Some practice with the ideal gas law

In an ideal gas, pressure p, volume V and temperature T in Kelvin satisfy the *Ideal Gas Law.* We give this law below in three different forms:

$$pV = Nk_BT \quad (1)$$

$$pV = nRT \quad (2)$$

$$pV = \frac{m}{M_{mol}}RT \quad (3)$$

In the first line, N is the number of particles that make up the quantity of gas and $k_B \approx 1.38 \times 10^{-23}$ is Boltzmann's constant.
In the second line, n is the number of mol of gas and $R \approx 8.31\, J/(Kmol)$ is the gas constant.
In the third line, m is the mass of the quantity of gas and M_{mol} is the mass of one mol of gas.
The number of particles in one mol of gas is Avogadro's number $N_A \approx 6.0221 \times 10^{23}$.
For dry air, we have, $M_{mol} \approx 29\, g/mol$.

a. Check that the three forms of the ideal gas law given above are all equivalent to each other.

b. If we keep the temperature and the amount of gas constant, what happens to the volume if we increase the pressure by a factor α, that is $p \to \alpha p$? Why can we not expect this behavior to be true for arbitrarily large α in a real gas?

c. If we keep the temperature and the volume of gas constant, what happens to the pressure if we increase the amount of gas by a factor α, that is $m \to \alpha m$? Why can we not expect this behavior to be true for arbitrarily large α in a real gas?

d. If we keep the volume and the amount of gas constant, what happens to the pressure if we increase the temperature from $100\, K$ to $200\, K$?

e. If we keep the volume and the amount of gas constant, what happens to the pressure if we increase the temperature from $100°C$ to $200°C$?

f. Sketch a graph of p as a function of V for 1 mol of an ideal gas. Do this for number of different temperatures

g. Derive a formula for the density ρ of the gas from the ideal gas law. Use this to calculate the density of dry air at a temperature of $20°C$ and at atmospheric pressure (approximately 100 kPa).

h. An oven contains 20 Litres of air (assumed to be an ideal gas). It can communicate freely with the surrounding air, which is at atmospheric pressure. The oven is heated from $20°C$ to $200°C$. What is the mass of the air that leaves the oven in this process? Assuming that all the air outside the oven (including tha air that came from the oven) has a temperature of $20°C$, what is the volume of the displaced air?