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### Egg in the Bottle

- Air inside expanded; egg traps that air in there
- Air inside cools & decreases pressure in the bottle
- Air molecules inside and outside are pushing on the egg
- Pressure on the inside is lower than the outside, so egg is pushed into bottle
- Gravity is not involved in pulling egg into the bottle
  - Proof: tried it upside down
- Need higher pressure outside bottle than inside
  - Blow air into bottle
  - Heat bottle up

### Chapter 12: Intermolecular Forces and Liquids

#### Ideal Gases

- Last semester, treated all gases as ideal gases
- Assumptions/Characteristics
  - No intermolecular forces (molecules are so far apart, there's no interactions)
  - Gas molecules had no volume (not true)
  - Elastic collisions with other molecules (no loss of energy)
- 22.4 L gas vs. 18 mL liquid water
- Most all gases behave as ideal gases in standard situations
  - Exceptions: extreme situation

#### Gases, Liquid, Solids

- What's changing as a gas condenses into a liquid and then freezes into a solid?

	Gas	Liquid	Solid
Volume	Fill container	Fixed volume	Fixed volume
Shape	Assume shape of bottle	Assumed shape of bottle	Fixed shape
Motion	Vibrational Translational Rotational	Vibrational Translational Rotational	Rotational (very small) Vibrational

- Glass is thicker at the bottom than it is at the top
  - When glass is flattened out, the edges are thick
  - Panes are cut and installed thick-side down
  - Glass is a solid, not a liquid (no translational movement)
- Solid: not enough energy to overcome intermolecular forces
- Liquid: more energy through heat to overcome intermolecular forces
- Gas: even more energy to overcome intermolecular forces enough to get so far away that the forces have no more effect on molecules
- Stronger intermolecular forces, something will melt at a higher temperature

Clicker: Intermolecular attractions are electrostatic in nature. The magnitude (strength) of these interactions is dependent on

**A** The amount of charge on the particles

B The mass of the particles

**C** The size of the particles

D The density of the particles

E The kinetic energy of the particles

- Strength is dependent on the amount of charge (product of that charge)
- Size is a factor as well because the smaller the ion is, the closer the ions can get to each other
- Density and kinetic energy are not factors on the strength
  - Increased energy does not affect the strength of intermolecular forces
  - Increased energy only helps to overcome the intermolecular forces
- The larger the atom is, the easier it is to lose track of electrons
- The smaller the atom is, the harder it is to lose track of electrons
- Mass doesn't affect strength; only size is important

#### Intermolecular Forces

- Ions have full charges; polar molecules have a dipole (positive & negative end); nonpolar molecules (no charge)
- Ion-Ion (CH. 13)
  - Easy to see
  - Positive with negative
  - Obviously stronger than dipole-dipole
- Ion-Dipole
- Dipole-Dipole
  - Molecule that is polar
  - One side is negative & other is positive
  - Partial charges (vs ion's full charges)
- Hydrogen Bonds
  - Special case of dipole-dipole
  - H attached to very electronegative element
  - H-bond with another electronegative element on a neighboring molecule
  - Water (partial negative on oxygen & partial positive on hydrogen)
    - Hydrogen bond between O & H
  - Stronger than dipole-dipole interactions
- Dipole-Induced Dipole
- Induced Dipole-Induced Dipole
  - London forces = induced dipole (temporary)
  - Ex: large atom with large electron cloud
    - Nucleus moves faster than the electron cloud can adjust
    - Nucleus is closer to one side of the atom than the other for a moment
    - For that moment, there is a dipole

- o Even weaker than a dipole-dipole
- o Everything exhibits these London forces b/c everything can be deformed out of it's normal state
  - Ions, polar molecules, etc.

Clicker: Which of the following compounds would be expected to form intermolecular hydrogen bonds in the liquid state?

A-CH<sub>3</sub>OCH<sub>3</sub>    B-CH<sub>4</sub>    C HF    D CH<sub>3</sub>CO<sub>2</sub>H    E Br<sub>2</sub>    F CH<sub>3</sub>OH

- Dimethyl ether (polar): H has to be bound to O, F, or N (very electronegative elements)
- HF: H is bound to F & can bind to a neighboring F
- CH<sub>3</sub>CO<sub>2</sub>H: H is connected to an O
- Br<sub>2</sub>: no H is even present
- CH<sub>3</sub>OH: looks like water; not as strong but still has an H bond

Clicker: Rank the following atoms or molecules in order of increasing strength of intermolecular forces in the pure substance.

A CO<sub>2</sub>    B NH<sub>3</sub>    C CHCl<sub>3</sub>    D CCl<sub>4</sub>    ADCB

- CO<sub>2</sub>: Induced dipole
- NH<sub>3</sub>: Hydrogen bonding
- CHCl<sub>3</sub>: polar (dipole-dipole)
- CCl<sub>4</sub>: induced dipole
- Induced dipole depends on size (polarize ability) of molecules
  - o CCl<sub>4</sub> is larger than CO<sub>2</sub>
  - o So it will be stronger