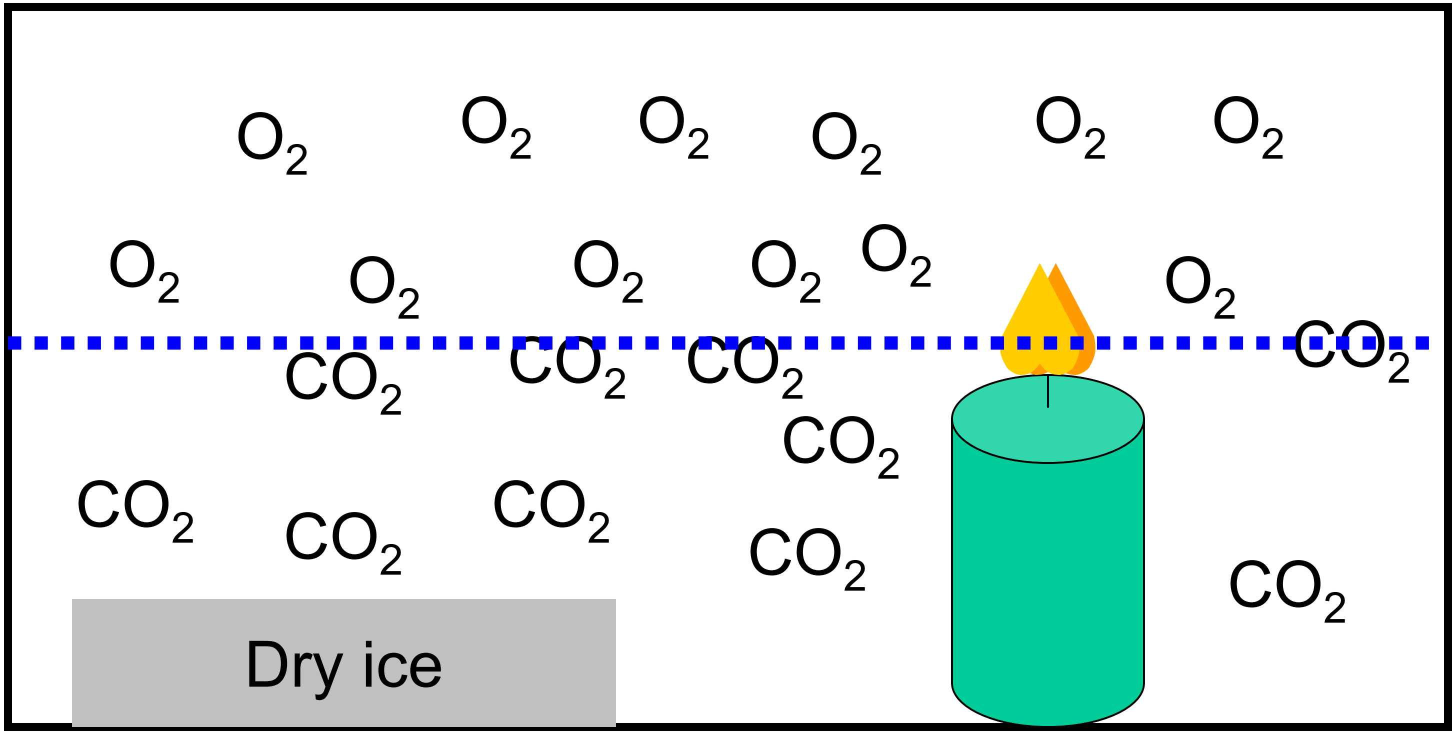


The density of a gas

As the CO_2 sublimes and fills the terrarium
It displaces the oxygen.

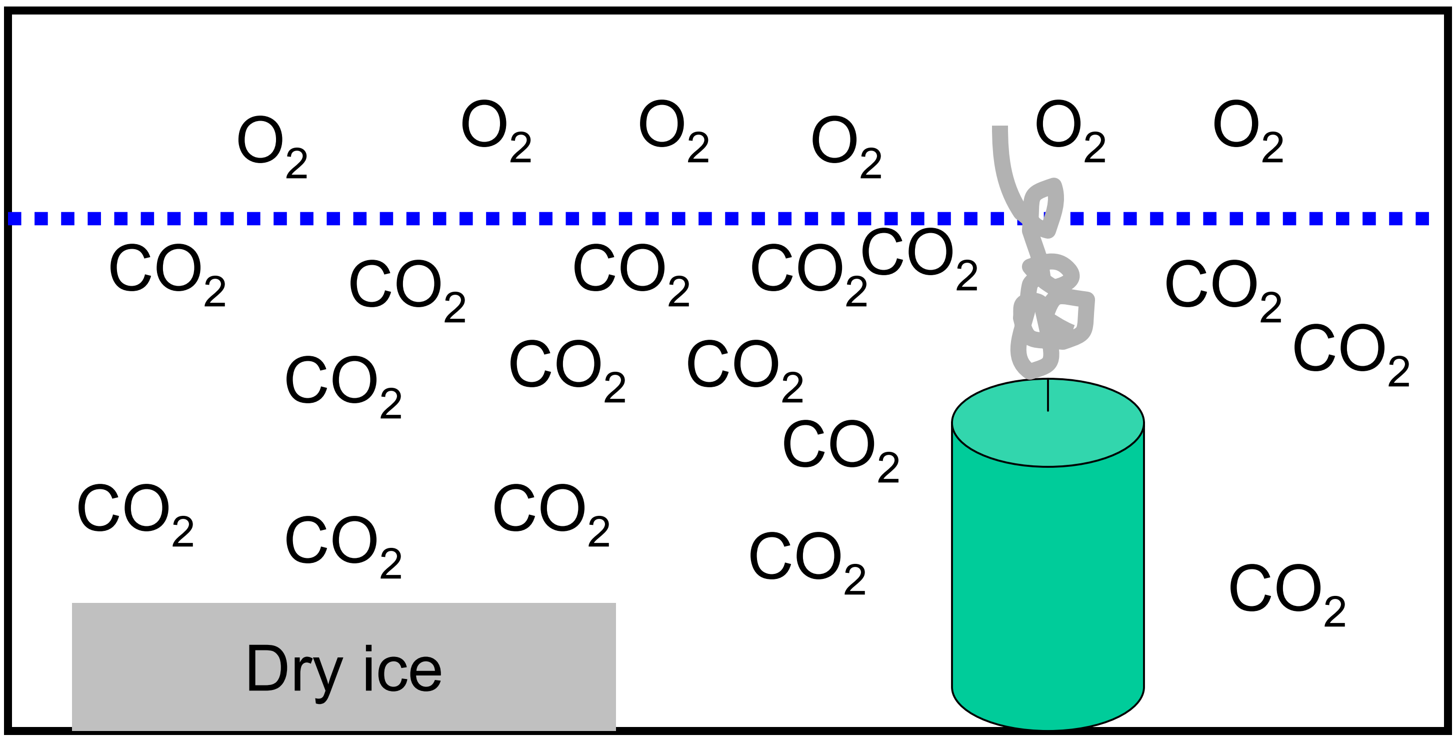
$$2\,(\text{-}CH_2\text{-}) + 3\,O_2 \rightarrow 2\,H_2O + 2\,CO_2$$



The density of a gas

As the CO_2 sublimes and fills the terrarium
It displaces the oxygen.

2 (-CH_2-) + ~~3 O_2~~ → 2 H_2O + 2 CO_2



The density of an solid

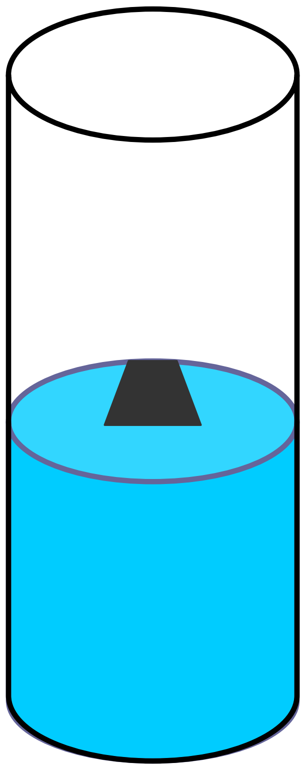
Density = Mass / Volume

$\rho = m / V$

The density of water is 1 gram / cm^3

An object that is less dense than water will float.

$\rho < 1\ gm / cm^3$



The density of an solid

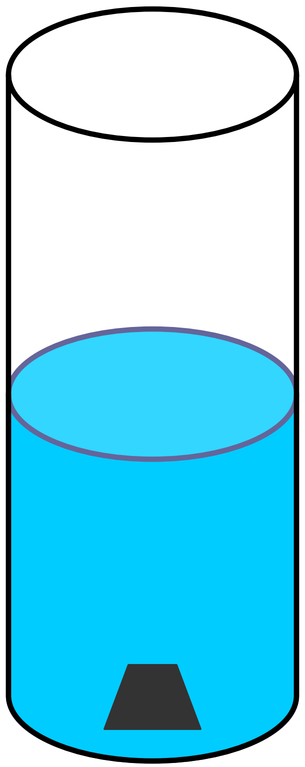
Density = Mass / Volume

$\rho = m / V$

The density of water is 1 gram / cm^3

An object that is more dense than water will sink.

$\rho > 1$ gm / cm^3



The density of an solid

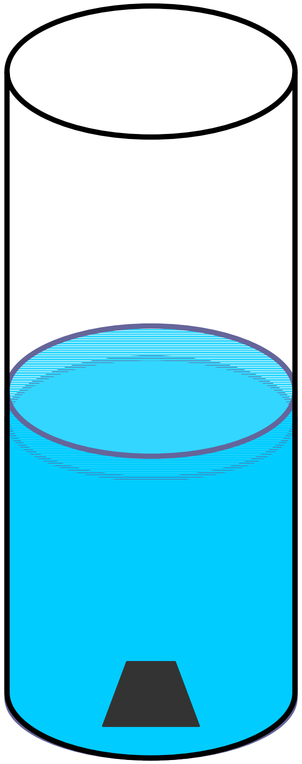
Density = Mass / Volume

$\rho = m / V$

Notice that the water will rise (be displaced) and the displaced volume Is equal to the volume of the solid.

We can use the displaced volume to measure the volume of an irregular solid.

Archimedes measured the king's crown in ancient Greece using this method.

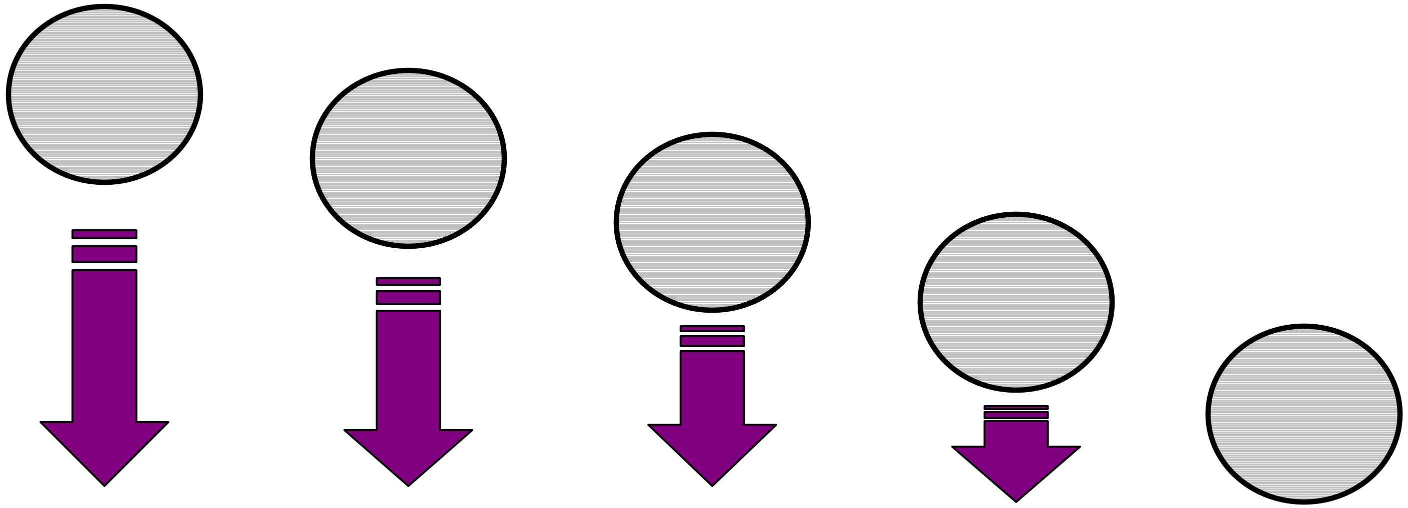


The density of a bubble

Density = Mass / Volume

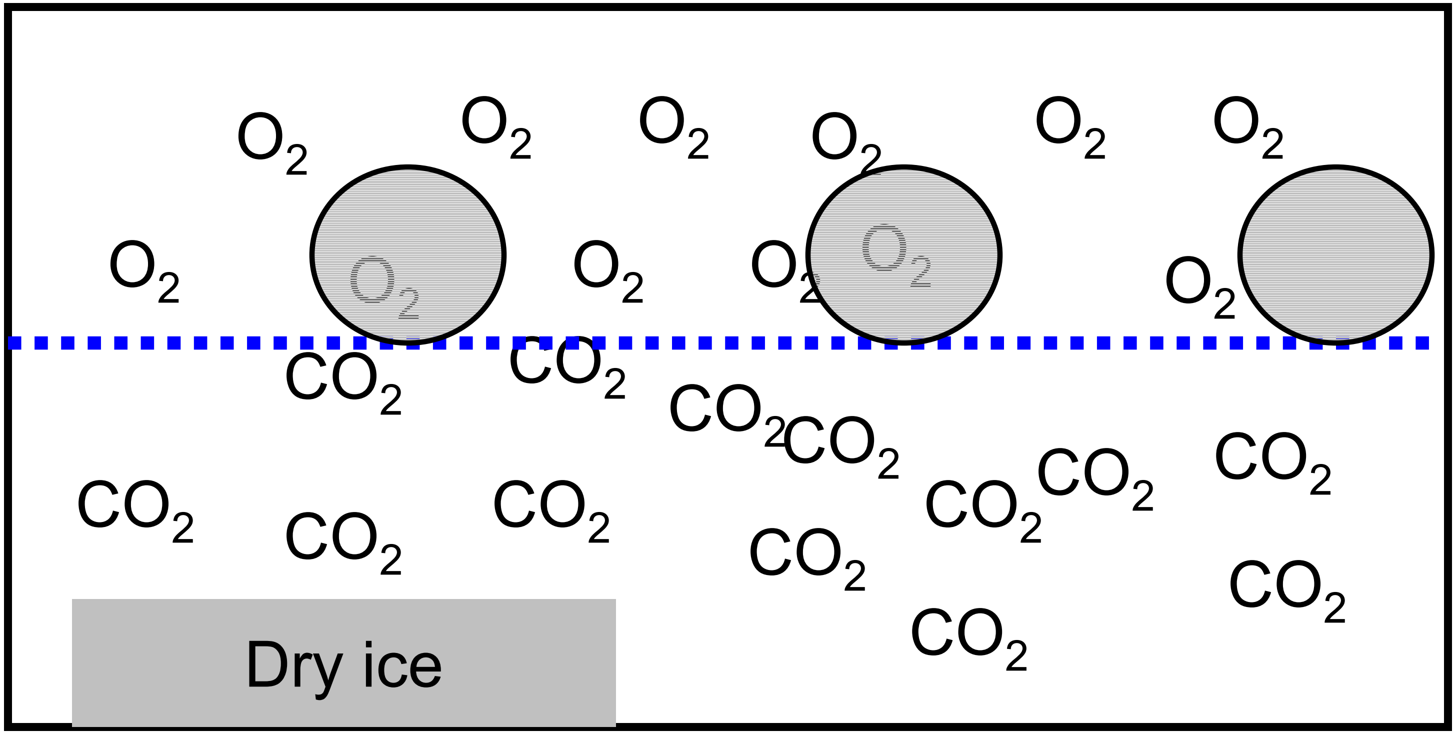
$$\rho = m / V$$

The density of a bubble is equal to the total mass (including the air and the soap film) divided by the volume. Because of the soap bubbles are more dense than air.



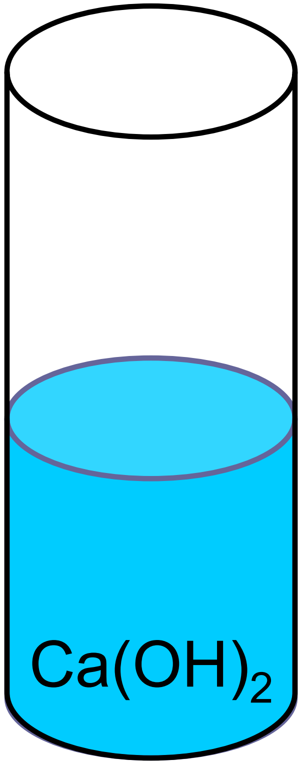
The density of a gas

However, a soap bubble will float on CO_2.



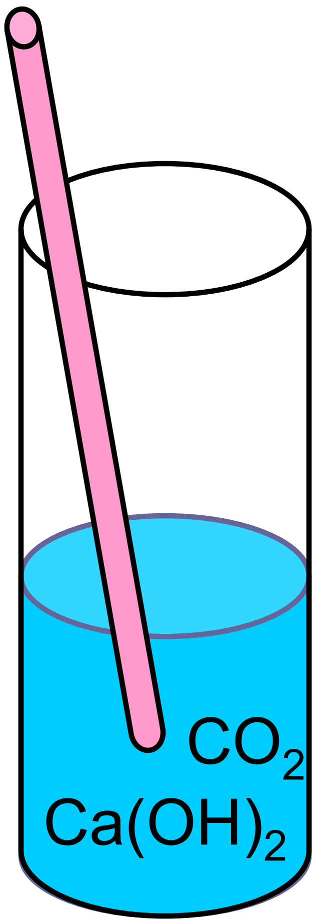
Forming limestone: a chemical change

If we start with lime water (calcium hydroxide)



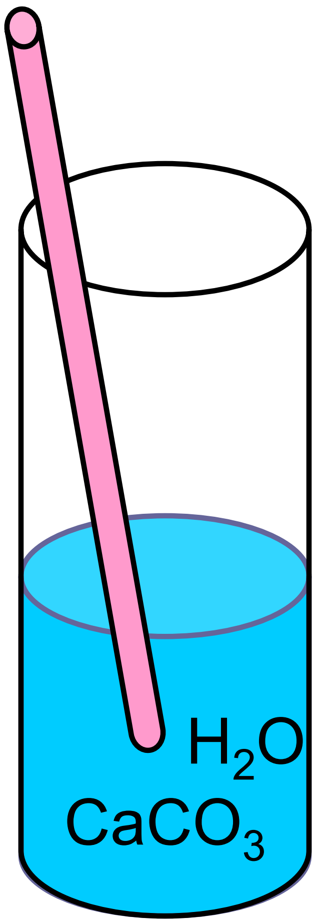
Forming limestone: a chemical change

and we add carbon dioxide….



Forming limestone: a chemical change

there is a reaction to form calcium carbonate.



$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

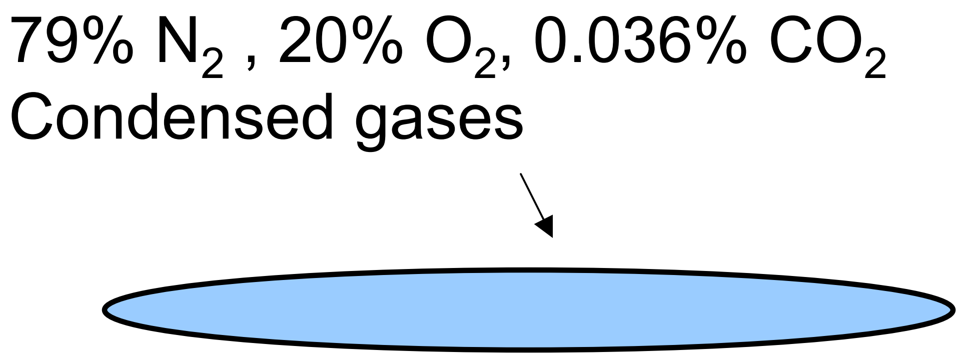
Condensing the atmosphere

Inflate a balloon. The gas in the balloon is mixture of nitrogen, oxygen, and carbon dioxide.

79% N_2 , 20% O_2, 0.036% CO_2

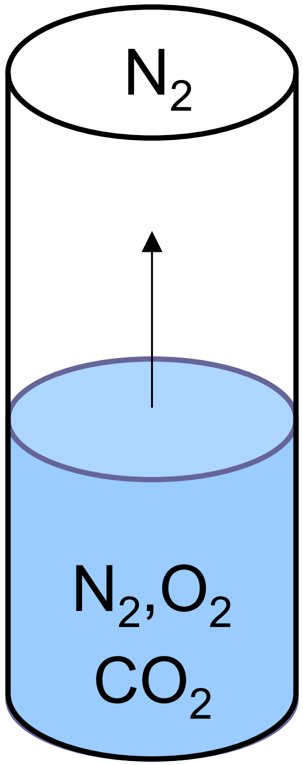
Condensing the atmosphere

Place the balloon in contact with liquid nitrogen. The carbon dioxide and oxygen will condense. The nitrogen will dissolve in the oxygen. The balloon will shrink.



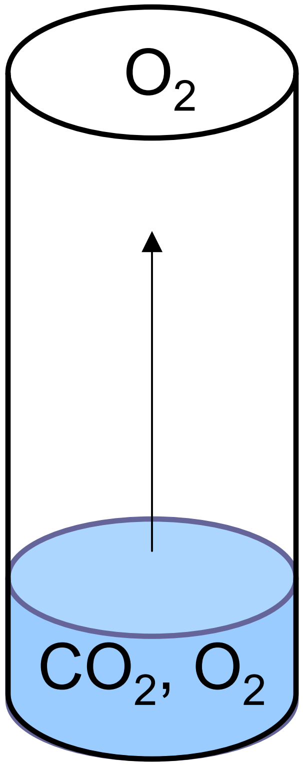
Separating the gases in the atmosphere

If we carefully pour the liquid air into a (very cold!) test tube it will slowly begin to vaporize. Nitrogen is the most volatile. It has the lowest boiling point.



Separating the gases in the atmosphere

Oxygen will start to vaporize once the nitrogen has all gone.



Separating the gases in the atmosphere

Finally only CO_2 is left.