



An essential element

1. is required for a plant to complete its life cycle;
2. cannot be replaced by another element;
3. is directly involved in the plant's metabolism; and
4. is required by many different plants.

Adapted from Arnon, D., & Stout, P. (1939, July). The essentiality of certain elements in minute quantity for plants with special reference to copper. *Plant Physiology*, 14(3), 599–602.



Name _____

Date _____

1

1

Hydrogen

1.007

2

2

Helium

4.0026

3

3

Li

Lithium

6.941

4

4

Be

Beryllium

9.012

5

5

B

Boron

10.81

6

6

C

Carbon

12.0111

7

7

N

Nitrogen

14.0067

8

8

O

Oxygen

15.9994

9

9

F

Fluorine

18.998

10

10

Ne

Neon

20.179

11

11

Na

Sodium

22.98977

12

12

Mg

Magnesium

24.305

13

13

Al

Aluminum

26.9815

14

14

Si

Silicon

28.0855

15

15

P

Phosphorus

30.973

16

16

S

Sulfur

32.06

17

17

Cl

Chlorine

35.453

18

18

Ar

Argon

39.948

19

19

K

Potassium

39.098

20

20

Ca

Calcium

40.08

21

21

Sc

Scandium

44.955

22

22

Ti

Titanium

47.88

23

23

V

Vanadium

50.9415

24

24

Cr

Chromium

51.996

25

25

Mn

Manganese

54.938

26

26

Fe

Iron

55.847

27

27

Co

Cobalt

58.933

28

28

Ni

Nickel

58.69

29

29

Cu

Copper

63.546

30

30

Zn

Zinc

65.39

31

31

Ga

Gallium

69.72

32

32

Ge

Germanium

72.63

33

33

As

Arsenic

74.92

34

34

Se

Selenium

78.96

35

35

Br

Bromine

79.904

36

36

Kr

Krypton

83.90

37

37

Rb

Rubidium

85.467

38

38

Sr

Strontium

87.62

39

39

Y

Yttrium

88.905

40

40

Zr

Zirconium

91.224

41

41

Nb

Niobium

92.906

42

42

Mo

Molybdenum

95.94

43

43

Tc

Technetium

(98)

44

44

Ru

Ruthenium

101.07

45

45

Rh

Rhodium

102.906

46

46

Pd

Palladium

106.42

47

47

Ag

Silver

107.868

48

48

Cd

Cadmium

112.41

49

49

In

Indium

114.82

50

50

Sn

Tin

118.71

51

51

Sb

Antimony

121.76

52

52

Te

Tellurium

127.60

53

53

I

Iodine

126.905

54

54

Xe

Xenon

131.29

55

55

Cs

Cesium

132.905

56

56

Ba

Barium

137.3

57

57

La

Lanthanum

138.905

72

72

Hf

Hafnium

178.49

73

73

Ta

Tantalum

180.948

74

74

W

Tungsten

183.85

75

75

Re

Rhenium

186.207

76

76

Os

Osmium

190.2

77

77

Ir

Iridium

192.22

78

78

Pt

Platinum

195.08

79

79

Au

Gold

196.967

80

80

Hg

Mercury

200.59

81

81

Tl

Thallium

204.383

82

82

Pb

Lead

207.2

83

83

Bi

Bismuth

208.980

84

84

Po

Polonium

(209)

85

85

At

Astatine

(210)

86

86

Rn

Radon

(222)

87

87

Fr

Francium

(223)

88

88

Ra

Radium

(226.0)

89

89

Ac

Actinium

(227.028)

104

104

(261)

105

105

(262)

106

106

(263)

107

107

(262)

108

108

(265)

109

109

(266)

58

58

Ce

Cerium

140.12

59

59

Pr

Praseodymium

140.908

60

60

Nd

Neodymium

144.24

61

61

Pm

Promethium

(145)

62

62

Sm

Samarium

150.36

63

63

Eu

Europium

151.96

64

64

Gd

Gadolinium

157.25

65

65

Tb

Terbium

158.925

66

66

Dy

Dysprosium

162.50

67

67

Ho

Holmium

164.930

68

68

Er

Erbium

167.26

69

69

Tm

Thulium

168.934

70

70

Yb

Ytterbium

173.04

71

71

Lu

Lutetium

174.96

90

90

Th

Thorium

232.038

91

91

Pa

Protactinium

231.036

92

92

U

Uranium

238.029

93

93

Np

Neptunium

(241)

94

94

Pu

Plutonium

(244)

95

95

Am

Americium

(243)

96

96

Cm

Curium

(247)

97

97

Bk

Berkelium

(247)

98

98

Cf

Californium

(251)

99

99

Es

Einsteinium

(252)

100

100

Fm

Fermium

(257)

101

101

Md

Mendelevium

(258)

102

102

No

Nobelium

(259)

103

103

Lr

Lawrencium

(260)

14

14

Si

Silicon

28.0855

Atomic number

Symbol

Name

Atomic mass

18

18

Ar

Argon

39.948

Master 1.3, Chemical Symbols of the Elements

Symbol	Element	Symbol	Element	Symbol	Element
Ac	Actinium	He	Helium	Ra	Radium
Ag	Silver	Hf	Hafnium	Rb	Rubidium
Al	Aluminum	Hg	Mercury	Re	Rhenium
Am	Americium	Ho	Holmium	Rf	Rutherfordium
Ar	Argon	Hs	Hassium	Rh	Rhodium
As	Arsenic	I	Iodine	Rn	Radon
At	Astatine	In	Indium	Ru	Ruthenium
Au	Gold	Ir	Iridium	S	Sulfur
B	Boron	K	Potassium	Sb	Antimony
Ba	Barium	Kr	Krypton	Sc	Scandium
Be	Beryllium	La	Lanthanum	Se	Selenium
Bh	Bohrium	Li	Lithium	Sg	Seabogium
Bi	Bismuth	Lr	Lawrencium	Si	Silicon
Bk	Berkelium	Lu	Lutetium	Sm	Samarium
Br	Bromine	Md	Mendelevium	Sn	Tin
C	Carbon	Mg	Magnesium	Sr	Strontium
Ca	Calcium	Mn	Manganese	Ta	Tantalum
Cd	Cadmium	Mo	Molybdenum	Tb	Terbium
Ce	Cerium	Mt	Meitnerium	Tc	Technetium
Cf	Californium	N	Nitrogen	Te	Tellurium
Cl	Chlorine	Na	Sodium	Th	Thorium
Cm	Curium	Nb	Niobium	Ti	Titanium
Co	Cobalt	Nd	Neodymium	Tl	Thallium
Cr	Chromium	Ne	Neon	Tm	Thulium
Cs	Cesium	Ni	Nickel	U	Uranium
Cu	Copper	No	Nobelium	Uub	Ununbium
Db	Dubnium	Np	Neptunium	Uuh	Ununhexium
Er	Erbium	O	Oxygen	Uun	Ununnilium
Es	Einsteinium	Os	Osmium	Uuo	Ununoctium
Eu	Europium	P	Phosphorus	Uuu	Unununium
F	Fluorine	Pa	Protactinium	Uuq	Ununquadium
Fe	Iron	Pb	Lead	V	Vanadium
Fm	Fermium	Pd	Palladium	W	Tungsten
Fr	Francium	Pm	Promethium	Xe	Xenon
Ga	Gallium	Po	Polonium	Y	Yttrium
Gd	Gadolinium	Pr	Praseodymium	Yb	Ytterbium
Ge	Germanium	Pt	Platinum	Zn	Zinc
H	Hydrogen	Pu	Plutonium	Zr	Zirconium

Master 1.4, Essential Plant Nutrients

1	H Hydrogen 1.008	2	He Helium 4.003	3	Li Lithium 6.941	4	Be Beryllium 9.012	5	B Boron 10.81	6	C Carbon 12.011	7	N Nitrogen 14.007	8	O Oxygen 16.004	9	F Fluorine 18.998	10	Ne Neon 20.179
11	Na Sodium 22.987	12	Mg Magnesium 24.305	13	Al Aluminum 26.982	14	Si Silicon 28.086	15	P Phosphorus 30.974	16	S Sulfur 32.06	17	Cl Chlorine 35.45	18	Ar Argon 39.948	19	K Potassium 39.098	20	Ca Calcium 40.08
21	Sc Scandium 44.956	22	Ti Titanium 47.88	23	V Vanadium 50.942	24	Cr Chromium 51.996	25	Mn Manganese 54.938	26	Fe Iron 55.847	27	Co Cobalt 58.933	28	Ni Nickel 58.69	29	Cu Copper 63.546	30	Zn Zinc 65.38
31	Ga Gallium 69.723	32	Ge Germanium 72.64	33	As Arsenic 74.922	34	Se Selenium 78.96	35	Br Bromine 79.904	36	Kr Krypton 83.80	37	Rb Rubidium 85.468	38	Sr Strontium 87.62	39	Y Yttrium 88.906	40	Zr Zirconium 91.224
41	Nb Niobium 92.906	42	Mo Molybdenum 95.94	43	Tc Technetium (98)	44	Ru Ruthenium 101.07	45	Rh Rhodium 102.906	46	Pd Palladium 106.42	47	Ag Silver 107.865	48	Cd Cadmium 112.41	49	In Indium 114.82	50	Sn Tin 118.71
51	Sb Antimony 121.75	52	Te Tellurium 127.6	53	I Iodine 126.905	54	Xe Xenon 131.29	55	Cs Cesium 132.905	56	Ba Barium 137.33	57	La Lanthanum 138.905	58	Ce Cerium 140.12	59	Pr Praseodymium 140.908	60	Nd Neodymium 144.24
61	Pm Promethium (145)	62	Sm Samarium 150.36	63	Eu Europium 151.96	64	Gd Gadolinium 157.25	65	Tb Terbium 158.925	66	Dy Dysprosium 162.50	67	Ho Holmium 164.93	68	Er Erbium 167.26	69	Tm Thulium 168.934	70	Yb Ytterbium 173.05
71	Lr Lawrencium (260)	72	Hf Hafnium 178.49	73	Ta Tantalum 180.948	74	W Tungsten 183.85	75	Re Rhenium 186.207	76	Os Osmium 190.2	77	Ir Iridium 192.22	78	Pt Platinum 195.08	79	Au Gold 196.967	80	Hg Mercury 200.59
81	Tl Thallium 204.38	82	Pb Lead 207.2	83	Bi Bismuth 208.980	84	Po Polonium (209)	85	At Astatine (210)	86	Rn Radon (222)	87	Fr Francium (223)	88	Ra Radium (226)	89	Ac Actinium (227)	90	Th Thorium 232.038
91	Pa Protactinium 231.036	92	U Uranium 238.029	93	Np Neptunium (241)	94	Pu Plutonium (244)	95	Am Americium (243)	96	Cm Curium (247)	97	Bk Berkelium (247)	98	Cf Californium (251)	99	Es Einsteinium (252)	100	Fm Fermium (257)
101	Md Mendelevium (258)	102	No Nobelium (259)	103	Lr Lawrencium (260)	104	Rf Rutherfordium (261)	105	Db Dubnium (262)	106	Sg Seaborgium (266)	107	Bh Bohrium (264)	108	Hs Hassium (277)	109	Mt Meitnerium (268)	110	Ds Darmstadtium (271)
111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130

Master 1.6, Sources of Essential Nutrients

Name

Date



Essential Nutrient	Source		
	Air	Water	Soil
Boron (B)			
Calcium (Ca)			
Carbon (C)			
Chlorine (Cl)			
Copper (Cu)			
Hydrogen (H)			
Iron (Fe)			
Magnesium (Mg)			
Manganese (Mn)			
Molybdenum (Mo)			
Nickel (Ni)			
Nitrogen (N)			
Oxygen (O)			
Phosphorus (P)			
Potassium (K)			
Sulfur (S)			
Zinc (Zn)			

Master 1.7, Using Nitrogen

Name _____

Date _____



Nitrogen is an important building block of many molecules found in cells. A lack of nitrogen limits the growth of many plants. This fact is surprising since the air is nearly 80 percent nitrogen. However, the nitrogen gas in the air cannot be used directly by plants. First, it must be combined with other elements such as hydrogen or oxygen before plants can use it.

When plants and animals die, they are decomposed (broken down) in the soil by microbes. This microbial decomposition process releases nitrogen from the organic matter in a form that plants need (i.e. as ammonium, or after further microbial action, as nitrate).

Plants of the legume family, which include peas, beans, alfalfa, peanuts, and soybeans, are unusual. They can convert nitrogen gas to a usable form all by themselves. This is because they have a close relationship with bacteria that live in their roots. The bacteria use sugars from the plants for energy. The bacteria use some of this energy to take nitrogen gas from the air and convert it into a form that the plant can use.

Questions

1. What happens to plants if soil microbes are not present to convert either nitrogen gas to a usable form, or to release nitrogen from dead plants and the soil's organic matter?
2. What could you do to help plants grow in soil that doesn't contain enough usable nitrogen?