

The imagination is the power of
the mind over the possibilities
of things.--Wallace Stevens

The Dreaded Nine-bottle Problem

Almost all salts [a salt is an ionic compound] exist in water solutions as separated ions. When solutions of different salts are mixed, the ionic species present may remain in solution as separate entities [i.e., no reaction occurs], may combine to form a precipitate or may react chemically to produce gases or precipitates which slowly change into other compounds upon standing in water.

In this experiment you will be provided with nine different salt solutions, each numbered but otherwise unidentified. All of the solutions are colorless. They are:

NaBr	Na ₂ SO ₄	NH ₄ Cl
NaOH	KClO ₃	BaCl ₂
Na ₂ S	KIO ₃	Pb(NO ₃) ₂

The object of the experiment is to identify each solution, using either the interactions occurring (if any) when small quantities of the solutions are mixed with one another, or any physical evidence.

To carry out the experiment successfully, you must obviously know what interactions are expected for each mixture. Intelligent preliminary study is therefore essential, and as part of your pre-laboratory preparation you will determine the expected behavior when pairs of solutions are combined.

The information on the following pages is all that is strictly necessary to let you solve the problem, but you may certainly consult your text book or references of any kind.

Solubility of salts

A salt is classified as **soluble** (no precipitate) if more than 1 g will dissolve in 100 mL of water. It is **insoluble** (forms a precipitate) if no more than 0.1 g will dissolve. Between these is the category called "sparingly soluble" which may or may not give a visible precipitate under some conditions. For the problem at hand we note the following:

Adapted from: [Ionic Interactions and Qualitative Analysis](#), *Chemical Principles in the Laboratory*, 3rd. ed., Robert F. Bryan and Robert S. Boikess

[this is NOT a complete list; these are only addenda to the rules you have been studying--you will need to use all of this information]

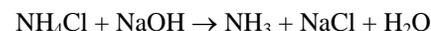
all iodates are soluble except Ba(IO₃)₂ and Pb(IO₃)₂

Ba(OH)₂ is more or less soluble but it often *appears* to precipitate due to the presence of dissolved CO₂ in the hydroxide solution (BaCO₃ is very insoluble)

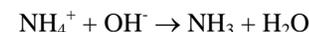
Other chemical reactions

1. Two gases, recognizable by their odors, may be produced on mixing some of the solutions:

a. ammonia, NH₃, is produced when ammonium salts react with bases:



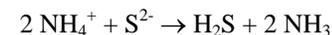
OR



b. hydrogen sulfide, H₂S, is generated by reaction of sulfide salts with ammonium salts:



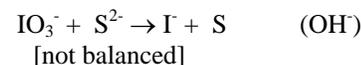
OR



[in this case, the odor of H₂S is generally more noticeable than that of NH₃]

2. While Pb(OH)₂ is insoluble, addition of *excess* hydroxide ions will cause the precipitate to dissolve! This can give some confusing results. *Remember*, precipitation is generally instantaneous while dissolution is much slower.

3. Compounds of the iodate ion may oxidize compounds of the sulfide ion to form elemental sulfur, a fine white precipitate, and iodide ion:



In terms of what you will be able to see, *there is no difference between elemental sulfur and any other white precipitate.*

The chemicals

Sodium bromide is a white, crystalline solid, freely soluble in water, with a saline, feebly bitter taste. It is used in photography. It has medical and veterinary applications as a sedative, hypnotic, and anticonvulsant.

Sodium sulfate is used for standardizing dyes, in printing textiles, and in the manufacturing of glass and paper pulp. It is used medically as a diuretic.

Potassium chlorate is a very reactive oxidizing agent. In solid form it explodes with sulfuric acid and inflames with explosion when exposed to organic materials. It is used in fireworks, matches, dyeing and as a source of oxygen in chemical reactions.

It is irritating to the gastrointestinal tract. A toxic dose is approximately 5 grams.

Sodium sulfide is extremely hygroscopic, discoloring on exposure to air. It is unstable and may explode upon percussion or rapid heating. It has the odor of dihydrogen sulfide gas and its solutions are strongly basic.

Analysis

Your goal is to determine the identity of each solution. Once you have done this, write a balanced *net-ionic* equation for each reaction which you observed in the lab. You should have one equation for each reaction marked on the grid [duplicates, if any, need not be written].

Summarize by giving the identity of each solution by number and formula.

	8	7	6	5	4	3	2	1
9								
	8							
		7						
			6					
				5				
					4			
						3		
							2	

	8	7	6	5	4	3	2	1
9								
	8							
		7						
			6					
				5				
					4			
						3		
							2	

(you're welcome)