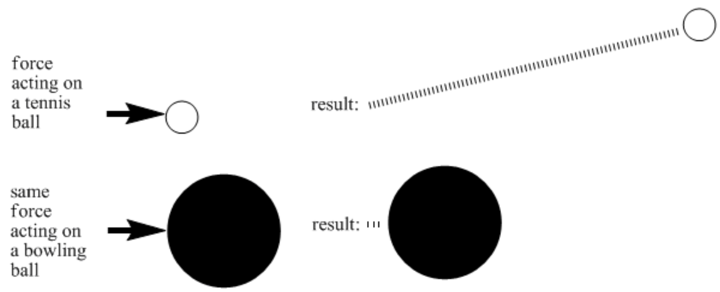
7.3: Kinetic-molecular Theory

Temperature is an indicator of how much energy is available in the surroundings. The higher the temperature, the more energy there is available, and the faster molecules can go. Different kinds of matter require different amounts of energy to get moving. That's why some compounds are gases at room temperature while others are solids.

There are many reasons for these differences. One factor is the mass of a molecule. If you hit a tennis ball with a tennis racket, you can be sure that it will sail through the air, but the same thing might not be true if you hit a bowling ball with a tennis racket. By putting an equal amount of energy into a tennis ball and a bowling ball, you would make the tennis ball move much faster than the bowling ball. Lighter objects need less energy to reach high speeds.



For a molecular example, let's look at halogens. All the elemental halogens are simple diatomic molecules. Their chemical properties have many similarities, but they have very different boiling points and melting points. Iodine, with the greatest mass, is a solid at room temperature, while fluorine has the lowest mass and is a gas at pretty much all the temperatures you are likely to encounter on Earth.

Name & formula	**MW, g/mol**	**mp, ° C**	**bp, ° C**
fluorine, F_2	**38.0**	**-219.6**	**-188.4**
chlorine, Cl_2	**70.9**	**-100.98**	**-34.6**
bromine, Br_2	**159.8**	**-7.2**	**58.8**
iodine, I_2	**253.8**	**113.5**	**184.3**

Clearly the mass of a molecules influences its state. Does the mass of a molecule alone allow us to predict its behavior? No. A much more important factor involves another difference between gases, liquids and solids: attraction between molecules. The molecules in solids are not just sitting still; they are sitting still *together*. Getting a crystal of iodine to evaporate requires coaxing molecules away from each other, and overcoming this attraction between them.

There are many different types of intermolecular attractions. The halogens in the table above cling to each other via the weakest type: London dispersion interactions. We will start by looking at those interactions, and then move to stronger kinds, such as dipole interactions and hydrogen bonding.

Exercise 7.3.1

Based on the data in the table above, what would you predict for the melting point and boiling point of nitrogen, N_2, and oxygen, O_2?

Answer

As far as we can tell from these data, the melting point of nitrogen and oxygen would be somewhere around -220^oC, whereas the boiling point would be around -180^oC. We would expect these numbers to be similar to fluorine, which has a similar mass. In fact, the melting and boiling points of oxygen are about -219^oC and -183^oC, respectively. The melting and boiling points of nitrogen are about -210^oC and -196^oC, respectively.

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