Investigation 21

Reactions of hydrocarbons with bromine water

Rationale

Students investigate and compare the reactivity of saturated and unsaturated hydrocarbons with bromine water. They plan their own equipment and procedure, and complete a pre-lab safety form and risk assessment record.

Background knowledge

Students have learned about the major functional groups of hydrocarbons and IUPAC nomenclature.

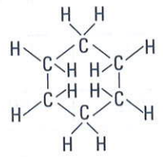
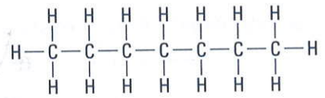
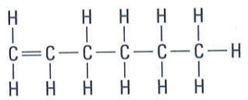
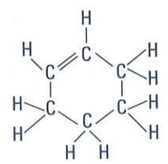
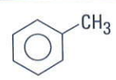
Hints

- Students are encouraged to use semi-micro test-tubes, with 5–10 drops of hydrocarbons and 2–3 drops of bromine water.
- Bromine water could be prepared for the class a few minutes beforehand by reducing KBr to bromine as follows: Place 10 mL 2 M sulfuric acid in a clean test-tube and add 0.5 g solid KBr. Shake the tube to dissolve the solid. Add hydrogen peroxide (100 vol) solution drop by drop, while shaking, until a deep brown colour develops. Place bromine water in a dropper bottle and give to students.

Syllabus

Identify data, plan and perform a first-hand investigation to compare the reactivity of appropriate alkenes with the corresponding alkanes in bromine water in solution. Gather and present information from first-hand or secondary sources to write equations to represent all chemical reactions encountered.

RESULTS **TABLE 1**

Hydrocarbon	Structural formula	Reaction with bromine
cyclohexane		No reaction
n-heptane		No reaction
1-hexene		Colour fades
cyclohexene		Colour fades
polyunsaturated oil	$R-CH=CH-CH_2-CH=CH-R^1$	Colour fades slowly
toluene		No reaction

Discussion

1 Double bond in the chain or cyclic structure, but not in the benzene ring.

2 addition reaction

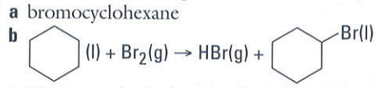
3 $Br_2(l) + H_2O(l) \rightarrow HOBr(aq) + Br^-(aq) + H^+(aq)$

4 $CH_3–CH_2–CH_2–CH_2–CH=CH_2 + HOBr \rightarrow$
$CH_3–CH_2–CH_2–CH_2–CHOH–CH_2Br(l)$
(All other reactions will form the same functional groups in the products.)

5 $CH_3–CH_2–CH_2–CH_2–CH=CH_2(l) + Br_2(l) \rightarrow$
$CH_3–CH_2–CH_2–CH_2–CHBr–CH_2Br(l)$
(All other reactions observed will form di-bromo alkane.)

6 Toluene has a benzene ring containing conjugate double bonds, which are not reactive due to delocalised electrons that oscillate between the two carbons, thus making covalent bonds very strong.

7 **a** bromocyclohexane

b 

c This is a substitution reaction, where one hydrogen is substituted for a bromine atom, whereas alkenes react by an addition reaction, where two bromines are added to the chain after one double bond breaks and frees two electrons. Each electron is shared with one bromine atom.

FOLLOW-UP

1 *Ethene is produced by the catalytic cracking of long-chain hydrocarbons. Long chains are broken into smaller saturated and unsaturated hydrocarbons. This process is repeated several times until ethene is produced. The catalyst is a class of crystalline aluminosilicates called zeolites. Their special spherical structure provides active sites for breaking long chains.*

2 **a** *cyanoethene $CH_2=CH–C\equiv N$*
ethenylbenzene $CH_2=CH–C_6H_5$
'vinyl chloride' $CH_2=CH–Cl$

b *acrylic material, polystyrene, polyvinylchloride (PVC plastic)*

3 **a** *clear, tough, resistant to heat and sun*
b *strong but flexible, resistant to sun, hydrophobic*
c *light, good insulator, chemically inert, hydrophobic*

4 **a** *High density is achieved by long, straight-chain monomers, which when polymerised form intertwined chains with a regular packing arrangement. This brings molecules close to each other, forming crystals of very hard, dense, tough material.*

b *Low density is achieved by using monomers with longer (larger than CH_3) side chains that stiffen the polymer, or by the manufacturing process of aerating—trapping air while the polymer is being shaped.*

c *The chains in strong plastics are stiffened by using monomers with long side-chains and cross-linking. The chlorine in PVC and benzene in polystyrene make them rigid and tough.*

d *The hard, elastic properties of a polymer such as rubber are achieved by the cross-linking of chain polymers with (for example) sulfur. This provides flexiblity and elasticity.*

Sample risk assessment record

INVESTIGATION 21: Reactions of hydrocarbons with bromine water

Assessment team: _____ Date: _____ Year/group: *12*

Ref: *Heinemann Chemistry Practical Manual*

Chemicals used	Conc. (mol/L)	Amount	User code	DG class/ haz	Procedure as per Appendix D?	What are the hazards?
n-heptane	pure	10 drops	11-12	3 Not haz	yes	Moderately toxic, highly flammable
cyclohexane	pure	10 drops	11-12	3 Not haz	yes	Moderately toxic, highly flammable
cyclohexene	pure	10 drops	11-12	3 DHS, CW	yes	Moderately toxic, highly flammable
1-hexene	pure	10 drops	11-12	3 Not haz	yes	Moderately toxic
toluene	pure	10 drops	11-12	3 DHS	yes	Toxic by all routes of exposure
bromine water	dilute	3 drops	11-12	8/6.1	yes	Toxic by all routes of exposure
Product:						
bromoalkanols	dilute	10 drops	11-12	3	not listed	Toxic by all routes of exposure

Disposal of waste

If students use only a few drops of each hydrocarbon, set up in a fume cupboard a 400 mL beaker containing 100 g perlite or cat litter. Students should empty their test-tubes into the beaker. Leave the perlite with waste to evaporate overnight in the fume cupboard, then wrap it up in plastic or paper and dispose of it in the garbage bin.

How are risks controlled?

- wear safety glasses
- use gloves
- fume cupboard
- wash hands after use
- use small quantities (specify): Use only 10 drops or less of each hydrocarbon

Assessment of risk:

Risk for this investigation is **not significant**, provided appropriate control measures are in place as indicated above.

Approved by: _____ Date: _____

Investigation 22

Ethanol as a solvent

Rationale

Students design an investigation to gather meaningful information about the class of substances that dissolve readily in ethanol. They select their own substances, elements and compounds, fill in a pre-lab safety form and complete a risk assessment record.

Syllabus

Plan, choose equipment for and perform a first-hand investigation to gather information about the range of substances that can be dissolved by ethanol.

Background knowledge

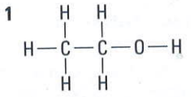
Students have learned about the bonding and structure of ethanol, and know that it has polar molecules with hydrogen bonding as the intermolecular forces.

Hints

- Students should test at least the following substances: salt, sugar, iodine, water, acetone, variety of alkanols, esters, acids, bases, sulfur, oil.
- Encourage students to use very small quantities of solid (the size of a rice grain) or just a few drops of liquid solute.

Discussion

1



All C–C bonds are non-polar, while C–H bonds are slightly polar but cancel each other out due to their orientation. C–O and O–H bonds are very polar due to the high electronegativity of oxygen. Because of the bend in the molecule at the oxygen atom (due to its lone pairs of electrons), the polar bonds do not cancel each other out; therefore, the molecule is polar.

2 a water, alkanols, short-chain alkanoic acids, acetone, esters
b These are all polar compounds.
c All can form hydrogen bonds with ethanol.

3 a sugar, some salts, iodine
b Except for iodine, they are either polar or ionic.

4 Iodine is non-polar, so cannot dissolve in highly polar water. Ethanol is less polar than water. It contains a non-polar part, CH_3–CH_2–, which more easily dissolves non-polar molecules.

5 a sulfur, some salts such as lead iodide
b They contain either non-polar molecules, or have very strong ionic bonds, or are covalent network solids (which are also non-polar).

6 Water, acetone and sugar are dissolved by ethanol, breaking their intermolecular forces, some of which formed new hydrogen bonding with ethanol. Iodine dissolved in ethanol to produce a brownish solution. This is due to the solvent effect—that is, the reflection of light from iodine molecules in ethanol, rather then the formation of new products. Some solvents, such as hexane and TTE, dissolve iodine into a crimson-coloured solution.

FOLLOW-UP

1 *Aftershave, flavouring such as vanilla essence, perfumes, many disinfectants.*

2 *Molasses (sucrose) from the sugar industry is the starting material for the production of ethanol by fermentation using yeast:*
$C_6H_{12}O_6(l) \rightarrow 2CH_3CH_2OH(l) + 2CO_2(g)$
The addition of water to ethene at high temperatures and with acid (as a catalyst) are the main starting materials in the chemical industry:
$CH_2{=}CH_2(g) + H_2O(g) \rightarrow CH_3CH_2OH(g)$

3 *As a fuel, additive to petrol (gasohol), as a raw material in the production of ethene by dehydration.*

4 CH_3–CH_2–$OH(l) \rightarrow CH_2{=}CH_2(g) + H_2O(g)$ *using concentrated sulfuric acid as a catalyst. Strong heating of ethanol over a porous pot, in the absence of oxygen, also results in the dehydration of ethanol to give ethene.*

Sample risk assessment record

INVESTIGATION 22: Ethanol as a solvent

Assessment team: _____ Date: _____ Year/group: *12*

Ref: *Heinemann Chemistry Practical Manual*

Chemicals used	Conc. (mol/L)	Amount	User code	DG class/ haz	Procedure as per Appendix D?	What are the hazards?
ethanol	pure liquid	5 mL	7-12	3	yes	Highly flammable
cyclohexane	pure liquid	10 drops	11-12	3	yes	Toxic by all routes of exposure
iodine	solid	size of a rice grain	11-12	8/5.1/DHS	yes	Toxic by all routes of exposure
oxalic acid	solid	size of a rice grain	7-12	DHS	yes	Moderately toxic if ingested
sodium hydroxide	solid	1 pellet	11-12	8/DHS	yes	Highly corrosive to skin and eyes

Disposal of waste

All liquid solutes that dissolve in ethanol can be washed down the sink. Collect insoluble organic matter in a fume cupboard in a beaker containing cat litter or perlite. Leave the collected organic matter to evaporate overnight. Wrap the perlite in plastic or paper and dispose of it in the garbage.

How are risks controlled?

- wear safety glasses
- use gloves
- wash hands after use
- use small quantities (specify): Use small amounts of solid (size of a rice grain) and a few drops of liquid solute

Assessment of risk:

Risk for this investigation is **not significant**, provided appropriate control measures are in place as indicated above.

Approved by: _____ Date: _____