

# Termodinamica 2

slides da:

Mazzoldi-Nigro-Voci

Elementi di Fisica

Meccanica e termodinamica

Capitoli 12,13

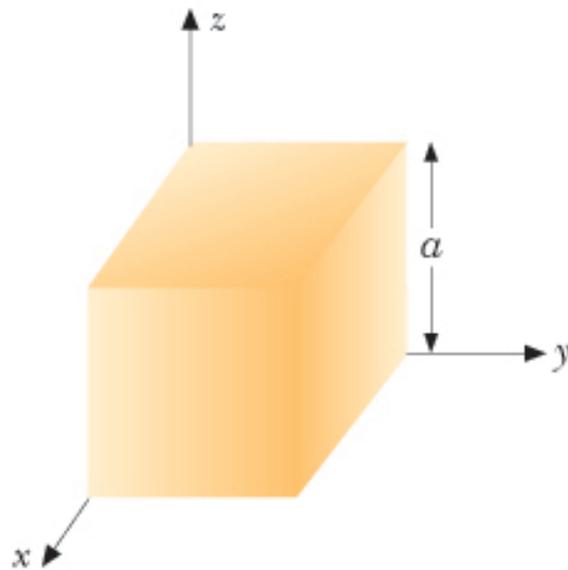
e da:

Raymond A. Serway, John W. Jewett, Jr.

Fisica per Scienze ed Ingegneria - Volume 1

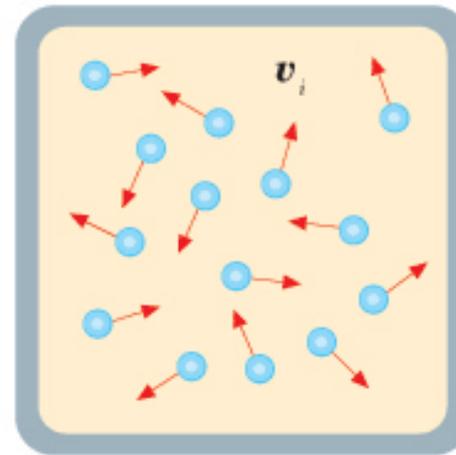
Capitoli 19,20

## Sistema termodinamico



(a)

Gas perfetto!



$$\mathbf{v}_m = \sum_i \mathbf{v}_i = 0$$

(b)

**Figura 13.27**

Rappresentazione simbolica di un contenitore di forma cubica contenente un gas (a) e di un gas secondo il modello di Bernoulli (b).

# Equazione di stato per un gas perfetto

$$p V = n R T$$

riunisce la legge di Boyle  
per le trasformazioni isoterme

$$pV = \text{cost.}$$

e le leggi di Volta-Gay Lussac  
per le trasformazioni  
isobare ed isovolumiche

$$\frac{T}{V} = \text{cost.}$$

$$\frac{T}{p} = \text{cost.}$$

pressione in Pascal  
volume in  $\text{m}^3$   
temperatura in Kelvin

n numero di moli  
R costante universale dei gas (J/mol K)

$$R = 8.31 \text{ J/mol K}$$

n numero di moli

$$n = \frac{\textit{massa del campione}}{\textit{massa molecolare}}$$

Viewing: Atomic weight

Group Legend

Alkali Metal	Actinides
Alkali Earth	Lanthanides
Metal	Non-metal
Trans. Met.	Halogen
	Noble Gas

1																	18	
1	1 H 1.0079																	2 He 4.0026
2	3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.941	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.8
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc (97.91)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.6	53 I 126.9	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (144.9)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261.1)	105 Db (262.1)	106 Sg (263.1)	107 Bh (262.1)	108 Hs (265.1)	109 Mt (266.1)	110 Uun (269)	111 Uuu (272)	112 Uub (277)	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)

Lanthanide Series	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (144.9)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.5	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
Actinide Series	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244.1)	95 Am (243.1)	96 Cm (247.1)	97 Bk (247.1)	98 Cf (251.1)	99 Es (252.1)	100 Fm (257.1)	101 Md (258.1)	102 No (259.1)	103 Lr (262.1)

n numero di moli

$$n = \frac{\text{massa del campione}}{\text{massa molecolare}}$$

mole = quantità di materia contenente  $6.022 \cdot 10^{23}$  molecole

$6.022 \cdot 10^{23}$  = numero di Avogadro

Legge di Avogadro

volumi uguali di gas diversi, alla stessa temperatura e pressione, contengono lo stesso numero di molecole

1 mole di acqua = 2g di H + 16g di O = 18g

1 mole di NaCl = 23g di Na + 35g di Cl = 58g

quanto spazio occupano?      volume = massa / densità

$0.018 \text{ kg di acqua} / 1000 \text{ kg/m}^3 = 1.8 \cdot 10^{-5} \text{ m}^3 = 18 \text{ cm}^3$

$0.058 \text{ kg di NaCl} / 2160 \text{ kg/m}^3 = 26.9 \text{ cm}^3$

1 mole di idrogeno ( $H_2$ ) = 2g di H

1 mole di elio (He) = 4g di He

1 mole di azoto ( $N_2$ ) = 28g di N

$$V = RT / p$$

$$\begin{aligned} \text{volume azoto} &= 8.31 * 273.15 / 1.01325 * 10^5 = \\ &= 2.24 * 10^{-2} \text{ m}^3 = 22.4 \text{ dm}^3 \end{aligned}$$

$$\text{volume molare a STP} = 22.4 \text{ dm}^3$$

### Viewing: Atomic weight

Group Legend

Alkali Metal	Actinides
Alkali Earth	Lanthanides
Metal	Non-metal
Trans. Met.	Halogen
	Noble Gas

1																	18							
1	<b>H</b> 1.0079																	<b>He</b> 4.0026						
2	<b>Li</b> 6.941	<b>Be</b> 9.0122																	<b>B</b> 10.811	<b>C</b> 12.011	<b>N</b> 14.007	<b>O</b> 15.999	<b>F</b> 18.998	<b>Ne</b> 20.18
3	<b>Na</b> 22.99	<b>Mg</b> 24.305																	<b>Al</b> 26.982	<b>Si</b> 28.086	<b>P</b> 30.974	<b>S</b> 32.066	<b>Cl</b> 35.453	<b>Ar</b> 39.948
4	<b>K</b> 39.098	<b>Ca</b> 40.078	<b>Sc</b> 44.956	<b>Ti</b> 47.88	<b>V</b> 50.941	<b>Cr</b> 51.996	<b>Mn</b> 54.938	<b>Fe</b> 55.847	<b>Co</b> 58.933	<b>Ni</b> 58.693	<b>Cu</b> 63.546	<b>Zn</b> 65.39	<b>Ga</b> 69.723	<b>Ge</b> 72.61	<b>As</b> 74.922	<b>Se</b> 78.96	<b>Br</b> 79.904	<b>Kr</b> 83.8						
5	<b>Rb</b> 85.468	<b>Sr</b> 87.62	<b>Y</b> 88.906	<b>Zr</b> 91.224	<b>Nb</b> 92.906	<b>Mo</b> 95.94	<b>Tc</b> (97.91)	<b>Ru</b> 101.07	<b>Rh</b> 102.91	<b>Pd</b> 106.42	<b>Ag</b> 107.87	<b>Cd</b> 112.41	<b>In</b> 114.82	<b>Sn</b> 118.71	<b>Sb</b> 121.76	<b>Te</b> 127.6	<b>I</b> 126.9	<b>Xe</b> 131.29						
6	<b>Cs</b> 132.91	<b>Ba</b> 137.33	<b>La</b> 138.91	<b>Hf</b> 178.49	<b>Ta</b> 180.95	<b>W</b> 183.84	<b>Re</b> 186.21	<b>Os</b> 190.23	<b>Ir</b> 192.22	<b>Pt</b> 195.08	<b>Au</b> 196.97	<b>Hg</b> 200.59	<b>Tl</b> 204.38	<b>Pb</b> 207.2	<b>Bi</b> 208.98	<b>Po</b> (209)	<b>At</b> (210)	<b>Rn</b> (222)						
7	<b>Fr</b> (223)	<b>Ra</b> (226)	<b>Ac</b> (227)	<b>Rf</b> (261.1)	<b>Db</b> (262.1)	<b>Sg</b> (263.1)	<b>Bh</b> (262.1)	<b>Hs</b> (265.1)	<b>Mt</b> (266.1)	<b>Uun</b> (269)	<b>Uuu</b> (272)	<b>Uub</b> (277)												

Lanthanide Series	58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> (144.9)	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.97	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.5	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.93	70 <b>Yb</b> 173.04	71 <b>Lu</b> 174.97
Actinide Series	90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> (237)	94 <b>Pu</b> (244.1)	95 <b>Am</b> (243.1)	96 <b>Cm</b> (247.1)	97 <b>Bk</b> (247.1)	98 <b>Cf</b> (251.1)	99 <b>Es</b> (252.1)	100 <b>Fm</b> (257.1)	101 <b>Md</b> (258.1)	102 <b>No</b> (259.1)	103 <b>Lr</b> (262.1)

**Viewing: Atomic weight**

Date Legend

Undiscovered as of

Isolated by Year: 1840

Pre-1600

	1																	18
1	1 <b>H</b> 1.0079																	2 <b>He</b> 4.0026
2	3 <b>Li</b> 6.941	4 <b>Be</b> 9.0122											5 <b>B</b> 10.811	6 <b>C</b> 12.011	7 <b>N</b> 14.007	8 <b>O</b> 15.999	9 <b>F</b> 18.998	10 <b>Ne</b> 20.18
3	11 <b>Na</b> 22.99	12 <b>Mg</b> 24.305											13 <b>Al</b> 26.982	14 <b>Si</b> 28.086	15 <b>P</b> 30.974	16 <b>S</b> 32.066	17 <b>Cl</b> 35.453	18 <b>Ar</b> 39.948
4	19 <b>K</b> 39.098	20 <b>Ca</b> 40.078	21 <b>Sc</b> 44.956	22 <b>Ti</b> 47.88	23 <b>V</b> 50.941	24 <b>Cr</b> 51.996	25 <b>Mn</b> 54.938	26 <b>Fe</b> 55.847	27 <b>Co</b> 58.933	28 <b>Ni</b> 58.693	29 <b>Cu</b> 63.546	30 <b>Zn</b> 65.39	31 <b>Ga</b> 69.723	32 <b>Ge</b> 72.61	33 <b>As</b> 74.922	34 <b>Se</b> 78.96	35 <b>Br</b> 79.904	36 <b>Kr</b> 83.8
5	37 <b>Rb</b> 85.468	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.906	40 <b>Zr</b> 91.224	41 <b>Nb</b> 92.906	42 <b>Mo</b> 95.94	43 <b>Tc</b> (97.91)	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.6	53 <b>I</b> 126.9	54 <b>Xe</b> 131.29
6	55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33	57 <b>La</b> 138.91	72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.84	75 <b>Re</b> 186.21	76 <b>Os</b> 190.23	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.08	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.38	82 <b>Pb</b> 207.2	83 <b>Bi</b> 208.98	84 <b>Po</b> (209)	85 <b>At</b> (210)	86 <b>Rn</b> (222)
7	87 <b>Fr</b> (223)	88 <b>Ra</b> (226)	89 <b>Ac</b> (227)	104 <b>Rf</b> (261.1)	105 <b>Db</b> (262.1)	106 <b>Sg</b> (263.1)	107 <b>Bh</b> (262.1)	108 <b>Hs</b> (265.1)	109 <b>Mt</b> (266.1)	110 <b>Uun</b> (269)	111 <b>Uuu</b> (272)	112 <b>Uub</b> (277)						

Lanthanide Series	58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> (144.9)	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.97	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.5	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.93	70 <b>Yb</b> 173.04	71 <b>Lu</b> 174.97
Actinide Series	90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> (237)	94 <b>Pu</b> (244.1)	95 <b>Am</b> (243.1)	96 <b>Cm</b> (247.1)	97 <b>Bk</b> (247.1)	98 <b>Cf</b> (251.1)	99 <b>Es</b> (252.1)	100 <b>Fm</b> (257.1)	101 <b>Md</b> (258.1)	102 <b>No</b> (259.1)	103 <b>Lr</b> (262.1)