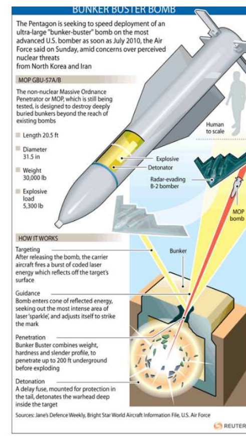
1 Cognitive reasoning in the chemical sciences 1.5

1. The following are six proportionality problems.

A bronze copy of the Statue of Liberty reduces its volume from its original volume of 4100 m^3 to 2 m^3. The original mass is 3 x 10^7 kg. Assuming this French copy has the same density as the original statue, what is the mass of the French copy?

Jardin du Luxembourg

To one significant figure, how much energy does the new bunker buster deliver?



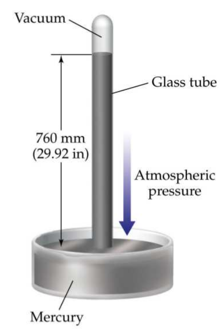
Robert runs a mile in 4.0 minutes. A mile is 1.6 kilometers. At the same speed, how fast does he run a kilometer?

Atmospheric pressure is the same pressure as the pressure under 760 mm of Hg.

This means a column of Hg 760 mm tall exerts one atmosphere of downward pressure.

The density of mercury is 13.5 g/mL. How tall does a column of water have to be to exert a downward pressure of 1.0 atmosphere?

The density of seawater is 1.03 g/mL. A submarine 300 m under the surface experiences what pressure from the water on top of it.



mass	velocity
200 grams	100 mph
50 grams	200 mph
5000 grams	20 mph

The numbers on the left give the maximum speed and typical mass of a baseball, a golfball, and a bowling ball.

Please suggest a proportionality law which accounts for the relation between ball mass and speed.

mass kg	heartbeat (hb) min^{-1}
0.8 kg	300 min^{-1}
60 kg	70 min^{-1}
20,000 kg	10 min^{-1}

The numbers on the left give the mass and heart-beat of a Guinea pig, a human (represented by Enrico Fermi), and a humpback whale.

Please suggest a an approximate proportionality law which accounts for the relation between heart-beat and mass.

2. Cows have nine times the mass of goats and move one-third as fast.

(a) Cows and goats share a fenced-in pasture with a small open gate to the outside. If the pasture initially consists of 50% cows and 50% goats, initially what percentage of the animals leaving the pasture are goats? What percentage are cows?

(b) The pasture is now twice as big as before, but the number of cows and goats in the pasture remains the same. Does the number of cows leaving the pasture change? If so, by how much? Does the ratio of cows and goats leaving the pasture change?

(c) If the pasture initially consists of 75% cows and 25% goats, initially what percentage of the animals leaving the pasture are goats? What percentage are cows?

(d) It's a hot day. Cows are moving 25% faster but goats are moving 50% faster. If the pasture initially consists of 75% cows and 25% goats, initially what percentage of the animals leaving the pasture are goats? What percentage are cows?

(e) There are two equal-sized pastures, both fenced-in. There is a small gate which connects the two pastures. The first pasture contains only cows, while the second contains only goats. Initially, there are two times as many cows in the first pasture as there are goats in the second pasture. If after a short time the first pasture contains 97% cows and 3% goats, at this instant in time, to three significant figures, what is the ratio of the total number of animals in the first pasture compared to the total number of animals in the second pasture?

3. Inert gases do not interact with one another, except in that they reach the same common temperature. Therefore two inert gases in the same flask obey the common equation $pV = (n_1 + n_2)RT$, where n_1 and n_2 are the number of moles respectively of gas molecules types 1 and 2. We can also introduce, if needed, the concept of partial pressure, where $p_1V = n_1RT$ and $p_2V = n_2RT$. With these definitions $p = p_1 + p_2$.

Please now solve the questions below:

1) The atmosphere of the moon *Oberon* is a mixture of only carbon dioxide and helium. It has a an atmospheric pressure of 1.4 atm. A sample of Oberon's atmosphere is collected in a sealed balloon. The balloon has elastic walls. This balloon is brought back to Earth, and brought to conditions of STP. When the balloon is chilled to -100 °C but is left otherwise on a laboratory bench, the carbon dioxide becomes entirely solid while the helium remains entirely gaseous, it is found that the balloon volume has contracted to 0.3 times its initial laboratory volume.

Assume the volume of solid carbon dioxide is negligible. Assume all gases obey the ideal gas law. On Oberon, what is the CO_2 partial pressure?

2) The atmosphere of the moon *Ariel* consists entirely of H_2 and O_2. The Ariel atmosphere is 2.0 atm. A sample of Oberon's atmosphere is collected in a sealed balloon. The balloon has elastic but extremely strong walls. This balloon is brought back to Earth, and brought to conditions of STP. A spark is set off, igniting the H_2 and O_2 converting as much H_2 and O_2 as possible to H_2O. The balloon heats up to 110 °C but it does not break and its volume, although it could have changed, stays constant! Assume all gases obey the ideal gas law. On Ariel, what is a possible O_2 partial pressure?

3) A 2L flask is opened and then closed on the planet *Titania*. Titania has a temperature of 250 K. The only gases in the atmosphere are He and N_2. This sealed flask is then brought to the Earth. At 0 °C, the pressure in the flask is measured at 1.4 atm. The density is measured at 0.8 g/L. What is the partial pressure of He on Titania?

4) Two sealed flasks are connected to one another by an initially closed thin tubing of negligible volume. The first flask is 2L big and contains 0.1 mole He at 300K. The second flask is 6L big at 200K and contains 0.2 mole Xe. The tubing is opened allowing the two gases to mix with one another. Assume that no energy is gained or lost from contact with either the walls of the flasks or the walls of the tubing. What is the final Xe partial pressure and what is v_{rms} of the Xe atoms?