On the gas laws

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Warm-up problems

1. Draw three diagrams to show the arrangement of particles in a solid, liquid and gas. Can you use these to explain why, whilst most solids have densities in the range 500 to $1000\,\mathrm{kg\,m^{-3}}$, gases in general are about 10^3 times less dense than this.

2. Write down the definition of *pressure*. For a gas, how does the force in the definition arise (draw a diagram to show this)?

3. The gas laws are relationships between pairs of the following quantities (whilst the others are held constant): mass of gas m, pressure P, temperature T and volume V. Make a list of all the different possible pairings from amoungst these quantities.

Regular problems

4. For the syringe below, containing a gas at the same pressure and temperature as the atmosphere outside (i.e. in equilibrium), draw two force diagrams for the casing of the syringe on its own and the piston on its own, to show that they are both in equlibrium.

5. If you were to take a volleyball scuba diving with you what would be its volume on your dive at a depth where the pressure is $3.9 \times 10^5\,\mathrm{Pa}$ if it started at the surface with a volume of $1.55\,\mathrm{l}$, under a pressure of $1.01 \times 10^5\,\mathrm{Pa}$? Assume that the temperature is constant with depth. **If its mass is $270\,\mathrm{g}$, what would be the force of upthrust on it at this depth?

6. A student takes the following readings of the diameter D of a balloon:

Conditions	T/°C	D/cm
Room temperature	13	18.3
Freezer	−5	17.6

Assuming that Charles' law is true, that the volume is proportional to the temperature, what temperature does the student's experiment predict that the volume will become zero? Can you identify a possible problem with the student's experiment?

7. You decide to go on a long hot air balloon ride, so you decide to bring some shampoo to wash your hair with. However there is some gas inside the shampoo bottle when you start to climb into the basket at the beginning of your journey. In fact, because you are a good scientist you decide to constantly take measurements of your surroundings. The shampoo bottle contains 435 ml of gas, under a pressure of 1.1 atm, at a temperature of 30 °C. When you climb high into the air the bottle starts to expand eventually exploding and covering you and your companions with shampoo. Eager to explain this phenomenon you take some measurements: the pressure, you note, has dropped to 0.73 atm and the temperature has dropped to 5 °C. To what volume did the gas inside the bottle expand?

8. Explain how a drinking straw works using the idea of pressure (use a diagram to aid your explanation). Is there a limit to the distance that water can be sucked up a straw (the vapour pressure of water is 2.3 kPa at 20 °C)?

Extension problems

9. The summit of Mount Everest can be at a temperature of −50 °C and the pressure at its summit is roughly one-third that at sea level. The density of air at sea level 1.25 $\mathrm{kg\,m^{-3}}$ at 20 °C. What is the density of air at the summit of Everest, and can you use this to explain why climbers use oxygen at high altitudes? Often an air-oxygen mix is used to conserve the precious and heavy oxygen: what proportions would you recommend so that each breath has the same amount of oxygen in as at sea level?

10. Charles' law states that the volume of a gas is proportional to temperature. How can it be that, when I pump my bicycle tyre up (and the volume decreases) the temperature goes up?