

Avogadro's Constant (N_A):
Where it Comes From ?
What it Means?
And Who has Measured it?



6.02e23

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Welcome to University of Houston

High School Outreach Program

Spring 2009



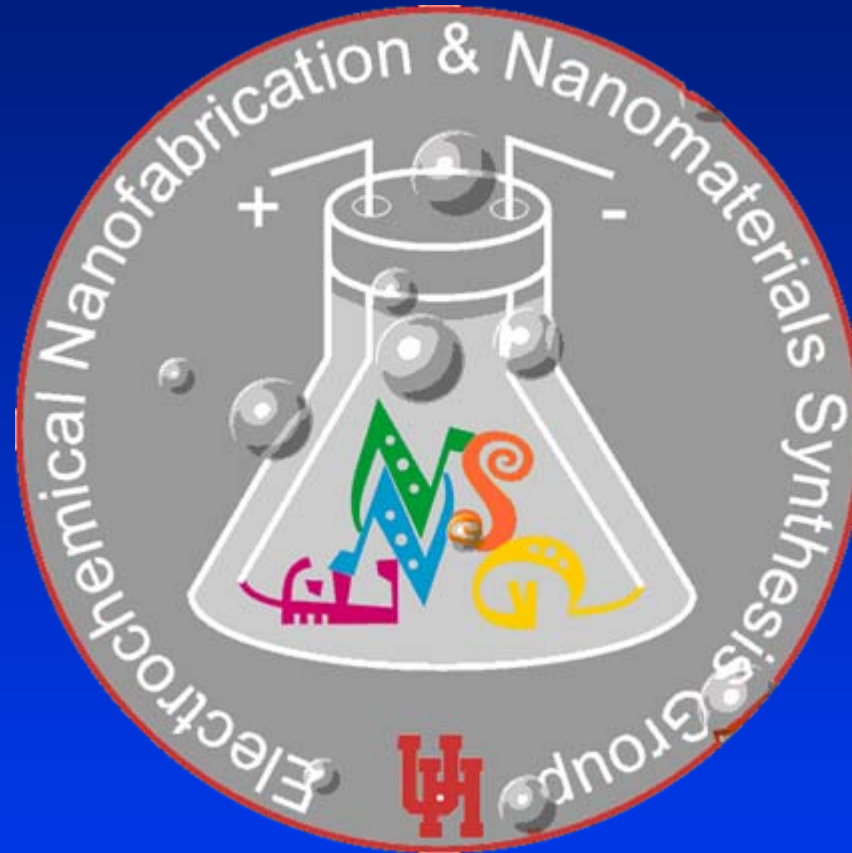
Spring 2010



Fall 2010



Education Material Available at:



www2.egr.uh.edu/~ecnfg/outreach

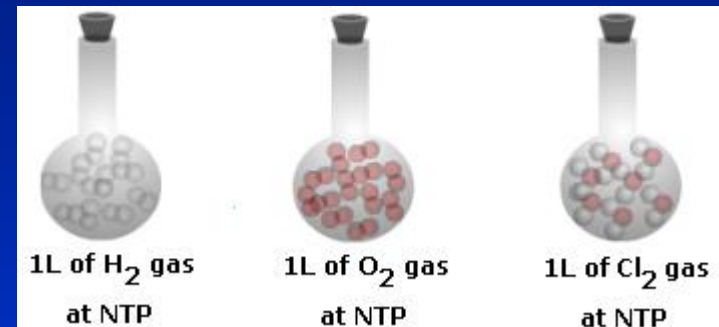
Who is This Funny Looking Italian Guy



Amadeo Avogadro
1776-1856

Equal volumes of gasses under the same conditions of pressure and temperature contain the same number of molecules

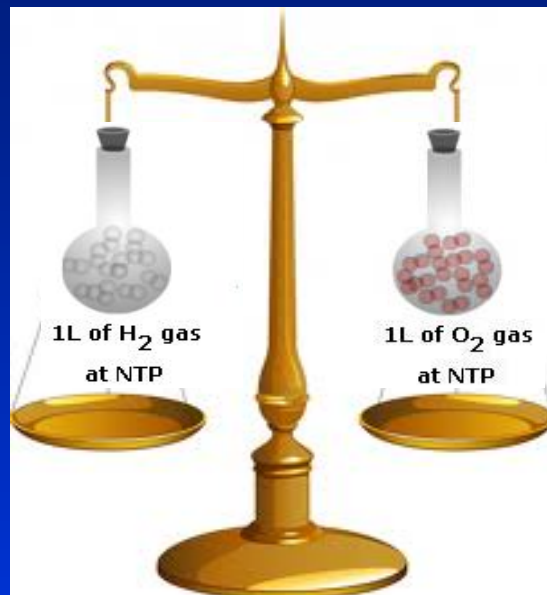
Avogadro's Law



“Volumi eguali di gas nelle stesse condizioni di temperatura e di pressione contengono lo stesso numero di molecole.”
Amadeo Avogadro

An Important Conclusion

Measuring the weight of equal volumes of different gasses we can get the relative weight ration of their atoms/molecules




This fact establishes a fundamental property of different elements and that is their atomic weight or i.e. molar mass

Some hippie Russian guy took this idea further and made the life of all chemists easier



An Epic Agreement:

1 mole of H₂ is 2 g, and 1 mole of O₂ is 32 g



s-block
1 New Designation
IA Original Designation

Atomic #
Symbol
Atomic Mass

Non-Metals
13 14 15 16 17
IIIA IVA VA VIA VIIA

s-block
18
VIIIA

s-block
3 4
Li Be
6.941 9.0122

d-block
Transition Metals
3 4 5 6 7 8 9 10 11 12
IIIB IVB VB VIB VIIB VIIIB IB IIB

p-block
5 6 7 8 9 10
B C N O F Ne
10.81 12.011 14.007 15.999 18.998 20.179

1	1	2											13	14	15	16	17	2
1	H												13	14	15	16	17	He
	1.0094												10.81	12.011	14.007	15.999	18.998	4.00260
2	3	4											5	6	7	8	9	10
2	Li	Be											B	C	N	O	F	Ne
	6.941	9.0122											10.81	12.011	14.007	15.999	18.998	20.179
3	11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
3	Na	Mg	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	IB	IIB	13	14	15	16	17	18	
	22.990	24.305										26.982	28.086	30.974	32.06	35.453	39.948	
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
	39.098	40.08	44.956	47.88	50.942	51.996	54.938	55.847	58.933	58.69	63.546	65.39	69.72	72.59	74.922	78.96	79.904	83.80
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
	85.468	87.62	88.906	91.224	92.906	95.94	(98)	101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.75	127.60	126.91	131.29
6	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
6	Cs	Ba	to 71	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
	132.91	137.33		178.49	180.95	183.85	186.21	190.2	192.22	195.08	196.97	200.59	204.38	207.2	208.98	(209)	(210)	(222)
7	87	88	89	104	105	106	107	108	109	110								
7	Fr	Ra	to 103	Unq	Unp	Unh	Uns	Uno	Une	Uun								
	(223)	226.03		(261)	(262)	(263)	(262)	(265)	(266)	(267)								

(Mass Numbers in Parentheses are from the most stable of common isotopes.)

Phases
Solid
Liquid
Gas

Metals

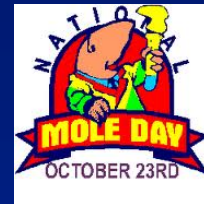
Rare Earth Elements
Lanthanide Series
Actinide Series

d-block
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

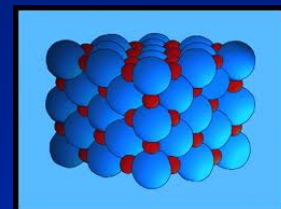
f-block
89 90 91 92 93 94 95 96 97 98 99 100 101 102 103
Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr

Mole is Measure of Quantity of Matter

Mole ; [mol]

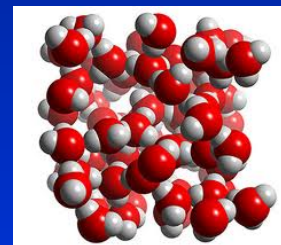


Hydrogen is the lightest element in the periodic table. So it was decided that one mole of this element has 1 g of mass. The molar masses of other elements were established by simple comparison i.e. using the ratio between the mass of 1 mol of H (C) and mass of 1 mol of other elements.



Solid
NaCl

One mole of matter is the certain amount /weight, that contains an arbitrary number of elementary particles (**this number we have to agree on**) having the same property as the bulk of this matter (compounds=molecules, elements=atoms)

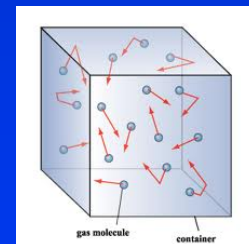


Liquid
H₂O

One mole of any matter has the **same number** of elementary particles (molecules or atoms)

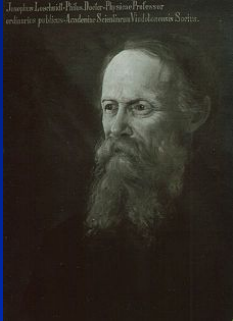
What is this number ?

This is the number of atoms that the weight of 12 g of C₁₂ carbon contains (this is an agreement). Historically, first element to serve as an etalon in definition of mole was oxygen

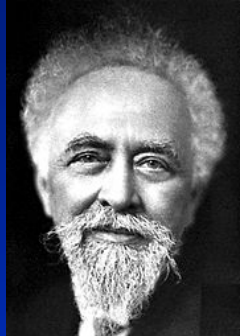


Gas
N₂

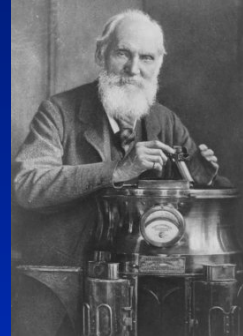
Who Has Measured the N_A First?



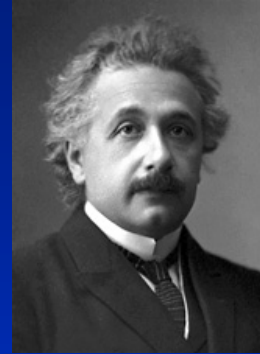
Johann Josef Loschmidt
1821-1895



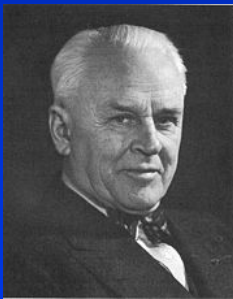
Jean Perrin
1870-1942



Lord William B. Kelvin
1824-1907



Albert Einstein
1879-1955



Robert Millikan
1868-1953

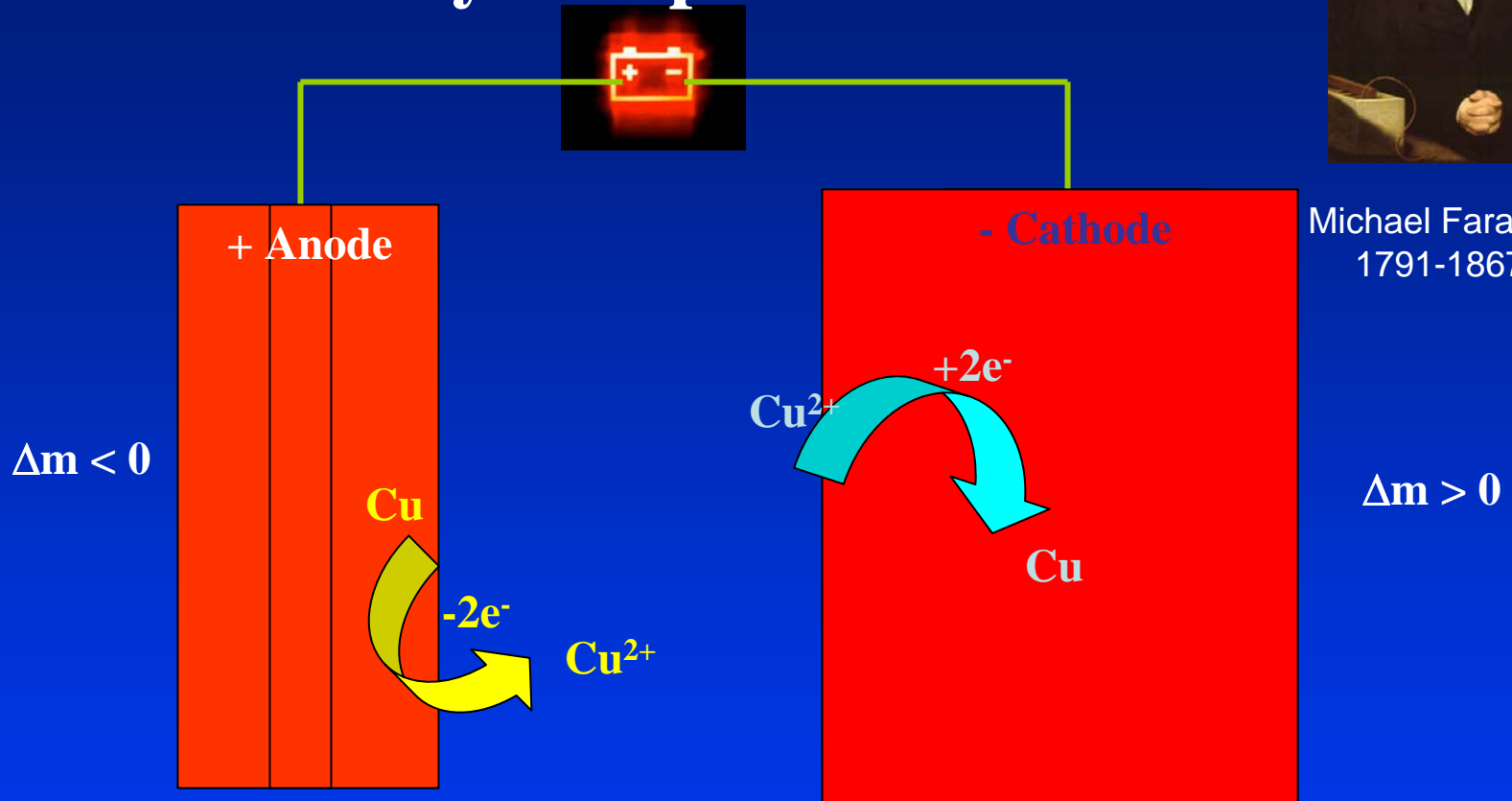
Currently Accepted Consensus for Accurate Value of N_A
(NIST 1971)

$$N_A = 6.0221499 \times 10^{23}$$

Electrochemical Measurement of N_A i.e. Faraday's Experiment

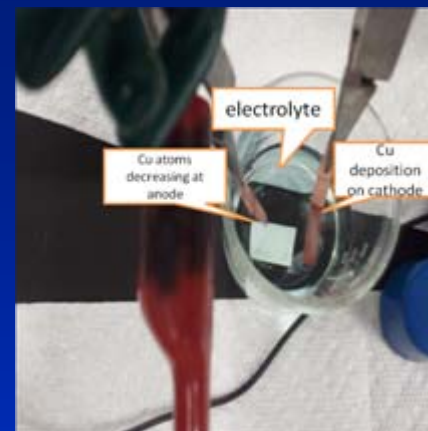
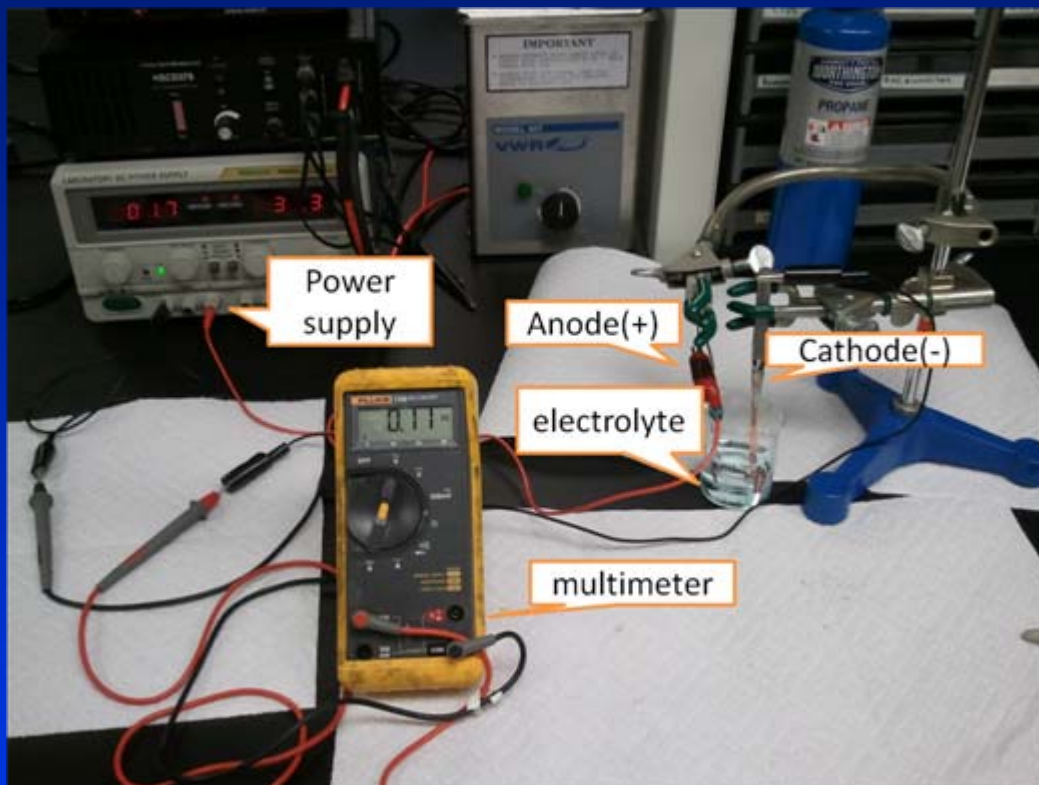


Michael Faraday
1791-1867



Cathode and Anode are Cu
Electrolyte is $0.05 \text{ M H}_2\text{SO}_4$

Experimental Set Up



Time / min	1	2	3	4	5	6	7	8	9	10
Current /A										

Let's Do It, and Let's Measure N_A

1. Average Current:

exp#1 .165A; exp#2 .185A

2.-3. Charge = Average Current*time passed (600 sec)

exp#1 99.6C; exp#2 111C

4. # of electrons passed = Charge / 1.6022×10^{-19} C

exp#1 6.217E2; exp#2 6.928E2

5. Number of Cu Atoms Dissolved = #electrons passed / 2 (Cu = Cu²⁺ + 2e⁻)

exp#1 3.18E2; exp#2 3.464E2

6. Mass of Cu dissolved (Δm)

exp#1 .33g; exp#2 .33g

7. # of Cu atoms per gram = #Cu Atoms dissolved / Δm

exp#1 9.418E21; exp#2 1.49E22

8. N_A = #of Cu atoms per gram * 63.5 g/mol

exp#1 5.98E23; exp#2 6.66E23

$\langle N_A \rangle = 6.32E23$