Kinetic Theory with Algebra

Suppose that the box contains N molecules (N in the whole box, not N molecules in each cubic meter as in some texts). Suppose that the box has length a meters and ends of dimensions b meters by c meters.

In the course of their random motion with many collision the molecules will exchange momentum, p, and will not all keep the same velocity. However, if the temperature is kept constant, we believe their velocities will range around a fixed average velocity, which we call v meters/sec. To calculate the pressure on one end of the box we deal only with molecular impacts on that end. So to simplify the problem we pretend that the N molecules are regimented in three equal groups, one lot moving up-and-down, one lot to-and-fro across the width, and one lot moving forwards-and-backwards along the length. For the pressure on one end we then consider the last lot only. Symmetry-considerations suggest we should imagine the molecules equally divided among the three groups. Making these assumptions, answer the questions below, using m kilograms for the mass of one molecule.

(i) When one molecule hits the front end head-on and rebounds, its change of momentum is .... ______________.

(ii) Between successive impacts on the *front end* a molecule travels to the other end and back: a total distance ______________meters.

(iii) In a total time t seconds, a molecule moving with velocity v meters/sec travels a total distance .... ______________.

(iv) $\therefore$ in t seconds, a molecule can make ______________ round trips and so can make this number of impacts on the front end.

(v) $\therefore$ in t seconds, a molecule makes ______________ impacts on the front end of box, suffering at each impact a change of momentum

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(vi) $\therefore$ total change in momentum, due to impacts of *one* molecule, suffered by front end in t seconds is .... ______________.

(vii) But there are N molecules in the box, of which ______________are in the group moving forward and backward between the ends.
$\therefore$ the total change of momentum, due to impacts of all molecules concerned, suffered by the front end in t seconds is ______________

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(viii) But, $Ft = \Delta p$ $\therefore F = \Delta p/t$
and in this case the average *Force*, during their period of t seconds, on the front end of the box is[1] ....______________.

(ix) $P = F/A$, and the area of the end face is ______________.
$\therefore$ average *Pressure* on the end of the box is ______________.

(x) The volume of the box is ....______________m^3.
$\therefore$ the product ....$PV =$ ______________.
But m is the mass of one molecule, and there are N molecules, so the *total mass of gas* in the box M kg = ______________kg.
Substituting M into the algebra above, we have

$PV =$ ____________________________

(xi) Providing we use a closed box or other apparatus allowing no leakage of gas, then M is constant. Suppose we keep temperature constant; then other experiments in physics suggest that the average velocity v remains constant. Then in this case when the volume is changed the result of (x) above suggests that ....______________

(xii) If we measure the *volume* of a sample of gas, say in a globe, and find its mass (by weighing the globe full of gas and then evacuated), and measure the *pressure* of the sample with a barometer, then the result of (x) above enables us to calculate a very important piece of information, the value of ______________, which is the ______________ of the molecules.

(xiii) UNITS TO BE USED. In making the calculation of (xii) above if the volume is in m^3 the mass should be in ......______________
and the pressure should be in ....______________

(xiv) We have already derived two useful things from our molecular theory, a behavior-suggestion in (xi) and a very interesting measurement in (xii), and more results will emerge; but we must pay for them by the assumptions that go into the machine. *List on a separate sheet as many assumptions as you can*, (a) of general physical laws assumed to apply to molecules, (b) of special properties, of behavior, size, etc., assumed for molecules.

[1] Here, t is the time during which the average force would have to act to produce this momentum-change. Therefore t IS the time t seconds for which we have calculated the total momentum-change.