HYPORHEIC GAME INTRODUCTION

The hyporheic zone is the region beneath a stream or river where water from the stream flows before returning to the stream. This region is very important environmentally because it is rich in microbial activity and cleanses the stream water of many nutrients and pollutants. This game focuses on the hyporheic zone and its role in the nitrogen cycle.

HYPORHEIC GAME RULES (2-6 PLAYERS)

GAME EQUIPMENT:

Cards (cut sheets into 9 cards each), 1 game board (4 pages taped together), 1 token per player (polished rocks or tokens borrowed from another game), 4 types of nutrients: NO_3^-, NO_2^-, NH_3, NH_4^+ (cut sheets into 80 pieces each), and N_2 victory coins (cut sheets into 20 coins).

TO START THE GAME:

Each player chooses a token and places it in start. Shuffle the cards and place them face down on the "draw" pile. Roll the die and let the high roller go first. In the event of a tie roll until the tie is broken.

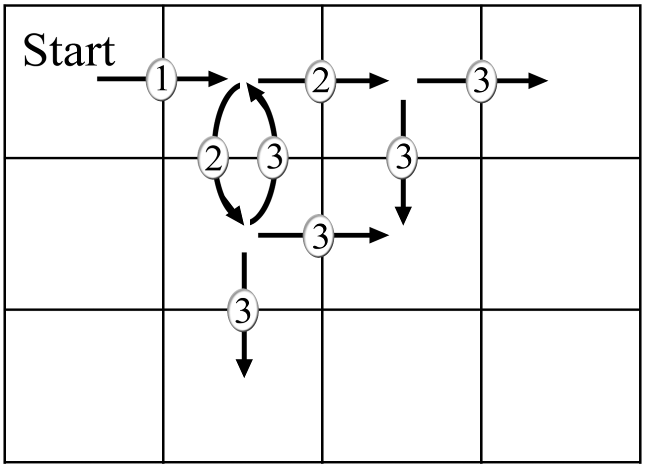
OBJECT OF THE GAME (WINNING):

Be the first person to collect SIX N_2 victory coins. For a longer or shorter game this number may be adjusted if agreed upon before play begins.

MOVING PIECES:

Roll the die and move the number of spaces shown. Within the surface water your first move must be to the right unless blocked by an X. After that each of the remaining moves may be up, down or right. (You may never move left in the surface water unless directed to do so by a card.) Within the hyporheic zone you must move according to the arrows.

For instance on your first move you may do any of the following moves if you roll a three.



X SQUARES:

You may under no circumstances move onto or through a square with an X on it. This means that you may move up or down for your first move if you start your turn immediately to the left of an X.

LANDING ON AN OCCUPIED SQUARE:

If you land on a square already occupied by an opponent, you have two choices. 1) You may send the opponent back to start. Then proceed as if you had landed on an unoccupied square. 2) If it is a nutrient square, collect those nutrients, then if you still have space and your opponent has nutrients, take two nutrients of your selection from your opponent. Next if you have landed on a draw space, draw and follow the directions on the card. Finally, you may roll again (unless you drew a roll again).

NUTRIENTS:

There are four types of nutrients in this game: NO_3^-, NO_2^-, NH_3, NH_4^+. You may never have more than **six nutrients** in your possession. You can acquire nutrients in three ways.

1) You land on a square with nutrients on it and take them from the nutrient bank.

2) You are instructed to take them by a card.

3) You land on an occupied square and take them from the occupant. (see "Landing on an Occupied Square")

You can lose nutrients in three ways.

1) You play them in the hyporheic zone in order to execute an equation. (See: Hyporheic Paths)

2) You are instructed to remove them by a card.

3) Someone lands on your square and chooses to take two of your nutrients. (see "Landing on an Occupied Square")

REACHING THE RIGHT SIDE OF THE BOARD:

If you reach the right side of the board continue on to the left side, this board is periodic (i.e. wrap-around), simulating an infinite series of bedforms.

GAME BOARD REGIONS:

The region above the sand (with all of the squares) represents the surface water. The hyporheic zone is all of the area below the surface water (any of the circles with A's or O's are part of the hyporheic zone.).

HYPORHEIC PATHS:

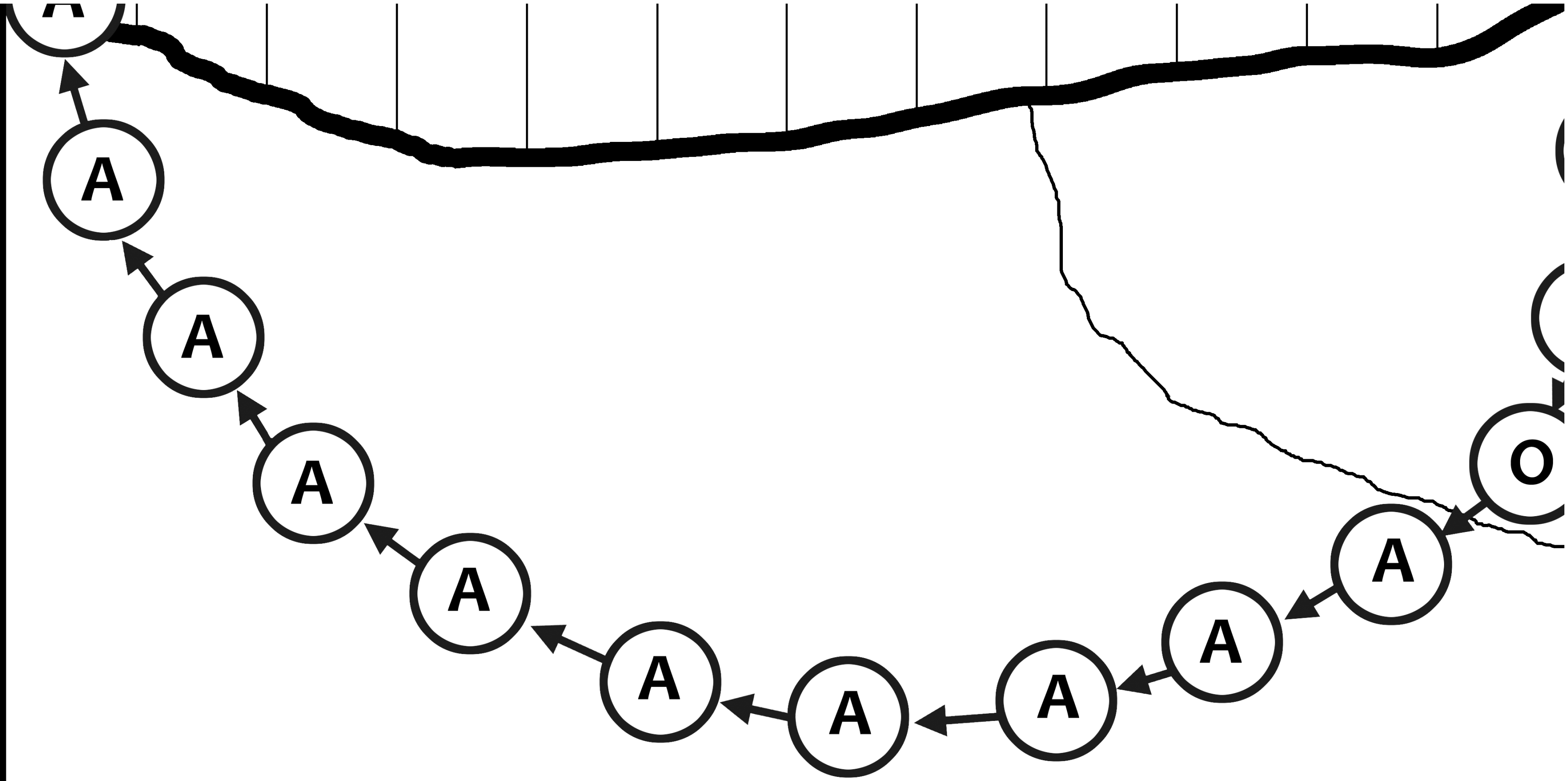
Once you have entered a hyporheic path your movement is limited. You must follow the arrows the number of spaces corresponding to your die roll until you exit the hyporheic path. If you land in the oxic zone you must execute an oxic equation if you can and similarly if you land in the anoxic zone you must execute an anoxic equation if you can. To execute an equation you must have all of the compounds shown in bold on the left side, you will trade them in and get out the compounds shown in bold on the right hand side of the equation. For instance, if you are in the anoxic region and have two NO_2^- you could exchange them for a N_2 victory coin, using the equation: $\mathbf{2NO_2^-} + 6e^- + 8H^+ \rightarrow \mathbf{N_2(g)} + 4H_2O$.

CARDS:

If the draw pile runs out, shuffle the discard pile and place them face down in the draw position. You must always do as directed by the card, if it is possible to do so. If the card directs you to take two nutrients and you already have five, then you only take one, because you cannot have more than six in your possession. If the card directs you to move forward and you hit an X, you stop before the X. If it directs you to move down and you are already in the lowest grid square, you cannot follow the instructions. In the instance that the card tells everyone to move, you may not end up on an occupied square. For instance if it tells everyone to go 3 steps forward and there is someone three steps in front of you, who is sitting behind a wall and thus cannot move forward, then you will move two steps forward and stop. Without the X you would both move three steps and not interfere with each other.

N_2 VICTORY COINS:

You get a victory coin by executing any of three anoxic equations in the hyporheic zone. You can never lose a victory coin. You need six coins to win the game. These do not count in your limit of six nutrients.



DRAW

DISCARD

Oxic Equa

$2NH_3 + 3O_2 \rightarrow 2$

$2NO_2^- + O_2 \rightarrow 2$

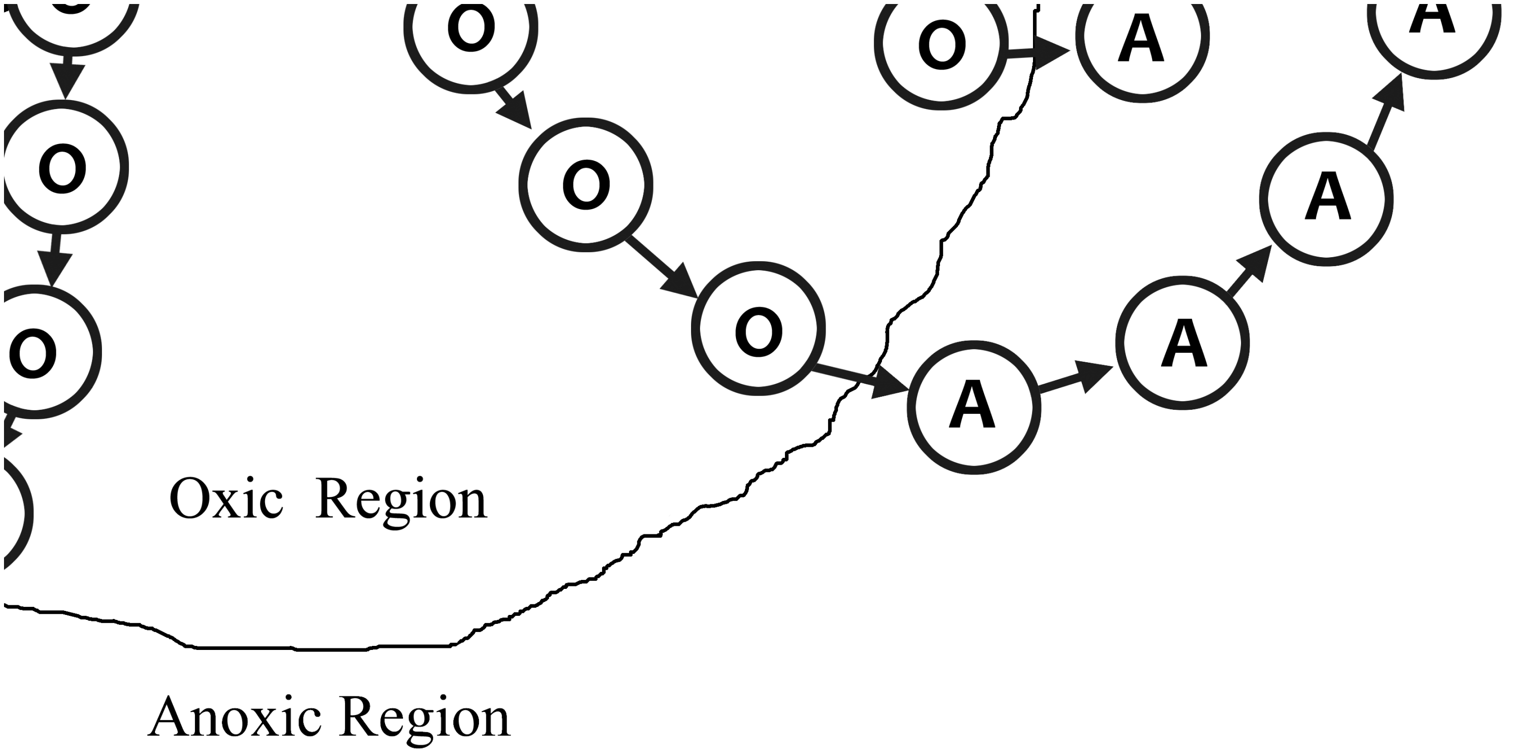
$NH_3 + O_2 \rightarrow N$

$4NH_4^+ + 3O_2 \rightarrow 2$

TH

Start

1			NO_2^-	NH_3			NH_4^+	Draw			NO_3^-
2 NO_3^-		NH_3				☒		NO_3^-		NH_4^+	☒
3 $3NO_2^-$	NH_4^+		NO_3^-				NH_3		NO_2^-	NH_3	Draw
4	NO_2^-				NH_3		Draw				☒
5 Draw		NH_3		NH_4^+	☒						NH_3
6								NH_4^+	Draw		
7								NH_3			
8			Draw								
A											



tions

$NO_2^- + 2H^+ + 2H_2O$

NO_3^-

$NO_2^- + 2e^- + 3H^+$

$2NH_4^+ + 2NO_2^- + 4H^+ + 2H_2O$

Anoxic Equations

$NO_3^- + 2e^- + 2H^+ \rightarrow NO_2^- + H_2O$

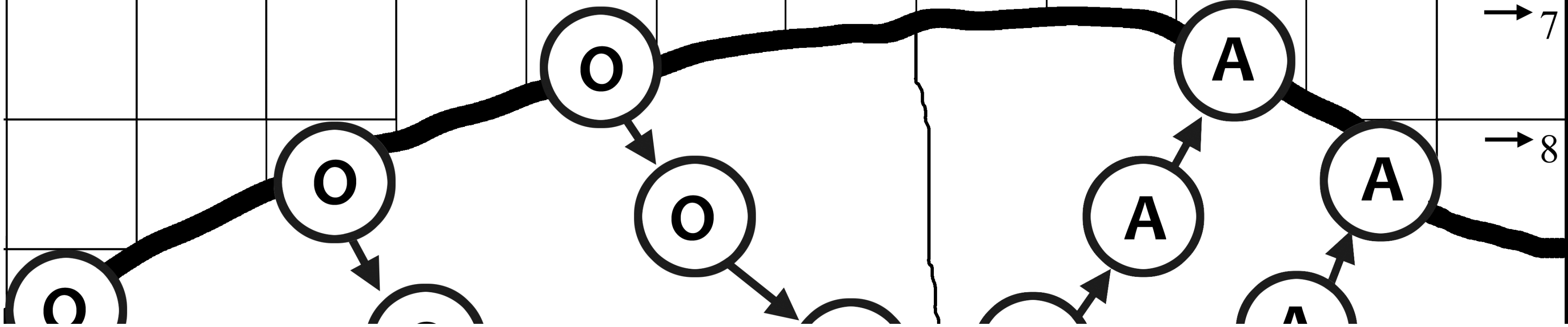
$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2(g) + 6H_2O$ (1 point)

$2NO_2^- + 6e^- + 8H^+ \rightarrow N_2(g) + 4H_2O$ (1 point)

$NH_4^+ + NO_2^- \rightarrow N_2(g) + 2H_2O$ (1 point)

IE HYPORHEIC GAME

	$2NH_4^+$	Draw	$2NO_3^-$	$3NO_2^-$	$3NH_4^+$	$2NO_2^-$		NH_3	$2NO_2^-$		→ 1
$2NO_2^-$		NO_2^-		$2NO_2^-$	$2NH_3$	Draw		$2NO_2^-$	Draw	NH_3	→ 2
	$2NO_3^-$	X	$2NH_4^+$	X	$2NO_2^-$		NH_3		NH_4^+		→ 3 NO_2^-
NO_2^-			Draw				X			$2NO_2^-$	→ 4
			X		NH_3				$2NO_2^-$	Draw	→ 5
	X										→ 6
											→ 7
											→ 8



More Acidic

The pH increases when an acid is dumped into the stream causing more ammonium ions.

Every player must change all collected NH_3’s in possession into NH_4^+ ions.

Cow Pie

Ammonium ions are excreted directly into streams by aquatic and sometimes non-aquatic animals.

All players may collect as many NH_4^+ ions as they would like.

Switch Places

Switch places with any other player of your choice.

More Basic

The pH decreases when a strong base is dumped into the stream causing more ammonia.

Every player must change all collected NH_4^+ ions in possession into NH_3’s.

Fertilizing Farmer

Nitrates (NO_3^-) are commonly applied to crops as fertilizer to increase yield. Much of the fertilizer runs off the crops into the drainage ditches and neighboring streams.

Everyone in the surface water must take two NO_3^- compounds.

Switch Places

Switch places with any other player of your choice.

Decaying Fish

Decaying animal and plant matter are decomposed by bacteria releasing ammonium ions into the stream in a process called ammonification.

You must take two NH_4^+ ions.

Gun Powder

Potassium Nitrate (KNO_3), a.k.a. saltpetre, is an ingredient in gunpowder.

A soldier using an antique rifle accidently dumps some into a stream during a civil war reenactment.

You must take two NO_3^- compounds.

Quick Dive

Jump to the start of your hyporheic path of choice.

Quick Dive

Jump to the start of your hyporheic path of choice.

Storm Surge

Rain upstream increases the amount and speed of the water flowing through the stream channel.

Every player must move 3 squares forward.

(In the surface water this means right and on the hyporheic paths this means follow the arrows. Stop before hitting an X or another player.)

Opposing Eddies

Water can run against the primary current, frequently in a whirlpool shape. You get caught in an eddy.

Roll the die and move left the number of squares shown.

(Stop before hitting an X or another player.)

Nutrient Trading

Allowing nutrient sources to trade pollution allowances in order to meet water quality goals rewards and encourages entities to pollute less and is a means of improving water quality.

Trade up to 2 compounds of your choice with the player of your choice.

Drought

A lack of precipitation causes the stream water level to drop due to decreased streamflow.

Every player in the surface water must move 3 squares down.

(Stop before hitting an X, the bottom, or another player.)

Hyporheic Flushing

Disturbing the sediments mobilizes the water and solutes in the hyporheic zone.

All players on a hyporheic path must return to start.

Nutrient Trading

Allowing nutrient sources to trade pollution allowances in order to meet water quality goals rewards and encourages entities to pollute less and is a means of improving water quality.

Trade up to 2 compounds of your choice with the player of your choice.

Clogging Clay

A layer of clay is temporarily deposited on the sediment boundary reducing flow into the hyporheic paths

No one may move in or enter a hyporheic path on his/her next turn.

Plant Prevalence

Plants require nitrogen to grow. They absorb nitrogen in the form of nitrate (NO3-) and ammonium ions (NH4+).

Lose an NO_3^- and an NH_4^+ if you have one or more in your possession.

Decaying Plants

Decaying animal and plant matter are decomposed by bacteria releasing ammonium ions into the stream in a process called ammonification.

You must take two NH_4^+ ions.

Swift Current

The water in the stream does not all travel at the same rate. Frequently water near the center moves faster than water at the edges and the speed also increases when the stream narrows.

Roll Again

Nitrate Poisoning

While nitrate (NO_3^-) is naturally found in vegetables, too much is dangerous, especially to infants.

All players lose all of their NO_3^- compounds.

Super Swift Current

Double Roll Again

Roll the die twice and add the results together. Move this number of spaces.

(Your first move must still be forward if possible.)

Swift Current

The water in the stream does not all travel at the same rate. Frequently water near the center moves faster than water at the edges and the speed also increases when the stream narrows.

Roll Again

Algal Bloom

An algal bloom occurs due to too many nutrients. In addition to consuming nutrients, when the algae decays, it uses up oxygen creating hypoxic conditions, which cannot support much life.

Remove all nutrients from the player of your choice

Swift Current

The water in the stream does not all travel at the same rate. Frequently water near the center moves faster than water at the edges and the speed also increases when the stream narrows.

Roll Again

Septic Systems

Some nitrate (NO_3^-) which is produced by a septic system, leaks into groundwater, and makes its way into the stream.

Collect two NO_3^- compounds.

Hypoxia

Hypoxia describes a region lacking oxygen. The amount of oxygen in the water can decrease to the point where it is hard or impossible for aquatic life to breathe, creating a “dead zone”. This results from a surplus of nutrients.

No one may use equations in the oxic region on his/her next turn.

Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-

Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-
Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-	Ammonia NH_3	Ammonium NH_4^+	Nitrite NO_2^-	Nitrate NO_3^-

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

N_2

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas

Victory Point

Nitrogen gas