

Name _____

Chemistry 392 Physical Chemistry II Lab Manual



Chemistry Department • College of William and Mary • Sixth Edition

Safety in the Laboratory

I. Preparing for the laboratory

1. Shoes **must** be worn in the laboratory at all times. **Open-toed shoes or sandals are not allowed.**
2. Avoid loose clothing and confine loose hair before entering the laboratory. Dangling clothing or hair is a fire hazard.
3. Wear appropriate work clothes to lab. Even with careful habits, work stains and holes are common in lab wear.
Lab aprons are recommended but not required. Aprons are available at the College Bookstore.
4. Read and understand the procedure **before** carrying out the exercise. Before lab is the appropriate time for study.

II. While working in the laboratory

1. **Chemical splash goggles must be worn at all times.** (Virginia law) Prescription glasses may be worn **under** the splash goggles. Contact lenses are a hazard in the laboratory because they absorb and concentrate chemical fumes.
2. **No food is allowed in the laboratory.** Do not eat, drink, lick your fingers or rub your eyes while in the lab. Wash your hands frequently during lab and just before you leave.
3. **Never put broken glass in a trash can!** Discard it in a designated broken glass container.
4. Handle chemicals with care. You should consider all organic chemicals to be flammable, toxic or both. Never taste chemicals or deliberately breathe their vapors. Avoid contact between chemicals and skin or clothing. Wipe up spills immediately—especially near the balances and on bench tops or reagent dispensing area. Replace caps on bottles and jars promptly. Wipe spills from the outside of reagent bottles before leaving them.
5. **NEVER** light a burner until you have surveyed the area and found it free from flammable liquid and gases.
6. Support apparatus firmly with clamps to prevent the equipment from falling or getting knocked over.
7. Dispose of waste chemicals and solvents in a suitable manner. Special waste containers are furnished for some dangerous chemicals. Others, where soluble in water, may be flushed down the drain followed by copious amounts of water. If you have questions concerning disposal of any chemical, consult the instructor.
8. Cell phones, iPods or similar devices with earphones may not be used—these distractions may impair lab safety.

**Physical Chemistry II
Laboratory Manual**

CHEMISTRY 392

Sixth Edition

**Department of Chemistry
College of William and Mary**

The first essential in chemistry is that thou shouldst perform practical work and conduct experiments, for he who performs not practical work nor makes experiments will never attain to the least degree of mastery.

Jabir ibn Hayyan (ca. 721-815), said to be an alchemist at the court of Baghdad

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Chem 392 General Information

Course

The structure of Chemistry 392 will be somewhat different than that of 391. Chem 392 has a site on Blackboard that contains the experiments, announcements, supplementary information, and modifications to lab procedures. Eight experiments are planned, each requiring a lab report. Students will work in pairs, following the posted Chem 392 schedule. Some experiments may have start times that differ from 1:00 pm, as identified in the schedule. Students are expected to come to lab prepared and to submit a written answer to a question about that experiment.

The experiments are posted on Blackboard. Most begin with a one- to two-page summary, followed by instructions for performing the experiment. Detailed theory and guidelines for analyzing the results follow. Each description ends with a list of references, which may include sections in Engel and Reid. Some references have values of the parameters being measured; these can be useful for making comparisons in lab reports. The book *Experiments in Physical Chemistry* by C. W. Garland, J. W. Nibler and D. P. Shoemaker, (8th Edition, McGraw Hill, 2009; abbreviated in this manual as GNS) is available in Swem Library for your reference.

Lab Reports

Science has little or no lasting value if measurements, observations and discoveries are not effectively communicated. Scientists need to describe and evaluate their studies in a clear and concise manner. The Chem 392 lab reports offer W&M chemistry students the opportunity to develop their scientific writing skills.

A lab report should be submitted for each of the eight experiments. A list of the required information to be included in each lab report is listed at the end of each experiment. These include a short statement of the purpose of the experiment, a summary of experimental (or computational) observables, derived quantities, and answers to any questions found in the manual. A **brief conclusion** that contains a final summary, comparison to the literature (if indicated), and potential sources of error is also expected. Spectra, graphs and other paper output from instruments or Xerox copies thereof, should be labeled and stapled to the back of the lab report.

In all cases, each student's report must be his or her own work. Collaboration in the calculations or writing of the report is not allowed, except in constructing the Deslandres table in the N₂ Lab (see the experimental procedure for details).

Lab Notebooks

A lab notebook should be maintained as described in the Chem 391 Laboratory Manual (General Information) and in GNS (pp. 7–9). Students may continue to use the notebook from Chem 391. Students are required to bring notebooks to each lab.

Grading

Lab reports constitute 150 points. Each lab report carries a point value ranging from 15 to 25 points depending on the level of analysis. Laboratory reports are due as indicated on the Chem 392 schedule. Note the lab report for an experiment is due after all students have completed the lab. Lab reports should be submitted at 1:00 pm in lab or to Prof. Wustholz when lab is closed (a folder will be placed outside ISC 2041 for this purpose). Consistent with the Chem 391 policy, students are allowed two free week-late reports to be used at your discretion. Please label the free late reports with “Late Report 1”, etc. Additional late reports turned in within seven days of the due date will be penalized by 25%. Reports that are more than seven days late will be penalized by 50%.

Passing grades will be awarded to students who participated in the eight experiments and submitted eight passing lab reports. If two or more reports are outstanding after 5:00 pm on the last day of classes, the course grade will be no higher than D –. **No reports will be accepted after 5:00 pm on the last day of classes.**

In addition to credit for lab reports, 10% of the final grade is determined by laboratory technique and citizenship. Being a good lab citizen means arriving on time, being prepared, sharing lab resources and cleaning up.

Lab	Points	Grader
1 Computational I	15	Wustholz
2 NMR	15	Wustholz
3 IR	20	Wustholz
4 N ₂	25	Bagdassarian
5 Unimolecular Decomposition	20	Bagdassarian
6 MS	20	Wustholz
7 Cavity Ring-down Spectroscopy	20	Wustholz
8 Computational II	15	Wustholz

Other matters

A. Breakage

Each student has the responsibility to report directly to the instructor or to the lab specialist any breakage for which he or she is responsible.

B. Clean-up

Each student is expected to leave the site of the experiment in good order at the end of the day. Glassware should be cleaned thoroughly, the lab bench wiped off, used paper discarded, and glassware and equipment returned to their designated storage areas.

C. Laboratory safety

Students are expected to follow the Departmental Safety Guidelines on the inside covers of this manual and to use good judgment to minimize hazards and the potential for injury in the laboratory. **Wearing safety glasses is the personal responsibility of each student.** Safety glasses can be purchased in the Bookstore. Please cooperate in making the laboratory a neat and safe place to work.

Safety in the Laboratory concluded

During the first laboratory period

1. Locate the fire extinguishers; however, in case of a large fire, get yourself and others well away from the danger.
2. Locate the emergency eye-washes and shower in and near your lab. If a mishap involving the eyes occurs, wash them at an eye-wash fountain for a minimum of 15 minutes. Report all injuries no matter how minor.
3. Inform the instructor early in the semester of any allergies, sensitivities or other medical conditions (including pregnancy) which might be aggravated by exposure to chemicals or chemical fumes.

Just before leaving the laboratory

1. Clean the bench top with towel and water. Make certain that all laboratory equipment is properly stored.
2. Check the gas valves—make certain they are turned off!

At all times — in and out of the laboratory

Use common sense. If something looks dangerous, it probably is. If someone near you appears to be using poor judgment, help him or her out. Point out the hazard. An accident prevented is an important and valuable service, not only for that person but for everyone whose time would be wasted.

Numerical Constants

$$\begin{aligned} R &= 8.314 \text{ J/mol-K} &= 0.08205 \text{ L-atm/mol-K} \\ &= 1.987 \text{ cal/mol-K} &= 62.36 \text{ L-torr/mol-K} \end{aligned}$$

$$1 \text{ atm} = 101.325 \text{ kPa} = 760 \text{ torr}; 1000 \text{ microns} = 1 \text{ torr}$$

$$p^\circ = 1 \text{ bar} = 0.98692 \text{ atm}$$

$$1 \text{ L} = 1 \text{ dm}^3$$

$$T(\text{K}) = T(\text{C}) + 273.15$$

$$\ln_e A = (\log_e 10) (\log_{10} A)$$

Periodic Table of the Elements

1	1																2				
H 1.008	2																He 4.003				
3	4	3										4				13	14	15	16	17	18
Li 6.941	Be 9.012															B 10.81	C 12.01	N 14.01	O 16.00	F 19.00	Ne 20.18
11	12	3										4				13	14	15	16	17	18
Na 22.99	Mg 24.31															Al 26.98	Si 28.09	P 30.97	S 32.07	Cl 35.45	Ar 39.95
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36				
K 39.10	Ca 40.08	Sc 44.96	Ti 47.88	V 50.94	Cr 52.00	Mn 54.94	Fe 55.85	Co 58.93	Ni 58.69	Cu 63.55	Zn 65.39	Ga 69.72	Ge 72.59	As 74.92	Se 78.96	Br 79.90	Kr 83.80				
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54				
Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.94	Tc (98)	Ru 101.1	Rh 102.9	Pd 106.4	Ag 107.9	Cd 112.4	In 114.8	Sn 118.7	Sb 121.8	Te 127.6	I 126.9	Xe 131.3				
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86				
Cs 132.9	Ba 137.3	La* 138.9	Hf 178.5	Ta 180.9	W 183.9	Re 186.2	Os 190.2	Ir 192.2	Pt 195.1	Au 197.0	Hg 200.6	Tl 204.4	Pb 207.2	Bi 209.0	Po (209)	At (210)	Rn (222)				
87	88	89	104	105	106	107	108	109	110	111	112					114	116				
Fr (223)	Ra 226.0	Act 227.0	Rf (261)	Db (262)	Sg (263)	Bh (262)	Hs (265)	Mt (266)	Ds (271)	Rg (272)	Cn (277)					Fl (287)	Lv (289)				

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58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce 140.1	Pr 140.9	Nd 144.2	Pm (145)	Sm 150.4	Eu 152.0	Gd 157.3	Tb 158.9	Dy 162.5	Ho 164.9	Er 167.3	Tm 168.9	Yb 173.0	Lu 175.0
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th 232.0	Pa 231	U 238.0	Np 237.0	Pu 244	Am (243)	Cm (247)	Bk (247)	Cf (251)	Es (252)	Fm (257)	Md (258)	No (259)	Lr (262)