SECTION A
Pharmacology Guidelines

Chapter 1: Understanding Minimum Inhibitory Concentrations (MICs)

The National Committee on Clinical Laboratory Standards and the Clinical and Laboratory Standards Institute (CLSI) help to determine the susceptibility testing guidelines for most common organisms and antimicrobial agents in each species. Minimum Inhibitory Concentration (MIC) ranges for sensitive organisms are then set for specific antibiotics. To obtain an MIC for a bacteria, antibiotic concentrations are doubled in concentrations between the range of 0.06–512 μg/mL (0.06, 0.12, 0.25, etc.) to determine the susceptibility of bacteria. As antibiotic concentrations are increased, bacteria stop dividing or are killed. Bacteria that continue to proliferate at concentrations that are inhibitory for the same species are considered resistant. Typically, laboratories report susceptibilities as sensitive, intermediately sensitive or resistant to a particular antibiotic. In general, if a bacterium is resistant to an antibiotic *in vitro*, it should not be considered for *in vivo* (clinical) use. If an organism is considered to have "intermediate" sensitivity to an antibiotic the antibiotic may still be efficacious *in vivo* (clinically) in situations where high concentrations can be achieved (urine, topical therapy). If bacteria are susceptible to a particular antibiotic then it may be useful *in vivo* (clinically) if other variables are favorable (pharmacokinetics, toxicity, penetration to the site of action, etc.). When comparing between antibiotics that are both sensitive, the "breakpoint" must be considered. The breakpoint is also set by the National Committee on Clinical Laboratory Standards. The breakpoint is the concentration of antibiotic that cannot be exceeded *in vivo* (clinically) due to its pharmacokinetics and toxicity. The greater the difference between the MIC of the organism and the breakpoint helps to determine which antibiotic may be more efficacious.

Chapter 2: Static versus Cidal Antibiotics

The definitions of "bacteriostatic" and "bactericidal" antibiotics appear to be straightforward. A "bacteriostatic" antibiotic implies that it only produces "static" effects on bacteria versus a "bactericidal" antibiotic that kills the organisms. However, these categories are not absolute and drugs can act as either "static" or "cidal" under different conditions. Their mechanism of action may be influenced by growth conditions, bacterial density, test duration, and extent of reduction in bacterial numbers. Often agents that are "cidal" may fail to kill every organism in a large inoculum within 18–24 h. Furthermore, agents that are "static" may only kill some bacteria over 18–24 h, but may continue to kill organisms after the test period, but not enough to be called "cidal" (>99.9% in 24 h). Clinically, this is even more arbitrary. Most antibacterials are better described as potentially being both bactericidal and bacteriostatic depending on the organism and the concentrations achieved at the site of action. For theoretical purposes the following description of each is presented.

Bacteriostatic

For bacteriostatic antibiotics (those that prevent growth) the percent time that serum antibiotic concentrations are above the MIC of the organism should be >50% for most patients or closer to 100% for severely ill patients with immunosuppression or with debilitated patients. The dose here can remain the same but the dosing

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frequency can be increased to improve efficacy (i.e., from BID to TID). These are considered time dependent antibiotics. This differs from concentration dependent (or dose dependent) antibiotics that are considered "cidal". Examples of antibiotics categorized primarily as bacteriostatic agents include: Chloramphenicol, macrolides, tetracyclines, clindamycin, linezolide, and rifampin.

Bactericidal

For bactericidal antibiotics, the peak concentrations of antibiotic are important and should approximate 4–8 times the MIC concentrations of the organism. To maximize the clinical efficacy here, the dose must be increased and the frequency can stay the same. Examples of antibiotics that are considered bactericidal include: Aminoglycosides, penicillins, cephalosporins, carbapenems,vancomycin, fluoroquinolones, metronidazole, nitrofurantoin, and co-trimazole.

Chapter 3: *In Vitro* versus *In Vivo* Efficacy

In vitro culture and sensitivity will assist in antibiotic selection but may not always dictate *in vivo* efficacy. Many other factors also play a role in determining the *in vivo* outcome. Poor owner compliance, administration of an unstable compounded product, poor gastrointestinal absorption (altered formulation, drug/drug, drug/food interactions, variable gastrointestinal transit time, malabsorption, etc.) may all affect the ability of a drug to be absorbed. Following absorption, the distribution of drugs to the site of the infection may also be a challenge. Penetration of drugs into some physiological spaces including the eye, CNS, prostate, intracellular spaces, and into abscesses is often very difficult and is dependent on protein binding, lipophilicity, size, and degree of ionization of the drug molecule. A good example of this is the third generation cephalosporins. While all cephalosporins may appear to be effective judged on their MICs, if being used for CNS disease only cephalosporins with low protein binding can penetrate across the blood brain barrier in sufficient quantities to maintain therapeutic levels (Table 3.1). In addition, some organisms such as *Staphylococcus* spp. that appear to be sensitive *in vitro* to trimethoprim/sulfamethoxazole (TMS) combinations are able to circumvent the drug *in vivo* by utilizing the host's folate rendering the drug inactive. This is also true for *Enterococcus spp.* where both TMS and cephalosporins appear sensitive *in vitro* but should not be used clinically.

Chapter 4: Approaching Infectious Disease Cases

Is this an infection?

Determine if an infection is the problem: does the animal have two or more of the following?

- Fever,
- leukocytosis,
- increased fibrinogen,
- discospondylitis,
- or other evidence of bacterial infection.

Is eosinophilia or other signs of parasitic infection present?

Where is the infection?

Determine the most likely site of infection based on labs, physical evidence, physical exam, radiographic evidence, history, and so on.

What are the most likely pathogens at this site?

Identify the most likely pathogens (enterics, anaerobes, gram positives, fungus, viruses, parasites) and choose an empiric drug therapy to target these.

Empirically, what will cover these pathogens?

Select a drug that targets the most likely pathogens and that can achieve appropriate drug levels at the site of infection.

What other factors must be considered?

Consider local factors that might alter the efficacy of drug therapy (necrotic tissue, purulent material, biofilm on foreign body, poor blood supply, poor oxygen supply,

Table 3.1 Properties of Cephalosporins

Class	Drugs	Route	Dose Adjustment*	CNS penetration	Organisms Covered
First Generation	Cefadroxil (Duricef)	PO	Yes		**Primarily gram positives:** Methacillin sensitive *S. aureus*, *S. pseudintermedius*, *S. intermedius*, Grp A + *B Streptococcus* **Some gram negatives:** *E. coli*, *Klebsiella*, *P. mirabilis* **No coverage of**: Methicillin resistant *Staphylococcus*, *Enterococci* or penicillin resistant *Streptococcus*. **Anaerobic coverage:** Poor, no *B. fragilis* coverage.
	Cefazolin (Ancef, Kefzol)	IM/IV	Yes		
	Cephalexin (Keflex, Rilexine)	PO	Yes		
Second Generation	Cefaclor (Ceclor)	PO	No		**Gram positive coverage:** Similar to first generation **Gram negative coverage:** Enhanced compared to 1st generation **Anaerobic coverage:** Some coverage with cefoxitin and cefotetan for *B. fragilis*
	Cefoxitin (Mefoxin)	IM/IV	Yes		
	Cefuroxime (Ceftin, Zinacef)	PO/IM/ IV	Yes		
Third Generation	Cefdinir (Omnicef)	PO	Yes		**Gram positive coverage:** Maintains varying degrees of gram positive coverage **Gram negative coverage:** Enhanced coverage compared to 1st and 2nd generation agents. Covers: *Citrobacter*, *Enterobacter Salmonella*, *Serratia*, *E. coli*, *Klebsiella*, *Proteus*, *Pasteurella*, etc. Ceftazidime covers Pseudomonas, *Enterobacter* is often resistant. Ceftiofur covers *Actinobacillus*, *Mannheimia* **Anaerobe coverage:** Some anaerobe coverage. Only Ceftiofur covers Bacteroides and Fusobacterium No other agents cover Bacteroides
	Cefixime (Suprax)	PO	Yes		
	Cefotaxime (Claforan)	IM/IV	Yes	+++	
	Cefovecin (Convenia)	SC	Yes		
	Cefpodoxime (Simplicef, Vantin)	PO	Yes		
	Ceftazidime (Fortaz)	IM/IV	Yes	+++	
	Ceftiofur (Naxcel)	IM/SC	Yes		
	Ceftriaxone (Rocephin)	IM/IV	Yes	+++	
Fourth Generation	Cefipime (Maxipime)	IM/IV	Yes	+++	**Gram positive coverage:** Broad spectrum gram positive coverage **Gram negative coverage:** Broad spectrum gram negative coverage. Covers Pseudomonas similar to ceftazidime. **Anaerobic coverage:** Some coverage, no Bacteroides coverage
Fifth Generation	Ceftaroline (Teflaro)	IV	Yes		**Gram positive coverage:** Enhanced coverage of gram positives (methicillin resistant *Staphylococcus*, *E. faecalis*) **Gram negative coverage:** Same gram negative coverage as 3rd and 4th generation generation No Pseudomonas coverage **Anaerobic coverage:** Limited anaerobic coverage

Notes

PO = Oral, IM = Intramuscular, IV = Intravenous, SC = Subcutaneous routes of delivery

*Dose adjustments in renal impairment required

CNS penetration= (+++) can be used in CNS infections for susceptible organisms

etc.). Consider drug penetration into difficult sites (CNS, abscesses, eye, prostate).

What patient factors should be considered?

Select a drug that is safe based on patient specific parameters (species, age, breed, contraindications, drug interactions, and underlying medical conditions).

What route of administration should be used?

Select a route to administer the drug based on the severity of the animal's condition, owner's ability to administer the drug, cost of therapy, and compliance.

What dose should be used?

Select a dose and dosing frequency based on the severity of the infection and patient specific parameters (age, renal function, liver function, etc.) to maintain therapeutic concentrations sufficient to cure the infection and prevent relapse. Monitor the animal for side effects and reduce the dose if necessary.

How long should the animal be treated?

Select a length of time and set goals of therapy (reduced fever, fibrinogen, leukocytosis, titers, improvement in physical signs, negative skin scrapings, negative fecals, etc.). Typically treatment should be based on clinical resolution of signs and symptoms. Treatment should continue for 3–5 days past this point. In some cases prolonged therapy is indicated (fungal, *Mycobacterium*, prostatitis, pyothorax, endocarditis, bone infections, pyelonephritis, etc.)

When should I perform culture and sensitivity?

Culture and sensitivity are recommended in all animals with severe bacterial infections or in any animal not responding to empiric therapy. Typically, cultures should be drawn while the animal is not receiving antibiotics or has not taken antibiotics for 2–3 days (although this is dependent on the severity of the infection).

Chapter 5: Why Antibiotics Fail

1 Host factors
(a) Immune status (immunosuppression, steroids, cyclosporine, cancer, FeLV, etc.)
(b) Underlying disease (hypothyroidism, allergies, diabetus, incontinence, etc.)
(c) Foreign bodies (foxtails, urolithiasis, artificial implants, surgical equipment, remaining tooth root, etc.)
2 Antibiotic properties
(a) Selection (compliance, stability of compounded agents, correct administration, correct length of treatment, etc.)
(b) Pharmacokinetics/pharmacodynamics (absorption, dose, frequency, route, etc.)
(c) Metabolism/elimination (increased metabolism/elimination, drug interactions, etc.)
(d) Adverse event profile (toxicity, vomiting drug, not adjusting dose in renal/hepatic disease, etc.)
3 Site of infection
(a) Intracellular organisms (only some achieve adequate intracellular concentrations-chloramphenicol, tetracyclines, fluoroquinolones, macrolides, TMS, rifampin, etc.)
(b) Chronic prostatitis (only some penetrate in adequate concentrations: clindamycin, macrolides, chloramphenicol, fluoroquinolones, trimethoprim)
(c) Surgical intervention required (abscesses, necrotic tissue/bone, drainage, poor blood supply, and so on do not permit drug to achieve sufficient concentrations)
(d) CNS (only some drugs penetrate: chloramphenicol, metronidazole, TMS, doxycycline, carbepenems, linezolide, rifampin, fluoroquinolones, high-dose penicillins, some third generation cephalosporins (ceftriaxone, cefotaxime, ceftazidime, cefixime, cefepime)
4 Pathogens
(a) Species (lacks the target for the antibiotic, can circumvent the drug and use the hosts nutrients (folate), slow growing-requiring prolonged therapy, etc.)
(b) Virulence factors (increased virulence by mutation, crossing host species, naïve hosts, etc.)
(c) Resistance (innate or acquired resistance to antibiotic, can form dormant cysts, forms, are environmentally resistant to heat, dryness, etc.).

Chapter 6: Adjusting Doses in Renal Failure

Staging recommendations for chronic kidney disease (CKD) in animals has been set by the International Renal Interest Society (IRIS) (Table 6.1). These recommendations can be found on their website at www.iris-kidney.com. Staging is based initially on fasting blood creatinine, assessed on at least two occasions in the stable patient. The patient is then substaged based on proteinuria and systemic blood pressure. Patients with CKD often need dose adjustments in antibiotic, antifungal, antiviral and antiparasitic drug therapy or toxicity due to drug accumulation may occur. There are multiple methods for dose adjusting including dose reduction, lengthening the dosing interval or both. Typically, loading doses do not have to be altered in renal disease. Dose reduction involves reducing each dose while maintaining the normal dosing interval. This establishes more constant drug concentrations, but in patients with severe renal disease, drug accumulation and toxicity may still occur. Alternatively, extending the dosing interval may decrease the risks of toxicity but may increase the potential for subtherapeutic drug concentrations. Dosing guidelines for adjustment of drugs in renal failure are set in human medicine based on the stage of renal disease as determined by the Glomerular Filtration Rate (GFR). There are three categories of renal disease (mild, moderate, and severe). Initial dosing starts with these guidelines and is then adjusted to the patient's response and serum concentrations of drug.

Several antibiotic categories require close attention in renal disease. Aminoglycosides are best avoided when possible in renal disease. If necessary, serum drug concentrations should be monitored and adjusted. Penicillins and carbepenems accumulate readily in renal disease and can be associated with neuromuscular toxicity, myoclonus, seizures, and coma. Meropenem has a reduced tendency to cause seizures and is the preferred drug to imipenem in severe renal disease. Tetracyclines are associated with an antianabolic effect that can

Table 6.1 IRIS (International Renal Interest Society). Staging system for chronic kidney disease (CKD)

Step 1: Staging is initially based on fasting blood creatinine assessed on at least two occasions in the stable patient. (Blood creatinine concentration apply to average size dogs: those of extreme size may vary.)	**Blood creatinine, µmol/l or mg/dl**		
Renal function remaining	**Cat**	**Dog**	**Comments**
100%	<140 <1.6	<125 <1.4	History suggests the animal is *AT RISK* of developing CKD in the future due to a number of factors (e.g., exposure to nephrotoxic drugs, breed, high prevalence of infectious disease in the area)
Stage 1	<140 <1.6	<125 <1.4	**Nonazotemic.** Some other renal abnormality present (e.g., inadequate urinary concentrating ability without identifiable non renal cause, abnormal renal palpation or renal imaging findings, proteinuria of renal origin, abnormal renal biopsy results, increasing blood creatinine concentrations in samples collected serially).
33% Stage 2	140–250 1.6–2.8	125–180 1.4–2.0	**Mild renal azotemia** (lower end of the range lies within reference ranges for many laboratories, but the insensitivity of creatinine concentration as a screening test means that animals with creatinine values close to the upper reference limit often have excretory failure). Clinical sings usually mild of absent.
25% Stage 3	251–440 2.9–5.0	181–440 2.1–5.0	**Moderate renal azotemia.** Many extrarenal clinical sign may be present
<10% Stage 4	>440 >5.0	>440 >5.0	**Severe renal azotemia.** Increasing risk of systemic clinical signs and uremic crises

(*Continued*)

Table 6.1 (*Continued*)

Step 2: Cases are then sub-staged based on the proteinuria and blood pressure; Note that UP/C and blood pressure vary independently of each other and the stage of CKD

Urine protein/creatinine ratio (Up/C)		
Dogs	**Cats**	**Comments**
0–0.2	0–0.2	Non-proteinuric
0.2–0.5	0.2–0.4	Borderline proteinuric
0.5–0.6	0.4–0.6	Proteinuric

Risk of target organ damage from hypertension (systolic blood pressure mm/Hg)	
Dogs/Cats	**Comments**
130–150	Minimal risk
150–160	Low risk
160–180	Med risk
>180	High risk

increase the uremic state of patients with severe renal disease. Doxycycline is preferred over other tetracyclines in this situation. Expired or compounded doxycycline that may be readily hydrolyzed to a renal toxic metabolite should also be avoided. Nitrofurantoin also has a toxic metabolite that may accumulate in renal disease and cause peripheral neuritis.

Interval adjustment

In general, as extrapolated from human medicine, the following antibiotics/antifungals should have the dosing interval adjusted (i.e., every 8 h can be given every 12 h in moderate renal disease and every 12 h can be given every 24 h in severe disease): Cefazolin, cefepime, cefotaxime, cefoxitin, cefpodoxime, ceftazidime, ceftizoxime, cefuroxime, cephalexin, meropenem, sulfamethoxazole, trimethoprim, vancomycin, amoxicillin, ampicillin/sulbactam, ticarcillin, piperacillin, enrofloxacin, tetracycline, flucytosine, and valacyclovir. All animals should be monitored closely for response and toxicity.

Dose adjustment

The following antibiotics/antifungals should have the dose adjusted (i.e., 100% of the dose should be decreased to 75% with moderate renal disease and down to 50% with severe renal disease). Cefixime, clarithromycin, amoxicillin/clavulanate, ticarcillin/clavulanate, erythromycin, metronidazole, piperacillin/tazobactam, penicillin G, ciprofloxacin, enrofloxacin, fluconazole, itraconazole, rifampin, and famciclovir. Although no data is available, if serum proteins are low cefovecin doses should be reduced to avoid toxicity.

No dose adjustment

The following antibiotics/antifungals typically do not require dose adjusting in renal failure; azithromycin, chloramphenicol, clindamycin, dicloxacillin, nafcillin, penicillin VK, doxycycline, linezolid, minocycline, ketoconazole, and pyrimethamine.

Chapter 7: Pregnancy Risk Categories

The FDA has established pregnancy risk factor categories for human patients based mostly on studies in laboratory animals. In order to extrapolate data to canine and feline patients, we have modified the five FDA risk categories (A, B, C, D, or E) to include teratogenic or embryo toxic potential in all species. Due to ethical concerns, most drugs do not undergo controlled studies in pregnant companion animals or humans. The following categories will be used throughout this book to assist the veterinarian in determining the risk:benefit ratio when a drug is used in a pregnant animal.

Categories

A. Controlled studies in pregnant women and animals fail to demonstrate a risk to the fetus in early or late pregnancy. Fetal harm is considered low risk.
B. Animal reproduction studies have not demonstrated fetal risk and/or reproduction studies have shown an adverse effect (other than a decrease in fertility) but results could not be confirmed in controlled studies.
C. Studies in animals have revealed adverse effects to the fetus (teratogenic, embryocidal, or other) but there are no controlled studies available to confirm reports. Drugs should be given only if the potential benefit justifies the risks.
D. There is positive evidence of human and animal fetal risk in pregnancy, but the benefit from use in pregnancy may be acceptable despite the risk (if the drug is needed in a life threatening situation or to treat a serious disease for which safer drugs cannot be used or are ineffective).
E. Studies in animals or humans have demonstrated fetal abnormalities or there is evidence of fetal risk and the risk of use of the drug in pregnancy clearly outweighs any possible benefit. The drug is contraindicated in pregnancy.

Chapter 8: Lactation Guidelines: Penetration of Drugs into Milk

The transport of drugs into milk from the maternal circulation occurs through multiple routes. Drugs traverse biologic membranes by passive diffusion so that the concentration will be dependent on the concentration gradient as well as the lipid solubility of the drug, degree of ionization, and protein binding. The significance of drug penetration into milk is unknown for most species. Although plasma:milk ratios of drugs are well known for food animals, few studies have focused on "safe" concentrations of drugs in canine or feline neonates. Fortunately, most antibiotics do not cross into milk in high levels (<1%). Therefore, the risk following exposure to maternal milk containing low levels of antibiotic should not be considered high. The most common side effects of low concentrations of antibiotic drugs in neonatal animals would be colic and diarrhea. Oral thrush caused by overgrowth of *Candida* yeast may also occur. Although rare, as with adults, allergic reactions (such as skin rashes) may also occur.

Antibiotics considered to be safe in lactating animals include the aminogylcosides (poorly absorbed by the gut), erthromycins, penicillins, and the cephalosporins. Antibiotics that should be avoided in lactating animals would be those categories of drugs that traditionally would be avoided in young animals (fluoroquinolones, chloramphenicol, sulfamides, etc.). Fluoroquinolones have been associated with arthropathy in animal studies and tetracyclines have been shown to cause inhibition of fibula growth and tooth enamel dysplasia. Chloramphenicol has been associated with significant side effects (polychromasia, anisocytoisis, target cells, and basophilic granulation) in 8–12 week-old puppies. Potentiated sulfonamides are generally considered safe in older animals but may be associated with hepatitis, anemia, KCS, or polyarthritis in neonates. Metronidazole is generally considered safe in neonates but due to its mutagenic and carcinogenic properties it is often not considered the drug of choice if a safer drug can be substituted.

Chapter 9: Safe Writing Skills

Veterinarians frequently provide handwritten prescriptions to their clients that may be filled at human pharmacies where pharmacists often lack training in veterinary pharmacology. These prescriptions present a very high possibility for error or misinterpretation. Care must be given as to how drug names, strengths, dosages, and directions for use are expressed to avoid significant errors. The following safe writing skills are suggested as a mechanism to help prevent errors and avoid wasted time in clarification of prescriptions.

1. Never use the abbreviation "SID". Although commonly used in veterinary medicine for "once daily", it is not recognized in human medicine and frequently is misinterpreted as "QID" or four times daily. The abbreviations "Q.D." or "O.D." may also be misinterpreted. Instead, write out "once daily".
2. Never place a decimal after a whole number (5.0 mg). If the decimal is missed it will result in a 10-fold over dose. Instead write "5 mg".
3. For numbers that are less than one (1), always place a zero (0) in front of the decimal (0.8 mL is correct, not .8 mL). This has resulted in 10-fold overdoses.
4. Always place a space between a number and units to make certain it is clear. Write "25 mg" not "25mg".
5. Always write out the word "unit". A handwritten U or u can be misinterpreted as a zero. This has resulted in numerous 10-fold overdoses of insulin.
6. Always write out "international units" instead of IU. Handwritten "IU" has been mistaken for "IV".
7. Do not use chemical names that start with a number, such as 5-FU, instead write their proper names (e.g., Flurouracil) since five-fold overdoses can occur, or it could be interpreted as 5-flucytosine.
8. For drugs that are commonly abbreviated, such as BUT, HCTZ, Pred, or MTX, write out the proper names.

9. Do not use "ug" or "mcg" abbreviations, instead write out "micrograms" for clarification.
10. Always write clearly and provide an indication for use (for pain, for nausea, etc.) for added confirmation.

Chapter 10: Basic Math Skills

Dilutions

When doing dilutions always think in parts. A 1:10 dilution of a drug means that there is one part drug in a total of 10 parts. So a total of 9 parts of diluent must be added to 1 part drug for a total of 10 parts. A 1:10 dilution of ivermectin would be 1 mL of ivermectin to 9 mL of drug. A 1:20 dilution would be 1 mL ivermectin to 19 mL of diluent. A 1:2 dilution of ivermectin is 1 mL of ivermectin to 1 mL of diluent.

Note: This is not to be confused with a 1:1 parts mixture (not a dilution) where 1 part ivermectin is mixed with 1 part of a second vehicle.

Percent solutions

When working with percent fluids the units will always be expressed in mL/100 mL or grams/100 mL. For instance, a 1% ivermectin solution means that there is 1 gram of ivermectin in 100 mL of solution. That is the same as 1000 mgs/100 mLs or 10 mg/mL.

Percent weights

When working with percent weights the units are always expressed in grams/100 grams. For instance, Ponazuril is available in a 127 gram tube that is 15% active drug. That means that there are 15 g of ponazuril per 100 g of paste, or 15,000 mg/100 g of paste. This is 150 mg/gram paste. Note: when further diluting this aqueous paste one cannot assume that it has the same specific gravity as water. In this case, 127 g of paste (1 tube) = 120 mL of paste.

Converting units

When converting units just use their equivalents and remember to line up units so they cancel. If a dose is in micrograms (µg or mcg) convert it to milligrams first, since most drugs are in mg/mL. For instance, a 24 microgram dose of ivermectin is divided by 1000 because 1000 micrograms = 1 milligram. This is a dose of 0.024 mg.

Weight conversions

1 gram (g) = 1000 milligrams (mg)
1milligram (mg) = 1000 microgram (µg or mcg)
1 microgram (µg) = 1000 nanograms (ng)
1 pound (lb) = 0.454 kg = 454 grams (g) = 16 ounces (oz)
1 kilogram (kg) = 1000 grams (g) = 2.2 pounds (lb)
1 gram (g) = 15.43 grains (gr) = 1000 mg
1 ounce (oz) = 28.4 grams

Liquid conversions

1 gallon = 4 quarts = 8 pints = 3.785 L
1 quart = 2 pints = 32 fl.oz = 946 mL
1 pint = 2 cups = 16 fl.oz = 473 mL
1 cup = 8 fl.oz = 237 mL = 16 tablespoons
1 tablespoon = 15 ml = 3 teaspoons (tsp)
1 teaspoon = 5 ml
1 liter (L) = 1000 mL = 10 deciliters (dL)
1 deciliter = 100 mL
1 milliliter (mL) = 1 cubic centimeter (cc)

Milliequivalents

When trying to calculate milliequivalents, remember that a mEq is 1/1000 of an equivalent. In general this is just the molecular weight of the chemical divided by its valence. Common molecular weights are shown here. For instance, if you want to know how many milligrams are equivalent to 1 mEq of potassium chloride just get the molecular weight of potassium chloride (74.55 g) and divide it by the valence (1). So the equivalent weight is 74.55 g divided by 1 = 74.55 grams. To convert this to mEq it must be divided by 1000, which is 0.07455 g or 74.55 mg. So, 1 mEq of potassium chloride = 74.55 mgs.

Electrolyte	Molecular wt (g)	Valence
Sodium chloride	58.44	1
Sodium bicarbonate	84.0	1
Sodium lactate	112.0	1
Potassium chloride	74.55	1
Potassium gluconate	234.25	1
Calcium gluconate	430.4	2
Calcium chloride (anhydrous)	111.0	2
Magnesium sulfate (anhydrous)	120.4	2
Magnesium chloride anhydrous)	95.21	2