MEDLAB BASICS · STUDY SHEET

Laboratory Mathematics

Units, solutions, molarity and normality, dilutions and titers, Beer's law, centrifuge force, QC statistics, sensitivity and predictive value, cell counts and clearance, each worked step by step

19 sources + more detail
medlabbasics.com/sheets/lab-math.html
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1 Units and prefixes

PREFIX	SYMBOL	FACTOR	BENCH EXAMPLE
kilo	k	10^{3}	1 kg = 1000 g
deci	d	10^{-1}	1 dL = 100 mL (conventional units are often 'per dL')
centi	c	10^{-2}	1 cm = 10 mm
milli	m	10^{-3}	1 mL = 1000 µL
micro	µ	10^{-6}	1 µL = 1 mm^3
nano	n	10^{-9}	Wavelength in nm
pico	p	10^{-12}	MCH in pg
femto	f	10^{-15}	MCV in fL

CHANGE	HOW	EXAMPLE
Cells per µL to per L	$\times 10^{3}/\mu L = \times 10^{9}/L$ (same number); $\times 10^{6}/\mu L = \times 10^{12}/L$	WBC 8.0 × $10^{3}/\mu L$ = 8.0 × $10^{9}/L$
Percent to fraction	÷ 100	Hct 40% = 0.40 L/L; lymphocytes 33% = 0.33
g/dL to g/L	× 10	Hgb 13.5 g/dL = 135 g/L
mg/dL to mmol/L	× 10 (dL to L), ÷ molar mass (mg to mmol)	Glucose 180 mg/dL × 10 ÷ 180.16 = 9.99 mmol/L (factor 0.0555)
mmol/L to mEq/L	× valence (charge)	Calcium 10 mg/dL = 2.5 mmol/L = 5.0 mEq/L
°C to °F	°F = (9/5 × °C) + 32	37 °C = 98.6 °F; 4 °C = 39.2 °F; −20 °C = −4 °F
°C to K	K = °C + 273.15	37 °C = 310.15 K

EXAM TIP Write the unit on every number and cancel units as you go. Most wrong answers on calculation items are a factor of 10 (dL against L, per 100 mL against per L) or a step left out.

2 Solutions

EXPRESSION	MEANS	WORKED EXAMPLE
% w/v	g of solute per 100 mL of solution	0.85% NaCl: 0.85 g/100 mL, so 8.5 g made up to 1000 mL
% v/v	mL of solute per 100 mL of solution	500 mL of 70% ethanol from 95%: 70 × 500 ÷ 95 = 368 mL of 95%, made up to 500 mL
% w/w	g of solute per 100 g of solution	Concentrated H_2SO_4 labeled 96% (w/w): 96 g acid per 100 g of liquid
Molarity (M, mol/L)	Moles of solute per liter of solution; g = M × L × molar mass	0.9% NaCl = 9 g/L ÷ 58.44 g/mol = 0.154 mol/L
Molality (mol/kg)	Moles of solute per kg of solvent (not solution)	5.844 g NaCl (0.100 mol) in 500 g water = 0.200 mol/kg
Normality (N, Eq/L)	Equivalents per liter; N = M × equivalents per mole	1 M H_2SO_4 = 2 N; 1 M NaOH = 1 N; 1 M $CaCl_2$ = 2 N
Equivalent weight	Molar mass ÷ equivalents per mole	H_2SO_4 98.08 ÷ 2 = 49.04 g/Eq; 500 mL of 0.1 N needs 0.1 × 0.5 × 49.04 = 2.45 g

- Equivalents per mole: replaceable H^+ for an acid, OH^- for a base, total positive charge for a salt.
- Hydrate swap: g of new form = g of old form × (molar mass of new ÷ molar mass of old). 17.8 g $Na_2HPO_4 \cdot 2H_2O$ (177.99) = 17.8 × 268.07 ÷ 177.99 = 26.8 g of the heptahydrate.
- Concentrated acid: M = specific gravity × 1000 × purity (as a fraction) ÷ molar mass. 96% H_2SO_4, SG 1.84: 1.84 × 1000 × 0.96 ÷ 98.08 = 18.0 M (36.0 N).

SAFETY When diluting a concentrated acid, add the acid slowly to the water, never water to acid: the heat released can make the liquid boil and spatter.

3 Dilutions, serial dilutions and titers

TASK	FORMULA	WORKED EXAMPLE
Dilution of one tube	Sample ÷ (sample + diluent); written 1:total	100 µL serum + 900 µL diluent = 1:10
Make a set volume (C1V1 = C2V2)	V1 = C2 × V2 ÷ C1; diluent = V2 − V1	50 mL of a 2 unit solution from 10 unit stock: V1 = 2 × 50 ÷ 10 = 10 mL stock + 40 mL diluent (1:5)
Serial dilution	Multiply the tube factors	Three 1:10 tubes = 1:1000. Tubes of 1:5, 1:2 and 1:10 = 1:100
Twofold series	Equal volumes each step: 1:2, 1:4, 1:8, 1:16 ...	Tube 4 of a twofold series = 1:16
Patient result	Result read × total dilution factor	1:10 dilution reads 45: report 450
Titer	Reciprocal of the highest dilution still positive	Positive to 1:32, negative at 1:64: titer 32
Significant rise	Fourfold (two tubes) between acute and convalescent sera	Titer 8 then 32

EXAM TIP A dilution of 1:5 is 1 part in 5 parts total (1 sample + 4 diluent). A ratio of 1:4 or 1+4 names the parts, not the total. Read the stem for which one it means; the Solution Dilution and Dilution Factor calculators do both.

4 Beer's law, standard curves and centrifuge force

CALCULATION	FORMULA	WORKED EXAMPLE
Beer's law	A = a × b × c (absorptivity × path length × concentration)	Absorbance doubles when concentration doubles (inside the linear range)
Unknown from one standard	C unknown = (A unknown ÷ A standard) × C standard	0.25 ÷ 0.50 × 100 mg/dL = 50 mg/dL

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4 Beer's law, standard curves and centrifuge force CONTINUED

CALCULATION	FORMULA	WORKED EXAMPLE
With a reagent blank	Subtract the blank from both readings first	Blank 0.050, standard 0.450, unknown 0.250: (0.200 ÷ 0.400) × C standard
%T to absorbance	A = 2 − log %T	50 %T: A = 0.301; 10 %T: A = 1.0
Standard curve	Plot A (y) against standard concentration (x); read unknowns off the line	Dilutions of a 150 g/L hemoglobin reference: 1:2 = 75, 1:3 = 50, 1:4 = 37.5 g/L
RCF (× g)	$1.118 \times 10^{-5} \times r$ (cm) × RPM²	15 cm rotor at 3000 RPM: 1509 × g
RPM for a set RCF	√(RCF ÷ $(1.118 \times 10^{-5} \times r)$)	1509 × g at 15 cm: 3000 RPM

EXAM TIP Doubling the RPM gives four times the force; doubling the radius gives twice the force. Procedures give × g, not RPM, because the same speed gives more force in a bigger rotor.

5 Statistics and QC numbers

STATISTIC	FORMULA	WORKED ON 10 CONTROL VALUES: 90, 91, 89, 84, 88, 93, 80, 90, 85, 87
Mean	Sum ÷ n	877 ÷ 10 = 87.7
Median	Middle value in rank order; with an even n, the average of the middle two	80 84 85 87 88 89 90 90 91 93: (88 + 89) ÷ 2 = 88.5
Mode	Most frequent value	90
SD	√(Σ(x − mean)² ÷ (n − 1))	√(132.10 ÷ 9) = 3.83
CV	SD ÷ mean × 100	3.83 ÷ 87.7 × 100 = 4.4%
±2 SD range	Mean ± 2 SD (about 95% of results)	87.7 ± 7.66 = 80.0 to 95.4
z-score	(Result − mean) ÷ SD	80: (80 − 87.7) ÷ 3.83 = −2.01 (beyond 2 SD)
Standard error	SD ÷ √n	3.83 ÷ 3.16 = 1.21
95% CI of the mean	Mean ± 1.96 × SE	87.7 ± 2.37 = 85.3 to 90.1
SDI (peer group)	(Lab mean − peer mean) ÷ peer SD	(5.0 − 4.8) ÷ 0.2 = 1.0

EXAM TIP SD is the spread of single results and sets control limits; the confidence interval uses SD ÷ √n and says how well the mean is known. Dividing by n instead of √n, or using ±2 SD for a confidence interval, are the classic slips. See the QC Statistics and Westgard Rules Check calculators.

6 Sensitivity, specificity and predictive value

Worked 2 × 2 table: a new assay against the reference method on 500 specimens (prevalence 100 ÷ 500 = 20%).

	REFERENCE POSITIVE	REFERENCE NEGATIVE	TOTAL
New test positive	TP 92	FP 20	112
New test negative	FN 8	TN 380	388
Total	100	400	500

MEASURE	FORMULA	WORKED
Sensitivity	TP ÷ (TP + FN): positives among those with the condition	92 ÷ 100 = 92%
Specificity	TN ÷ (TN + FP): negatives among those without it	380 ÷ 400 = 95%
PPV	TP ÷ (TP + FP): condition present among positive results	92 ÷ 112 = 82%
NPV	TN ÷ (TN + FN): condition absent among negative results	380 ÷ 388 = 98%
Efficiency (accuracy)	(TP + TN) ÷ all tested	472 ÷ 500 = 94.4%

EXAM TIP Sensitivity and specificity are read down the columns and do not change with prevalence; predictive values are read across the rows and do. The same assay at 2% prevalence has a PPV of only 27% (worked in depth below).

7 Counts, blood bank odds and clearance

CALCULATION	FORMULA	WORKED EXAMPLE
Absolute count	Total count × relative value (as a fraction)	WBC 8.0 × 10³/µL, lymphocytes 33%: 2.64 × 10³/µL
Absolute retic	Retic % × RBC (×10⁶/µL) × 10 = ×10³/µL	6% × 2.8 × 10 = 168 × 10³/µL
Corrected retic	Retic % × (patient Hct ÷ 45)	6% × 25 ÷ 45 = 3.3%; RPI 3.3 ÷ 2 days = 1.7
WBC corrected for nRBCs	WBC × 100 ÷ (100 + nRBC per 100 WBC)	15 × 100 ÷ 125 = 12 × 10³/µL
Red cell indices	MCV = Hct × 10 ÷ RBC; MCH = Hgb × 10 ÷ RBC; MCHC = Hgb × 100 ÷ Hct	RBC 4.5, Hgb 13.5, Hct 40.5: MCV 90 fL, MCH 30 pg, MCHC 33.3 g/dL
Hemocytometer	Cells counted × dilution ÷ (area in mm² × 0.1 mm depth) = cells/µL	150 cells in 8 mm², 1:20: 150 × 20 ÷ 0.8 = 3750/µL
Antigen-negative units	Units needed ÷ (product of the fractions negative), rounded up	2 units lacking antigens found on 70% and 30% of donors: 0.30 × 0.70 = 0.21; 2 ÷ 0.21 = 9.5, screen 10
Creatinine clearance	(U × V) ÷ P, V in mL/min; × 1.73 ÷ BSA to correct	U 100 mg/dL, 1440 mL in 1440 min, P 1.0 mg/dL: 100 mL/min
Timed urine total	Concentration × volume (in matching units)	Protein 25 mg/dL × 1500 mL (15 dL) = 375 mg/24 h

EXAM TIP Every row here has a calculator: Red Cell Indices, Reticulocyte Count, WBC Corrected for nRBCs, Manual Cell Count, Antigen-Negative Units and Measured Creatinine Clearance. The chemistry calculations on the exam list (transferrin saturation, indirect bilirubin, A/G ratio, LDL) are on the Reference Ranges page.

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