STANDARD OPERATING PROCEDURE:

The Thermite Reaction

Note: **The Thermite Reaction is potentially a very hazardous activity; however the hazards it presents can be safely managed with suitable controls in place. It should only be performed as a demonstration by experienced teachers and technicians in conjunction with current Safety Data Sheets (SDSs) and a site-specific Risk Assessment. Intense heat, brilliant light and molten metal are produced by this reaction. The demonstration should be performed outside on a fire resistant solid surface such as concrete in a windless area well away from any combustible or flammable materials.**

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1. Introduction

The Thermite Reaction is an excellent example of a highly exothermic (heat evolving) and redox reaction involving the oxidation of a metal powder and reduction of a metal oxide. The most commonly performed reaction involves igniting a mixture of aluminium powder and iron (III) oxide to yield molten iron and alumina (aluminium oxide) according to the equation:

$$2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe$$

The Thermite Reaction is an example of a more reactive metal displacing a less reactive metal from a compound. In this reaction, aluminium being more reactive displaces iron from the iron (III) oxide and removes the oxygen. The iron is reduced and the aluminium is oxidised. The iron generated is molten due to the amount of heat released during the reaction. The reaction can reach up to a temperature of about 3000°C.

Industrially, the Thermite Reaction is used for welding metal parts such as railway rails, for underwater welding and in metal refining.

2. Context

- These instructions are for the use of highly experienced chemistry teachers and technicians only.
- Do not attempt this experiment without assistance from an experienced colleague.

3. Safety notes

This activity has many potential hazards which need to be evaluated:

- For all chemicals consult current SDSs and conduct a site-specific risk assessment for the Thermite Reaction. Science ASSIST has developed an example risk assessment for this activity.
- Note that preparation for this demonstration may take several days to allow time for conducting a risk assessment, developing risk-mitigation measures and for the purchase and preparation of materials. A trial of the reaction on a smaller scale should be considered if staff have no prior experience with the reaction. The performance of the

activity is also subject to weather conditions: a day of mild weather without strong breezes should be chosen for this activity. Do not conduct the activity on a day when a total fire ban is in force.

- Select a suitable location for the reaction. As this reaction is highly exothermic and produces molten metal and sparks, select an outside area on a fire resistant solid surface such as concrete, protected from wind and well away from any flammable or combustible materials.
- The reaction produces brilliant light, intense heat, smoke, molten metal, flying sparks and shrapnel which may be thrown a great distance, therefore students are to be observers only and must stand at least 10 metres from the reaction. A Perspex safety screen should be used to help protect from any sparks.
- Check that the flowerpots are free of cracks, and that the bucket and support stand are sturdy and securely placed.
- Do **not** pre-prepare and store the iron oxide/aluminium powder mixture. Only prepare it just before use. Use chemicals which are of good quality and not out of date.
- It is important to ensure that there is no trace of moisture in the reactants, flowerpots, glassware, or sand as this could lead to a violent explosive reaction.
- Note that the Thermite Reaction is self-sustaining and cannot be extinguished by removing oxygen either by smothering with sand or using a fire extinguisher.
- Water should **not** be used to attempt to extinguish the reaction, since addition of water to hot iron produces potentially explosive hydrogen gas.
- A fire extinguisher should be on hand, not for extinguishing the reaction, but in case of flying sparks igniting spot fires.
- Once ignition is initiated (by lighting the magnesium fuse or sparkler or by addition of glycerol to potassium permanganate), the demonstrator must retreat quickly to at least 10 metres from the reaction.
- The demonstrator and observers should not look directly at the burning magnesium ribbon, if this ignition method is used.
- Since the reaction products will remain red hot for some time, the apparatus must not be moved until cooled. Cordon off the area until cooled sufficiently and then wearing safety glasses and heat-protective gloves dismantle the apparatus. Retrieve the iron with tongs.
- Students, wearing gloves, may handle/inspect the cast iron produced when it is cold.

4. Regulations, licences and permits

Not applicable

5. Equipment

- PPE for demonstrator: face shield, heat protective gloves, lab coat, closed in shoes and long trousers
- PPE for observers: Safety glasses for student and other observers standing at least 10 metres away
- Metal trash can or metal bucket ¾ filled with **dry** sand
- Sturdy metal retort stand (base may need weighting)
- Perspex safety screen

- Metal clamp to hold flowerpots (a ring clamp is recommended over a four-pronged clamp)
- Two **new** dry 10cm clay flowerpots with a large central drainage hole in their base. *During the experiment the inner pot will crack or shatter but the outer pot will remain intact. Do not reuse this outer pot as it may contain unseen cracks. During the experiment the molten iron will drop through the holes of the pots and onto the sand.*
- Small filter paper to fit in the base of one flowerpot. *This prevents the powder from falling out the bottom and will burn away during the experiment to allow the molten iron to flow through.*
- Plastic beaker and glass rod for mixing the chemicals
- Large dry glass test tube for packing down the reactants in the flowerpots
- Metal tongs
- Gas lighter (if using magnesium ribbon or a sparkler)
- Fire extinguisher on hand for spot fires
- 6 g aluminium metal, fine granular or aluminium powder
- 18 g iron (III) oxide powder (Fe_2O_3)
- Choice of ignition:
    - Method A: 18cm strip of magnesium ribbon
    - Method B: a sparkler
    - Method C: 8 g potassium permanganate and 3-4mL glycerol. The glycerol is added **last** to react with the potassium permanganate to initiate ignition. The reaction of permanganate with glycerol can take up to a few minutes to start. Fine permanganate crystals will react faster than coarser crystals.

6. Operating procedure

1. Do not rush the set-up of this activity. Plan carefully considering the weather conditions. Do not conduct on days when a total fire ban is in force.
2. Ensure that this demonstration is conducted outside, on a fire resistant solid surface, in a windless area, and that all observers are wearing safety glasses and positioned at least 10 metres from the reaction
3. Remove any flammable or combustible materials from the demonstration area.
4. Instruct observers not to directly look at the burning magnesium ribbon, if this ignition method is used.
5. Stack one clay flowerpot inside the other.
6. Place the small filter paper in the bottom of the inner flowerpot (see picture).

(Image by G. Ward, 2015)

7. Just prior to conducting the reaction, combine the aluminium powder and iron (III) oxide gently in a dry plastic beaker. Ensure that the reactants are well-mixed by stirring with a glass rod. Transfer the mixture to the inner flowerpot.
8. Using the large test tube gently pack down the mixed powders.
9. Place both flowerpots inside the clamp and suspend them over the centre of the metal bucket of dry sand to catch the molten iron (see picture).

(Image by G. Ward, 2015)

10. Select your ignition method - A, B OR C:
    A. Stand an18cm strip of magnesium ribbon in the iron oxide/aluminium powder mixture by inserting at least two-thirds of the depth of the reactant mixture.
    B. Push the metal handle of a sparkler down through both flowerpot holes including the filter paper so the sparkler stands upright and the grey sparkler material just touches the chemicals.
    C. Using the test tube, make a depression in the iron oxide/aluminium powder mixture and transfer the potassium permanganate into this. Then make a smaller depression in the potassium permanganate for the glycerol.
11. Initiating ignition:
    A. Light the magnesium ribbon with a gas lighter.
    B. Light the sparkler with a gas lighter.
    C. Pour the glycerol onto the potassium permanganate. In cold weather, the glycerol should be pre-warmed for easier pouring.
12. Once ignition has been initiated, quickly retreat to at least 10 metres away from the reaction.
13. When the reaction is complete, allow it to cool completely before using tongs to remove the piece of iron for examination. At this point you could demonstrate the magnetic properties of the iron produced.

7. Trouble shooting/emergencies:

- First aid for chemicals: See current SDSs for more detailed information
  - **If swallowed:** Do not induce vomiting. Rinse mouth with water, and then give water to drink. Seek urgent medical attention.
  - **If in eyes:** Hold open and irrigate with copious quantity of water for at least 15 minutes. Seek urgent medical attention.
  - **Skin/clothes:** Remove contaminated clothing and flush skin and hair with running water. Seek medical attention.
  - **If inhaled:** Remove to fresh air and seek medical attention if symptoms persist. For further advice contact the Poisons Information Centre on 131 126.
- **Burns:** Hold burnt area under cool running water for 20 minutes. Only remove clothing if it is not stuck to burn. Cover with non-adherent burns dressing, plastic wrap or loosely applied aluminium foil. Do not apply lotions, ointments, or adhesive coverings. Seek urgent medical attention.

8. Waste disposal

- The cast iron produced can be used in the classroom to show magnetic properties.
- If ignition was by method A or B, the cast iron product can be disposed of in the general waste. If ignition was by method C, the product should be disposed of via a licenced waste disposal contractor.
- Dispose of both flowerpots in the general waste. Do not reuse outer flowerpot for the next Thermite Reaction demonstration as it has been stressed and possibly contains unseen cracks.

9. Related material

- Example risk assessment
- Videos are available on YouTube. The teacher should review these carefully before showing to students, as there are various Thermite methods shown using different chemicals and also links to other dubious, explosive experiments, which may not be appropriate for students.

References:

NSW Department of Education and Communities '*Chemical Safety in Schools (CSIS)*' resource package. NSW DEC website http://www.dec.nsw.gov.au/ DEC Intranet, login required. (Accessed August 2015)

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'Safety Data Sheet: Aluminium powder', September 2011. Chem-Supply website. https://www.chemsupply.com.au/documents/AL0301CH0S.pdf

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History of reviews

Date	Version Number	Notes
Oct 2014	Version 1.0	Draft version
Sept 2015	Version 2.0	This replaces earlier draft version Includes updated photos and information