Introduction

Scientific inquiry can refer to the systematic approaches used by scientists to answer questions of interests. There are a number of advantages in using inquiry-based approach in scientific investigations. It can be used for learning and teaching about the content of a topic as well as the skills and processes in carrying out an investigation. Students can obtain significant gains in formulating hypothesis; making assumptions; designing and conducting investigations; making observations; recording and analyzing data; synthesizing knowledge; and the development of openness, responsibility and satisfaction (Lechtanski, 2000).

The inquiry-based approaches can be classified into three types: structured inquiry, guided inquiry and open inquiry (Colburn, 2004). The structured inquiry approach is similar to verification where step-by-step instructions are provided to the students. The role of students will be to decide on what observations to be recorded and to interpret the data collected. In the guided inquiry, the topic of investigation is often given to the students. The students will then have to choose the type of data to be collected and design experimental procedures to collect the data. For the open inquiry, the students will work on their own problem. They have to set up the topic for investigation; decide the data to be collected; and design the experimental procedures. Fig. 1 depicts the relationship between structured inquiry, guided inquiry and open inquiry.

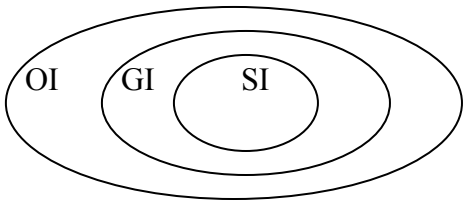

Fig. 1: Relationship between structured inquiry, guided inquiry and open inquiry
(OI: Open inquiry; GI: Guided inquiry; SI: Structured inquiry)

To help students make the transition from carrying a verification approach investigation to undertaking a inquiry-based investigation, teachers can facilitate students' thinking about the investigation by asking guiding questions instead of directing their action. The questions could be either presented verbally or in the form of a written worksheet. Besides, teachers can implement the changes gradually by reducing the supports of the investigations e.g. remove the data table first, and then the step-by-step procedures and finally the problems for investigation. Inquiry-based experiments provide opportunities for students to think independently and to gain problem-solving skills that will help them throughout life.

The following is a list of possible investigations extracted from the projects in the first to the tenth Hong Kong Chemistry Olympiad for Secondary Schools (1995/1996-2004/2005). It serves as a reference for teachers in planning inquiry-based experiments for the revised Sixth Form Chemistry Curriculum. Various types of Chemistry investigations are included. Most of the projects involved solving authentic problems which is a key element for stimulating students' curiosity in learning and engaging them in scientific inquiry. The list is by no means exhaustive and students can certainly come up with more titles based on their own ideas. Further details of the

projects can be found in the summaries which are available at http://resources.emb.gov.hk/~science/hkcho.

Theme: Household Chemistry

Title	**Possible Investigations**	**Curriculum Links**
Drain Cleaners – Unclog the Clogged	• Investigate the chemical nature of the active ingredients in drain cleaners • investigate the corrosive nature of drain cleaners • determine the temperature change when drain cleaners are added to water • compare their effectiveness in unclogging pipes	Acid and Base
The Anti-oxidizing Recipe	• determine and compare the contents of antioxidants (Total Antioxidant Activity, TAA) in different samples e.g. fruits, vegetables and herbs • investigate the stability of antioxidants under different conditions e.g. heat, acid and air	Stoichiometry, Drugs
The Wisdom behind Ginger Vinegar	• determine and compare the calcium contents in ginger vinegar, milk and Chinese soups • determine the iron content in ginger vinegar by spectrometric method	Stoichiometry
How 2 Stop the Odour?	• investigate and compare the effectiveness of different household substances (e.g. activated carbon, baking soda and drain cleaner) in removing hydrogen sulphide • determine the amount of hydrogen sulphide absorbed by household substances using iodometric titration	Stoichiometry
Biodiesel	• prepare biodiesel from cooking oil by transesterification with methanol • compare the properties (e.g. viscosity, flammability, amount of soot produced during combustion, heat of combustion) and performance of biodiesel with diesel • compare the properties of biodiesel and biodiesel blended with ethanol	Ester, Energetics
Natural Pest Repellant	• extract plant essential oils from peels of different citrus fruit (e.g. lemon, grapefruit, pomelo and orange) by steam distillation and solvent extraction • investigate the presence of alpha-terpineol (a natural pest repellant) in the extracts by chromatography • investigate the ability of the extracts as natural repellants for mosquitoes	Structure Determination of Organic Compounds, Green Chemistry

Theme: Earth Chemistry

Title	**Possible Investigations**	**Curriculum Links**
Simulation of Ozone Depletion Reactions	• design and construct an laboratory ozone generator • devise a method for the determination of ozone in air • Investigate the effects of chemicals e.g. hydrocarbon, halogens and aerosol propellants on the concentration of ozone in air	Halogeno-compounds
What have diapers got to do with soil?	• investigate the effects of diaper polymer (sodium polyacrylate) on the properties of soil e.g. pH and conductivity • determine the ratio of diaper polymer-soil for the optimum growth of plant e.g. green bean	Polymers
A Perfect Domestic Waste Cleaner	• investigate the efficiency of Fenton's reagent (a solution of H_2O_2 with Fe^{2+}(aq) catalyst) in removing organic pollutants in wastewater • determine and compare the chemical oxygen demand (COD) of waste water before and after treatment • investigate the efficiency of Fenton reaction at different pH	Green Chemistry
Analysis of Lead and Zinc in Soil	• determine the concentrations of lead(II) and zinc ions in different soil samples by colorimetric method (formation of coloured complex with dithizone solution) • investigate the mobility of heavy metal ions by thin layer chromatography • investigate the feasibility of removing lead(II) ions from soil by electrochemical remediation	Complex Formation
Water Purifying System	• design and construct a water purifying system • determine and compare the quality (e.g. pH, dissolved oxygen, ammonium and phosphate ions) of water before and after treatment	Stochiometry
Wastewater Treatment with Wetland Mud	• investigate the ability of wetland mud in removing heavy metal ions, ammonium ions and organic matter in wastewater	Stochiometry

Theme: Chemical Detective

Title	**Possible Investigations**	**Curriculum Links**
Fingerprint Detective – Electrolysis	• determine the optimum conditions (e.g. metal surface, concentration of electrolyte, voltage, current and time) for developing fingerprint by electrolysis • compare the endurance of fingerprints formed by iodine fuming and electrolysis	Electrolysis
The Everlasting Evidence	• investigate the detection of bloodstain with luminol • investigate whether luminol can detect substances with similar appearance with blood • investigate the effects of different conditions (e.g. pH, temperature, organic solvent, household cleansing agents, working surfaces) on the functioning of luminol	Chemistry of Organic Compounds
Oil Facts	• investigate the deterioration of cooking oil by measuring the degree of unsaturation, amount of hydroperoxides, aldehydes and carboxylic acids and change in viscosity • compare the deterioration rate of peanut oil, corn oil, canola oil and olive oil, etc.	Chemistry of Organic Compounds
An Insight on Lycopene	• extract lycopene from tomato • confirm the presence of lycopene by thin layer chromatography • investigate the antioxidizing properties of lycopene • investigate the effects of heat and storage time on lycopene • determine and compare the lycopene contents in vegetables e.g. water melon, grape fruit	Alkenes
Hidden Doctor	• devise a chemical method to determine the content of polyphenol in tea • investigate which kind of tea contains the highest content of polyphenol • investigate whether the amount polyphenol in tea will decrease with time upon storage • investigate whether there is any difference in the amounts of polyphenol extracted by soaking and boiling	Drugs
Carbon Monoxide Detector and Meter	• design and construct a carbon monoxide detector based on the chemical reaction between palladium(II) chloride and carbon monoxide • design and construct a carbon monoxide meter based on the chemical reaction between diamminesilver(I) and carbon monoxide	Complex Formation

Theme: Electrochemistry

Title	Possible Investigations	Curriculum Links
Ion Selective Electrode - Analysis of Hydrogen Sulphide in Smoke and Sewage	• design and construct an ion-selective electrode for the determination of H_2S in smoke and sewage • determine and compare the H_2S contents in sewage collected from different locations • investigate the effectiveness of a scrubbing solution of $I_2/I^-(aq)$ in removing H_2S in sewage	Electrode Potential
Antimony Electrode for pH measurement	• design and construct an antimony electrode for pH measurement • compare the performance of the antimony electrode with glass electrode • investigate the performance of antimony electrode at different temperatures and compare with that of glass electrode • investigate the limitations of using antimony electrodes for pH measurement and suggest suitable modifications for use in school laboratory	pH and its Measurement
Energy from the Air	• design and construct a metal-air fuel cell • investigate the relationship between cell e.m.f. and concentrations of electrolyte • investigate the relationship between cell e.m.f. and nature of anodes • determine the discharge curve of a the fuel cell	Fuel Cell
Aluminium-Air Cell (Half Fuel Cell)	• design and construct an aluminium-air fuel cell from soft drink cans • investigate the current produced using electrolytes e.g. NaOH, KOH, NH_4OH and NaCl at different concentrations • investigate the cell e.m.f. and current produced using different metals (e.g. Mg, Al, Fe and Zn) as anode	Fuel Cell
An Investigation on Electro-coagulation	• investigate the best conditions (e.g. electrode material, with or without stirring) for carrying out electro-coagulation • evaluate the effectiveness of the method in removing pollutants in waste water by measuring the change in biochemical oxygen demand (BOD_5) and light transmittance • determine and compare the effectiveness of the method in removing pollutants in different waste water samples	Electrolysis
Lead-acid Battery at Low Temperature	• investigate the effect of temperature on the current delivered by lead-acid batteries • design and construct a lead-acid battery which can operate at low temperature by investigating the effects of distance between electrodes, surface area of electrodes, concentration of electrolytes, etc. on cell current	Secondary Cell

Theme: Chemistry of Drinks

Title	**Possible Investigations**	**Curriculum Links**
Nature's Medicine - Tea	• determine the catechin (a polyphenol antioxidant) content in tea by its reactions with lead(II) ethanoate and acidified $KMnO_4$ solutions • investigate which kind of tea has the highest catechin content • investigate and compare the caffeine contents in different teas	Stoichiometry, Drugs
From Milk to Paint	• prepare a paint from milk by mixing with calcium hydroxide, calcium sulphate and a pigment • investigate and compare the performance (e.g. resistant to heat, water and organic solvent) of the milk paint with commercial paints	Polymers
Iron in Tonic Drinks	• determine the iron contents in food samples by dry ashing and colorimetry • investigate and compare iron contents in Chinese herbal drinks and fruit juices	Stoichiometry
An Investigation of Caffeine Content in Tea	• extract caffeine from tea by solvent extraction • investigate the factors affecting the efficiency of caffeine extraction • investigate and compare the caffeine contents in different teas	Drugs
Revitalized Water: Is it a Miraculous Drink?	• investigate the credibility of portable water treatment device (e.g. Penergizer) by comparing the concentrations of $Ni^{2+}(aq)$ and $Pb^{2+}(aq)$ ions in water using EDTA titration	Complex Formation
The Miracles of Orange	• design and prepare an instant vitamin C drink with low sugar content • determine the vitamin C contents in orange juices by DCPIP and iodometric titrations • determine and compare the contents of reducing sugar in different orange juices	Stoichiometry, Drugs

Theme: Materials in the New Millennium

Title	**Possible Investigations**	**Curriculum Links**
Investigation of a Microporous Material – Zeolite	• prepare zeolite by mixing sodium silicate nonahydrate ($Na_2SiO_3 \cdot 9H_2O$) and sodium aluminate • extract zeolite from laundry powder • Investigate the ability of zeolite in removing water hardness by comparing the concentration of $Ca^{2+}(aq)$ before and after treatment using EDTA titration • investigate the ability of zeolite in removing heavy metal ions (e.g. $Cu^{2+}(aq)$, $Ni^{2+}(aq)$ and $Cr^{3+}(aq)$) and organic substances (e.g. cyclohexane) in water • investigate the catalytic effect of zeolite in esterification	Silicon and Silicates
The Final Fantasy 'Apollo 2000' – Fireproof Paint	• prepare fireproof paints by adding different chemicals (e.g. starch, borax, boric acid, $BaCO_3$, $Ca(OH)_2$, $Mg(OH)_2$ and $NaHCO_3$) into commercial paint • investigate the fireproofing ability of the prepared paints by measuring the temperature on the unpainted side using a temperature sensor	Energetics
An Exotic Material from Milk – Casein	• extract casein from milk by mixing with different acidic substances (e.g. HCl, H_2SO_4, ethanoic acid and lemon juices) • prepare a glue by mixing casein with sodium carbonate solution • investigate the binding ability of the prepared glue • prepare a polymer by mixing casein with formaldehyde • investigate the ability of the casein-formaldehyde in removing silver ions from waste water	Polymers
Semi-conductors: Home-made Solar Cells	• design and construct a dye sensitized solar cell (red dye from raspberries as sensitizer, titanium dioxide as semiconductor, iodine and KI in ethylene glycol as electrolyte) • investigate the current and e.m.f. produced with different dyes, solvents, pH, concentrations of electrolyte and sizes of semiconductor	Redox Equilibrium
Superconductors	• prepare a superconductor ($YBa_2Cu_3O_{7-x}$) • determine the critical temperature of the superconductor • determine the value of x in the superconductor by iodometric titration	Bonding and Structure, Stoichiometry
The Space Ice	• investigate the effects of electric and magnetic field on the volume of ice • investigate the electrical conductivity of ice under the influence of an electric field	Bonding and Structure

Theme: Chemistry and the Environment

Title	**Possible Investigations**	**Curriculum Links**
Chitin for Treatment of Heavy Metal	• extract chitin from carb shells by dilute HCl(aq) • investigate the ability of chitin in removing heavy metal ions in waste water by determining the concentration of metal ions using EDTA titration • investigate the feasibility of recovering chitin after waste water treatment	Natural Polymers, Complex Formation
Respirator	• design and construct a respirator that can be used for removing acidic gases • investigate the ability of different chemicals e.g. CaO(s), $Ca(OH)_2$(s) and $CaCO_3$(s) in absorbing acidic gases • investigating the effectiveness of the respirator in removing acidic gases	Acid and Base
Too much chlorine in our tap water?	• investigate the free residual chlorine in tap water by the reaction with I^-(aq) • determine the free residual chlorine in water by colorimetry (N, N-diethyl-p-phenylenediamine) and commercial chlorine testing kit • investigate and compare the free residual chlorine in tap water samples collected from different locations	Halogens, Green Chemistry
Water Pollution	• determine the dissolved oxygen in water by the Winkler method • determine the nitrogen content in water by the Kjeldahl method • investigate and compare the quality of water samples collected from different coastal areas in Hong Kong based on the Water Quality Index (dissolved oxygen, BOD_5 and nitrogen content)	Stoichiometry
Comparison of River Water Quality in Hong Kong	• investigate the quality of water by measuring parameters e.g. total alkalinity, pH, total hardness and total dissolved solids • investigate and compare the quality of water samples collected from different rivers in Hong Kong	Stoichiometry
Phosphate Salts in Washing Powder	• determine phosphate ions in water by colorimetric method • investigate and compare the phosphate contents in different brands of washing powder	Stoichiometry

Theme: Energy Changes

Title	**Possible Investigations**	**Curriculum Links**
Hot Cup and Fever Eliminator	• design and construct a self-heating cup • investigate and compare the heat released from the reaction between water and different chemicals e.g. CaO(s) and $CaCl_2$(s) • design and construct a fever eliminator (cold pack) • investigate and compare the heat released from different chemical reactions	Energetics
Investigation of Hand-warmers	• investigate the chemical principles behind commercial hand-warmers e.g. oxidation of iron powder, heat of crystallization of sodium acetate and heat of solution of calcium chloride • investigate the maximum attainable temperature, the time to reach it and the duration of warmth kept in different commercial hand-warmers	Energetics
A New Discovery of Car Fuel	• determine the heat of combustion of different fuels e.g. diesel oil, petrol, ethanol, methanol and paraffin oil by simple calorimetry • investigate the effect of mixing different amount of ethanol with petrol on the heat of combustion • investigate and compare the energy produced per unit price of different renewable oils e.g. peanut oil, corn oil, canola oil, sesame oil, olive oil, lard, margarine, orange oil in order to find out which could be used as an alternative car fuel	Energetics
Making a Home-made Cell	• design and construct an electrochemical cell from household chemicals e.g. chlorine bleach, aluminium can and graphite rod • investigate the effects of salt, sodium hydroxide, copper cathode, temperature and swirling on the e.m.f. and current of the cell • determine the discharge curve of the cell	Electrochemical cell
Energy Changes involving Recycling Aluminium Cans	• construct an electrochemical cell using Cu(s)/Cu^{2+}(aq) and Al(s, from aluminum cans)/Al^{3+}(aq) half-cells • design and construct a fuel cell using an aluminium can, a graphite electrode and saturated sodium chloride solution • investigate the relationship between the e.m.f. of the fuel cell and the concentration of sodium chloride solution	Electrochemical cell
Chemistry Lunch Box	• design and construct a self-heating lunch box • investigate the exothermic reactions (e.g. oxidation of iron powder, crystallization of sodium acetate, dissolution of calcium chloride and sodium thiosulphate) that could be used in the lunch box	Energetics

Theme: Colour Chemistry

Title	**Possible Investigations**	**Curriculum Links**
Investigation of Hair Colourants	• dyeing hair with metal sulphides • investigate the compatibility of bleach and dye for hair	Solubility Product, Redox reactions
How Good is Red Cabbage as a Dye?	• extract dye from red cabbage • investigate the components of red cabbage dye by paper chromatography • determine the pH range of red cabbage dye • investigate the effects of temperature and the presence of mordant on the dyeing quality on natural fibres e.g. cotton and silk	Acid-base indicators
Natural Colours as Indicators and Dyes	• extract colour pigments from red cabbage and blueberries • determine the pH ranges of the pigments as acid-base indicators • extract dyes from plant materials e.g. beetroot and tea leaves • investigate the effects of temperature, pH and the presence of mordant on the dyeing quality of the plant extracts	Acid-base indicators
Acid-Base Indicators from Plant Materials	• extract colour pigments from different plant materials e.g. sleeping Hibiscus, yellow ginger, cherry, Bauhinia and red cabbage • determine the colours of the pigments at different pH • investigate the feasibility of using the pigments as acid-base indicators • prepare homemade pH paper from the colour pigments	Acid-base indicators
Bleaching of Coloured Compounds by Hydrogen Peroxide	• investigate the effects of pH and concentration on the bleaching power of hydrogen peroxide on different dyes e.g. tea, coffee, chocolate, inks, soy sauce, tomato juice • investigate the effect of bleaching on the tensile strength of cloth	Green Chemistry
Analysis of Phenols and Colour of Green Tea	• investigate the presence of polyphenols in green tea by neutral iron(III) chloride solution • investigate the effects of air/oxygen, conc. nitric acid and polyphenol oxidate (in fresh potatoes) on the colour of green tea	Chemistry of Organic Compounds, Drugs

Theme: Food Chemistry

Title	Possible Investigations	Curriculum Links
Protein – a New Insight	• investigate the ability of egg white to serve as an antidote for lead poisoning • compare the amount of lead precipitate formed with egg white and soya bean milk at different pH and the time required for precipitation	Group VI Elements
Determination of Nitrogen Content in Food	• determine the nitrogen contents in foodstuffs (e.g. sausage) by Kjeldahl method	Stoichiometry
To Analyze the Sucrose Contents in Soft Drinks	• determine the sucrose contents in softdrinks by comparing the optical activity of the samples with those of standard sucrose solutions • compare the sucrose contents in different soft drinks	Stereoisomerism
Apple Browning	• investigate the effects of pH, temperature, oxidizing and reducing agents, ethanol and salt solution on the rate of apple browning • investigate the ways to prevent apple browning	Chemical Kinetics
Analysis of Chloride Contents in Different Foodstuffs	• determine the chloride contents in foodstuffs by Volhard's method (back-titration of excess $Ag^+(aq)$ with standard potassium thiocynate solution) • compare the chloride contents in mineral water and dairy products	Halogens, Stoichiometry
Determination of Chloride Ion Content in Cheese by Volhard's Method	• determine the chloride content in cheese by Volhard's method • compare the chloride contents in western and Chinese cheeses	Halogens

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