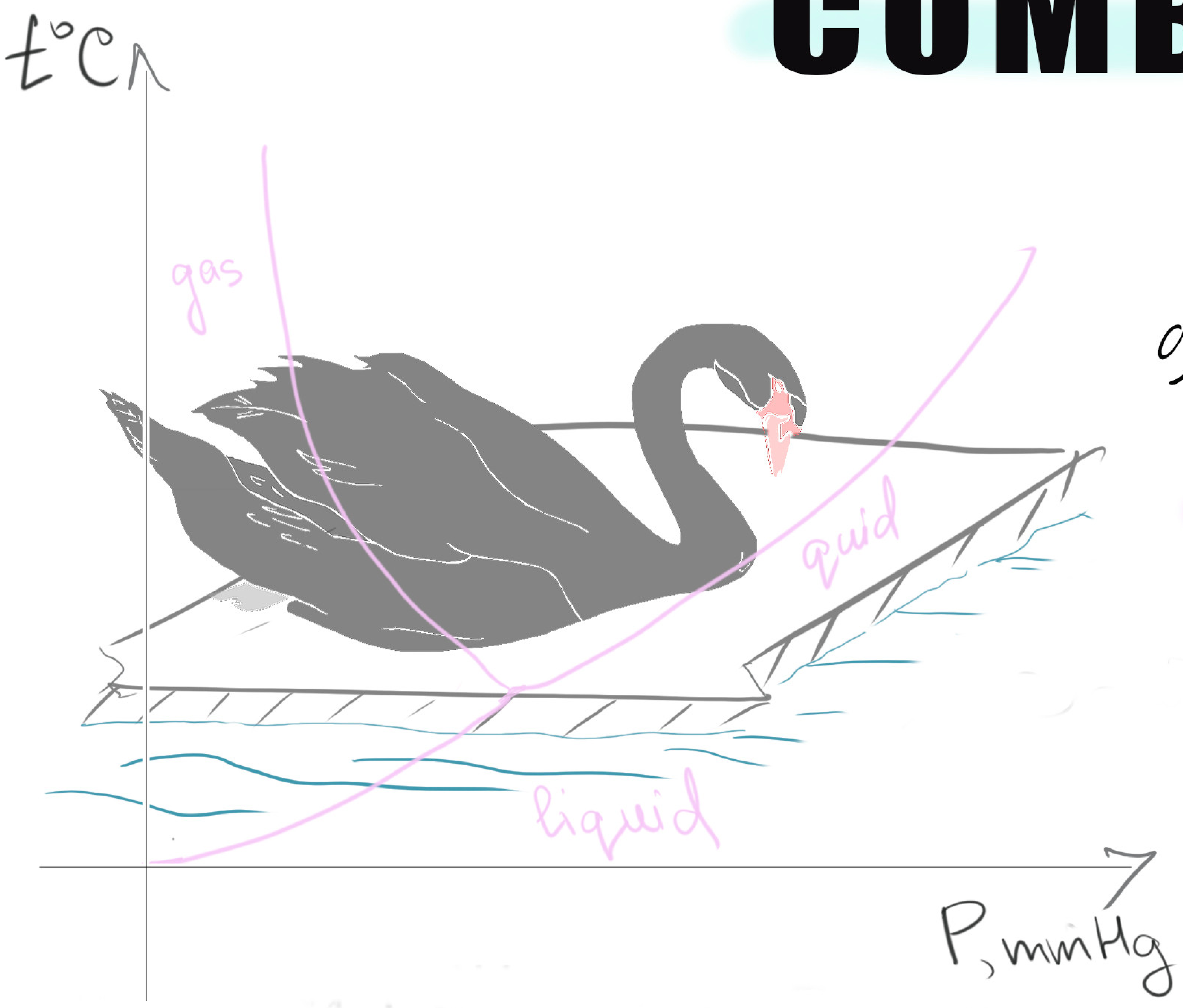
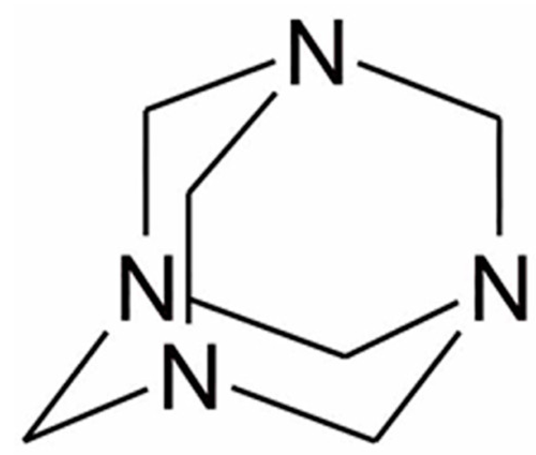
MATHEMATICAL MODEL OF A SOLID FUEL TABLET COMBUSTION

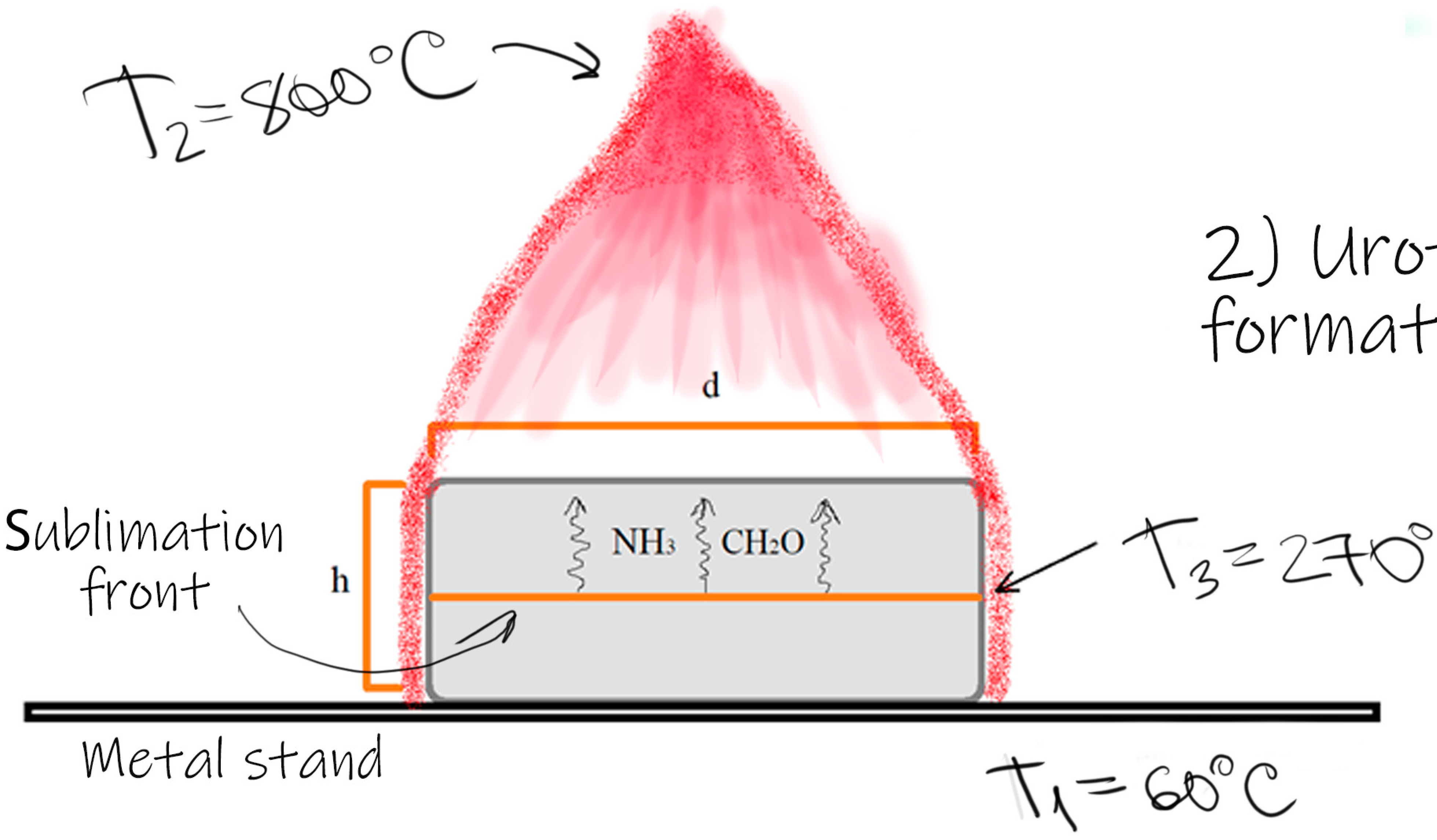


Sublimation is the process of transition of a substance from a solid state to a gaseous state, bypassing the liquid phase.

Urotropin (a solid fuel tablet compressed fuel with a small amount of paraffin)



Mathematical model of a solid fuel tablet combustion:



1) Heat equation:

$$\frac{\partial T}{\partial t} = c\Delta T, \text{ де } \Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}.$$

2) Urotropin sublimation reaction with the formation of ammonia and formaldehyde:

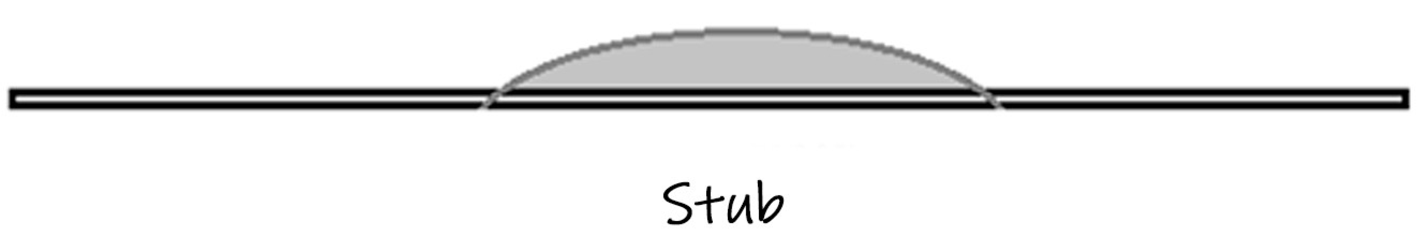
$$(CH_2)_6N_4 + 6H_2O \rightarrow 4NH_3 + 6CH_2O$$

3) Combustion reactions of ammonia and formaldehyde in the combustion zone:

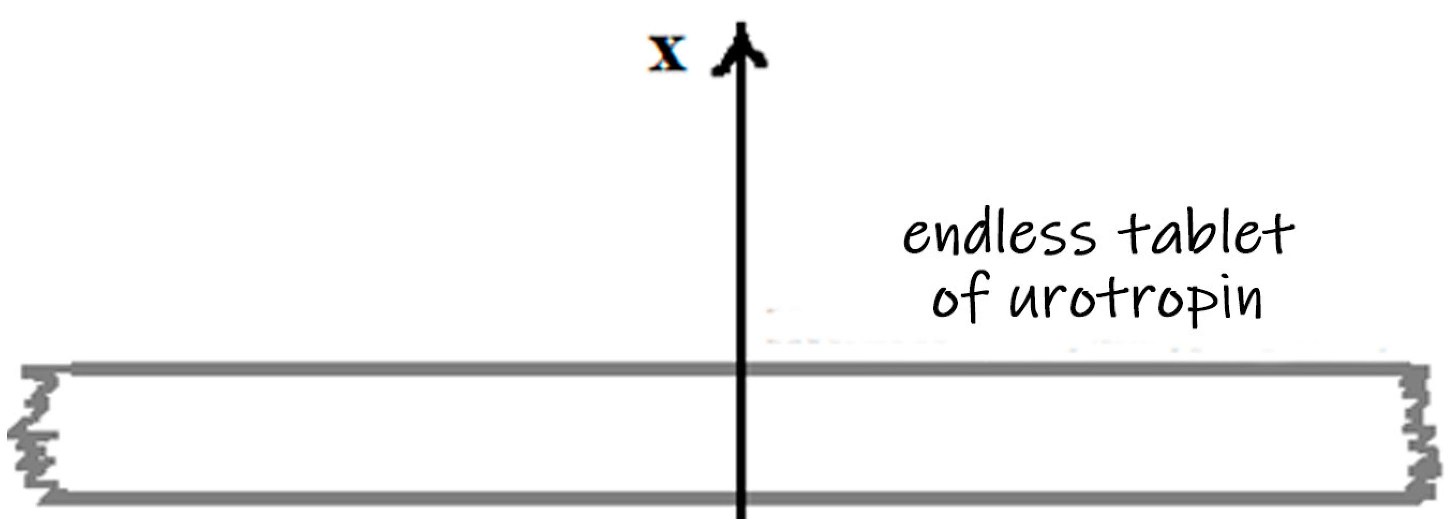
$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O;$$
$$CH_2O + O_2 \rightarrow CO_2 + H_2O.$$

Filtration flow of sublimated substances are described by a nonlinear law Forchheimer filtration:

$$\rho \boldsymbol{g} - \nabla p - \frac{\mu}{k}\boldsymbol{V} - \beta \frac{\rho V^2}{\sqrt{k}} \cdot \frac{\boldsymbol{V}}{V} = 0$$



One-dimensional model of combustion urotropin tablet:



The equation of thermal conductivity for one-dimensional models of combustion urotropin tablet:

$$\frac{\partial T}{\partial t} = c\frac{\partial^2 T}{\partial x^2}$$

Veronika Dushkevych, Sergii Poslavskyi
Kharkiv, Ukraine

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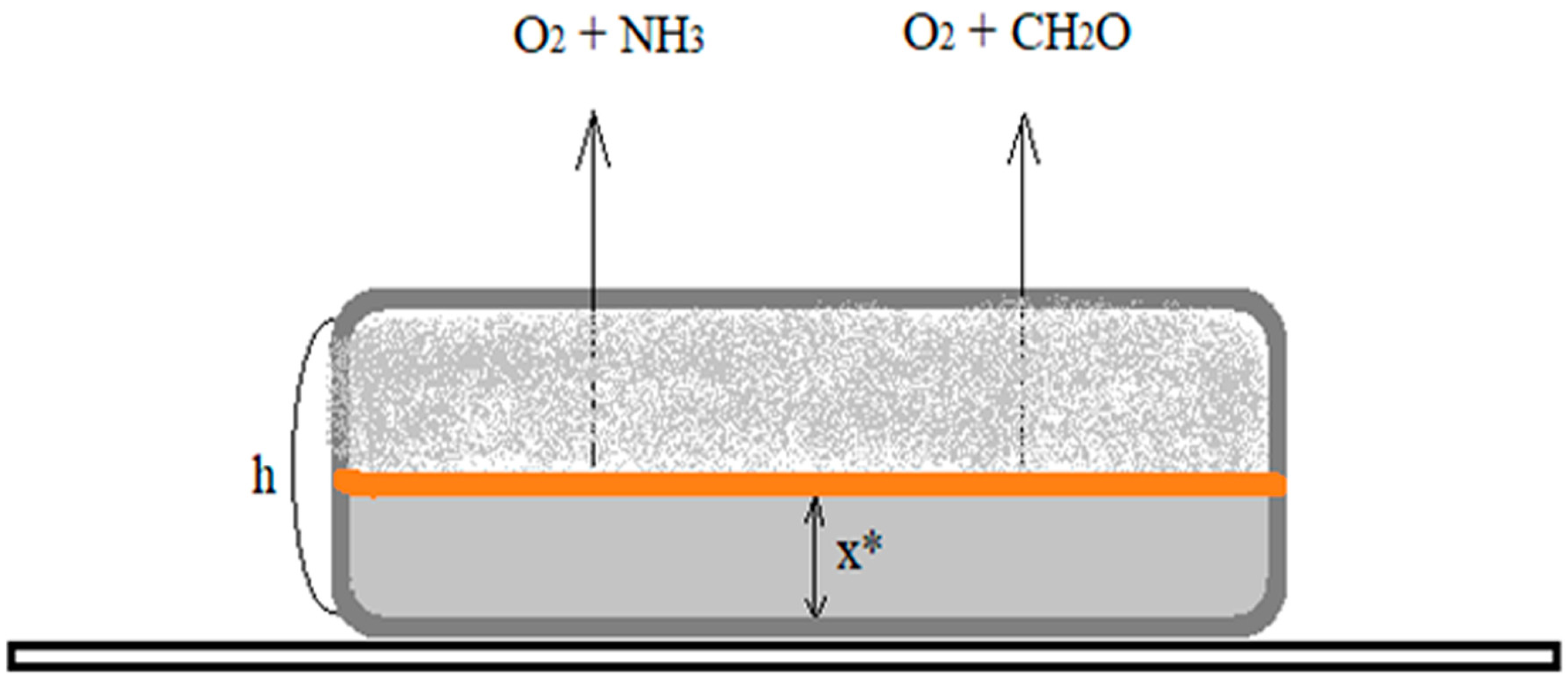
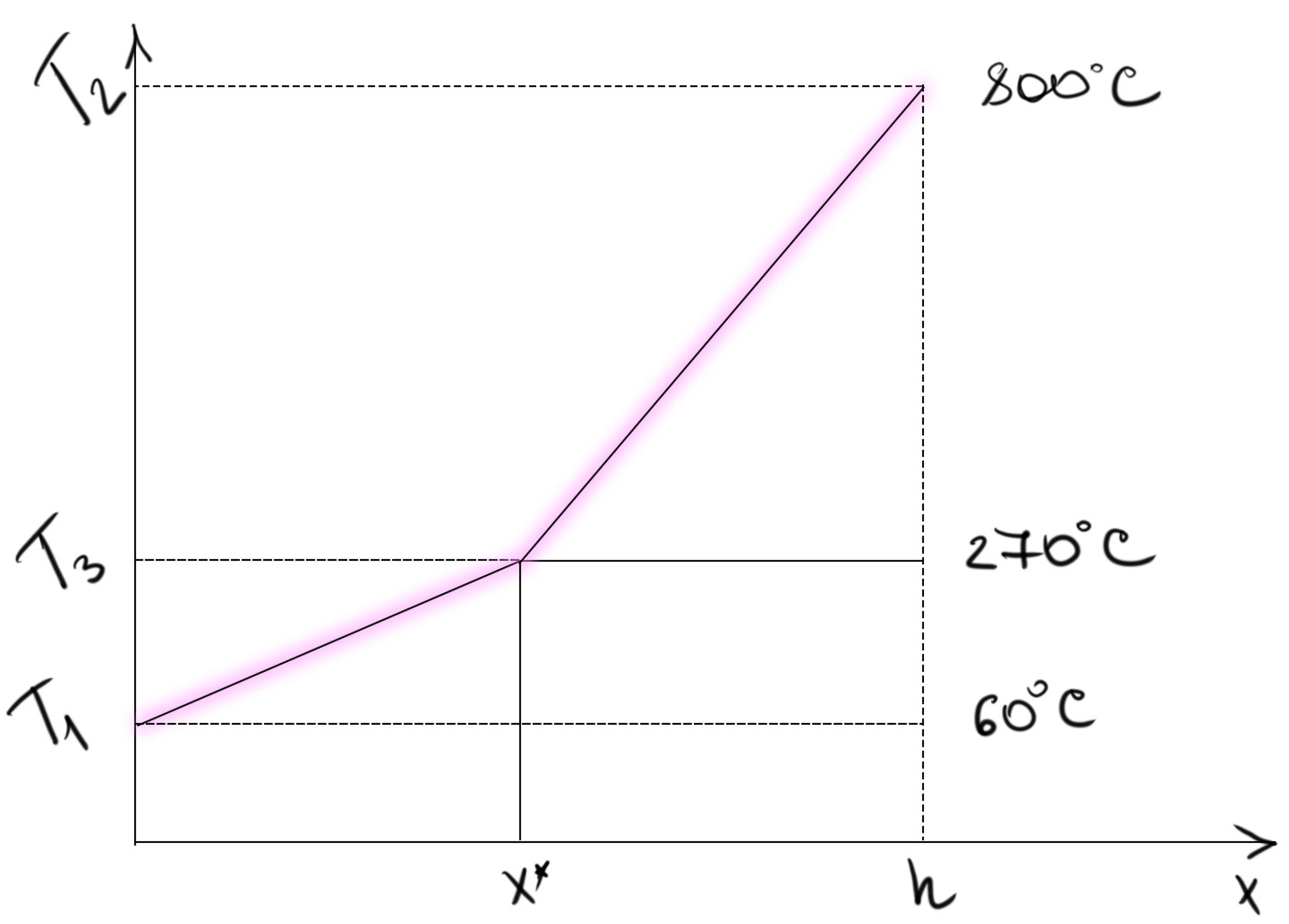
The process of releasing ammonia and formaldehyde in the process of sublimation



h - the height of the tablet;
x * - the height of the tablet below the front line

Temperature distribution in a solid fuel of a urotropin tablet:



Boundary conditions:

$$T(0) = T_1$$

$$T(h) = T_2$$

The density of heat flow, which is spent on sublimation and heating of fuel:

$$q = \rho V \left(C + c \left(T_2 - T_3 \right) \right)$$

$C \sim 600$ kJ / kg - specific heat of urotropin sublimation;
$c \sim 1$ kJ / kg · K - specific heat capacity of the sublimate;
ρV – sublimate mass flow density.

The amount of heat passes through any isothermal surface of the body in the direction of another isothermal surface of the temperature difference and back, in proportion to the distance between the isothermal surface (**expression of Fourier's law**):

$$\vec{q} = -\lambda \operatorname{grad} T,$$ where

λ is the coefficient of thermal conductivity

The main flows:

Heat flow

- for sublimation of urotropin;
- for heat the sublimation products;
- for heat loss through a metal tag.

The flow of substances

Stefan problem

The problem is a generalization of a classical Stefan problem for the case of a gas phase moving through a porous medium.

$$T(x^*) = T_3$$

Dirichlet condition at the tablet-gas interface

$$\frac{dx^*}{dt} = \left[-k \frac{dT}{dx} \right](x^*)$$

Stefan condition, that determines the speed of the interfacial boundary

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