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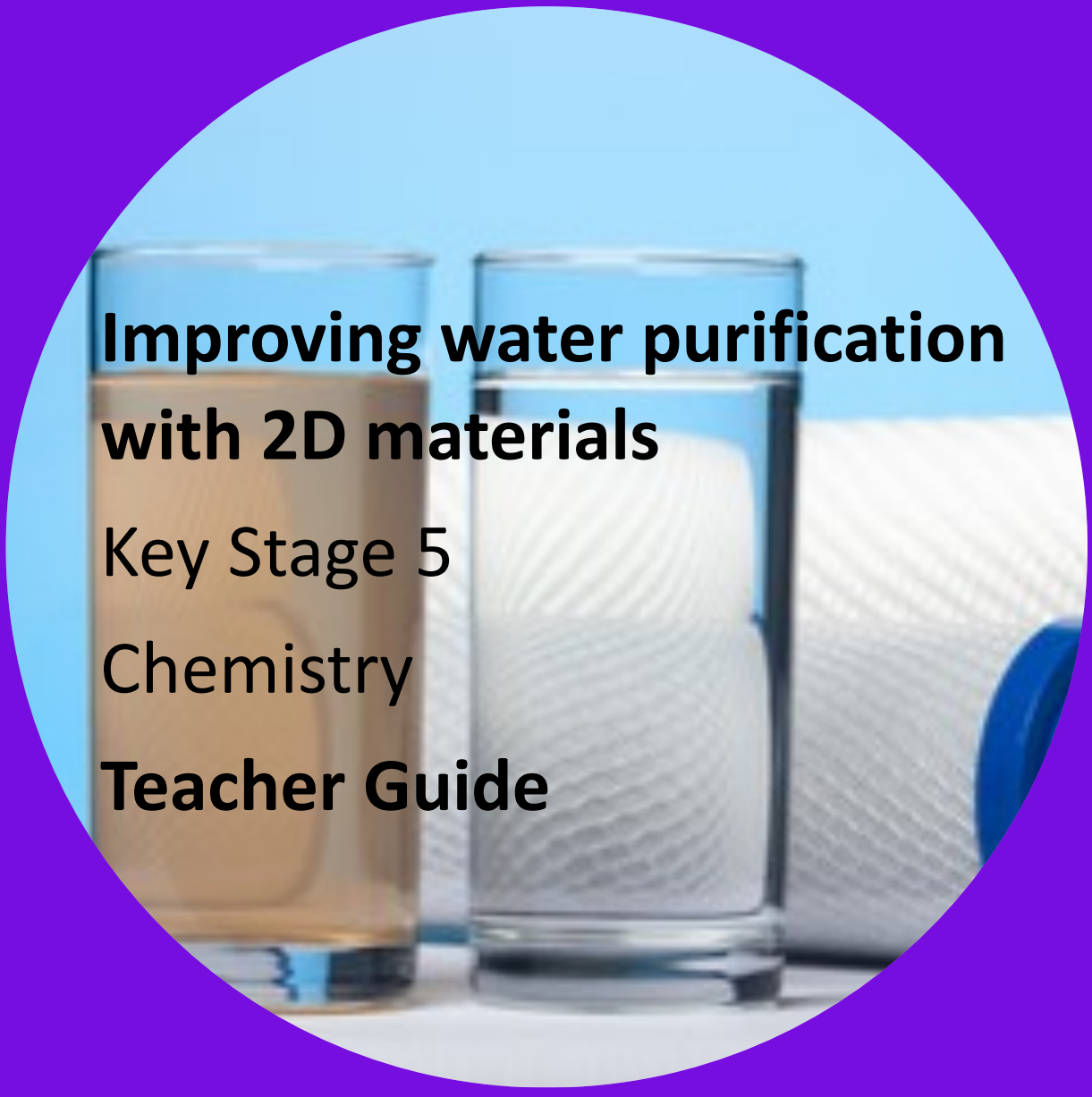

Improving water purification with 2D materials

Key Stage 5

Chemistry

Teacher Guide

2021

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Resource One
Model Answers

Answers

1. List the different types of post-synthetic modification.

There are 3 types of PSM:

- Ligand exchange
- Metal exchange
- Functional group conversion

2. Which group on the periodic table is most commonly used in **metal-organic frameworks**? And what is their typical coordination number?

Transition metals are typically used in MOFs. They commonly have a coordination of 6.

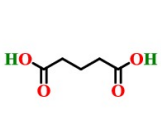
(between 2-9 is an acceptable answer also)

3. Explain how a **coordination bond** works.

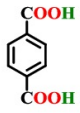
In a coordination bond a ligand formally donates a lone pair of electrons to a metal cation

4. Draw a ligand that could be used to make a MOF.

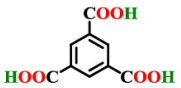
Any molecule with 2 or more carboxylic acid or amine groups are present is acceptable. E.g.



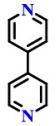
Glutaric Acid



BDC

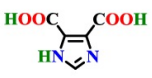


BTC



4,4' BPy

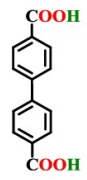
Imidazole



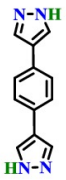
H_3 Imdc

Pyrazine

Triazole



BPDC



BPB

Resource One
Model Answers

Answers

5. Choose one MOF application and research why MOFs are good for that application.

Answers should aim to include but are not limited to:

- Detail about the application
- Explanation of why MOFs suit that application
- An example of a MOF used in this application, e.g., UiO, MIL, ZIF, HKUST etc.
- An image or diagram of the MOF being used in this application
- Additional detail that was not discussed in the resource

Resource Two Model Answers

Answers

1. List 2 types of **top-down** synthesis and 2 types of **bottom-up** synthesis methods (see the diagram on page 24)

Answers should include:

2 top-down methods

- Micromechanical (sticky-tape method)
- Grinding
- Ultrasound (sonication)
- Freeze-thaw
- Intercalation

AND 2 bottom-up methods

- Surfactant-assisted
- Crystal growth modifiers
- Interfacial (layering)
- Ultrasonic spraying
- Surface assembly

2. List the pros and cons of **top-down** and **bottom-up** methods

Students should take their answers from both the text and this table:

	Top-Down	Bottom-Up
Pros	High crystallinity, high purity	Single step synthesis, high yield
Cons	Multi-step synthesis, low yield	Low crystallinity, low purity

Resource Two
Model Answers

Answers

3. Explain why 2D MONs are better than 3D MOFs for catalysis applications

2D MONs all of the active sites are exposed on the surface of the material. In 3D MOF lots of these active sites are trapped within the MOF. So, in MONs, more molecules can reach the active sites and bind, meaning there is more catalytic affect. Also, the high surface-to-volume ratio means a smaller amount of MONs needs to be used to get the same effect.

4. Explain what happens in **top-down** and **bottom-up** synthesis methods

In top-down synthesis, a layered 3D material is synthesised, then subject to an energetic process (see above list) which peels apart the material into free-standing nanosheets. In bottom-up synthesis, a range of techniques (see list in answer 1)are used to force the reagents in a synthesis to form free-standing nanosheets with no additional steps.

5. There are lots of other single element **2D materials** than graphene, research one other single element **2D material** and present your findings to your peers

There are lots of other single element 2D materials than graphene, research one other single element 2D material. Answers should include but are not limited to:

- A chosen single element 2D material
- Its structure/electronic configuration
- Properties of the material
- Applications is it used for

Resource Three Model Answers

Answers

1. What is the resolution on a scanning electron microscope (SEM)?

SEM has a resolution of 10 nm

2. What type of sample do SCXRD and PXRD measurements require?

SCXRD and PXRD require crystalline solid samples

3. ^{1}H is the most common type of nuclei used in **NMR spectroscopy**. Name 5 other commonly used nuclei in **NMR**

Any 5 of the following answers (answers must use the superscript notation to be correct):

^{2}H, ^{3}He, ^{11}B, ^{13}C, ^{14}N, ^{15}N, ^{17}O, ^{19}F, ^{31}P, ^{35}Cl, ^{37}Cl, ^{43}Ca, ^{195}Pt

4. What type of sample can be used in **IR spectroscopy**?

Solid, liquid and gas samples can be used in IR spectrometers.

5. Explain how an atomic force microscopy (AFM) works

Answers must include all the following points:

- A small (atomic sized) *tip taps over a surface*
- A *laser reflects off the tip* into a detector
- The *changes in the reflection are detected* as the cantilever passes over the surface
- This creates an image

6. What are the range of wavelengths for infrared and X-ray radiations? Research this independently.

IR wavelength: 780 nm – 1mm

X-ray wavelength: 0.1 nm – 1 pm (10^{-8} – 10^{-12} m)

(must include units)

Resource Four
Model Answers

Answers

1. Define a **polymer**

A polymer is a material made up of large molecules composed of repeating building blocks.

2. Which type of bonding is present in **polymers**?

Covalent bonding is present in polymers

3. Explain why **polymers** are often selected over traditional materials such as wood.

Polymers are selected over traditional materials because of their relative low cost, low energy manufacture and easy processibility.

4. Explain the difference between a homopolymer and a copolymer

Homopolymers are made from a single type of monomer whereas a copolymers I made from two or more monomers

5. Choose one of the seven common polymer examples and research them in further depth – present your findings to your peers. Answers should include but are not limited to:

- The chemical name and the common name (where relevant)
- The chemical structure – written and drawn
- The monomers used
- Properties – beyond those listed in the table
- Applications and explanation as to why this polymer is used for those applications

Resource Five
Model Answers

Answers

1. What are the synthetic **membrane** subcategories?

Organic (polymer), inorganic and composite.

2. List 3 types of **mixed matrix membrane**

Conventional nanocomposite, thin film nanocomposite and surface located nanocomposite.

3. What is the trade off that limit's **membrane** performance?

Flux vs selectivity – how fast the water flows and how well it rejects contaminants.

4. Explain why composites offer “the best of both worlds”

Composites combine the flexibility and ease of processing of polymers and the stability and tunability of inorganic materials.

5. Explain the benefits MONs have over other inorganic fillers in **MMMs**

MONs have organic parts as well as inorganic, this gives them better compatibility with the polymer matrix than other inorganics. MONs are also 2D, allowing for a thinner membrane with higher flux. Lastly, MONs are more tunable than other inorganics, giving better control over the selectivity.

Resource Six
Model Answers

Answers

1. How many people worldwide do not have access to an uncontaminated water source?

2 billion people around the world do not have regular access to uncontaminated water sources

2. What are the two ways to remove pollutants from water?

Pollutants can be removed from water by absorption and filtration

3. List 2 things we would want to filter from water

2 of the following; salt, pharmaceutical molecules, organic dye molecules, antibiotics, oils and microplastics (other sensible answers should be accepted)

4. Explain how absorption works in terms of water purification

Absorption uses compounds with either active sites or pore spaces. An active site is a group within a compound that the pollutants can attach to. This is either through physical bonds and forces, such as hydrogen bonding and intermolecular forces, or chemical bonds like covalent bonds. When compounds have pore spaces, this means there are voids within the compound that particles can get trapped in.

5. Explain how the size exclusion effect works in terms of water purification

Filtration works by a principle called size exclusion. This is where the holes or pores in the membrane are small enough to exclude the pollutant but large enough to allow water to flow through. Because size exclusion only prevents the pollutant molecules from passing through based on their size, there are no active sites to get used up like in absorption.

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