

# Atoms

# Learning Outcomes

- 1. Understand the difference between 1) elements and compounds, 2) pure substances and mixtures.
- 2. Understand the difference between homogeneous and heterogeneous mixtures.
- 3. Describe the nuclear model of the atom and account for 1) where the protons and neutrons are located, 2) the charge and relative mass of protons, neutrons, and electrons, 3) where the electrons can be, 4) how much empty space is in the atom, and 5) where the majority of the atom's mass is located.
- 4. Determine the ion charge from the number of protons and electrons, and determine the number of protons and electrons in an ion.
- 5. State the relationship of two atoms to one another when the number of protons, neutrons, or electrons change.

## Matter Composition



\* Chemical methods of separation include electrolysis.

# **Question 1**

Classify the following matter:

- (a) Water  $(H_2O)$ .
- (b) Iron Metal
- (c) Lemonade
- (d) 3% Commercial Hydrogen Peroxide Solution
  - (H<sub>2</sub>O<sub>2</sub> dissolved in water)
- (e) Carbon Dioxide (CO<sub>2</sub>)
- (f) Gold in a River (gold in water)

## Matter Composition



\* Chemical methods of separation include electrolysis. <sup>†</sup> Physical methods of separation include filtration, distillation, and crystallization.

# Question 2

Classify the following matter:

(a) Apple Juice (sugar and other compounds dissolved in water)

(b) Salad Dressing(oil and vinegar mixed together with other solid matter)

(c) No-Pulp Orange Juice

(d) High-Pulp Orange Juice

# Learning Outcomes

- 1. Interpret an element's atomic symbol to determine the number of protons and name (for elements 1 through 36 in addition to Ag, Pt, Au, Hg, and Pb).
- 2. Determine atomic numbers, mass numbers, charge, and isotope symbols for an isotope based on the number of subatomic particles.
- 3. Describe Mendeleev's periodic law and explain why the periodic table is arranged in order of increasing atomic number.
- 4. Use the periodic table to classify elements by group and predict the charge for elements that form predictable ions.

### Atoms: The Smallest Unit of Matter

Similar to how LEGO bricks are the smallest pieces of a LEGO set, atoms are the smallest units that make up matter



### Atoms Observed Via Scanning Tunneling Microscopy (STM)



# History of Atomic Chemistry

0:00 to 5:25

https://www.youtube.com/watch?v=thnDxFd kzZs

#### Plum-Pudding Model: Uniform Distribution of Electrons in a Positive Charge Medium

Analogy: Positive Charge: Cake Medium Electrons: Plum Bits





### How to Test If the Plum Pudding Model Was Correct?



(a) Rutherford's expected result

### How to Test If the Plum Pudding Model Was Correct?

Rutherford's gold foil experiment



### How to Test If the Plum Pudding Model Was Correct?

Rutherford's gold foil experiment



# What Does the Atom Look Like?

The atom is made up of protons, neutrons, and electrons. They are called subatomic particles.



# Problem 3

If an atom is the size of a football stadium, which of the following objects when placed at the center of the stadium is the respective size of the nucleus?

(a) Grain of rice
(b) Marble
(c) Football
(d) Car
(e) Hot Air Balloon

### **Subatomic Particles**

TABLE 4.1	Subatomic Particles		
	Mass (kg)	Mass (amu)	Charge
proton	$1.67262  imes 10^{-27}$	1.0073	1+
neutron	$1.67493  imes 10^{-27}$	1.0087	0
electron	$0.00091  imes 10^{-27}$	0.00055	1-

 $1 \text{ amu} = 1.660539 \times 10^{-27} \text{ kg}$ 

# Elements Are Defined by Their Number of Protons (Atomic Number)



# Problem 4

Identify the following elements based on the number of protons they have.

(a) 2
(b) 6
(c) 8
(d) 29

## Problem 5

Which element is the following atom? (NOT drawn to scale!!)



Ions are Atoms that have Extra or Missing Electrons

**Cations: Positive Charge** 

#### Cats have paws!

Anions: Negative Charge



Ions are Atoms that have Extra or Missing Electrons

### **Cations: Positive Charge**

#### Cats have paws!

### **Anions: Negative Charge**



### Formation of Cations and Anions

Lithium cation formation:

### $Li \longrightarrow Li^+ + e^-$

Fluoride anion formation:

$$F + e^- \longrightarrow F^-$$

## Problem 6

### An atom has 8 electrons and is neutral. Which element is this atom?

### A General Chemical Symbol Also Includes the Mass Number



Z = # of protons X = Element symbol A = # of protons + # of neutrons (A = p + n or A = Z + n)

#### Isotopes Are Atoms With The Same Number of Protons But Different Number of Neutrons



Graduated from Analy high school in 1926!!

Why Are Element Masses Found on the Periodic Table Often Not Whole?



If chlorine has 17 protons and 17 neutrons shouldn't it have a mass of 34 amu and not 35.45 amu?

### Why Are Mass Numbers Often Not Whole?

Isotope	Natural Abundance (%)
$^{35}\mathrm{Cl}$	75.77
$^{37}\mathrm{Cl}$	24.23



 $m = (0.7577) (34.97 \text{ amu}) + (0.2423) (36.97 \text{ amu})_{{}_{35}\text{Cl}} (36.97 \text{ amu})$ 

m = 35.45 amu

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# The Periodic Table!!

Interpret an element's atomic symbol to determine the number of protons and name (for elements 1 through 36 in addition to Ag, Pt, Au, Hg, and Pb).

	1A 1						Me	etals										8A 18
1	1 H	2A 2		Nonmetals3A4A5AMetalloids131415													7A 17	2 He
2	3 Li	4 Be		5         6         7         8         9           B         C         N         O         F													10 Ne	
3	11 Na	12 Mg	3B 3	4B 4	5B 5	6B 6	7B 7	8	— 8B — 9	10	1B 11	2B 12	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 <b>Rn</b>
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 <b>Bh</b>	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
		22	Lantha	nides	58 Ce	59 Pr	60 Nd	61 <b>Pm</b>	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
			Acti	nides	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

## Problem 7

Isotope Name	Isotope Symbol	Atomic $\#$	${\rm Mass}~\#$	Protons	Neutrons	Electrons	Charge
				12	12		2+
			19	9			0

#### When Placed in the Order of The Periodic Table, Properties of the Elements can be Predicted

The properties (colors) of these elements form a repeating pattern.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Η	He	Li	Be	В	С	Ν	0	F	Ne	Na	Mg	Al	Si	Р	S	Cl	Ar	K	Са

### A Vertical Arrangement Is More Insightful

Elements with similar properties align in vertical columns.

1 H							2 He
3	4	5	6	7	8	9	10
Li	Be	B	C	N	O	F	Ne
11	12	13	14	15	16	17	18
Na	Mg	Al	Si	P	S	Cl	Ar
19 K	20 Ca						

## The Periodic Table!!

	1A 1						Me	etals										8A 18
1	1 H	2A 2				Ļ		3A 13	4A 14	5A 15	6A 16	7A 17	2 He					
2	3 Li	4 Be				L		5 B	6 C	7 N	8 0	9 F	10 Ne					
3	11 Na	12 Mg	3B 3	4B 4	5B 5	6B 6	7B 7	8	— 8B — 9	10	1B 11	2B 12	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 <b>Os</b>	77 Ir	78 <b>P</b> t	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 <b>Rn</b>
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 <b>Bh</b>	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
			Lantha	nides	58 Ce	59 Pr	60 Nd	61 <b>Pm</b>	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 <b>Ho</b>	68 Er	69 Tm	70 Yb	71 Lu
			Acti	nides	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

## Metals





Properties: Conducts heat and electricity, malleable, typically shiny, tend to lose electrons in chemical reactions

### Nonmetals





Sulphur

Carbon

### Properties: Poor conductors and tend to gain electrons in chemical reactions

# Semiconductors (Metalloids)





Silicon wafer after die cutting. This prepares many integrated circuits. A die is an integrated circuit.

Germanium

# Properties: Intermediate between metals and nonmetals.

### Semiconductors Absorb Visible Light!



#### Mono-crystalline solar cell panel

### Elements in the Periodic Table Can be Further Sub-classified

For CHEM 42 it is especially important to identify the transition metals, halogens, and noble gases.

Alk: met	ali als																0	Noble gases
ļ	Alkaline earth metals Halogens															s↓		
1																	8A	
	1	↓ ↓		Group numbers														2
ł	H	2A		3A 4A 5A 6A 7A														He
	3	4				6	7	8	9	10								
I	i	Be				Ν	0	F	Ne									
1	1	12		Transition metals $13$ $14$ $15$ $16$ $17$														18
N	la	Mg		Iransition metals													Ar	
1	0	20	21	22	22	24	25	26	27	20	20	30	21	22	22	24	25	26
L L	9 z	20	21	ZZ Ti	25 V	24 Cr	25 Mn	20 Fe	$\frac{27}{Co}$	Z0 Ni	29 Cu	50 7n	Ga	52 Ge		54	33 Br	50 Kr
	~	Ca	30	11	V	CI	IVIII	IC	0	INI	Cu	LII	Ua	UC	AS	50	DI	
3	7	38	39	40	41	42	43	44 D	45	46	47	48	49	50	51	52 T	53	54
R	b	Sr	Y	Zr	Nb	Mo	Ic	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	le	1	Xe
5	5	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
C	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Ро	At	Rn
8	7	88	89	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
F	r	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og
				B	58	59	60	61	62	63	64	65	66	67	68	69	70	71
		Lan	thani	des	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
					00	01	02	03	04	05	06	07	08	00	100	101	102	102
		P	Actinio	des	90 Th	Pa	92 11	95 Nn	94 Pu	Am	90 Cm	97 Bk	98 Cf	99 Fs	Fm	Md	102 No	IUS Ir
III ra U Np ru Am Cm BK										DK	CI	LS	1 m	witu	140	LI		

#### The Periodic Tables Makes it Easier to Predict The Ionic Charge

