

## Supplementary Information

"Implementing Sustainable Undergraduate Laboratories Using the IUPAC Guiding Principles of Responsible Chemistry"

Type colour key:	equipment	hazard	solvent	status	waste
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### 1. Data of Figures 1 and 2

type	value	course	stage
equipment	reflux condenser	CHEM30110	3rd Year (Stage 3)
equipment	reflux condenser	CHEM00010	1st Year (Stage 1)
equipment	rotary evaporator	CHEM20040	2nd Year (Stage 2)
equipment	rotary evaporator	CHEM20040	2nd Year (Stage 2)
equipment	reflux condenser	CHEM20040	2nd Year (Stage 2)
equipment	reflux condenser	CHEM20040	2nd Year (Stage 2)
equipment	rotary evaporator	CHEM20050	2nd Year (Stage 2)
equipment	reflux condenser	CHEM20050	2nd Year (Stage 2)
equipment	reflux condenser	CHEM20050	2nd Year (Stage 2)
equipment	reflux condenser	CHEM20050	2nd Year (Stage 2)
equipment	reflux condenser	CHEM20050	2nd Year (Stage 2)
equipment	reflux condenser	CHEM20110	2nd Year (Stage 2)
equipment	reflux condenser	CHEM10050	1st Year (Stage 1)
equipment	reflux condenser	CHEM30220	3rd Year (Stage 3)
equipment	rotary evaporator	CHEM30220	3rd Year (Stage 3)
equipment	reflux condenser	CHEM30260	3rd Year (Stage 3)
equipment	reflux condenser	CHEM30360	3rd Year (Stage 3)
equipment	reflux condenser	CHEM30360	3rd Year (Stage 3)
equipment	rotary evaporator	CHEM30110	3rd Year (Stage 3)
equipment	rotary evaporator	CHEM30110	3rd Year (Stage 3)
equipment	reflux condenser	CHEM30110	3rd Year (Stage 3)
equipment	reflux condenser	CHEM30110	3rd Year (Stage 3)
hazard	Congo red	CHEM30360	3rd Year (Stage 3)
hazard	phenolphthalein	CHEM30360	3rd Year (Stage 3)
hazard	barium	CHEM10010	1st Year (Stage 1)
hazard	barium	CHEM10010	1st Year (Stage 1)
hazard	HCl	CHEM00010	1st Year (Stage 1)
hazard	HCl	CHEM00010	1st Year (Stage 1)
hazard	ammonia	CHEM00010	1st Year (Stage 1)
hazard	HCl	CHEM00020	1st Year (Stage 1)
hazard	NaOH	CHEM00020	1st Year (Stage 1)
hazard	barium	CHEM00020	1st Year (Stage 1)
hazard	HCl	CHEM00010	1st Year (Stage 1)
hazard	HCl	CHEM00010	1st Year (Stage 1)
hazard	HCl	CHEM00010	1st Year (Stage 1)
hazard	bromine	CHEM10050	1st Year (Stage 1)

type	value	course	stage
hazard	bromine	CHEM10050	1st Year (Stage 1)
hazard	HCl	CHEM20110	2nd Year (Stage 2)
hazard	HCl	CHEM20110	2nd Year (Stage 2)
hazard	acetic acid	CHEM20110	2nd Year (Stage 2)
hazard	bromine	CHEM20110	2nd Year (Stage 2)
hazard	HCl	CHEM10040	1st Year (Stage 1)
hazard	NaOH	CHEM10040	1st Year (Stage 1)
hazard	phenolphthalein	CHEM10040	1st Year (Stage 1)
hazard	HCl	CHEM10130	1st Year (Stage 1)
hazard	H <sub>2</sub> SO <sub>4</sub>	CHEM10130	1st Year (Stage 1)
hazard	potassium dichromate	CHEM10130	1st Year (Stage 1)
hazard	potassium dichromate	CHEM10130	1st Year (Stage 1)
hazard	NaOH	CHEM20030	2nd Year (Stage 2)
hazard	H <sub>2</sub> SO <sub>4</sub>	CHEM20040	2nd Year (Stage 2)
hazard	HNO <sub>3</sub>	CHEM20040	2nd Year (Stage 2)
hazard	acetic acid	CHEM20040	2nd Year (Stage 2)
hazard	NaOH	CHEM20040	2nd Year (Stage 2)
hazard	H <sub>2</sub> SO <sub>4</sub>	CHEM20050	2nd Year (Stage 2)
hazard	acetic acid	CHEM20050	2nd Year (Stage 2)
hazard	bromine	CHEM20050	2nd Year (Stage 2)
hazard	H <sub>2</sub> SO <sub>4</sub>	CHEM10050	1st Year (Stage 1)
hazard	acetic acid	CHEM10050	1st Year (Stage 1)
hazard	H <sub>2</sub> SO <sub>4</sub>	CHEM10130	1st Year (Stage 1)
hazard	H <sub>2</sub> SO <sub>4</sub>	CHEM20090	2nd Year (Stage 2)
hazard	ammonia	CHEM20090	2nd Year (Stage 2)
hazard	acetic acid	CHEM10050	1st Year (Stage 1)
hazard	Congo red	CHEM20120	2nd Year (Stage 2)
hazard	Congo red	CHEM20120	2nd Year (Stage 2)
hazard	HCl	CHEM20140	2nd Year (Stage 2)
hazard	acetic acid	CHEM20140	2nd Year (Stage 2)
hazard	NaOH	CHEM20140	2nd Year (Stage 2)
hazard	HCl	CHEM30060	3rd Year (Stage 3)
hazard	NaOH	CHEM30200	3rd Year (Stage 3)
hazard	acetic acid	CHEM30210	3rd Year (Stage 3)
hazard	HCl	CHEM30250	3rd Year (Stage 3)
hazard	HCl	CHEM30220	3rd Year (Stage 3)
hazard	NaOH	CHEM30220	3rd Year (Stage 3)
hazard	H <sub>2</sub> SO <sub>4</sub>	CHEM30320	3rd Year (Stage 3)
hazard	HCl	CHEM30360	3rd Year (Stage 3)
hazard	bromine	CHEM30110	3rd Year (Stage 3)
hazard	potassium dichromate	CHEM30110	3rd Year (Stage 3)
solvent	water	CHEM30360	3rd Year (Stage 3)
solvent	water	CHEM30110	3rd Year (Stage 3)
solvent	water	CHEM30110	3rd Year (Stage 3)
solvent	water	CHEM30110	3rd Year (Stage 3)

type	value	course	stage
solvent	water	CHEM30110	3rd Year (Stage 3)
solvent	ethanol	CHEM00010	1st Year (Stage 1)
solvent	water	CHEM00010	1st Year (Stage 1)
solvent	water	CHEM00010	1st Year (Stage 1)
solvent	water	CHEM00010	1st Year (Stage 1)
solvent	water	CHEM00010	1st Year (Stage 1)
solvent	water	CHEM00020	1st Year (Stage 1)
solvent	water	CHEM00020	1st Year (Stage 1)
solvent	water	CHEM00020	1st Year (Stage 1)
solvent	water	CHEM00010	1st Year (Stage 1)
solvent	water	CHEM00010	1st Year (Stage 1)
solvent	water	CHEM00010	1st Year (Stage 1)
solvent	water	CHEM00010	1st Year (Stage 1)
solvent	ethanol	CHEM20110	2nd Year (Stage 2)
solvent	ethanol	CHEM20110	2nd Year (Stage 2)
solvent	water	CHEM20110	2nd Year (Stage 2)
solvent	water	CHEM20110	2nd Year (Stage 2)
solvent	water	CHEM10040	1st Year (Stage 1)
solvent	dichloromethane	CHEM20040	2nd Year (Stage 2)
solvent	dichloromethane	CHEM20040	2nd Year (Stage 2)
solvent	methanol	CHEM20040	2nd Year (Stage 2)
solvent	acetone	CHEM20040	2nd Year (Stage 2)
solvent	ethyl acetate	CHEM20040	2nd Year (Stage 2)
solvent	toluene	CHEM20040	2nd Year (Stage 2)
solvent	water	CHEM20040	2nd Year (Stage 2)
solvent	water	CHEM20040	2nd Year (Stage 2)
solvent	water	CHEM20040	2nd Year (Stage 2)
solvent	water	CHEM20040	2nd Year (Stage 2)
solvent	water	CHEM20040	2nd Year (Stage 2)
solvent	water	CHEM20040	2nd Year (Stage 2)
solvent	dichloromethane	CHEM20050	2nd Year (Stage 2)
solvent	dichloromethane	CHEM20050	2nd Year (Stage 2)
solvent	ethanol	CHEM20050	2nd Year (Stage 2)
solvent	methanol	CHEM20050	2nd Year (Stage 2)
solvent	methanol	CHEM20050	2nd Year (Stage 2)
solvent	ethyl acetate	CHEM20050	2nd Year (Stage 2)
solvent	diethyl ether	CHEM20050	2nd Year (Stage 2)
solvent	water	CHEM20050	2nd Year (Stage 2)
solvent	water	CHEM20050	2nd Year (Stage 2)
solvent	water	CHEM20050	2nd Year (Stage 2)
solvent	water	CHEM20050	2nd Year (Stage 2)
solvent	water	CHEM10130	1st Year (Stage 1)
solvent	ethanol	CHEM20100	2nd Year (Stage 2)
solvent	water	CHEM20090	2nd Year (Stage 2)
solvent	dichloromethane	CHEM20110	2nd Year (Stage 2)



type	value	course	stage
solvent	water	CHEM30110	3rd Year (Stage 3)
solvent	water	CHEM30110	3rd Year (Stage 3)
solvent	water	CHEM30110	3rd Year (Stage 3)
solvent	water	CHEM30110	3rd Year (Stage 3)
solvent	water	CHEM30110	3rd Year (Stage 3)
solvent	water	CHEM30110	3rd Year (Stage 3)
status	implemented	CHEM30360	3rd Year (Stage 3)
status	implemented	CHEM30360	3rd Year (Stage 3)
status	proposed	CHEM30360	3rd Year (Stage 3)
status	proposed	CHEM30360	3rd Year (Stage 3)
status	proposed	CHEM30360	3rd Year (Stage 3)
status	proposed	CHEM30360	3rd Year (Stage 3)
status	implemented	CHEM10010	1st Year (Stage 1)
status	proposed	CHEM10010	1st Year (Stage 1)
status	proposed	CHEM10010	1st Year (Stage 1)
status	implemented	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM00010	1st Year (Stage 1)
status	implemented	CHEM00010	1st Year (Stage 1)
status	proposed	CHEM00010	1st Year (Stage 1)
status	implemented	CHEM20110	2nd Year (Stage 2)
status	proposed	CHEM10040	1st Year (Stage 1)
status	proposed	CHEM10130	1st Year (Stage 1)
status	proposed	CHEM10130	1st Year (Stage 1)
status	proposed	CHEM30110	3rd Year (Stage 3)
status	implemented	CHEM30110	3rd Year (Stage 3)
status	implemented	CHEM30110	3rd Year (Stage 3)
status	implemented	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM30110	3rd Year (Stage 3)
status	proposed	CHEM30110	3rd Year (Stage 3)
waste	down_sink	CHEM30360	3rd Year (Stage 3)
waste	down_sink	CHEM30360	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30360	3rd Year (Stage 3)
waste	down_sink	CHEM10010	1st Year (Stage 1)
waste	down_sink	CHEM10010	1st Year (Stage 1)
waste	down_sink	CHEM00010	1st Year (Stage 1)
waste	down_sink	CHEM00020	1st Year (Stage 1)
waste	down_sink	CHEM00020	1st Year (Stage 1)
waste	down_sink	CHEM00020	1st Year (Stage 1)
waste	down_sink	CHEM00020	1st Year (Stage 1)

type	value	course	stage
waste	down_sink	CHEM00010	1st Year (Stage 1)
waste	down_sink	CHEM00010	1st Year (Stage 1)
waste	haz_halogenated	CHEM00010	1st Year (Stage 1)
waste	down_sink	CHEM00010	1st Year (Stage 1)
waste	haz_halogenated	CHEM20110	2nd Year (Stage 2)
waste	haz_nonhalogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_nonhalogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_nonhalogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20040	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20040	2nd Year (Stage 2)
waste	down_sink	CHEM00010	1st Year (Stage 1)
waste	down_sink	CHEM10130	1st Year (Stage 1)
waste	down_sink	CHEM10130	1st Year (Stage 1)
waste	haz_halogenated	CHEM20110	2nd Year (Stage 2)
waste	down_sink	CHEM10050	1st Year (Stage 1)
waste	down_sink	CHEM20120	2nd Year (Stage 2)
waste	down_sink	CHEM20140	2nd Year (Stage 2)
waste	haz_nonhalogenated	CHEM20140	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20140	2nd Year (Stage 2)
waste	red_bin	CHEM20140	2nd Year (Stage 2)
waste	haz_nonhalogenated	CHEM30060	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30060	3rd Year (Stage 3)
waste	down_sink	CHEM30110	3rd Year (Stage 3)
waste	haz_nonhalogenated	CHEM20110	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20110	2nd Year (Stage 2)
waste	haz_halogenated	CHEM20110	2nd Year (Stage 2)
waste	red_bin	CHEM20110	2nd Year (Stage 2)
waste	haz_nonhalogenated	CHEM30210	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30210	3rd Year (Stage 3)
waste	red_bin	CHEM30250	3rd Year (Stage 3)
waste	red_bin	CHEM30250	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30260	3rd Year (Stage 3)
waste	haz_nonhalogenated	CHEM30270	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30270	3rd Year (Stage 3)
waste	down_sink	CHEM30310	3rd Year (Stage 3)
waste	red_bin	CHEM30310	3rd Year (Stage 3)
waste	down_sink	CHEM30320	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30360	3rd Year (Stage 3)
waste	red_bin	CHEM30360	3rd Year (Stage 3)

type	value	course	stage
waste	haz_nonhalogenated	CHEM30110	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30110	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30110	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30110	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30110	3rd Year (Stage 3)
waste	haz_halogenated	CHEM30110	3rd Year (Stage 3)

## 2. Data of Figure 3

Module Information
CHEM00010
CHEM00020
CHEM10030
CHEM10150
CHEM10040
CHEM10050
CHEM10130
CHEM10010
CHEM20030
CHEM20040
CHEM20050
CHEM20060
CHEM20080
CHEM20090
CHEM20100
CHEM20110
CHEM20120
CHEM20140
CHEM30060
CHEM30110
CHEM30200
CHEM30210
CHEM30220
CHEM30230
CHEM30250
CHEM30260
CHEM30270
CHEM30310
CHEM30320
CHEM30360

## 3. Data of Figure 4

Implements	Implementation Difficulty	IUPAC Responsible Chemistry Benefit
This includes the use of gloves when not necessary (handling of safe chemicals) as well as throwing away clean/uncontaminated gloves when these can be safely reused (within the same session, not on the long term)	4	7
identify where liquid chemical wastes should be disposed of	6	7.5
This generated the formation of large volumes of contaminated glass.	5	6
pH indicators some of the indicators traditionally used are toxic for the environment	2	7.5
sucrose used in an experiment was found to be excessive	2	5.5
the mother solution was made in an inadequate and too large volume of solvent.	2	6
plastic/disposable cuvettes	4	6.5
printers	3	6.5
a second Gas-Chromatography	7	6.5
Atomic Absorption Spectroscopy (AAS)	7	6
other equipment and machinery	6	6.5
"reflux." prevent waste of large volumes of solvent but large consumption of water. Water less condensers, use air	9	7.5
"use of syringes/needles"	4	7
Long prepare for the flowing sessions	5	6
Cyrene was proposed as an alternative for dimethylformamide	4	8

## 4. Data of Figure 5

Floor	Implements	State	Catalog
physical	This includes the use of gloves when not necessary (handling of safe chemicals) as well as throwing away clean/uncontaminated gloves when these can be safely reused (within the same session, not on the long term)	long term	protocol optimisation
physical	identify where liquid chemical wastes should be disposed of	long term	protocol optimisation
physical	This generated the formation of large volumes of contaminated glass.	implemented	protocol optimisation
physical	pH indicators some of the indicators traditionally used are toxic for the environment	in process	chemical substitution
physical	sucrose used in an experiment was found to be excessive	implemented	protocol optimisation
physical	the mother solution was made in an inadequate and too large volume of solvent.	implemented	protocol optimisation
introductory	plastic/disposable cuvettes	in process	equipment upgrade
introductory	printers	long term	protocol optimisation
introductory	a second Gas-Chromatography	in process	equipment upgrade
introductory	Atomic Absorption Spectroscopy (AAS)	in process	equipment upgrade
introductory	other equipment and machinery	in process	equipment upgrade
synthetic	"reflux." prevent waste of large volumes of solvent but large consumption of water. Water less condensers, use air	implemented	equipment upgrade
synthetic	"use of syringes/needles"	implemented	protocol optimisation
synthetic	Long prepare for the flowing sessions	long term	protocol optimisation
synthetic	Cyrene was proposed as an alternative for dimethylformamide	in process	chemical substitution

## 5. Data of Figure 9

Implements	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8
This includes the use of gloves when not necessary (handling of safe chemicals) as well as throwing away clean/uncontaminated gloves when these can be safely reused (within the same session, not on the long term)	4	4	3	3	3	3	3	2
identify where liquid chemical wastes should be disposed of	3	5	4	3	4	3	3	2
This generated the formation of large volumes of contaminated glass.	3	4	3	2	3	2	3	2
pH indicators some of the indicators traditionally used are toxic for the environment	4	5	4	2	3	2	4	2
sucrose used in an experiment was found to be excessive	3	3	3	2	2	2	3	1
the mother solution was made in an inadequate and too large volume of solvent.	3	4	3	2	2	2	4	1
plastic/disposable cuvettes	3	4	3	2	3	3	3	1
printers	3	4	3	3	4	3	3	2
a second Gas-Chromatography	3	3	3	3	3	4	4	3
Atomic Absorption Spectroscopy (AAS)	3	3	3	3	3	3	4	3
other equipment and machinery	3	4	3	3	3	3	3	2
"reflux." prevent waste of large volumes of solvent but large consumption of water. Water less condensers, use air	4	5	4	2	3	2	3	2
"use of syringes/needles"	3	4	4	3	3	3	3	2
Long prepare for the flowing sessions	3	3	3	3	4	3	3	3
Cyrene was proposed as an alternative for dimethylformamide	5	5	4	2	3	2	4	3