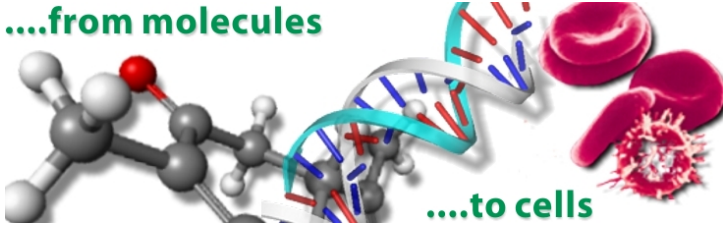
MACQUARIE University

Welcome to Chemistry HSC Enrichment 2018

Hosted by Department of Molecular Sciences



Program

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9.10 am – 11.20 am - The Production of Materials
Ethene, polymers and ethanol
Electrochemistry

11.45 am – 1.15 pm The Acidic Environment

2.00 pm – 4.10 pm Chemical Monitoring and Management
Monitoring and Management in the Chemical Industry
Chemistry and the Atmosphere and Monitoring Water Quality

4.30 pm – 5.30 pm Top Marks Education Study Skills Workshop

For all lecture notes and recordings see https://goto.mq/chemhsc2018

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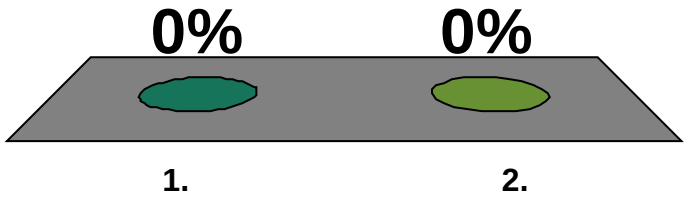
Production of Materials
Ethene, Polymers and Ethanol

I like chemistry a lot

1. True
2. False



60

Representing Ethene (Ethylene)

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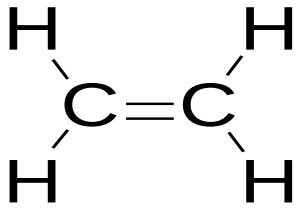
See HSC Booklet – first topic



$H_2C{=}CH_2$

CH_2CH_2

C_2H_4

Alkenes as Valuable Building Blocks

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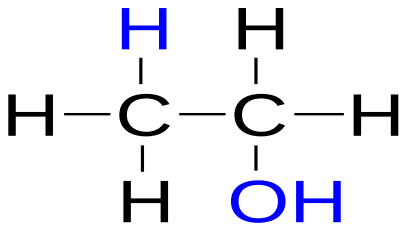
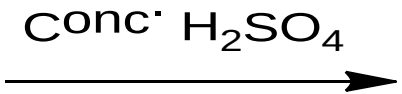
- Ethene and other alkenes are essential building blocks for making important compounds
  - *Solvents (eg ethanol)*
  - *Polymers (eg polyethylene, polystyrene, polyvinyl chloride)*

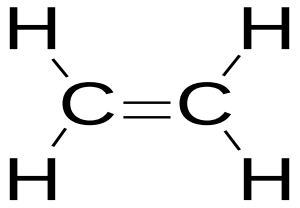
  But does not occur naturally in great amounts

Synthesis of Ethene from Ethanol



Ethanol





Ethene

+

H_2O

This reaction involves a loss of water (H_2O)

= Dehydration Reaction

Industrial Synthesis of Ethene

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- Industrially, ethene (and other alkenes) produced from fractions obtained by the distillation of crude oil/petroleum
- The various fractions contain long-chained alkanes and alkenes
- Broken down into small molecules, including alkenes such as ethene, in a process known as ‘cracking’
- Thermal cracking and catalytic cracking (occurs at lower temperatures using zeolites - aluminosilicates)
- *Catalytic cracking often examined e.g. see 2008 Q16, 2012 Q26, 2013 Q8, 2014 Q4*

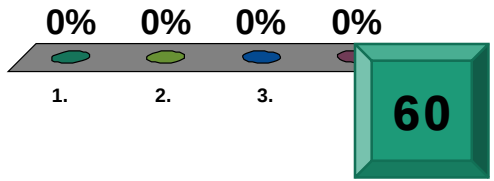
Which equation best represents catalytic cracking of a petroleum fraction?

1. $C_{16}H_{34}(l) \xrightarrow{\text{zeolite}} C_{16}H_{34}(s)$

2. $n C_2H_4(g) \longrightarrow \left(CH_2 - CH_2 \right)_n (s)$

3. $C_{16}H_{34}(l) \xrightarrow{\text{zeolite}} C_7H_{16}(s) + 3C_2H_4(g) + C_3H_6(g)$

4. $C_7H_{16}(s) + 3C_2H_4(g) + C_3H_6(g) \xrightarrow{\text{zeolite}} C_{16}H_{34}(l)$



Major Reaction Type of Alkenes

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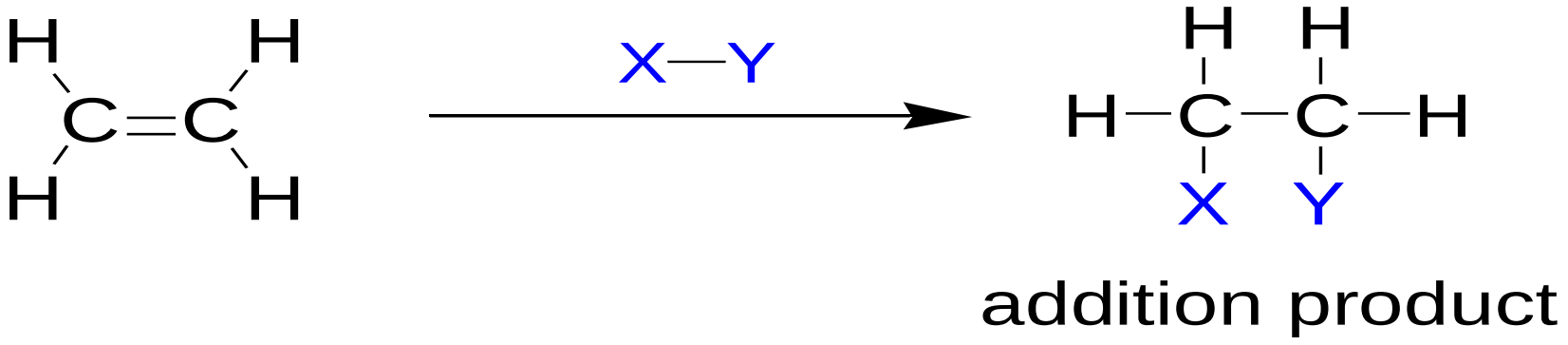
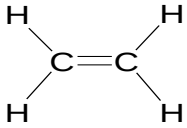
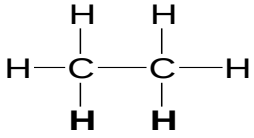
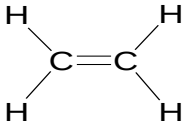
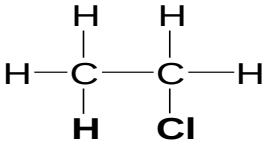
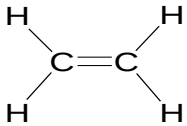
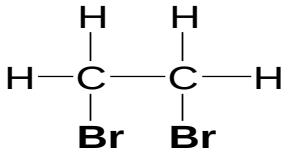
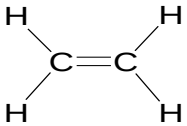
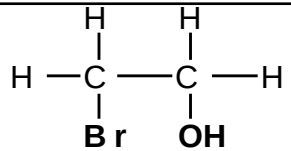
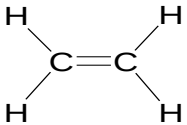
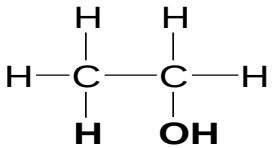
Addition reaction:

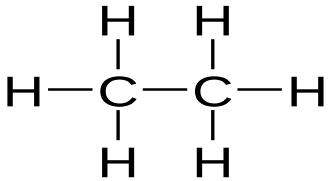


addition product

Representative Alkene	X-Y	Addition Product	Reaction Type
	H–H (with catalyst) (H_2)		Hydrogenation
	H–Cl (HCl)		Hydrogen halide addition
	Br–Br (Br_2)		Halogenation
	Br–Br (Br_2) in H_2O		Halohydrin formation
	H–OH (H_2O) (with H_2SO_4 catalyst)		Hydration

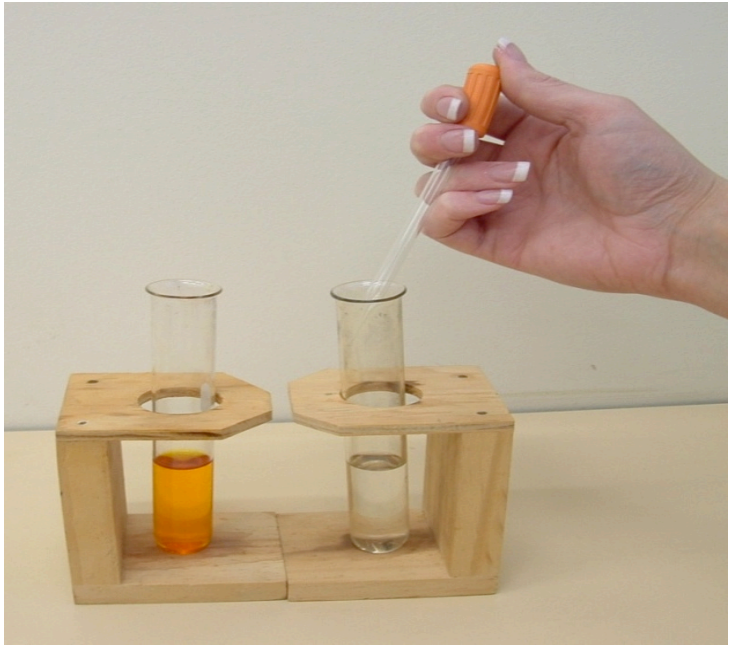
Reactions of Alkenes

- **Alkanes** (*e.g.* H_3CCH_3 ethane), due to the lack of the double bond, DO NOT undergo addition reactions



- This allows alkenes and alkanes to be readily distinguished from each other
- For example, if an alkene is present, addition of an orange-red solution of Br_2 in a solvent leads to almost instantaneous decolourisation of the Br_2

Reactions of Alkenes



- *Addition Br_2 to an unsaturated compound or distinguishing between alkanes and alkenes examined almost every year, e.g. 2005 Q16; 2008 Q16; 2009 Q6; 2010 Q11, Q24; 2011 Q11; 2013 Q8; 2016 Q15, 2017 Q7*

Exam 2016 Q15: Identify compounds W, X, Y and Z from the following.

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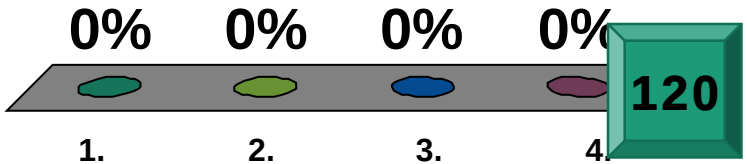
Compound W rapidly decolourises bromine water and is insoluble in water. Compound X is unreactive to bromine water and is insoluble in water. Compound Y is unreactive to bromine water and is soluble in water. Compound Z is unreactive to bromine water and is partially soluble in water.

1. W: C_3H_6 X: C_3H_8 Y: CH_3OH Z: C_4H_9OH
2. W: C_3H_8 X: C_3H_6 Y: CH_3OH Z: C_4H_9OH
3. W: C_3H_6 X: C_3H_8 Y: C_4H_9OH Z: CH_3OH
4. W: C_3H_8 X: C_3H_6 Y: C_4H_9OH Z: CH_3OH



Reactions of Alkenes

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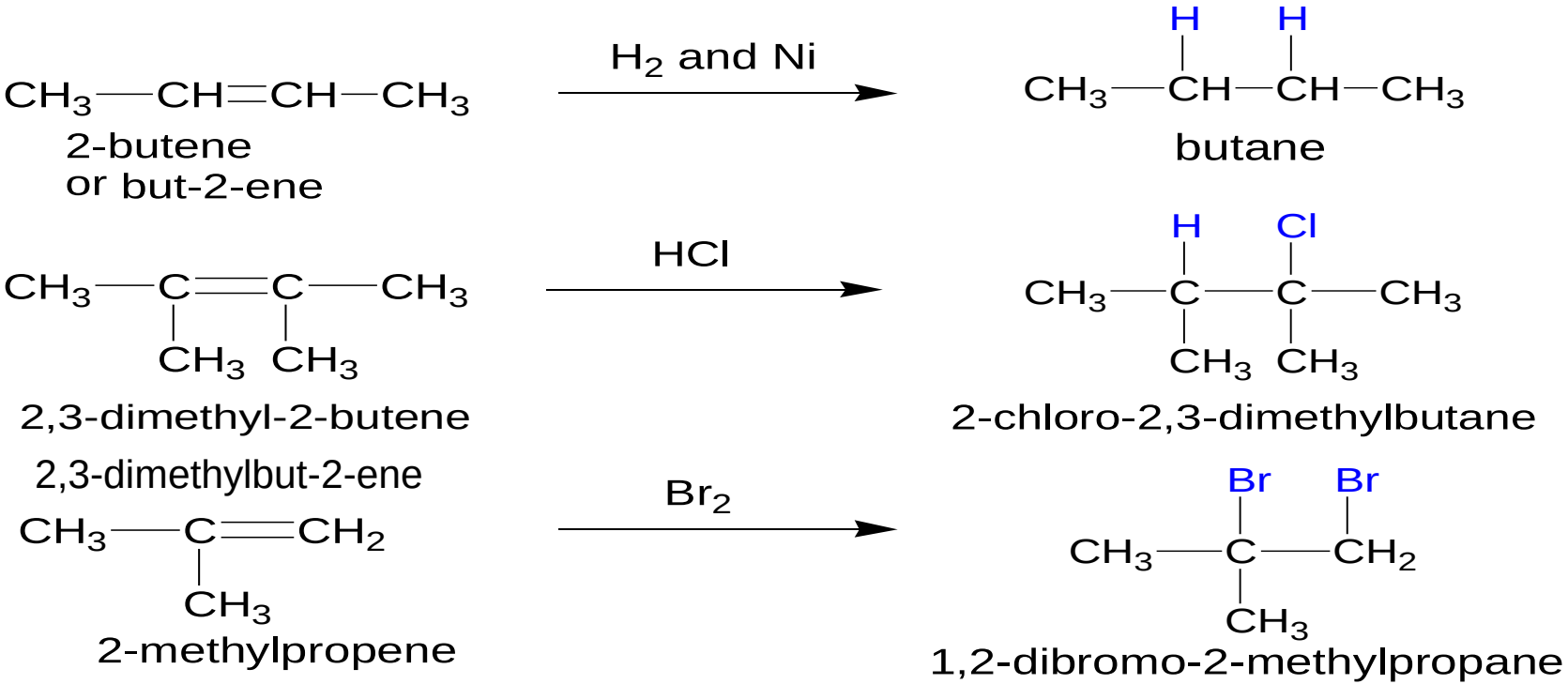
- ***You should be able to write balanced equations for addition reactions, name the starting materials and products and be able to recognise the starting material, reagents used or product when given the other compounds***

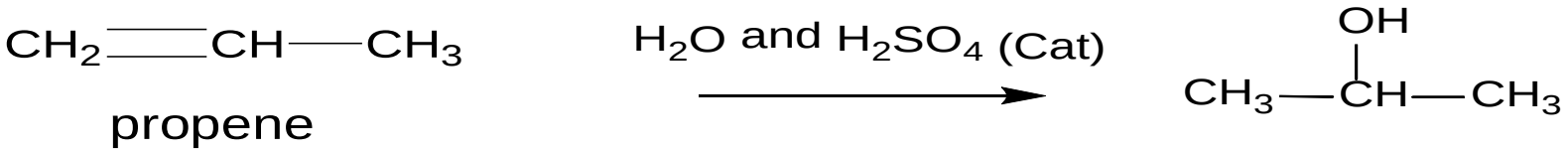
Reaction of Alkenes Questions 2nd page

With a partner name the starting alkene, then draw the expected product from treatment of the alkene with the reagent indicated



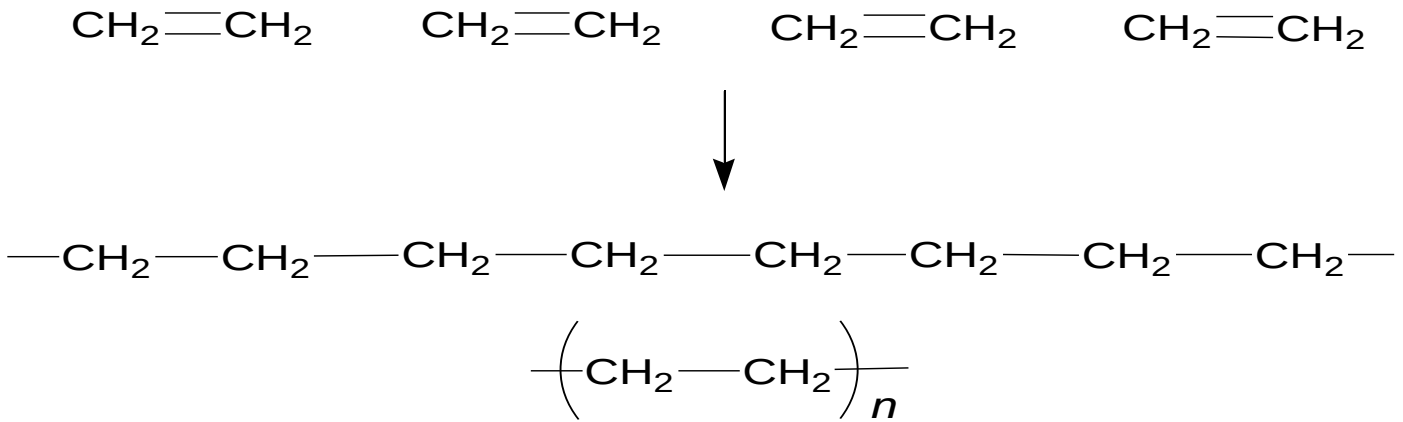
Reaction of Alkenes Questions

With a partner draw and name the starting alkene

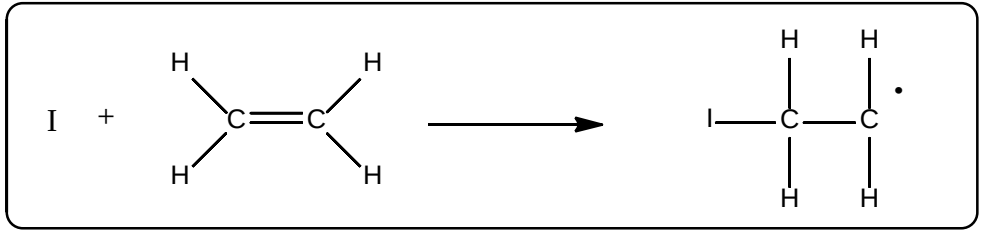


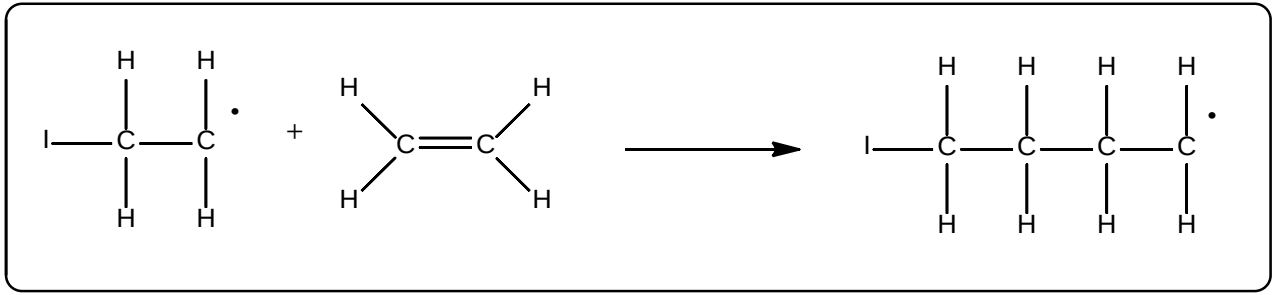
Addition Polymers

- Small building-blocks (monomers) ***add*** together to form a ***polymer***, with no atoms lost
- When ethene molecules combine together in addition polymerisation, polyethylene is formed



Addition Polymers





Starting Monomers of Common Addition Polymers and their uses

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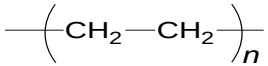
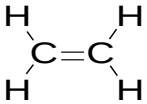
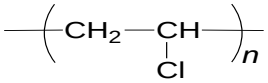
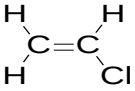
Polymer	Polymer Structure	Monomer (Building Block)	Examples of Use
Polyethylene (LDPE and HDPE)		 ethene	LDPE: wrapping materials, carry bags, lining milk cartons, squeeze bottles, electrical insulation HDPE: bowls, kitchen utensils, buckets, milk crates, freezer bags
Polyvinyl chloride (Polychloroethene)		 vinyl chloride	Electrical insulation, drainage pipes, guttering, garden hoses

More Starting Monomers of Common Addition Polymers and uses

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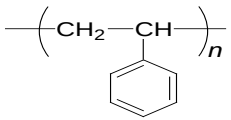
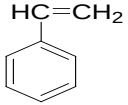
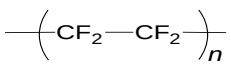
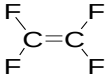
Polymer	Polymer Structure	Monomer (Building Block)	Examples of Use
Polystyrene (Polyethenylbenzene)		 styrene (ethenylbenzene)	Foam (drink cups, and packaging), tool handles, containers, insulation
Polytetrafluoroethylene PTFE, or Teflon (Polytetrafluoroethene)		 tetrafluoroethylene (tetrafluoroethene)	Non-stick cookware surfaces, electrical insulation, pipe thread sealant

Man skating on Teflon

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Teflon Information

http://en.wikipedia.org/wiki/Polytetrafluoroethylene

Addition Polymers Properties

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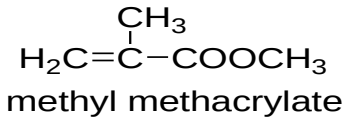
- For a given type of polymer, the **longer** the polymer chain (higher molecular weight), the **higher** the melting point and the **harder** the substance is
- The **less branched** a polymer is, the more ordered the chains are and more crystalline the substance is. This leads to a **more dense**, **higher melting point**, **tough** and **hard** substance
- The **bigger** the side group, the **less flexible** the substance is, *e.g.* polystyrene (benzene, C_6H_5 group) is typically a hard, stiff plastic compared to polyethylene – see demonstration

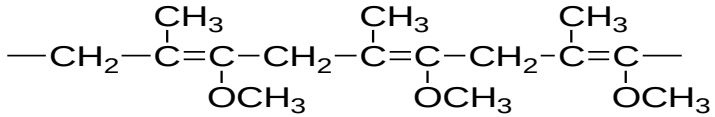
Addition Polymers – Past Exams

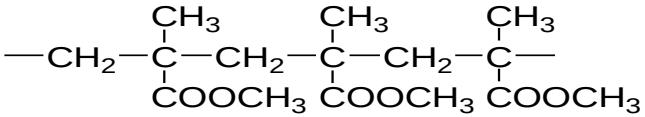
- *How alkenes can be used to make new materials*
- *Identifying the monomer(s) or polymer in a polymerisation reaction (when given one of the two)*
- *Relating the properties exhibited by a polymer(s) to the structure of the polymer(s) and uses of that polymer(s)*
- *In 2011 needed to compare the properties of polystyrene with a biopolymer*
- *In 2012 needed to recognise polymerisation of ethene in the presence of a catalyst shown by using models*
- *In 2013 needed to show how polyetheylene and a biopolymer are formed*
- *In 2015 needed to describe the steps involved in the process of addition polymerisation*
- *In 2016 needed to identify an application of polystyrene and the reason for its suitability for that application and the monomer given the polymer structure*

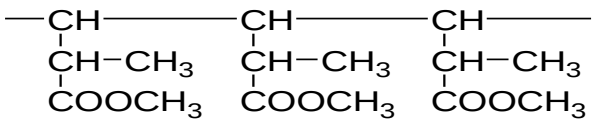
Which polymer is made by polymerisation of methyl methacrylate?

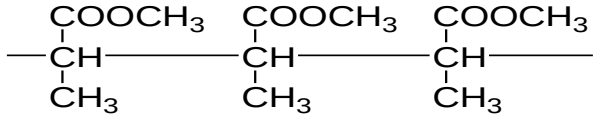


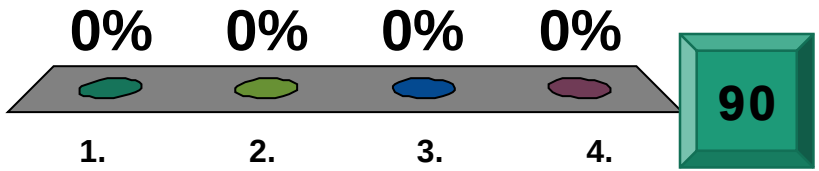
Used to make perspex

1. 

2. 

3. 

4. 



Condensation Polymers

- These are formed when the monomer units react together to **eliminate** (or '**kick-out**', or '**remove**, or '**lose**') a smaller molecule, which is often water

Carothers and colleagues examining the nylon stocking

Reaction of a Carboxylic Acid and an Amine – Formation of an Amide

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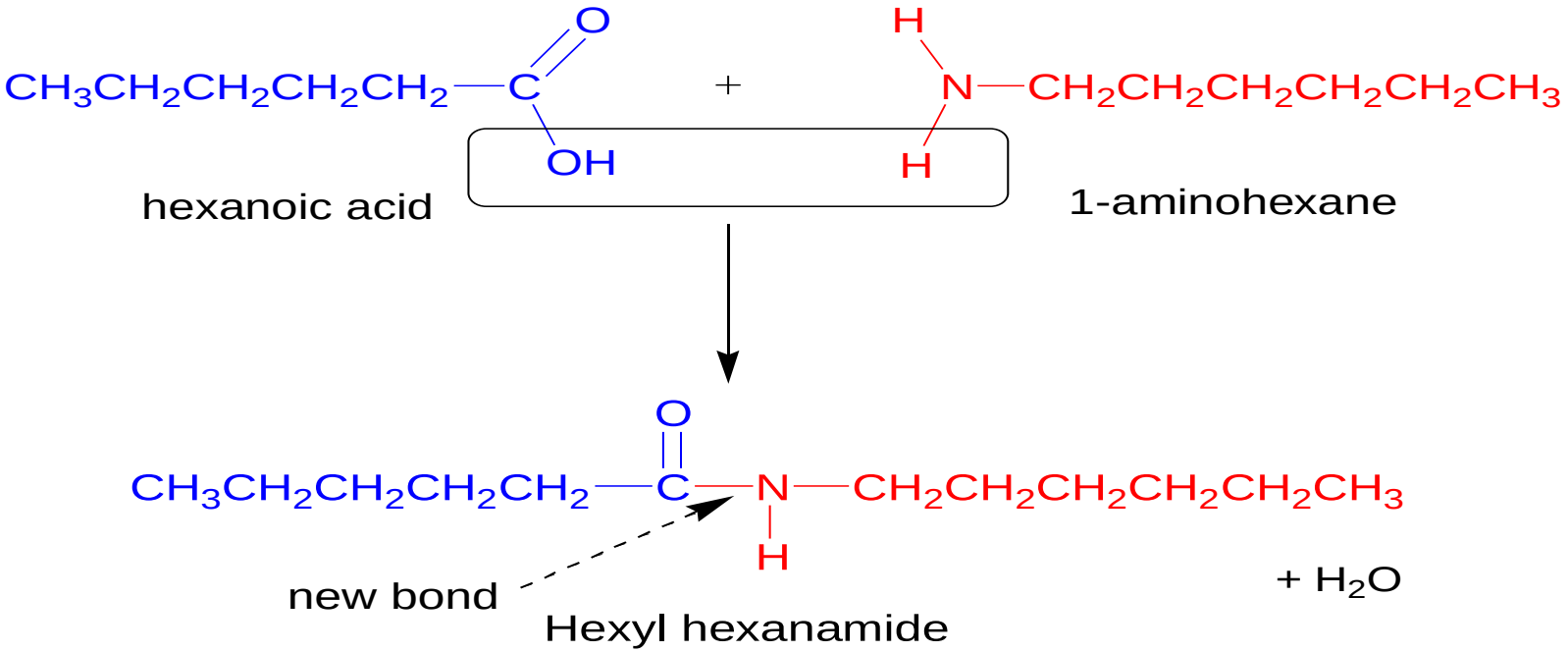
This is an example of a condensation reaction



Reaction of a Carboxylic Acid and an Alcohol – The Formation of an Ester

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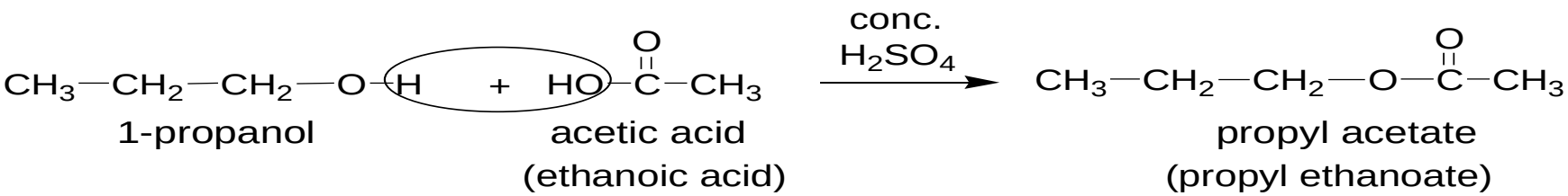
This is also an example of a condensation reaction

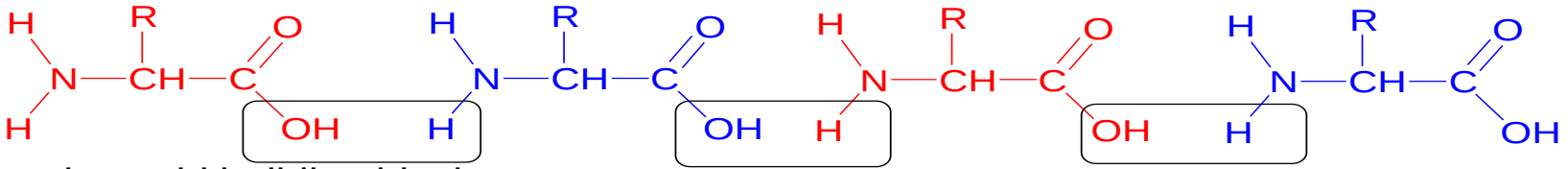


1-propanol

acetic acid
(ethanoic acid)

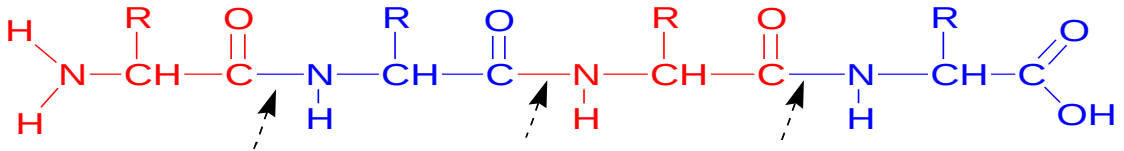
propyl acetate
(propyl ethanoate)

Difunctional Molecules – Condensation of Amino Acids



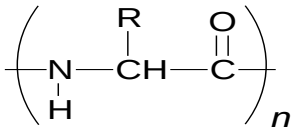
amino acid building blocks

R = an attached group, for example, if R = CH_3, the amino acid is Alanine



+ 3 H_2O

a polypeptide



the repeat unit of a polypeptide

denotes a new bond

Reaction of a Diacid and a Dialcohol - Formation of a Polyester

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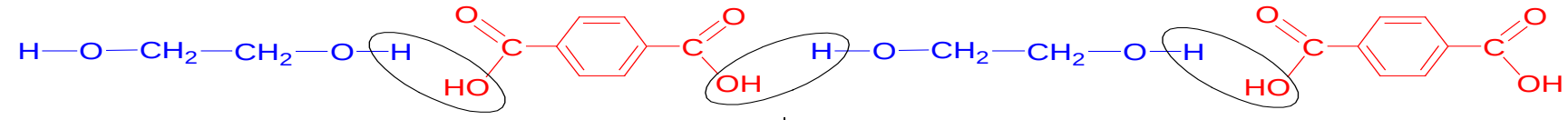
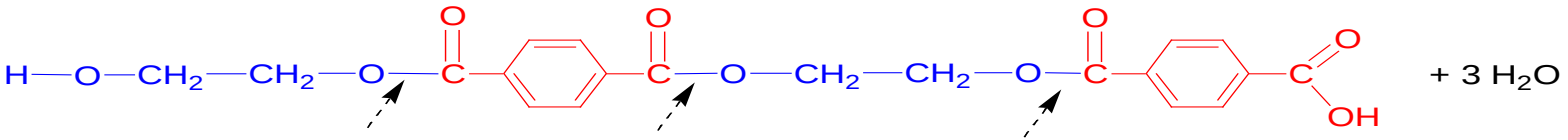
another example of a condensation polymer



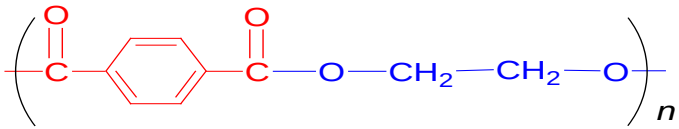
1,2-ethanediol

terephthalic acid



a polyester

denotes a new bond



the repeat unit in polyethylene tetraphthalate, PET

Reaction of a Diacid and a Diamine – Formation of a Polyamide (Nylon 6,6)

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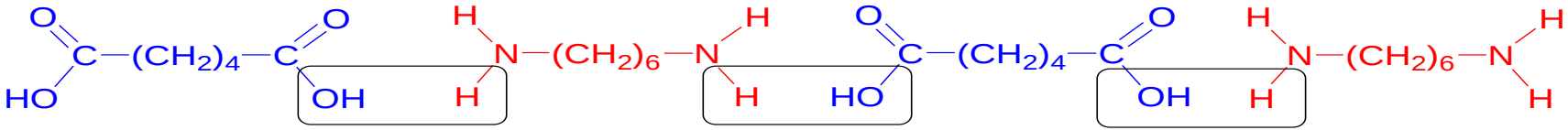
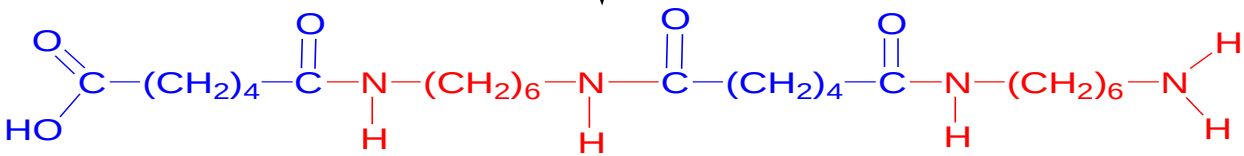
a condensation polymer

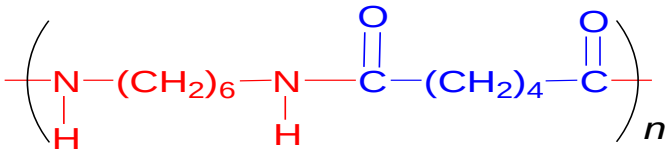


1,6-hexanedioic acid 1,6-diaminohexane



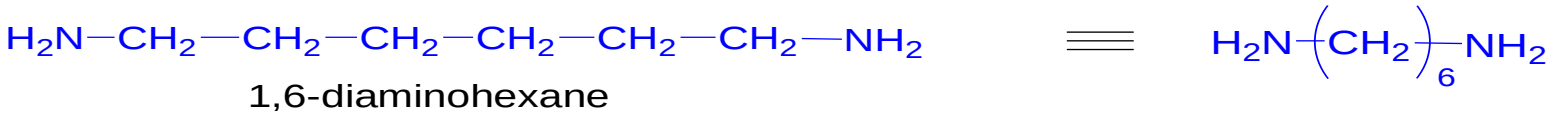
+ 3 H_2O

a polymer



the repeat unit in nylon 6,6

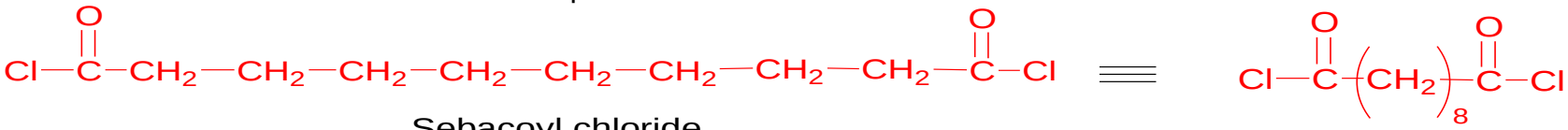
Synthesis of Nylon 6,10 – a Demonstration



1,6-diaminohexane

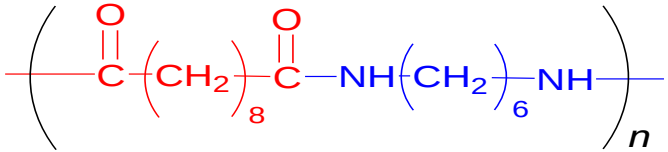
as a 5% (by weight) solution in water, with 1 pellet of sodium hydroxide

+



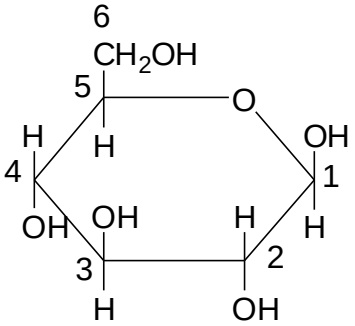
Sebacoyl chloride

as a 5% (by weight) solution in hexane

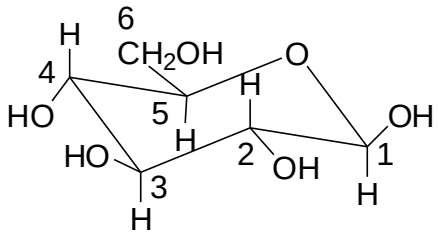


nylon 6,10

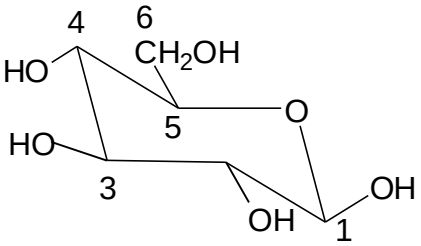
Cellulose – condensation polymer of Glucose



Glucose



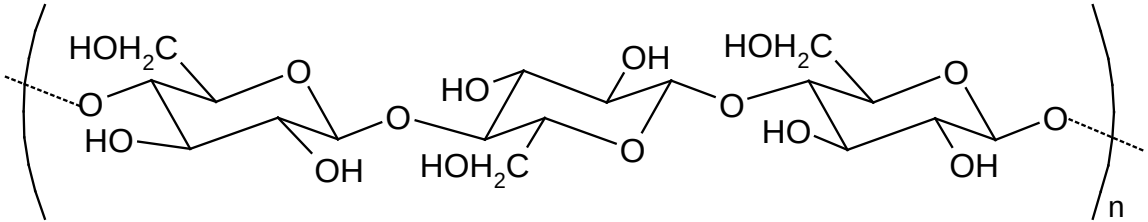
Glucose in its puckered ring (chair) arrangement



Glucose "stripped down" for clarity

Glucose is a β-sugar (beta sugar), which means that C6 and the OH group on C1 are on the same side (face) of the ring.

Cellulose – condensation polymer of Glucose



cellulose

Cellulose - an Important C source

- Cellulose contains basic building blocks for making starting molecules for industry, such as ethene (2 C atoms), propene (3 C atoms) and butene (4 C atoms, a starting point for synthetic rubber)
- Considerable scientific effort looking at cellulose as an alternative source of chemicals now obtained from oil
- Industries producing ethanol from cellulose for use as a biofuel

Condensation Polymers – Past Exams

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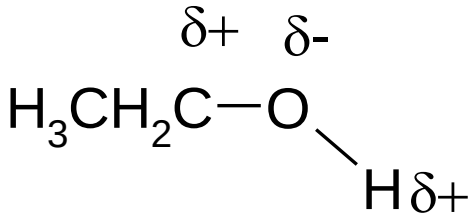
- *Identifying the monomer(s) or polymer in a polymerisation reaction (when given one of the two)*
- *Related to this questions are also often asked about esters, their properties, names and how made*
- *Recognising the structure of cellulose, that it is a condensation polymer formed from loss of water, is a major component of biomass, and is of interest as a source of chemicals we now obtain from oil*
- *Discussing preparation, properties and provide structures of polymers, including cellulose, was a feature of 2010, 2011, 2013 and 2016 exams*
- *2016 exam asked about the need for research into biopolymers (related to environmental friendliness of biopolymers)*
- *2017 exam asked how cellulose can be converted into polyethylene – various concepts*

Ethanol As a Solvent



- Ethanol is a commonly used **solvent**
- It is a polar molecule
- The C-O and O-H bonds are polar due to the O atom being more electronegative than the C and H
- It can hydrogen-bond and undergo dipole-dipole interactions with polar molecules helping them to dissolve (like dissolves like)
- It also has a non-polar portion (CH_3CH_2) which helps it dissolve less polar molecules

Ethanol Production – Fermentation

- Ethene from catalytic cracking is the main industrial source of ethanol
- Fermentation is a process in which glucose (typically) is broken down to ethanol and carbon dioxide by the action of enzymes present in yeast
- A suitable grain or fruit is mashed up with water; yeast is added; air is excluded (anaerobic); and the mixture is kept at about 25 - 37 ^{o}C
- Enzymes in the mixture convert any starch/sucrose to glucose and/or fructose and then glucose/fructose to ethanol and CO_2

$$C_6H_{12}O_6(aq) \rightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$$

Ethanol as Fuel

- Ethanol readily burns through a **combustion/oxidation reaction** to give carbon dioxide, water and energy

$$CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + H_2O(g) + \text{energy}$$

$\Delta H = -1360$ kJ/mol heat of combustion

Ethanol as Fuel

- Ethanol is increasingly being used as a **fuel** due to it being a **renewable resource** – referred to as **biofuel**
- Commonly being produced from starch or sugars from a wide variety of crops, including sugar cane and corn
- Considerable debate due to land required for crops and energy-pollution balance (inc greenhouse gas)
- Methods are being developing to get ethanol from cellulosic waste such as wood, bagasse (waste from sugar production), crop stubble and municipal green waste

Ethanol – Past HSC Exams

- *Production of ethanol from hydration and fermentation, its use as a solvent and comparison to water, combustion reactions of it and other alcohols and fuels, its use as a fuel, including the advantages and disadvantages, and hydrogen-bonding properties are all commonly assessed*
- *2017 exam asked students to outline the steps, with equations for conversion of cellulose to polyethylene*

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For Further Information

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For all lecture notes and recordings see

https://goto.mq/chemhsc2018

THANK YOU AND GOOD LUCK