TRANSPORT AND REACTION PROPERTIES

Table 13.2-1 Properties of Common Incompressible, Newtonian Fluids at 37^{o}C

Fluid	**Shear Viscosity μ (Pa-s)**	**Density ρ(kg/m^3)**	**Kinematic Viscosity $\upsilon \equiv \mu/\rho$(m^2/s)**
Air	1.90×10^{-5}	1.14	1.67×10^{-5}
Water	6.93×10^{-4}	$9.94\text{x}10^{2}$	6.98×10^{-7}
Blood Plasma	1.2×10^{-3}	$1.02\ \text{x}10^{3}$	1.18×10^{-6}
Blood (high shear rates)	3×10^{-3}	$1.05\ \text{x}10^{3}$	2.86×10^{-6}
Glycerin	0.313	$1.25\ \text{x}10^{3}$	2.49×10^{-4}

Table 7.2-1 Atomic and Molecular Volumes
for the Fuller Prediction of Gas-Phase Diffusion Coefficients*

Atoms and Atomic Increments: $\hat{\upsilon}(10^{-3}\,m^3 / kg\ atom)$			
C	16.5	(Cl)	19.5
H	1.98	(S)	17.0
O	5.48	Aromatic ring	-20.2
(N)	5.69	Heterocyclic ring	-20.2
Simple Molecules: $\hat{\upsilon}(10^{-3}\,m^3 / kg\ atom)$			
H_2	7.07	CO	18.9
D_2	6.70	CO_2	26.9
He	2.88	N_2O	35.9
N_2	17.9	NH_3	14.9
O_2	16.6	H_2O	12.7
Air	20.1	$(CC1_2F_2)$	114.8
Ar	16.1	(SF_6)	69.7
Kr	22.8	$(C1_2)$	37.7
(Xe)	37.9	(Br_2)	67.2
Ne	5.59	(SO_2)	41.1

*Parentheses indicate that the listed value is based on only a few data points.

Table 7.3-1 Atomic and Molecular Volumes
for the Wilke-Chang Prediction of Liquid-Phase Diffusion Coefficients

Atoms and Atomic Increments: $\hat{\upsilon}(10^{-3}\,m^3\,/\,kg\ atom)$			
Bromine	27.0	Oxygen in methyl esters	9.1
Carbon	14.8	Oxygen in higher esters	11.0
Chlorine	24.6	Oxygen in acids	12.0
Hydrogen	3.7	Oxygen in methyl ethers	9.9
Iodine	37.0	Oxygen in higher ethers	11.0
Nitrogen	15.6	Sulfur	25.6
Nitrogen in primary amines	10.5	Benzene ring	-15.0
Nitrogen in secondary amines	12.0	Naphthalene ring	-30.0
Oxygen	7.4		
Simple Molecules: $\hat{\upsilon}(10^{-3}\,m^3\,/\,kg\ atom)$			
Air	29.9	H_2S	32.9
Br_2	53.2	I_2	71.5
$C1_2$	48.4	N_2	31.2
CO	30.7	NH_3	25.8
CO_2	34.0	NO	23.6
COS	51.5	N_2O	36.4
H_2	14.3	O_2	25.6
H_2O	18.9	SO_2	44.8

Table 7.3-2 Ionic Conductances at Infinite Dilution in Water at 25°C
for the Prediction of Ionic Mobilities
(Abstracted from Perry *et al.*, 1963)

Cation (c)	Λ_c^∞ [cm^2/(ohm-eq)]	Anion (a)	Λ_a^∞ [cm^2/(ohm-eq)]
Ag^+	61.9	Br^-	78.4
Ba^{2+}	63.6	Cl^-	76.35
H^+	349.8	ClO_3^-	64.6
Li^+	38.7	ClO_4^-	67.4
Na^+	50.10	F^-	55.4
K^+	73.5	I^-	76.8
NH_4^+	73.6	NO_3^-	71.46
Ca^{2+}	59.5	OH^-	198.6
Cu^{2+}	56.6	CO_3^{2-}	69.3
Mg^{2+}	53.0	SO_4^{2-}	80.0
Zn^{2+}	52.8	$Acetate^-$	40.9

Table 7.3-3 Effect of Temperature on Limiting Ionic Conductance*
(Abstracted from Perry *et al.*, 1963)

Ion	A_1	$A_2 \times 10^2$	A_2 x 10^4
H^+	4.816	-1.031	-0.767
Li^+	0.890	0.441	-0.204
Na^+	1.092	0.472	-0.115
K^+	1.433	0.406	-0.318
Cl^-	1.540	0.465	-0.128
Br^-	1.544	0.447	-0.230
I^-	1.509	0.438	-0.217

$$^{*}\ \Lambda_i^o(T) = \Lambda_i^o(25^oC) + A_1\left[T(^oC) - 25\right] + A_2\left[T(^oC) - 25\right]^2 + A_3\left[T(^oC) - 25\right]^3$$

Table A4-1. Diffusion Coefficients for Binary Gases at 101.3 kPa (Hines and Maddox, 1985)

System	$\mathcal{D}_{12}$ (10^{-4} m^2/s)	T (^oK)
Air-carbon dioxide	0.177	317.2
Air-ethanol	0.145	313
Air-helium	0.765	317.2
Air-water	0.288	313
Carbon dioxide-argon	0.133	276.2
Carbon dioxide-helium	0.612	298
Carbon dioxide-nitrogen	0.167	298
Carbon dioxide-nitrous oxide	0.128	312.8
Carbon dioxide-sulfur dioxide	0.064	263
Carbon dioxide-water	0.198	307.2
Helium-benzene	0.610	423
Helium-ethanol	0.821	423
Helium-water	0.902	307.1
Hydrogen-ammonia	0.783	298
Hydrogen-benzene	0.404	311.3
Hydrogen-cyclohexane	0.319	288.6
Hydrogen-methane	0.694	288
Hydrogen-sulfur dioxide	1.23	473
Hydrogen-water	1.121	328.5
Nitrogen-ammonia	0.2230	298
Nitrogen-benzene	0.102	311.3
Nitrogen-carbon monoxide	0.318	373
Nitrogen-helium	0.687	298
Nitrogen-hydrogen	0.784	298
Nitrogen-sulfur dioxide	0.104	263
Nitrogen-water	0.256	307.5
	0.359	352.1
Oxygen-benzene	0.101	311.3
Oxygen-carbon dioxide	0.153	293.2
Oxygen-carbon tetrachloride	0.0749	296
Oxygen-helium	0.729	298
Oxygen-nitrogen	0.181	273.3
Oxygen-water	0.352	352.3

Table A4-2. Diffusion Coefficients at Infinite Dilution in Water (Cussler, 1997, Snell *et al*., 1965, p 204)

Solute s	$\mathcal{D}_s^\infty$ (10^{-9} m^2/sec)	T (°C)
Acetone	1.16	25
Air	2.00	25
Ammonia	1.64	25
Argon	2.00	25
Benzene	1.02	25
Carbon dioxide	1.92	25
Carbon monoxide	2.03	25
Chlorine	1.25	25
Helium	6.28	25
Hydrogen	4.50	25
Hydrogen sulfide	1.41	25
Methane	1.49	25
Nitric oxide	2.60	25
Nitrogen	1.88	25
Oxygen	2.10	25
Ethanol	0.84	25
Methanol	0.84	25
n-Butanol	0.77	25
Propanol	0.87	25
Acetic acid	1.21	25
Benzoic acid	1.00	25
Formic acid	1.50	25
Nitric acid	2.60	25
Propionic acid	1.06	25
Sulfuric acid	1.73	25
Human Serum Albumin	0.061	20
Fibrinogen	0.020	25
Glucose	0.673	20
Glycine	1.06	25
Hemoglobin	0.069	25
Ovalbumin	0.078	25
Phenylalanine	0.705	25
Ribonuclease	0.102	20
Sucrose	$(0.5228-0.265C_s)^+$	25
Tryptophan	0.659	25
Urea	$(1.380-0.0782C_s+0.00464C_s^2)^+$	25
Urease	0.035	25
Valine	0.83	25

$^+$Diffusion coefficients as a function of solute concentration C_s[mol/L].

Table A4-3. Oxygen and Carbon Dioxide Diffusion in Fluids and Tissues (Altman and Dittmer, 1971, p 21-22)

Medium	$\mathcal{D}_s$ (10^{-9} m^2/s)	α_s 10^{-5}ml(STP)/(ml-Pa)	T* (°C)
	s=Oxygen		
Water	2.30	0.031	20
Water	2.85	0.026	30
Water	3.30	0.024	37
Gelatin (15%)	$\alpha_1\mathcal{D}_{12} = 4.6\times10^{-16}$ m^2/(s-Pa)		20
Methemoglobin (8% sol'n.)	1.87	0.025	25
Methemoglobin (33% sol'n.)	0.70	0.033	25
Serum protein (8% sol'n.)	1.85	0.025	25
Serum protein (30% sol'n.)	0.77	---	25
Connective tissue (dog)	0.97	0.023	37
Connective tissue (frog)	0.62	0.031	20
Erythrocytes (human)	. $\alpha_1\mathcal{D}_{12} = 2.1\times10^{-16}$ m^2/(s-Pa)		20
Lung tissue (rat)	2.30	0.018	37
Muscle (frog)	0.75	0.031	20
Muscle (frog)	1.17	0.023	37
Myocardial tissue (rat)	1.50	0.021	20
Serum (ox)	1.87	0.021	37
	s=Carbon Dioxide		
Water	1.85	0.684	25
Water	2.18	0.521	35
Water	2.55	0.560	37
Hemoglobin (33% sol'n.)	0.83	0.65	22
Hemoglobin (33% sol'n.)	1.17	0.43	37
Brain tissue	1.00	0.96	22
Connective tissue (frog)	0.88	0.76	20
Diaphragm (dog)	0.60	0.72	22
Erythrocytes (ox)	0.83	0.65	22
Muscle (dog)	1.00	0.77	22
Muscle (frog)	1.95	0.77	22
Nerve	0.12	0.77	22
Skin (frog)	0.70	0.72	22
Smooth muscle (cat)	1.07	0.77	22

* $\mathcal{D}_s$ increases by about 2% per increase of 1°C in temperature.

Specific Permeability $\hat{P}_s^G$ [10^{-12} ml(STP)/(s-m-Pa)] of Gases Through Homogeneous Synthetic Membranes at 37°C

(Adapted from Galletti, 1968)

Gas, s / Material	Oxygen	Carbon Dioxide	Nitrogen	Helium
Silicone Rubber	4910	24600	2450	3200
Teflon	126	304	63.8	748

Table 8.5-1 Enzyme Reaction Rate Parameters
(Zubay *et al.*, 1993)

Enzyme	**Substrate**	**$k_{cat}(s^{-1})$**	**K_m(mol/L)**
Acetylcholinesterase	Acetylcholine	1.4×10^4	9×10^{-5}
Carbonic Anhydrase	CO_2	1×10^6	0.012
Carbonic Anhydrase	HCO_3^-	4×10^5	0.026
Catalase	H_2O_2	4×10^7	1.1
Crotonase	Crotonyl-CoA	5.7×10^3	2×10^{-5}
Fumarase	Funarate	800	5×10^{-6}
Fumarase	Malate	900	2.5×10^{-5}
β–Lactamase	Benzylpenicillin	2.0×10^3	2×10^{-5}

Table 8.5-2 Activation Energies (ΔE_a*) of Some Catalytic Reactions
(Snell *et al*, 1965, p. 352)

Reaction	**Catalyst**	**Act. Energy (kJ)**
Sucrose → Glucose + Fructose	Acid (pH<<7)	108.8
	Invertase	48.1
$2H_2O_2 \rightarrow 2H_2O + O_2$	None	75.3
	Colloidal Platinum	49.0
	Liver Catalase	20.9