Antoine Lavoisier and the Process of Scientific Inquiry

1. **a)** Antoine Lavoisier (and Marie-Anne Lavoisier)—French chemist, contributors to the development and communication of science

b) discovery and establishment of the law of conservation of mass

c) 1743–1794

d) Lavoisier's laboratory in France

e) Lavoisier wanted to prove that it was impossible and illogical for anything to have negative weight.

f) Lavoisier conducted a series of controlled experiments, recorded the precise mass of all substances before and after reaction, and found that the total mass of the substances used was equal to the total mass of the substances produced.

2.

Questioning and Predicting

- could substances have negative weight?
- hypothesized that it was impossible and illogical for anything to have negative weight
- predicted that matter was neither created nor destroyed in chemical reactions

Planning and Conducting

- designed series of controlled experiments
- drew schematic diagrams of apparatus and experimental setup

Processing and Analyzing

- recorded all steps
- measured and compared the mass of all substances used and produced

Evaluating

- total mass of mercury(II) oxide was the same as the total mass of mercury and of oxygen
- total mass of the substances used was equal to total mass of the substances produced
- experimental results supported prediction

Applying

- repeated his experiment with different metals
- results confirm substances cannot have negative weight

Communicating

- lab findings were published and shared
- other scientists had meticulous notes and results so they could assess and replicate Lavoisier's findings
- developed law of conservation of mass

Writing Chemical Names and Formulas of Ionic and Covalent Compounds

1. a) aluminum bromide

b) platinum(II) sulfide

c) strontium sulfite

d) scandium oxide

e) titanium(IV) nitrite

f) ammonium sulfate

g) lithium selenide

h) lead(II) bisulfate or lead(II) hydrogen sulfate

i) sodium acetate

j) cesium chloride

k) potassium chromate

l) calcium carbonate

m) cadmium hydroxide

n) zinc phosphate

o) barium chloride

p) tin(II) permanganate

q) lithium hypochlorite

r) gold(III) sulfate

s) sodium nitrate

t) chromium(III) chloride

u) potassium carbonate

v) iron(III) bisulfide or iron(III) hydrogen sulfide

w) silver nitrate

x) uranium(VI) fluoride

2. a) BeO
b) K_3P
c) NaF
d) $HgBr_2$
e) $CuSO_4$
f) SnO
g) ZnI_2
h) $Ca(NO_3)_2$
i) $Mn(OH)_3$
j) $CoSO_4$
k) Ag_2S
l) $Bi_3(PO_4)_5$
m) CrF_3
n) $K_2Cr_2O_7$
o) $Ni(CN)_2$
p) $Pb(CO_3)_2$
q) NH_4ClO_4
r) $NaHCO_3$
s) $Mg(CN)_2$
t) $LiHSO_4$
u) Re_3As_7
v) $Sr(CH_3COO)_2$
w) $BrCrO_4$
x) $NaMnO_4$

3. a) SiF_2
b) CO
c) ICl_3
d) CCl_4
e) BI_3
f) PBr_3
g) IF_5
h) $SeBr_2$
i) ClO_2
j) PBr_5
k) N_2O_4
l) SO_3
m) SO_2
n) N_2O_3
o) Cl_2O
p) SF_6
q) NO
r) C_3S_2
s) B_2H_6
t) As_2O_3

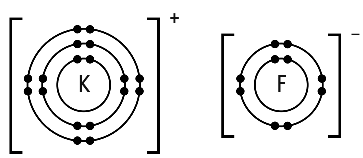
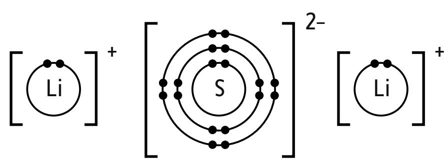
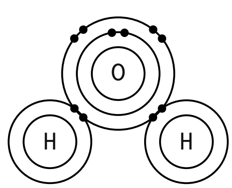
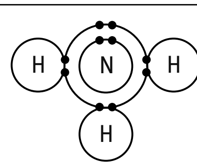
4. a) silicon dioxide
b) chlorine dioxide
c) phosphorus pentachloride
d) tellurium dioxide
e) selenium trioxide
f) carbon disulfide
g) arsenic trichloride
h) carbon dioxide
i) bromine pentafluoride
j) diphosphorus trisulfide
k) selenium difluoride
l) dinitrogen pentoxide
m) arsenic tetrabromide
n) disulfur pentoxide
o) sulfur monochloride
p) phosphorus trifluoride
q) diphosphorus pentoxide
r) dinitrogen monoxide
s) chlorine heptoxide
t) iodine monochloride

Bohr Models

1.

Atom/Ion	Atomic Number	Number of Protons	Number of Electrons	Number of Neutrons	Charge	Number of Electron Shells
hydrogen atom	1	1	1	1	0	1
potassium atom	19	19	19	12	0	4
fluorine atom	9	9	10	10	0	2
fluorine ion	9	9	9	10	–1	2
lithium atom	3	3	3	4	0	2
sulfur atom	16	16	16	16	0	3
sulfide ion	16	16	18	16	–2	3
oxygen atom	8	8	8	8	0	2
nitrogen atom	7	7	7	7	0	2

2.

Compound	Bohr Model Diagram
a) KF Name: potassium fluoride Type of bonds: ionic Number of bonds: 1	
b) Li_2S Name: lithium sulfide Type of bonds: ionic Number of bonds: 2	
c) H_2O Name: water Type of bonds: covalent, single bonds Number of bonds: 2	
d) NH_3 Name: nitrogen trihydride or ammonia Type of bonds: covalent, single bonds Number of bonds: 3	

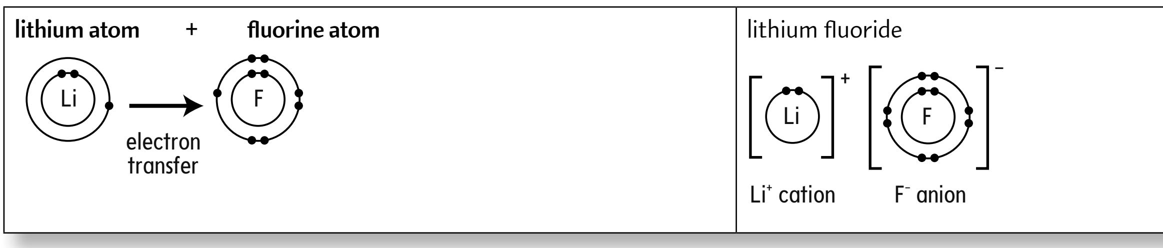
The valence shells of all the atoms in each compound are full.

Bonds and Energy

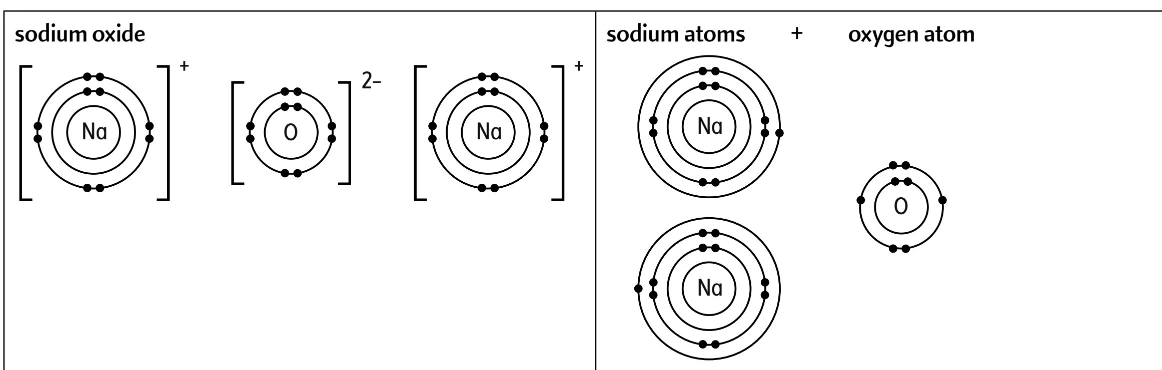
1. a) Ionic compounds (binary ionic compounds): composed of ions of one metal element and ions of one non-metal element joined by ionic bonds.

   b) Ionic bond. Electron transfer between atoms (metal atom loses electron while non-metal atom gains electron) results in a strong attraction that forms between oppositely charged ions. Upon formation of ionic compounds, ions attain full valence shells and greater stability.

   c) Lithium atom loses 1 electron and it becomes a +1 charged cation. Fluorine atom gains 1 electron and it becomes a –1 charged anion. An ionic bond is formed and energy is released.



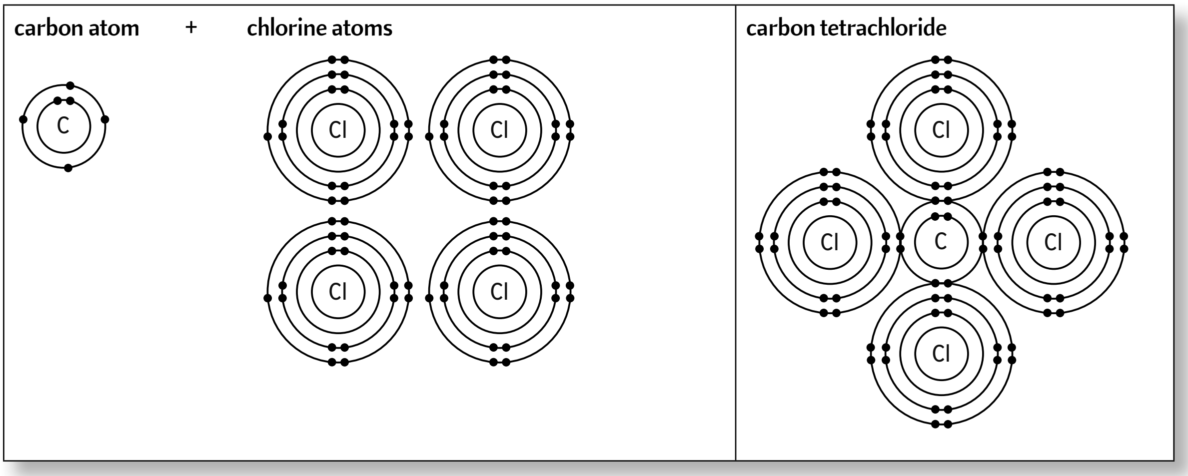
   d) Energy is needed to break two ionic bonds.



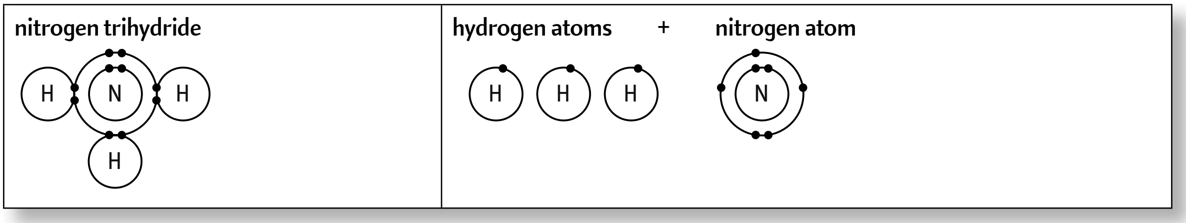
2. a) Covalent compounds (binary covalent compounds): made up of the atoms of two non-metal elements joined by covalent bonds.

   b) Covalent bond. Electrons are shared between non-metal atoms resulting in a strong attraction between the atoms. Upon formation of covalent compounds, atoms achieve full valence shells and greater stability.

c) Four covalent bonds are formed and energy is released.

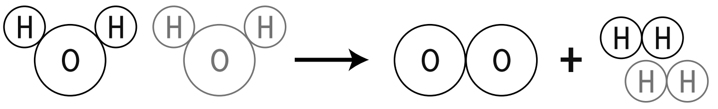


d) Energy is needed to break three covalent bonds.

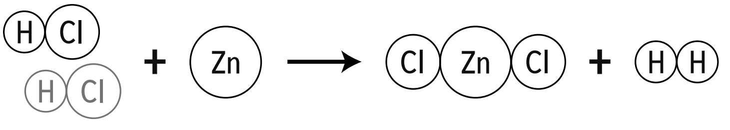


Balancing Equations

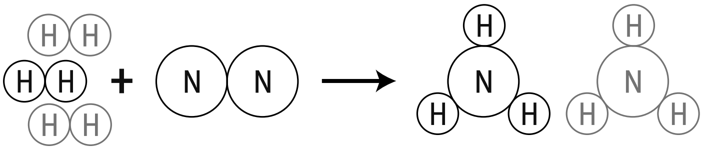
1. a)



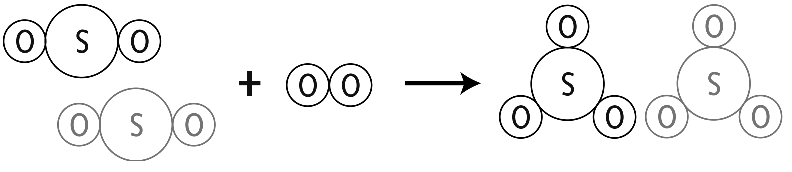
b)



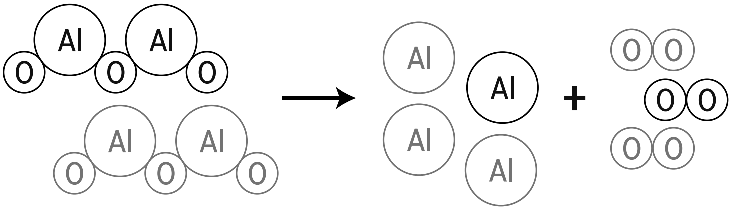
c)



d)



e)



2. a) $2H_2O \longrightarrow O_2 + 2H_2$

b) $2HCl + Zn \longrightarrow ZnCl_2 + H_2$

c) $3H_2 + N_2 \longrightarrow 2NH_3$

d) $2SO_2 + O_2 \longrightarrow 2SO_3$

e) $2Al_2O_3 \longrightarrow 4Al + 3O_2$

3. a) water ⟶ oxygen + hydrogen

b) hydrogen chloride (hydrochloric acid) + zinc ⟶ zinc chloride + hydrogen

c) hydrogen + nitrogen ⟶ nitrogen trihydride (or ammonia)

d) sulfur dioxide + oxygen ⟶ sulfur trioxide

e) aluminum oxide ⟶ aluminum + oxygen

4. a) $2Fe + O_2 \longrightarrow 2FeO$

b) $S_8 + 8O_2 \longrightarrow 8SO_2$

c) $2Cr_2O_3 \longrightarrow 4Cr + 3O_2$

d) $C + O_2 \longrightarrow CO_2$; already balanced

e) $2Mg + O_2 \longrightarrow 2MgO$

f) $2KClO_3 \longrightarrow 3O_2 + 2KCl$

g) $CoBr_2 \longrightarrow Co + Br_2$; already balanced

h) $6Na + N_2 \longrightarrow 2Na_3N$

i) $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

j) $2BN + 3F_2 \longrightarrow 2BF_3 + N_2$

k) $Mg(ClO_3)_2 \longrightarrow MgCl_2 + 3O_2$

l) $CO_2 + H_2O \longrightarrow H_2CO_3$; already balanced

m) $I_2 + 2NaBr \longrightarrow 2NaI + Br_2$

n) $K_2SO_4 + BaCl_2 \longrightarrow 2KCl + BaSO_4$

o) $CaO + H_2O \longrightarrow Ca(OH)_2$; already balanced

p) $XeF_6 + 3H_2O \longrightarrow XeO_3 + 6HF$

q) $H_3PO_4 + 3NaOH \longrightarrow Na_3PO_4 + 3H_2O$

r) $2NH_3 + 3CuO \longrightarrow 3Cu + N_2 + 3H_2O$

s) $C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$

t) $2AgNO_3 + MgCl_2 \longrightarrow 2AgCl + Mg(NO_3)_2$

u) $3FeCl_2 + 2Na_3PO_4 \longrightarrow Fe_3(PO_4)_2 + 6NaCl$

v) $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

w) $NaCl + AgNO_3 \longrightarrow NaNO_3 + AgCl$; already balanced

x) $3Br_2 + 2FeI_3 \longrightarrow 2FeBr_3 + 3I_2$

y) $2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$

z) $Ca(OH)_2 + 2NH_4Cl \longrightarrow 2NH_3 + CaCl_2 + 2H_2O$

Chemical Reactions and Equations

1. sodium + water ⟶ hydrogen + sodium hydroxide
$2Na(s) + 2H_2O(\ell) \longrightarrow H_2(g) + 2NaOH(aq)$

2. potassium chlorate ⟶ potassium chloride + oxygen
$2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$

3. sodium sulfate + calcium chloride ⟶ calcium sulfate + sodium chloride
$Na_2SO_4(aq) + CaCl_2(aq) \longrightarrow CaSO_4(s) + 2NaCl(aq)$

4. lithium + chlorine ⟶ lithium chloride
$2Li(s) + Cl_2(g) \longrightarrow 2LiCl(s)$

5. phosphorus + oxygen ⟶ diphosphorus pentoxide
$P_4(s) + 5O_2(g) \longrightarrow 2P_2O_5(s)$

6. aluminum oxide ⟶ aluminum + oxygen
$2Al_2O_3(s) \longrightarrow 4Al(s) + 3O_2(g)$

7. lead(II) nitrate + potassium iodide ⟶ lead(II) iodide + potassium nitrate
$Pb(NO_3)_2(aq) + 2KI(aq) \longrightarrow PbI_2(s) + 2KNO_3(aq)$

8. ammonia + oxygen ⟶ nitrogen monoxide + water
$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$

9. iron + copper(II) sulfate ⟶ copper + iron(II) sulfate
$Fe(s) + CuSO_4(aq) \longrightarrow Cu(s) + FeSO_4(aq)$

10. carbon tetrahydride + oxygen ⟶ carbon dioxide + water + energy
$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(\ell)$ + energy

Open and Closed Systems

1. a) Open, because the gas formed can escape from the beaker.

b) Closed, because there is a rubber stopper at the mouth of the beaker.

2. a) *x*-axis: time (min); *y*-axis: total mass (g)

b) The graph line for Trial 1 will be a downward-curving line that shows a decrease in mass over time. The graph line for Trial 2 will be a straight horizontal line at the 50 g mark.

3. a) Trial 1: total mass decreased over time. Trial 2: total mass stayed constant.

b) Trial 1: The system was open, and this allowed hydrogen gas (one of the products) to escape from the system. This made it seem like matter was destroyed during the chemical reaction. The total mass of the flask and content was decreasing over time to reflect that hydrogen gas has escaped, not disobeying the law of conservation of mass.

Trial 2: The system was closed, and this ensured that hydrogen gas (one of the products) remained in the flask. The mass stayed constant over the course of the reaction, demonstrates that matter was neither created nor destroyed during a chemical reaction. This experimental setup demonstrated the law of conservation of mass.

4.

Closed System:

matter cannot enter or leave

Open System:

matter can enter or leave freely

Intersection Area:

energy can enter or leave freely

reflects the law of conservation of mass

2.2 Assessment

1. G
2. D
3. B
4. F
5. E
6. A
7. C
8. H
9. C
10. A
11. C
12. B
13. C
14. D
15. C

16. A
17. B
18. B
19. E
20. D
21. D
22. C
23. B
24. E
25. D
26. D
27.