How long will my crystal last?

Cryo-cooled crystals are killed by photons/area, not time. Therefore, the amount of time your crystal can survive in the x-ray beam depends on flux density (photons/area/time) of the beamline you use.

The following table lists flux densities derived from beamline flux (photons/s) and beam size (used to compute area) parameters extracted from the `biosync.rcsb.org` website. **DISCLAIMER:** Flux depends on a lot of factors. You should check with your beamline scientist about what it is the day you collect data. It is intended here that these numbers reflect a "worst case scenario" at each beamline. This is because BioSync usually lists the maximum available flux and many ultra-bright sources are attenuated in practice. If you attenuate by 10x, then the lifetimes listed below should be multiplied by 10. In as many cases as possible, beamline scientist have been contacted for up-to-date values. In some cases below (indicated by a "?") one or more parameters were not provided in BioSync and had to be inferred or guessed at. For example, some entries report a "flux", but do not specify the x-ray wavelength. In these cases, 1 Å was assumed. If you are a beamline scientist and you see that your values are wrong, or if you have up-to-date "typical" values, then please contact me! (JMHolton@lbl.gov).

In addition to flux density (photons/area/time), the lifetime of a protein crystal will depend on a number of other parameters, such as photon energy (wavelength) and the concentration of heavy atoms. So, for this example a "typical" crystal is taken as a 100 μm thick lysozyme crystal, and the photon energy at which each beamline flux is reported is taken as the "typical" photon energy. All these "typical" values are taken together to compute a "typical" rate at which the sample absorbs energy: the "dose rate" (Gy/s). Dose is expressed in Gray (Gy) or Joules/kg.

The "`max xtal lifetime`" column is the time it will take a lysozyme crystal to absorb 30 MGy at the rate given in the "`dose rate`" column. 30 MGy has been described as a maximum recommended dose to a protein crystal (Owen et. al. *PNAS* 2006). This is recommended as the maximum **total** exposure time of a native data set. The last column "`min site lifetime`" is the time it will take lysozyme to absorb 2 MGy, which is the lowest dose ever observed to damage half of the SeMet side chains in a sample (Holton *JSR* 2007). The lowest damage half-dose known for a Br-C bond is 0.5 MGy (Oliéric *et. al. ACTA* D 2007), and the lowest half-dose of any kind was 0.3 MGy for the active site of the metalloprotein putidaredoxin (Corbett *et al. ACTA* D 2007). Therefore, the last column is the maximum **total** exposure time recommend for the first complete data set of a SeMet MAD, SAD or multi-SAD experiment (this includes the inverse-beam pass and all wavelengths). This is also an advisable maximum shutter-open time for a native experiment where the chemical integrity of an active site is important. A second pass with longer exposures is always possible (you can merge it with the first), but you want to make sure you get complete data before the heavy atom sites change and/or before you get bonds breaking in your active site or ligand.

These are guidelines. Real life can be a lot more complicated than this. Some sites decay quickly, and others are quite “robust”. Crystal lifetime also depends on your sample composition. A table of commonly-used elements and the concentration that will cut the crystal lifetime in half is listed in Holton JSR (2009). To calculate how long your particular crystal composition will behave at a particular wavelength, you can use the program RADDOSE (Murray et.al. *J. Apl. Cr.* 2004).

Radiation damage can get complicated, but, in general, the "lethal dose" for any two crystals of the same protein in the same buffer that are cooled under the same conditions at shot at the same wavelength … will be the same. This means that as you move from beamline to beamline or attenuate a given beamline, the lifetime of your crystals will be inversely proportional to photons/µm^2/s. Since diffracted intensity is also proportional to photons/µm^2, the total amount of spot intensity you can get before your crystal is “dead” will be invariant from beamline to beamline. The biggest difference is how much time it will take to collect the data. You should bear these differences in mind when planning your experiments.

source	model	optic	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime
home	RU-200	Yale	1.5e8	300	2.1e+03	4.3 Gy/s	81 d	5.4 d
home	RU-200	blue	3.2e7	100	4.1e+03	8.26 Gy/s	42 d	67 h
home	FR-E	Cu	9.8e8	100	1.2e+05	253 Gy/s	33 h	2.2 h
home	FR-E+	Cu	1.2e9	100	1.5e+05	310 Gy/s	27 h	1.8 h
source	model	optic	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime

synch	line	type	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime
ALS	4.2.2	MAD	1e12	200x100	5.0e+07	16.5 kGy/s	30 m	2 m
ALS	5.0.1	MONO	2.0e11	100	2.5e+07	12.9 kGy/s	39 m	2.6 m
ALS	5.0.2	MAD	1.5e12	100	1.5e+08	130 kGy/s	3.9 m	15 s
ALS	5.0.3	MONO	3.0e11	100	3.8e+07	19.4 kGy/s	26 m	1.7 m
ALS	8.2.1	MAD	3.5e11	100	3.5e+07	17.7 kGy/s	28 m	1.9 m
ALS	8.2.2	MAD	3.5e11	100	3.5e+07	17.7 kGy/s	28 m	1.9 m
ALS	8.3.1	MAD	1.0e12	60x80	2.1e+08	154 kGy/s	3.3 m	13 s
ALS	12.3.1	MAD	2e11	100	2.0e+07	14.1 kGy/s	35 m	2.4 m
ALS	12.3.1	SAXS	4e13	200?	1.0e+09	707 kGy/s	42 s	2.8 s
SSRL	BL1-5	MAD	1.5e10	200	3.8e+05	178 Gy/s	47 h	3.1 h
SSRL	BL6-2	XAFS	2e13	400x150	3.3e+08	241 kGy/s	2.1 m	8.3 s
SSRL	BL7-1	MAD	3e10	200	7.5e+05	558 Gy/s	15 h	60 m
SSRL	BL7-3	XAS	1e12	20x2	2.5e+10	4.07 MGy/s	7.4 s	0.49 s
SSRL	BL9-1	MAD	9e10	200	2.2e+06	1.09 kGy/s	7.7 h	31 m
SSRL	BL9-2	MAD	8e11	200	2.0e+07	9.66 kGy/s	52 m	3.5 m
SSRL	BL9-3	EXAFS	2e12	20x300	3.3e+08	469 kGy/s	64 s	4.3 s
SSRL	BL11-1	MAD	2.1e11	200	5.2e+06	2.54 kGy/s	3.3 h	13 m
SSRL	BL12-2	MAD	4.0e12	100x200	2.0e+08	96.6 kGy/s	5.2 m	21 s
SSRL	BL11-3	MONO	5e10	200	1.2e+06	582 Gy/s	14 h	57 m
SSRL	BL14-1	MAD	2e11	200	5.0e+06	4.32 kGy/s	1.9 h	7.7 m
SSRL	BL4-3	XAFS	1e12	20x20	2.5e+09	769 kGy/s	39 s	2.6 s
SSRL	BL2-3	EXAFS	1e10	2	2.5e+09	804 kGy/s	37 s	2.5 s
SSRL	BL14-3	EXAFS	2e10	5	8.0e+08	6.99 MGy/s	4.3 s	0.29 s
CHESS	F1	MONO	3.0e11	100	3.0e+07	14.2 kGy/s	35 m	2.3 m
CHESS	F2	MAD	8e11	3x944	2.3e+08	148 kGy/s	3.4 m	14 s
CHESS	F3	SAD	4e9	300	4.4e+04	37.8 Gy/s	9.2 d	15 h
CAMD	GCPCC	MAD	5.0e9	200	1.2e+05	188 Gy/s	44 h	3 h
synch	line	type	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime

Last updated 3/9/2018. For latest go to http://bl831.als.lbl.gov/damage_rates.pdf

synch	line	type	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime
APS	5ID-B	POWDER	5e12	1000x300	1.7e+07	8.25 kGy/s	61 m	4 m
APS	8-BM	MAD	1e11	200	2.5e+06	858 Gy/s	9.7 h	39 m
APS	14-BM-C	MONO	6e11	130x200	2.3e+07	11 kGy/s	46 m	3 m
APS	14-ID-B	LAUE	7e13	15x20	2.3e+11	132 MGy/s	0.23 s	0.015 s
APS	17-BM	POWDER	8e11	200	2.0e+07	8.72 kGy/s	57 m	3.8 m
APS	17-ID	MAD	7e11	200	1.8e+07	9.87 kGy/s	51 m	3.4 m
APS	18-ID	SAXS	2e13	50x150	2.7e+09	2.69 MGy/s	11 s	0.74 s
APS	19-BM	MAD	6e+08	60x50	2.0e+05	77.3 Gy/s	4.5 d	7.2 h
APS	19-ID	MAD	3e+10	100x20	1.5e+07	7.81 kGy/s	64 m	4.3 m
APS	21-ID-D	MAD	5e12	50	2.0e+09	1.13 MGy/s	27 s	1.8 s
APS	21-ID-F	MONO	1e12	50	4.0e+08	190 kGy/s	2.6 m	11 s
APS	21-ID-G	MONO	1e12	50	4.0e+08	190 kGy/s	2.6 m	11 s
APS	22-BM	MAD	7e12	40x80	2.2e+09	750 kGy/s	40 s	2.7 s
APS	22-ID	MAD	7e12	40x80	2.2e+09	750 kGy/s	40 s	2.7 s
APS	23-BM-B	MAD	2e11	200?	5.0e+06	2.47 kGy/s	3.4 h	13 m
APS	23-ID-B	MAD	6e12	80x20	3.8e+09	2.11 MGy/s	14 s	0.95 s
APS	23-ID-D	MAD	1e13	75x25	5.3e+09	3.01 MGy/s	10 s	0.66 s
APS	24-ID-C	MAD	2.5e12	40x60	1.0e+09	357 kGy/s	84 s	5.6 s
APS	24-ID-E	MONO	2.85e12	20x120	1.2e+09	563 kGy/s	53 s	3.5 s
APS	31-ID	MAD	2.6e12	120x80	2.7e+08	105 kGy/s	4.8 m	19 s
NSLS-II	17-ID-1	MAD	5e12	7x5	1.4e+11	67 MGy/s	0.45 s	0.03 s
NSLS-II	17-ID-2	MAD	2e12	1x1	1.3e+12	626 MGy/s	0.048 s	0.0032 s
NSLS	X3A	MAD	3.8e10	200	9.5e+05	451 Gy/s	18 h	74 m
NSLS	X3B	EXAFS	9e11	200x700	6.4e+06	6.48 kGy/s	77 m	5.1 m
NSLS	X4A	MAD	2e10	300	2.2e+05	136 Gy/s	61 h	4.1 h
NSLS	X6A	MAD	1.5e12	100x500	3.0e+07	10.3 kGy/s	49 m	3.2 m
NSLS	X8C	MAD	1.1e10	200?	2.8e+05	204 Gy/s	41 h	2.7 h
synch	line	type	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime

Fluxes are subject to change since 3/9/2018. For latest go to http://bl831.als.lbl.gov/damage_rates.pdf

synch	line	type	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime
NSLS	X9A	MAD	2.4e10	200	6.0e+05	662 Gy/s	13 h	50 m
NSLS	X12B	MAD	2e10	300x500	1.3e+05	66 Gy/s	5.3 d	8.4 h
NSLS	X12C	MAD	2e10	300x500	1.3e+05	66 Gy/s	5.3 d	8.4 h
NSLS	X25	LAUE	2.4e11	200	6.0e+06	1.19 kGy/s	7 h	28 m
NSLS	X26C	LAUE	5.1e10	200	1.3e+06	631 Gy/s	13 h	53 m
NSLS	X29A	MAD	3.5e11	150	1.6e+07	11.6 kGy/s	43 m	2.9 m
CLSI	08ID-1	MAD	5e12	150x50	6.7e+08	317 kGy/s	95 s	6.3 s
CLSI	08B1-1	MAD	1e11	190x210	2.5e+06	1.41 kGy/s	5.9 h	24 m
LNLS	D03B-MX1	MONO	1e+10	400x600	4.2e+04	49.4 Gy/s	7 d	11 h
LNLS	W01B-MX2	MAD	5e11	500x250	4.0e+06	4.03 kGy/s	2.1 h	8.3 m
ALBA	XALOC	MAD	2e12	200	5.0e+07	23.8 kGy/s	21 m	84 s
BESSY	14.1	MAD	1.6e11	50	6.4e+07	44.2 kGy/s	11 m	45 s
BESSY	14.2	MAD	1.9e11	200	4.8e+06	3.28 kGy/s	2.5 h	10 m
BESSY	14.3	MONO	0.9e11	200	2.2e+06	798 Gy/s	10 h	42 m
DIAMOND	I02	MAD	1.5e12	25	2.4e+09	1.14 MGy/s	26 s	1.8 s
DIAMOND	I03	MAD	3e12	100	3.0e+08	148 kGy/s	3.4 m	13 s
DIAMOND	I04	MAD	3e11	10x5	6.0e+09	3.67 MGy/s	8.2 s	0.54 s
DIAMOND	I04-1	MONO	3.5e11	50	1.4e+08	53.5 kGy/s	9.3 m	37 s
DIAMOND	I24	MAD	1e12	80	1.6e+08	83.2 kGy/s	6 m	24 s
ELETTRA	5.2R	MAD	1e13	200	2.5e+08	116 kGy/s	4.3 m	17 s
DESY	X12	MAD	1.6e10	200?	4.0e+05	226 Gy/s	37 h	2.5 h
ESRF	BM14	MAD	4.5e11	750x300	2.0e+06	1.06 kGy/s	7.8 h	31 m
ESRF	BM30A	MAD	0.5e11	300	5.6e+05	275 Gy/s	30 h	2 h
ESRF	ID14-1	MONO	1e11	200x50	1.0e+07	4.08 kGy/s	2 h	8.2 m
ESRF	ID14-2	MONO	1e11	100	1.0e+07	4.06 kGy/s	2.1 h	8.2 m
ESRF	ID14-3	MONO	4e11	700	8.2e+05	329 Gy/s	25 h	1.7 h
ESRF	ID23-2	MONO	4e11	10	4.0e+09	1.32 MGy/s	23 s	1.5 s
synch	line	type	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime

synch	line	type	flux	beamsize	flux density	dose	max xtal	min site
			ph/s	µm	ph/µm^2/s	rate	lifetime	lifetime
ESRF	ID29	MAD	1e13	50x30	6.7e+09	2.91 MGy/s	10 s	0.69 s
ESRF	MASSIF1	MONO	3e12	100x60	5.0e+08	230 kGy/s	2.2 m	8.7 s
ESRF	MASSIF_3	MONO	1.5e13	15	6.7e+10	30.6 MGy/s	0.98 s	0.065 s
ESRF	ID30B	MAD	6e12	20	1.5e+10	6.99 MGy/s	4.3 s	0.29 s
MAX_II	I711	MAD	1e11	300	1.1e+06	758 Gy/s	11 h	44 m
MAX_II	I911-1	MONO	3e11	200x400	3.8e+06	3.87 kGy/s	2.2 h	8.6 m
MAX_II	I911-2	MONO	1e11	300	1.1e+06	653 Gy/s	13 h	51 m
MAX_II	I911-3	MAD	3e11	200x300	5.0e+06	2.89 kGy/s	2.9 h	12 m
MAX_II	I911-4	MONO	1e11	300x600	5.6e+05	208 Gy/s	40 h	2.7 h
MAX_II	I911-5	MONO	5e10	200x300	8.3e+05	424 Gy/s	20 h	79 m
MAX_IV	BIOMAX	MAD	3e13	20x5	3.0e+11	82.8 MGy/s	0.36 s	0.024 s
PETRA3	P13_MX1	SAD	2e13	50	8.0e+09	8.6 MGy/s	3.5 s	0.23 s
PETRA3	P14_MX2	SAD	5e12	10x5	1.0e+11	101 MGy/s	0.3 s	0.02 s
PETRA3	P11	MAD	1.3e13	96x16	8.5e+09	4.77 MGy/s	6.3 s	0.42 s
SLSPSI	X06DA	MAD	4e11	70x90	6.3e+07	38.8 kGy/s	13 m	51 s
SLSPSI	X06SA	MAD	2e12	100	2.0e+08	126 kGy/s	4 m	16 s
SLSPSI	X10SA	MAD	2e12	20x75	1.3e+09	581 kGy/s	52 s	3.4 s
SOLEIL	PROXIMA_1	MAD	5e12	250	8.0e+07	80.6 kGy/s	6.2 m	25 s
SOLEIL	PROXIMA_2	MAD	1.0e12	10x5	2.0e+10	9.56 MGy/s	3.1 s	0.21 s
SOLEIL	CRISTAL	MONO	12e12	400x30	1.0e+09	148 kGy/s	3.4 m	14 s
SRS	PX10.1	MAD	1e13	200	2.5e+08	82.3 kGy/s	6.1 m	24 s
SRS	PX14.2	MAD	1.4e13	400x300	1.2e+08	55.4 kGy/s	9 m	36 s
AICHISR	BL2S1	MONO	1.9e10	190x180	5.6e+05	313 Gy/s	27 h	1.8 h
AUSIE	MX1	MAD	1.5e11	130x90	1.3e+07	5.67 kGy/s	88 m	5.9 m
AUSIE	MX2	MAD	1.4e12	10x20	7.0e+09	3.34 MGy/s	9 s	0.6 s
BSRF	1W2B	MAD	2e11	600x1000	3.3e+05	216 Gy/s	39 h	2.6 h
BSRF	3W1A	MAD	5e10	600x800	1.0e+05	77.4 Gy/s	4.5 d	7.2 h
synch	line	type	flux	beamsize	flux density	dose	max xtal	min site
			ph/s	µm	ph/µm^2/s	rate	lifetime	lifetime

synch	line	type	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime
NSRRC	BL13B1	MAD	1.2e11	200	3.8e+06	1.83 kGy/s	4.6 h	18 m
NSRRC	BL13C1	MONO	3.5e10	200	1.1e+06	523 Gy/s	16 h	64 m
NSRRC	BL17B2	MAD	4e9	200	1.0e+05	56.4 Gy/s	6.2 d	9.9 h
NSRRC	BL15A	MAD	1.4e11	200	4.5e+06	2.13 kGy/s	3.9 h	16 m
NSRRC	TPS_05A	MAD	2.7e12	50	1.4e+09	658 kGy/s	46 s	3 s
PAL	4A	MAD	1e12	300	1.1e+07	8.26 kGy/s	61 m	4 m
PAL	6B	MAD	1e11	300	1.1e+06	1.12 kGy/s	7.4 h	30 m
PAL	6C1	MAD	1e11	300	1.1e+06	960 Gy/s	8.7 h	35 m
PAL	5C_4A	MAD	7e11	80x300	2.9e+07	17.8 kGy/s	28 m	1.9 m
PAL	11C	MAD	5e11	1x1	1.8e+11	112 MGy/s	0.27 s	0.018 s
PAL	7A_6B_6C1	MAD	1e12	360x120	2.3e+07	14.2 kGy/s	35 m	2.4 m
PF	BL-5A	MAD	8.6e11	200	2.2e+07	11.9 kGy/s	42 m	2.8 m
PF	BL-6A	MAD	1.0e10	200?	2.5e+05	156 Gy/s	53 h	3.6 h
PF	BL-17A	MAD	6.6e9	200?	1.6e+05	242 Gy/s	34 h	2.3 h
PF	BL-18B	MAD	4.0e10	400x500	2.0e+05	47.1 Gy/s	7.4 d	12 h
PF	AR-NW12A	MAD	2e11	200	5.0e+06	2.77 kGy/s	3 h	12 m
PF	AR-NE3A	MAD	8e11	200	2.0e+07	11 kGy/s	46 m	3 m
PF	AR-NW14A	LAUE	1e12	200?	2.5e+07	6.9 kGy/s	72 m	4.8 m
PF	BL-1A	MAD	4e11	30x10	1.3e+09	729 kGy/s	41 s	2.7 s
SLRI	BL7.2W	?	1e9	200?	2.5e+04	50.9 Gy/s	6.8 d	11 h
SPRING8	BL12B2	MAD	6e9	250	1.2e+05	61.9 Gy/s	5.6 d	9 h
SPRING8	BL24XU	MAD	1e12	200?	2.5e+07	2.72 kGy/s	3.1 h	12 m
SPRING8	BL26B1	MAD	1e11	200?	2.5e+06	1.41 kGy/s	5.9 h	24 m
SPRING8	BL26B2	MAD	1e11	200?	2.5e+06	1.41 kGy/s	5.9 h	24 m
SPRING8	BL32B2	MAD	1e10	200	2.5e+05	141 Gy/s	59 h	3.9 h
SPRING8	BL38B1	MAD	9.3e10	87x180	5.9e+06	3.84 kGy/s	2.2 h	8.7 m
SPRING8	BL40B2	SAXS	1e11	250x250	1.6e+06	811 Gy/s	10 h	41 m
synch	line	type	flux ph/s	beamsize µm	flux density ph/µm^2/s	dose rate	max xtal lifetime	min site lifetime

synch	line	type	flux ph/s	beamsize µm	flux density ph/µm²/s	dose rate	max xtal lifetime	min site lifetime
SPRING8	BL41XU	MAD	1.5e13	50	6.0e+09	3.04 MGy/s	9.9 s	0.66 s
SPRING8	BL44B2	MONO	1.1e11	200?	2.8e+06	1.62 kGy/s	5.1 h	21 m
SPRING8	BL44XU	MAD	3e11	50	1.2e+08	63.9 kGy/s	7.8 m	31 s
SPRING8	BL45XU	MAD	3e11	300x400	2.5e+06	858 Gy/s	9.7 h	39 m
SPRING8	BL32XU	MAD	6e10	10	6.0e+08	193 kGy/s	2.6 m	10 s
synch	line	type	flux ph/s	beamsize µm	flux density ph/µm²/s	dose rate	max xtal lifetime	min site lifetime