Metric conversions:

In order to perform metric conversions, you need to be able to identify BASE units and PREFIXED units. Base units are the units that everything else in the metric system is built upon; for example, grams, meters, liters, seconds, joules, pascals etc. Prefixed units are base units with a prefix attached, i.e. **kilo***meter* (km), **micro***liter* (μL), **milli***second* (ms), **mega***joule* (MJ) and so forth. The prefix simply tells you what order of magnitude (power of ten) of the base unit you are talking about. You don't even have to know what the base unit is if you know the prefix! If I told you there was a **kilo***mike* (don't get any ideas), then you would automatically know that you had $1\text{x}10^3$ mikes (scary) whatever a mike might be! So now that we can identify base units and prefixed units, what good does that do us?

Say I ask you to convert 0.00671 seconds (s) to milliseconds (ms). First thing you need to do is decide which is the base unit and which is the prefixed unit. Hopefully, you knew that seconds are the base unit (no prefix) and milliseconds are the prefixed unit (milli is the prefix). Next, decide what units go on top and what units go on the bottom. In this case, we are converting FROM s TO ms. We want s on the bottom so that they cancel out which means ms must go on the top.

$$0.00671\ \boldsymbol{s} \times \frac{\boldsymbol{ms}}{\boldsymbol{s}}$$

Next, PUT A 1 IN FORNT OF THE PREFIXED UNIT!!! Again, you don't have to do it this way, but a lot of you ignored this advice on the quiz and it cost you!

$$0.00671\ \boldsymbol{s} \times \frac{1\ \boldsymbol{ms}}{\boldsymbol{s}}$$

Now put the exponent you have memorized in front of the BASE unit (you MUST memorize these prefixes and exponents!!!!!)

$$0.00671\ \boldsymbol{s} \times \frac{1\ \boldsymbol{ms}}{1\times10^{-3}\ \boldsymbol{s}}$$

Now comes the answer. Remember, metric conversions have infinite sig. figs.!

$$0.00671\ \boldsymbol{s} \times \frac{1\ \boldsymbol{ms}}{1\times10^{-3}\ \boldsymbol{s}} = 6.71\ \boldsymbol{ms}$$

Example: Convert 36.95 megawatts (MW) to watts (W)… (do we care what a watt is? NO!)

$$36.95\ \boldsymbol{MW} \times \frac{1\times10^{6}\ \boldsymbol{W}}{1\ \boldsymbol{MW}} = 3.695\times10^{7}\ \boldsymbol{W}$$

Example: How many liters in $5.62\text{x}10^5$ μL?

$$5.62\times10^{5}\ \boldsymbol{\mu L} \times \frac{1\times10^{-6}\ \boldsymbol{L}}{1\ \boldsymbol{\mu L}} = 0.562\ \boldsymbol{L}$$

That's all fine and well, but what if you are asked to convert from one prefixed unit to another? It turns out it is essentially the same, but you need to make 2 steps instead of 1. WHEN CONVERTING BETWEEN TWO PREFIXED UNITS, ALWAYS CONVERT THE FIRST PREFIED UNIT TO THE BASE UNIT AND THEN FROM THE BASE UNIT TO THE SECOND PREFIXED UNIT! Huh? Observe:

How many decigrams are in 739.22 centigrams?
First, write the conversion for centigrams to grams:

$$739.22\ cg \times \frac{1\times10^{-2}\ g}{1\ cg}$$ (notice that the 1 is still in front of the prefixed unit)

now write the conversion for the base unit to the second prefixed unit (dg) and answer:

$$739.22\ cg \times \frac{1\times10^{-2}\ g}{1\ cg} \times \frac{1\ dg}{1\times10^{-1}\ g} = 73.922\ dg$$

See? It is the same process, but with two steps instead of one.

Example: How many milliwatts (mW) are in 1.21 gigawatts (GW)? (again, don't worry about watts, I just to say 1.21 gigawatts, and they are just units)

$$1.21\ GW \times \frac{1\times10^{9}\ W}{1\ GW} \times \frac{1\ mW}{1\times10^{-3}\ W} = 1.21\times10^{12}\ mW$$

Example: The Borh radius is 53 nanometers. What is that distance in cm?

$$53\ nm \times \frac{1\times10^{-9}\ m}{1\ nm} \times \frac{1\ cm}{1\times10^{-2}\ m} = 5.3\times10^{-6}\ cm$$

Okay, here are some for you to try:

1) 23.6 kilojoules (kJ) to joules (J)
2) 58216 microliters to dekaliters
3) 46.875 terabytes to kilobytes
4) How many femtoseconds in 22.16 milliseconds
5) If something has a mass of $3.78\text{x}10^{-2}$ megagrams, what is its mass in centigrams?

Before I get much further in this "review", I want to remind you about conversions factors. A conversion fact is simply a way of changing from one unit to another. 1 in = 2.54 cm is a conversion factor because it allows you to convert from inches to centimeters or centimeters to inches. Densities can be thought of as conversion factors: 11.35 g per cm^3 is a conversion factor because it lets you convert from a volume (cm^3) to a mass (g) or vise versa. Anything with two or more units is just a conversion factor. You don't have to know what those units are or what they mean as long as the convert from one thing to another. Finally, I want to remind you that these conversion factors can be written in one of several ways:

2.54 cm = 1 in   2.54 cm per in $\frac{2.54\ cm}{1\ in}$ $2.54\ {}^{cm}\!/_{in}$

Each one of these is equivalent to the others and they are all the exact same conversion factor.

<u>Conversion between systems of measure</u>:
The main difference between this and the metric conversions is that you will not have to memorize these conversions; they will be given to you. That should make it easier… maybe). So, how do you do this? Let's start off fairly easy and work our way up.

Example: How many liters in 43.7 gallons?

First thing you want to do on ANY conversion problem is write what you are given and what you are asked for. On a problem like this it may seem to be a waste of time, but as the problems get more complicated, it will be vital in order to keep track of what you are doing.

What is given? 43.7 gallons
What is asked for? Liters

Great, I know where to start, but where do I go from there? I need a conversion factor that will allow me to get from gallons to liters, so I look in my book and see that 1 gal = 3.785 L. Looks good to me… I'll give it a try. Remember, that units only cancel if they are on opposite sides of the division bar.

$$43.7\ gal \times \frac{3.785\ L}{1\ gal} = 165\ L$$

Cool, my answer ended up in L, which is exactly what I needed.

If only all of the problems were quite that straight forward. So how do you deal with more complicated problems? In the last problem you were able to find a direct conversion between gallons and liters. There will not always be a direct conversion, which is when you are really going to have to think.

Example: How many inches are in 0.018 m?

What is given? 0.018 m
What is asked for? inches

Since the 0.018 m is the only value given, we know that we must start there. So we go to our handy dandy conversion table and look for a conversion from meters to inches… and come up empty handed. What now? Now we need to use a little bit of intuition. We look at the conversion table a see that about the only conversion involving inches also involves cm. Can we work with that? Maybe, but in order to use that conversion, we must be in units of either inches or centimeters. We are starting in meters… what can be done? Hmmm, meter and centimeters… That is a metric conversion!! We can do that!

$$0.018\ m \times \frac{1\ cm}{1 \times 10^{-2}\ m}$$

Now I am in centimeters and can use the cm to inch conversion!

$$0.018\ m \times \frac{1\ cm}{1 \times 10^{-2}\ m} \times \frac{1\ in}{2.54\ cm} = 0.71\ in$$

I am in inches and that is what the question asked for!

Example: What is the volume in fluid ounce of a vat containing 0.02391 megaliters?

What is given? 0.02391 ML
What is asked for? fl. oz.

Again, the only place to start is with 0.02391 ML, but again, my conversion table has failed me; there is not a ML to fl. oz. conversion anywhere to be found. In fact, ML doesn't appear anywhere in my table, but I see fluid ounces in 2 places: 1 qt = 32 fl.oz. and 1 fl.oz. = 29.6 mL. Hmmm, ML and mL, I think I can do something about that! All I need to do is convert ML to mL, which is a prefix unit to prefix unit metric conversion!

$$0.02391\ ML \times \frac{1 \times 10^{6}\ m}{1\ ML} \times \frac{1\ mL}{1 \times 10^{-3}\ m}$$

Now I am in mL and can use the 1 fl.oz. = 29.6 mL conversion

$$0.02391\ ML \times \frac{1 \times 10^{6}\ m}{1\ ML} \times \frac{1\ mL}{1 \times 10^{-2}\ m} \times \frac{1\ fl.oz.}{29.6\ mL} = 8.08 \times 10^{4}\ fl.oz.$$

NOTE: the 1 fl.oz. = 29.6 mL conversion is NOT exact, so it limits sig. figs.

These conversions are all about doing whatever it takes to get from one unit to another. Above, there was no meter to inch conversion, so we had to see what was available and sort of… build a bridge. This is what you need to practice. Some advice; the process is the same for every one of these so don't get wrapped up in each individual problem, but pay attention to overall thought process.

Practice: (use the "SI Units and Conversion Factors" table in your book to do these)

1) Convert 103 kg to ounces
2) What is the equivalent of 653 nm in angstroms?
3) How many liters are there in 6.375 pints
4) 0.75 tons is equal to how many kg?
5) How many atomic mass units (amu) are in $3.89266\text{x}10^{-17}$ pounds?
6) What is the distance in μm of 8.00 ft?
7) How many millimeters in a marathon (26.22 miles)
8) What is the volume in nL of 2.336 gallons?

Multidimensional units:

HUH? What is that word? It is referring to square units (square feet, in^2) and cubic units (cm^3, cubic meters). I think that the best way to explain this is to just start with a rule: If you are converting from one cubic unit to another cubic unit, the conversion factor MUST be cubes also. This rule also applies to $unit^2$ to $unit^2$ conversions. Here is what I mean…

Example: Say you are asked to convert from 56.3 m^3 to km^3. Start off by writing the regular conversion for meters to kilometers:

$$56.3\ m^3 \times \frac{1\ km}{1\times10^3\ m}$$

Look at this, do the units cancel? No, you have m^3 on top and m on the bottom. Both of these units are cubic units, so you have to cube the conversion factor.

$$56.3\ m^3 \times \left(\frac{1\ km}{1\times10^3\ m}\right)^3$$

Now, remember back to algebra; EVERYTHING in the parentheses must be cubes, not just the units, so don't forget to cube the $1\text{x}10^3$ when you put this in your calculator.

$$56.3\ m^3 \times \left(\frac{1\ km}{1\times10^3\ m}\right)^3 = 5.63\times10^{-8}\ km^3$$

EVERY conversion from one cubic (or square) unit to another MUST be cubed (or squared), so you are going to have to continue to think as you go through the steps:

Example: How many square meters are in 1502 in^2?

What is given? 1502 in^2
What is asked for? m^2.

Again, no direct conversion from inches to meters is available, so we'll have to find a way. While doing that, we are going to have to keep track of whether we are going square the conversion factors too. I know that a good conversion from English to metric lengths is inches to cm and then I know how to go from cm to meters, so here I go:

$$1502\ in^2 \times \frac{2.54\ cm}{1\ in} \times \frac{1\times10^{-2}\ m}{1\ cm}$$

Now, which conversions do I need to square? Well, the first needs to be squared because I am converting from in^2 to cm^2, and the second also needs to be squared because I am going from cm^2 to m^2.

$$1502\ in^2 \times \left(\frac{2.54\ cm}{1\ in}\right)^2 \times \left(\frac{1\times10^{-2}\ m}{1\ cm}\right)^2 = 0.9690\ m^2$$

(remember that you have to actually square 2.54 and $1\text{x}10^{-2}$)

So what would be an example of when the conversion factor should NOT be cubed? Good question. The answer is that if you are converting from a cubic unit to a non-cubic unit, you do NOT cube the conversion.

Example: How many minutes would it take to fill a 1500. m^3 hot air balloon if it is being filled at a rate of 1.25x10^5 cm^3 per minute?

What is given? 1500. m^3 and 1.25x10^7 cm^3 per minute
What is asked for? min.
Where do you start? 1500. m^3 (Keep in mind the hint I gave you. When you can, start with the number that has a single unit. 1500. m^3 has one unit [m^3] and 1.25x10^7 cm^3 per min has two [m^3 and min])

We are starting in m^3, but have to be in cm^3 to use the 1.25x10^7 cm^3/min conversion, so the first step should be to convert m^3 to cm^3. This is a cubic unit to cubic unit conversion, so you MUST cube the conversion factor:

$$1500.\ m^3 \times \left(\frac{1\ cm}{1\times10^{-2}\ m}\right)^3$$

The next step is to convert from cm^3 to minutes. Are minutes a cubic unit? No, so we are converting from a cubic unit to a non-cubic unit… we do NOT cube the conversion factor!

$$1500.\ m^3 \times \left(\frac{1\ cm}{1\times10^{-2}\ m}\right)^3 \times \frac{1\ min}{1.25\times10^{7}\ cm^3}$$

The m^3 cancel, the cm^3 cancel, and I am left with minutes, which is what I am asked for. The answer is 120. minutes.

Example: Convert 33.33 ft^3 to cm^3

What is given? 33.33 ft^3
What is asked for? cm^3

$$33.33\ ft^3 \times \left(\frac{12\ in}{1\ ft}\right)^3 \times \left(\frac{2.54\ cm}{1\ in}\right)^3 = 9.438\times10^5\ cm^3$$

Each step was a unit^3 to unit^3 conversion, so each step had to be cubed.

Example: What is the mass of 52.10 cm^3 of ethanol? (for ethanol, 1 cm^3 = 0.789 g)

$$52.10\ cm^3 \times \frac{0.789\ g}{1\ cm^3} = 41.1\ g$$

You are converting from a unit^3 to a non-cubed unit, so the conversion is not cubed.

Density:

The book defines density as $d = \frac{mass}{volume} = \frac{m}{v}$ which is obviously accurate. So I could tell you that the density of sea water at 20.0 ^oC is 0.9997021 g per cm^3, which would follow the above equation because it has mass units over volume units. Great, but look at the density again and you might notice that this is a conversion factor just like any of the ones above. This one happens to convert grams to cm^3 instead of inches to centimeters. That means that you can USE it like any other conversion factor.

Example: What is the volume of 1.224x10^5 g of seawater?

$$1.2249\times10^5\ g \times \frac{1\ cm^3}{0.9997021\ g} = 1.2253\times10^5\ cm^3$$

Example: What is the mass in kg of a 98.0 cm^3 block of aluminum? (d = 2.70 g/cm^3)

$$98.0\ \boldsymbol{cm^3} \times \frac{2.70\ \boldsymbol{g}}{1\ \boldsymbol{cm^3}} \times \frac{1\ \boldsymbol{kg}}{1\times 10^3\ \boldsymbol{g}} = 0.265\ \boldsymbol{kg}$$

At this point, I think you have several problems you can try to work through. I know you may have done several of them, but try them again and practice the thought process and the concepts above and on the previous review. If you can do the problems I have given as homework and you can do the problems I gave in class, you will be able to handle anything I can throw at you on the exam.

- All of this is systematic. I tried to give you plenty of practice problems so that you would see the patterns. If you didn't catch the patterns, GO BACK AND LOOK AGAIN!
- Think things through. If you made it through this, you know how to do the work, it is just a matter of applying what you learned to the problem in front of you.
- Don't get confused by the wording of the question. Break down the question into three parts: where are you starting, where are you going, and what outside knowledge might be useful. If you know where you are starting, then there are only a few places the next immediate step can go. Same thing with the next step after that. Pretty soon you are at the end!
- USE UNITS!!! Units are the roadmaps of chemistry. Carry through your units as you go, make SURE things cancel, don't just cross out the top unit of one step and the bottom of the next step. If you get to the end and you have the wrong units, you made a mistake somewhere.