Thames & Kosmos®

Experiment Manual

CHEM C3000

CHEMISTRY EXPERIMENT KIT

Warning!

This set contains chemicals that may be harmful if misused. Read cautions on individual containers and in manual carefully. Not to be used by children except under adult supervision. Only for use by children 12 years of age or older. This kit must only be used under the strict supervision of adults who have familiarized themselves with the experiments and safety precautions stated in the manual. Children must not conduct any of the experiments without the presence of a parent or other responsible adult.

Caution!

Kit contains experiments with combustion, hazardous chemicals, glass components and sharp components. Some chemicals have been classified as posing a health hazard. Read and follow the instructions and keep them available for reference. Do not allow chemicals to come into contact with any part of your body, especially mouth or eyes. Keep small children and animals away from the experiments. Keep the experiment kit out of the reach of small children at all times. Wear included safety glasses at all times. Supervising adults must wear eye protection as well (not included).

For their safety, all users must strictly adhere to these warnings and precautions, as well as those inside this experiment manual, as part of the Terms of Use of this experiment kit.

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Before you start...

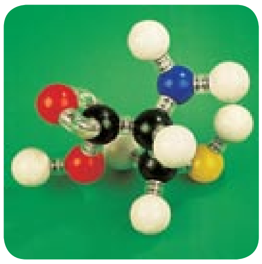
Experiments

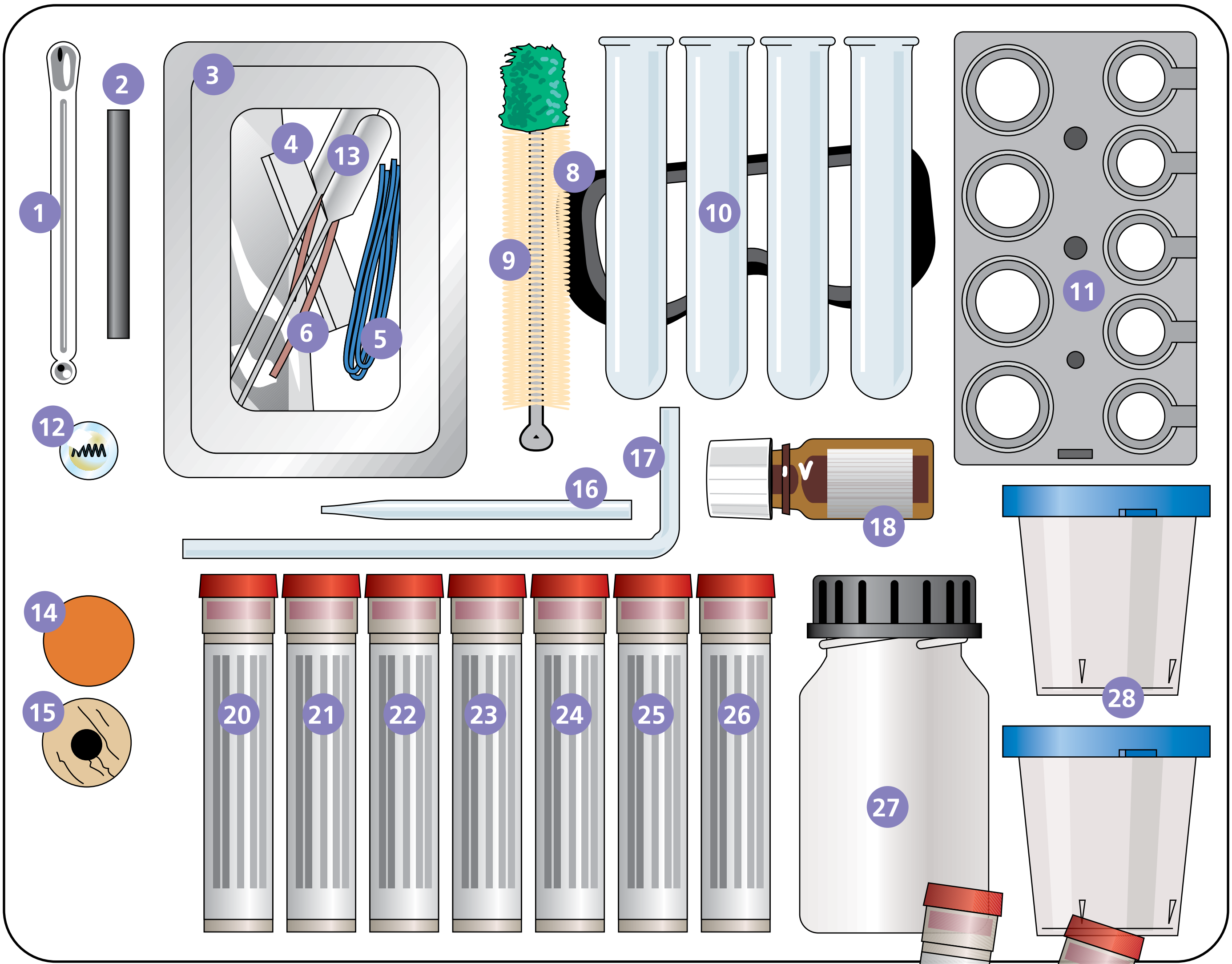






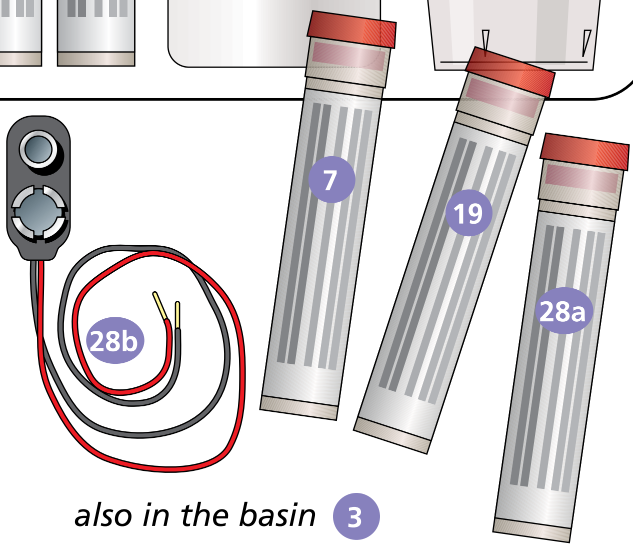




Tray One Contents

No.	Description	Part No.
1	Measuring spoon	035017
2	Carbon rod	026217
3	Basin	070167
4	Lid opener	070177
5	Four connection wires	000343 (each)
6	Copper wire	000063
7	Magnesium strip	771761
8	Protective safety glasses	052347
9	Test tube brush	000036
10	Four test tubes	062118 (each)
11	Test tube stand	070187
12	6 V, 50 mA bulb	009028
13	Two dropper pipettes	071208
14	Rubber stopper without hole	071078
15	Cork stopper with hole	071118
16	Pointed glass pipe	065308
17	Angled glass pipe	065378
18	Bottle for litmus solution incl. safety cap and dropper insert	704062
19	Hexamethylenetetramine	032952
20	Sodium hydrogen sulfate	033402
21	Sodium carbonate	033412
22	Potassium hexacyanoferrate(II)	033422



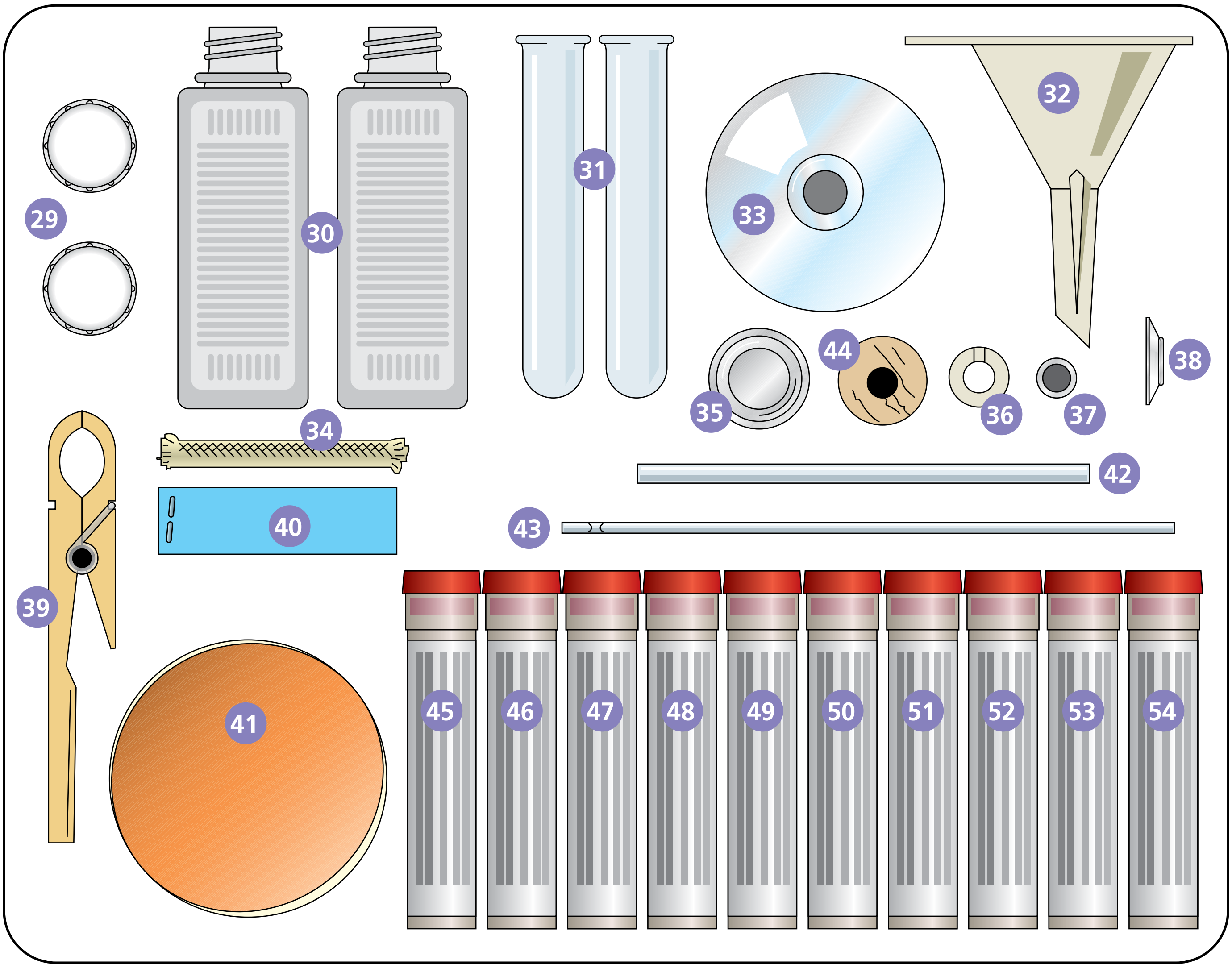
also in the basin 3

No.	Description	Part No.
23	Calcium hydroxide	033432
24	Ammonium iron(III) sulfate	033442
25	Ammonium chloride	033452
26	Copper(II) sulfate	033462
27	Screw-top jar	061127
28	Two measuring cups with lids	087907 (each)
28a	Litmus powder	771500
28b	Clip for 9-V square battery	042106
28c	Not pictured: sheet of filter paper	080062

Additional Materials
Read each experiment completely before beginning it, so you know what additional items you may need. Most additional items can be found around your home, but you may need to have an adult buy something at the supermarket or drug store.

Caution!
Individual parts in this kits have sharp or pointed edges or corners. Do not injure yourself!

Thames & Kosmos reserves the right to technical alterations.



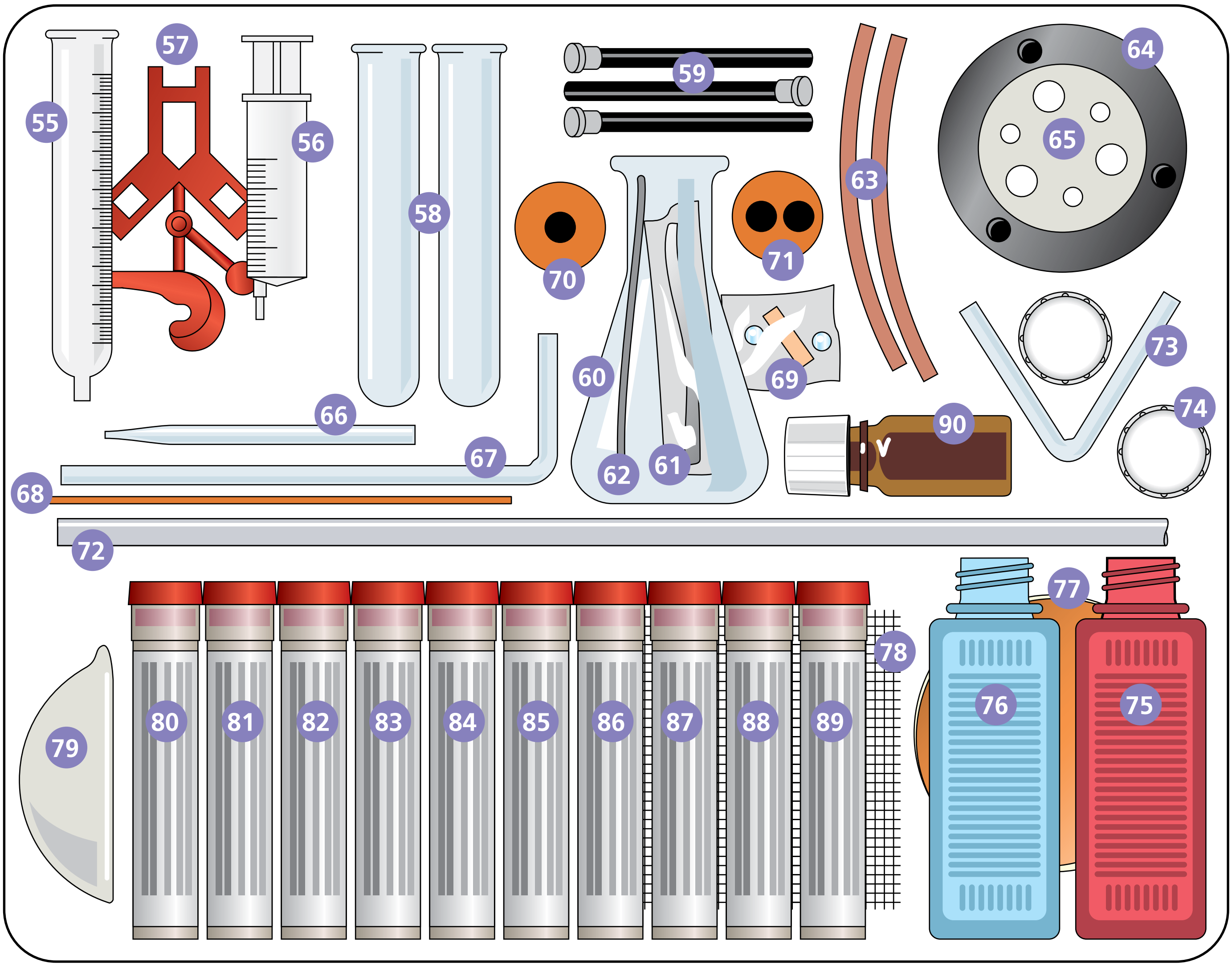
Tray Two Contents

No.	Description	Part No.
29	Two screw-top lids	075088 (each)
30	Two plastic bottles (1)	086298 (each)
31	Two test tubes	062118 (each)
32	Plastic funnels	086228
33	Alcohol burner base	061117
34	Wick	051056
35	Burner cap	021797
36	Insulator gasket	048067
37	Wick holder	021777
38	Aluminum disk	021787
39	Test tube holder	000026
40	Litmus paper, blue	056026
41	Filter paper	080156
42	Straight glass pipe	065188
43	Heating rod	065458
44	Stopper with one hole	071118
45	Calcium hydroxide	033432
46	Sodium hydrogen carbonate	033532
47	Tartaric acid	033472
48	Luminol preparation (luminol-sodium sulfate mixture, 5% m/m)	033482

No.	Description	Part No.
49	Potassium hexacyanoferrate(III)	033492
50	Calcium sulfate	033502
51	Ammonium chloride	033452
52	Copper(II) sulfate	033462
53	Iron filings (iron powder)	033512
54	Potassium permanganate preparation (2)	033522
	Not pictured:	
	C2000 labels	440537

(1) One bottle for hydrogen peroxide solution (3%), the other for saving solutions you prepare yourself.

(2) The potassium permanganate preparation used in Thames & Kosmos CHEM C2000 (potassium permanganate-sodium sulfate mixture, 1:2 m/m) can be used wherever a potassium permanganate solution is required.



Tray Three Contents

No.	Description	Part No.
55	Graduated cylinder	065038
56	Plastic syringe	086258
57	Lab stand clamp	035036
58	Two test tubes	062118 (each)
59	Three lab stand legs	011307 (each)
60	Erlenmeyer flask	062138
61	Magnesium	771761
62	Iron wire	032133
63	Two pieces of rubber tubing	044473
64	Tripod stand platform	100026
65	Lab stand base (and feet)	083247
66	Pointed glass pipe	065308
67	Angled glass pipe	065378
68	Plastic straw for syringe	087107
69	Bag of C3000 small parts,	450022
	contents:	
	Tube coupling for syringe	
	Two glass balls	
70	Rubber stopper with one hole	071028
71	Rubber stopper with two holes	071038
72	Lab stand rod	035057
73	Acute angled glass pipe	065268

No.	Description	Part No.
74	Two screw-top lids	075088 (each)
75	Plastic bottle, red (for hydrochloric acid)	086098
76	Plastic bottle, blue (for sodium hydroxide)	086198
77	Filter paper	080156
78	Wire mesh	100187
79	Evaporation dish	063057
80	Activated charcoal	033202
81	Ammonium carbonate	033212
82	Potassium iodide	033352
83	Potassium bromide	033332
84	Potassium permanganate	033232
85	Copper(II) sulfate	033242
86	Sodium thiosulfate	033252
87	Sulfur	033262
88	Tartaric acid	033272
89	Zinc powder	033282
90	Small bottle for silver nitrate solution	033533
	Not pictured:	
	C3000 labels	440547

In Experiment 340, you tried out the classic method of soap production. All purpose oils contain chain-shaped molecules with a different structure, but not the fatty acids needed to make soap.

Water Has Skin

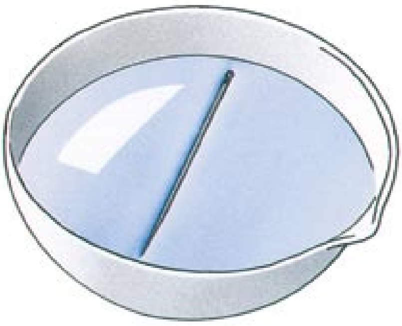


FIGURE 167: *Water has skin.*

EXPERIMENT 342

1. Rinse out the evaporation dish thoroughly to remove every trace of soap residue.

2. Fill the dish almost to the rim with water and place a thin sewing needle on the water's surface. The needle actually remains on the surface even though it is made out of steel, which has a greater density than water.

3. Look closely. You will notice that the needle sinks a little into the water, forming a sort of trench. It really does look as if the water had an elastic skin that stretches a little under the weight of the needle (Fig. 167). You will notice the same thing if you look closely at a water strider (Fig. 168).

4. Now dissolve some soap in a little de-mineralized water to make a strong soap solution, and add a few drops of the solution to the dish. Within a few seconds, the needle will sink.

FIGURE 168: *The water strider uses surface tension to keep itself on top of the water (Photo: Diffené, Neustadt/W., Germany).*

Water does indeed act as if it had a skin stretched over its surface. A light object, such as a sewing needle, placed on it will press the skin in a little. The resistance of the skin, called **surface tension**, is stronger than the gravitational force on the needle. Hence, the needle floats.

What explains the effect of the soap? To answer this question, we first have to take a close look at the soap particles. Let's take sodium stearate:

$$C_{17}H_{35}COONa \rightarrow C_{17}H_{35}COO^- + Na^+$$

When it is dissolved in water, the salt decomposes into $C_{17}H_{35}COO^-$ anions and Na^+ cations. The soap anions have two faces: The hydrocarbon chain is **lipophilic (fat-loving)**, just like the hydrocarbon chains of fats. The negatively charged COO^- group, which is responsible for the ionic nature of the soap anions, is **hydrophilic (water-loving)**.

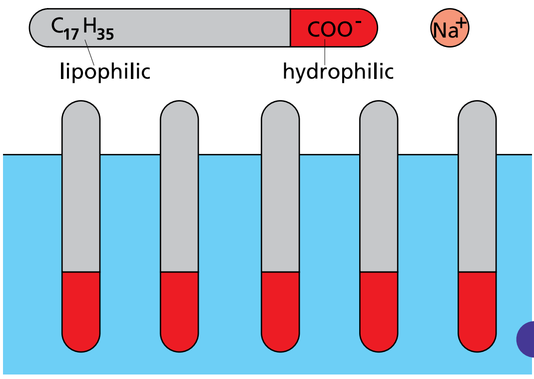


FIGURE 169: *Soap anions reduce the surface tension of water.*

On the surface of a soap solution, the hydrophilic COO^- groups submerge themselves face-down in the water, while the lipophilic hydrocarbon chains stick up out of the water (Fig. 169). In that way, the water's surface becomes "perforated," or punctured with lots of little holes. The surface tension drops, the skin stretches, rips, and cannot hold the needle. Substances that reduce the surface tension of water in this way are called **surfactants**.

When washing clothes, the surface tension of water gets in the way of cleaning. It makes the water contract into droplets, so the material being washed isn't sufficiently bathed in the water.

EXPERIMENT 343

Place a drop of water on an old piece of linen with the dropper pipette. Because of its surface tension, the water droplet retains its spherical shape and fails to penetrate into the material. Repeat the experiment with a drop of soap solution. The droplet will immediately collapse and soak into the material (Fig. 170).

The addition of soap lets the suds get to the dirt more effectively and fulfill their duty — namely, to attach to and remove dirt particles.

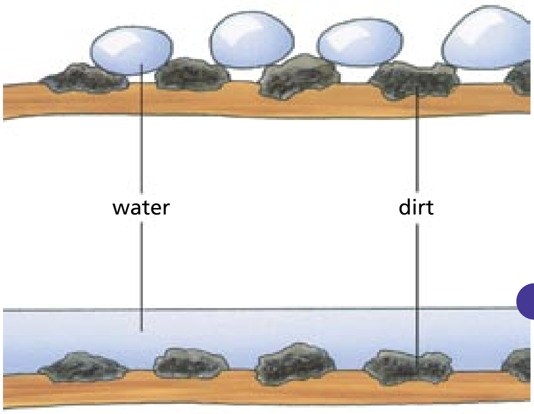


FIGURE 170: *Reducing the surface tension of water lets it wet the fabric more effectively.*

Removing Dirt Particles

The idea with washing is for the oiliest dirt to decompose and get rinsed away with the suds. Because oil and water repel each other, though, that is easier said than done.

EXPERIMENT 344

Pour a little cooking oil into a test tube that has about 10 ml of water in it. Add some dusty dirt or coal dust and shake vigorously. The droplets or the layer of oil will turn gray while the water remains clear.

EXPERIMENT 345

Make some fine soap shavings and use them to prepare a soap-water solution. Take the test tube with the dirt-oil-water mixture from the last experiment and add an equal quantity of the soapy water to it. This time, the oil and water won't separate so quickly — all the liquid in the test tube looks gray. The dirt and the oil have been distributed evenly in the suds. Disposal Instructions: A1

The oil and the water become attached to each other by the soap. The soap ions turn their lipophilic side, i.e. the hydrocarbon chain, to the dirt particles, and surround them with a sort of soap envelope. But the outside of the envelope is hydrophilic, because it consists of the negatively charged COO^- groups. The H_2O dipoles turn their positive side (their H atoms) toward the soap envelope and their negative side (their O atom) outward (Fig. 171). The dirt particles, surrounded by a negatively charged envelope of water, all repel one another. In that way, the dirt becomes distributed evenly through the water and is easily rinsed away with the suds. The term **emulsion** is used for this kind of a mixture of two substances that, in themselves, do not mix. In this case, a requirement for the emulsion to form is the presence of the soap, which acts as an *emulsifier*.

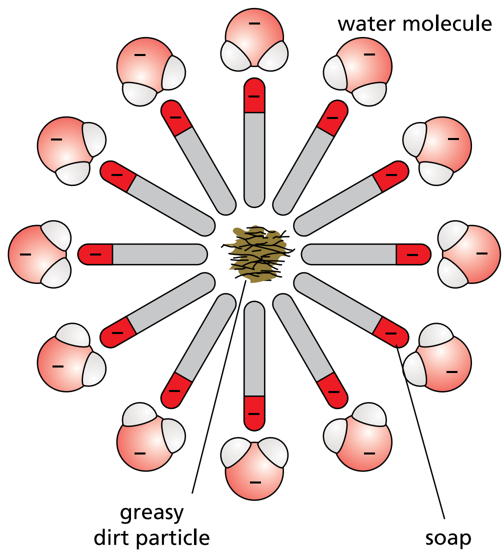
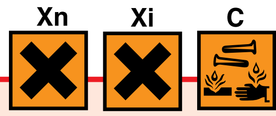


FIGURE 171: *Soap ions bind dirt and water.*

Advantages of Modern Laundry Detergents

In the old days, the only material used to wash things — everything from people's hair to the kitchen floor — was soap. These days, soap has been largely supplanted by **synthetic detergents**, which are much more effective and lack some of soap's drawbacks. Surfactant materials as a group — both soaps and synthetic agents — are sometimes identified by the general term **tensides** (as in the word *tension* — although tensides *lower* the surface tension of water).



Sodium hydroxide is caustic. Luminol is hazardous to health and an irritant. Hydrogen peroxide is an irritant. See the warnings on p. 9-11!

EXPERIMENT 346

Add some limewater to a clear soap solution and shake! Instead of foam, you will get an insoluble, flaky soap scum or **lime soap** on the liquid's surface. Disposal: A1

EXPERIMENT 347

Repeat the experiment with laundry detergent instead of soap. This time, you will get a lot of foam and no soap scum. Disposal: A1

EXPERIMENT 348

Prepare a clear soap solution and add a few drops of hydrochloric acid. You will get a thick precipitate. Shake briefly. Again, you will end up with a scum of undissolved flakes on the surface. Disposal: A1

QUESTION 50: Why can't the scum be made of lime soap this time?

When the alkaline soap anions encounter the H_3O^+ ions (of the added acid), insoluble fatty acids form, e.g.:

$$\underset{\text{stearic acid anion/polar}}{C_{17}H_{35}COO^-} + H_3O^+ \rightarrow \underset{\text{stearic acid/nonpolar}}{C_{17}H_{35}COOH} + H_2O$$

Fatty acids are not good for washing. In fact, just the opposite — they make the thing you're washing even dirtier.

EXPERIMENT 349

Repeat Experiment 348 with a laundry powder solution. This time, you will get no greasy precipitate. Disposal: A1

The surfactants most commonly used in modern laundry detergents have a structure similar to soap, i.e. they consist of lipophilic hydrocarbon chains and a negatively charged atom group. Instead of the COO^- group of fatty acids, synthetic detergents often contain an OSO_3^- or SO_3^- group derived from sulfuric acid. The calcium salts of synthetic surfactants are water-soluble, so modern laundry detergents are not affected by hard water. Since the surfactant anions are only weakly alkaline, i.e. only slightly attract H_3O^+ ions, there is also no separation of fatty acid-like precipitates in an acidic solution.

In addition to tensides, washing detergents contain many other materials that play special roles or have an overall positive influence on the outcome of the wash. That goes above all for the detergent boosters, which remove Ca^{2+} ions and Mg^{2+} ions from the wash water through the formation of complexes, thereby preventing insoluble buildup from accumulating on the heating elements of the washing machine or on the wash itself. The environmentally harmful phosphates, which used to over-fertilize rivers, have been replaced by gentler substances.

FIGURE 172: *Excessive algae growth due to an oversupply of phosphates and other nutrients*

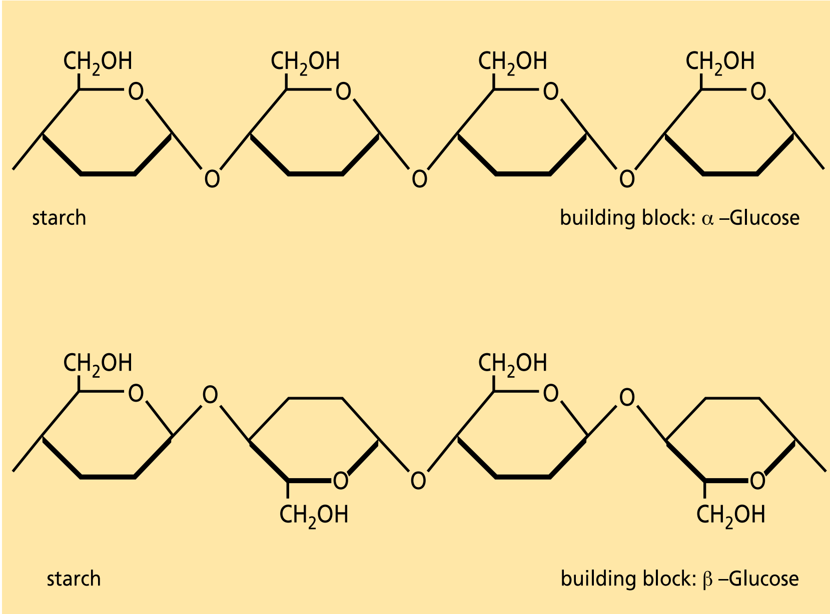


FIGURE 188: *Sections of starch and cellulose macromolecules.*

Starch molecules are made of α-glucose, while cellulose molecules are made of β-glucose (Fig. 188). Due to electrical powers of attraction, the molecule chains in cellulose are twisted together like a rope. That explains the insolubility of cellulose in water.

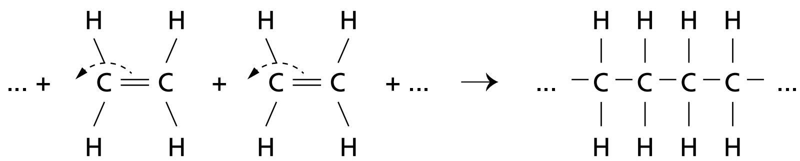
Humans and carnivorous animals are unable to digest cellulose, because they lack the necessary enzymes. For herbivores, the conversion of cellulose into glucose is no problem. They either produce enzymes themselves, or — in the case of cud chewers like cows — store bacteria in their stomachs that supply them with the necessary enzymes.

But cellulose does not just provide a building material for plants or nutrition for herbivores, it is also a valuable raw material for the chemical industry. You already learned a little about the chemical conversion of wood into glucose. Cellulose is also the basis for artificial fabrics such as rayon, plastics (e.g. celluloid), and paper. Cellulose chemistry is one of the most important and interesting fields in chemistry.

From Ethylene to Polyethylene

You know about ethylene (or ethene) from Chapter 24. It is the simplest hydrocarbon with a double bond. Using high pressure and certain catalysts, researchers have learned how to line up ethylene molecules into macromolecules.

The processes involved can be quite complex. Simplifying greatly, we can say that the double bonds of the ethylene molecules are "opened up," and the released bonds then act to link the individual members of the chain to one another. This type of linkage is the **addition polymerization** mentioned on p. 148:



The material formed by these CH_2 chains is known as **polyethylene** (PE). The linear or branched chain molecules consist of up to 2,000 monomers, i.e. individual ethylene molecules.

FIGURE 189: *Plant for obtaining ethylene, the raw material used in the production of polyethylene (BASF factory photo, Ludwigshafen, Germany).*

EXPERIMENT 369

Cut a small piece of a plastic supermarket bag or plastic wrap and hold it in the burner flame with a pair of pliers (lay down a piece of aluminum foil). The sample will melt, drip, and burn with a flame that starts small and grows bigger. Polyethylene will continue to burn after it is removed from the flame. Disposal Instructions: A3

QUESTION 54: What does the smell remind you of?

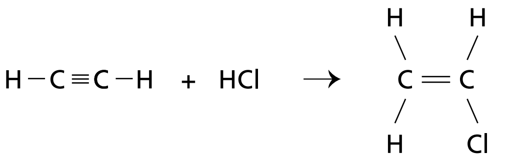
If you compare a polyethylene molecule with a paraffin molecule containing 20-40 carbon atoms, the smell will make sense. The hydrocarbon chains of polyethylene and paraffin are exactly alike.

Polyethylene has no taste or smell and is completely nontoxic. That is why it is such a good material for kitchen utensils or food packaging. Because of its non-reactivity to other chemicals, it also finds a lot of uses in the chemistry lab and in industry. In addition, polyethylene is an outstanding electrical insulator. There are many different kinds of hard polyethylene products, depending on the exact mode of manufacture. All of them will warp with heat. Materials with this quality are known as **thermoplastics**.

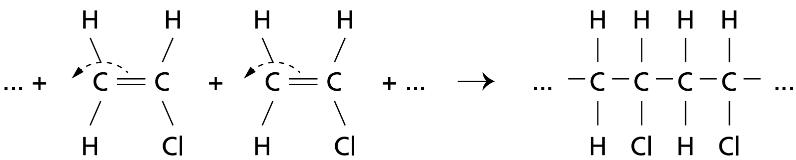
FIGURE 190: *Laboratory equipment made out of polyethylene and other plastics have long had their place in the lab (VITLAB GmbH & Co.)*

Polyvinyl Chloride, a.k.a. PVC

We already mentioned some of the advantages and disadvantages of the bulk plastic PVC in connection with our discussion of the environmental problems posed by chlorine-containing products (p. 69). Now let's look into the chemistry of polyvinyl chloride. If hydrogen chloride is combined with **ethyne** (formerly known as acetylene), the simplest hydrocarbon with a triple bond, they form vinyl chloride or — to use the more technically correct term — monochloroethene:



The hydrocarbon has attached itself to the ethyne, and a double bond has formed from the triple bond. If the double bond is now "opened up" — just as we saw with ethylene — the vinyl chloride molecules join together into a macromolecule chain, polyvinyl chloride:



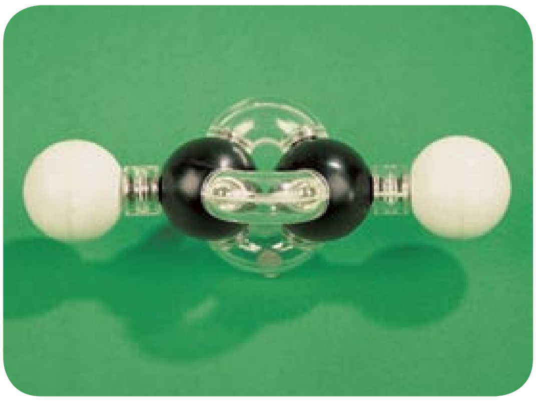


FIGURE 191: *Ethyne, the simplest hydrocarbon with a triple bond.*