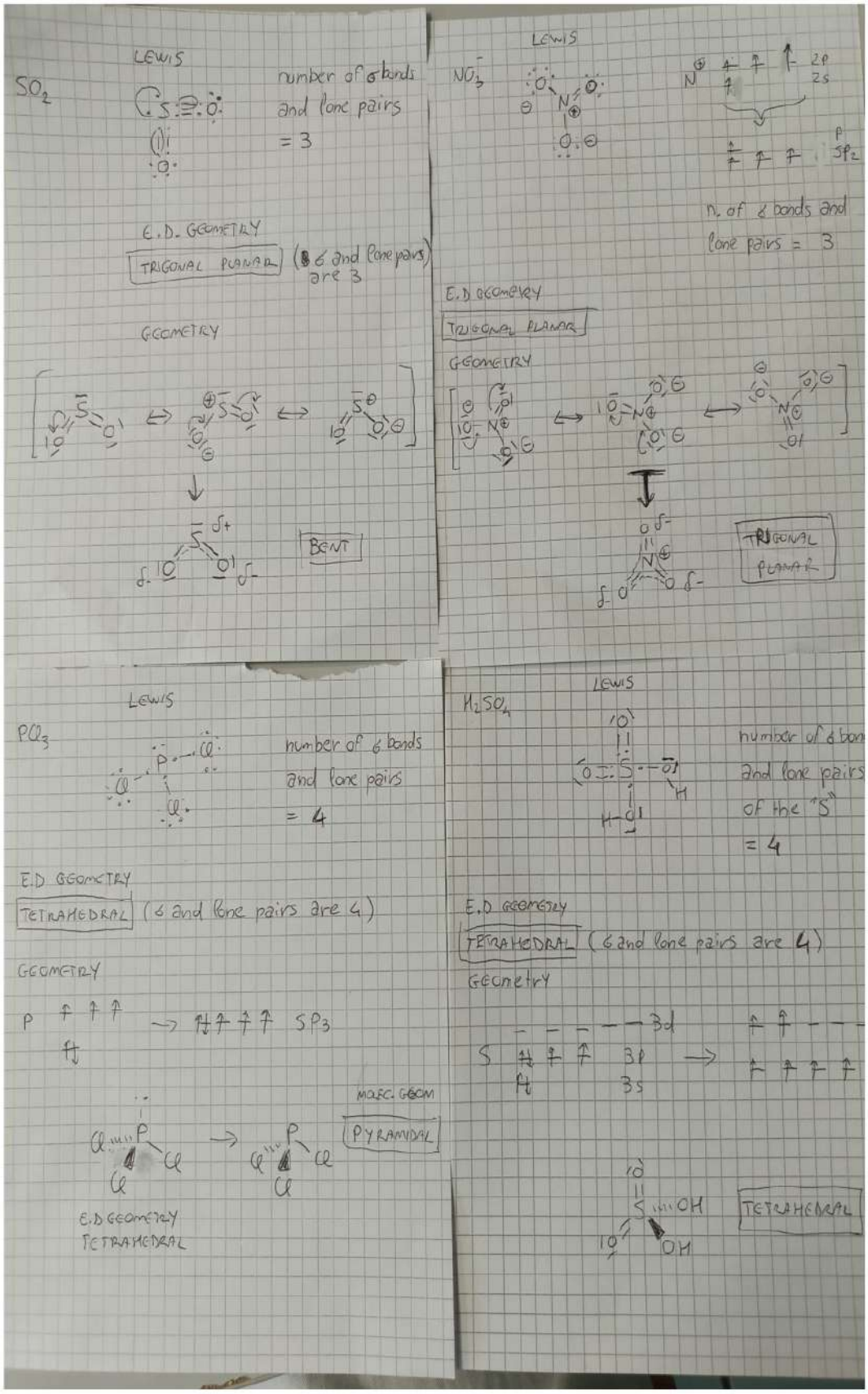
Exercise 1 – Lewis Structures and Molecular Geometry

For each of the following chemical species:

1. Draw the Lewis structure, showing all bonding and non-bonding electron pairs.
2. Identify the central atom.
3. Determine the electron-domain geometry and the molecular geometry according to the VSEPR theory.

Chemical species:

a. SO_2 (sulfur dioxide)
b. NO_3^- (nitrate ion)
c. PCl_3 (phosphorus trichloride)
d. H_2SO_4 (sulfuric acid)

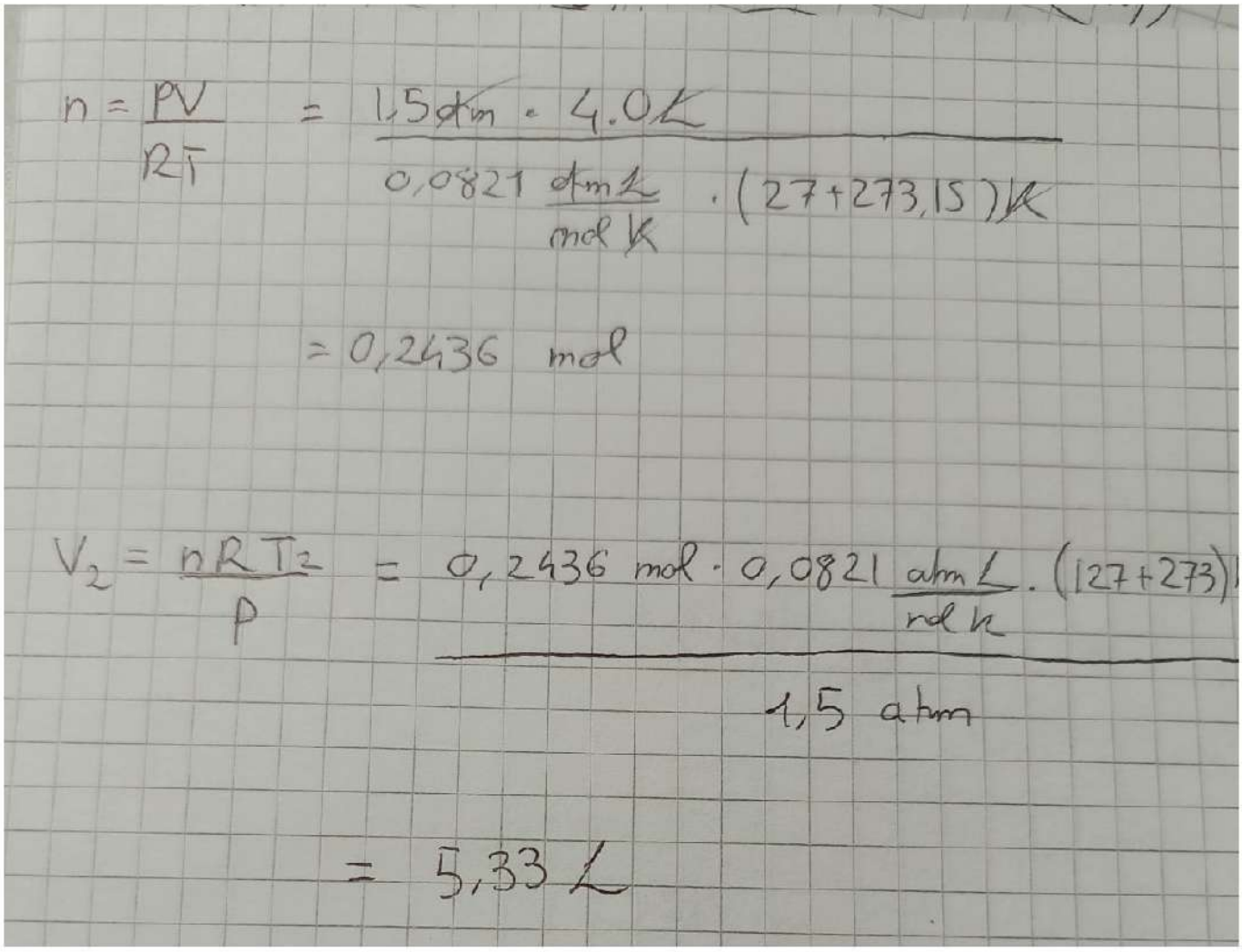


Exercise 2 – Gas Laws

A sample of an ideal gas occupies a volume of 4.0 L at a temperature of 27 °C and a pressure of 1.5 atm.

1. Calculate the volume occupied by the gas when the temperature increases to 127 °C, keeping the pressure constant.
2. Calculate the number of moles of gas under the initial conditions.

Given: R = 0.0821 L atm mol^{-1} K^{-1}.
Assume that the gas behaves ideally.



Exercise 3 – Chemical Equilibrium

A solution is prepared by dissolving 6.0 g of acetic acid (CH_3COOH), 0.82 g of sodium acetate (CH_3COONa) and 0.0365 g of hydrochloric acid (HCl) in water. The final volume of the solution is 1.0 L.

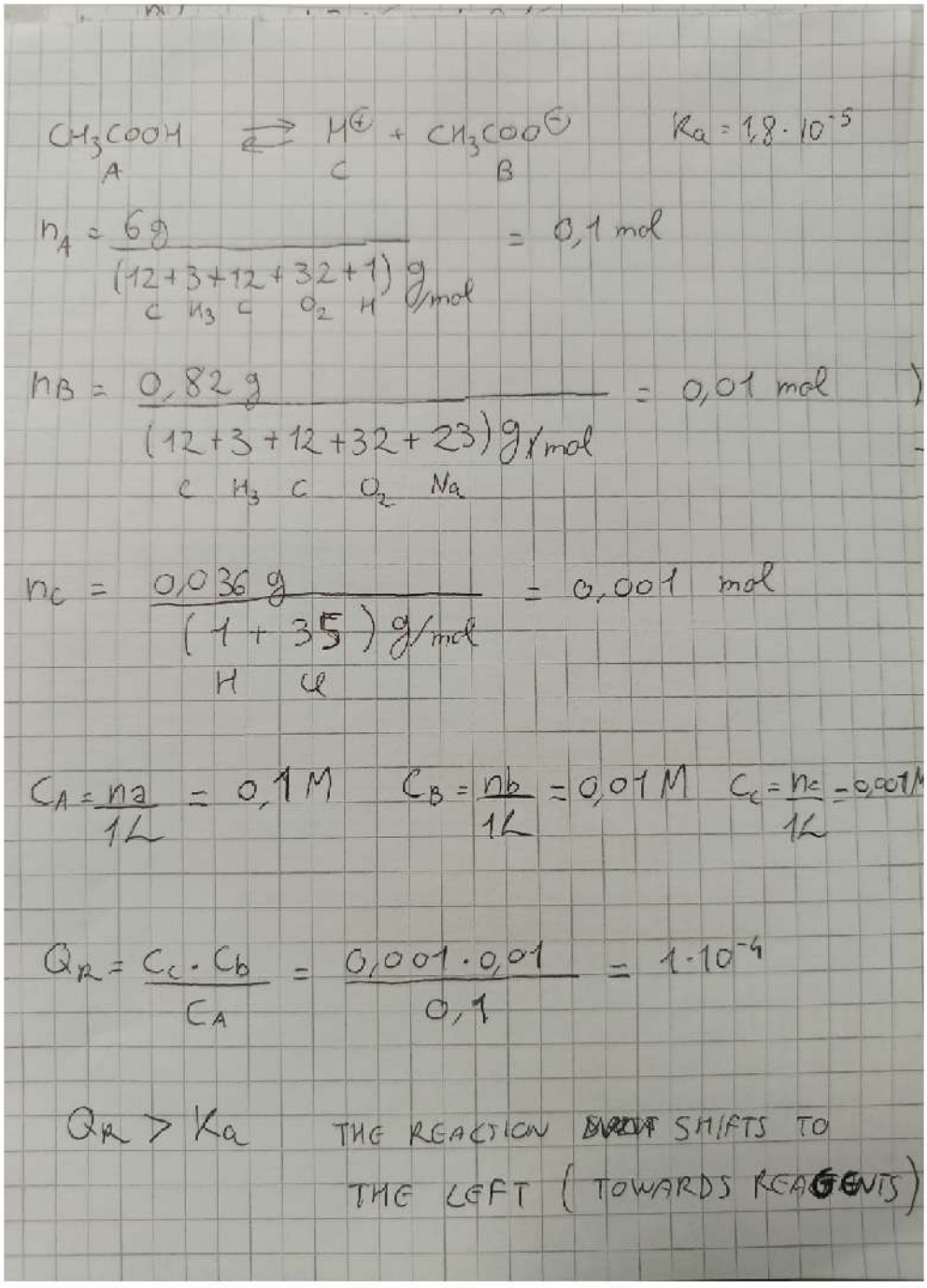
Acetic acid dissociates according to the following equilibrium:

$CH_3COOH(aq) \blacksquare H^+(aq) + CH_3COO^-(aq)$

At the given temperature, the equilibrium constant is $K_a = 1.8 \times 10^{-5}$.

Calculate the reaction quotient, Q_c, using the initial concentrations, and determine whether the reaction will proceed towards the products or towards the reactants to reach equilibrium.

Assume that hydrochloric acid and sodium acetate dissociate completely in water.



Exercise 4 – Thermodynamics: Hess's Law and Gibbs Free Energy

Calculate the standard Gibbs free energy change (ΔG°) for the following reaction:

$2C(s) + 3H_2(g) + O_2(g) \rightarrow C_2H_2(g) + 2H_2O(l)$

Known reactions:

Reaction 1

$C_2H_2(g) + 5/2\ O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$

$\Delta G^\circ_1 = -1235$ kJ/mol

Reaction 2

$C(s) + O_2(g) \rightarrow CO_2(g)$

$\Delta G^\circ_2 = -394$ kJ/mol

Reaction 3

$H_2(g) + 1/2\ O_2(g) \rightarrow H_2O(l)$

$\Delta G^\circ_3 = -237$ kJ/mol

Tasks:

1. Combine the three reactions appropriately to obtain the overall reaction.
2. Calculate the corresponding ΔG° using Hess's law.

