

## ADVANCED SUBSIDIARY GCE CHEMISTRY B (SALTERS)

Candidates answer on the question paper.

**OCR supplied materials:**

- *Data Sheet for Chemistry B (Salters)* (inserted)
- *Advance Notice: 'Polymers on the move'* (inserted)

**Other materials required:**

- Scientific Calculator

**Duration:** 1 hour 45 minutes




Candidate forename		Candidate surname	
Centre number		Candidate number	

### INSTRUCTIONS TO CANDIDATES

- The insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Answer **all** the questions.
- Do **not** write in the bar codes.

### INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
-  Where you see this icon you will be awarded marks for the quality of written communication in your answer.  
This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- The insert '*Polymers on the move*' is provided for use with question 5.
- A copy of the *Data Sheet for Chemistry B (Salters)* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **100**.

- 1 In 2008, many people in Zimbabwe died because of a cholera epidemic, caused largely by a lack of water treatment.

(a) It is possible to stop the spread of diseases like cholera by treating water with chlorine. The chlorine forms chloric(I) acid,  $\text{HClO}$ , and hydrochloric acid,  $\text{HCl}$ , when it reacts with the water.

(i) Write the equation for this **reversible** reaction of chlorine with water.

[2]

(ii) Explain what is meant by the (I) in the name of chloric(I) acid.

..... [1]

(iii) Explain why adding chlorine to drinking water can stop the spread of cholera.

.....  
..... [1]

(b) Chloric(I) acid,  $\text{HClO}$ , can be produced by adding solid calcium chlorate(I), which is a salt of chloric(I) acid, to water.  $\text{HClO}$  can also be formed by adding the gas chlorine dioxide,  $\text{ClO}_2$ , to water.

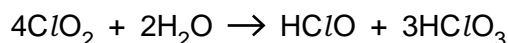
(i) Give the formula of calcium chlorate(I).

..... [1]

(ii) Chlorine dioxide reacts with water in a disproportionation reaction.

A disproportionation reaction is one in which an element is both oxidised and reduced during the reaction.

Explain why the reaction below is an example of a disproportionation reaction. Give details of the oxidation states involved.



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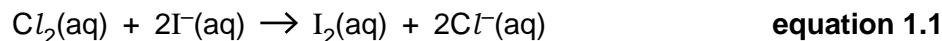
- (iii) Suggest **two** reasons why it may be preferable to use calcium chlorate(I) rather than chlorine for treating drinking water.

.....

.....

..... [2]

- (c) A student decides to analyse some swimming pool water to find the amount of chlorine it contains. The student takes a  $250\text{ cm}^3$  sample of the water and treats it with an excess of potassium iodide solution.

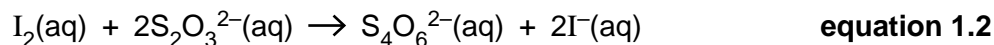


- (i) Write the half-equation for the conversion of iodide ions to iodine in the process shown by **equation 1.1**.

→

[2]

- (ii) The student titrates the treated sample with sodium thiosulfate solution to find out how much iodine has formed. The equation for the reaction is shown below.



The titration requires  $12.30\text{ cm}^3$  of  $0.00100\text{ mol dm}^{-3}$  sodium thiosulfate solution.

Calculate the number of moles of thiosulfate ions,  $\text{S}_2\text{O}_3^{2-}$ , used.

moles  $\text{S}_2\text{O}_3^{2-} = \dots\dots\dots\text{mol}$  [1]

- (iii) Give the number of moles of iodine,  $\text{I}_2$ , in the  $250\text{ cm}^3$  sample of treated water, using your answer to (ii) and **equation 1.2**.

moles  $\text{I}_2 = \dots\dots\dots\text{mol}$  [1]

- (iv) Calculate the concentration of the  $\text{Cl}_2$  in the original swimming pool water sample, in  $\text{mol dm}^{-3}$ .

Give your answer to **two** significant figures.

**(d)** Give the outer sub-shell structure of an iodide ion.

[2]

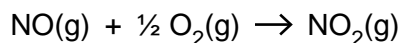
**(e)** Give **one** use for chlorine other than water treatment.

..... [1]

[Total: 20]

2 Many gases can pollute our troposphere, including ozone and oxides of nitrogen.

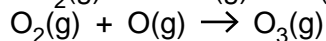
(a) Oxides of nitrogen are involved in the production of ozone, as shown in the equations below.



**equation 2.1**

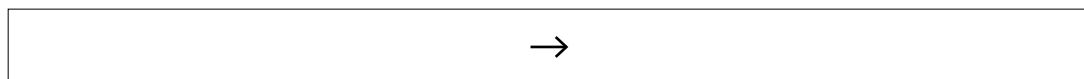


**equation 2.2**



**equation 2.3**

(i) Write the overall equation for the reaction sequence shown in **equations 2.1 to 2.3**.



[1]

(ii) Identify the catalyst involved in this series of reactions. Explain your choice.

.....

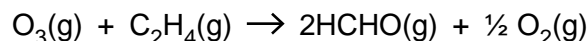
..... [2]

(iii) The chemicals taking part in these reactions are radicals. Explain what is meant by the term *radical*.

.....

..... [1]

(b) Ozone reacts with hydrocarbons in the troposphere to form smog. One example is the reaction of ozone with ethene to form methanal, HCHO, which is found in smog.



**equation 2.4**

(i) Draw the full structural formula for a molecule of methanal.

[1]

(ii) Methanal can be made from methanol in a laboratory. Give the reagents and conditions required for this reaction.

.....

.....

..... [3]

- (iii) The reaction represented by **equation 2.4** occurs at different rates in winter and summer, because of the seasonal temperature differences.

Describe and explain how the rate of a reaction varies with temperature.



*In your answer, you should make it clear how the steps you describe are linked to one another.*

.....

.....

.....

.....

.....

.....

.....

..... [3]

- (iv) The presence of ozone in the troposphere can cause other problems, apart from smog formation. Give **one** other problem associated with tropospheric ozone.

.....

..... [1]

(c) The presence of ozone in the stratosphere is important to humans.

Describe and explain:

- why the presence of ozone in the stratosphere is important to humans and
- the natural processes by which ozone is formed in the stratosphere.



*In your answer, you should make it clear how the steps you describe are linked to one another.*

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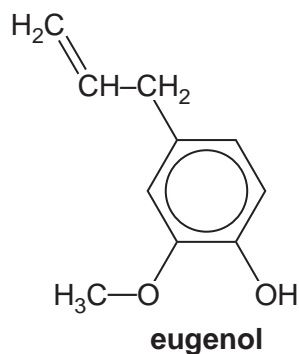
.....

.....

..... [7]

**[Total: 19]**

- 3 Eugenol is a liquid that can be extracted from some spices. Eugenol is used by dentists as a painkiller.



- (a) Name **two** functional groups, other than a benzene ring, which are present in eugenol.

.....  
.....  
..... [2]

- (b) Describe the colour change you would see when bromine water is added to eugenol.

.....  
..... [2]

- (c) Eugenol is only slightly soluble in water.

- (i) Name the type of intermolecular bond present between molecules of water. Explain how these intermolecular bonds form.

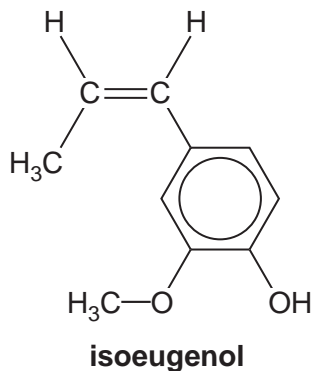
.....  
.....  
.....  
..... [3]

- (ii) Explain, using ideas of intermolecular bonds, why eugenol is only slightly soluble in water.

.....  
.....  
..... [1]



(d) Eugenol can be converted into isoeugenol.



(i) Explain why isoeugenol can exist as two *E/Z* isomers.

.....  
.....  
..... [2]

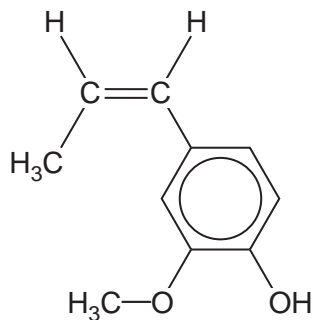
(ii) Isoeugenol reacts with hydrogen by an addition reaction. Give the conditions that are required for this reaction.

.....  
..... [2]

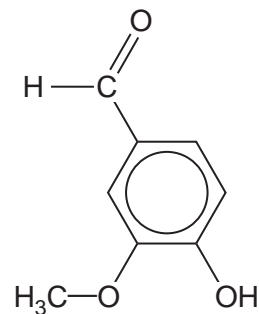
(iii) Under certain conditions, isoeugenol reacts with water by an addition reaction. Draw the structures of the two isomeric products that could form.

[2]

- (e) Isoeugenol can be converted to vanillin, which is used as a food flavouring.



**isoeugenol**



**vanillin**

- (i) Name the functional group that is present in vanillin but not in isoeugenol.

..... [1]

- (ii) This functional group can be identified by infrared spectroscopy. State the wavenumber range of the peak that it would give.

..... [1]

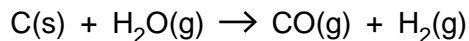
- (iii) Explain what is meant by the *fingerprint region* in an infrared spectrum and explain the significance of the fingerprint region.

.....  
.....  
.....  
..... [2]

**[Total: 18]**

- 4 Methanol is manufactured from carbon monoxide and hydrogen. It is used as a fuel and for making chloroalkanes.

- (a) The carbon monoxide and hydrogen for making methanol can be produced by reacting the carbon in coke with steam.



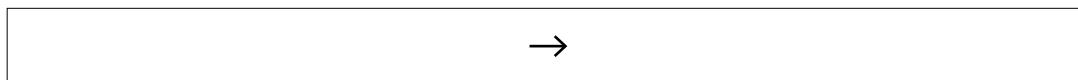
**equation 4.1**

Draw a 'dot-and-cross' diagram to represent the bonding in a molecule of carbon monoxide. The molecule contains a dative covalent bond.

[2]

- (b) In order to obtain the correct ratio of carbon monoxide to hydrogen for the next stage of the process, some of the carbon monoxide is reacted with more steam, forming carbon dioxide and hydrogen.

- (i) Write the equation for the reaction between the carbon monoxide and steam. Include state symbols.



[1]

- (ii) The carbon dioxide produced in the reaction in (i) is disposed of once it has been separated from the hydrogen. Suggest **one** method for disposal of the carbon dioxide, other than releasing it straight into the atmosphere.

.....  
.....  
..... [1]

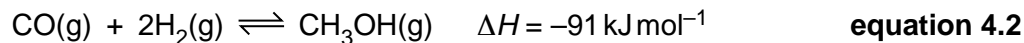
- (iii) Calculate the atom economy for the production of hydrogen in (i).

atom economy = ..... % [1]

- (iv) Comment on the usefulness of the reaction in (i), in terms of atom economy.

.....  
..... [1]

- (c) Methanol can be made from the carbon monoxide and hydrogen.



- (i) The reaction represented by **equation 4.2** is an example of a dynamic equilibrium.

Explain what is meant by the term *dynamic equilibrium*.

.....  
.....  
..... [2]

- (ii) Describe and explain the effect of the following changes on the **yield** of methanol produced in the reaction represented by **equation 4.2**.

Carrying out the reaction at a higher temperature: .....

.....  
.....  
.....

Increasing the total pressure of the reaction system: .....

.....  
.....  
.....  
..... [4]

- (iii) Describe **and** explain the effect that the use of a catalyst would have on the rate at which methanol is produced.



*In your answer, you should use appropriate technical terms, spelled correctly.*

.....  
.....  
..... [2]

(d) Methanol can be converted into chloromethane.

(i) Give the reagent and condition required.

.....  
.....  
..... [2]

(ii) If this chloromethane gas gets into Earth's atmosphere, a C–Cl bond can be broken by UV radiation from the Sun.

The bond enthalpy of the C–Cl bond is  $+346 \text{ kJ mol}^{-1}$ .

Calculate the minimum energy (in Joules) needed to break a **single** C–Cl bond.

Avogadro constant,  $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$

minimum energy = .....J [2]

(iii) Calculate the frequency of radiation that is needed to break one C–Cl bond.

Planck constant,  $h = 6.63 \times 10^{-34} \text{ J Hz}^{-1}$

frequency = .....Hz [2]

(iv) It has been found that halogenoalkanes have been responsible for some of the ozone depletion in the stratosphere.

Describe how halogenoalkanes deplete ozone and give the evidence for the ozone depletion.

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.....  
.....  
.....  
.....

5 This question is based on the Advance Notice article '**Polymers on the move**' which is provided as an insert to this paper.

- (a) Explain what is meant by the term *thermoplastic* used in the article to describe certain types of polymer. Give **one** example of a polymer identified in the article as being thermoplastic.

Meaning of *thermoplastic*: .....

.....

Example..... [2]

- (b) Burning fuel for transport is one of the major sources of atmospheric carbon dioxide. Give **one** other industrial source of carbon dioxide emissions.

..... [1]

- (c) From the 1970s, vehicle components made from metal, glass and wood have been replaced with parts made from polymer materials. Suggest **two** reasons for this, apart from cost.

.....

.....

..... [2]

- (d) ABS is made from two different monomers. What term is used to describe a polymer that is formed from two different monomers?

..... [1]

- (e) (i) Draw a diagram of the repeating unit in poly(chloroethene).

[1]

- (ii) Draw a diagram of the repeating unit in poly(butadiene).

[1]

- (f) A radical chain reaction is described in **Box 1** of the article.
- (i) Name the **stage** of a radical chain reaction that is occurring in both **reaction 1** and **reaction 2**.  
..... [1]
- (ii) Name the stage that causes a radical chain reaction to start.  
..... [1]
- (g) The phrase “*because they can’t get a chemical ‘grab’ on the unreactive surfaces*” is used in **Box 1** to explain why some adhesives are ineffective on poly(ethene).
- (i) Explain, in terms of intermolecular bonds, what is meant by this phrase.  
.....  
..... [1]
- (ii) Name the strongest type of intermolecular bonds that can form between chains of poly(ethene).  
..... [1]
- (h) Explain why polyurethanes are classed as **addition** polymers.  
.....  
..... [1]

- (i) One method that is described for dealing with waste polyurethane foam is to '*recover some of the energy by burning it in an incinerator*'.

- (i) Suggest how this could '*recover some of the energy*'.

.....  
..... [1]

- (ii) Name **two** gases that could be produced when waste polyurethane foam is burnt.

Explain why each of these gases is described as '*not particularly environmentally friendly*'.

.....  
.....  
.....  
.....  
.....  
..... [4]

- (j) Information about the two polymers below is given in **Table 1** of the article.

Choose **one** property of each polymer and explain how the property is linked to the use of the polymer.

**Poly(propene)**

Property: .....

Link between property and use: .....

.....

**Poly(chloroethene)**

Property: .....

Link between property and use: .....

..... [2]

[Total: 20]

**END OF QUESTION PAPER**



## Polymers on the move

Adapted from an article in the RSC's Education in Chemistry, November 2007

**With transport being one of the major sources of anthropogenic CO<sub>2</sub> emissions, and transport costs being so sensitive to fuel prices, there is an urgency for car and aircraft manufacturers to reduce the weights of their products, and replace metals wherever possible with plastics and composites. *David Birkett***

The oil price shock of the 1970s led to the first big increase in the use of plastics in transport. Metal bumpers, wooden dashboards, leather-covered steel steering wheels, and glass headlamp covers were soon replaced by plastics, such as

ABS – acrylonitrile (2-propenenitrile) butadiene styrene – a tough plastic made by polymerising 2-propenenitrile and styrene (phenylethene) in a preformed latex of polybutadiene rubber.

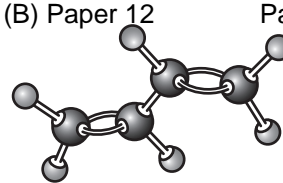
Polymer	Properties and Uses				
	Impact strength /kJ m <sup>-2</sup>	Maximum use temperature /°C	Density /g cm <sup>-3</sup>	General	Uses
Acrylonitrile butadiene styrene (ABS)	14–55	75–95	1.04–1.07	Rigid, tough, excellent for injection moulding	Car facia panels
Fluoroplastics (PTFE, FEB)	13 – no break	205–280	1.17	Exceptional anti-stick/low friction characteristics	Engine gaskets and bearings
Nylons	4.0–5.0	80–110	1.13	Rigid, tough, hard-wearing	Carburettor parts, gear wheels
Poly(propene)	5–20	80	0.902	Extremely tough, exceptional fatigue resistance	Car accelerator pedals
Poly(chloroethene) (PVC)	2.0–45	60	1.38	Flexible, durable, good impact strength	'Imitation leather' fabrics

**Table 1** Properties and uses of some polymers used in car manufacture

(Information from: 'Plastics, a guide to some workshop practices and industrial processes'

Published in 1994 by ICI and York University Polymer Industry Education Centre ISBN: 1 85342 700 4)

Polybutadiene is made from the monomer buta-1,3-diene. The polymerisation reaction occurs by the two double bonds opening up, providing linking points to other monomer units and creating a new double bond between the central pair of carbon atoms.



**Fig. 1** A model of the buta-1,3-diene monomer

Windscreens used to sit loosely in rubber surrounds until chemists discovered that bonding them in place with polyurethane adhesives meant that the strength of glass could contribute to the roll-over strength of a car, so that there was room to reduce the body weight. The rubberised hair in seat cushions was replaced with polyurethane foam and new applications for plastics and elastomers appeared such as cup holders and sound insulation foam under the bonnet.

Not all were inspired by the desire to reduce the weight of the vehicles – often lower cost or greater design flexibility were more important – but the overall effect was improved fuel efficiency. By 1977 plastics contributed 4.6 per cent of the average weight of a vehicle.

(where the applied polymer is typically of lower molecular mass) or powder coatings (where the polymer is applied electrostatically as a powder to the vehicle and melted later).

When all the layers have been applied, the vehicle is heated to  $>150^{\circ}\text{C}$  to increase the molecular mass of some of the layers or to melt others, and allow them to form a continuous coating. Moves to reduce the energy consumption of this step by lowering the bake temperature would probably lead to problems with the final performance of the adhesives.

However, as more and more of the steel bodywork of the typical car is replaced by plastics or composites the nature of the paint system will have to change. Corrosion protection will become less important, but protection against ultraviolet light degradation of the plastic will be an issue. Paints designed to adhere to metals will generally adhere much less well to polymeric substrates. And, since a  $150\text{--}180^{\circ}\text{C}$  bake is not possible for many of the cheaper plastics, some designers are leaving the plastic unpainted, relying on added pigments for colour and ultraviolet protection. If the paint bake cycle is eliminated, the adhesives holding the car together will have to be redesigned, and it may not be possible to maintain the same high-temperature performance under the bonnet.

In-flight polymers: using plastics will save fuel

© Amazing Images / Alamy

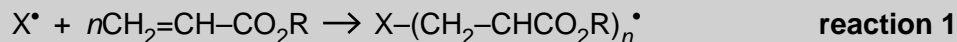
## Sticky problems

Interestingly, vehicle paints were traditionally based on several layers of different high molecular mass polymers dissolved in solvents. However, because of concerns with solvent emissions, these have now largely been replaced by water-based paints

This leads on to considerations of how plastic panels, particularly the notoriously hard to bond polyalkenes such as poly(propene), will be fixed to one another or to the remaining metal structures. In recent years several adhesive manufacturers have developed two-part acrylic (esters of propenoic or methyl propenoic acid) adhesives that can bond polyalkenes very well (see **Box 1**).

### Box 1 Bonding polyalkenes

There is a broad class of adhesives known as acrylics, based on esters of acrylic (propenoic) or methacrylic acid:  $\text{CH}_2=\text{CH}-\text{CO}_2\text{R}$  or  $\text{CH}_2=\text{C}(\text{CH}_3)-\text{CO}_2\text{R}$ . These are polymerised by a free radical initiated polyaddition:



Traditionally the free radical,  $\text{X}^\bullet$ , is generated by the reaction of a hydroperoxide, such as cumene hydroperoxide,  $\text{C}_6\text{H}_5\text{C}(\text{CH}_3)_2\text{OOH}$ , with a reducing agent such as a substituted hydrazine, a dihydropyridine or a thiourea. The resulting free radical,  $\text{C}_6\text{H}_5\text{C}(\text{CH}_3)_2\text{O}^\bullet$ , is of the alkoxy type.

Acrylic adhesives bond a wide range of plastics, for instance polycarbonate or ABS, but are ineffective on poly(ethene) or poly(propene) because they can't get a chemical 'grab' on the unreactive surfaces.

However, in the late 1990s a new class of acrylic adhesives began to appear where the free radicals were generated by a different mechanism involving trialkyl boranes,  $\text{R}_3\text{B}$  (generally stabilised by complexing with an amine) and traces of atmospheric oxygen. This reaction produces alkyl radicals, e.g.  $\text{CH}_3\text{CH}_2^\bullet$ , which are much more reactive than alkoxy radicals and can abstract a hydrogen from a polyalkene surface:



The radical on the surface can now initiate polymerisation of the acrylic monomer, but now the growing chain is chemically bound to the surface.

These are finding application in the car industry but the products are relatively new, so there are no long-term data on the durability of the bonds.

### Scrap heap challenge

A factor that is becoming increasingly important for car designers to consider is the recyclability of the materials they use. Most of the steel from scrapped cars is already recycled, but polymers present problems. Simple thermoplastics such as nylon or polycarbonate, once segregated, can be

melted down and reused, albeit in less stringent applications, but composites, for instance glass-reinforced poly(propene), or thermosets, such as vulcanised rubber, present difficulties.

Consider, for example, polyurethane foam seating, one of the biggest uses of synthetic polymers in cars.

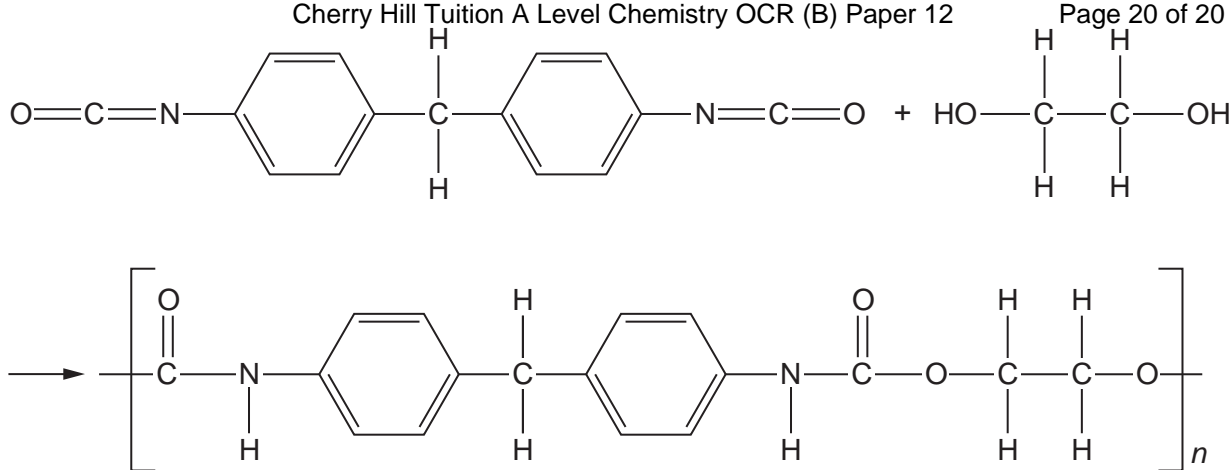
The cushions from an old car will generally have been compressed or otherwise damaged, so can't be reused. The foams can't be melted down without decomposing, so what can we do?

Three approaches are being used, but none of them is wholly satisfactory.

- Digest the foam in ethylene glycol (ethane-1,2-diol) to yield polyols suitable for synthesising rigid insulating poly-urethane foam.
- Chop the foam up and compress it, and use the resulting material in, for instance, carpet backing.
- Recover some of the energy used to make the foam by burning it in an incinerator.



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**Fig. 2** An example of the formation of a polyurethane repeating unit from its monomers

The first two methods require markets for the products and the third method produces gases that are not particularly environmentally friendly.

### Long-term forecast

Even if fuel costs fall in the near future, petroleum will eventually become scarce and replacement liquid fuels (biofuels, oil-from-coal or synthetic fuels using hydrogen from the electrolysis of water) are more expensive without subsidy. The long-term forecast is therefore for relatively high fuel costs. Pressures from green activists, governments

and customers for lower carbon emissions from transport are more likely to increase rather than relax.

Weight reduction will therefore continue to be a key objective of manufacturers, and plastics and composites will play an ever increasing role. On the other hand, most plastics are oil-based, so their own costs will also increase. As the polymer content of cars increases, recyclability of the materials will also need to be built in. Whichever way you look, there's an interesting road ahead for polymer chemistry.

**END OF ADVANCE NOTICE ARTICLE**