Scheme of work

Combined Science: Synergy
Guiding Spaceship Earth towards a sustainable future

This resource provides guidance for teaching the Guiding Spaceship Earth towards a sustainable future topic from our new GCSE in Combined Science: Synergy (8465). It has been updated from the draft version to reflect the changes made in the accredited specification. There have been no changes to the required practical. However, there have been minor changes in the specification content in sections 4.8.1.1 Bonding and structure in forms of carbon, 4.8.1.3 Fractional distillation of crude oil, 4.8.1.4 Cracking hydrocarbons, 4.8.2.2 Metal extraction by electrolysis, 4.8.2.4 Energy resources and 4.8.2.6 Preventing unwanted energy transfers.

The scheme of work is designed to be a flexible medium term plan for teaching content and development of the skills that will be assessed.

It is provided in Word format to help you create your own teaching plan – you can edit and customise it according to your needs. This scheme of work is not exhaustive; it only suggests activities and resources you could find useful in your teaching.

4.8 Guiding Spaceship Earth towards a sustainable future

4.8.1 Carbon chemistry

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4.8.1.1	Diamond is very hard, has a very high melting point and does not conduct electricity. In diamond, each carbon atom forms four covalent bonds with other carbon atoms in a giant covalent structure. In graphite, each carbon atom forms three covalent bonds with three other carbon atoms, forming layers of hexagonal rings. There are no covalent bonds between the layers. One electron from each carbon is delocalised. Graphene is a single layer of graphite and so is one atom thick. It has properties that make it useful in electronics and composites.	Explain the properties of diamond and graphite in terms of their structures and bonding.	1	Link the properties of diamond to the structure in diagrammatic form. Present a reasoned explanation of the properties of graphite linked to structure. You have been asked to explain why graphite conducts electricity at the school open evening. What would you say? MS 5b Visualise and represent 2D and 3D forms including two dimensional representations of 3D objects.	Research the properties of diamond and graphite. Model the structure of diamond and graphite using model kits.	Video clips: BBC Bitesize Properties of diamonds YouTube: Structure of diamond and graphite BBC Bitesize Properties and structure of graphite RSC resource 'Allotropes of Carbon' including video clips from RI Christmas lectures Teachit Science resource (23739) 'Diamond v graphite'

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4.8.1.1 cont.	Fullerenes are molecules of carbon atoms with hollow shapes. The structure of fullerenes is based on hexagonal rings of carbon atoms but they may also contain rings with five or seven carbon atoms. The first fullerene to be discovered was buckminsterfullerene (C_{60}), which has a spherical shape. Carbon nanotubes are cylindrical fullerenes. They have high tensile strength, high electrical conductivity and high thermal conductivity.	Explain the properties of fullerenes and graphene in terms of their structures and bonding.	1	Give pupils images/models of fullerenes and nanotubes. Discuss what properties they think they might have. Extended writing: describe the history of fullerenes and suggest future applications.	Model the structure of fullerenes and nanotubes using model kits Research properties and uses of fullerenes and nanotubes.	Video clips: BBC Bitesize Discovery and uses of graphene YouTube: Bucky Balls, Graphene and Nano Tubes Britannica article 'Fullerene: Chemical compound' RSC resource 'Allotropes of Carbon' including video clips from RI Christmas lectures
4.8.1.2	Crude oil is a finite resource found in rocks. Crude oil is the remains of an ancient biomass consisting mainly of plankton that was buried in mud.	Recall that crude oil is a main source of hydrocarbons and is a feedstock for the petrochemical industry.	1	Explain what is meant by the formula C_nH_{2n+2} Ask pupils to suggest what stereochemistry is by looking up the definition of the root word stereo-. Then make molecular models and work	Show table which includes names and molecular formula of alkanes. Pupils deduce general formula for alkanes Plot boiling points of alkanes against	Exampro user guide PowerPoint

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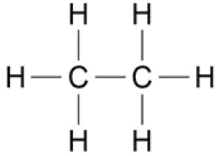
	Crude oil is a mixture of a very large number of compounds. Most of the compounds in crude oil are hydrocarbons, which are molecules made up of hydrogen and carbon atoms only. Alkane molecules can be represented in the following forms: C_2H_6 or  Knowledge of the names of specific alkanes other than methane, ethane, propane and butane is not required.	Recognise that crude oil is a finite resource. Recall that carbon can form four covalent bonds. Explain that the vast array of natural and synthetic organic compounds occur due to the ability of carbon to form families of similar compounds, chains and rings. Describe the fractions as largely a mixture of compounds of formula C_nH_{2n+2} which are members of the alkane homologous series.		out general formula for the alkanes. Discussion question: how could the chemical synthesis of hydrocarbons play a role in reducing global warming? Draw the covalent bonding in: • methane • ethane • propane • butane. Describe the strength of bonds within and between alkane molecules. Link to the boiling points and size of alkanes. Define the term saturated. WS 1.2, MS 5b Recognise substances as alkanes given their formulae.	number of carbons. Make predictions of the boiling points of other alkanes. Which are gases at room temperature? Do all alkanes have the same properties?	
4.8.1.3	Some properties of hydrocarbons depend on	Write balanced equations for the complete combustion	2	Pupils list all the objects in their immediate vicinity	Investigate the properties of hydrocarbons in terms	Video clips:

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	the size of their molecules, including: • boiling point • viscosity, • flammability. These properties influence how hydrocarbons are separated and how they are used as fuels. Knowledge of trends in properties of hydrocarbons is limited to boiling points, viscosity and flammability. The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by fractional distillation. The fractions can be processed to produce fuels and feedstock for the petrochemical industry. Many of the fuels on which our modern lifestyle	of hydrocarbons with a given formula. Describe and explain the separation of crude oil by fractional distillation. Describe, explain and exemplify the processes of fractional distillation. Explain how modern life is crucially dependent upon hydrocarbons.		which are manufactured from hydrocarbons. Why is there less demand for the thicker oils that result from fractional distillation? Pupils link the products of complete combustion of alkanes with global warming.	of boiling point, viscosity and flammability with increasing molecular size. Ask pupils to explain the precautions taken during this investigation. Identify the products of combustion of alkanes. Pupils use the whole classroom to model a fractionating column. Points of exit for fractions provided by gaps between tables. Pupils can be given cards with: • name of fraction • boiling point • drawing of length of chain • molecular formula. Other pupils have cards which provide detail about the column, eg 'heat	BBC Bitesize Combustion of carbon BBC Bitesize Combustion of natural gas RSC resource – Oil refining Teachit Science resource (19679)'Crude oil – fractional distillation'

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	depends such as petrol, diesel oil, kerosene, heavy fuel oil and liquefied petroleum gases, are produced from crude oil. Knowledge of the names of other specific fractions or fuels is not required. The combustion of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are oxidised. The complete combustion of a hydrocarbon produces carbon dioxide and water. Many useful materials on which modern life depends are produced by the petrochemical industry. These include solvents, lubricants, polymers and detergents.				source', temperatures within column. They work together to position themselves correctly.	
4.8.1.4	Hydrocarbons can be broken down to produce smaller, more useful molecules by catalytic	Describe the production of materials that are	1	Describe the process of cracking.	Demo or practical: crack paraffin over porous clay pot.	Video clips YouTube: Hydrocarbon

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	cracking or by steam cracking. The products of cracking include alkanes and another type of hydrocarbon called alkenes. Recall of the formulae or names of individual alkenes, other than ethene, is not required. There is a high demand for fuels with small molecules and so some of the products of cracking are useful as fuels. Alkenes are used to produce polymers and as starting materials for the production of many other chemicals. Small ethene molecules polymerise to produce long-chain molecules of poly(ethene).	more useful by cracking.		Explain the process of cracking. Write balanced symbol equations for the cracking of alkanes. Describe the balanced symbol equation including moles present, long alkane reactant, specific reaction conditions, and alkene and short alkane products. WS 1.2 Balance chemical equations as examples of cracking given the formulae of the reactants and products.	Research uses of common alkenes. Demo or practical: catalytic dehydration of ethanol to form ethene. Demo: making nylon. Demo: addition polymerisation of phenylethene.	Cracking and Why It Is Done RSC experiment – Addition polymerisation Teachit Science resource (19676) 'Tracking cracking'

4.8.2 Resources of materials and energy

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4.8.2.1	Metals react with oxygen to produce metal oxides. The reactions are oxidation reactions because the metals gain oxygen. Reduction involves the loss of oxygen. Unreactive metals such as gold are found in the Earth as the metal itself but most metals are found as compounds that require chemical reactions to extract the metal. Knowledge and understanding are limited to the reduction of oxides using carbon. Metals less reactive than carbon can be extracted from their oxides by reduction with carbon. Knowledge of the details of processes used in the extraction of metals is not required.	Define the terms oxidation and reduction. Explain reduction and oxidation in terms of loss or gain of oxygen, identifying which species are oxidised and which are reduced. Explain, using the position of carbon in the reactivity series, the principles of industrial processes used to extract metals, including extraction of a non-ferrous metal.	1	Write word and balanced symbol equations for the reactions of metals with oxygen to produce metal oxides. Use these to identify where reduction and oxidation has taken place. WS 1.2 Identify the substances which are oxidised or reduced in terms of gain or loss of oxygen. WS 1.4 Explain in terms of the reactivity series why some metals are extracted with carbon and others by electrolysis. WS 1.4 Interpret or evaluate specific metal extraction processes when given appropriate information.	Demo reaction: reacting metals with oxygen. Experiment: reduction of iron oxide by carbon. Experiment: extracting metals with charcoal.	Video clips: BBC Bitesize Alkali metals and their reactions to air and water RSC Reacting metals with oxygen RSC Experiment – reduction of iron oxide by carbon RSC Experiment – extracting metals with charcoal

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4.8.2.2	Metals can be extracted from molten compounds using electrolysis. Electrolysis is used if the metal is too reactive to be extracted by reduction with carbon or if the metal reacts with carbon. Large amounts of energy are used in the extraction process to melt the compounds and to produce the electrical current. Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolit using positive electrodes (anode) made of carbon. The anodes have to be replaced from time to time.	Explain why and how electrolysis is used to extract some metals from their ores.	1	Recall the reactivity series. Give reasons why some metals have to be extracted by electrolysis. Write balanced equations for the reactions that occur at both electrodes. Draw a cartoon strip to describe how aluminium is extracted from its ore, including what happens at the anode and cathode. Students can produce a paper model of the process using cut out electrodes and electrons. Students produce an entry in the diary of Humphrey Davy or Robert Bunsen describing how they produced pure metals using electrolysis. WS 1.4 Explain technological applications of science.	Students can extract zinc from zinc iodide using electrolysis. Class demonstration or demo: reaction of zinc with iodine Research how aluminium is extracted from its ore. Ask pupils to suggest how they would test Faraday's first law of electrolysis. What measurements would they take?	Nuffield Foundation – Reaction of zinc with iodine Science aid.co.uk – Extraction of Aluminium Bitesize – Aluminium extraction Bitesize – Iron and aluminium

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4.8.2.3	(HT only) The Earth's resources of metal ores are limited. Copper ores are becoming scarce and new ways of extracting copper from low-grade ores include phytomining and bioleaching. These methods avoid traditional mining methods of digging, moving and disposing of large amounts of rock. Phytomining uses plants to absorb metal compounds. The plants are harvested and then burned to produce ash that contains the metal compounds. Bioleaching uses bacteria to produce leachate solutions that contain metal compounds. The metal compounds can be processed to obtain the metal. For example, copper can be obtained from	Evaluate alternative biological methods of metal extraction (bacterial and phytoextraction).	1	Extended writing: describe the processes of • phytomining • bioleaching. Evaluate the impacts and benefits of biological methods of extracting metal. WS 1.4 Evaluate environmental implications of the applications of science.	Research information for the processes of: • phytomining • bioleaching. Include percentage of metal extracted, concentration of global warming gases released, amount of electricity used etc. Use this data in an evaluation. It may be possible to model phytomining in the laboratory by watering geraniums with dilute copper sulphate for a period of time. The leaves can be burnt and copper can be extracted from the ash by rinsing in dilute hydrochloric acid and electrolysing the solution.	BBC Bitesize – extyracting metals and making alloys BBC article 'Biomining: How microbes help to mine copper Video clip YouTube: Phytomining and Bioleaching

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	solutions of copper compounds by displacement using scrap iron or by electrolysis.					
4.8.2.4	Non-renewable resources of energy include: • coal • crude oil • natural gas • nuclear fuel A renewable energy resource is one that is being (or can be) replenished as it is used. Example of renewable energy resources include: • plants that provide biofuel • wind turbines • hydroelectricity • tidal barrages or undersea turbines • solar panels that produce electricity or heat water.	Describe the main energy resources available for use on Earth (including fossil fuels, nuclear fuel, biofuel, wind, hydroelectricity, the tides and the Sun). Compare the ways in which energy resources are used. Distinguish between renewable and non-renewable resources.	1	Define renewable energy resource and give examples. Define non-renewable energy resource and give examples. Explain the advantages and disadvantages of each type of energy resource with respect to other sources, eg the advantages and disadvantages of coal over nuclear power. Role-play a meeting between a group of local councillors/MPs, local environmental groups and electricity companies trying to get a new power station built. Which type of power station would each group want? How persuasive are each group in getting their choice?	Investigations into output of a model wind turbine or solar cell. Research the different types of energy resources that are available to generate electricity. For each type of energy resource find the environmental impacts. Explain why each type of energy resource is used to generate electricity even though it does have these environmental impacts.	S-cool, the revision website – Non-renewable Energy Sources Cyberphysics – Energy Resources The Energy Story – Chapter 20: Hydrogen and Future Energy Sources Pass My Exams – Electricity Generation Video clip YouTube: Energy Resources

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				Evaluate the use of different energy resources for a given situation, eg generating electricity in remote locations. The evaluation should include ethical and environmental issues. Compare the use of different fuels in the generation of electricity, heating homes and transport. Determine the most suitable fuel for a particular use depending on the characteristics of the fuel. Identify the political, social, ethical and economic considerations of choosing fossil fuels or nuclear fuels to generate electricity. For a given location determine the best way of generating electricity. WS 1.4 Explain technological applications of science.		

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				WS 1.4 Explain patterns and trends in given data about the use of energy resources. WS 1.4 Evaluate the use of different energy resources. WS 4.4, MS 1c, 2c, 4a Interpret data with energy quantities given, using the prefixes kilo, mega, giga and tera.		
4.8.2.5	Energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed. Whenever there are energy transfers in a system only part of the energy is usefully transferred. The rest of the energy is dissipated so that it is stored in less useful ways. This energy is often described as being 'wasted'.	Describe with examples where there are energy transfers in a system, where there is no net change to the total energy of a closed system (qualitative only). Describe, with examples, how in all system changes, energy is dissipated so	1	Ask students to explore questions such as: • Can energy be created or destroyed? • What happens to energy that is lost? • How can we reduce the amount of energy being wasted by a machine? • What is the best way to reduce heat loss in the home?		Video clips - YouTube: GCSE BBC Bitesize Revision Physics 5 Energy Transfer 2 Teachit Science resource (23331) 'Energy transfers' Teachit Science resource (23332) 'Energy transfers – peer assessment'

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		that it is stored in less useful ways.		Presenting and writing descriptions and explanations: • Describe what happens to the electrical energy that goes into an appliance, such as a radio – in terms of energy stores and how the amount of energy in each store changes. MS 1a, 1c, 3c Make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system.		
4.8.2.6	Unwanted energy transfers can be reduced in a number of ways, for example through:	Explain ways of reducing unwanted energy transfer, eg through lubrication and thermal insulation.	1	Presenting and writing arguments: • Evaluate the use of various types of insulation in the home. Look in particular at	Investigate ways of reducing the energy loss in a rollercoaster – so that a marble dropped down a U-shaped track	YouTube: How to insulate Your Home: Types of Loft Insulation

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	• lubrication – work done against the frictional forces acting on an object causes a rise in the temperature of the object and dissipates useful energy. • the use of thermal insulation – the higher the thermal conductivity of a material the higher the rate of energy transfer by conduction across the material.	Describe the effects, on the rate of cooling of a building, of the thickness and thermal conductivity of its walls (qualitative only).		the effectiveness of loft insulation, double glazing and cavity wall insulation. The evaluation could be based on cost, U-value, thermal conductivity, payback time or lifetime of the insulation fitted. Communication for audience and purpose: • Design a poster to illustrate the reasons why insulating the home is beneficial for both the homeowner and the environment. Select specific examples and suggest what could happen if insulation was not used in the home. WS 1.4 Explain technological applications of science.	will roll higher up the opposite side of the track. Working critically with primary and secondary evidence: • What is the best type of insulation to use in the home? Plan and carry out an investigation to find out which type of insulation will reduce heat loss the most. Investigate how the thickness of the insulating material used affects heat loss. Obtaining and presenting primary evidence: Design a building that will have very low heating bills. This can be a 2D or 3D model – it is possible using a	Episodes of 'Grand Designs' may get students thinking about the design of buildings and insulation. Good examples include: • YouTube: Grand Designs – S9E09 The Cambridgeshire Eco Home Cambridgeshire Revisited • YouTube: Grand Designs Australia – S04E06 Forest Lodge Eco [Full Episode] Energy changes that take place in a rollercoaster: BBC Bitesize – Gravitational potential energy Pass My Exams – Conservation of

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					beaker of hot water and a thermometer to find out how effective the insulation is in a 3D model that has been built.	Energy & Energy Transfer
4.8.2.7	The energy efficiency for any energy transfer can be calculated using the equation: efficiency = useful output energy transfer ÷ total input energy transfer	Calculate energy efficiency for any energy transfer. (HT only) Describe ways to increase efficiency.	1	Ask students to explore questions such as: • Which type of power station is the most efficient? • Which type of light bulb would cost the least amount of money to use? Prepare a presentation on different types of light bulb. Find out the cost of buying and running the light bulbs in a home for one year. Determine whether energy saving light bulbs will save money over incandescent light bulbs. State the equation used to find efficiency. MS 3c	Research different types of power station to find out if combustion-based power stations are less efficient that either nuclear or wind. Investigate ways of increasing the efficiency of a coal-fired power station. Calculate the efficiency of a machine as either a decimal or a percentage. Rearrange the equation to determine the total energy put into the machine or the useful energy output. Students may have to analyse data to	Energy efficiency calculations: BBC Bitesize – Efficiency Efficiency of power stations video clip: YouTube: Which Power Source Is most Efficient? Pass My Exams – Energy Transfer Diagrams and Efficiency Cyberphysics – Sankey diagrams Teachit Science resource (23330) 'Energy efficiency'

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				Recall and apply this equation. MS 1a, 1c, 3c Calculate or use efficiency values as a decimal or as a percentage.	determine the useful energy output if they are told the energy input and the amount of wasted energy. Interpret data on efficiencies of different machines.	
4.8.2.8	Life cycle assessments (LCAs) are carried out to assess the environmental impact of the materials used and the energy resources needed for products in each of these stages: • extracting and processing raw materials • manufacturing and packaging • use and operation during its lifetime • disposal at the end of its useful life including transport and distribution at each stage.	Describe the basic principles in carrying out a life cycle assessment of a material or product. Interpret data from a life cycle assessment of a material or product.	1	Describe what a LCA is using a suitable example. Use information to interpret the LCA of a given material or product. Discuss the negative issues relating to LCAs and why caution should be used when using them. WS 1.3, 1.4, MS 1a, 1c, 1d, 2a, 4a Interpret data from LCAs of materials or products given appropriate information.	Use the internet to carry out simple comparative LCAs for shopping bags made from plastic and paper.	BBC Bitesize – making life cycle assessments TED talk video 'Paper beats plastic? How to rethink environmental folklore' Practical action resource 'Lifecycle analysis PowerPoint'

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	Energy, water, resource consumption and production of some wastes can be fairly easily quantified. Allocating numerical values to pollutant effects is less straightforward and requires value judgements, so LCA is not a purely objective process. Selective or abbreviated LCAs can be devised to evaluate a product but these can be misused to reach pre-determined conclusions, eg in support of claims for advertising purposes.					
4.8.2.9	The reduction in use, reuse and recycling of materials by end users reduces the use of limited material resources. It can also cut the use of energy resources and the production of waste. Metals can be recycled by melting and recasting or reforming into different products. The amount of	Describe a process where a material or product is recycled for a different use, and explain why this is viable.	1	Discuss the issues relating to using limited resources to generate energy. Extended writing: describe the environmental impacts of obtaining raw materials from the Earth. WS 1.4 Evaluate factors that affect decisions on recycling.	Research methods of producing/obtaining metal/glass/building materials/clay ceramics/plastics. Identify in these methods the limited resources that are used to generate the energy.	Video clip - YouTube: Recycling Plastics

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	separation required for recycling depends on the metal and the properties required of the final product. For example, in steel making some scrap steel is added to the iron from a blast furnace to reduce the amount of iron that needs to be extracted from iron ore.				Research how glass is recycled. Research how metal is recycled and alternatives for use of scrap metals (eg in obtaining iron in a blast furnace).	