

MCAT Formula Sheet

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1 Mechanics

1.1 Translational Motion

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$v_f = v_0 + a t$$

$$v_f^2 = v_0^2 + a t$$

1.2 Force

Center of Mass

$$com = \frac{m_1 x_1 + m_2 x_2}{x_1 + x_2}$$

Newtons 1st Law

inertia, momentum, impulse

*Newtons Second Law

$$F = m a$$

$$Weight = F_g = m g$$

Frictional Force

$$f_{max} = \mu N$$

$$\mu_k < \mu_s \dots \text{always}$$

Uniform Circular Motion

$$F_c = m a_{circ.} = \frac{m v^2}{r}$$

$$a_{circ.} = \frac{v^2}{r}$$

Inclined Plan

$$F_{normal} = m g \cos \theta$$

1.3 Equilibrium

Torque Forces

$$\tau = \mathbf{F} \cdot \mathbf{d}$$

Tension on Pendulum

$$T = m g \cos \theta$$

1.4 Work

* Work

$$W = F d \cos \theta$$

$$W_{total} = \Delta E$$

*Kinetic Energy

$$KE = \frac{1}{2} m v^2$$

Units: Joules = N*m

*Potential Energy

$$U_{gravity} = m g h$$

$$U_{spring} = \frac{1}{2} k x^2$$

Conservation of Energy

$$E_{total} = KE + U$$

$$\Delta E = \Delta K + \Delta U = 0$$

$$E = m c^2$$

Power

$$P = \frac{\Delta W}{\Delta t}$$

Units: watt = J/s

*Spring Force and Work

$$F = -k x$$

$$W = \frac{1}{2} k x^2$$

2 Fluids

2.1 Hydrostatics

Specific Gravity

SG = %object submerged

$$SG = \frac{\rho_{\text{substance}}}{\rho_{\text{water}}} = \frac{\text{height above surf}}{\text{total height}}$$
$$\rho_{\text{water}} = \frac{1g}{cm^3} = \frac{10^3 kg}{m^3}$$

Archimedes Principle

$$F_{\text{buoy}} = \rho_{\text{fluid}} g V_{\text{submerged}}$$

= weight of volume of displaced fluid

$$V_{\text{submerged object}} = V_{\text{displaced fluid}}$$

Pressure

$$P = \frac{F}{A}$$

$$\text{units: Pa} = \frac{N}{m^2}$$

Static Pressure

- pressure of object submerged in fluid

$$P_{\text{fluid}} = \rho g h$$

h is height of fluid above object

Absolute Pressure

- adds atm pressure for open container

$$P_{\text{total}} = P_{\text{atm}} + P_{\text{fluid}} = P_{\text{atm}} + P_{\text{gauge}}$$
$$= P_{\text{atm}} + \rho g h$$

Gauge Pressure

- pressure due to liquid alone

$$P_{\text{gauge}} = P_{\text{total}} - P_{\text{atm}} = P_{\text{fluid}}$$

Weight

$$F_g = \rho g V = mg$$

Pascals Principle

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2} \text{ (equal pressure)}$$

$$A_1 d_1 = A_2 d_2 \text{ (same } \Delta V \text{)}$$

$$W = F_1 d_1 = F_2 d_2 \text{ (energy conserved)}$$

small force, small area, big distance

- large force, large area, small distance

Float or Sink?

$$\rho_{\text{fluid}} V_{\text{disp}} g = mg$$

$$\Rightarrow \rho_{\text{fluid}} V_{\text{disp}} = \rho_{\text{obj}} V_{\text{obj}}$$

$$\Rightarrow \frac{V_{\text{disp}}}{V_{\text{obj}}} = \frac{\rho_{\text{obj}}}{\rho_{\text{fluid}}}$$

2.2 Flow

Viscose Force

$$F_{\text{viscosity}} = \eta A \frac{V}{d}$$

$$\text{Unit of } \eta = \frac{F d}{A V} = Pa \cdot s$$

$$1 \text{ Poise} = \frac{1}{10} Pa \cdot s$$

Poiseuille Flow

$$\frac{V}{t} = \frac{\Delta P \pi R^4}{8 \eta L}$$

* Continuity Eqn

$$A v = \text{constant}$$

$$\rho A v = \text{constant}$$

$$A_1 V_a = A_2 V_2$$

Turbulence

$$V_{\text{critical}} = \frac{R \eta}{2 \rho r}$$

Surface Tension

Bernoulli's Equation

$$p + \frac{1}{2} \rho V^2 + \rho g h = \text{constant}$$

Venturi Effect

2.3 Gas Phase

Kelvin Scale

STP

0C or 273K, 1 atm

1mole @STP = 22.4L

2.3.1 Ideal

* Ideal Gas Law

$$PV = nRT$$

* Avagadros Principle

$$\frac{n}{V} = k$$

* Boyles Law

$$PV = k$$

$$P_1V_1 = P_2V_2$$

* Charles Law

$$\frac{V}{T} = k$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

G-L Law

$$\frac{P}{T} = k$$

Combined Gas Law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

2.3.2 Non-ideal

Vanderwalls Eqn of State

$$(P + \frac{n^2a}{V^2})(V - nb) = nRT$$

$$P_1 = P_o + a \left[\frac{n}{v} \right]^2$$

$$V_1 = V_c - nb$$

n is # of moles

a is a +/- constant

b is a constant

2.3.3 Partial Pressure

Mole Fraction

$$X_A = \frac{n_A}{n_T} = \frac{\text{moles } A}{\text{mole total}}$$

Daltons Law of Partial Pressures

$$P_T = P_A + P_B + P_c + ..$$

$$P_A = P_T X_A$$

Henrys Law?

2.3.4 KineticMT

Average Molecular Speed

$$k = \frac{1}{2}mv^2 = \frac{3}{2}k_B T$$

Root Mean Square

$$U_{rms} = \sqrt{\frac{sRT}{M}}$$

3 Electromagnetism

3.2 Magnetism

3.1 Electrostatics

Coulombs Law

$$F = k_e \frac{q_1 q_2}{r^2}$$

Electric Field

$$E = \frac{F_e}{q} = \frac{kQ}{r^2}$$

Q is source charge of E field

q is the charge feeling the E field

Units: $\frac{N}{C}$ or $\frac{V}{m}$

Electric Potential Energy

$$U = q\Delta V = qEd = k_e \frac{qQ}{r}$$

“work to move to point from ∞ ”

Electric Potential

$$V = \frac{U}{q}$$

Units: J/C

Definition of magnetic field B

Motion of charged particles in magnetic fields; Lorentz force

3.3 Circuits

*Current

$$I = \frac{Q}{\Delta t}$$

Units: Amps=C/s

Potential Difference (Voltage)

$$\Delta V = \frac{W}{q} = \frac{kQ}{r}$$

Units: J/c

Same as **EMF** in batteries

Kirchoff's Laws

????????? what do these mean

Conductivity: Metallic

Conductivity: Electrolytic

Meters

3.3.2 Capacitance

Capacitance

$$C = \frac{Q}{V}$$

Parallel Plates

$$V = Ed$$

Energy Storage

$$U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$$

Parallel Capacitors

$$C_{eq} = C_1 + C_2 + \dots$$

Serial Capacitors

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

Dialectrics?

3.3.1 Resistance

Resistivity

$$R = \frac{\rho L}{A}, \text{ where } \rho \text{ is some constant}$$

* Ohms Law

$$V = IR$$

Serial Resistors

$$R_{equiv} = R_1 + R_2 + \dots$$

Parallel Resistors

$$\frac{1}{R_{equiv}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

Power Dissipated by Resistors

$$P = IV = \frac{V^2}{R} = I^2 R$$

3.4 Electrochemistry

Galvanic vs Electrolytic

	Galvanic	Electrolytic
ΔG°	(-)	(+)
EMF	(+)	(-)
Sign of an	(-)	(+)
Sign of cat	(+)	(-)

For both types, "AnOx RedCat"

= Ox @ an, Red@ cat

$\Rightarrow e^-$ flow from an to cat

Standard Reduction Potential

$\uparrow E^\circ \Rightarrow \uparrow \text{Probability its reduced}$

(see Gibbs Free Energy below)

Standard EMF (induced voltage)

$$E_{cell}^\circ = E_{red}^\circ + E_{cat}^\circ$$

measured under standard conditions

Gibbs Free Energy

$$\Delta G^\circ = -nFE^\circ$$

$$\Delta G^\circ = -RT \ln K_{eq}$$

$$\Rightarrow E^\circ = \frac{RT}{nF} \ln K_{eq}$$

F=Faradays Constant $\sim 10^5$

R=gas constant ~ 8

n=moles of e^- transferred

RT/F has units of volts

Nernst Equation

$$E = E^\circ - \frac{RT}{nF} \ln Q$$

(comes from: $\Delta G = \Delta G^\circ + RT \ln Q$)

$\uparrow Q \Rightarrow \downarrow E$

Faradays Law of Electrolysis

$$It = nF$$

n = moles of e^-

Oxidations Rules

- Elemental forms are always zero.

- Number given in table below are overridden when combined with an element of higher electronegativity

-don't confuse with formal charge

Element	ox #
G 1A	+1
G 2A	+2
H	+1(w/ non-metal)
	-1 (w/ metal)
O	-1 (in peroxides O_2^-)
	-2 (everything else)
G 7A	-1
Cl	-1 (except w/ O of F)
S	-2??

Common Oxidizing Agents

-oxidizing agents almost always contain oxygen

-reducing often contain metal ions of hydrides

Ox	Red
O_2	CO
H_2O_2	C
Halogens	B ₅ H ₆
H ₂ SO ₄	Sn ²⁺
HNO ₃	Hydrazine
NaClO	Zn(Hg)
KMnO ₄	Lindlars
CrO ₃ , Na ₂ Cr ₂ O ₇	NaBH ₄
PCC	LiAlH ₄
NAD ⁺ , FADH	NADH, FADH

4 Periodic Motion

4.1 Oscillatory Motion

Angular Frequency

$$\omega = \frac{\pi}{t}$$

$$\text{for SHM: } \omega = \sqrt{\frac{k}{m}}$$

units: radians/sec

Amplitude

-max displacement from equilibrium

$$A = \frac{x(t)}{\cos(\omega t)}$$

Period

$$T = \frac{2\pi}{\omega}$$

- the time it takes motion to repeat itself

Frequency

$$f = \frac{1}{T}$$

Unit: Hz = 1 oscillation/sec

Phase

$$x(t) = A \cos(\omega t + \phi)$$

ϕ = phase constant

$\phi > 0 \Rightarrow \text{left shift}$

$\phi < 0 \Rightarrow \text{right shift}$

ϕ doesn't effect A or f

4.2 Wave Motion

General definition of waves

a traveling disturbance that transports energy but not matter

Longitudinal Wave

oscillation in same direction as propagation (e.g., sound)

Transverse Wave

oscillation perpendicular direction of propagation (e.g., a stadium wave)

Period

time over which wave pattern repeats

Wavelength

distance over which pattern repeats

Propagation Speed

$$v = \frac{\lambda}{T} = \lambda f$$

4.2.1 Sound

Intensity

$$dB = 10 \log_{10}\left(\frac{I}{I_0}\right)$$

Doppler Effect*

can actually apply to any wave

5 Optics

5.1.2 EMR Spectrum

5.1 Physical Optics

Classification of electromagnetic spectrum

Properties of electromagnetic radiation:

Visual spectrum, color

Velocity equals constant c , in vacuo

Photon Energy

Electromagnetic radiation consists of perpendicularly oscillating electric and magnetic fields; direction of propagation is perpendicular to both

$$E = hf$$

Polarization of light: linear and circular

5.1.1 Interf and Diffrac

Interference Maxima

$$d \sin \theta = m \lambda$$

d =distance btwn slits

$m=1,2,3,\dots$

Diffraction Limit (Rayleigh Criterion)

$$\theta_d = \frac{1.22 \lambda}{D}$$

D =diamter of circular apature

θ =angle of seperation

X-ray diffraction

$$2d \sin \theta = m \lambda$$

Diffraction Grating

$$\frac{\lambda}{\Delta \lambda} = mN$$

5.2 Spectroscopy

Infrared

Vibration	Peak (cm-1)	Shape
O-H	3100-3500	broad
N-H	3100-3500	sharp
C=O	1700-1750	sharp

*Peaks given in wave numbers

*Fingerprint: region below 1400

$$Wave\# = \frac{1}{\lambda} \propto f = \frac{c}{\lambda}$$

$$Abs = 2 - \log(\% Transmittance)$$

$$\Rightarrow \downarrow \%T \Rightarrow \uparrow Abs$$

NMR Spectroscopy

Group	$\delta(ppm)$
Alky	0-3
Alkynes	2-3
Alkenes	4.6-6
Aromatics	6-8.5
Aldehydes	9-10
COOH	10.5-12

$\# peaks = n + 1$, where n is the number of non-identical protons less than 3 bonds away

$$area\ under\ peak(s) \propto \# identical\ H^+$$

UV-Vis

$$\downarrow |HOMO - LUMO| \Rightarrow \downarrow f_{absorption}$$

$$\uparrow conjugation \Rightarrow \downarrow f_{absorption}$$

5.3 Geometrical Optics

applies when object size $\ll \lambda$

5.3.1 Reflex and Refrac

Refractive Index

$$n = \frac{c}{v}$$

* Snell's Law

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2}$$

5.3.2 Thin Lenses

* Spherical Lense Eqn

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

Power

$$P = \frac{1}{f}$$

units: diapters, $D=m^{-1}$

Magnification

$$M = \frac{-i}{o}$$

Image height

$$\frac{o}{i} = \frac{h_o}{h_i}$$

Radius of Curvature

$$R = 2f$$

5.3.3 Spherical Mirrors

Eqn

$$\frac{1}{f} = \frac{1}{i} + \frac{1}{o} = \frac{2}{R}$$

6 Thermodynamics

6.1 Heat Eqns

PV Diagrams

W = -area on PV graph

$$W = \int_{path} \mathbf{F} \cdot d\mathbf{s} = \int P dv$$

First Law of Thermodynamics

$$\Delta U = Q - W$$

$Q = 0$	Adiabatic
$W = 0$	Isovolumetric/Isochoric
$\Delta U = 0$	Isothermal
$\Delta P = 0$	Isobaric

Specific Heat

$$c = \frac{Q/\Delta T}{m}$$

Heat Capacity

$$mc = \frac{Q}{\Delta T}$$

Heat of Absorption

$$Q = mc\Delta T$$

Heat of Transformation

$$Q = mL$$

Heat Transfer

Conduction = molec collisions

Convection = fluid motion

Radiation = electromag waves

Thermal Expansion

$$\Delta L_{linear} = \alpha L_0 \Delta T$$

$$\Delta A_{area} = ??$$

$$\Delta V_{volume} = \beta V_0 \Delta T$$

Entropy

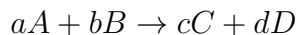
$$\Delta S = \frac{Q_{rev}}{T}$$

Q_{rev} = heat lost in reverse rxn

T = temp in kelvin

6.2 Chemical Equilibria

General Rxn



Equilibrium Constant

$$rate_{forward} = rate_{reverse}$$

$$K_c = K_{eq} = \frac{K_{forw}}{K_{rev}} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Reaction Quotient

$$Q_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

6.3 Isobaric Rxns

Standard Conditions (°)

25°C or 298 K, 1 atm, 1 M concentration

Physiological Conditions

....

Heat of Reaction

$$\Delta H_{rxn}^{\circ} = \sum_i \Delta H_{f products}^{\circ} - \sum_i \Delta H_{f reactants}^{\circ}$$

- same applies for entropy and all other state functions (e.g. pressure, density, temperature, volume, enthalpy, internal energy, free energy; see Hess's Law)

Bond Enthalpy

$$\Delta H_{rxn}^{\circ} = \sum_i \Delta H_{broken} - \sum_i \Delta H_{formed}$$

Gibbs Free Energy

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G^{\circ} = -RT \ln(K_{eq})$$

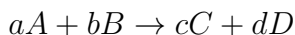
$$\Delta G = \Delta G^{\circ} + RT \ln \frac{Q}{K_{eq}} = RT \ln \frac{Q}{K_{eq}}$$

T is in Kelvin!

6.4 Isovolumetric Calorimetry

7 Kinetics

General Rxn



Definition of Rate

$$rate = \frac{\Delta[A]}{a} = -\frac{\Delta[B]}{b\Delta t} = \frac{\Delta[C]}{c\Delta t} = \frac{\Delta[D]}{d\Delta t}$$

for simplicity i will say rate = dP/dt,

where P=[Products]

$$\text{units: } \frac{mol}{l \cdot s} = \frac{M}{s}$$

General Rate Law

$$\frac{dP}{dt} = k[A]^x[B]^y$$

k=rate constant of rxn

x and y must be determined experimentally for a given rxn at a given temp

example:

[A]	[B]	rate
1.0	1.0	2.0
1.0	2.0	8.1
2.0	2.0	15.9

$$\Rightarrow rate = k[A]^1[B]^2$$

$$(\Delta[reactants])^x = (\Delta rate)$$

Zero Order

$$\frac{dP}{dt} = k[A]^0[B]^0 = k$$

First Order

$$\frac{dP}{dt} = k[A \text{ or } B]$$

Second Order

$$\frac{dP}{dt} = k[A]^1[B]^1$$

$$\frac{dP}{dt} = k[A \text{ or } B]^2$$

Broken Order

fractional exponents

Mixed Order

rate constants vary over time

Collision Theory

$$rxn \text{ rate} = Z \times f$$

Z = total # collisions per time

f = fraction of effective collisions

Arrhenius Eqn

$$k = Ae^{\frac{-E_a}{RT}}$$

k = rate constant of rxn

A = frequency of collisions (s⁻¹)

E_a = activation energy

R = ideal gas constant

T = temperature IN KELVIN

M-M Eqn

8 Solution Chemistry 8.2 Colligative Properties

8.1 Definitions and Rules

Dilutions

$$M_i V_i = M_f V_f$$

Mole Fraction

$$X_A = \frac{\text{mole } A}{\text{total moles of all species}}$$

Molarity (M)

$$M = \frac{\text{moles solute}}{\text{liters solution}}$$

Molality (m)

$$m = \frac{\text{mole solute}}{\text{kg solvent}}$$

Normality

$$N = \frac{\# \text{ equivs of interest}}{\text{liters soln}}$$

? or is it “# g equivalent weights?”

“molarity of the ‘stuff’ of interest”

Osmolality

$$\text{Osmoles} = \frac{\# \text{ separate molecules}}{L_{\text{solution}}}$$

Solubility Rules

1. Water soluble IF *cation* = alkali metal (G1) or ammonium (NH₄⁺)

2. Water soluble IF *anion* = nitrate (NO₃⁻) or acetate (CH₃COO⁻)

Refer to Kaplan text for additional rules to know...

Equivalents

amnt of substance that will produce or react with 1 mole of H⁺ or OH⁻ ions

Vapor Pressure Depression (Raoult's Law)

$$P_A = X_A P_A^\circ$$

Boiling Point Elevation

$$\Delta T_b = i K_b m$$

i = # of particles into which compound dissociates

m = molality of soln

Freezing Point Depression

$$\Delta T_f = i K_f m$$

“amount that normal freezing point is lowered”

Osmotic Pressure

$$\Pi = i M R T$$

R = ideal gas constant

Diffusion

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

r = diffusion rate

M = molar masses of gasses

Henry's Law?

8.3 Acids and Bases

Estimation

$$\log(n \times 10^m) \approx m + 0.n$$

$$k_a = \frac{[X]^2}{[IC] - X} \approx x^2, \text{ when acid is weak}$$

pH and pOH

$$pH + pOH = 14$$

Acid Disassociation

$$k_a = \frac{[H^+][A^-]}{[HA]}$$

Base Disassociation

$$k_b = \frac{[OH^-][HA]}{[A^-]}$$

Water Autoionization

$$k_w = [H^+][OH^-]$$

$$= k_a k_b$$

$$= (10^{-7})(10^{-7}) = 10^{-14}$$

Henderson-Hasselbalch

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

$$pOH = pK_b + \log \frac{[HA]}{[A^-]}$$

- HA=weak acid and HB=weak base

- can only be used in buffer region

Neutralization w/ reactants 1:1

$$M_a V_a = M_b V_b$$

Equivalence Point for acidic (negative?) AA

$$\frac{pK_{aR-group} + pK_{aCOOH}}{2} \approx \frac{pK_{aR-group} + 9}{2}$$

Equivalence Point for basic (pos- itive?) AA

$$\frac{pK_{aR-group} + pK_{aNH2}}{2} \approx \frac{pK_{aR-group} + 2}{2}$$

pH approximation

$$\log(m \times 10^n) \approx n + \frac{m}{10}$$

$$\Rightarrow pH = -\log([H^+]) \approx -n - \frac{m}{10}$$

9 Atomic Physics

Atomic Structure

$$E_{electron} = \frac{-R_H}{n^2}$$

$$E_{photon} = \frac{hc}{\lambda}$$

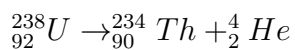
Electronic Configuration

??? n+l rule

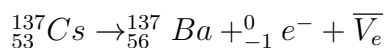
Exponential Decay Formula

$$n = n_o = e^{-\lambda t}$$

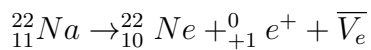
Alpha Decay



Beta-minus Decay



Beta-plus Decay



9.1 Periodic Table

Left to Right

$\uparrow Z_{eff}$

\downarrow Atomic Radii

\uparrow IE & EA

\downarrow Ionic Radii (except no Δ for metalloids)

Top to Bottom

slight $\downarrow Z_{eff}$

\uparrow Atomic Radii

\uparrow IE & EA

\uparrow Ionic Radii (including metalloids)

10 Genetics

Recombination Frequency

Hardy Weinberg Equilibrium

Mendelian Inheritance

11 SI Units

SI Prefixes

<i>Symbol</i>	<i>Prefix</i>	10^x
T	tera	12
k	kilo	3
–	–	0
c	centi	-2
m	milli	-3
μ	micro	-6
n	nano	-9
p	pico	-12
f	femto	-15

12 Orgo Nomenclature

Group	Prefix	Suffix
COOH	carboxy-	-oic acid
Anhydrides	-alkanoyloxy	anhydride
	-carbonyl	
Esters	alkoxycarbonyl-	-oate
Amides	carbomoyl-	-amide
nitrile	cyano-	-nitrile
Aldehydes	oxo-	-al
Ketones	oxo- ket-	-one
Alcohols	hydroxy-	-ol
thiol	mercapto-	-thiol
amine	amino-	-amine
alkene	alkenyl	-ene
alkyne	alkynyl	-yne
alkane	alkyl	-ane
ether	alkoxy	-ane
alkyl halide	halo-	-ane
nitro	nitro	-ane

groups are in order of priority from top (highest) to bottom (lowest priority)