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Part 2 Post-16 – The isolation of the platinum group metals (PGM)

Teacher 's notes

This is a comprehension exercise on the solvent extraction of platinum, supported by a demonstration of the partition of iodine between two solvents. Students will probably require a brief description of the overall process of extracting platinum before they read the passage *Solvent extraction of platinum.* Alternatively, they could read *The platinum story,* or watch the video if available.

Curriculum links

Equilibrium; partition coefficients; revision of amines.

Timing

60 –70 mins

Level

Post-16 chemistry courses

Apparatus

- Two boiling tubes with bungs
- Rack for boiling tubes
- Dropping pipette.

Chemicals

- 100 cm^3 hexane
- 100 cm^3 1 mol dm^{-3} aqueous potassium iodide solution
- A few small crystals of iodine.

Safety

- Wear eye protection
- Hexane is flammable
- Iodine is harmful by skin contact and gives off a toxic vapour that is dangerous to the eyes
- It is the responsibility of the teacher to carry out a risk assessment.

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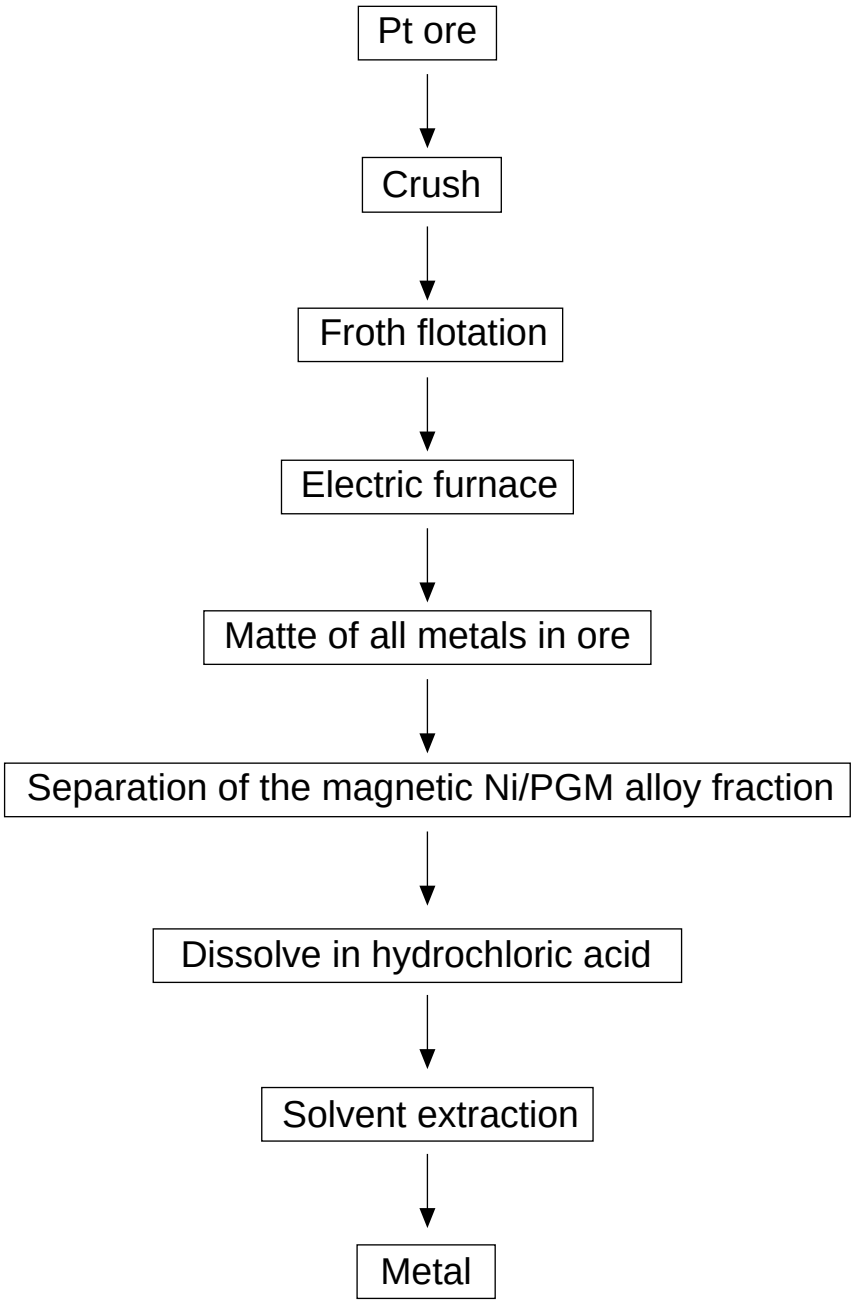
Possible lesson plan

1. Introduce the topic by showing the video (if available) and summarise with the following OHP showing the flow chart of platinum extraction.

Flow chart of platinum extraction as a whole



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2. Demonstrate the nature of differential solubility in two immiscible solvents by showing how iodine distributes between an aqueous solvent and an organic solvent. This could alternatively be done as a class experiment.

Practical details

Use boiling tubes and bungs

a) To demonstrate the colour in each solvent:

Boiling tube 1
Dissolve one small crystal of iodine in a 2 cm depth of 1 mol dm^{-3} aqueous potassium iodide solution. A yellow/brown solution forms.

Boiling tube 2
Dissolve one small crystal of iodine in a 2 cm depth of hexane. A pink/purple solution forms.

b) To demonstrate partition:

To boiling tube 1, add 2 cm depth of hexane and shake well.

What do you see? Discuss the partition of iodine between the two solvents.

Optional

Remove the organic layer using a dropping pipette and add a further 2 cm depth of hexane and shake.

Mention that the organic solvents used in the extraction of platinum contain dissolved amines. (The platinum metal is recovered finally from the organic solvent by precipitation via an aqueous solvent, and then strongly heating the solid compound to leave platinum metal.)

3. Use the worksheet *Solvent extraction of platinum*.

Background notes for teachers on solvent extraction

The platinum group of metals consists of platinum, palladium, rhodium, iridium, ruthenium and osmium. They may be separated from each other (after extraction from their ores) by precipitation reactions. An alternative to this is **solvent extraction.**

The platinum group metals (PGM) occur in minute quantities in deposits of copper-nickel sulfide ore. This material is mined commercially in a number of places in the world, but the three principal areas are in Canada, countries of the former USSR and South Africa (in the Merensky Reef, Transvaal). The Merensky deposits, though the major source, yield less than 10 grams of platinum from three tonnes of ore.

The crushed ore is concentrated by:

- **physical beneficiation**, (a technical term for the physical processes of crushing, sieving and flotation);
- **pyrometallurgical** techniques (the smelting processes); and
- **hydrometallurgical** techniques (the dissolving processes).

This eventually yields a concentrate containing around 50% PGM by mass. The remainder is largely gold, silver, copper, nickel and other base metals. The PGM are traditionally separated from one another and the other metals by a series of selective

precipitation techniques. These are generally inefficient in terms of the degree of separation achieved, and usually the precipitate has to be dissolved again and reprecipitated at least once more to get a pure product. Even when it proves possible to remove the desired elements completely from solution, the precipitate requires thorough washings to remove contamination from the original solution.

In the past few years the application of solvent extraction techniques has been used as a more efficient alternative for the separation of the PGM.

Once the initial capital investment in equipment has been made, solvent extraction processing has considerable advantages over the conventional precipitation processes. These include:

- greater safety because the platinum solutions (which have some allergenic properties) are in a closed system;
- reduced overall processing time – particularly for the major elements (*eg* platinum);
- improved yield from fewer steps; and
- the solvent can be reused.

In solvent extraction the base metals, such as iron, must be removed first because they tend to behave in a similar way to the PGM and are therefore more difficult to separate later on.

For a particular batch of ore, the steps involved in solvent extraction run continuously (see overleaf) and can be controlled automatically using sophisticated analytical instrumentation. Consequently, labour costs are reduced compared with a conventional batch process.

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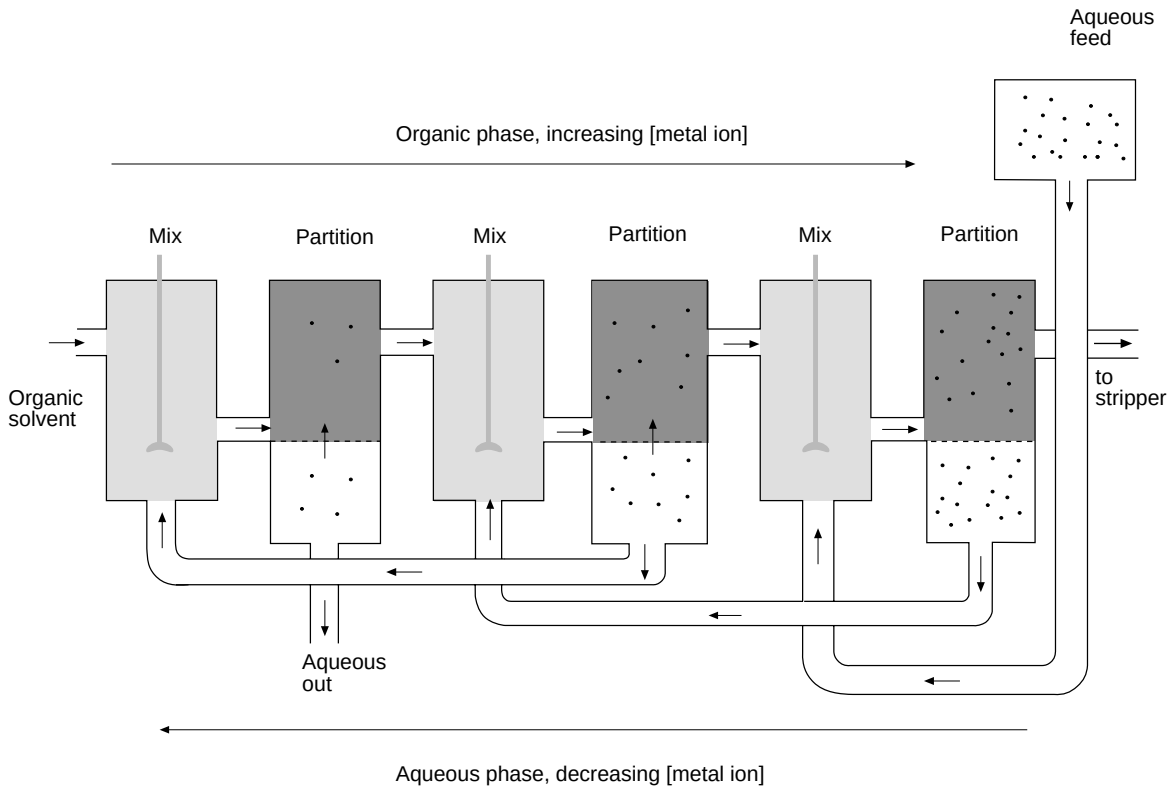

A schematic diagram showing the principle of continuous counter current solvent extraction. Organic solvent moves from left to right through a series of mixers and separating tanks, picking up metal ions as it does so. The aqueous phase moves from right to left, losing metal ions as they are extracted into the organic solvent. The whole process has the same effect as a large number of successive batch solvent extractions. The metal ions are then stripped from the organic solvent which is recycled.

Solvent extraction

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Answers to questions on the solvent extraction of platinum

1. (a) (i) Upper layer.

   (b) (i) Organic upper layer.

   (ii) Iodine is a molecular compound therefore, as "like dissolves like", a covalently bonded molecule is likely to dissolve to a greater extent in the organic layer.

   (iii) Greater than one.

2. a) Tertiary b) secondary c) quaternary d) primary

3. $RNH_2 + HCl \rightarrow RNH_3^+Cl^-$

4. a) Quaternary ammonium.

   [The relative efficiency of extraction of $[PtCl_6]^{2-}$ by the different classes of amines is :

   quaternary > tertiary > secondary > primary]

   b) Partition coefficient 1.0 implies equal distribution of solute between the organic and aqueous layers.

   c) Primary and secondary amines.