Chemistry and Commercial Fertilizers

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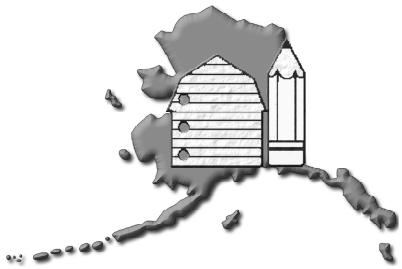
Objectives
Apply the science of chemistry to the production and use of commercial fertilizers.

Suggested grade levels
11-12

Alaska Content Standards
Science, D1,D3

Terms to Define
guaranteed minimum analysis
broadcast
urease
nitrification
microbial
hydrolysis
homogenous
apatite



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A. Introduction

Fertilizers are materials that are added to the soil or plant to supply one or more elements that are essential for plant growth.

Prior to WWII, animal and other manures were commonly used on farms. WWII brought a need for fixed N explosives, so 11 plants were constructed. After the war, they were used to produce fertilizer. Some tax laws passed in 1951 created an impetus for private industry to produce ammonia fertilizers. Use of N fertilizers accelerated the development of other commercial fertilizer materials.

B. Fertilizer grade and calculations

Fertilizers are sold or marketed according to their grade or analysis. All states require a grade or analysis on the label.

A fertilizer grade is the legally guaranteed minimum analysis of a nutrient present in the material. States have a system of laws and regulations that ensure the fertilizer is properly labeled and delivers the amount of nutrients stated on the bag.

Example: A label contains N, P, and K at a rate of 20-10-10 respectively. This label means there is 20% by weight of Nitrogen, 10% by weight of P_2O_5, and 10% by weight of K_2O. This is interesting. The fertilizer contains 10% of a compound, not the individual elements of P and K. So, how much P and K is actually contained in this fertilizer?

Formula weight of P_2O_5 = 142 grams/mole
Molecular weight of P = 31 grams/mole

62 grams/mole / 142 grams/mole = 43% P in P_2O_5
(43% P) x (0.10 or 10% by weight of P_2O_5) = 4.3% P in the bag of fertilizer
Can you determine how much K is in K_2O?

C. Nitrogen fertilizers

1. Raw material for the creation of most N fertilizers is anhydrous ammonia; anhydrous ammonia is created by the Haber-Bosch process:

$3\ H_2 + N_2$ + heat, pressure, & catalyst $\longrightarrow$ $2\ NH_3(g)$ = anhydrous ammonia

Anhydrous ammonia (82-0-0) is the lowest cost N fertilizer with the highest N analysis

It is sold as a liquid under pressure. It is injected into the soil and undergoes hydrolysis to produce ammonium as seen in the following reaction:

$$NH_3(g) + H_2O \longrightarrow NH_4OH \longrightarrow NH_4 + OH^- \longrightarrow NO_3^-$$

2. Urea (46-0-0) is the most common granular material. It is manufactured in small, medium, and large granules and is white, almost translucent, in color.

Urea undergoes hydrolysis to ammonium with assistance from the urease

enzyme.

Surface application of urea is potentially subject to volatilization if pH is high and there is just enough moisture to dissolve the granules but not move them down into the soil.

3. Ammonium nitrate (34-0-0)

Clays added to aid in formation of granules. Granules are white but not as translucent. Produce ammonium nitrate by mixing nitric acid with ammonia:

$$HNO_3 + NH_3 \longrightarrow NH_4NO_{23}$$

Ammonium nitrate is water soluble and more subject to leaching.

4. Ammonium sulfate (21-0-0-24)

More expensive, but it is a source of sulfur. Use this if you have a sulfur deficiency.

D. Phosphorous fertilizers

Raw material is rock phosphate or apatite:

Apatite + sulfuric acid $\longrightarrow$ superphosphate
Apatite + phosphoric acid $\longrightarrow$ triple superphosphate

E. Potassium fertilizers

KCl (0-0-60) or K_2SO_4 are the main raw materials for potassium fertilizers.

F. Blended fertilizers, granular homogenous fertilizers, complete fertilizers

• Blended fertilizer is a fertilizer mix produced by mechanically mixing solid fertilizer materials (granules of N, P, and K).
• A granular homogenous fertilizer is a mixed fertilizer produced by creating granules from the fertilizer material. In other words, each granule contains N, P, and K.
• A complete fertilizer contains N, P, and K- all the primary nutrients

G. Quick release vs. Slow release fertilizers

• Quick release fertilizers are readily available and are very water soluble
• Slow release fertilizers are less soluble fertilizers where the dissolution of the fertilizer in the granule has been reduced due to the addition of an additive or a coating that delays the rate of dissolution

-- Advantages of slow release fertilizers:

Less prone to leaching

Lower potential to cause injury to the plants and they can be applied at higher rates without risk of injury to plants

Higher N use efficiency by plants

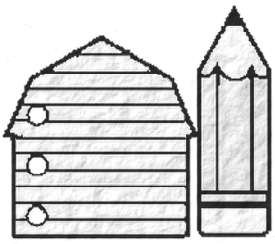
Less subject to volatilization

-- Disadvantages of slow release fertilizers:

They are expensive because the price is driven by the turf and horticulture markets even though they represent less than 1% of all fertilizer use world wide

-- Ways to make slow release fertilizers:

1. Polymer coated fertilizers — the problem of slowing N release from various compounds has been approached by coating N fertilizer materials with different types of materials



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Peter Bierman, UAF Cooperative Extension Service Land Agent in Palmer, contributed to this lesson.

2. Sulfur coated urea- urea with a coating of elemental sulfur + a binding agent + a sealant

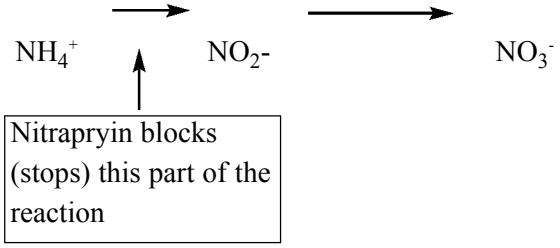
3. Synthetic organic compounds are combined with urea to produce slowly available forms of urea
Example: Urea formaldehydes- the urea to formaldehyde ratio influences its solubility (i.e. the more formaldehyde, the lower the solubility); release is controlled by microbial breakdown or hydrolysis so therefore the process is temperature dependent. Early spring applications may result in poor response due to cool soil temperatures

4. Natural organic nitrogen carriers- include various sewage sludge and plant and animal residues

H. Stabilized nitrogen or Nitrogen stabilizers

• N stabilizers typically refer to products mixed with or added to N fertilizer materials that either act as a urease inhibitor or a nitrification inhibitor. Some N stabilizers may contain both a urease and nitrification inhibitor. The resulting N fertilizer material is said to be stabilized because it is not as subject to losses from volatilization or leaching.

• Nitrification inhibitors: The first commercial N stabilizer that was widely used in North America was nitrapryin. The product was developed by Dow Chemical Company and sold under the trade name N-serve Nitrogen Stabilizer. Used widely in corn producing areas of the U.S. Material is a liquid that was mixed with anhydrous ammonia.



A urease and nitrification inhibitor is dicyandiamide or DCD and it is used with granular urea.

NBPT-N-(n-butyl) thiophosphoric triamide- sold under the trade name Agrotain. It is said to inhibit urease activity for up to 2 weeks

Because microbial reactions in Alaska soils are already slowed by cool soil temperatures, the use of nitrification and urease inhibitors may reduce N availability to crops.

I. Application Methods

• Broadcast- uniform application on the surface
• Broadcast + incorporation- uniform application on the surface followed by tillage, etc. to mix it into the soil
• Band- placing fertilizer in a narrow and smaller zone closer to the roots
• Point- applying a fertilizer at a specific point or on each individual plant
• Split applications- applying 2 or more fertilizer applications to coincide with peak nutrient uptake by plants

Commercial Fertilizers Problems Solutions (problems on separate student sheet)

1. Nitrogen: since the label indicates pure nitrogen by weight, then the pounds of N in the bag is simply 40% of 50 pounds which equals 20 lbs.

Phosphorous: remember that the 20% on the label means 20% of P_2O_5 by weight not just P. So, you need to figure out how much P is in the bag and then calculate the pounds.

Formula weight of P_2O_5 = 142 grams/mole
Molecular weight of P = 31 grams/mole

62 grams/mole / 142 grams/mole = 43% P in P_2O_5
(43% P) x (0.20 or 20% by weight of P2O5) = 8.6% P in the bag of fertilizer

8.6% P x 50 pounds = 4.3 pounds of P in the bag

Potassium: remember that the 20% on the label means 20% of the K_2O by weight not just K. So, you need to figure out how much K is in the bag and then calculate the pounds.

Molecular weight of K = 39 grams/mole
Formula weight of K_2O = 94 grams/mole

39 x 2 = 78 grams/mole / 94 grams/mole = 0.83 = 83% K in K_2O
(83% K) x (0.20 or 20% by weight of K_2O) = 16.6% K in the bag of fertilizer

16.6% K x 50 pounds = 8.3 pounds of K in the bag

2. Anhydrous ammonia
advantage: low cost with high N analysis
disadvantage: liquid under pressure which can be dangerous to use and it must be incorporated into the soil

Urea
Advantage: it is a common material and cheap, is safer to use, it can be stabilized because it requires the urease enzyme to produce ammonium and there are urease inhibitors
Disadvantage: it is subject to volatilization if it is not incorporated into the soil and there is enough moisture present

Ammonium nitrate
Advantage: safe to use, it is in a form that is readily available for plant uptake
Disadvantage: it is very water soluble so there is risk of leaching

Ammonium sulfate
Advantage: contains sulfur if your soil has a sulfur deficiency; soils in many parts of Alaska are deficient in sulfur for optimum growth of cereals and grass forages, so it is a useful nitrogen source for those crops
Disadvantage: it is expensive

3. Advantages of slow release fertilizers:
Less prone to leaching
Lower potential to cause injury to the plants and they can be applied at higher rates without risk of injury to plants
Higher N use efficiency by plants
Less subject to volatilization

4. Nitrogen stabilizers are a compound or chemical that interrupts, stops, or delays a reaction that produces a plant available form of nitrogen. This will decrease losses of plant available nitrogen to volatilization or leaching. See examples of the reactions above.

Name _____

Nitrogen Cycle Problems

Commercial Fertilizers Problems

1. A 50 pound bag of fertilizer has the following label on it:

N-P-K
40-20-20

How many pounds of N, P, and K are in this bag of fertilizer?

2. Name the four common nitrogen fertilizers and one advantage and disadvantage of each.

3. What are some advantages to slow release fertilizers?

4. How do nitrogen stabilizers work?