Activity 5 - Compounds and Their Formulas

Goals

- Identify the elements and number of atoms in the formula of a compound.
- Compare some physical properties of a compound with the properties of the elements from which it was formed.
- Determine the subscripts in the formula of a compound.
- Describe the types of elements in ionic and covalent compounds.
- Identify the bonding in a compound as ionic or covalent.

Pre-lab Questions *(answer these on a separate sheet using complete sentences)*

1. Why are color, texture, state, density, and melting point considered physical properties?
2. Why do the physical properties of the elements change when they combine to form a compound?
3. How is the number of atoms in a molecule indicated in the formula?
4. Why do compounds of metals and nonmetals consist of ions?
5. What is a covalent bond?
6. What compound in toothpaste is a preventative for cavities?

Concepts to Review

Formulas
Ions
Ionic and covalent bonds
Formation of ionic and covalent compounds
Naming ionic and covalent compounds

Introduction

Almost everything you see around you is made of compounds. A compound consists of two or more different elements that are chemically combined. Although there are currently (as of 2015) 118 elements known, there are millions of different compounds.

In a compound, there is a definite proportion of each element. This is represented in the formula, which gives the lowest whole number ratio of each kind of atom. For example, water has the formula H_2O.This means that two atoms of hydrogen and one atom of oxygen are combined in every molecule of water. Every water molecule is represented by this, and only this, formula.

A mixture consists of two or more substances (elements or compounds), which are not chemically combined. Thus, the components maintain their original physical properties, and they can be separated by physical methods such as use of a magnet, filtration, or evaporation.

Properties of Elements and Compounds

When we observe a compound or an element, we can describe physical properties such as color and luster. We can measure other physical properties such as density, melting point and boiling point. When elements undergo chemical combination, the physical properties change to the physical properties of the new compound, which is a novel substance different from its components. For example, when silver tarnishes, the physical property of the shiny silver metal changes to a dull gray color as silver combines with sulfur to form tarnish, Ag_2S. A chemical change has occurred when the reaction between the elements has caused a change in their physical properties.

Types of Bonds in Compounds

Atoms form compounds to become more stable, usually by forming octets in their outer shells. The attractions between the atoms in a compound are called *chemical bonds*. For example, when a metal combines with a nonmetal, the metal loses electrons to form a positive ion and the nonmetal gains electrons to form a negative ion. The attraction between the positive ions and the negative ions is called an *ionic bond*. When two nonmetals form a compound, they share electrons and form *covalent bonds*. The combinations of atoms in covalent compounds are called *molecules*.

Table 1. A selection of compounds and their corresponding bonding type.

Compound	Types of Elements	Characteristics	Type of Bonding
NaCl	Metal, nonmetal	Ions, (Na^+, Cl^-)	Ionic
CCl_4	Two nonmetals	Molecules	Covalent
$MgBr_2$	Metal, nonmetal	Ions, (Mg^{2+}, Br^-)	Ionic
NH_3	Two nonmetals	Molecules	Covalent

Safety

$Pb(C_2H_3O_2)_4$ metal, nonmetals Ions Pb^{4+} $C_2H_3O_2^-$ Ionic

$C_{12}H_{24}O_{11}$ many nonmetals molecule Covalent

Wear safety glasses at all times!

Act in accordance with the laboratory safety rules of Cabrillo College.

Avoid contact with all chemical reagents and dispose of those used in experiments in appropriate waste containers.

Caution: Acids are corrosive; they will cause chemical burns to your skin. Know the location of solid sodium bicarbonate ($NaHCO_3$) in the lab as well as the aqueous solution of sodium bicarbonate. Use either the solid or the solution of sodium bicarbonate to neutralize any spills of the 6 *M* $HCl_{(aq)}$ solution. Should you happen to spill the acid solution on your skin, use the sodium bicarbonate solution to neutralize it right away and rinse off with water. Have a classmate notify the instructor immediately.

Caution: To sample the odor of a gas, first fill your lungs with fresh air and hold it while you use your hand to fan some of the vapors from the reaction tube toward you. Carefully note the odor.

Materials:

A selection of elements and compounds as identified on your experimental pages, samples of iron (Fe) filings, sulfur (S), iron filings and sulfur mixture (Fe + S), iron (II) sulfide (FeS), and 6 *M* HCl (hydrochloric acid).

Equipment: bar magnet, spatula, dropper, test tubes and test tube rack.

Experimental Procedure

A. Interpreting Formulas of Compounds

Observe the compounds in the laboratory display. Describe the physical properties of each compound. Write the formula for each compound. From the formula of each compound, state the number of atoms of <u>each element</u> present in that compound. From the display of elements, observe and record some of the physical properties of the individual elements.

B. Physical Properties of FeS and its Elements

1. Your instructor may do this part of the experiment as a demonstration. Obtain samples of Fe, S, a mixture of Fe and S, and FeS. These may be in prepared test tubes or sample containers. Describe the physical properties of each sample.
2. Using a chemistry handbook (Chemical Rubber Company—CRC), look up the density, melting and boiling points of Fe, S, and FeS. Record these values.
3. Test each of the samples for magnetic attraction by running a bar magnet under the sample in each container. (*Do not place the magnet directly into the samples!* The attracted particles cling to the magnet and make it difficult to clean.) If there is magnetic attraction, you will see particles follow the magnet. Record your observations.
4. (Optional) This part of the experiment involves a reaction that produces H_2S gas, which is toxic in more than trace amounts. Check with your instructor before proceeding. Place a small amount of each sample (enough to cover the tip of a spatula) in a test tube. **WORKING IN THE HOOD,** slowly add 15 drops of 6 *M* HCl (**corrosive**) into each test tube. Observe any reaction. **CAREFULLY** note any odor.
5. Describe each sample as an element, mixture, or compound.

Activity 5 - Compounds and Their Formulas

Name_____

Section_____ **Date**_____

Exercise A. Interpreting Formulas of Compounds

1. Complete the following table using the samples placed around the room.

Formula of compound	Physical properties of compound	Number of atoms of each element	Physical properties of the elements
Example: $CuSO_4$ Copper(II) Sulfate	Deep blue crystals	1 Cu, 1 S, 4 O	Cu - shiny, copper metal; S - yellow chunks; O - colorless gas
$FeSO_4$ Iron(II) Sulfate	white flaky Crystal	1 Fe, 1 S, 4 O	Fe - grey shiny hard metal S - yellow rock O - colorless gas
$FeCO_3$ Iron(II) Carbonate	Brown Crystalline material	1 Fe, 1 C, 3 O	Fe - grey shiny C - dull grey solid or black powder O - colorless gas

2. When elements combine to form compounds, are the physical properties of the compound the same as those of the elements? Explain.

No. The elements have very different physical properties from the compounds they form. They look different, and have different properties.

3. Does the formula of a compound vary or is matter constant in composition? Explain your answer.

water H_2O, H_3O, H_4O, H_3O_2, H_2O_2

varying ratios

water is always H_2O, it does not vary.

⇒ matter is constant in it's ratios of elements that comprise a substance.

⇒ Fixed whole number ratios

Exercise B. Physical Properties of FeS and Its Elements

1. Complete the following table from your observations of FeS and its elements.

Sample	**Physical properties** (color, state, luster?)	**Density**-d (g/mL)	**M.P.** (°C)	**B.P.** (°C)	**Magnetic attraction**	**Reaction with HCl? Odor?**	**Description of Sample** (element, mixture, compound)
Fe	shiny grey metal spheres						
S	yellow powder						
Fe + S	shiny yellow spheres mixed w/yellow	X	X	X			
FeS	dull grey powder						

Use the results in your chart to answer the following questions:

2. How does the attraction to the magnet differ for the elements, mixture, and compound? Explain.

Elements Compound

3. Why do the physical properties of Fe and S differ from those of FeS?

(ex - a magnet)

4. Can the elements in the Fe + S mixture and the compound FeS be separated using the same methods? Explain.

Questions and Problems

1. Complete the table for the given compounds

Compound	**Units in compound (ions or molecules)**	**Type of bonds (ionic or covalent)**
LiBr	ions	ionic
$CaCl_2$		
CCl_4	molecules	Covalent
NH_3		
K_2S		
MgO		

2. List the number of atoms of each kind of element in the following formulas:

Formula	**Number and Kind of Atoms in the Compound**
H_2O	2 atoms H and 1 atom O
$CuCl_2$	_____
Al_2S_3	_____
$Ba(NO_3)_2$	_____
$C_6H_{12}O_6$	_____

3. Write formulas of the following compounds from the number of atoms given. The elements are listed in the order in which they appear in the formula.

1 atom of C and 2 atoms of O _____ CO_2 _____

1 atom of N and 3 atoms of H _____

1 atom of C and 4 atoms of Cl _____

2 atoms of Fe and 3 atoms of O _____

1 atom of Ba, 1 atom of S, 4 atoms of O _____

4. Identify the elements in each compound as a metal and nonmetal, or two nonmetals. Indicate the bonding in each as ionic or covalent.

	Elements	**Type of Bonding**
$BaCl_2$	metal and nonmetal	ionic
C_3H_8	two non-metals	Covalent
Li_2O		
PCl_3		
NaBr		
SO_3		

Indicate whether each of the following is a chemical or physical change:

tearing a piece of paper in two _____

burning a match _____

grinding pepper _____

rusting iron nail _____

freezing water for ice cubes _____

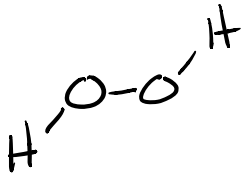
Chemical Change → Addition, Subtraction, or recombination of the elements in a compound.

Physical Change - Change of physical State
Solid ⇄ liquid or liquid ⇄ gas
also Change in shape

Compounds - Combinations of Elements in fixed whole-number ratios

H_2O vs H_2O_2

water

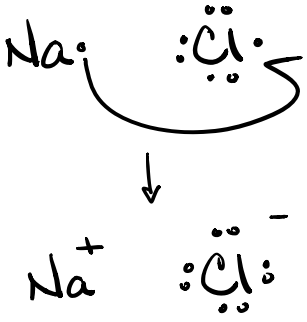


Hydrogen peroxide

Ionic

\+ Cation − Anion

Electrostatic attraction

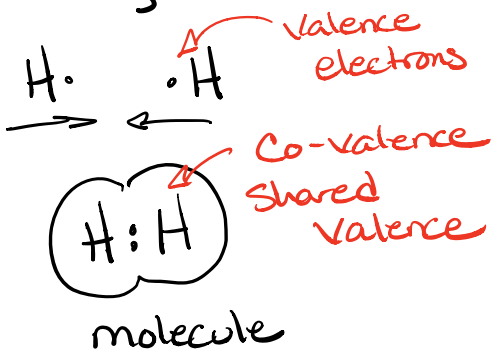


$NaCl$ Ionic Compound

Look for the presense of a metal ⟹ Ionic bond

Covalent

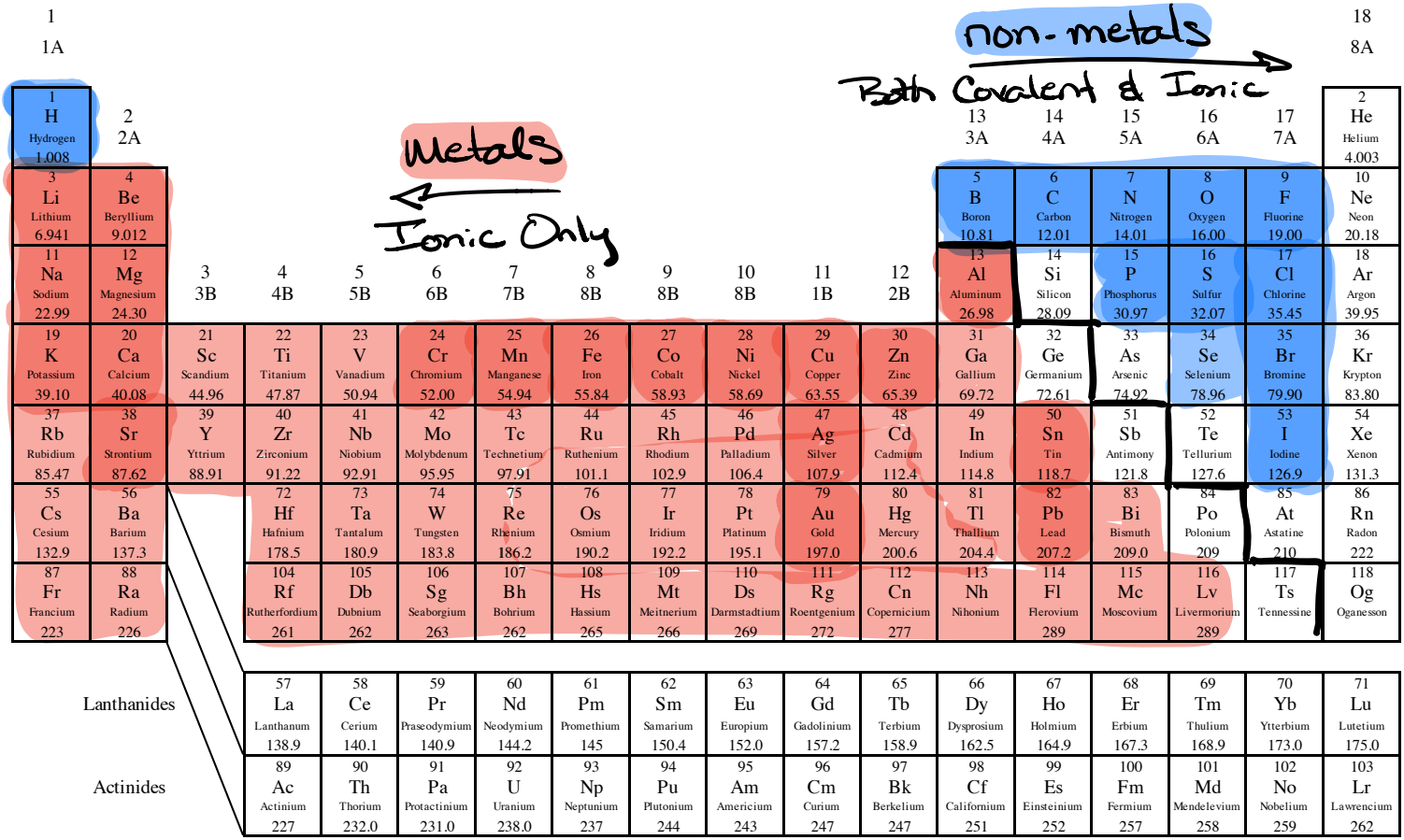
Sharing of electrons



molecule

Bonding is Covalent = Sharing of e^-

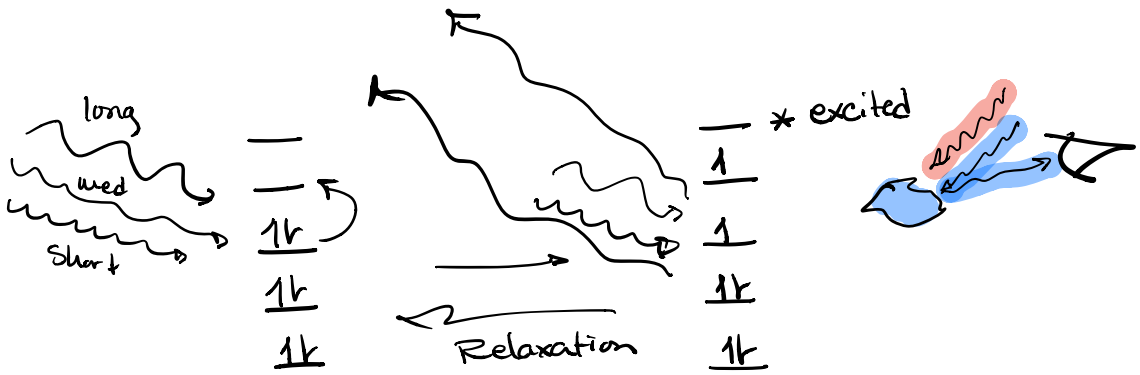
Covalent are comprized all non-metals



1 1A												13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H Hydrogen 1.008	2 2A																2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.30	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.84	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.95	43 Tc Technetium 97.91	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Cesium 132.9	56 Ba Barium 137.3		72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222
87 Fr Francium 223	88 Ra Radium 226		104 Rf Rutherfordium 261	105 Db Dubnium 262	106 Sg Seaborgium 263	107 Bh Bohrium 262	108 Hs Hassium 265	109 Mt Meitnerium 266	110 Ds Darmstadtium 269	111 Rg Roentgenium 272	112 Cn Copernicium 277	113 Nh Nihonium	114 Fl Flerovium 289	115 Mc Moscovium	116 Lv Livermorium 289	117 Ts Tennessine	118 Og Oganesson

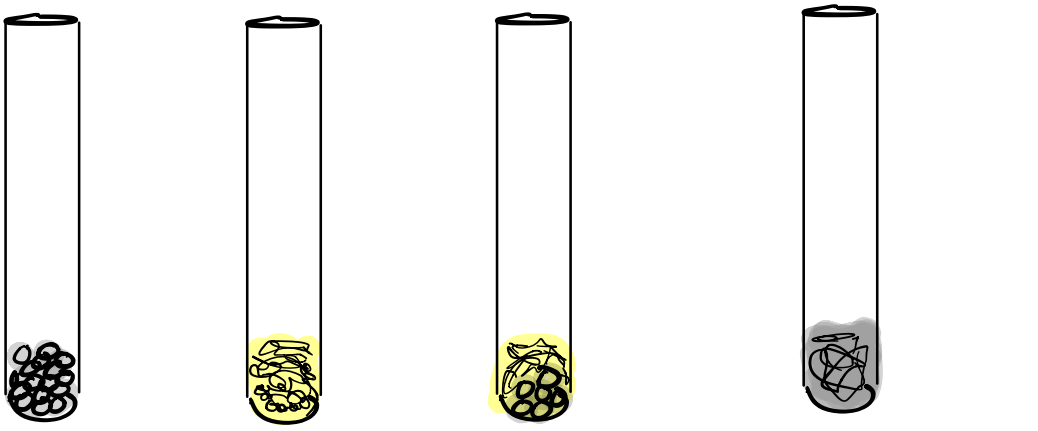
Lanthanides	57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium 145	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinides	89 Ac Actinium 227	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium 237	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 262

where does color come from?



Metal
or
Compound

Part B Experimental



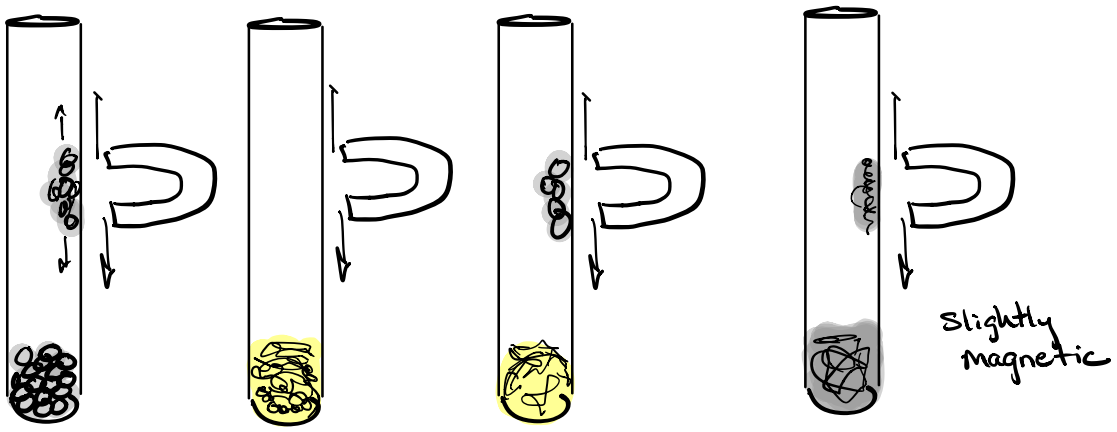
Fe

S

Mixture of elements
Fe + S

Ionic Compound
Iron(II) Sulfide
FeS
Fe^{2+} S^{2-}

Magnetic Test



Fe
magnetic

S
not magnetic

Mixture of elements
Fe + S
Iron magnetic
Sulfur not magnetic

Ionic Compound
Iron(II) Sulfide
FeS
Fe^{2+} S^{2-}

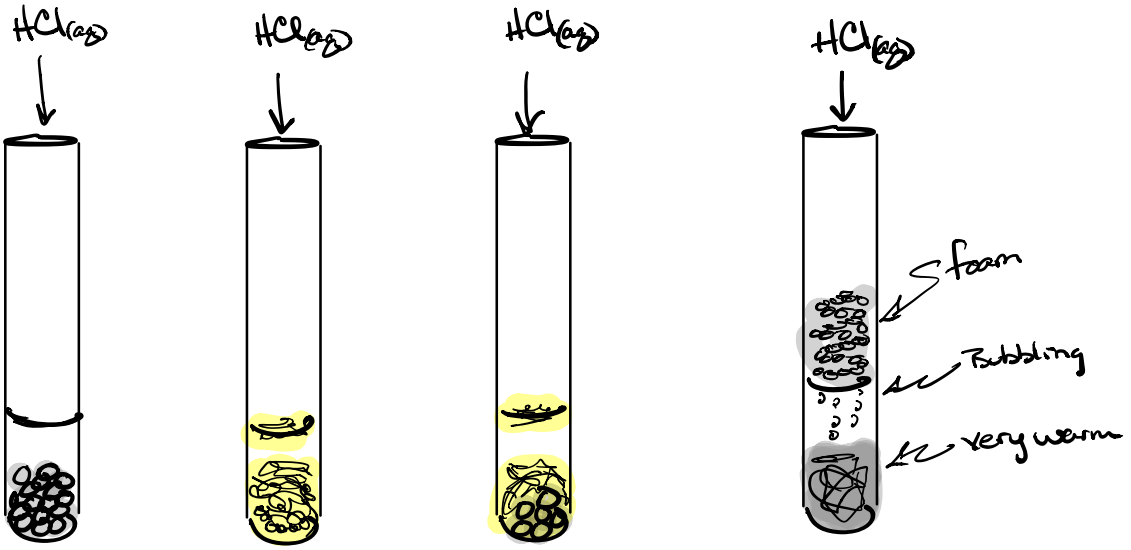
Slightly magnetic

* Mixtures can be seperated by physical means
  ⇒ using a magnet

* Compounds (Ionic & Covalent) cannot be seperated by physical means

Test Compands with hydrochloric acid $HCl_{(aq)}$

$HCl_{(aq)}$ dissolved in H_2O



Fe

- gets warm
- no bubbles
- no odor

S

- some floating Sulfur
- no heat
- no bubbles
- no odor

mixture of elements

Fe + S

- some floating Sulfur
- a little heat
- no bubbles
- no odor

Ionic Compand

Iron(II) Sulfide

FeS

Fe^{2+} S^{2-}

- Gas formation (bubbles & foam)
- Some heat
- Strong Rotten egg Smell

Elemental Form

$$FeS_{(s)} + 2HCl_{(aq)} \rightarrow H_2S_{(g)}\uparrow + FeCl_{2(aq)}$$

Rotten egg Smell

	Elemental	Elemental
Mixture	Fe	S
	$[Ar]3d^6 4s^2$	$[Ne]3s^2 3p^4$

	Cation	Anion
Ionic Compound	Fe^{2+}	S^{2-}
	$[[Ar]3d^6 4s^0]^{2+}$	$[[Ne]3s^2 3p^6]^{2-}$