Six solutions

Introduction
This is an ill-defined problem in that the 'best method' has not been defined. Each student group has to find the best balance between the method that uses fewest additional chemicals or test papers, and the one that takes the shortest time. There is no one correct answer.
Teachers who have not used the problems before should read the section Using the problems before starting.

Prior knowledge
Familiarity with redox reactions, the ability to apply the electrochemical series (standard electrode potentials, E^{o} list), associated colour changes such as dichromate changing from orange to green when it is reduced in the presence of $H^{+}(aq)$ and tests for ions. A detailed knowledge is unnecessary as students are encouraged to consult textbooks and data books during the exercise.

Resources
Data books and inorganic textbooks should be available for reference.
Unnamed, but numbered bottles containing solutions of bromine water, iodine solution, iron(II) sulphate,$_1$ potassium dichromate, silver nitrate and sodium sulphite should be provided at the start of the exercise.

The precise concentrations are unimportant – laboratory reagents can be used where available, otherwise approximately 5 g solid per 100 cm^3 of solution. The iodine solution and potassium dichromate should be made up so that their colours roughly match that of the bromine water.

Students can request apparatus and chemicals during the practical session, and these should be issued if they are safe to use. In particular, flame test equipment will probably be required, but it should not be on view.

General
4–6.

Risk assessment
A risk assessment must be carried out for this problem.

Special safety requirements
There are hazards if the solutions are heated; and the staining effect of silver nitrate and iodine solutions should be noted.

Possible methods
1. The colourless solutions are the iron(II) sulphate, silver nitrate and sodium sulphite. Add each of these in turn to the three coloured solutions.

	Bromine water	Iodine solution	Dichromate solution
Iron(II) sulphate	decolorises	no change	orange/brown*
Silver nitrate	off-white precipitate	off-white precipitate	red precipitate
Sodium sulphite	decolorises	decolorises	yellow*

* green in the presence of dilute acid

a. The colourless solutions are identified as follows:
— silver nitrate – precipitate each time, in particular the off-white precipitates;
— sodium sulphite – decolorises two of the three coloured solutions; and
— iron(II) sulphate – decolorises one of the three coloured solutions.

b. The coloured solutions are identified from the results table.
To confirm the identities of the halogens, starch solution (blue/black colour with iodine) or an organic solvent (colour of lower layer) could be used.

2. Perform standard ion tests such as **a–e** below.
a. Flame tests (sodium and potassium).

b. Adding metals to the solutions, such as:
— copper, displacing silver from silver nitrate; and
— zinc or magnesium, displacing silver from silver nitrate and iron from iron(II) sulphate.

c. Electrolysis identifies the silver nitrate because black (finely divided) silver is produced at the cathode.

d. Standard tests for ions, such as:
— hexacyanoferrate(III) for Fe^{2+};
— a chloride solution for silver nitrate;
— brown ring test for nitrate;
— barium nitrate solution for sulphate and sulphite; and
— warming sodium sulphite solution with dilute hydrochloric acid to give sulphur dioxide (this may not work in this case because the solutions are too dilute).

e. In principle, the solutions could be evaporated to dryness, with further heating of any residual solids in a fume cupboard. This is a time consuming method and the solutions are so dilute that only small quantities of solids would become available. Thus the method is not recommended although reactions will occur:
— bromine water leaves no solid;
— iodine leaves a solid (potassium iodide and iodine) which gives purple fumes of iodine;
— silver nitrate gives a white solid which decomposes to give brown fumes of nitrogen dioxide as well as oxygen; and
— potassium dichromate gives oxygen and a greenish solid. The other two samples do not break down in a recognisable way.

Suggested approach

During trialling the following instructions were given to students and proved to be extremely effective:

1. Divide your group into two subgroups and move to different parts of the room so that the two can work independently.

2. Working in your subgroup of two or three, plan how to label the solutions correctly. Write this up in note form. This discussion plays an important part in devising a suitable method, and can save much wasted time and effort. Several minds focusing on a problem together can achieve much more than the same minds working independently.

3. Get your method checked for safety and then carry out the practical work to find how well it works. If you can think of any improvements, to your method, get it checked again for safety and try it if it hasn't been tried before.

4. Write a brief account of what your subgroup did. You should record any changes to your initial scheme and describe the problems you met.

5. The two subgroups should come together and to discuss each method and their various advantages and disadvantages in order to select the best procedure for the identification. This could be one of the procedures in its entirety or a procedure involving the 'best bits' from each. Remember that the 'best method' is the one that uses fewest additional chemicals or test papers but which does not take too long to complete.

6. Working as a group, prepare a short (ca 5-minute maximum) presentation to give to the rest of the class. If possible all group members should take part: any method of presentation (such as a blackboard, overhead projector, etc) can be used. Outline the problem, describe what you did and explain your choice of best method. After the presentation, be prepared to accept and answer questions and to discuss what you did with the rest of the class.

Notes

1. Ammonium iron(II) sulphate can be used in place of iron(II) sulphate; if the iron(II) sulphate has been in stock for a long time, ammonium iron(II) sulphate is better because it is less susceptible to oxidation on standing. The solution is oxidised by oxygen from the air to a yellow/brown colour – it keeps better if it is made up with boiled water because boiling drives out dissolved oxygen.

Six solutions

Devise experiments to label the numbered solutions correctly by using chemicals and apparatus in the laboratory.
Six solutions are provided. They are unnamed but are known to be bromine water, iodine solution, iron(II) sulphate, potassium dichromate, silver nitrate and sodium sulphite.

Any chemicals and any test papers can be used, but the best method is the one that uses fewest of these and takes the shortest time to carry out.

Note that iodine does not dissolve in water but it does dissolve in potassium iodide solution: thus ‘iodine solution’ contains both iodine and potassium iodide dissolved in water.

You should refer to any sources of information that you think might help such as your notebooks, textbooks and data books.

Ask for assistance if you get stuck.

Safety

Normal safety procedures when handling chemicals should be adhered to and eye protection worn. Both iodine solution and silver nitrate solution can stain skin and clothing. There are particular hazards which could arise depending how you tackle the problem.

You must ask get your method checked for safety before starting on the practical work.