KINGDOM OF SAUDI ARABIA
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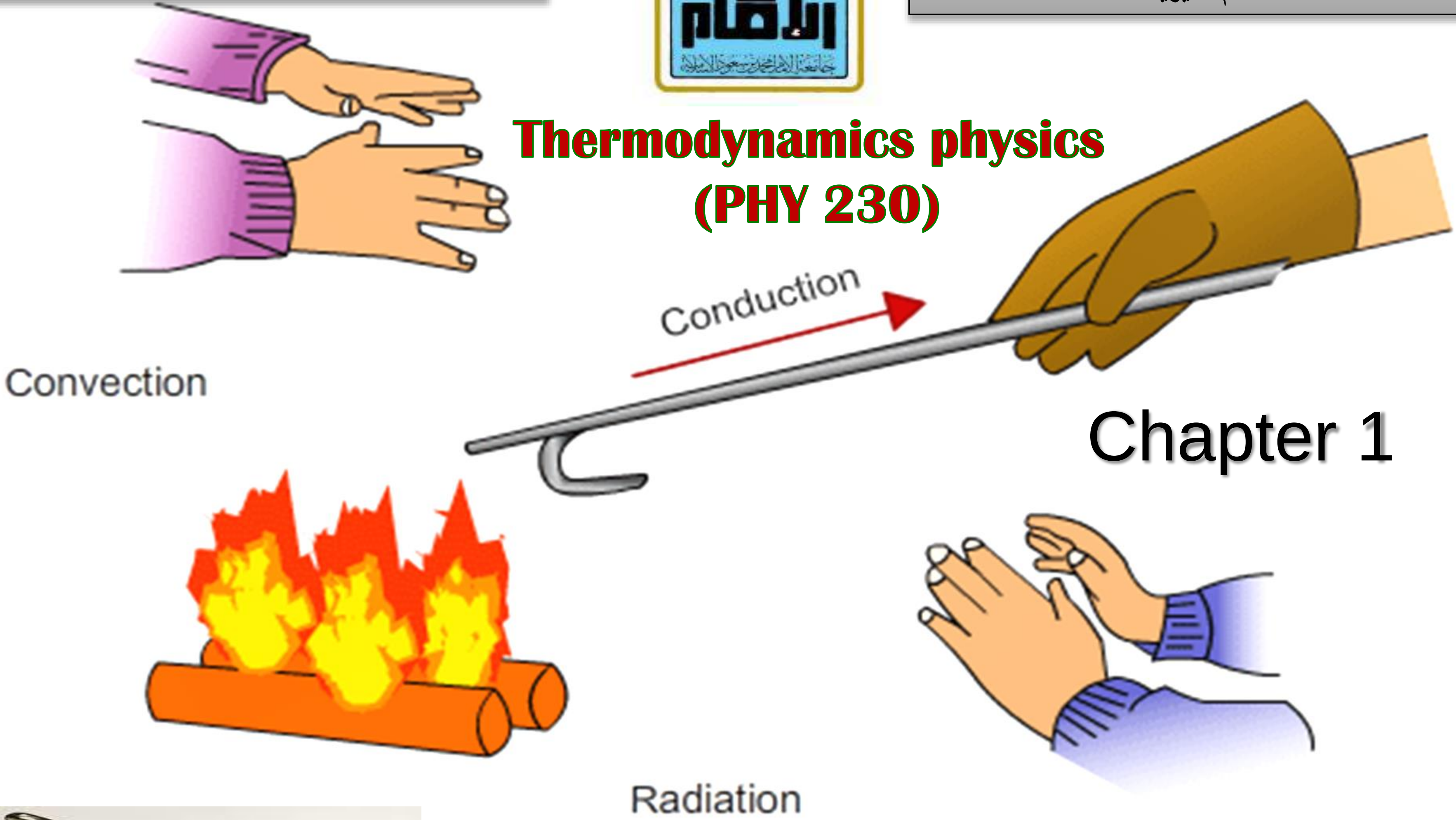
المملكة العربية السعودية
جامعة الإمام محمد بن سعود الإسلامية
كلية العلوم
قسم الفيزياء

Thermodynamics physics
(PHY 230)

Chapter 1



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المملكة العربية السعودية
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Chapter 1

Temperature

الديناميكا الحرارية : علم من علوم الفيزياء يركز عى دراسة الحرارة
والمفهوم الاساسي لهذا العلم هو درجة الحرارة

1- Introduction

Thermodynamics is the study of heat in the field of physics. The central concept of thermodynamics is temperature. Since temperature is not expressible in terms of basic mechanical quantities such as mass, length, and time, it is evidently a fundamental notion that sets thermodynamics apart from other branches of physics.

2- Definitions

نظام

- **System**: some portion of the physical world. The system could be a container of gas, a piece of metal, a magnet. The system must not interact chemically with the vessel that contains it. A system may exchange energy with other systems, which constitute the surroundings of the given system.

فضاء

- **Universe**: The system, together with its surroundings, comprise a universe.
- **Open system**: The system can exchange mass and energy with its surroundings.
- **Closed system**: It cannot exchange mass with its surroundings but can exchange energy in other forms.
- **Isolated system**: It cannot exchange mass or energy in any form with its surroundings

نظام
امثله عى انظمة
١- وعاء غاز
٢- قطعه معدن
٣- مغناطيس
النظام يتبادل الطاقه مع الانظمه الاخرى التي تكون محيطة

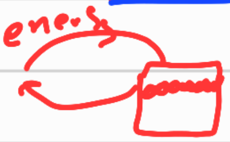
✓ الفضاء (الكون)

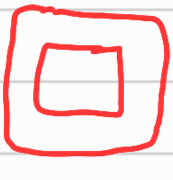
universe

مفتوح
open system

مغلق
closed system

معزول
Isolated system





Exchange of mass and energy

Exchang of energy but not mass

No exchange in mass or energy

- **Properties** (thermodynamic variables or thermodynamic coordinates): The quantities we use to describe the macroscopic behavior of a system (V, P, T….)

V: الحجم Volume

P : Pressure ضغط

T: درجة الحرارة

تتناسب مع الكتلة

- **Extensive property**: It is proportional to the mass. An example is the volume V: if the mass is doubled, the volume is doubled (assuming that the density remains constant).

لا تعتمد على الكتلة

- **Intensive property**: It is independent of the mass. Temperature T is an intensive property; its value is not affected by a change of mass. Pressure P and density ρ further examples of intensive properties.

- An extensive property can be converted to an intensive property by dividing by the mass. This is called a specific value:

كمية نوعية

$$\text{Specific value} = \frac{\textit{Value of the extensive property}}{\textit{mass of the system}}$$

حالة النظام

- **The state of a system** is defined as a condition uniquely specified by a set of properties. Examples of such properties are pressure, volume, and temperature.

- The thermodynamic state of a single component system is also specified by two independent variables.

حاله الاتزان هي الحالة التي يكون فيها احدى الخصائص منتظمة

- An equilibrium state is one in which the properties of the system are uniform.

انواع الخصائص

Extensive

الطول
الكتلة
الحجم
Volume
length

لون
كثافة
درجة الحرارة
الطول
الكتلة
الحجم

intensive

لون
كثافة
درجة الحرارة
density
Temperature
Pressure

$$\text{الكمية النوعية} = \frac{\text{مقدار الكمية}}{\text{الكتلة}}$$

$$\text{specific value} = \frac{\text{Value}}{\text{mass}}$$

$$\text{S. Volume} = \frac{\text{volume}}{\text{mass}} \qquad m^2/kg$$

للتعرف على حالة النظام تكون من خلال خصائصه (T، ضغط حجم)

حالة عدم الاتزان تكون احدى الخصائص تتغير مع الزمن

- A non-equilibrium state characterizes a system in which gradients exist and whose properties vary with time.

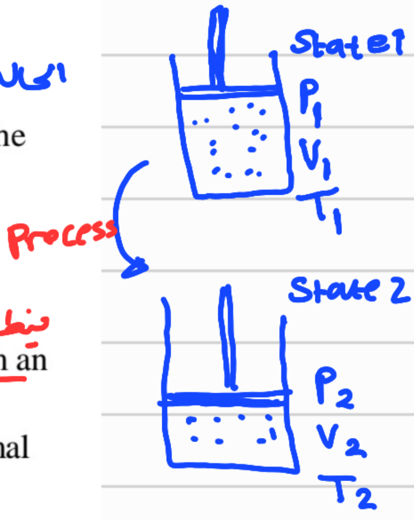
معدل تغير

- State variables are properties that describe equilibrium states.

الحاله تصف خصائص النظام المتزن

- If the pressure P, the volume V, and the temperature T are the state variables of the system, the equation of state takes the form

$$f(P,V,T) = 0$$



$f(P,V,T)$

- Cyclic process: the initial and final states are the same.

ينطلق النظام من حالة اتزان

- Quasi-static process: at each instant, the system departs only infinitesimally from an equilibrium state.

في كل لحظة

- Reversible process is a process whose direction can be reversed by an infinitesimal change in some property.

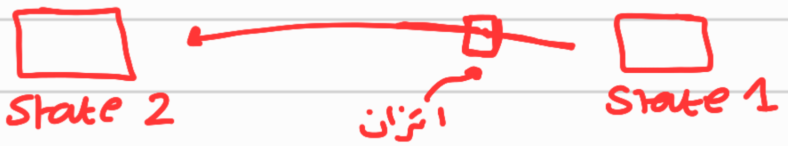
تمكين عكس اتجاهها

- An irreversible process involves a finite change in a property in a given step and includes dissipation (energy loss). All natural processes are irreversible.
- An isobaric process is a process in which the pressure is constant.
- An isochoric process is a process in which the volume is constant.
- An isothermal process is a process in which the temperature is constant.

Process (عملية) ⟹ تغير من حالة الى حالة

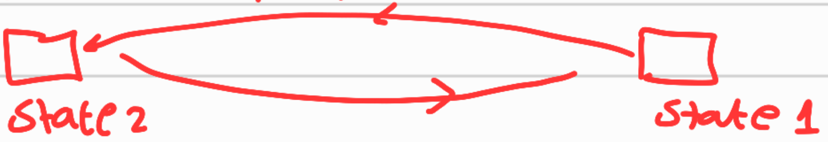
1) Cyclic process : الحالة الابتدائية و النهائية تكون نفسها

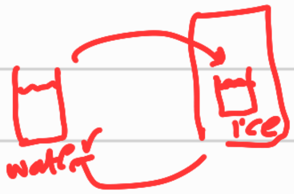
2) Quasi-static process



الوصول الى حالة الاتزان التدريجي خلال عملية التحويل

3) Reversible (قابلة للعكس)





امكانية عكس العمليه دون اي ضياع للطاقة

4) irreversible (غير عكسية) تتضمن ضياع للطاقة و لايمكن ارجاعها بسهولة

(الاحتراق)

ثلاث انواع من العمليات الحرارية

Isobaric ↓ يحدث التحول بثبوت الضغط ↓ P is constant

Isochoric ↓ يحدث التحول بثبوت الحجم ↓ V is constant

Isothermal ↓ يحدث التحول او التغير بثبوت درجة الحرارة T is constant

3- Units

In international system, the unit of pressure is the pascal (Pa), equal to 1 $N.m^{-2}$

Other units of pressure in common use are

- 1 bar = 10^5 Pa,
- 1 atmosphere (atm) = 1.01 X 10^5 Pa.
- 1 torr = 133.3 Pa.

The atmosphere is based on the use of a manometer to measure pressure.

منه قياس الضغط الجوي باستخدام جهاز مانومتر

4- Temperature and the zeroth law of thermodynamics

القانون الصفري للديناميكا الحرارية

If two systems are separately in thermal equilibrium with a third system, they are in equilibrium with each other.

اذا كان نظامين متزنين بشكل منفصل مع نظام ثالث اذا هما متزنين حراريا

$$P = \frac{F}{A} \Rightarrow N/m^2 = N.m^{-2} = Pa$$

$$\text{باسكال} = N/m^2$$

$$1\ bar = 10^5\ Pa$$
$$1\ atm = 1.01 \times 10^5\ Pa$$
$$1\ torr = 133.3\ Pa$$

$$\begin{tikzcd} Pa \arrow[rr, bend left, "\div"] & 10^5 & bar \arrow[ll, bend left, "\times"] \end{tikzcd}$$

$$\begin{tikzcd} Pa \arrow[rr, bend left, "\div"] & 1.01 \times 10^5 & atm \arrow[ll, bend left, "\times"] \end{tikzcd}$$

$$\begin{tikzcd} Pa \arrow[rr, bend left, "\div"] & 133.3 & torr \arrow[ll, bend left, "\times"] \end{tikzcd}$$

5- Temperature scales

مقاييس درجه الحرارة

To assign a numerical value to the temperature of a system. we choose as a thermometer a substance that has a so-called thermometric property that changes with temperature and is easily measured. An example is the volume of a fluid that expands on heating

مثال

حجم السائل الذي يتمدد بالحرارة

لتحديد قيمه رقميه لدرجه الحراره يجب اختيار مادة ذات خاصيه حراريه وسهل قياسها

We choose a thermometric property X that is linearly related to the temperature over as wide a range as possible:

$$\boxed{X = aT + b}$$

تناسب خطي

ثابت ثابت

a and b are constants

يجب ان تكون الخاصيه الحراريه متناسبه خطيا مع الحرارة قدر الامكان

We choose reference points to define the scale. Prior to 1954, two fixed points were used, the ice and steam points of water. The scale was determined by assigning the numerical values 0°C (C for Celsius) to the ice point

مثال اخر حول الخواص الحراريه وهي ضغط الغاز

An excellent choice for the thermometric property is the pressure of a gas. The constant-volume gas thermometer, shown in Figure , is a practical method for measuring the temperature of an object.

ملاحظات من خلال التجربة

Several observations were made when this method was used

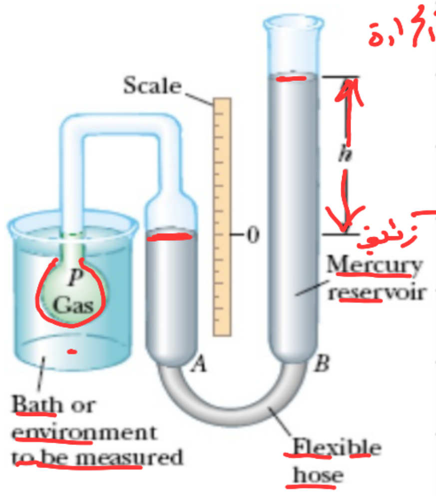
الرسم البياني بين P و T تقريبا خطيه على مدى واسع

a. The P- T curve is very nearly linear over a wide range of temperature.

عند الضغوط المنخفضه يصبح اكثر خطي

b. The curve is increasingly linear as the pressure decreases. .

c. A linear extrapolation of the plot gives P = 0 at T = -273.15°C.



Simplified constant-volume gas thermometer. The pressure is given by P = hρg,

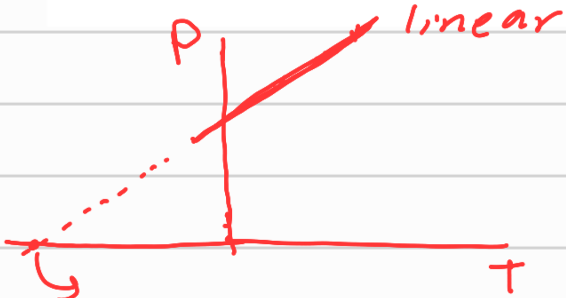
الضغط يزداد مع الحرارة

ميزان حرارة معتمد على ضغط الغاز

كثافه الزئبق

فرق الارتفاع بين الانبوبين

تسارع الجاذبيه



الضغط = صفر

$T = -273.15C^o$

الضغط يصبح مقداره صفر عندما تكون درجه الحرارة = $-273.15C^o$

$P = aT + b$ ✓

P ضغط

T درجه الحرارة

a و b ثوابت

$P = a(\overset{C}{T}+273.15)$

$P = a(\underset{K}{T})$

✓

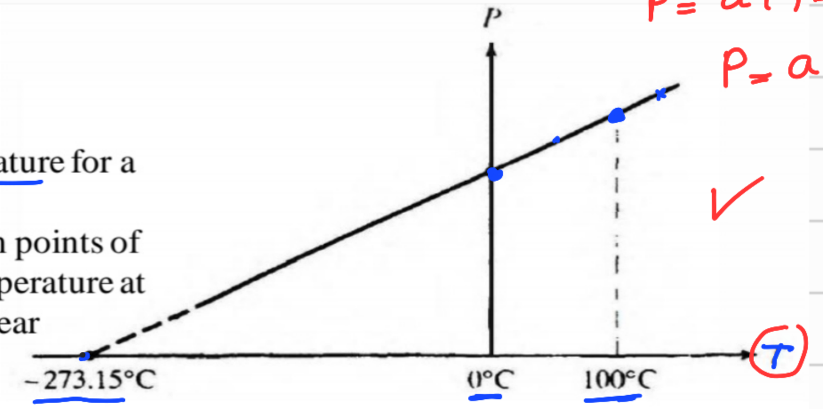


Figure: Pressure versus temperature for a gas thermometer. The ice and steam points of water are fixed points. The temperature at zero pressure is obtained by linear extrapolation.

For a gas thermometer, then.

$$P = aT + b.$$

$\rightsquigarrow 0 = a(-273.15)$

$T = -273.15$ بعد تعويض $P=0$

The zero pressure point give: $0 = -273.15a + b.$

Thus $P = a[T(°C) + 273.15].$

$P = a\,(T+273.15)$

We can now choose an absolute scale such that there are 100°C between the ice and steam points. We want $P = aT(K).$

$P = a\,T(K)$

where K is the abbreviation for kelvin. the unit of temperature on the absolute scale (no degree sign). It follows that

$$T(K) - T(°C) = 273.15.$$

C = 10

K 10+273.15

283.15K

C ⇝ 30° degree

30 ⇝ K

نقطه جديدة جديد لنعرف كم ، ميل a

slope

Now we need only one reference point to define the slope a in Equation P=a.T(K). The reference point was taken to be the triple point of water. the pressure and temperature at which ice and liquid water coexist in equilibrium with saturated vapor. The triple point temperature of water is 0.01 °C. that is 0.01 degrees above the ice point at atmospheric pressure. We obtain

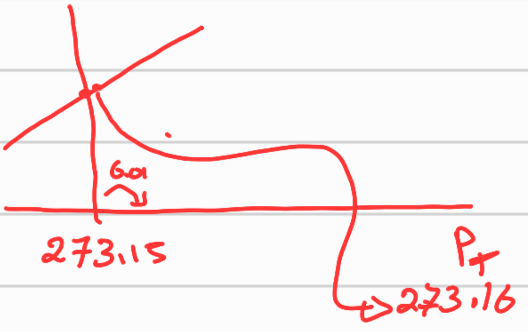
$$\frac{T(K)}{273.16} = \frac{P}{P_{TP}},$$

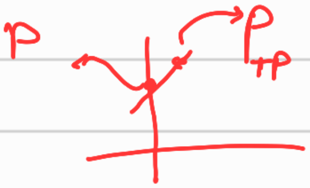
نحن ، نقطة اكبر ب ٠.٠١ من نقطة الجليد

where P_{TP} is the pressure at the triple point.

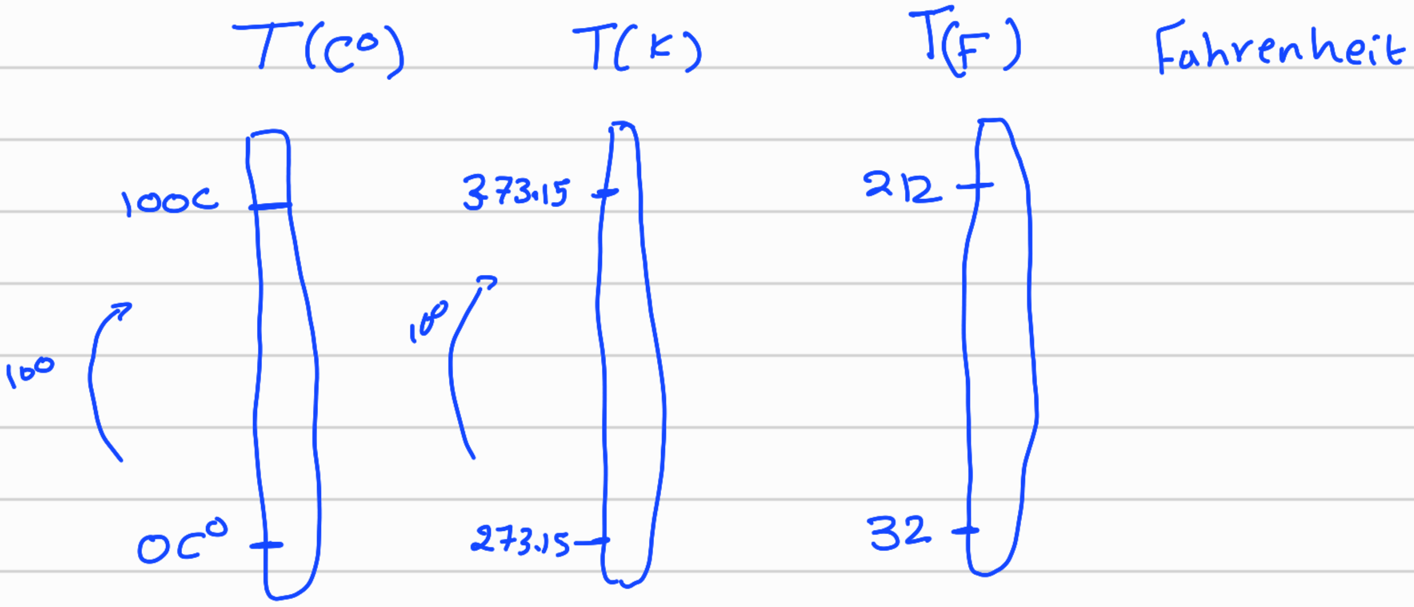
Another temperature scales is in use. The Fahrenheit scale is related to the Celsius scale by the equation

$$T(°F) = \frac{9}{5}T(°C) + 32.$$





$$\frac{P_{TP}}{P} = \frac{273.16}{T(K)}$$



$T(K) = T(C) + 273.15$

$T(C) = T(K) - 273.15$

ex Convert 50C° to Kelvin

$T(K) = 50 + 273.15$

$= 323.15\ K$

$T(F) = \frac{9}{5} T(C) + 32$ ✓

$T(C) = \frac{5}{9}(T(F) - 32)$

ex Convert 37C° to (F)

$T(F) = \frac{9}{5}(37) + 32$

$= 98.6\ F$

6- Equation of state

6-1- Equation of state of an ideal gas

معادلة الغاز المثالي

The equation of state of a system composed of m (g) of a gas whose molecular weight is M is given approximately by:

$$PV = \frac{m}{M} RT.$$

where R is a universal constant having the same value for all gases:

$$R = 8.314 \times 10^3 \frac{\text{J}}{\text{kilomole} \cdot \text{K}}.$$

Since n = m / M is the number of kilomoles of the gas, we can write

$$PV = nRT.$$

This equation is called the equation of state of an ideal gas or perfect gas. It includes the laws of Boyle, Gay-Lussac Charles and Avogadro.

الغاز المثالي
او الغاز التام

$$\boxed{PV = nRT}$$

P : ضغط Pressure
- Pa
- atm
- bar torr

V : الحجم Volume
- m3
- L
- mL
- mm3

n : عدد المولات $n = \frac{m}{M}$

$$\text{عدد المولات} = \frac{\text{الكتلة}}{\text{الكتلة}}$$

R : universal constant

الثابت العالمي للغاز

$R = 8.314 \times 10^3$ J/kmole, K

T = درجة الحرارة يجب ان تكون الحراره بوحده K

$PV = nRT$ $\quad\quad PV = \frac{m}{M} RT$

✓ ✓ ✓ ✓

حجم جم آ جم آ

معادلة فاندرفال للغاز الحقيقي

6-2 Van der Waal's equation for a real gas

The characteristic equation of an ideal gas represents the behavior of real gases fairly well for high temperatures and low pressures. However, when the temperature and pressure are such that the gas is near condensation, important deviations from the ideal gas law are observed. عندما تكون الغاز قريبا من درجه التكاثف يحدث انحراف كبير عن تصرف الغاز المثالي

Van der Waals derived his equation from considerations based on kinetic theory, taking into account to a first approximation the size of a molecule and the cohesive forces between molecules. His equation

معادلة فاندرفال

$$\boxed{\left(P + \frac{a}{v^2}\right)(v - b) = RT}$$

بدل → $PV = nRT$

ثوابت

where a and b are characteristic constants for a given substance. For a = b = 0, precedent Equation reduces to the equation of state for an ideal gas.

اذا كانت قيم a و b = 0 اذا تتحول المعادله الى معادله الغاز المثالي

Ideal gas $PV = nRT$

✓ عندما تكون درجات الحرارة عاليه او الضغط منخفض فان الغاز يتصرف بطريقة تتناسب مع الغاز المثالي

✓ لكن عندما يقترب الغاز من التكاثف (من غاز ← سائل) يصبح تصرف الغاز لا تنطبق مع الغاز المثالي (يحدث انحراف)

✓ استنتج العالم فاندرفال معادلته بالاعتماد على النظريه الحركيه والتغيرات من حجم الجزيئات والقوى بين الجزيئات

التمدد الانضغاط

7- Expansivity and compressibility

Suppose that the equation of state of a given substance is written in the form

حجم ←

$$v = v(T, P).$$

→ درجة الحرارة

→ ضغط

Taking the differential, we obtain

$$dv = \left(\frac{\partial v}{\partial T}\right)_P dT + \left(\frac{\partial v}{\partial P}\right)_T dP.$$

We define $\boxed{\beta} \equiv \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P$. The expansivity or coefficient of volume expansion.

and $\boxed{\kappa} \equiv -\frac{1}{v}\left(\frac{\partial v}{\partial P}\right)_T$. Is the isothermal compressibility

For an ideal gas, v = RT/ P. and $\beta = \frac{1}{v}\left(\frac{R}{P}\right) = \boxed{\frac{1}{T}}$.

and

$$\kappa = -\frac{1}{v}\left(-\frac{RT}{P^2}\right) = \boxed{\frac{1}{P}}.$$

For a liquid or a solid in contrast to a gas, β and K are nearly constant over a fairly wide range of temperature and pressure.

From precedent equation equations we have

$$dv = \beta v dT - \kappa v dP.$$

We assume that the volume change is small when the temperature and pressure are changed so that to a first approximation, v ≈v0 (a constant) β and K are constants. Then

$$dv \approx \beta v_0 dT - \kappa v_0 dP.$$

Integrating, we have

$$\int_{v_0}^{v} dv = \beta v_0 \int_{T_0}^{T} dT - \kappa v_0 \int_{P_0}^{P} dP.$$

Then

$$v = v_0[1 + \beta(T - T_0) - \kappa(P - P_0)].$$

معادله لحساب التمدد للسوائل والغازات

This is an approximate equation of state for a liquid or a solid.

في حالة التغيرات في درجة الحرارة والضغط

7 : التمدد و الانضغاط

Expansivity compressibility

$$v = v(T, P)$$

باشتقاق العلاقة

$$\boxed{dv = \left(\frac{\partial v}{\partial T}\right)_P dT + \left(\frac{\partial v}{\partial P}\right)_T dP}$$

معامل التمدد بثبوت الضغط (β)

β : expansivity

: Coefficient of expantion

$$\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P$$

معامل التمدد بثبوت درجه الحرارة (K)

K : Isothermal comperessibility

$$K = -\frac{1}{v}\left(\frac{\partial v}{\partial P}\right)_T$$

$$\boxed{dv = \beta v dT - K v dP}$$ ✓

في حاله الغاز المثالي Ideal gas

$$V = \frac{RT}{P}$$ ومن

نحسب قيمه β الغاز المثالي

$$\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)$$

$$= \frac{1}{v}\left(\frac{R}{P}\right) = \frac{1}{\frac{\cancel{R}T}{\cancel{P}}}\left(\frac{\cancel{R}}{\cancel{P}}\right)$$

$$\boxed{\beta = \frac{1}{T}}$$

نحسب قيمه K للغاز المثالي

$$\boxed{V = \frac{RT}{P}}$$

$$y = \frac{1}{x}$$

$$\frac{dy}{dx} = -\frac{1}{x^2}$$

$$K = -\frac{1}{v}\left(\frac{\partial V}{\partial P}\right)$$

$$= +\frac{1}{v}\,\frac{RT}{+P^2} = \frac{1}{\frac{\cancel{RT}}{\cancel{P}}}\,\frac{\cancel{RT}}{P^{\cancel{2}}}$$

$$\boxed{K = \frac{1}{P}}$$

في حاله السوائل و الغازات (يكون التمدد و الانضغاط قليل)

approximation $v \simeq v_0$

لان التمدد و التقلص قليل في السوائل و المواد الصلبه فان الحجم يعتبر نفس مقدار الحجم الاصلي

the change in volume is too small

$$dv = \beta v\, dT - K v\, dP$$

$$dv = \beta v_0\, dT - K v_0\, dP$$

في هذه المعادله نعتبر v_0 و k و β ثوابت

$$\int_{v_0}^{v} dv = \int_{T_0}^{T} \beta v_0 \, \underline{dT} - \int_{P_0}^{P} k v_0 \, dP$$

$$\int_{v_0}^{v} \underline{dv} = \beta v_0 \int_{T_0}^{T} \underline{dT} - k v_0 \int_{P_0}^{P} \underline{dP}$$

$$(v - v_0) = \beta v_0 (T - T_0) - k v_0 (P - P_0)$$

$$v = v_0 + \beta v_0 (T - T_0) - k v_0 (P - P_0)$$

$$v = v_0 \left[1 + \beta (T - T_0) - k (P - P_0) \right]$$

v ← الحجم النهائي

v_0 ← الحجم الاصلي