

An Introduction to Chemical Research

Guidelines for Success

Ruth Ann Murphy



CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

Contents

Preface.....	xix
Acknowledgments.....	xxi
About the Author.....	xxiii

UNIT I The Five W's of Chemical Research 1

Chapter 1	The <i>What</i> of Chemical Research.....	3
1.1	Definitions for Chemical Research.....	4
1.2	Essential Elements of Chemical Research.....	5
	Chemical Research Must Include Chemistry!	5
	Chemical Research Must Be Novel	7
	Chemical Research May Be Classified as Applied or Theoretical (Pure).....	8
	Chemical Research Must Be Focused.....	8
	Chemical Research Must Be Accurate.....	9
	Chemical Research Must Be Analytical	10
1.3	More Elements of Chemical Research.....	13
	Chemical Research Should Be Timely	13
	Chemical Research Should Be Documented	13
	Chemical Research Should Be Pronounced Correctly (The Last Word).....	13
Chapter 2	The <i>Who</i> of Chemical Research.....	16
2.1	Essential Elements of a Successful Chemical Researcher.....	17
	Academic Preparation.....	17
	Natural Curiosity.....	18
	Work Ethic	18
	Commitment to Lifelong Learning	20
	Teamwork Enthusiast.....	20
2.2	Some Myths Concerning Chemical Researchers.....	21
	Chemical Researchers Must Be Geniuses with Ultra-High IQs.....	21
	Chemical Researchers Must Be in Their Mid-Twenties	21
	Chemical Researchers Are All the Same	21
	Chemical Researchers Work Alone – in a Lab with a Lot of Test Tubes	22
	Chemical Researchers Stay in Their “Ivory Towers” and Are Not Interested in Everyday Events	22

Chapter 3	The <i>Why</i> of Chemical Research	25
3.1	The Positive Potential of Chemical Research	26
	Chemical Research Can Lengthen the Lifespan	26
	Chemical Research Can Improve the Quality of Life.....	26
	Chemical Research Can Correct Errors	26
	Chemical Research Can Protect the Public from Charlatans	27
	Chemical Research Can Safeguard a Country's Economy.....	27
	Chemical Research Can Fortify a Country's Defense System	27
	Chemical Research Can Increase the Body of Knowledge.....	28
3.2	Some Current and Urgent Opportunities in Chemical Research.....	28
	Medical Needs	28
	Environmental Concerns.....	28
	Aesthetic (Promoting Beauty and Artistic Taste) Benefits.....	29
3.3	A World without Chemical Research.....	29
	Healthcare Problems Soar.....	29
	Environmental Necessities Languish	29
	Efficiency Deteriorates.....	30
	Shortages of Materials Emerge	30
Chapter 4	The <i>When</i> of Chemical Research	33
4.1	Prioritizing Chemical Research	34
	Sufficient Time	34
	Research-Focused Universities	34
	Teaching-Focused Universities	35
	Importance of Scheduling	35
4.2	Scheduling Chemical Research.....	35
	Availability of Resources	35
	Type of Reaction or Study	36
	Technical Support	36
	Time Preferences of Researcher	37
4.3	Competing in Chemical Research.....	37
	Competition Between Labs.....	37
	Historical Reminder	37
4.4	Selecting Timely Topics.....	38
	Today's Topics of Interest	38
	Yesterday's Topics.....	38

Chapter 5	The <i>Where</i> of Chemical Research	40
5.1	Considerations for Selecting a Research Site	41
	Safety	41
	The Priority of Research	41
	Major Specializations.....	42
	Laboratory Resources	42
	Support Personnel	42
	Access and Ownership.....	42
	Academic, Governmental, and Industrial Sectors.....	43
	Restrictions	43
	Personal Preferences	43
5.2	An Exploration of Types of Research Sites	44
	United States or International	44
	Field Work.....	44
	Personal Property	44
	Interdisciplinary Centers.....	44

UNIT II The How of Chemical Research 49

Chapter 6	Graduate School: A Powerhouse for Chemical Research	51
6.1	Considering Graduate School–To Go or Not	
	To Go? That Is the Question!	52
	Greater Responsibility	52
	Higher Income	52
	An Exhilarating Experience	53
	Negatives.....	54
6.2	Coming Up with a Short List – What Are the Best Possibilities?	54
	Number of Schools	54
	Types of Graduate Degrees	54
	Considerations	55
6.3	Applying to Graduate School – A Multi-Step, Chain Reaction!	56
	Instructions	56
	Documents	56
	Standard Tests	56
6.4	Paying for Graduate School – “There’s No Free Lunch”?.....	58
	Financial Support.....	58
	Time	58
6.5	Selecting a Graduate School – A Momentous Decision!.....	58
6.6	Attending a Graduate School – A Boundless Opportunity!.....	59
	Phase One: Coursework	59
	Phase Two: Research Emphasis	59
	Phase Three: Dissertation and Graduation.....	60
	Opportunities.....	61

Chapter 7	Ethics: An Essential Element of Chemical Research	63
7.1	The Importance of Ethics in Chemical Research.....	64
7.2	Artificial Intelligence (AI) in Chemistry: A Double-Edged Catalyst	66
	Introduction: The New, Indispensable (?) Lab Assistant	66
	The Promise: Accelerating Discovery and Innovation.....	67
	The Perils: Navigating the Ethical Tightrope.....	67
	Conclusion: Charting a Responsible Course	67
7.3	Specific Actions Required for Ethical Chemical Research.....	68
	Conscientious Supervision.....	68
	Responsible Communication	68
	Commitment to Excellence.....	70
	Appropriate Citations.....	70
	Strict Adherence to the Law.....	70
	Concern for Others.....	71
	Prevention of Bias.....	71
	Standards of Conduct.....	71
	Compensation Criteria	71
	Stewardship of Resources	71
	A Love of Learning.....	72
Chapter 8	Safety: Another Essential Element of Chemical Research.....	74
8.1	A Tragic Chemical Research Incident	75
8.2	An Act of Congress: OSHA Is Created.....	76
	The Creation of OSHA	76
	Safety Data Sheets (SDSs).....	77
	Chemical Hygiene Plan (CHP)	77
8.3	Chemical Research Hazards and Protective Measures	78
	Chemical Hazards	78
	Physical Hazards.....	79
	Biological Hazards.....	79
	Personnel and Visitor Hazards	79
	Other Hazards	80
	Artificial Intelligence (AI)	82
8.4	A Plan for Safety in Chemical Research.....	82
8.5	Safety Supplies and Equipment for the Chemical Research Lab.....	84
	Standard Lab Safety Equipment	84
	Further Information.....	84
8.6	Keys to Maintaining a “Culture Of Safety”	85
	Key 1. Avoiding Accidents.....	85
	Key 2. Respecting Chemicals	85
	Key 3. Planning Experiments.....	85
	Key 4. Labelling Containers	85

Key 5. Limiting Furnishings	85
Key 6. Removing Clutter	86
Key 7. Banning “Lone Wolf” Research	86
Key 8. Dressing Appropriately.....	88
Key 9. Remaining Observant	88
Key 10. Working Outdoors Safely	88
Key 11. Managing Unknown Risks	88
Key 12. Harnessing Technology: Friend or Foe?.....	89
Key 13. Working Responsibly	89
Key 14. Sharing Information	89
Key 15. Dealing with Pregnancy	90
Key 16. Remaining Knowledgeable	90

Chapter 9	Hazardous Waste Management: Some Rules for Chemical Research	94
9.1	Some History of Hazardous Waste Management.....	95
9.2	The Case for Hazardous Waste Management	97
9.3	Some Basic Principles of Hazardous Waste Management.....	97
9.4	Methods for Hazardous Waste Management	100
	Careful Planning	100
	Accurate Reporting	100
	Selecting and Preparing Chemicals for Disposal.....	100
	Collaborating.....	101
	Considerations for Dealing with a Disposal Company.....	101
	Classifications of Waste Generators.....	102
	Additional Information	103
Chapter 10	Topic Selection: A Seed of Chemical Research	107
10.1	Considerations in Topic Selection for Chemical Research.....	108
	The Researcher’s Interests	108
	Uniqueness of the Topic.....	109
	Qualifications for the Study	110
	Costs of Supplies.....	110
	Equipment Costs	110
	Time Constraints	111
10.2	Resources for Topic Selection in Chemical Research.....	111
	The Scientific Literature	111
	Conference Presentations.....	112
	Artificial Intelligence (AI)	112
	Chemistry and Related Textbooks	113
	Communications with Colleagues	113
	Current Events	113

Other Disciplines	114
Personal Experiences	115
Chapter 11 The Scientific Method: A Foundation of Chemical Research	117
11.1 The Scientific Method – A Parts List	118
11.2 More Products of the Scientific Method – Laws and Theories.....	119
Laws	119
Theories.....	122
11.3 Friction and Phlogiston Explained – The Scientific Method to the Rescue!	123
Friction.....	123
Phlogiston	123
Chapter 12 Research Project Design: A Plan for Chemical Research	126
12.1 Is the Project Design Contemporary?	127
12.2 Is the Project Design Fundable?	128
12.3 Is the Project Design Ethical and Legal?	128
12.4 Can the Project Be Completed in a Safe Manner?.....	130
12.5 Is the Project Design Sufficiently Focused?	130
12.6 Is the Project Design Interesting?	130
12.7 What Resources Are Needed for the Project?.....	131
12.8 What Are Some Useful Terms for Research Project Design?	132
12.9 How Does the Chemical Researcher Plan for Success?	135
Chapter 13 Literature Searches: Ideas for Chemical Research.....	139
13.1 Librarians and Related Specialists	141
13.2 Journals	141
Peer-Reviewed, Refereed, or Scholarly Journals	141
Non-Peer-Reviewed Journals.....	142
13.3 Platforms	142
13.4 The Internet.....	143
13.5 Handbooks	143
13.6 Other Titles and Sources	144
13.7 Recommendations for Literature Searches	145
Chapter 14 Financial Support: Fuel for Chemical Research.....	150
14.1 The Need for Grant Funding.....	151
Personnel Stipends	151
Instrumentation Costs	152
Travel Expenses	152

	Publication Fees	152
	Conclusion	152
14.2	Types of Grants	152
	Portable and Non-Portable Grants	152
	Equipment and Special Purpose Grants	153
	Internal and External Grants	153
	Grants with Special Restrictions	153
14.3	The Process of Grant Funding	153
	The Origins of Foundations	153
	Concerns of Foundations	153
14.4	Selecting the Foundation.....	155
	Eligibility	155
	Goals	155
	Assets	156
	Policies	156
14.5	Requirements for a Grant Application	156
	Getting Started – A Word of Warning	156
	Following Instructions	157
	Letter of Intent	157
	Proof of Resources	157
	Historical View.....	158
	Accreditation and Status	158
	Administrative Support	159
	The Budget.....	159
14.6	Managing Chemical Research Grants.....	161
	Arrival of Funds	161
	Approvals	161
	Grant Revisions.....	161
	Unused Funds.....	161
	Summary	166
Chapter 15	Procurement: Supplies for Chemical Research.....	168
15.1	General Principles of Ordering for Chemical Research	169
15.2	Types of Orders	170
	Project Orders	170
	Regular Orders	170
	Rush Orders	170
	Sale Orders.....	171
	Trial Orders	171
	Equipment Orders	172
	In-House Orders.....	172
	Grant-Funded Orders	172
	Local Orders.....	172
	Special (Custom) Orders.....	173
	Safety Orders	173

	Wish-List Orders.....	173
15.3	Managing Orders	174
	Initiating Orders.....	174
	Monitoring Orders	180
	Receiving Orders.....	182
	Returning Orders.....	185
Chapter 16	The Laboratory Notebook: An Invaluable Tool for Chemical Research	189
16.1	The Importance of the Chemical Research Lab Notebook.....	190
16.2	Selection of the Chemical Research Notebook.....	191
	Paper Notebooks	191
	Electronic Notebooks.....	192
16.3	The Components of the Chemical Research Notebook	192
	Cover Page	192
	Table of Contents	192
	Data.....	192
	Signatures.....	195
16.4	The Developing Lab Notebook: From Document to Lab Partner.....	196
Chapter 17	Data Collection: The Harvest of Chemical Research.....	200
17.1	The Ubiquity of Errors – Errors, Errors, Everywhere.....	201
17.2	Significant Figures Really Are Significant!	202
	Accuracy and Precision.....	202
	Addition and Subtraction	203
	Multiplication and Division	204
17.3	Conquering Contamination.....	205
	Glassware	205
	Ventilation (Fume) Hoods.....	205
17.4	Selecting Supplies	207
	Volumetric Labware	207
	Storage Bottles	208
	Purity of Chemicals.....	208
	Miscellaneous Helpful Products	208
17.5	Selecting and Protecting Instruments.....	209
	Balances	209
	Other Instruments.....	209
17.6	Researcher Bias? Experimental Strategies Can Help!	211
	Avoiding Bias.....	211
	Using Time Wisely	212
	Staying on Schedule – and Alert.....	212
	Protecting Data.....	212
	Adopting a Culture of Responsibility	212

Chapter 18	Teamwork: Collaboration for Chemical Research	216
18.1	Teamwork in Chemical Research	217
	Definitions.....	217
	Shared Resources	218
	Graduate School Committees	218
	Respect.....	219
	Communications and Cooperation.....	219
18.2	Key Players in Chemical Research	222
	Supervisors: Selecting a Research Supervisor	222
	Supervisors: Working with Research Supervisors	222
	The Dissertation (or Thesis) Committee	223
	Colleagues and Other Peers	223
	Interdisciplinary Colleagues	224
	Administrators.....	225
	Staff.....	225
	The Local Community	225
	Organizations	226
	Family and Friends	226
18.3	The Most Valuable Player (MVP) in Chemical Research.....	227
18.4	Closing Thoughts	227

UNIT III The Communication of Chemical Research..... 229

Chapter 19	Data Analysis: The Product of Chemical Research.....	231
19.1	Some Terminology for Data Analysis and Presentation	232
	Means, Median, and Mode.....	233
	Standard Deviation.....	236
	Other Terms.....	237
19.2	Data Displays – Tables, Graphs, and More.....	238
	Tables	238
	Graphs	239
	International System of Units (SI) Prefixes	245
19.3	Ten Steps to Effective Data Displays.....	245
Chapter 20	Sharing Chemical Research: Written Presentations	248
20.1	General Considerations	250
	Getting Started	250
	Avoiding Errors.....	250
	Adapting to the Readership.....	250
	Maintaining Professionalism	252
	Adding Alliterations.....	253
	A Handy Little Trio of Terms	253

	Rhyming – Pros and Cons.....	253
	Eliminating Unneeded Repetitions	253
	Technical Writing Course	254
	Artificial Intelligence (AI)	254
	Preparing the Submission	254
20.2	Poster Presentations	255
	Overview	255
	Appearance	256
	Abbreviations	256
	Title	258
	Author(s).....	259
	Abstract	259
	Introduction.....	259
	Purpose/Hypothesis.....	260
	Materials and Experimental Method.....	260
	Results with Graphs and Tables	260
	Discussion with Conclusions	261
	Acknowledgments.....	261
	References.....	261
20.3	Journal Articles, Communications, and “Letters to the Editor”	261
	General Remarks.....	261
	Journal Selection.....	262
	Criteria for Publishable Manuscripts	262
20.4	Emails	263
20.5	Text Messages	266
20.6	Letters	266
20.7	Forms, Etc., and a Word of Warning	267
Chapter 21	Sharing Chemical Research: Spoken Communications	271
21.1	Some General Guidelines	272
	Basics	272
	Appearance	273
	Discretion.....	273
	Pronunciation	273
	Visual Aids	273
	Time Limits.....	274
21.2	Elevator Speeches	274
21.3	Informal Discussions	274
21.4	In-Person Meetings	275
21.5	Telephone Calls.....	276
21.6	Electronic Meetings	276
21.7	Conference Presentations.....	276
21.8	Panel Discussions.....	277
21.9	Debates.....	277

21.10 Some Power Phrases – What to Say When	278
21.11 Communication Apprehension: Coping Strategies	279
21.12 The “Last Word”	283

UNIT IV The Impact of Chemical Research..... 287

Chapter 22 The Baconian Dream Realized: The Fruition of Chemical Research	289
22.1 Defining the Baconian Dream.....	290
22.2 Approaching the Baconian Dream.....	290
22.3 Confronting “Problems in Paradise”	294
Chemical Contamination	294
Threats to Wildlife	294
Radioactive Risks.....	295
Methyl Isocyanate Tragedy	295
Apples a la Pesticide?	295
Catastrophic Oil Spill.....	295
Fashions with Formaldehyde	296
Vaccine Hesitancy	296
Refrigerant Concerns	296
Sunscreen Scares	296
Food Additive Fears	297
22.4 Achieving the Baconian Dream – A Challenge	297
Safety Prioritized	297
Ongoing Research.....	297

UNIT V Epilogue 303

Chapter 23 Public Perceptions and Final Reminders: A Frontier of Chemical Research.....	305
23.1 The Historical View of Science by Society.....	307
An Era of Respect for Chemistry	307
Game-Changing Discoveries in Chemistry.....	307
A Backlash Against Chemistry	307
23.2 The Current View of Science by Society	308
Two Divisions of Society	308
Misunderstandings by Non-Scientists.....	308
Chemophobia	308
Fake Claims and Serious Concerns.....	308
23.3 A Future View of Science by Society	309
Opportunities Abound!.....	309
Precautions	311
Summary and Conclusion	311

Appendices	315
Appendix A: Useful Forms for Chemical Research	317
Appendix A.1: Safety Planning Form for a Chemical Research Project	317
Appendix A.2: Sample Research Study Design Form	318
Appendix A.3: Sample Grant Application Form	319
Appendix A.4: Requisition Form for Ordering Chemicals and Supplies	323
Appendix B: Biographical Notes: Shining Stars Supporting Chemical Research	325
Appendix C: Glossary: Helpful Terms for Chemical Research	327
Appendix D: Periodic Table	331
Index	333