الجمهورية الجزائرية الديمقراطية الشعبية

People's Democratic Republic of Algeria

Ministry of higher education and scientific research وزارة التعليم العالي والبحث

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قسم الهندسة الميكانيكية

Cryogenics course

L3 Energetic

Sommaire

1- Thermodynamic review

2- Gas cycles (Brayton) – stady of the turbojet

3- Phase change cycles (Rankine)

4- Main industrial methods for obtaining low temperatures

5- Ideal liquefaction cycles minimal work

6- Real liquefaction cycles

7- Gas separation

I- Thermodynamics review

I.1. Review

I.1. Cryogenics

The term cryogenc is derived from :

Kruo (greek) = cold

Genisis (greek) = production

I.1.1. Definition

Cryogenic is the scientific discipline dedicated to investigating temperatures below 120 K, encompassing the generation, preservation, and application of extremely low temperatures in various industrial sectors

I.1.2. Cryogenic fluids

Are gases liquefied by cooling to a temperature below their boiling points (Taleau 1). Argon, helium, hydrogen, nitrogen and oxygen are the most commonly transported, handled and stored industrial gases in liquid form in cryogenics.

Table I.1 Boiling points of cryogenic fluids

Gaz	Point d'ébullition (°C)
Acétylène	-84
Acide chlohydrique	-85
Azote	-195
Argon	-185
Dioxyde de carbone	-78
Hélium 3	-269
Hélium 4	-268
Hydrogène	-252
Méthane	-161
Monoxyde de carbone	-192
Oxygène	-183
Trifluorure de bore	-100

I.1.3. Applications of cryogenics

Cryogenics is open to several areas of application as :

-Food preservation using liquid nitrogen

- The suspension of metabolism

-The study of superconductivity (absence of electrical resistance)

-The study of superfluidity (absence of viscosity for a liquid)

-The transformation into a fine powder of all kinds of materials

- Recovery of more than 90% of the layer's destructive gases ozone,

-The creation, from liquid nitrogen, of all kinds of snow.

-Rocket propulsion

I.2. Thermodynamic transformations

I.2.1. Behavior of a cryogenic fluid

There are tree forms of states of mater (Fig. 1)

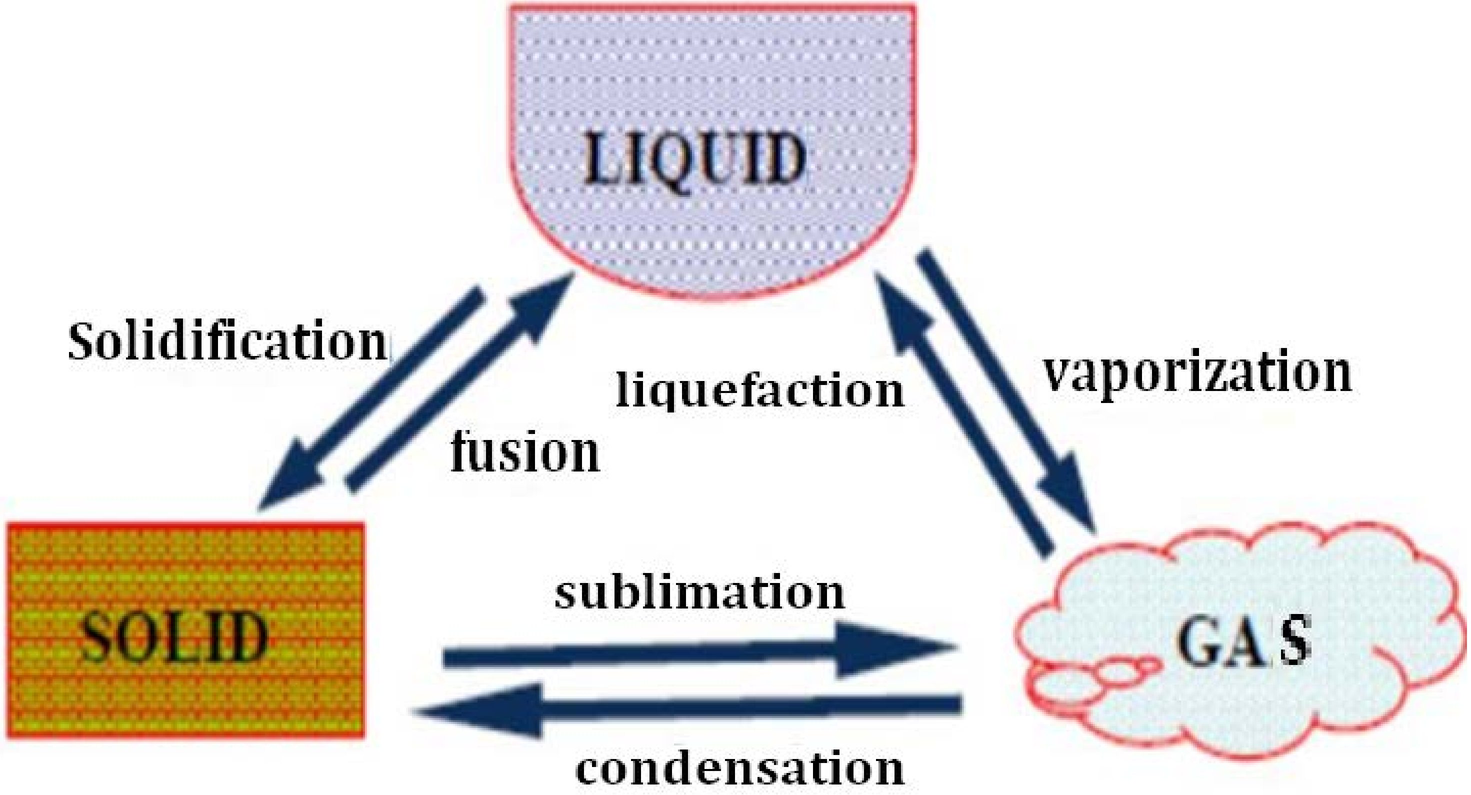

Fig. 1 Forms of states of mater

I.2.2. Phase diagram

This is the phase equilibrium diagram, which represents the different phases of a pure body as a function of pressure and temperature (Fig. 2). The transition from one phase to another requires a heat input, whether it is a sensible or latent heat input.

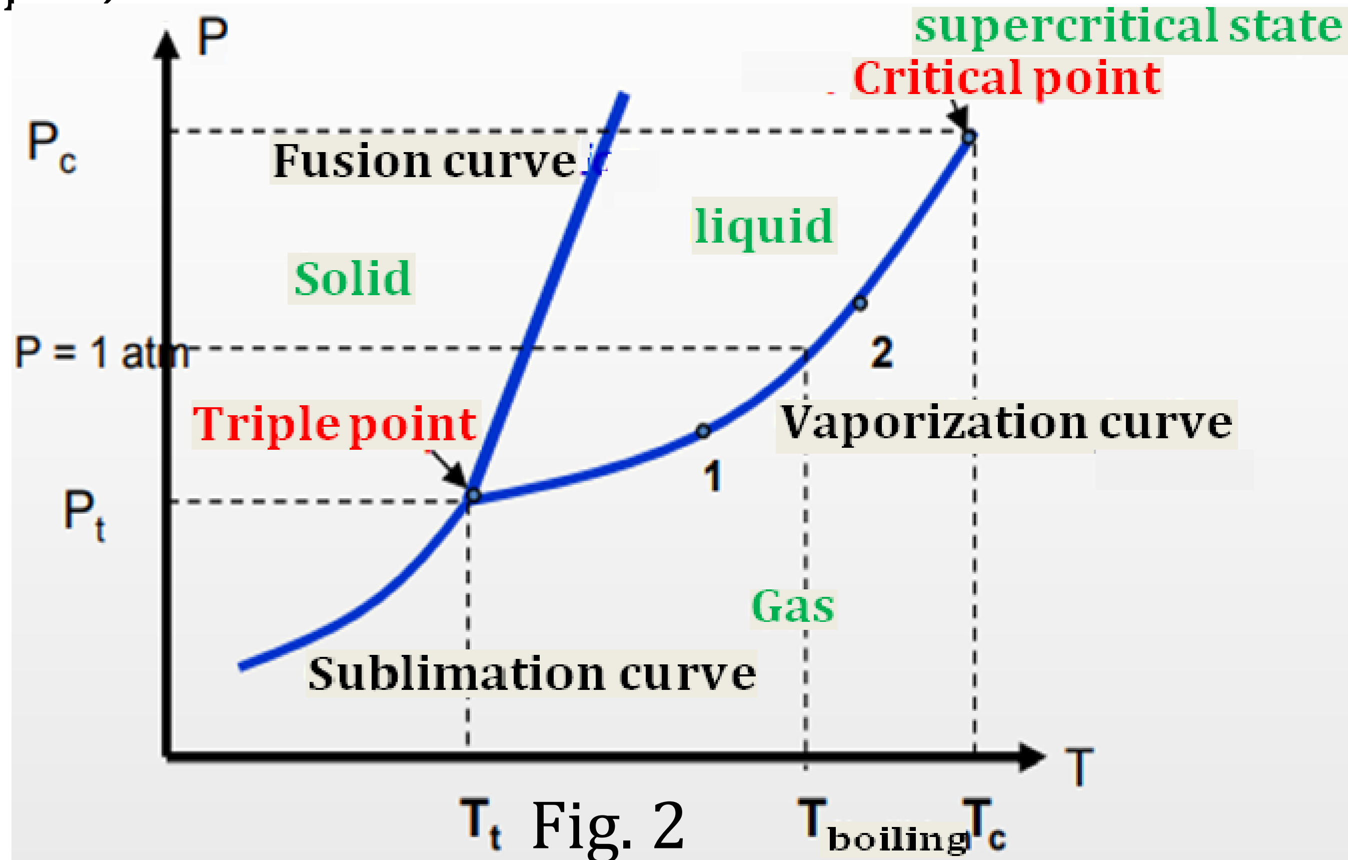

Fig. 2

I.2.2.1. Triple point (*Pt,Tt*)

Is the coexistence of the three phases ; solid, liquid and gas in equilibium.

I.2.2.2. Critical point (*Pc, Tc*) Beyond this point, there is no difference between the liquid and the gas : monophasic supercritical state.

I.2.2.3. Vapor pressure

Is the pressure of gas in equilibrium with the liquid or the solid, this vapor pressure follows a certain type of law :

$$\log(P) = -\frac{A}{T} + B$$

Where *A* and *B* are s specific constants of the sustance

I- Thermodynamics review

Sensible Heat (*Qs*) : Quantity of heat exchanged without phase change but with temperature change

$$Q_s = mC_p \Delta T$$

Latent (***Ql***): Quantity of heat exchanged with phase change at a constant temperature.

$$Q_s = mL_V$$

I.3. Obtaining cooling

The idea relies on the use of a low-temperature cryogenic fluid that warms up upon contact with a solid body. Generally, the types of cryogenic processes are based on isentropic expansion.

I.3.1. Joule-Thomson relaxation

A gas (P_1 V_1 T_1) enters an insulated conduit through a valve, causing a sudden cooling with a pressure drop (Fig. 3) in the process.(Fig. 3) with (P_2 V_2 T_2).

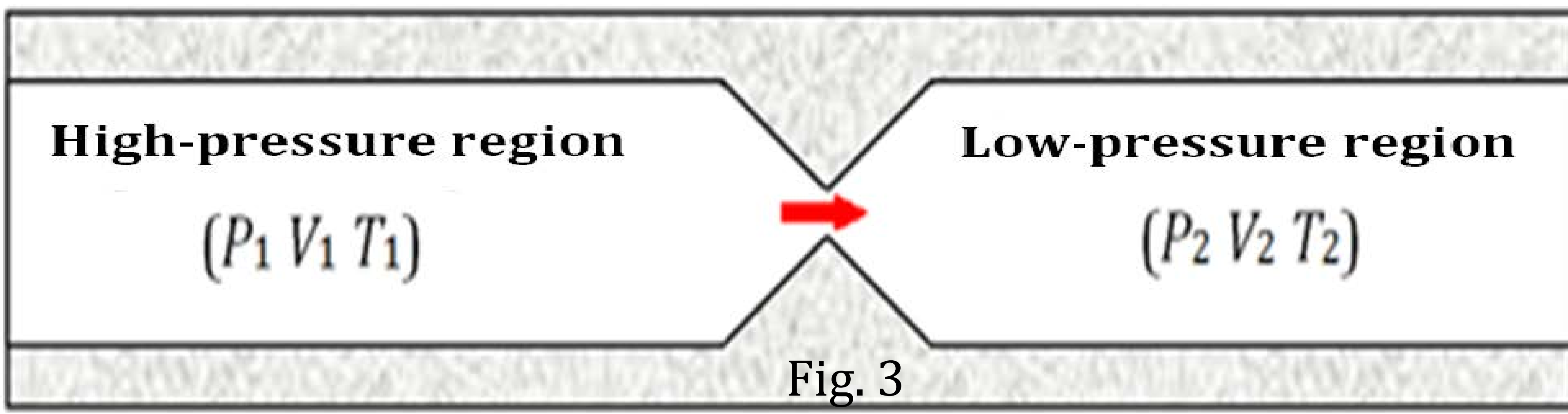

Fig. 3

I- Thermodynamics review

$$\Delta U = Q + W = W_1 + W_2$$

The compression wotk W_1 (Work received

$$W_1 = -\int_{V_1}^{0} P_1 dv = P_1 V_1$$

The relaxation work W_2(asigned work)

$$W_2 = -\int_{0}^{V_2} P_2 dv = -P_2 V_2$$

The variation of internal energy

$$\Delta U = U_2 - U_1 = P_1V_1 - P_2V_2 \Rightarrow U_2 + P_2V_2 = U_1 + P_1V_1$$

$$\Delta U = U_2 - U_1 = P_1V_1 - P_2V_2 \Rightarrow U_2 + P_2V_2 = U_1 + P_1V_1$$

$$U_2 + P_2V_2 = H_2 \text{ et } U_1 + P_1V_1 = H_1$$

So, we can conclude

$$H_2 = H_1 \Rightarrow \Delta H = 0$$