CHEM1001 Worksheet 8: Ideal Gases and Molecular Shapes

Model 1: The Ideal Gas Law

The Ideal Gas Law explains the behaviour of an *ideal* gas with regards to the relationship between temperature, pressure and volume for a specific amount. It is *ideal* because the law neglects to include intermolecular interactions and molecular volumes, but it is still a very good approximation for most cases. The Ideal Gas Law is written as:

$$PV = nRT$$

P is the pressure, commonly in atmospheres (atm), V is the volume, commonly in litres (L), n is the number of moles (mol), T is the absolute temperature (K) and R is the gas constant which has a numerical value of 0.08206.

Critical thinking questions

1. By rearranging the ideal gas law, determine the units of R.

2. What does the ideal gas law predict will happen if a balloon is blown up and then taken outside on a hot day? (*Hint*: the pressure and the amount of gas stays the same but the temperature increases.)

3. If heat is applied to a sealed container of a gas, what happens to the pressure? Explain why this happens by considering what happens to the *molecules* in the gas when heat is added.

4. Why is the absolute temperature used in the ideal gas equation? Describe 2 situations where using a Celsius or Fahrenheit scale would give nonsense answers.

5. What does the equation tell you about the movement of the molecules of an ideal gas at absolute zero?

6. What volume will 2.0 mol of $O_2(g)$ occupy at 18 °C and a constant pressure of 1.0 atm?

7. What volume will 2.0 mol of $SF_6(g)$ occupy at 18 °C and a constant pressure of 1.0 atm?

Model 2: Changes in the properties of gases

When doing calculations involving a *change* in one or more of the properties of a gas we can simplify the calculations. For example, in Q2 in Model 1, a sealed balloon was initially (*i*) inside and was finally (*f*) outside. We thus have two equations:

Initially: $P_iV_i = n_iRT_i$
Finally: $P_fV_f = n_fRT_f$

As the balloon is sealed, $n_i = n_f$. Because the balloon is stretchy, $P_i = P_f$. So, with a little rearranging, we get:

$$\frac{V_f}{T_f} = \frac{nR}{P} = \frac{V_i}{T_i}$$

or

$$\frac{V_f}{V_i} = \frac{T_f}{T_i}$$

So we do not need to know or work out the value of *n* or *P* to calculate what the change in volume or temperature will be. You can easily perform similar rearrangement to work out other systems where some of the variables change and others are kept constant.

Critical thinking questions

1. If a balloon holds 4.2 L of gas in a room at 22 °C, what will its volume be if it is taken outside to a scorching 38 °C?

2. The valve is opened between a *full* 10 L tank at 3 atm and a completely *empty* 8 L tank. What will be the final pressure in the tanks?

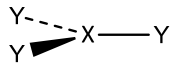
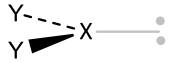
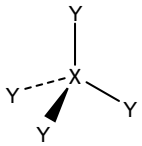
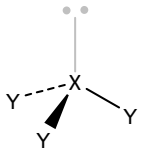
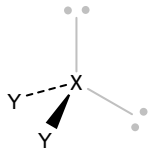
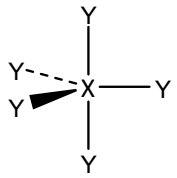
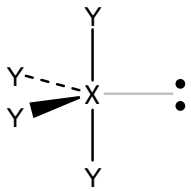
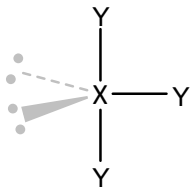
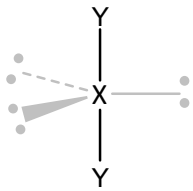
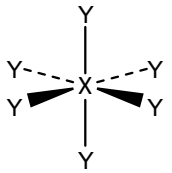
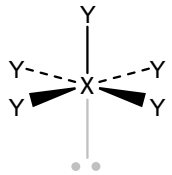
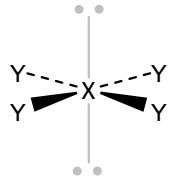
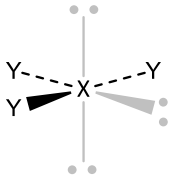
3. A sample of helium is held at constant temperature. It occupies 0.80 L of a cylinder with a piston controlled pressure of 1.5×10^5 Pa. If the external pressure on the piston is increased to 2.1×10^5 Pa, what will the new volume be? (*Hint*: a Pascal (Pa) is a different unit from pressure and 1 atm = 101.3 kPa – however you should *not* need to convert the pressure to atmospheres to answer this question.)

4. If the following reaction occurs in a closed, solid vessel that is held at constant temperature, by how much will the pressure change? (*Hint:* make sure you balance the reaction first!)

$$N_2(g) + \quad O_2(g) \rightarrow NO_2(g)$$

Model 3: Molecular Shape (Continuation from Worksheet 7)

The Lewis structures in the previous section provide information about how a molecule is 'put together' and how many bonding electrons and lone pairs they have. They do not provide information about the *shape* of the molecule. However, as shown in Worksheet once the Lewis structure is worked out, you can easily work out the shape. The **molecular shape** or **geometry** is the arrangement of the bonds. If lone pairs are present, they help to dictate what this arrangement is but are not included when the geometry of the molecule is described. The table below shows the geometries possible when the number of bond areas (n) and the number of lone pairs (m) is between 4 and 6.

$n + m$	$m = 0$	$m = 1$	$m = 2$	$m = 3$
3	 trigonal planar	 bent		
4	 tetrahedral	 trigonal pyramidal	 bent or V shaped	
5	 trigonal bipyramidal	 see-saw	 T-shaped	 Linear
6	 octahedral	 square-based pyramid	 square planar	 T-shaped

Critical thinking questions

1. By first drawing their Lewis structures, work out the shapes of the following molecules and ions.

   (a) PCl_3 (b) NO_2^- (c) SF_4

(d) ClF_3 (e) SiF_6^{2-} (f) NO_3^-

(g) XeF_4 (h) XeO_3 (i) BF_3

Covalent bonds between two different atoms are *polar*: the electrons are unequally shared leading to a small positive charge at one end and a small negative charge at the other end of the bond. In a molecule containing polar bonds, the molecule will itself be polar and will have a permanent dipole moment if these bonds are not symmetrically arranged around the central atom.

2. Which of the following molecules has a permanent dipole moment?

(a) BF_3 (b) ClF_3 (c) PCl_3

(d) CF_4 (e) SF_4 (f) XeF_4