Hydroponic Nutrients.

The first step to being able to create Hydroponic nutrients is to understand the difference between soil fertilizers, and the requirements of plants. Most growers are aware of soil fertilizers such as those called by numbers 20-20-20, but what does 20-20-20 really mean?

Does it mean 20% Nitrogen (N), and 20% Phosphorous (P), and 20% Potassium (K)
The N.P.K ratio.
No, it's not that simple.
It's, 20% Nitrogen (N) and 20% Phosphorous Pentoxide (P_2O_5) and 20% Di-Potassium Oxide (K_2O). (depending on the country of origin, these units change by continent)

This translates to the actual % of the N.P.K as follows.
20% Nitrogen (N), 8.8% Phosphorous (P), and 16.6% Potassium (K).

However a good Hydroponic nutrient contains all of these plus all the other minerals required for healthy growth. They will also be in the correct ratio to each other, according to plant type, and stage of growth, e.g. Vegetative, flowering or fruiting stage.

The minerals required for good growth are as follows:
Macro elements.

Nitrogen	(N)
Phosphorous	(P)
Potassium	(K)
Calcium	(Ca)
Magnesium	(Mg)
Sulphur	(S)

Micro elements:

Iron	(Fe)
Manganese	(Mn)
Boron	(B)
Copper	(Cu)
Zinc	(Zn)
Molybdenum	(Mo)
Sodium	(Na)
Chloride	(Cl)
Silicon	(Si)

There are other minerals found in plant tissue when analysed, but for our purposes these are the main requirements for Hydroponic growing, and the ones we have to monitor.

<u>Minerals and compounds used to supply the N.P.K and other elements needed,</u>
Many commercially available compounds are to be found in the horticultural and Hydroponic supply stores that are suitable for mixing to make Hydroponic nutrients, for the examples quoted, these have proved to be the most suitable for a healthy plant, and contain the minimum contaminants likely to upset the balance of trace elements, but the prices remain viable for commercial growers.

1/. Calcium Nitrate.

Greenhouse Grade Calcium Nitrate. NPK 15.5 - 0 - 0

This product is a refined, pilled, highly soluble material, consisting of Calcium Nitrate
$Ca(NO_3)_2$ with 5.7 - 6.5% Ammonium Nitrate (NH_4NO_3) and approximately 15% water of crystalisation (H_2O).

Typical analysis as follows.
Total Nitrogen (N) 15.5%   Nitrate (NO_3) 14.5% and Ammonium (NH_4) 1.0%

Calcium (Ca)	**18.8%**
Water insolubles	**0.2%**

Soluble impurities;

Copper (Cu)	**<0.0001%**
Magnesium (Mg)	**0.002%**
Lead (Pb)	**<0.0001%**
Aluminium (Al)	**<0.005%**
Potassium (K)	**0.005%**
Chloride (Cl)	**0.001%**
Manganese (Mn)	**<0.001%**
Sodium (Na)	**0.01%**
Iron (Fe)	**0.0015%**
Sulphate (SO_4)	**<0.02%**

The usual source of this material is from electrolysis of brine solutions, from sea water or brine lakes.

2/. Potassium Nitrate.

Greenhouse grade has the following typical analysis;

Potassium Nitrate (KNO_3)	**>99.0%**
K	**>38.4%**
N	**>13.7%**
Sodium (Na)	**<0.05%**
Chloride (Cl)	**<0.05%**
Calcium (Ca)	**<0.03%**
Water (H_2O)	**<0.04%**

The product is highly soluble, and is a major source of Potassium and Nitrogen in all Hydroponic nutrients.
The product is found naturally in Central India, South Africa, and Brazil as Nitre or Salt Petre. However most commercial production is from brine solutions, such as those found in the salt lakes in Utah, and the Dead Sea, where on evaporation the least soluble salt crystallizes first, namely Sodium Chloride, then follows Potassium Nitrate. The main contamination minerals to check for are Sodium and Chloride, as many crops are not tolerant to high levels of Sodium or Chloride, although a small quantity is often required for good growth. The levels given in the analysis above are suitable for any crop.

3/. Mono Potassium Phosphate. KH_2PO_4

Typical assay	KH_2PO_4		>99.7%
	P_2O_5		>52.1%
	K_2O		>34.5%
Arsenic		(As)	<0.00005%
Iron		(Fe)	<0.00018%
Fluoride		(F)	<0.0004%
Zinc		(Zn)	<0.0004%
Lead		(Pb)	<0.0005%
Water Insolubles			<0.05%
Water (H_2O)			<0.05%

Phosphorous is the 10th most abundant element in the earth, and 19th in sea water. Phosphate Rock is processed into several forms for use as a soil fertilizer, Phosphoric Acid is also used as a source of Phosphorous for Hydroponic solutions. Mono Potassium Phosphate is a very suitable form to add the required Phosphate to the nutrient.

<u>4/. Magnesium Sulphate (Epsom Salts)</u> $Mg(SO_4)\ 7H_20$

Typical assay	$Mg(SO_4)\ 7H_20$		>99.5%
	$Mg(SO_4)$		>49%
	MgO		>16%
	Mg		>10%
	SO_3		>33%
	SO_2		>26%
	S		>13%
Chloride (Cl)			<0.01%
Arsenic		(As)	<0.002%
Lead		(Pb)	<0.01%
Iron		(Fe)	<0.015%

Magnesium Sulphate occurs in nature as Keserite $MgSO_4.H_2O$.
Magnesium is ranked 8th in the earths crust and 5th in sea water.
Commercially Magnesium Sulphate Mg $(SO_4)\ 7H_20$ is made by the action of Sulphuric Acid on Magnesium Carbonate or Hydroxide. If a hot concentrated solution is cooled below 25 degrees C, Rhombic crystals of Mg $(SO_4)\ 7H_20$ Epsom salts is produced.
Magnesium metal is produced by electrolysis of brine solutions, and from this many magnesium compounds are produced.

<u>5/. Potassium Sulphate.</u> (Sulphate of Potash) K_2SO_4.

Typical assay Potassium	(K_2O)	50.5%
Chloride (Cl)		0.6%
Sodium (Na)		1.5%
Water (H_2O)		0.15%
Sulphur (S)		18.0%

Potassium Sulphate is manufactured from the mineral Schonite, $K_2SO_4.MgSO_4.6H_2O$. by a process of fractional crystallization. Sodium is often found at high levels in this compound, but only small quantities by ratio to the other sources of Potassium are used, so the final Sodium in the nutrient solution is suitable for most crops. Cheap grades with very high (excessive) levels of Sodium should not be used, choose the purer grades with the lowest Sodium level you can find.

6/. Iron Chelate. Sodium Ferric Ethylenediamine Tetra acetate (FeEDTA)
Molecular formula; $C_{10}H_{12}N_2O_8$ Na $Fe.3H_2O$

Typical analysis;	Iron (Fe)	13.2%
	Sodium (Na)	5.17%

Note* This product has to be stable in the range of pH we are to grow at.
Various grades and % content of Iron are available, make sure the one used is correct for the job, and has a known Iron % content. The relatively high Sodium content does not pose any problems as only small quantities by ratio to the rest of the minerals makes this suitable.
Other forms of Iron Chelate can be used, providing they are stable at the pH range the nutrient is being used at, some Chelate materials are not stable at the pH range plants are grown at, so check the solubility in the pH range intended.

7/. Boric Acid. Ortho Boric Acid H_3BO_3.

Typical analysis;	H_3BO_3.	>99.6%
	Chloride (Cl)	<0.014%
	Sulphate (SO_4)	<0.04%
	Calcium (Ca)	<0.002%
	Sodium (Na)	<0.021%
	Magnesium (Mg)	<0.005%

Naturally occurring in certain waters as Borax ($Na_2B_4O_7*10H_2O$)
Most important source is the mineral Rasorite found in the Mojave Desert of California.

8/. Manganese Sulphate. $MnSO_4.H_20$.

Typical analysis	$MnSO_4.H_20$.	>98%
	Water soluble (Mn)	>31%
	Iron (Fe)	<0.005%
	Chloride (Cl)	<0.02%

Manufactured from naturally occurring minerals Pyrolusite and Rhodocrosite, also Manganese nodules containing 24% Mn have been found in Lakes Michigan and Superior.

9/. Copper Sulphate . $CuSO_4$. $5H_20$

Typical analysis	$CuSO_4$. $5H_20$	>98%
	Copper (Cu)	>25%
	Iron (Fe)	<0.05%
	Lead (Pb)	<0.002%
	Arsenic (As)	<0.001%

Can be easily made by dissolving copper wire into Sulphuric Acid, the resulting liquid is evaporated to produce Copper Sulphate crystals $CuSO_4$. $5H_2$0

10/. Zinc Sulphate . $ZnSO_4$. $7H_2$0

Typical analysis	$ZnSO_4$. $H_2$0	>98%
	Zinc (Zn)	>35%
	Iron (Fe)	<0.008%
	Arsenic (As)	<0.0002%
	Cadmium (Cd)	<0.0015%
	Lead (Pb)	<0.0015%

A simple manufacturing process dissolves Zinc metal in Sulphuric acid, and evaporates the resulting liquid to produce Zinc Sulphate $ZnSO_4$. $7H_2$0
Very water soluble.

11/. Ammonium Molybdate $(NH_4)_6Mo_7O_{24}$

Typical analysis	$(NH_4)_6Mo_7O_{24}$	>98.5%
	Molybdenum Mo	>57.5%

Any impurities in this product will have little influence on the final formulation, as so little is added to the formula.
Molybdic Acid or Sodium Molybdate could be used as a replacement, but the formulation would need to be recalculated, as the % Mo is different in Molybdic Acid and Sodium Molybdate.

12/. Potassium Silicate. Liquid.
Many grades available. One such is Kasil 2236

Typical analysis	$K_2$0	10.8 to 11.2% by weight
	SiO_2	24.2 to 24.8% by weight

Note;
Alternate materials can be used to make up Hydroponic nutrients, for example, Manganese, Copper, and Zinc can be used in Chelate form, much more expensive, but preferred for some applications.

Magnesium Nitrate can supply Magnesium, when either extra Nitrate is needed or less Sulphate is required.

Sodium and Chloride are often found in sufficient quantities for plant growth in the base water being used, and as impurities in the other raw materials, only if very pure water is used, Chloride could be added, usually in the form of Calcium Chloride, and it would be rare to add Sodium, except in the case of Cherry Tomato production, where additions will improve the sugar level found in the fruit.

Whatever minerals are used, the final formulation must be totally soluble in water, not containing large quantities of insoluble material that can block fine drippers, filters, dosing pumps and solenoid valves.
Only when a mineral is totally dissolved in water can a plant take in the raw materials

they require to produce their own food supply. Carbon Dioxide, Water, and Oxygen are taken in along with the minerals, and the action of Sunlight on the leaves allows the plants to produce their own food from these raw materials.

Most formulations are provided in at least two parts, to keep the Calcium salts separate from the Sulphates, this is to avoid any possible chemical reaction, (to name one, Precipitation of insoluble Calcium Sulphate)
When finally diluted to the strength (CF or EC) we grow plants at, the Calcium and Sulphates remain stable, they are only precipitated when either nutrient concentrates are directly mixed, or when a heating system over heats in localized areas of heat exchangers, causing Calcium Sulphate to precipitated out. This can form as a scale on pipes and heat exchanger surfaces, eventually blocking pipes and fittings, reducing heating efficiency and removing the vital element Calcium from the nutrient, this in turn can cause Calcium deficiencies in the crop.

Calculating formulations;
Most Hydroponic formula have the minerals required in solution quoted as ppm (parts per million) to understand what these units are we have to use the metric system as follows;
1 part in 1.000.000 parts is 1ppm
If 1ppm of Nitrogen is needed in water, this would require 1gm in 1.000.000 gms of water, or 1 gm in 1000Kg. (as 1 liter of water weighs 1Kg, it follows that 1gm in 1000 liters of water is 1ppm)
When calculating for 360ppm Nitrogen in solution, we use the salt being used to supply the Nitrogen (using Potassium Nitrate for example) and need 360gms on Nitrogen in 1000 liters of water.
To calculate this we need the % of Nitrogen in Potassium Nitrate. (This is 14%) this % is usually available on the assay supplied with raw materials.
So when using Potassium Nitrate to produce a solution with 360ppm Nitrogen, we need;
360 divided by 14 x 100 = 2571.4
So 2571.4gms of Potassium Nitrate is needed in 1000 liters of water for 360ppm Nitrogen.

An example of the ppm range of elements required in a Hydroponic solution for general growing is as follows;

Element; ppm		CF range 15 TO 45 EC range 1.5 to 4.5
Nitrogen	(N)	100 - 300
Phosphorous	(P)	25 - 75
Potassium	(K)	150 - 450
Sulphur	(S)	40 - 120
Calcium	(Ca)	100 - 350
Magnesium	(Mg)	25 - 75
Sodium	(Na)	10 - 60
Chloride	(Cl)	5 - 80
Iron	(Fe)	2.0 - 10.0
Manganese	(Mn)	0.4 - 5.0
Boron	(B)	0.2 - 1.5
Zinc	(Zn)	0.1 - 3.0
Copper	(Cu)	0.1 - 1.0
Molybdenum	(Mo)	0.02 - 0.05

It is seen that if the CF is 15, (EC 1.5) the level required is the lower number, if the CF is at the higher level 45 (EC4.5) then the larger number is used, it all depends on the CF or EC level required by the crop as to which level you use.

Having this requirement of elements needed for your crop, and a list of ingredients to be used, you can calculate the weights of each salt to be used to produce the required formulation, if this is to difficult for you, then either buy pre mixed nutrients, adjusted for the salts in you own water supply, or get the formulation calculated by a suitably qualified person, and you may have to pay for this work to be done.

There are many formulations quoted in Hydroponic books and suppliers literature, we have not included any in our advice because most growers need a formulation to suit their water, climatic conditions and the type of crop being grown, there is no such thing as one perfect formulation. There are literally thousands of different formulations that are needed for different crop types and in different climatic conditions.
However if you choose one from a book, remember to have a water analysis done first to make sure it is suitable (see section on water requirements) and follow up with regular leaf analysis and nutrient analysis done in the first few months, this enables you the fine tune the formulation for your crop on your site. It is not unusual for commercial growers to continue adjustments, summer to winter, as the light factor changes between seasons, so the plants response to the levels of minerals in the solution changes, and adjustments to the levels of some minerals has to be made, also age of crop alters the plants requirements.
For example a young crop of Tomatoes needs less Potassium and more Nitrogen, however as the fruit sets the requirement for extra Potassium is greater, and it's easy to get into a situation where Potassium deficiency is seen in the crop if adjustments are not made.
Many crops need extra Nitrogen in summer and extra Phosphorous in winter, to list but one change.
Different crops require different ratios of minerals as they grow, some times it's best to leave the adjustments to the nutrient suppliers, they have many years of experience in crop nutritional needs.
When growing crops like Lettuces and Herbs, or any mix of crops where plants of different ages are in the system on the same nutrient, it becomes a case of producing a nutrient formulation that suits all stages of growth, a compromise but the younger plants may well be taking out the extra Nitrogen, while the older plants are needing extra Potassium, so in the end, a well balanced nutrient will take care of all stages of growth, and regular analysis will enable balancing of the formulation to suit the crop uptake.
It's only where a system is planted out all at one time, and grown to the end of the plants cycle together, that formulation changes are usually made, Tomatoes, Cucumbers and Capsicums for example.

Atomic weight of elements.

Name.	symbol.	Atomic weight
Boron	B	10.82
Calcium	Ca	40.08
Carbon	C	12.01
Chlorine	Cl	35.45
Copper	Cu	63.54
Hydrogen	H	1.008

Iron	Fe	55.85
Magnesium	Mg	24.32
Manganese	Mn	54.94
Molybdenum	Mo	95.95
Nitrogen	N	14.008
Oxygen	O	16.0
Phosphorous	P	30.975
Potassium	K	39.1
Silicon	Si	28.09
Sodium	Na	22.99
Sulphur	S	32.06
Zinc	Zn	65.38

% Elements in salts used in formulations.

Note; the % purity of these compounds varies by supplier, so remember to adjust these % by the purity, or take the % from the assay list for the product, (if stated at 94% pure in the assay, then these % should be multiplied by 0.94)

Calcium Nitrate	18.8%Ca	15.5%N
Potassium Nitrate (Saltpeter)	38%K	14%N
Magnesium Sulphate. (Epsom Salts)	9.8%Mg	13%S
Magnesium Nitrate	9.5%Mg	5.7%N
Mono Potassium Phosphate	28.6%K	22.7%P
Potassium Sulphate	40%K	16.5%S
Calcium Chloride	18.3%Ca	32.3%Cl
Ammonium Nitrate	35%N	
Manganese Sulphate	23%Mn	
Boric Acid	17.5%B	
Copper Sulphate	25%Cu	
Zinc Sulphate	22%Zn	
Ammonium Molybdate	58%Mo	
Sodium Molybdate	39.6%Mo	

Chelate materials % of elements change by supplier, check the pack, for example they can be.

Iron Chelate	13.2%Fe
Calcium Chelate	10%Ca
Copper Chelate	15%Cu

Magnesium Chelate	6%Mg
Manganese Chelate	14% Mn
Zinc Chelate	15%Zn

The choice of ingredients should be made by comparing the purity, price, and availability.
If Impurities are high, or supplies are not always available, choose the next best, the best price is not always the best choice.