

# **Balancing Reaction Equations Oxidation State Reduction-oxidation Reactions**

OCN 623 – Chemical Oceanography

Chemistry is the glue that holds together all the other fields of oceanography

Chemistry interacts directly with each of the other fields

Chemical distributions in the ocean secretly record and integrate the biological, physical and geological processes

There are 118 chemical elements many with multiple oxidation states and isotopes—lots of tracers to investigate the world

Balanced chemical reactions are the **math** of chemistry

They show the **relationship** between the reactants and the products

We will use thermodynamics later on to calculate the **feasibility** of reactions and to understand how equilibrium is established

The concept of **equilibrium** allows us to understand chemical processes such as ionic speciation, oxidation state distributions gas solubility, the carbonate system .....

Elements are electrically neutral, the number of protons in the nucleus exactly balances the number of electrons that fill the shells

Element	Electron Configuration
Hydrogen	$1s^1$
Helium	$1s^2$
Lithium	$1s^2 2s^1$
Beryllium	$1s^2 2s^2$
Boron	$1s^2 2s^2 2p^1$
Carbon	$1s^2 2s^2 2p^2$
Nitrogen	$1s^2 2s^2 2p^3$
Oxygen	$1s^2 2s^2 2p^4$
Fluorine	$1s^2 2s^2 2p^5$
Neon	$1s^2 2s^2 2p^6$
Sodium	$1s^2 2s^2 2p^6 3s^1$
Magnesium	$1s^2 2s^2 2p^6 3s^2$
Aluminium	$1s^2 2s^2 2p^6 3s^2 3p^1$
Silicon	$1s^2 2s^2 2p^6 3s^2 3p^2$
Phosphorus	$1s^2 2s^2 2p^6 3s^2 3p^3$
Sulfur	$1s^2 2s^2 2p^6 3s^2 3p^4$
Chlorine	$1s^2 2s^2 2p^6 3s^2 3p^5$
Argon	$1s^2 2s^2 2p^6 3s^2 3p^6$

Shells are filled in order with each additional electron occupying the lowest energy shell available

### The Periodic Table of Elements

Atomic Number = Number of Protons = Number of Electrons

Chemical Symbol

Chemical Name

Atomic Weight = Number of Protons + Number of Neutrons

6

**C**

CARBON

12

METALS										NON-METALS													
1 H HYDROGEN			2 He HELIUM																				
3 Li LITHIUM	4 Be BERYLLIUM																	5 B BORON	6 C CARBON	7 N NITROGEN	8 O OXYGEN	9 F FLUORINE	10 Ne NEON
11 Na SODIUM	12 Mg MAGNESIUM																	13 Al ALUMINUM	14 Si SILICON	15 P PHOSPHORUS	16 S SULFUR	17 Cl CHLORINE	18 Ar ARGON
19 K POTASSIUM	20 Ca CALCIUM	21 Sc SCANDIUM	22 Ti TITANIUM	23 V VANADIUM	24 Cr CHROMIUM	25 Mn MANGANESE	26 Fe IRON	27 Co COBALT	28 Ni NICKEL	29 Cu COPPER	30 Zn ZINC	31 Ga GALLIUM	32 Ge GERMANIUM	33 As ARSENIC	34 Se SELENIUM	35 Br BROMINE	36 Kr KRYPTON						
37 Rb RUBIDIUM	38 Sr STRONTIUM	39 Y YTIORIUM	40 Zr ZIRCONIUM	41 Nb NIOBIUM	42 Mo MOLYBDENUM	43 Tc TECHNETIUM	44 Ru RHODIUM	45 Rh RHODIUM	46 Pd PALLADIUM	47 Ag SILVER	48 Cd CADMIUM	49 In INDIUM	50 Sn TIN	51 Sb ANTIMONY	52 Te TELLURIUM	53 I IODINE	54 Xe XENON						
55 Cs CAESIUM	56 Ba BARIUM	57 La LANTHANUM	58 Ce CELESIUM	59 Pr PRASEODYMIUM	60 Nd NEODYMIUM	61 Pm PROMETHIUM	62 Sm SAMARIUM	63 Eu EUROPIUM	64 Gd GADOLINIUM	65 Tb TERBIUM	66 Dy DYSprosIUM	67 Ho HOLMIUM	68 Er ERBIUM	69 Tm THULIUM	70 Yb YtterBIUM	71 Lu LUTETIUM							
87 Fr FRANCIUM	88 Ra RADIUM	89 Ac ACTINIUM	90 Th THORIUM	91 Pa ProtactINIUM	92 U URANIUM	93 Np NeptUNIUM	94 Pu PLUTONIUM	95 Am AMERICIUM	96 Cm CURIUM	97 Bk BERKELEYIUM	98 Cf CALIFORNIA	99 Es EINSTEINIUM	100 Fm FERMIUM	101 Md MendeLIVIUM	102 No NobelIUM	103 Lr LAWRENCEIUM							

**KEY**

- Solid at room temperature
- Liquid at room temperature
- Gas at room temperature
- \* Radioactive
- \* Artificially Made

\*The atomic weights listed on this Table of Elements have been rounded to the nearest whole number. As a result, this chart actually displays the mass number of a specific isotope for each element. An element's complete, unrounded atomic weight can be found on the IUPAC Element web site: <http://education.jlab.org/elemental/index.html>

Last revised on June 22, 2004

1s

3s

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p (dumbbell shaped) orbitals

$p_x$     $p_y$     $p_z$

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d orbitals

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f orbitals

## A. Oxidation state or number

Oxidation: **Loss** of electrons from an element.  
Oxidation number **increases**

Reduction: **Gain** of electrons by an element.  
Oxidation number **decreases**

If we want to determine whether reaction is oxidation or reduction

Need to know **oxidation number** of the element and how it changes

Rules for determining oxidation number of an element

1. **Oxidation state of an element in its elementary state = 0**  
e.g.  $\text{Cl}_2$ , Na, P,....etc.

2. **Oxidation state of an element in a monatomic (only one atom) ion is equal to the charge on the ion**

e.g.  $\text{Na}^+ = +1$ ;  $\text{Cl}^- = -1$ ;  $\text{Fe}^{3+} = +3$

3. Oxidation state of certain elements is the same in all, or almost all of their compounds

e.g. Group 1A elements: Li, Na, K, Rb, Cs = +1

Group 2A elements: Be, Mg, Ca, Sr, Ba, Ra = +2

Group VII b elements: F, Cl, Br, I, At = -1 in binary compounds

Oxygen is almost always -2 (Except: when bonded to O or F)

H is almost always +1; Except with a metal, e.g. NaH, CaH<sub>2</sub> is -1

4. The sum of the oxidation states in a neutral species is = 0;

In a charged ion it is equal to the charge on the ion

e.g. Na<sub>2</sub>Se: Na = +1x2 = 2, thus Se = -2

MnO<sub>4</sub><sup>-</sup>: O = -2x4 = -8, thus Mn = 8-1 = 7

### The Periodic Table of Elements

**Atomic Number = Number of Protons = Number of Electrons**  
**Chemical Symbol**  
**Chemical Name**  
**Atomic Weight = Number of Protons + Number of Neutrons**

**KEY**

- ☐ = Solid at room temperature
- ☉ = Liquid at room temperature
- ☁ = Gas at room temperature
- ☛ = Radioactive
- ☛ = Artificially Made

\* The atomic weights listed on this Table of Elements have been rounded to the nearest whole number. As a result, this chart actually displays the mass number of a specific isotope for each element. An element's complete, unrounded atomic weight can be found on the I.U.P.A.C. Element web site: <http://education.jlab.org/elemental/index.html>

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5. **Fractional oxidation numbers are possible.** E.g., in  $\text{Na}_2\text{S}_4\text{O}_6$  (*sodium tetrathionate*), S has an oxidation number of +10/4:

$$\text{O: } 6(-2) = -12$$

$$\text{Na: } 2(+1) = 2$$

Residual = -10, which must be balanced by S:

$$\text{S: } 4(+10/4) = +10$$

6. **The oxidation number is designated by:**

- Arabic number below the atom, or
- Roman numeral or Arabic number after the atom (in parentheses)

What is the oxidation state of the elements in  $\text{KNO}_3$ ?

K= ?; O= ?; N=?

$\text{K}_2\text{Cr}_2\text{O}_7$ ? K= ?; O= ?, Cr= ?

**Oxidation is an increase in oxidation state**

e.g.  $\text{Cl}^-$  to  $\text{Cl}_2$  is -1 to 0

**Reduction is a decrease in oxidation state**

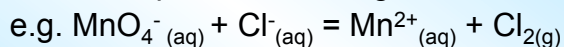
$\text{SO}_4^{2-}$  to  $\text{H}_2\text{S}$  is a reduction S VI to S -II

Recognising oxidation/reduction

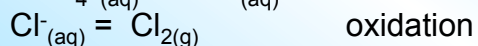
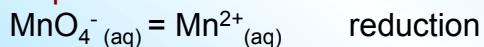
$\text{KMnO}_4$  to  $\text{MnO}_2$  oxidation or reduction?

## B. Balancing oxidation-reduction reactions

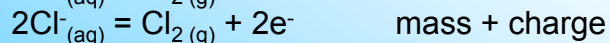
Conventionally always put the oxidised species on the left, the reduced species on the right



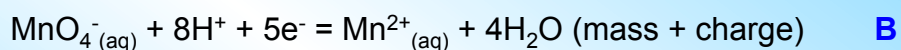
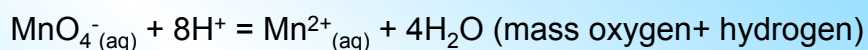
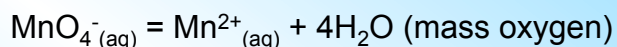
1. Separate the reaction into a reduction and oxidation part



2. Balance each 1/2 reaction with respect to mass then with respect to charge. Use  $e^-$ ,  $\text{H}^+$ ,  $\text{H}_2\text{O}$  or  $\text{OH}^-$



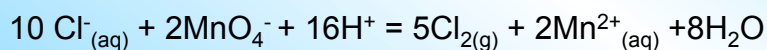
**A**



**B**

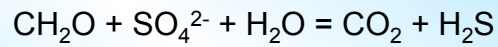
3. Combine half reactions so electron gain equals loss

$$5 \cdot \text{A} = 10 e^-; 2 \cdot \text{B} = 10 e^- \text{ i.e. } 5 \cdot \text{A} + 2 \cdot \text{B}$$



4. Check for atom and charge balance

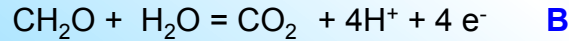
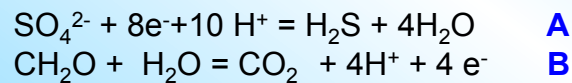
### C. Oxidation of organic matter



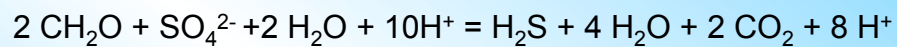
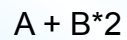
0                                  IV                  ox state of C

How did we get the oxidation state of the C in CH<sub>2</sub>O?

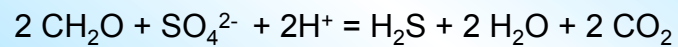
Separate into oxidation and reduction half reactions



Combine so electrons balance:



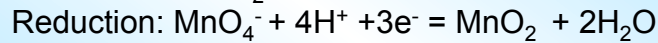
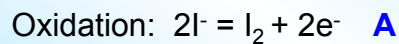
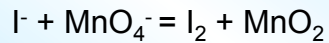
Simplify by subtracting 8 H<sup>+</sup> and 2 H<sub>2</sub>O from each side.



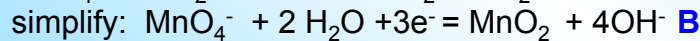
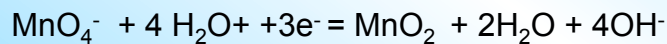
This reaction is the oxidation of organic matter through the reduction of sulphate, you will see this reaction later in reducing sediments.



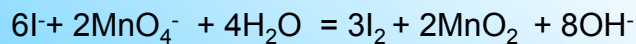
### D. An example in basic solution:



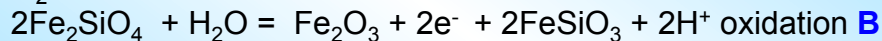
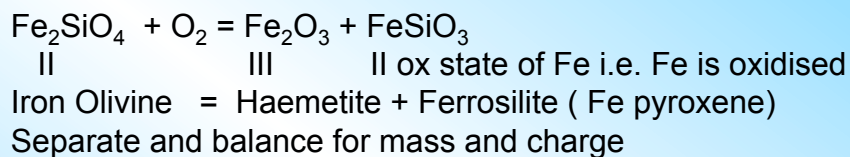
remove  $\text{H}^+$  by adding  $\text{OH}^-$  to each side \* 4 ( $4\text{H}^+ + 4\text{OH}^- = 4\text{H}_2\text{O}$ )



combine so electrons balance:  $\text{A} * 3 + \text{B} * 2$

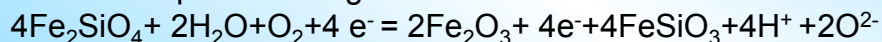


### E. A weathering reaction.

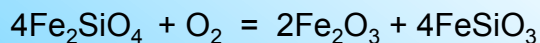


Note have added  $\text{H}_2\text{O}$  on LH side

Combine eqns balancing  $\text{e}^-$   $\text{A} + 2 * \text{B}$

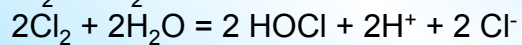
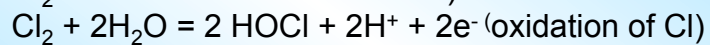
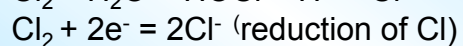
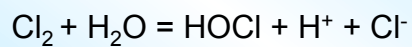


cancel  $4\text{e}^-$  on each side then cancel as  $2\text{H}_2\text{O} = 4\text{H}^+ + 2\text{O}^{2-}$



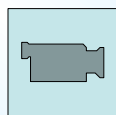
Removal of oxygen by oxidation of reduced iron compounds

Example where the same compound is being oxidised and reduced:



This may have been what happened to  $\text{Cl}_2$  released from the degassing of the early Earth.

The Periodic table



<https://youtu.be/VgVQKCcfwnU>

# Periodic Table of Beer Styles

**A brief description of beer styles with commercial examples**

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	
1. <b>Belgian wizen</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	2. <b>Lambic</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	3. <b>Belgian gold ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	4. <b>Belgian white</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	5. <b>Gueuze</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	6. <b>Tripel</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	7. <b>American wheat</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	8. <b>Faro</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	9. <b>Saison</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	10. <b>Pale ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	11. <b>American lite</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	12. <b>Munich helles</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	13. <b>Helles bock</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	
14. <b>Weizenbier</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	15. <b>Fruit beer</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	16. <b>Belgian pale ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	17. <b>American pale ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	18. <b>Ordinary bitter</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	19. <b>Scottish light 68°</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	20. <b>English mild</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	21. <b>Dry stout</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	22. <b>Foreign extra stout</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	23. <b>German pilsner</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	24. <b>American standard</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	25. <b>Dortmunder</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	26. <b>Doppelbock</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	
27. <b>Dunkelweizen</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	28. <b>Flanders red</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	29. <b>Belgian dark ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	30. <b>India pale ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	31. <b>Special bitter</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	32. <b>Scottish heavy 70°</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	33. <b>American brown</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	34. <b>Brown porter</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	35. <b>Sweet stout</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	36. <b>Imperial stout</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	37. <b>Bohemian pilsner</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	38. <b>American premium</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	39. <b>Munich dunkel</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	40. <b>Traditional bock</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4
41. <b>Weizenbock</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	42. <b>Oud bruin</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	43. <b>Dubbel</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	44. <b>American amber ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	45. <b>Extra special bitter</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	46. <b>Scottish Export 80°</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	47. <b>English brown</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	48. <b>Robust porter</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	49. <b>Oatmeal stout</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	50. <b>Russian imperial stout</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	51. <b>American pilsner</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	52. <b>American dark</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	53. <b>Schwarzbier</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	54. <b>Eisbock</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4
55. <b>Kölsch</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	56. <b>Bière de garde</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	57. <b>Oktoberfest</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	58. <b>Cream ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	59. <b>Smoked beer</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	60. <b>English old (strong) ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	61. <b>Altbier</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	62. <b>Vienna</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	63. <b>Steam beer</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	64. <b>Barleywine</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4	65. <b>Strong "Scottish" ale</b> 1.004-1.006 1.008-1.012 2.5-3.4 2.1-2.4 2.3-2.5 4.4			

**Key**

**Style number**  
8 (not description of beer style)

**Style name**  
Faro

**ABV**  
Alcohol by volume  
4.8-6.5  
15-20

**IBU**  
International Bittering Units

**Original gravity**  
1.044-1.056  
1.005-1.015

**Final gravity**

**SRM**  
Color by standard reference method

**Key to yeast type**

**Style family key**

**MIXED STYLES**

## Rejected elements of the periodic table

1 H																		2 Td	
Hélium																		Tedum	
3 Ac	4 Cx															5 M	6 Ct	7 Fl	8 P
Actium	Clorox															Moron	Carton	Florentine	Pylon
9 Bg	10 Hx	11 A	12 Pk	13 Su	14 V	15 Bs	16 L	17 As	18 Cr										
Belgium	Hydrox	Anodyne	Pekingese	Sumerian	Vinyl	Bosporus	Linoleum	Asinine	Crouton										
19 Dm	20 Am	21 At	22 Ch	23 Ca	24 To	25 Ge	26 An	27 Rp	28 Pr										
Delirium	Aspartame	Antipathy	Chagrin	Canadian	Talc	Geranium	Antigen	Rapine	Princeton										
29 Bz	30 Cn	31 Pz	32 Qt	33 Gu	34 X	35 Sn	36 Vi	37 Cd											
Byzantium	Collagen	Pizzazz	Quotidian	Gummi	Xena	Sin	Visine	Callnedon											
38 Im	39 Fg	40 Gb	41 Gv	42 Bn	43 Cb	44 Lu													
Imodium	Fahrvorg-nigen	Sanatorium	Asparagus	Hefnerium	Antigone	Grenadine													
		Gambinium	Genovesium	Bonanium	Colombium	Lucchesium													

■ Sentient Metals      ■ Dingy Gases  
■ Al Kaline Metals      ■ Solid Gases  
■ Fey Metals      ■ Criminal Elements  
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