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Classification

This document consists of 16 pages and 0 figures. (This cover sheet is page 1)

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Nomenclature

Short Title of Document or Addressee of Letter

F. G. Slack

Author

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Col. Serial 100C-M148
File 1.0; 1.1-5

May 20, 1944

Subject: <u>100ZM-563 - Nomenclature</u>

Gentlemen:

Dr. Urey arranged disposition of subject memorandum to SAM personnel, along with the enclosed cover letter. In the interest of increased cooperation and efficiency between the Carbide, Kellex and SAM Groups, we are sending similar memoranda to outside personnel with the hope that there will be a general agreement on this suitable set of symbols, and that their use will avoid misunderstandings that might arise from different nomenclature.

Yours very truly,

L. M. Currie

[redacted]

SECRET

Col.Ser. No. 100UM 568
May 3, 1944

To All SAM Employees Working with Barrier Problems:

With this memorandum there is being transmitted to you a copy of a report by Dr. F.G. Slack, on nomenclature relative to barrier problems. Dr. Slack has prepared this set of symbols and definitions after consultation with all those who seem to be interested in this problem. He has succeeded in getting a set which has been agreed to by most people, with but minor objections. Altogether, it appears that this is as near to agreement on a suitable set of symbols as we are likely to get, and I wish to request that all employees of the SAM Laboratories make use of them in all reports, and in all note-books.

I hope that those who are concerned with this problem will study them carefully and cooperate in avoiding the misunderstandings that arise from different sets of symbols.

Thanking you for your cooperation.

Very sincerely,

Harold C. Urey

Harold C. Urey
Director of Research

SECRET

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NOMENCLATURE

Columbia University April 28, 1944

I. Flow of Gases Through Barriers

Unless otherwise specified, all flow data shall be expressed at 25°C and 76.0 cm Hg at 0°C ($\rho_{Hg} = 13.6$ gm/cm^3)

Notation	Definition
F	General term for flow through a barrier in cc/cm^2/min
T F	Total flow of gas mixture through a barrier expressed in cc/min
F(He-CO_2 50/4)	Flow per unit area of He-CO_2 (40-60) mixture when p_f = 50.0 cm p_b = 4.0 cm (expressed in cc/cm^2/min)
F(N_2 76/25)	Flow per unit area of N_2 when p_f = 76.0 cm and p_b = 25.0 cm (expressed in cc/cm^2/min)
sp fl	Specific flow - cc/cm^2/min/cm Hg Δp. This is commonly limited to use with air and to 25°C. If not qualified sp fl (76/25) understood; otherwise state sp fl (uncorr) or sp fl (p_f/p_b) or sp fl (zero).
Q	Volume flow or velocity of gas, i.e., cc/cm^2/sec or cm/sec (under conditions of measurement which must be specified)
q	Specific mass flow gm/cm^2/sec

[redacted]

Notation	Definition
γ	Permeability = $\dfrac{\text{Measured net flow of gas through barrier}}{\text{Calculated net flow of gas by diffusion only through unit area under the same pressure and temperature conditions.}}$ (See Callihan et al., M-738 (5R-135) and Weil and Slack, M-780 (5-M190).
γ (N_2 76/25) or γ (air 76/25)	γ values for N_2 or air at $p_f = 76.0$ cm; $p_b = 25.0$ cm
γ 76	γ for N_2 or air for $p_f = 76.0$ cm; $p_b = \sim 74$ cm (i.e., Δp small)
γ 0	γ for $p_f + p_b = 0$; for N_2 or air, γ 0 may be taken as measured at $p_f \sim 4$ cm and $p_b \sim 2$ cm (i.e., Δp small).
S	Porosity slope factor (permeability pressure coefficient) defined by the equation: $\gamma = \gamma 0 \left[1 + S\,(p_f + p_b)\right]$ (See "Flow of Gases Through Barrier," 1/21/44, R. M. Deanesly - Columbia Serial No. 100XR-5025)

II. Separation Factors

Notation	Definition
M_h	Molecular weight of heavy component
M_l	Molecular weight of light component
c or N_l	Volume % or mol fraction of light component entering fore pressure side of barrier in control gas
c' or N_l'	Volume % or mol fraction of light component leaving low pressure side of barrier in product gas
c" or N_l''	Volume % or mol fraction of light component in reject gas
(1-c) or N_h	Volume % or mol fraction of heavy component entering fore pressure side of barrier
(1-c') or N_h'	Volume % or mol fraction of heavy component leaving low pressure side of barrier
f	General term for inert gas pair separation; unless otherwise stated it shall refer to (40-60) $He-CO_2$ mixture $$f = \frac{c'}{1-c'} \times \frac{1-c}{c}$$
f*	Ideal separation factor $= \sqrt{\frac{M_h}{M_l}}$
f(50/4)	Separation factor for $He-CO_2$ when measured in a standard turbulent holder at pressures $p_f = 50.0$ cm; $p_b = 4.0$ cm of Hg with C F = 20 ± 1 liters/min. See Jacobsohn, M-498 (10-M163, 2/11/44).
${}^{0.1}_{94\%}f^{75}_{8}$	Separation factor for $He-CO_2$ when measured in a diffusive mixing holder at $p_f = 75.0$ cm; $p_b = 8.0$ cm; cut = θ = 10% and mixing efficiency = E = 94%
${}^{\theta}_{E}f^{p_f}_{p_b}$	General form for above
s	Separation efficiency $= \frac{\log f}{\log f^*} \times 100\%$

Notation	Definition
α	General separation factor for C-616
α^*	Ideal separation factor for C-616
${}^{.1}_{93\%}\alpha^{20}_{4}$ or ${}^{.1}_{93\%}(\alpha-1)^{20}_{4}$	α or $(\alpha-1)$ when $p_f = 20.0$ cm, $p_b = 4.0$ cm, $\theta = 0.1$, $E = 93\%$
ϵ	$(\alpha-1)\ln 2$ (See B. A. Jacobsohn, 1C-M162, 2/10/44)
δ	$(\alpha-1)$

III. Cut and Mixing

Notation	Definition
C F	Circulation flow (measured at entrance to barrier holder) liters/min at 25°C and H = 76.0 cm
θ	Cut = $\frac{T\ F}{C\ F}$ (See A-763, page 16, B. A. Jacobsohn)
h	Half width of channel in case of two barriers or the distance from barrier to wall with single barrier
$\bar{u}$	Average velocity along channel in cm/sec
E	Mixing efficiency (See A-763, 1R-168, page 18, B. A. Jacobsohn)

IV. Temperature

In general, 25°C shall be considered standard temperature for measurements.

Notation	Definition
T	Temperature °K
$t^{o}C$	Temperature °C
T_f	Temperature °K at which a flow of gas takes place
T_m	Temperature of measurement °K

[redacted]

V. Pressure

Unless otherwise specified, all pressures should be stated in cm of Hg of density 13.6 gm/cm^3. (I.e., corrected to $0^\circ C$)

Notation	Definition
p	General term for pressure
p_f	Pressure at barrier on high pressure side of any barrier (fore pressure)
p_b	Pressure on low pressure side of any barrier (back pressure)
$\bar{p}$	Average of pressures on the high and low pressure sides of a barrier = $\frac{p_f + p_b}{2}$
Δp	Pressure drop across a barrier = $p_f - p_b$
H	Barometric pressure expressed in cm of Hg at $0^\circ C$
h	Water vapor pressure cm Hg at $0^\circ C$
p^*	Characteristic pressure, i.e., pressure at which $_{100^\circ C}f^{p^*} = 2.00$ (Pontius, R.G. Tests, A-1219; 1-R418)
P50; P65; P80	Pressures at which separation efficiency, s = 50%, 65%, 80%, etc.

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Partial pressures should be stated as such.

Reduced pressure may be stated as p/p^* when separation factor f is used; when separation efficiency s is used, the expression should be p/P65.

Shape factor of $f - p_f$ curve may be stated as P65/P85.

VI. Physical Constants

Notation	Definition
ρ	Density in gm/cm^3
λ	Mean free path in cm
c_p	Specific heat of a gas (constant pressure)
c_v	Specific heat of a gas (constant volume)
$\gamma = c_p/c_v$	Ratio specific heats of a gas
$D \sim \eta/\rho$	Diffusive coefficient
k	Thermal conductivity for vapor
η	Viscosity - poises or $dyne\text{-}sec/cm^2$
σ	Effective molecular diameter for collision of specified gas, i.e., σHe
σ	Standard deviation from mean
a_o	Edge of cubic cell
c_o	Lattice constant
g	Gravity constant = 980.27 cm/sec^2 in NYC
M	Molecular weight
n_o	Number of molecules per unit volume
$\bar{v}$	Average molecular velocity = $14.55 \times 10^3 \sqrt{T}/\sqrt{M}$ cm/sec
N_o	Avogadro's number = 6.023×10^{23} per gm mol
Re	Reynold's number
R	Gas constant per gm mol = 83.14×10^6 ergs/°C/gm mol
$\bar{V}$	Molar volume of gas

VII. British Terms (See 100XR-4962)

Notation	Definition
$G = \gamma 76/\gamma 0$	Gamma ratio - this may be related to the porosity slope factor (S) as defined by Deanesly by the equation $G = 1 + 150S$
$B = \frac{1}{G-1}$	
P65	Pressure in mm of Hg at which s = 0.65 for a 50/50 molar percent mixture of CO_2 and N_2
$L65 = \frac{P65}{B} = P65(G-1)$	See N. Kurti letter of 4/8/44 to G. Scatchard
ϵ	Defined by the equation $\Delta c = \epsilon c(1-c)$
s	Separation efficiency $= \epsilon/\epsilon_0$

NOTE:-

The definitions of s, ϵ, and P65 given here as used by the British are slightly different from the meanings given on pages 4, 5, and 7 in the American definitions. Unless specified, the American meaning will be assumed when these symbols are used.

VIII. Miscellaneous

Notation	Definition
r	Running number of stages in cascade
d	Hole diameter
$\bar{d}$	Average hole diameter
r	Hole radius
$\bar{r}$	Average hole radius
t	Time in seconds

Alphabetical List of Nomenclature

Notation	Definition
a_o	Edge of cubic cell
B (British)	$\frac{1}{G-1}$
c or N_1	Volume % or mol fraction of light component entering high pressure side of barrier in control gas
(1-c) or N_h	Volume % or mol fraction of heavy component entering high pressure side of barrier
c' or N_1'	Volume % or mol fraction of light component leaving low pressure side of barrier in product gas
(1-c') or N_h'	Volume % or mol fraction of heavy component leaving low pressure side of barrier
c" or N_1''	Volume % or mol fraction of light component in reject gas
C F	Circulation Flow (measured at entrance to barrier holder). Liters/min at 25°C and H = 76.0 cm
c_o	Lattice constant
c_p	Specific heat of gas (constant pressure)
c_v	Specific heat of gas (constant volume)
d	Hole diameter
$\bar{d}$	Average hole diameter
D ~ η/ρ	Diffusive coefficient
E	Mixing Efficiency (See A-763, 1R-168, page 18, B. A. Jacobsohn
F	General term for flow through barrier in $cc/cm^2/min$

Notation	Definition
F(He-CO_2 50/4)	Flow per unit area of He-CO_2 (40-60) mixture when p_f = 50.0 cm p_b = 4.0 cm (expressed in cc/cm^2/min)
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f	General term for inert gas pair separation; unless otherwise stated it shall refer to (40-60) He-CO_2 mixture $$f = \frac{c'}{1-c'} \times \frac{1-c}{c}$$
f*	Ideal separation factor $= \sqrt{\frac{M_h}{M_l}}$
f(50/4)	Separation factor for He-CO_2 when measured in a standard turbulent holder at pressures p_f = 50.0 cm; p_b = 4.0 cm of Hg with C F = 20 ± 1 liters/min. See Jacobsohn, M-498 (10-M163, 2/11/44)
${}^{0.1}_{94\%}f^{75}_{8}$	Separation factor for He-CO_2 when measured in a diffusive mixing holder at p_f = 75.0 cm; p_b = 8.0 cm; cut = θ = 10% and mixing efficiency = E = 94%
${}^{\theta}_{E}f^{p_f}_{p_b}$	General form for above
G (British)	$\gamma 76/\gamma 0$ = Gamma ratio - this may be related to the porosity slope factor (S) as defined by Deanesly by the equation G = 1 + 150S
g	Gravity constant = 980.27 cm/sec^2 in NYC
H	Barometric pressure expressed in cm of Hg at 0°C
h	Half width of channel in case of two barriers or the distance from barrier to wall with single barrier
h	Water vapor pressure cm Hg at C°C

Notation	Definition
k	Thermal conductivity for vapor
L65 (British)	$\frac{P65}{B} = P65(G-1)$ See N. Kurti letter of 4/8/44 to G. Scatchard
M	Molecular weight
M_h	Molecular weight of heavy component
M_l	Molecular weight of light component
N_l or c	Volume % or mol fraction of light component entering fore pressure side of barrier in control gas
N_l' or c'	Volume % or mol fraction of light component leaving low pressure side of barrier in product gas
N_h or (1-c)	Volume % or mol fraction of heavy component entering fore pressure side of barrier
N_h' or (1-c')	Volume % or mol fraction of heavy component leaving low pressure side of barrier
N_l'' or c''	Volume % or mol fraction of light component in reject gas
n_o	Number of molecules per unit volume
N_o	Avogadro's number = 6.023×10^{23} per gm mol
p	General term for pressure
p_f	Pressure at barrier on high pressure side of any barrier (fore pressure)
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$\bar{p}$	Average of pressures on the high and low pressure sides of a barrier = $\frac{p_f + p_b}{2}$

[redacted]

Notation	Definition
Δp	Pressure drop across a barrier $= p_f - p_b$
p^*	Characteristic pressure, i.e., pressure at which $_{100}{}^{o}f^{p^*}_{c} = 2.60$ (Bontius, P. G. Tests, A-1219; 1-R418)
P50; P65; P80	Pressures at which separation efficiency, s = 50%, 65%, 80%, etc.
P65 (British)	Pressure in mm of Hg at which s = 0.65 for a 50/50 molar percent mixture of CO_2 and N_2
Q	Volume flow or velocity of gas, i.e., $cc/cm^2/sec$ or cm/sec (under conditions of measurement which must be specified)
q	Specific mass flow $gm/cm^2/sec$
R	Gas constant per gm mol $= 83.14 \times 10^6$ ergs/°C/gm mol
Re	Reynold's number
r	Running number of stages in cascade
r	Hole radius
$\bar{r}$	Average hole radius
S	Porosity slope factor (permeability pressure coefficient) defined by the equation: $\gamma = \gamma_0 \left[1 + S\,(p_f + p_b) \right]$ (See "Flow of Gases Through Barrier," 1/21/44, R.M. Deanesly - Columbia Serial No. 100XR-5025)
s	$\dfrac{\log f}{\log f^*} \times 100\% =$ separation efficiency

[redacted]

Notation	Definition
s (British)	ϵ/ϵ_o = separation efficiency
sp fl	Specific flow - cc/cm^2/min/cm Hg Δp. This is commonly limited to use with air ________ and to 25°C. If not qualified sp fl (76/25) understood; otherwise state sp fl (uncorr) or sp fl (p_f/p_b) or sp fl (zero).
T	Temperature °K
T_f	Temperature °K at which a flow of gas takes place
T_m	Temperature of measurement °K
t°C	Temperature in °C
t	Time in seconds
T F	Total flow of gas mixture through a barrier expressed in cc/min
$\bar{u}$	Average velocity along channel in cm/sec
$\bar{v}$	Average molecular velocity = $14.55 \times 10^3 \sqrt{T}/\sqrt{M}$ cm/sec
$\bar{V}$	Molar volume of gas
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α^*	Ideal separation factor for C-616
$\overset{.1}{_{93\%}}\alpha^{20}_{4}$ or $\overset{.1}{_{93\%}}(\alpha-1)^{20}_{4}$	α or $(\alpha-1)$ when p_f = 20.0 cm, p_b = 4.0 cm θ = 0.1, E = 93%
ϵ	$(\alpha-1)\ln 2$ (See B. A. Jacobsohn, 1C-M162, 2/10/44)
ϵ (British)	Defined by the equation $\Delta c = \epsilon c(1-c)$
σ	$(\alpha-1)$
γ	$\frac{c_p}{c_v}$ Ratio of specific heats of gases

Notation	Definition
γ	Permeability = $\dfrac{\text{Measured net flow of gas through barrier}}{\text{Calculated net flow of gas by diffusion only through unit area under the same pressure and temperature conditions.}}$ (See Callihan et al., M-738 (5R-135) and Woil and Slack, M-780 (5-M190).
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γ 76	γ for N_2 or air for p_f = 76.0 cm; p_b = ~74 cm (i.e., Δp small)
γ 0	γ for $p_f + p_b = 0$; for N_2 or air, γ 0 may be taken as measured at $p_f \sim 4$ cm and $p_b \sim 2$ cm (i.e., Δp small)
λ	Mean free path in cm
ρ	Density in gm/cm^3
η	Viscosity - poises or dyne-sec/cm^2
σ	Effective molecular diameter for collision of specified gas, i.e., σ_{He}
σ	Standard deviation from mean
θ	$\dfrac{T\ F}{C\ F}$ = cut (See A-763, page 16, B. A. Jacobsohn)