<table>
<thead>
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<th>Teaching an environmental module: Cognitive and affective outcomes of secondary three students</th>
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<tr>
<td>Author(s)</td>
<td>Chin Long Fay, Chia Lian Sai, Goh Ngoh Khang, Lucille Lee Kam Wah, Christine Chin and Foo Choon Lan</td>
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</tbody>
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TEACHING AN ENVIRONMENTAL CHEMISTRY MODULE:
COGNITIVE AND AFFECTIVE OUTCOMES OF
SECONDARY THREE STUDENTS

by

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Teaching an Environmental Chemistry Module:
Cognitive and Affective Outcomes of Secondary Three Students

1. Introduction

The primary role of environmental education is to develop and nurture environmentally conscious citizens. It is only when people are made more aware of environmental issues and the effects of a degradation of their physical and social environment that concerted action can be taken to protect and conserve the environment. The Master Plan for the Conservation of Nature in Singapore (1992) aims to develop Singapore as a model “Green City” by the year 2000. Towards the achievement of this target, Singapore holds an annual “Clean and Green Week” each November to drive home the message on environmental protection and conservation especially among the young school population as well as society at large. Schools are therefore actively encouraged in “educating our children to appreciate the environment”. (Yip, 1993).

According to Yeoh and Yee (1993), the annual “Clean and Green Week” campaigns serve to alert the public and make them aware of at least ten different environmental issues, namely,

1. Land: minimise waste and conserve land.
5. My Environment: What to do to save the environment.
8. Environmental protection and public health.

2. An Environmental Chemistry Module

When Project SC21 (Science Curriculum for the 21st Century) was first mooted, the Chemistry team decided to develop a teaching module on Environmental Chemistry aimed at secondary two or three students. Five themes were identified to be developed into lessons and laboratory activities, namely, (a) Solid waste and its disposal, (b) Air
polution, (c) Acid rain, (d) Water pollution, and (e) Ozone depletion. Eventually, each theme was developed into a 2.5 hour lesson and experiments designed to illustrate the specific environmental chemistry concepts that were to be taught. (Please refer to the Appendix for details of the concepts and experiments conducted under the theme “Air Pollution”.)

3. Student Sample

We decided to approach two Independent boys schools to try out the Environmental Chemistry module. School A was able to arrange for one class of secondary three Express stream pupils to undergo the 15-hour module over a 8-week period outside normal curriculum time. In this case, the five themes were taught by members of the chemistry team. The second school, School B was not able to provide a similar arrangement; so the five themes were conducted by the selected class’s chemistry teacher during curriculum time. Two other secondary three Express classes, one for each school, were designated “control” classes for the purpose of the investigation. These control classes were not taught the Environmental Chemistry module, but were given the same pre- and post-tests as the two experimental classes.

4. Objectives of the Study

The main objectives of the study were as follows:

4.1 To teach the key concepts and processes related to the five themes of solid waste, air pollution, acid rain, water pollution and ozone depletion to secondary three Express students.

4.2 To compare the levels of cognitive achievement in the five themes between the “experimental” and “control” classes in the two schools.

4.3 To ascertain the views of the students on the appropriateness of the five themes on Environmental Chemistry for study by secondary three students.

5. Methodology

Two instruments were designed and constructed for the study. The first instrument was an achievement test of 16 items on the concepts and processes taught in the five themes. This cognitive test served as both the pre- and post-test on the achievement dimension. The second instrument was in the form of an evaluation questionnaire designed to elicit responses on (a) the appropriateness of the five themes for study by secondary three students, (b) the helpfulness of video-cassettes used, (c) the helpfulness of the lecture/discussions, (d) the helpfulness of the laboratory activities/experiments and (e) on what the students have personally gained from learning the five themes on Environmental Chemistry.
The pre-test was administered to all the students of the experimental and control classes at the start of the study. The “treatment” was given to the experimental classes following the pre-test, but was withheld from the control classes. At the end of the treatment after about 8 weeks, all the students in the four classes were given the post-test and the evaluation questionnaire. The design of the study may be represented thus:

\[ O_1 \times O_3 \text{ (Experimental)} \]
\[ O_2 \times O_4 \text{ (Control)} \]
\[ O_5 \times O_6 \text{ (Experimental)} \]
\[ O_7 \times O_8 \text{ (Control)} \]

6. Results and Discussion

This was a field study. As such it had to operate within the context of an ongoing school term at the two schools concerned. Due to practical constraints, the four classes involved in the study were not randomly selected. Nevertheless, care was taken to try to select classes that were as equivalent in ability as possible. In School A, the experimental class was available for the team of NIE instructors to conduct the lessons and laboratory sessions outside curriculum time. This was not so in School B, where the chemistry teacher conducted the lesson during curriculum time. But the team members and the chemistry teacher maintained close liaison to ensure that the students in the two schools were exposed to the same concepts and activities/experiments. Thus the first objective of the study can be said to have been achieved.

To ascertain the cognitive level of the four classes with respect to the five themes, a pre-test was conducted. The results are summarized in Table 1 below:

<table>
<thead>
<tr>
<th>School</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Experimental</td>
<td>23</td>
<td>20.11</td>
<td>2.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>19</td>
<td>18.98</td>
<td>2.23</td>
<td>1.37</td>
</tr>
<tr>
<td>B</td>
<td>Experimental</td>
<td>23</td>
<td>19.78</td>
<td>2.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>19</td>
<td>19.42</td>
<td>2.14</td>
<td>0.48</td>
</tr>
</tbody>
</table>

The t-values were both non-significant at the 0.05 level. Hence we can conclude that the experimental and control classes were equivalent in both the schools at the start of the study in terms of their knowledge of the five themes.
When the post-test was administered to the students eight weeks later, the following results were obtained, as shown in Table 2.

Table 2
Means and Standard Deviations of the Post-test

<table>
<thead>
<tr>
<th>School</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Experimental</td>
<td>23</td>
<td>30.76</td>
<td>3.23</td>
<td>10.55*</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>19</td>
<td>20.01</td>
<td>2.87</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Experimental</td>
<td>23</td>
<td>29.58</td>
<td>3.14</td>
<td>9.01*</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>19</td>
<td>21.31</td>
<td>2.95</td>
<td></td>
</tr>
</tbody>
</table>

* significant at the 0.05 level.

The t-values obtained were both significant at the 0.05 level. Hence it can be concluded that both the experimental classes had achieved significantly better results in the cognitive test as compared to their peers in the control groups. The gains are just as significant whether the programme (theory and practical classes) was conducted by the NIE team or the chemistry teacher.

As mentioned previously, an evaluation questionnaire was administered to the students of the experimental classes at the end of the study. Thirty six usable questionnaires were returned. The responses to the first question are shown in Table 3 below.

Table 3
Responses to the question “To what extend are each of the themes on Environmental Chemistry appropriate for secondary three students?”

<table>
<thead>
<tr>
<th>Theme</th>
<th>Very Appropriate</th>
<th>Appropriate</th>
<th>Inappropriate</th>
<th>Very Inappropriate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Solid Wastes</td>
<td>10</td>
<td>19</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>2. Air Pollution</td>
<td>11</td>
<td>23</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>3. Acid Rain</td>
<td>13</td>
<td>17</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>4. Water Pollution</td>
<td>16</td>
<td>18</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>5. Ozone Depletion</td>
<td>16</td>
<td>15</td>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>
Thus the vast majority of the respondents viewed the five themes as either very appropriate or appropriate for themselves and their peers.

The next question was to determine their views on the helpfulness or otherwise of the video-cassettes used during class. Results are shown in Table 4.

Table 4

Responses to the question “To what extent were the videos on the themes helpful in explaining the concepts and issues in each theme?”

<table>
<thead>
<tr>
<th>Theme</th>
<th>NA</th>
<th>Very Helpful</th>
<th>Helpful</th>
<th>Unhelpful</th>
<th>Very Unhelpful</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Solid Wastes</td>
<td>0</td>
<td>11</td>
<td>22</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2. Air Pollution</td>
<td>5</td>
<td>11</td>
<td>15</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3. Acid Rain</td>
<td>6</td>
<td>17</td>
<td>10</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>4. Water Pollution</td>
<td>5</td>
<td>15</td>
<td>12</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>5. Ozone Depletion</td>
<td>4</td>
<td>17</td>
<td>14</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

NA: Not Applicable (Absent)

The results showed that while a majority of respondents felt the videos were either very helpful or helpful, some 3-4 students felt otherwise. There were also several students who had missed viewing the video for each theme.

We also wanted to know how the students viewed the lecture/discussion sessions. Table 5 provides the responses to our question.
Table 5

Responses to the question “To what extent was the lecture/discussion helpful in enhancing your understanding of each theme?”

<table>
<thead>
<tr>
<th>Theme</th>
<th>NA</th>
<th>Very Helpful</th>
<th>Helpful</th>
<th>Unhelpful</th>
<th>Very Unhelpful</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Solid Wastes</td>
<td>4</td>
<td>9</td>
<td>20</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2. Air Pollution</td>
<td>4</td>
<td>12</td>
<td>19</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3. Acid Rain</td>
<td>6</td>
<td>10</td>
<td>19</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4. Water Pollution</td>
<td>4</td>
<td>14</td>
<td>18</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5. Ozone Depletion</td>
<td>6</td>
<td>13</td>
<td>13</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

The majority of respondents appeared to consider the lectures/discussions very helpful or helpful; but there were some dissenting views as well.

Next, respondents’ views were sought on the helpfulness of the laboratory activities/experiments. Results are shown in Table 6.

Table 6

Responses to the question “To what extent were the laboratory activities/experiments helpful in enhancing your understanding of each theme?”

<table>
<thead>
<tr>
<th>Theme</th>
<th>NA</th>
<th>Very Helpful</th>
<th>Helpful</th>
<th>Unhelpful</th>
<th>Very Unhelpful</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Solid Wastes</td>
<td>8</td>
<td>6</td>
<td>16</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2. Air Pollution</td>
<td>0</td>
<td>21</td>
<td>9</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>3. Acid Rain</td>
<td>6</td>
<td>11</td>
<td>15</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>4. Water Pollution</td>
<td>2</td>
<td>15</td>
<td>15</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>5. Ozone Depletion</td>
<td>7</td>
<td>11</td>
<td>12</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

There was a range of responses. Most respondents considered the laboratory activities/experiments helpful, but there were some dissenters as well as those who ticked NA (Not Applicable).
Finally, students were asked to respond to the question "in what way(s) do you think you have personally gained from learning the five themes on Environmental Chemistry? Results are shown in Table 7.

Table 7

<table>
<thead>
<tr>
<th>Response Statement</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I have become more conscious of environmental problems and will do my best to help reduce them.</td>
<td>10</td>
</tr>
<tr>
<td>2. There are many chemical aspects of environmental problems which I have become aware of.</td>
<td>4</td>
</tr>
<tr>
<td>3. I have learnt more about the five types of environmental problems and know the importance it is to us.</td>
<td>6</td>
</tr>
<tr>
<td>4. I obtained a lot of knowledge and know more about what causes pollution and what harm they have on us. The whole project was very interesting.</td>
<td>1</td>
</tr>
<tr>
<td>5. It has brought chemistry a whole lot closer and made it lots more relevant to life in general. I enjoyed the lab lessons particularly.</td>
<td>1</td>
</tr>
<tr>
<td>6. I am now more conscious about the effects of my actions on the environment. I also try to practise &quot;green&quot; habits whenever possible.</td>
<td>1</td>
</tr>
<tr>
<td>7. I learnt a bit more about protecting the earth.</td>
<td>1</td>
</tr>
<tr>
<td>8. I know what ozone looks like.</td>
<td>1</td>
</tr>
</tbody>
</table>

7. Conclusion

From the results obtained, it is clear that all the major objectives of the study have been achieved. We have now the evidence to show that the five themes on Environmental Chemistry are suitable for study by secondary three Express stream students, and are helpful in enhancing that environmental consciousness. Furthermore, the study served as a successful example of close cooperation between the chemistry team from NIE and the staff and students of the two schools concerned. We would like to record herein our deep appreciation to the principals, staff and students of our collaborating schools for the opportunity to share an experience of mutual benefit.
References


Teacher Notes

1. Students will view a video, namely, "Pollution control in Singapore" as an introduction to teach the topic: air-pollution. It is an 8-minute video. Teacher may raise some questions, concerning the air-pollution in Singapore, as a follow-up to the video report. (15 minutes)

2. Teacher introduces the objectives for the activities and the background information including air-composition, air-pollutants, and the effects of the air-pollutants to our lives (refer to Sections 1 and 2). (10 minutes)

3. Since the car exhausts of cars are greatly contributed to the serious pollution in Singapore, students will carry out a series of experiments (5 experiments altogether) to detect the presence of some major pollutants in the air. Teacher provides instructions and guidance for the students to take part of these activities (refer to Student Worksheet). (60 minutes)

4. Teacher discusses with the students the results of the experiments and summarises the whole learning experience on air-pollution. (15 minutes)
1. **Objectives**

By the end of this lesson and the activities, the students should be able to:

1.1 name the common pollutants in air which include solids, carbon monoxide, lead compounds, sulphur dioxide and nitrogen oxides.

1.2 state the sources of each of these pollutants.

1.3 describe the effect of each of these pollutants on our lives.

1.4 describe some chemical methods that can be used to identify the presence of the abovementioned common gaseous pollutants.

2. **Background Information**

Clean air comprises a mixture of many different gases, but mostly it consists of nitrogen and oxygen gases. By volume, about 78% is nitrogen and 21% is oxygen. The remaining 1%, mainly is argon (about 0.9%). The rest includes carbon dioxide, water vapour, methane, hydrogen, helium, neon, ozone and other gases in trace amounts.

Unfortunately, the air is polluted by substances added in directly or indirectly by man's activities, in a level which can be hazardous to human health or bring about discomfort. The air-pollution also damages the stonework of buildings and causes windows and curtains to become dirty very quickly.

Most air pollution is caused by burning fuels. The problems are therefore worst in industrial areas. When a fuel burns, it reacts with oxygen to form oxides. If the fuel burns completely, then all the carbon in it turned into carbon dioxide which is only slightly acidic. If there is not much air available, the carbon may form soot and smoke or it may be turned into carbon monoxide, which is a very poisonous gas. Carbon monoxide reacts with a substance in the blood (haemoglobin) and stops it carrying oxygen to the brain and other parts of the body.

In a car engine, petrol burns in the cylinder. A lead compound is added to the petrol to help it burn smoothly, but waste lead compounds pass out with the exhaust gases. These lead compounds are poisonous because they affect the brain. Once lead is absorbed into the body, it stays in the body and causes damage to the nervous system, kidney and heart.
Some fuels, like coal and coke, contain small amounts of sulphur. When these fuels burn, sulphur dioxide is produced. This is a colourless, choking gas which irritates our eyes and lungs. When sulphur dioxide gets into rain, the rain water becomes acidic. This acid rain harms plants and attacks the stonework of buildings.

Car engines need air to burn the petrol. When the mixture is sparked, nitrogen and oxygen in the air combine to produce nitric oxide and nitrogen dioxide. Nitrogen dioxide is an acidic gas which irritates our eyes and lungs like sulphur dioxide.

When solid fuels like coal and coke burn, they leave ash. The ash contains solid metal oxides, called basic oxides. If the ash contains oxides of reactive metals (e.g. sodium oxide and calcium oxide), it will form an alkaline solution with water. Oxides of less reactive metals (like aluminium oxide, iron oxide and copper oxide) are insoluble and do not react with water.

Table 1 summarises the types of pollutants, their main sources and effects to our lives.

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Main Sources</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids (smoke, soots and ash etc.)</td>
<td>car exhausts, burning</td>
<td>Unclean air for breathing</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>incomplete combustion of compounds</td>
<td>A poisonous gas.</td>
</tr>
<tr>
<td></td>
<td>containing carbon, especially in car</td>
<td>Inhal a small amount</td>
</tr>
<tr>
<td></td>
<td>exhausts</td>
<td>may cause dizziness, if continue till overdose,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>may cause death</td>
</tr>
<tr>
<td>Lead compounds</td>
<td>Car exhausts</td>
<td>Once lead is absorbed into the body, it stays</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in the body and causes damage to the brain,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nervous system, kidneys and heart.</td>
</tr>
<tr>
<td>Sulphur dioxide (SO₂)</td>
<td>Combustion of coal and fuels which contain sulphur compounds</td>
<td>An acidic gas, it irritates eyes &amp; lungs. Form acid rain which is harmful to both plants and buildings.</td>
</tr>
<tr>
<td>Oxides of nitrogen (NO &amp; NO₂)</td>
<td>Combustion of nitrogen in motor vehicles</td>
<td>Nitrogen dioxide, an acidic gas, it irritates eyes &amp; lungs. Forms acid rain which causes damage to metal surface.</td>
</tr>
</tbody>
</table>
3. Identification of Pollutants in Car Exhausts

3.1 The exhaust gases of cars are the most serious pollution problem in many cities. Car exhausts can be collected and the presence of most of the pollutants can be easily detected in the laboratory.

A series of experiments are devised (see attached worksheet) using car exhausts, to identify the presence of

a) solids,
b) carbon monoxide,
c) lead compounds,
d) sulphur dioxide, and
e) nitrogen dioxide.

The instructions for the students to identify the abovementioned pollutants in car exhausts are described in the worksheet. Questions and spaces are also provided in the worksheet for the students to record their observations and conclusions.

3.2 Apparatus and Materials (Per group of students)

1. a plastic garbage bag
2. a few strings and rubber bands
3. a piece of white cloth (approx. 30 cm x 30 cm)
4. 2 pair of gloves
5. 2 60-ml syringes
6. 10 droppers
7. 10 test-tubes
8. a test-tube rack
9. a test-tube holder
10. 2 10-ml measuring cylinders
11. universal indicator papers

3.3 Chemicals

1. 10% silver nitrate solution, AgNO₃
2. 6M ammonia solution, NH₄OH
3. 5M nitric acid, HNO₃
4. 10% sodium hydroxide solution, NaOH
5. 0.001% dithizone in trichloromethane (CHCl₃)
6. Acidified dichromate solution, K₂Cr₂O₇ in dil. H₂SO₄
7. Sodium sulphite, Na₂SO₃
8. 2M Hydrochloric acid, HCl
9. 0.06% hydrogen peroxide, H₂O₂
10. barium chloride solution, BaCl₂
11. de-ionized water
12. 0.1% N-1-naphthylethylenediamine
13. Sulphanilic acid (dissolve 5 g in 800 ml distilled water, followed by 50 ml of glacial acetic acid and 50 ml of the 0.1% N-1-naphthylethylenediamine solution, then top up to 1 litre by using distilled water)
14. Standard solutions of sodium nitrite solution, NaNO₂: 100, 50, 20, 10, 5, 2, 1 mg/l for long daytime exposure in city air.
IDENTIFICATION OF POLLUTANTS IN CAR EXHAUSTS

Student Worksheet

Name: ___________________________ Date: __________

School: __________________________

This worksheet outlines methods of the detection of solids, carbon monoxide, lead compounds, sulphur dioxide and nitrogen dioxide, as the common gaseous pollutants in the air. Plastic garbage bags are used to transport exhaust gas back to the laboratory for qualitative analyses.

1. Solids

Experiment 1

Hold a piece of damp white cloth a few centimetres from the exhaust pipe. Start the engine and simulate driving for 2 minutes. Remove the cloth and compare the colour with a part of the cloth not exposed.

What do you observed?

Please explain your observation.

2. Carbon monoxide (CO)

Ammoniacal silver nitrate is used as a test for reducing agents, of which carbon monoxide is an example. Ammoniacal silver nitrate is made by adding concentrated ammonia solution (ammonium hydroxide, NH₄OH) to a solution of silver nitrate (AgNO₃), where a brown-black precipitate of silver oxide is produced.

\[ 2\text{Ag}^+(aq) + 2\text{NH}_3(aq) \rightarrow \text{Ag}_2\text{O}(s) + \text{H}_2\text{O}(l) \]

Adding further ammonia causes the precipitate to redissolve, leaving the silver bonded to ammonia in the silver-ammonia compound \( \text{Ag(NH}_3)_2^+ \). This reaction is reversible, and it is the \( \text{Ag}_2\text{O} \) which reacts with \( \text{CO} \) to produce deposits of black metallic silver.

\[ \text{Ag}_2\text{O} + \text{CO} \rightarrow 2\text{Ag} + \text{CO}_2 \]

3. Lead compounds

The lead in petrol is expelled through the exhaust as small particles of lead metal and lead bromide. In the presence of nitric acid, lead is converted into lead ions. These lead ions can react with dithizone in trichloromethane (chloroform CHCl₃). A change in dithizone from green to yellow indicates lead.

Experiment 2

Precaution: Wear the gloves when carrying out this experiment. The direct contact with silver compound solution may leave you some black stains of silver, that take time to be removed.

1. Measure 2 ml. 10% silver nitrate solution and place it into a test-tube. Add in 6M ammonia solution, NH₄OH, drop by drop (about 10 - 15 drops) till the brown-black precipitates disappear.

2. Using a 60-ml syringe, collect the exhaust gases from the garbage bag and bubble them through the dilute ammoniacal silver nitrate solution (from Step 1). Repeat this step for more exhaust gases when necessary.

What do you observe?

What does the result tell you?

Experiment 3

1. Using a 60-ml syringe to withdraw the exhaust gases from the garbage bag and bubble the gases through 2 ml. 5M nitric acid in a test-tube.

2. Adjust the pH by adding in 3.5 ml. 10% sodium hydroxide solution. NaOH, first, then slowly drop by drop till it reaches pH 9.5. Universal indicator papers are used for measuring pH value of the solution.
3. Add 1 ml. of the dithizone (in trichloromethane) solution to the above test solution, and shake. Set the solution aside for a few minutes where necessary to allow more time for the possible reaction to take place.

What do you observe? 

Is lead present in the car exhausts? Why? 

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5. Sulphur Dioxide (SO₂)

Sulphur dioxide can be identified by bubbling the gas through a solution of acidified potassium dichromate solution (K₂Cr₂O₇). A change in solution from yellow to green indicates sulphur dioxide.

Alternatively, bubbling the exhaust gases through a solution of hydrogen peroxide, H₂O₂,

SO₂ + H₂O₂ → H₂SO₄

which is subsequently precipitated as barium sulphate in the presence of barium chloride solution.

Ba²⁺(aq) + SO₄²⁻(aq) → BaSO₄(s)

Experiment 4 - Teacher Demonstration

Teachers will show the students the above two identification methods by using sodium sulphite (Na₂SO₃) and dilute hydrochloric acid (HCl).

Na₂SO₃(s) + 2HCl(aq) → 2NaCl(aq) + H₂O(l) + SO₂(g)

Experiment 5

1. Using a 60-ml syringe, to withdraw the exhaust gases and bubble them through a 2 ml. acidified potassium dichromate (K₂Cr₂O₇) solution in a test-tube. You may need to repeat this step to ensure that there is enough gas for any possible reaction to take place.

What do you observe? 

Is sulphur dioxide present in the exhaust gases? 

2. By the same method, withdraw the exhaust gases and bubble them through a solution of hydrogen peroxide (H₂O₂) in a test-tube. Repeat this step for more exhaust gases in the solution. Add in a few drops of barium chloride solution.

What do you observe? 

What can you conclude from this experiment? 

5. Nitrogen Dioxide (NO₂)

Nitric oxide (NO) and nitrogen dioxide are the major oxides of nitrogen present in air as a result of pollution. Nitrogen dioxide is a light brown coloured gas which is determined colorimetrically. Nitrogen dioxide reacts with sulphamic acid and turns to pink from colourless in the presence of an indicator, namely N-1-naphthi-ethylenediamine.
Experiment 6

1. Using a 60-ml syringe to withdraw the exhaust gases and bubble them through 5 ml. sulphanilic acid in a test-tube.

   What do you observe? __________________________________________
   _____________________________________________________________
   _____________________________________________________________

   Is nitrogen dioxide present in the car exhausts? Why?
   _____________________________________________________________
   _____________________________________________________________

2. Compare the colour of your test solution obtained from step (1) to the colours of your teacher's series of standard solutions. You would then be able to estimate the amount of nitrogen dioxide in 60 ml. of exhaust gases.

   What is the concentration of nitrogen dioxide in your test solution? _____ mg/l

   Can you work out the amount of nitrogen dioxide in 60 ml of exhaust gases that you tested? _____ mg

   What is the amount of nitrogen dioxide in your plastic garbage bag, supposing the volume is 10 litres. _____ mg