Objective 2. Classify substances as elements, compounds, mixtures. Relate substance type to properties. Use properties to identify substances and separate mixtures.

Quiz Practice problems

Key ideas: elements are classified as metals and non-metals. Compounds are classified as ionic and molecular. Acids and bases are important and common substances. Each substance type has different properties. Properties are used to identify substances and separate mixtures.

It is hard to get solids to react with each other. So the solid is dissolved in a solvent to make a solution (solution is a homogeneous mixure) and the solutions are mixed together to get a reaction to occur. For solutions, use concentration in Molarity = moles/volume.

Skills: Use the periodic table to identify metal, non-metal, ionic compound, molecular compound.
Identify properties, e.g., state of matter, hard, soft, high/low b.p., pH, litmus, conductivity test.
Use properties to identify a substance.
Use a difference in a property to separate a mixture.
Prepare a solution from solid.

1. a. Metal properties: soft, conductors, shiny, lose electrons to form cations. See the Periodic Table.
(i) Give two examples of elements that are metals.
(ii) What is the charge of each metal when your example metal is contained in a compound?
b. Non-metal properties: hard, dull, insulators, gain electrons to form anions. See the Periodic Table.
(i) Give two examples of elements that are non-metals.
(ii) What is the charge of each non-metal when your example non-metal is contained in a compound?
c. The Periodic Table of the Elements is based on patterns and relationships.
(i) One way to classify elements is by metals, non-metal, and semi-metals. Some elements are more metallic than others. Some elements are more non-metallic than others. Going from left to right across a row in the Periodic Table, do elements show more metallic character or less metallic character? In other words, do elements behave more like metals or less like metals going from left to right across a row? Explain your reasoning.
(ii) Going down a column in the Periodic Table, do elements become more like metals or less like metals? Explain your reasoning.
d. Ionic compound properties: hard, brittle, high melting point. What type of elements form an ionic compound? Give one example of an ionic compound.
e. Molecular compound properties: soft, low melting point. What type of elements form a molecular compound? Give one example of a molecular compound.

Answers:
a. (i) Elements that are metals are on the left side and middle of the Periodic Table, e.g, sodium (Na) and aluminum (Al).
(ii) For the Main Group metals, Group number = charge.
Sodium ion has a +1 charge (Na^+). Na is in Group 1A.
Aluminum ion has a +3 charge (Al^{3+}). Al is in Group 3A.
b. (i) Elements that are non-metals are on the right side of the Periodic Table, e.g, chlorine (Cl) and oxygen (O).
(ii) For the Main Group non-metals, Group number = charge - 8.
Chloride ion has a -1 charge (Cl^-). Cl is in Group 7A.
Oxygen ion has a -2 charge (O^{-2}). O is in Group 6A.
c. (i) Going from left to right across a row in the Periodic Table, elements show less metallic character. For example, the Period 2 elements go from Li metal on the left to C, N, O, F non-metals on the right.
(ii) Going down a column in the Periodic Table, elements become more like metals. For example, the Group 4A elements go from C non-metal on the top to Pb metal on the bottom.
d. A metal and non-metal form an ionic compound. E.g., NaCl.
e. Two or more non-metals form a molecular compound. E.g., CO_2.

2. Of all the known substances, most are organic compounds. Organic compounds contain C, H, O, and N.
a. Classify each element as a metal or non-metal.
b. Are organic compounds ionic compounds or molecular compounds?
c. When an organic compound forms an anion and combines with sodium, what type of compound forms? Give reasons.

3. The Top 10 chemicals produced in the U.S. are:

2000 RANK (by mass)	CHEMICAL	2000 PRODUCTION (in 10^9 kg)	FORMULA	Element or Compound?	Element Type (metal or non-metal) Or Compound Type (ionic or molecular)
1	Sulfuric acid	39.62	H_2SO_4		
2	Ethylene	25.15	C_2H_4		
3	Lime	20.12	CaO		

4	Phosphoric acid	16.16	H_3PO_4		
5	Ammonia	15.03	NH_3		
6	Propylene	14.45	C_3H_6		
7	Chlorine	12.01	Cl_2		
8	Sodium hydroxide	10.99	NaOH		
9	Sodium carbonate	10.21	Na_2CO_3		
10	Ethylene chloride	9.92	$C_2H_4Cl_2$		

Reference: Chemical and Engineering News, 6/25/01 and http://scifun.chem.wisc.edu/CHEMWEEK/sulf&top/sulf&top.html

a. Classify each substance as an element or compound.
(i) If the substance is an element, classify the element as a metal or non-metal.
(ii) If the substance is a compound, classify the compound as ionic or molecular.
(iii) Which of the Top 10 chemicals is/are acids? Which of the Top 10 chemicals is/are bases?
b. Which compound has the highest melting point? Give reasons.
c. Sulfuric acid is used as the electrolyte in car batteries. What property of sulfuric acid makes it a good battery acid? Hint: the electrolyte is the ionic current that carries ions from one electrode to another in a battery.
d. Phosphoric acid gives soda its tart taste and is also used as a rust remover. What property of phosphoric acid makes it taste tart?
e. Ammonia is a cleaner that removes grease. Ammonia is a base, which means grease must be a _____.
f. Sodium carbonate, which is a base, is used in laundry detergent. Is the sodium ion or carbonate ion the basic part? Give reasons.
g. Farmers use lime to raise the pH of soil. Lime is a _____.
Answers:
a. (i), (ii), and (iii)

2000 RANK (by mass)	CHEMICAL	2000 PRODUCTION (in 10^9 kg)	FORMULA	Element or Compound?	Element Type (metal or non-metal) Or Compound Type (ionic or molecular)
1	Sulfuric acid	39.62	H_2SO_4	Compound	Molecular, acid
2	Ethylene	25.15	C_2H_4	Compound	molecular
3	Lime	20.12	CaO	Compound	Ionic, base
4	Phosphoric acid	16.16	H_3PO_4	Compound	molecular, acid
5	Ammonia	15.03	NH_3	Compound	molecular, base
6	Propylene	14.45	C_3H_6	Compound	molecular
7	Chlorine	12.01	Cl_2	Element	Non-metal
8	Sodium hydroxide	10.99	NaOH	Compound	ionic, base
9	Sodium carbonate	10.21	Na_2CO_3	Compound	ionic, base
10	Ethylene chloride	9.92	$C_2H_4Cl_2$	Compound	molecular

b. In general, ionic compounds have high melting points.
CaO melting point = 2613^oC - highest
NaOH melting point = 323^oC
Na_2CO_3 melting point = 851^oC
c. Sulfuric acid is a strong acid. Strong acids dissociate completely into ions ==> strong electrolyte.
d. One property of acids is acids taste tart (sour). Phosphoric acid, being an acid, tastes sour like vinegar and citric acid.
e. Ammonia is a base, which means grease must be an acid. The grease in this case is kitchen grease – fats, like lard, and vegetable oils are fatty acids.
f. Sodium carbonate, which is a base, is used in laundry detergent. Is the sodium ion or carbonate ion the basic part? Give reasons. Carbonate is the basic part. A base is a proton (H^+) acceptor so the negative charged carbonate ion (CO_3^{2-}) is attracted to the (+) charge.
g. Farmers use lime to raise the pH of soil. Lime is a base. Lime = CaO.

4. You find two liquids in your basement. One liquid is in a blue bottle and the other liquid is in a green bottle. You want to identify each liquid and know that one liquid is HCl and the other liquid is ammonia. Each liquid is colorless. You test the liquid in the green bottle and observe the following: the liquid turns blue litmus paper red but when phenolphthalein is added, nothing happens. The pH of this liquid is 4.2. You decide not to test the liquid in the blue bottle. What is the identity of the liquid in each bottle? Give reasons.
Answers:
Acid properties: blue litmus turns red, colorless in phenolphthalein, and has a pH less than 7.
Base properties: red litmus turns blue, pink in phenolphthalein, and has a pH greater than 7.

Liquid in green bottle is an acid based on observations so liquid is HCl. HCl is an acid.
Liquid in blue bottle is ammonia. Ammonia is a base.

5. Before you leave for spring break, you decide to check out your car to make sure it won't break down. When you look under the car, you see a few drops of liquid. The liquid could either be oil (a large hydrocarbon, $C_{20}H_{42}$), battery acid (sulfuric acid), or antifreeze (ethylene glycol, $C_2H_6O_2$). You perform the following tests on this liquid:

Test/Observation	Conclusion
(i) blue litmus stays blue	
(ii) red litmus stays red	
(iii) conductivity = 90 μS	

a. Draw a conclusion for each observation in the space above.
b. What is the identity of this liquid? If you can't definitively identify the liquid, what other observation or test would you need to do to identify the liquid under your car?
Answers:
(i) substance is base or neutral
(ii) substance is acid or neutral
(iii) low conductivity so substance is a weak or non-electrolyte so molecular compound.
b. The liquid cannot be sulfuric acid – this substance would turn blue litmus red and has high conductivity since it is a strong acid.
The liquid is either oil or antifreeze. Both of these substances are neutral and molecular compounds.
You could do a solubility test. Oil is not soluble in water but antifreeze is.
You could also test the freezing point or boiling point.

Solution preparation – see lab skills: how many g of solid to make ___ ml of solution?
Give mass of solid and volume of solution to make. Calculate concentration of solution.
Give volume and concentration of solution to be made. Calculate mass of solid to use.

6. Many pure substances are made into mixtures.
a. You pour 1 tablespoon of sugar ($C_{12}H_{22}O_{11}$) in enough water to make ½ cup (120 ml) of solution.
1 tablespoon of sugar = 3 teaspoons of sugar
1 teaspoon of sugar = 4 g of sugar
Molar concentration (symbol = M) is the moles of solute in 1 liter of solution.
Example: 1 M means 1 Molar concentration solution = 1 mole of solute in 1 liter of solution.
So 1 M sugar solution = 1 mole of sugar in 1 liter of solution.
(i) Calculate the mass of sugar in 1 tablespoon. (What is the conversion factor?)
(ii) Calculate the moles of sugar in 1 tablespoon. (What is the conversion factor?)
(iii) Calculate the Molar concentration of sugar . (Answer: between 0.25 and 0.33 M)

b. You want to make 250 ml of a 1 M sugar ($C_{12}H_{22}O_{11}$) solution.
(i) How many moles of sugar are in 250 ml of 1 M sugar solution? (What is the conversion factor?)
(ii) Calculate the mass of sugar to make this solution. (Answer: between 85 and 95 g)

c. You want to make ½ cup (120 ml) of a 1.5 M baking soda ($NaHCO_3$) solution. Calculate the mass of baking soda to make this solution. (Answer: between 13 and 17 g)
d. You need to use 0.25 moles of baking soda for a chemical reaction. You have ½ cup of 1.5 M baking soda solution. Calculate the volume of 1.5 M baking soda solution that contains 0.25 moles of baking soda.
Do you have enough 1.5 M baking soda solution to get the 0.25 moles of baking soda that you need? (Answer: no)
How much more 1.5 M baking soda solution do you need?
Answers:
a. (i) mass of sugar in 1 tablespoon = 1 tablespoon of sugar (3 teaspoons/1 tablespoon)(4 g sugar/1 teaspoon) = 12 g sugar
Round to 1 significant figure based on 1 tablespoon, which has 1 significant figure ==> 10 g sugar
(ii) 1 tablespoon of sugar = 12 g sugar (1 mole sugar/342 g sugar) = 0.035 moles sugar
Round to 1 significant figure based on 1 tablespoon, which has 1 significant figure ==> 0.04 moles sugar
(iii) Molar concentration of sugar = moles of sugar/volume of solution in L = 0.035 moles sugar/0.120 L = 0.292 M
Round to 1 significant figure based on 1 tablespoon, which has 1 significant figure ==> 0.3 M moles sugar
b. Molar concentration = moles/volume
rearrange equation and solve for moles = Molar concentration x volume

(i) moles of sugar are in 250 ml of 1 M sugar solution = (1 mole sugar/1 L) (0.25 L) = 0.25 moles sugar
(ii) Use molar mass as the conversion factor to convert moles to mass in g.
0.25 moles sugar (342 g sugar/mole sugar) = 85.5 g sugar
So measure 85.5 g sugar and add enough water to make 250 ml of solution.

c. use Molar concentration and volume to calculate moles. Then, convert moles to mass.
(1.5 moles $NaHCO_3$/L)(0.120 L)(84 g $NaHCO_3$/mole $NaHCO_3$) = 15.12 g $NaHCO_3$.
So measure 15.12 g $NaHCO_3$ and add enough water to make 120 ml of solution.

d. volume of 1.5 M baking soda solution that contains 0.25 moles of baking soda.
Molar concentration = moles/volume
rearrange equation and solve for volume = moles/Molar concentration
= 0.25 moles/1.5 M
= 0.1666 L
½ cup of 1.5 M baking soda solution = (0.120 L)(1.5 M) = 0.18 moles, which is less than 0.25 moles.
Need 0.1666 L – 0.120 L = 0.0466 L

7. Most substances are mixtures. Scientists spend a lot of time and energy trying to separate a mixture into its component pure substances.
You are at the beach with your lab partner. Your lab partner is about to put sugar in a glass of unsweetened lemonade when you (accidentally) knock the sugar out of your lab partner's hand with a beach ball. The sugar spills to the sand. Since your lab partner does not have any more sugar and can't stand drinking too tart lemonade, you two figure you can use your combined knowledge of chemistry and separate the sugar from the sand. All of a sudden, your lab partner dumps the sand/sugar mixture into the glass of lemonade and claims this will sweeten the lemonade and give 100% recovery of sand. Explain how this method will work and give a 100% recovery of sand.
Answers:
Use a difference in a property of a substance to separate a mixture.
Use solubility property: Sand is not soluble in water. Sugar is soluble in water.
Add the sand/sugar mixture into water (lemonade). The sugar dissolves and the sand does not. Drink the sweetened lemonade and the sand remains in the bottom of the glass. Or pour off the liquid leaving the solid sand behind.