Standard operating procedure for entering the areas containing high field Nuclear Magnetic Resonance (NMR) instrumentation in Department of Chemistry, University of Oslo.

1. When entering the rooms containing the NMR instrumentation or the room (Ø 336) between NMR laboratories, or above or below these rooms (Ø 338, 340, Ø 334, Ø 332) each person must observe and obey the instructions given by the visual signals on the doors.

The room directly beneath the DRX 500 MHz magnet (closed storage part of Ø 242 – without any room identification) is closed for regular access due to the high magnetic field present under this unshielded magnet. The rooms (Ø 236 and Ø 242) to the left and right of this room (when facing towards the Physics building) have a stay field above 5 Gauss close to the windows and close to the walls to the prohibited room higher than 1.8-2.0 meter from the floor. Room Ø 242 (phone room) is having higher than 5 Gauss in parts of the room. Under the 200 MHz, 300 MHz, and under one of the two shielded 600 MHz magnets it was not possible to measure any enhanced magnetic levels (200 MHz, 300 MHZ and 500 MHz stay fields were measured in 1994/1995 directly after installation of these three NMR instruments with a handheld device borrowed from Biophysics section of the Department of Physics at UiO. A similar measurement was performed under the first installed shielded 600 MHz instrument (AV600) when it was installed in 2003. No measurable enhanced field was measured, probably due to the active shielding of magnet, thick floor/ceiling between the floor levels and massive iron reinforcement in the concrete in the floor dissipating the magnetic fields. No measurements have been performed under the second shielded 600 MHz (AVII600) instrument (installed 2005) and the shielded 400 MHz (AVII400) instrument (installed in 2010).

2. No one must enter these areas with an implanted pacemaker (heart rate stabilization device). A person who has been in a war zone and been exposed to for instance a grenade attach which have left iron shrapnel in the body must not enter the premises. A person with otherwise implanted magnetic material must not enter the NMR areas. Magnetic materials in the body might move upon exposure to the large magnetic fields. Not obeying these rules can result in severe harm or death.

3. Anyone should avoid carrying instrumentation, devices, cylinders containing compressed gas, PCs, electrical equipment of any kind or other items containing ferromagnetic material or other materials that can be attracted by the large magnetic fields in the NMR premises. The NMR magnets pull towards them all ferromagnetic items with extreme force. The magnetic field increases exponentially getting closer to the magnet and can cause unexpected or sudden pulling of ferrous objects. Carrying such items close to magnets is potentially deadly and might destroy instrumentation worth millions of kroner.

4. Moving close to the NMR magnets with credit cards, ATM cards and similar cards erases these cards. Watches might be destroyed inside the 5 Gauss lines marked either with yellow/black tape on the floor or with yellow/black fences.

5. It is forbidden to use and dispose any magnetic materials like for instance a staple, a screw driver and other small tools in the NMR rooms. A lost staple can stick to a magnet and be impossible to remove.

6. The NMR rooms are equipped with oxygen (O_2) sensors. These sensors will beep loudly when the oxygen level falls below life sustaining level due to a slow magnet quench. The rooms must be left immediately when these sensors start beeping and safety personnel and the "vakt and alarm sentral" must be informed immediately. The sensors are battery driven and give out a moderate warning sound and start blinking when batteries need to be exchanged. The NMR personnel must be informed immediately. If in doubt - evacuate the premises and put a big note on the doors that no one can enter.

7. Very seldom a fast magnet quench does occur. A fast magnet quench is seen by a large plume of gas coming out of the top of the magnet. Evacuate immediately. Press the fire alarm to evacuate the building. In case of an extreme evolution of Helium or Nitrogen gas from one of the NMR magnets a safety plate at the bottom of the magnet will fall out (to avoid explosion of the magnet vessel) with release of very cold liquid helium and/or nitrogen. In this case the gas pressure in the rooms will rise considerably and the people in the laboratory will be exposed to a triple hazard. The high gas pressure will blow open the aluminum safety windows to release the high gas pressure. In extreme cases the doors will be pushed open and into the outside corridors The wooden frames might be removed from the wall.
Firstly the liquid is extremely cold and the individuals present can sustain frostbites.
Secondly the individuals will not be able to take up sufficient oxygen and must leave immediately to avoid suffocation.
Thirdly the high pressure might inflict bodily harm.

8. No documentation indicates harmful effects upon fetus or mother in pregnancy from the permanent magnetic fields around NMR magnets. The policy of the NMR lab is to inform about this and at the same time inform about the recommendation for anyone to avoid being inside the industry norm of 5 Gauss of magnetic field for prolonged periods.

9. No documentation indicate harmful effects from the radio signals involved in nmr spectroscopic experimentation.

The section below (four pages) is taken from the vendor´s (Bruker Biospin Corp) Safety instructions:

Safety 2

Introduction 2.1

In terms of safety the presence of a relatively strong magnet is what differentiates NMR spectrometers from most other laboratory equipment. When designing an NMR laboratory, or training personnel who will work in or around the laboratory, no other feature is of greater significance. As long as correct procedures are adhered to, working in the vicinity of superconducting magnets is completely safe and has no known harmful medical side effects. Negligence however can result in serious accidents. It is important that people working in the vicinity of the magnet fully understand the potential hazards. **Of critical importance is that people fitted with cardiac pacemakers or metallic implants should never be allowed near the magnet.**

The magnet is potentially hazardous due to:

1. The large attractive force it exerts on ferromagnetic objects.
2. The large content of liquid nitrogen and helium.

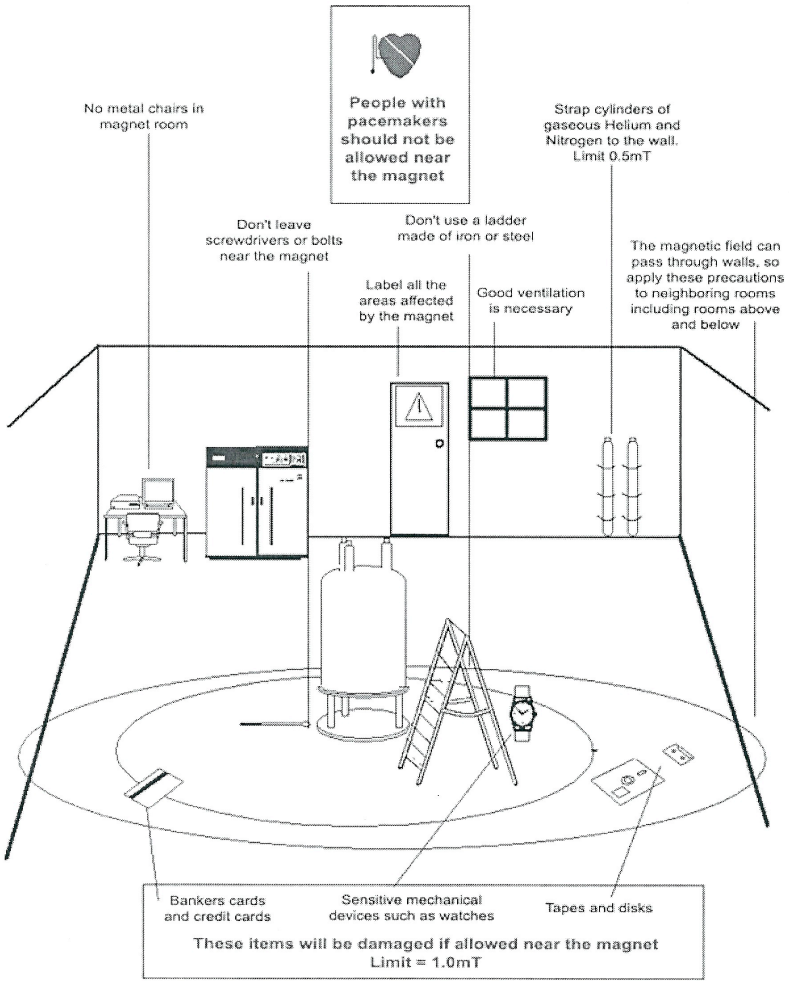
Magnetic Safety 2.2

A magnetic field surrounds the magnet in all directions. This field (known as the stray field) is invisible and hence the need to post warning signs at appropriate locations. Objects made of ferromagnetic materials, e.g. iron, steel etc. will be attracted to the magnet. If a ferromagnetic object is brought too close, it may suddenly be drawn into the magnet with surprising force. This may damage the magnet, or cause personal injury to anybody in the way!

Because the strength of the stray field drops significantly as one moves away from the magnet, it is useful to discuss safety in terms of two broadly defined regions, the inner and outer zone. In terms of organizing a laboratory as well as defining good work practices, the concept of an inner and outer zone is particularly useful.

The physical extent of these two zones will depend on the size of the magnet. The bigger the magnet, the stronger the stray magnetic fields and hence the larger the extent of the two zones. ***Figure 2.1.*** shows the concept of the two zones (not drawn to scale). Details of stray fields for various magnets can be found in the Site Planning Guides delivered with the BASH CD.

Figure 2.1. Safety Precautions within the Inner and Outer Zones



Safety Precautions within the Inner Zone *2.2.1*

The inner zone extends from the magnet center to the 1mT (10 Gauss) line. Within this region objects may suddenly be drawn towards the magnet center. The attractive force of the magnet can change from barely noticeable to uncontrollable

within a very short distance. **Under no circumstances should heavy ferromagnetic objects be located or moved within this zone**.

Any ladders used when working on the magnet should be made of non-magnetic material such as aluminum. Helium and nitrogen dewars which are used to top up the liquid levels inside the magnet must be made of non-magnetic material.

Do not allow small steel objects (screwdrivers, bolts etc.) to lie on the floor near the magnet. These could cause serious damage if drawn into the magnet bore, especially when no probe is inserted in the magnet.

Mechanical watches may be damaged if worn within the inner zone. Digital watches can be worn safely. Of course, the precautions for the outer zone which will now be discussed must also be adhered to within the inner zone.

Safety precautions within the outer zone 2.2.2

The outer zone extends from the 1mT line to the 0.3mT line. The magnet's stray field does not get blocked by walls, floors or ceilings and the outer zone may well encompass adjoining rooms. The stray field may erase information stored on magnetic tapes or discs. Bank cards, security passes or any devices containing a magnetic strip may be damaged. CD's will not be damaged, although CD drives may contain magnetic parts. When using pressurized gas cylinders made of steel, they should be located well beyond the outer zone (preferably outside the magnet room) and must always be properly fixed to the wall. The color display of computer monitors may suffer some distortion when located too close to the magnet, although permanent damage is unlikely. Once beyond the outer zone any special precautions on account of the magnet stray field are no longer necessary.

Cryogenic Safety 2.3

The magnet contains relatively large quantities of liquid helium and nitrogen. These liquids, referred to as cryogens, serve to keep the magnet core at a very low temperature.

Because of the very low temperatures involved, **gloves**, a **long sleeved shirt or lab coat** and **safety goggles** should always be worn when handling cryogens. Direct contact with these liquids can cause frostbite. The system manager should regularly check and make sure that evaporating gases are free to escape from the magnet, i.e. the release valves must not be blocked. Do not attempt to refill the magnet with helium or nitrogen unless you have been trained in the correct procedure.

Helium and nitrogen are non-toxic gases. However, because of a possible **magnet quench**, whereupon the room may suddenly fill with evaporated gases, adequate ventilation must always be provided.

Electrical Safety 2.4

The spectrometer hardware is no more or less hazardous than any typical electronic or pneumatic hardware and should be treated accordingly. Do not remove any of the protective panels from the various units. They are fitted to protect you

and should be opened by qualified service personnel only. The main panel at the rear of the console is designed to be removed using two quick release screws, but again, this should only be done by trained personnel. Please note that, unless disconnected, cooling fans on the rear panel will continue to run even with the panel removed.

Chemical Safety 2.5

Users should be fully aware of any hazards associated with the samples they are working with. Organic compounds may be highly flammable, corrosive, carcinogenic etc.

CE Certification 2.6

All major hardware units housed in the AVANCE with SGU consoles as well as peripheral units such as the HPPR, shim systems, probe and BSMS keyboards comply with the CE Declaration of Conformity. This includes the level of any stray electromagnetic radiation that might be emitted as well as standard electrical hazards. Note that to minimize electromagnetic radiation leakage, the doors of the console should be closed and the rear paneling mounted.

Further extensive safety information concerning superconducting magnets and safety are found in the following pdf appendixes:

Documentation concerning magnetic stay fields from Nuclear Magnetic Resonance (NMR) instruments at Department of Chemistry University of Oslo.

Safety_Notes_NMR_magnets.pdf
Safety_Recommendations_NMR_Magnets.pdf
Maintenance_Cryo_NMR_Magnets.pdf
NMR_Magnet_System_Nitrogen_Refilling.pdf and
NMR_Magnet_System_Helium_Refilling.pdf which must be read in conjunction with the previous NMR-Magnet_System_Nitrogen_Refilling.pdf document.

Tips and tricks in the NMR laboratories.

In NMR, unlike other types of spectroscopy, the quality of the sample has a profound effect on the quality of the resulting spectrum. So that the sample you prepare gives a spectrum in which useful information is not lost or obscured, you must follow a few simple rules.

1) Use the Correct Quantity of Material.

For one dimensional ^{1}H spectra of organic compounds (except polymers) the quantity of material required is often about 5 to 20 mg. It is possible to obtain spectra from smaller quantities, but at very low concentrations, the peaks from common contaminants such as water and grease tend to dominate the spectrum. 13C is *six thousand times* less sensitive than 1H, and a good rule of thumb is to provide as much material as will give a saturated solution. If about 0.25 mill moles can be dissolved in 0.5 ml, the ^{13}C spectrum will take no more than about half an hour to acquire. If the quantity of material is halved, the data accumulation time will be quadrupled. You should be aware that if you make up a sample at high concentration for ^{13}C, and then record a ^{1}H spectrum from it, the increased solution viscosity may result in a spectrum that has broader lines than you would get from a more dilute solution. The higher the magnetic field the less sample you need.

2) Remove Solid Particles.

Solid particles distort the magnetic field homogeneity because the magnetic susceptibility of a particle is different from that of the solution. A sample containing suspended particles thus has a field homogeneity distortion around every single particle. This causes broad lines and indistinct spectra that cannot be corrected. So that there are no solid particles in your samples, you must filter ALL samples into the NMR tube. You should filter samples through a small plug of glass wool tightly packed into a Pasteur pipette. If the plug is not tight enough, the filtration will be ineffective; if it is too big, some of your sample will remain trapped in it. Do not use cotton wool, since most NMR solvents dissolve material from the wool, which can easily be seen in ^{1}H spectra. After filtration the sample should be as clear as water though, of course, not necessarily colorless.

3) Make Samples to the Correct Depth.

In the magnet, the main field direction is vertical, along the length of the sample. Each end of the sample causes a major distortion of the field homogeneity, which is corrected using the spectrometer's shim controls. A partial correction is done for every sample, and takes a few minutes. A complete correction takes many hours using a high quality test sample. So that this lengthy task need be done as seldom as possible, your samples must be prepared so that they physically resemble the test sample so, after filtration; they must be made up to a similar depth. The samples must be 4 cm high. Shorter samples are very difficult to shim, and cause considerable delay in recording the spectrum. Samples that are too

long are also difficult to shim and are a waste of costly solvent. You should check your sample depth using a ruler. After preparation, you should ensure that the cap is pushed fully onto the tube to minimize solvent loss through evaporation.

4) Use Deuterated Solvents.

Samples must be prepared using solvents that contain deuterium in place of hydrogen. The NMR signal from the deuterium nuclei is called the NMR lock and is used by the spectrometer for stabilization. Deuterated solvents ($CDCl_3$, D_2O, $DMSO_{d6}$, CD_3OD, $Acetone_{d6}$, $Acetonitrile_{d3}$, $Benzene_{d6}$) are provided along with pipettes and syringes in the fume hood in Ø 340 for free use for users from the Department of Chemistry. Users from other locations are of course free to use the hoods but must bring their own supplies. All of the mentioned solvents, except for CDCl3 are placed in an exccicator (and have to be restored there after use). Methylene $chloride_{d2}$ has to be acquired on own/supervisors account. Other, more unusual deuterated solvents may be provided on request for one or at least a small amount of samples. Larger amounts have to be acquired on own/supervisors account.

5) Use Clean Tubes and Caps.

NMR-users from the Department of Chemistry (Kjemisk institutt) will get NMR-tubes at the Departments Central Store on their (supervisors) own account. After use NMR tubes they should be rinsed with clean acetone or some other suitable solvent, then dried with a blast of dry air or nitrogen. Be advised that acetone is hard to remove completely form NMR tubes. Do NOT dry tubes in a hot oven because it does not remove solvent vapor effectively, and solvent peaks will appear in your spectrum. Furthermore the tubes might bend if dried at high temperature. Tubes must be capped, and caps should be treated the same way as tubes. You must not use NMR tubes with a chipped or broken top because they are dangerous, and very likely to splinter lengthwise.

6) Label and Remove Your Samples.

This is best done with a permanent marker directly on the top of the tube, or on the cap. If you use a sticker or a piece of tape, your label must stick smoothly on the tube. Do not leave a flap. Remember that the tube has to spin at 20Hz (1200rpm) while it is in the magnet. If a sticker is lost in the magnet a lengthy procedure has to be performed to remove it. Remove your samples from the NMR laboratories. Sample tubes floating around in the labs or left in the BACS carousels will be put in the hazardous waste bin in the rightmost hood in Ø 340 without any warning.

7) Possible use of internal reference.

At earlier times a reference compound was always added to NMR solvents. Nowadays we do not regularly do this. Referencing is done with the help of the

residual 1H signal in the deuterated solvents. Tetra methyl silane (TMS) can be added to the sample as internal standard if needed is placed in the refrigerator along with a 10µl syringe. TMS-sodium salt (as internal standard for D_2O solutions) is to be found in an exccicator within the fume hood. Glass wool and cotton wool for filtration is provided in an exccicator within the fume hood. Glass sample vials (with plastic snap-cap) of two different sizes are to be found in the first and second top drawer to the left under the fume hood.

8) Degassing Samples.

Some samples might need to be degassed or have oxygen removed. The most effective way of doing this is by using the Freeze-Pump-Thaw technique, at least three cycles. Another method is to blow helium through the sample, be aware of danger of blowing away your sample and solvent. It is sometimes sufficient to flush the space above the sample surface with nitrogen. This should be done with great care to avoid blowing the solution out of the tube. Do *not* bubble nitrogen through the solution in an NMR tube. This wastes costly solvent through evaporation, and is not an effective method of removing oxygen.

9) Depth Gauge

Do not put the spinner into the depth gauge before inserting the tube into the spinner. It is very easy to break off the bottom of the tube if the spinner is held too rigidly. Put the tube and spinner into the depth gauge and push the tube to the bottom.
If you break a tube while inserting into the spinner please clean the spinner with isopropanol. Use no other solvent! Wear gloves if necessary. Check that there is no glass inside the spinner! Do not put the depth gauge alone or together with the spinner/tube into the magnet. If you by accident do it please report it to the staff immediately and leave a note in front of the computer screen and send an e-mail message to nmr-users@kjemi.uio.no describing the incident so other can plan for not using the nmr instrument.

10) BACS 60/120 Sample Changer.

Look at the ICONNMR screen for the next available location. The same location numbers are shown physically on the BACS sample changer. Put your sample at the desired location. For the BACS 120 system at the AVII 400 nmr spectrometer there are two easily confused parts. Locations 1-60 are in the inner oval and positions 61-120 at the outer oval ring. The sample changer is running in automation all time. The robot fingers are strong and may cause personal injury. The robot arm may move quickly and is physically strong, watch out when samples are being changed. Never put anything under the robot fingers. Do not put empty spinner on the rack. Put them in the empty spinner trays. There is a red emergency stop button that stops the robot immediately. Press the emergency stop the robot is about to hit a person or have grabbed a person. Never remove the sample left in front of the electronic device that keeps track of

the positional identity of the samples on the DPX 300 system. If this sample - the last one run - is removed the software crashes on this instrument.

11) Do not lean on magnets.

Do not lean on the top of the magnet. It might fall over.

12) Use the web booking system.

The web booking is found at:
http://www.mn.uio.no/kjemi/english/research/about/infrastructure/nmr/booking/

13) Use written instructions.

Use the written instruction/manuals when performing new experiments. Manuals are found at:
http://www.mn.uio.no/kjemi/english/research/about/infrastructure/nmr/manuals

Use the following manual for basic one dimensional experiments:
http://www.mn.uio.no/kjemi/english/research/about/infrastructure/nmr/manuals/kjm-mena4010/One-dimensional-1H-13C-15N-19F-31P-NMR-with-TopSpin-1.3-Desember-2009-ver2.pdf

Use the following manual for ICONNMR/BACS automation experiments on instruments DPX300, AVII400 and AV600:
http://www.mn.uio.no/kjemi/english/research/about/infrastructure/nmr/manuals/kjm-mena4010/DPX300-Iconnmr-Bacs-sample-changer-with-XwinNmr-3.5-and-TopSpin-1.3.pdf

Use the following instructions for remote processing 8for instance from home):
http://www.mn.uio.no/kjemi/english/research/about/infrastructure/nmr/manuals/kjm5250/Remote-processing-with-Topspin-1.3.pdf

14) Get personal help.

When in need of nmr experiments at temperatures outside (high or low) the standard temperature (25 degree Centigrade) set on the spectrometers you must request personal help from the nmr staff. Similarly when you are unsure about a procedure please always ask for help.