Lubricity in the Bathroom

Have you ever wondered what is happening when you strike a match against the rough paper on the side of the box and it catches fire? Friction is a force that acts between the two surfaces when they move past each other. It generates heat that sets off a chemical reaction which lights the match (see figure on the right).

Friction is a very important and useful force; it is responsible for keeping everything where it should be. Imagine a world without friction – you wouldn't be able to do anything because everything would be sliding around all the time and when something such as a car started to move, it wouldn't be able to stop. It would be like living in a world where every surface was an ice rink!

Friction can cause problems too though, such as wearing out surfaces that are rubbing together. In motors, parts experiencing too much friction can be catastrophic (see figure on the left), the result of excess friction in a wind turbine generator leading to a fire.

When there is too much friction, scientists can add substances to reduce it. These are called lubricants and are used in almost every mechanical device on the planet. Lubricants have a property called lubricity, which is the ability of a material to reduce friction between two surfaces. The study of lubricity is called tribology.

Click this **Do Something** button to try out some tribology for yourself

Lubricants in your bathroom

There are lubricants in your bathroom but sometimes they can be difficult to see. Your power shower motor will have many types of lubricant keeping it running smoothly. The toilet flush mechanism and the motor in an electric toothbrush will also have some kind of lubrication and without it nothing would work!

How do lubricants work?

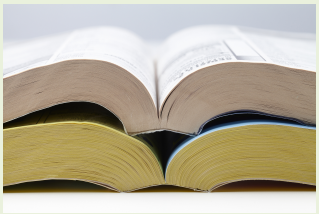
In order to understand how lubricants work, first you need to know how friction operates on a molecular level:

Animation: How friction and lubricity work

If you look at the polished metal surface of this piston head, it looks very smooth.

A little friction goes a long way!

The popular TV series *Mythbusters* tested the strength of friction by interlocking two telephone directories page by page and then trying to pull them apart again. It eventually took 3629 kg of force to separate the books, supplied by two tanks!

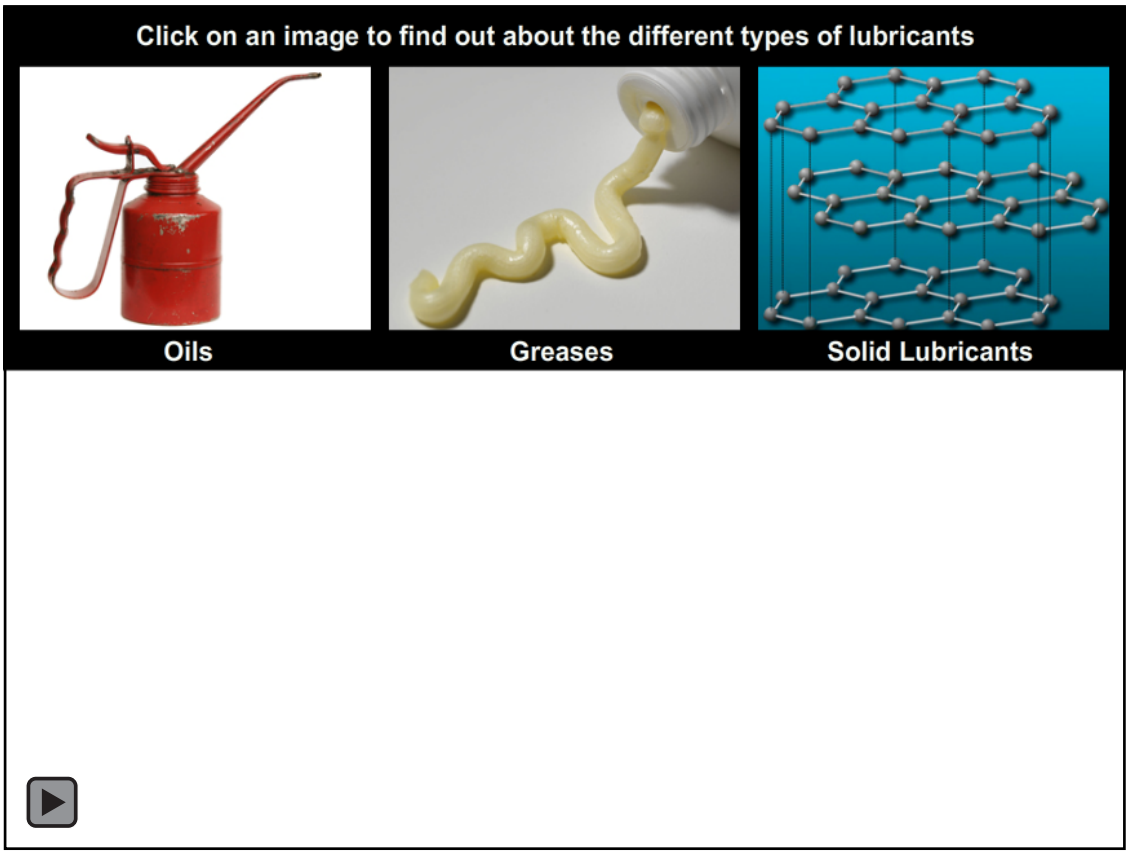


The strength came from the large number of pages lying next to each other. Each page experienced friction against the page on either side. Individually, each page only experienced a small amount of friction but together, the force added up!

While all lubricants fundamentally do the same task, not all lubricants are suitable to every application. Lubricants and applications are matched to each other based upon their physical properties.

As well as reducing friction, lubricants also carry out a number of other functions in a moving system including transferring heat, carrying debris and contaminants away, preventing corrosion and sealing against leakage of gases. Lubricants are therefore grouped into three distinct categories, each of which has their own physical attributes which make them suitable for their particular job:

A lubricant for every job



Superlubricity

This is a property of some materials where the molecular scale surface structures do not fit together enough to generate significant friction. It happens without a lubricant present and keeps the two surfaces separated enough to allow movement with minimal friction.

Graphite is a material that has this property. The hills and valleys of the surface can fit together “commensurately” as in the top image. This has a high level of contact between the two surfaces and so experiences high friction. Or they can come together “incommensurately” as in the bottom image. This stops the hills and valleys from interlocking and so reduces friction to almost nothing.


Commensurate surfaces – high friction


Incommensurate surfaces – low friction

A lubricant close up: Greases

Greases are used in situations requiring a thick lubricant that does not need to be replaced frequently. They are static lubricants so they don’t need to be pumped around a system. Greases work by becoming thinner

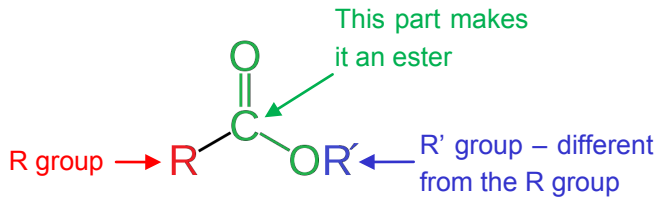
when they are put under pressure, for example, when engine components are moving. When the viscosity falls, they take on the lubricating properties of the base oil, meaning they can lubricate the engine but, when it stops, they become more viscous again.

Greases are made of a number of different components which when combined provide the properties required by the user. Here we will discuss Croda greases in particular which contain the following components:

- Base oil – such as a mineral oil, this makes up around 50-70% of the grease volume
- Thickening agents – between 5-40%, this thickens the oil to give a highly viscous product
- Additives – up to 20% of a grease is additive compounds to help it achieve the correct properties

The base oil makes up the majority of the grease as it is the lubricating properties of this component that are most important. Mineral or vegetable oils can be used as a base but often a synthetic organic compound called an ester is used instead because it can provide a range of unique properties that other base oils cannot.

Esters are an organic functional group with a carbonyl (C=O) next to an ether (-O-R) group. The "R" groups can be any organic molecules and are often different so they are called R and R'. Different R groups give different properties so esters are very flexible molecules



Ester base oils are more expensive than mineral or vegetable oils but they have several advantages that outweigh the costs:

1. **High thermal and oxidative stability** – this allows them to be used in places with high temperatures that would otherwise destroy mineral or vegetable oils through oxidation. More on oxidation in the box on the right
2. **Low pour point** – this is the temperature at which you cannot pour an oil anymore because it has solidified. Esters are liquid at lower temperatures than other oils which makes them useful in low temperature environments such as harsh winters in some areas of the world
3. **Biodegradable** – in applications where oil is exposed to the environment, biodegradability is important to ensure any leaked grease breaks down
4. **Low toxicity** – all factories require lubricants to run but if that factory is making food products then contamination from toxic oils can be problematic. While grease leaks are rare, it is important to use a non-toxic grease in food production in case of contamination.

Oxidation

Oxidation is the loss of electrons or the increase in the oxidation state of a molecule, atom or ion during a chemical process. For example during rusting, iron is oxidised:

	$Fe_{(metal)}$	→	Fe_2O_3
Oxidation state of iron:	0		+3

The opposite process is called reduction and is the addition of electrons.

OIL RIG will help you remember which is which: Oxidation Is Loss, Reduction Is Gain

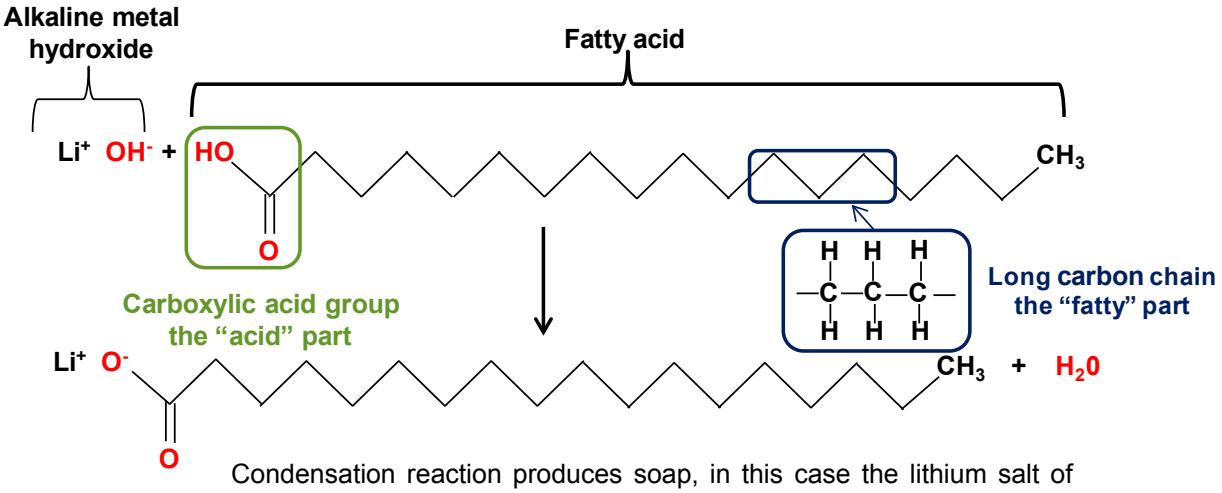
Deepwater Horizon

Oil spills are known for their destructive capacity, none more so than the recent Deepwater Horizon rig disaster in 2010. It is thought to have spilt 4.9 million barrels of crude oil before it was capped three months after the leak started.

Floating booms were used to collect surface oil. Dispersant chemicals were used on the surface and, for the first time, underwater at the point of the leak to try and disperse the oil.

Crude oil does not break down readily in sea water and as a result, large scale damage to the marine and coastal environments was caused. Biodegradable oils, while they are not designed to be released in such large quantities, do break down in the environment if released and are therefore favourable over mineral oils.

When the oil base has been chosen, the thickener must be selected. This increases the viscosity of the oil so that it stays in one place. Thickeners are usually soaps which are made by reacting an alkali metal hydroxide with a fatty acid, a process called saponification. This is shown in the reaction scheme below.



Condensation reaction produces soap, in this case the lithium salt of the carboxylate and water as a by product

Some esters can also be used as thickeners. These are normally polymers and can provide some lubricity as well as thickening the grease.

Additives are used in small quantities because they are very effective and usually quite expensive. A Croda example of an additive is Pripol™ which is a fatty acid polymer that modifies flow properties and prevents corrosion.

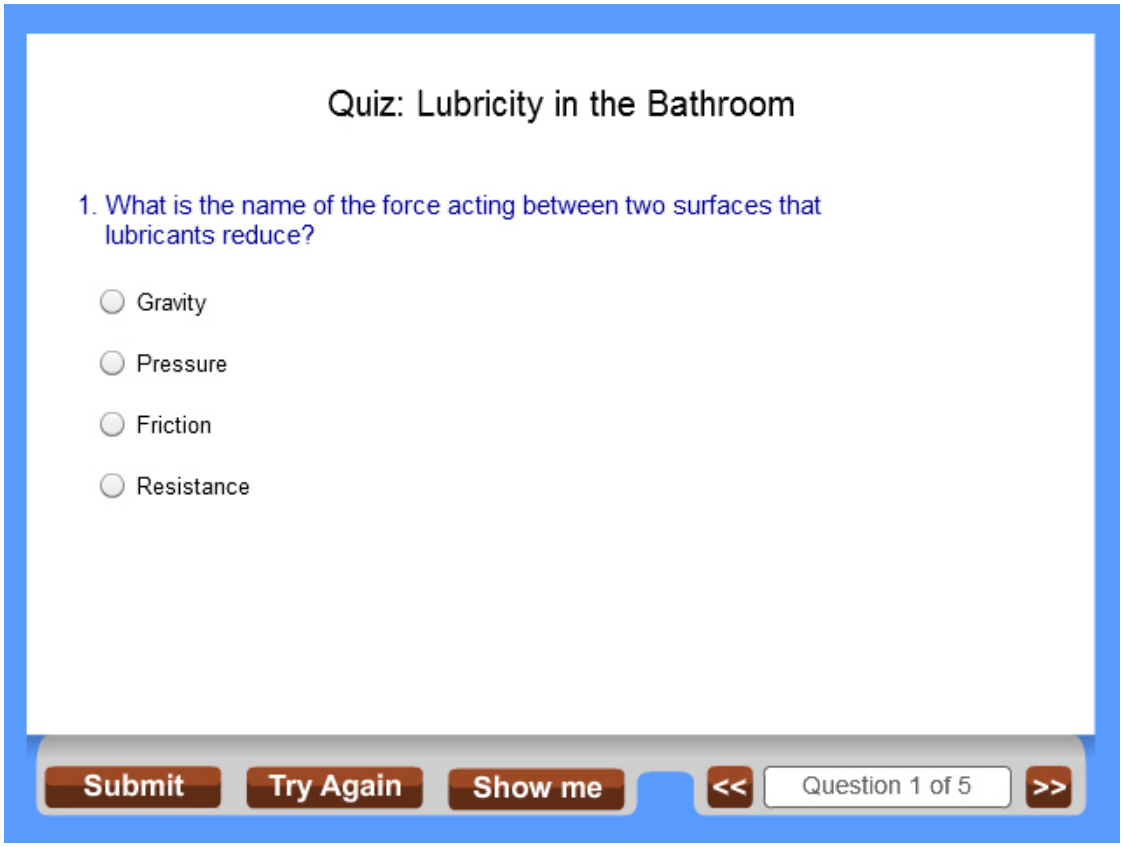
Conclusions

Lubricity is a property of some of the most important industrial chemicals in the world. Did you know that in 1999 there was an estimated 37,300,000 tonnes of lubricants used worldwide[1]? Without them there would be no manufacturing, no cars, or any kind of mechanical transport. There would be no motors or mechanisms at all and life would definitely be very different. Chemists are working hard all the time at places like Croda to come up with more environmentally friendly, more effective lubricants to keep the wheels of progress turning.

[1] Thorsten Bartels et al. "Lubricants and Lubrication" in Ullmann's Encyclopedia of Industrial Chemistry, 2005, Weinheim

Test your knowledge

Take the short quiz below to test your understanding of lubricity.



Become a Tribologist – A practical activity for students aged 14-16

Disclaimer:

Before carrying out any experiment or demonstration (or preparation work for these), teachers and technicians are responsible for complying with any of their employer's risk assessment requirements making use of up-to-date information and taking account of their own particular circumstances. Any local rules or restrictions issued by the employer must always be followed.

The study of lubricity is called tribology. Become a tribologist by testing how well different liquids lubricate.

1) Rub dry hands together vigorously – what happens? The skin warms up because of the friction caused by the movement.

2) If you now place an amount of lubricant between your hands and rub them again, you will find you have to rub harder or for longer to warm them up by the same amount. The better the lubricant, the harder it will be to warm your hands up.

3) Test several substances for their lubricity. Design your experiment to decide how to make it a fair test – what will you keep the same and what will you change with each substance? For example, variables include the force with which you rub your hands together, the time you rub them for and the amount of lubricant you apply for each test. What is the best way to work out how much heat your test has generated?

4) Rank your lubricants in order of their lubricity. What physical properties do the good lubricants have that the bad ones don't have? For example, is their viscosity different?

Suggestions of lubricant substances to test:

- Petroleum jelly
- Graphite
- Washing up liquid
- Water
- Hand cream
- Baby oil

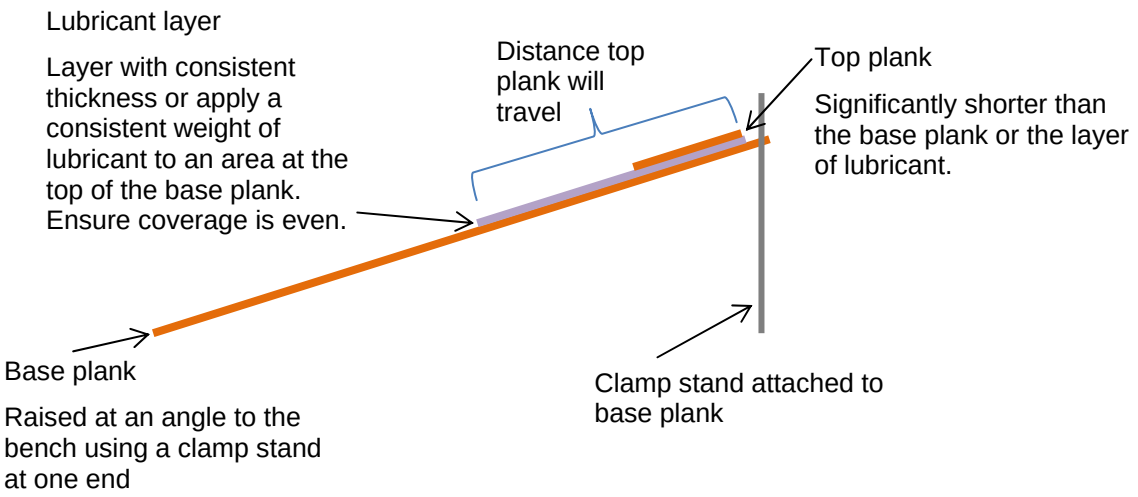
Extension activity for students aged 16-18 studying chemistry or physics

Students could conduct a more quantitative investigation into the lubricity of various substances.

Students conduct a literature study and report on the various methods for measuring lubricity in industrial chemistry and the basic chemistry surrounding a particular type of lubricant, for example, oils or greases.

The student can then design an experiment that they can use to test the lubricity of a range of substances falling into that category.

An example experiment could be constructing a testing rig similar to the one shown below to rank oils in terms of their lubricity.



Lubricants are applied in controlled amounts to the base plank. The top plank is placed at one end of the strip of lubricant and students time the plank sliding down the lubricant layer. Students can decide how best to apply lubricant, where to start and stop timing and what materials to make the planks from.