Centrifuge Operation and Safety

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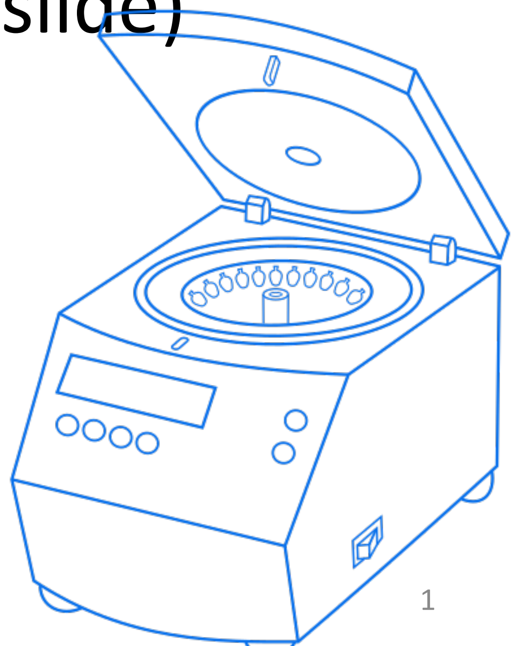
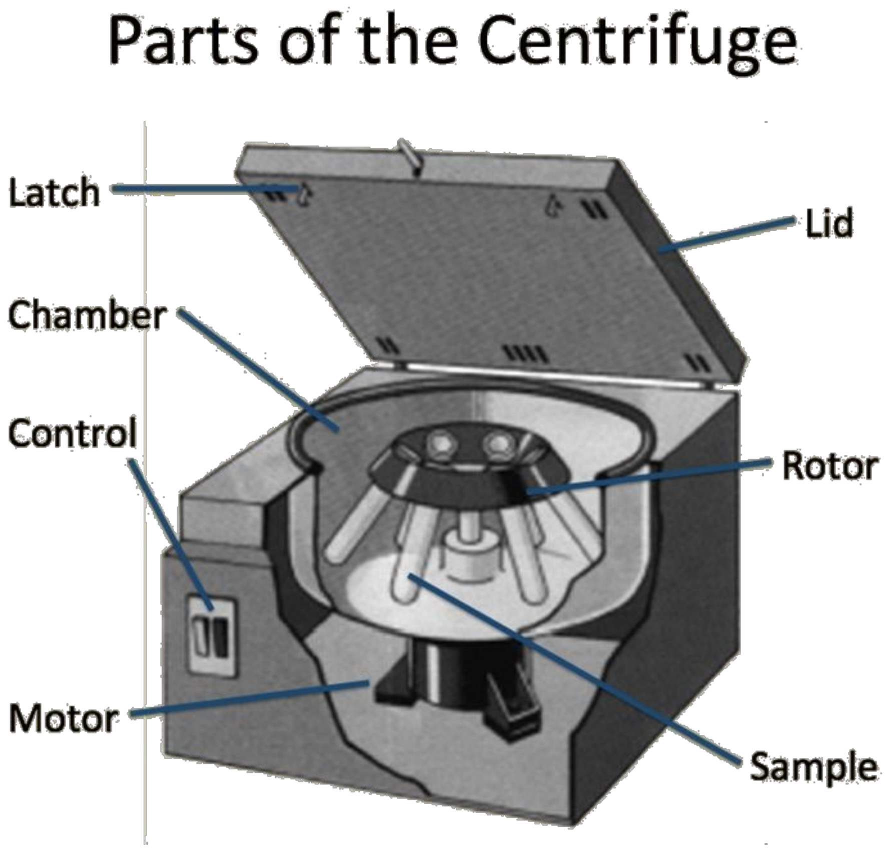
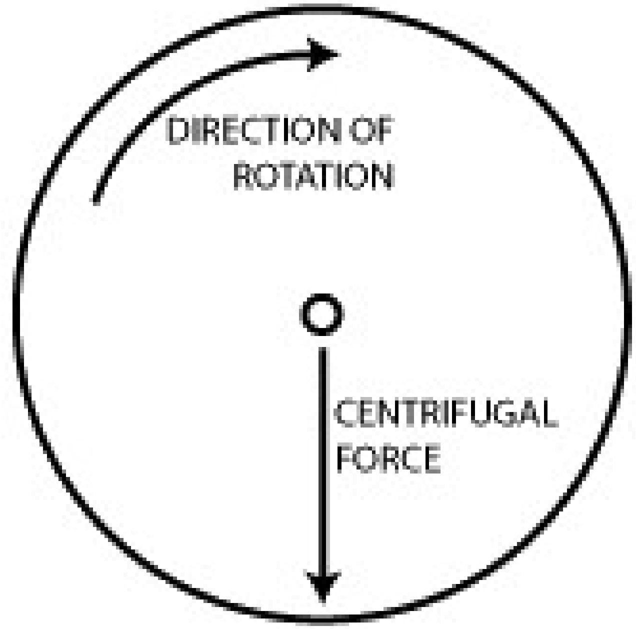
(Adapted from Yifeng Shi's slide)

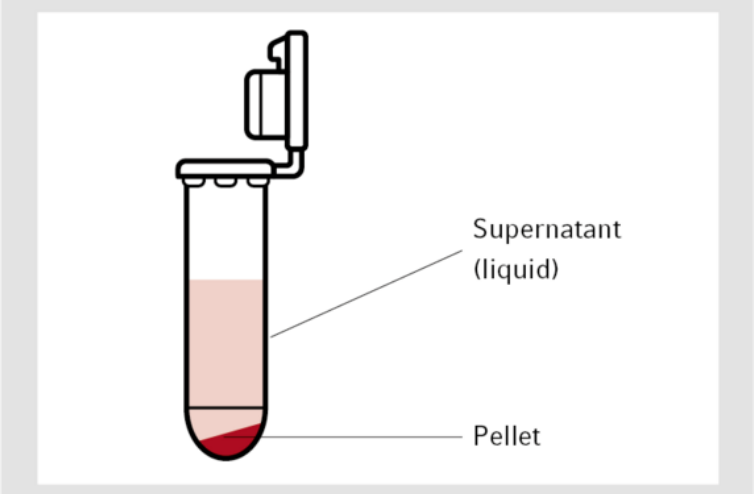
9/25/2023



Centrifuge Structure







Rotors and Tubes

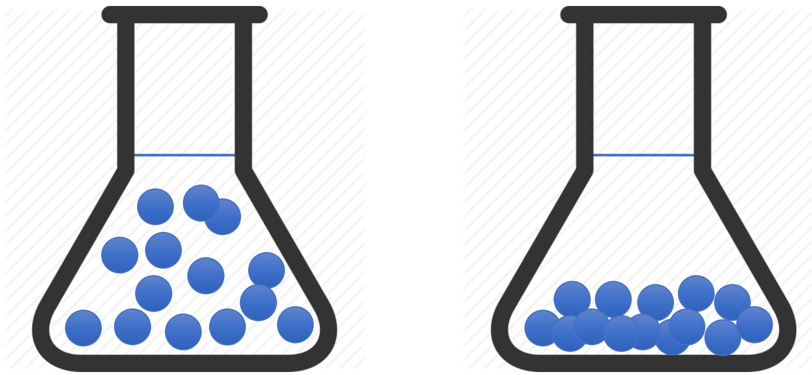
Capacity

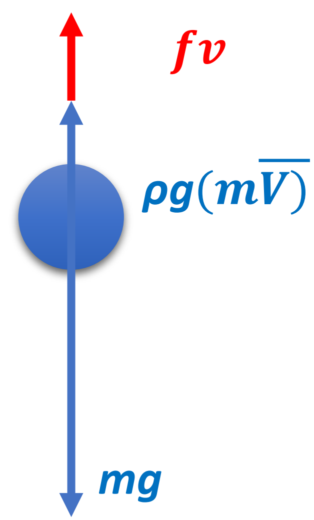
Number of components

Solvent Property

Maximum speed

Centrifuge Basics: precipitation of large particles



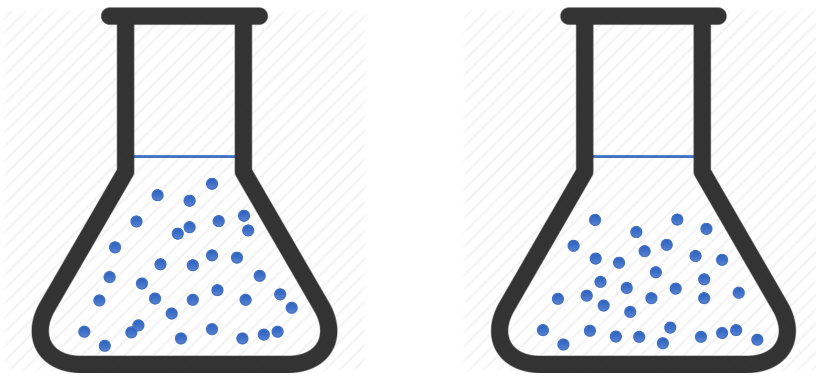


Driving force:

- Gravitational force : mg
- Buoyant force : $\rho g V = \rho g(m\overline{V})$

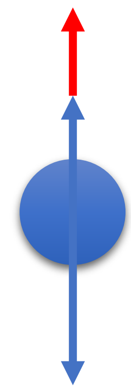
- Frictional force (drag force) : $F = fv$

Centrifuge Basics : precipitation of nanoparticles



Driving force:
- Gravitational force
- Buoyant force

- **Frictional force**



Driving force : $mg - m\overline{V}\rho_s g = m(1 - \overline{V}\rho_s)g$

Frictional force: fv $\quad$ *f:* frictional coefficient

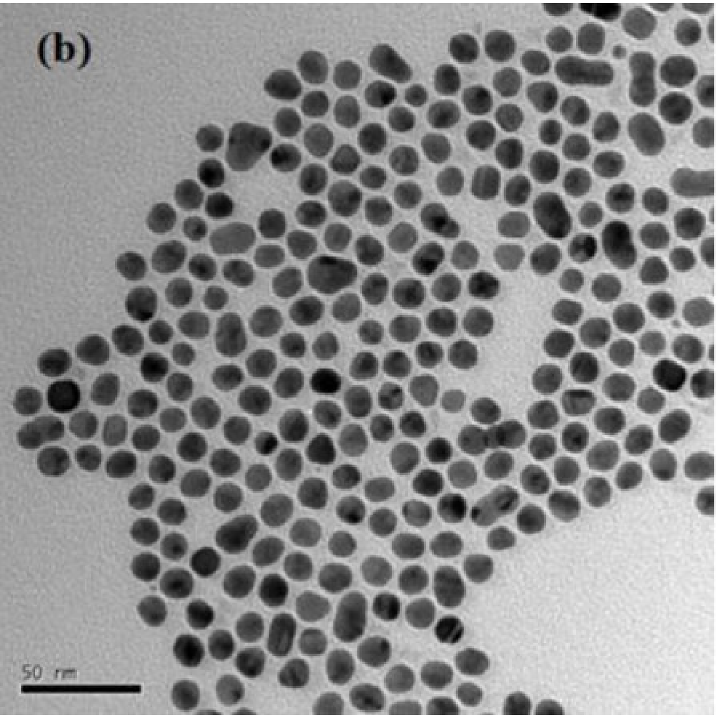
From Newton's second law: $m(1 - \overline{V}\rho_s)g - fv = ma$

When the force balanced: $m(1 - \overline{V}\rho_s)g - fv_t = 0$

Replace all g with $\omega^2 r$

$$v_t = \frac{m(1 - \overline{V}\rho_s)}{f} g = \frac{m(1 - \frac{V}{m}\rho_s)}{f} g = \frac{V(\rho_p - \rho_s)}{f} g$$

Centrifuge Basics



Gold nanoparticles in water with average size of 15.8nm

$$t = \frac{L}{v_t} = \frac{Lf}{\frac{4}{3}\pi R^3(\rho_p - \rho_s)\omega^2 r}$$ =10 min

$$f = \frac{kT}{D} = \frac{1.38 \times 10^{-23} \times 298}{36.5 \times 10^{-12}} = 1.127 \times 10^{-10} kg/s$$

$$\rho_p = \rho_{gold} = 1.932 \times 10^4 kg/m^3$$

$$\rho_s = \rho_{water} = 1 \times 10^3 kg/m^3$$

$R = 7.9 \times 10^{-9} m$ **Particle radius**

$r = 0.05m$ **Rotor radius**

$$\omega = 1576\frac{rad}{s} = 15049 rpm$$

L=0.025m

Leung, diffusion of gold nanoparticles in water and toluene,2015

Centrifuge Basics

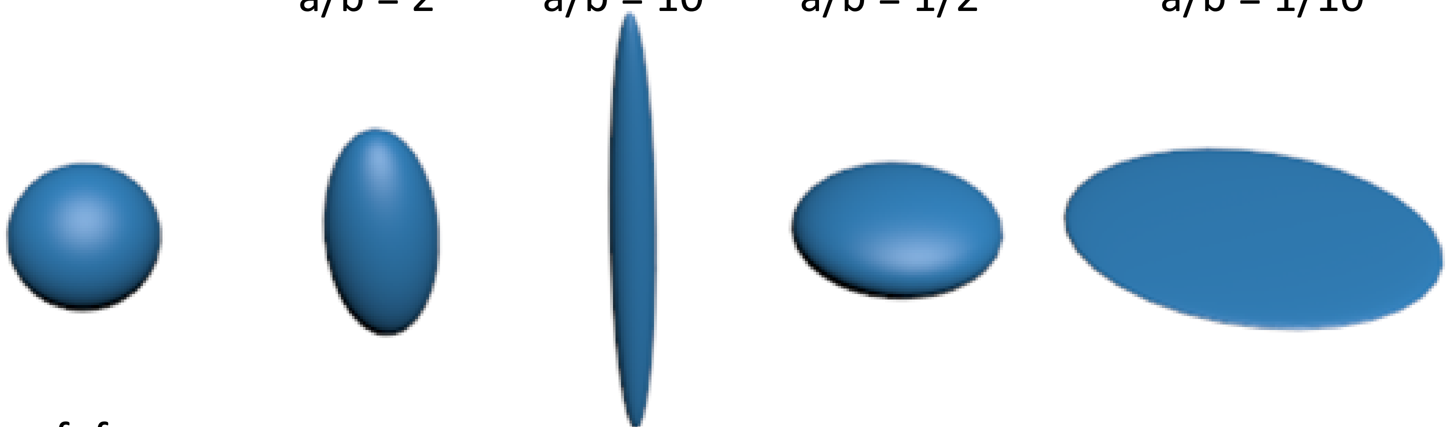
notes:

- Another way of calculating frictional coefficient f for a sphere is using stokes law: $f = 6\pi\eta R$
  Where η stands for dynamic viscosity of your solvent.

- If you are dealing with particle with anisotropic shape (rod, plate, etc.) you may modify the frictional coefficient based on the below chart. Particles like octahedra, decahedra, cuboctahedra may be approximately considered as spheres.

Sphere	Prolate ellipsoid a/b = 2	Prolate ellipsoid a/b = 10	Oblate ellipsoid a/b = 1/2	Oblate ellipsoid a/b = 1/10

*all the particles are of the same volume



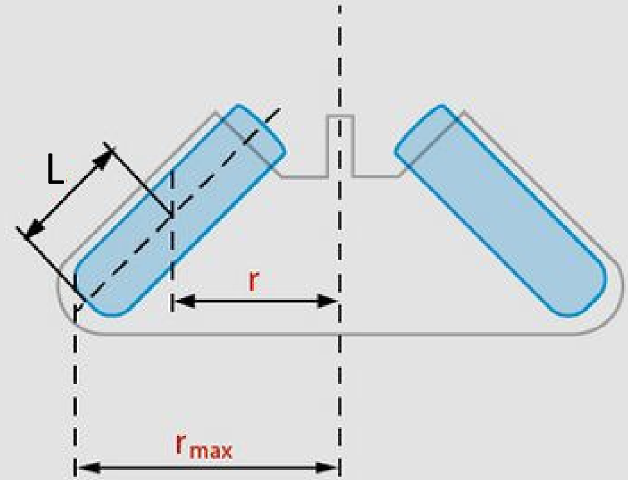
$f=f_0$	$f/f_0=1.044$	$f/f_0=1.543$	$f/f_0=1.042$	$f/f_0=1.458$

Conversion between rpm and rcf

	Rotor A	Rotor B
Speed	14,000 rpm	14,000 rpm
Radius	5.98 cm	9.50 cm
Gravity	13,100 × g	20,817 × g

$$rcf = r_{max} \times (2 \times \pi \times n)^2 / g$$

where
„r" is the max. rotational radius,
„n" is the rotating speed, measured in revolutions per unit of time,
„g" is the earth's gravitational acceleration.



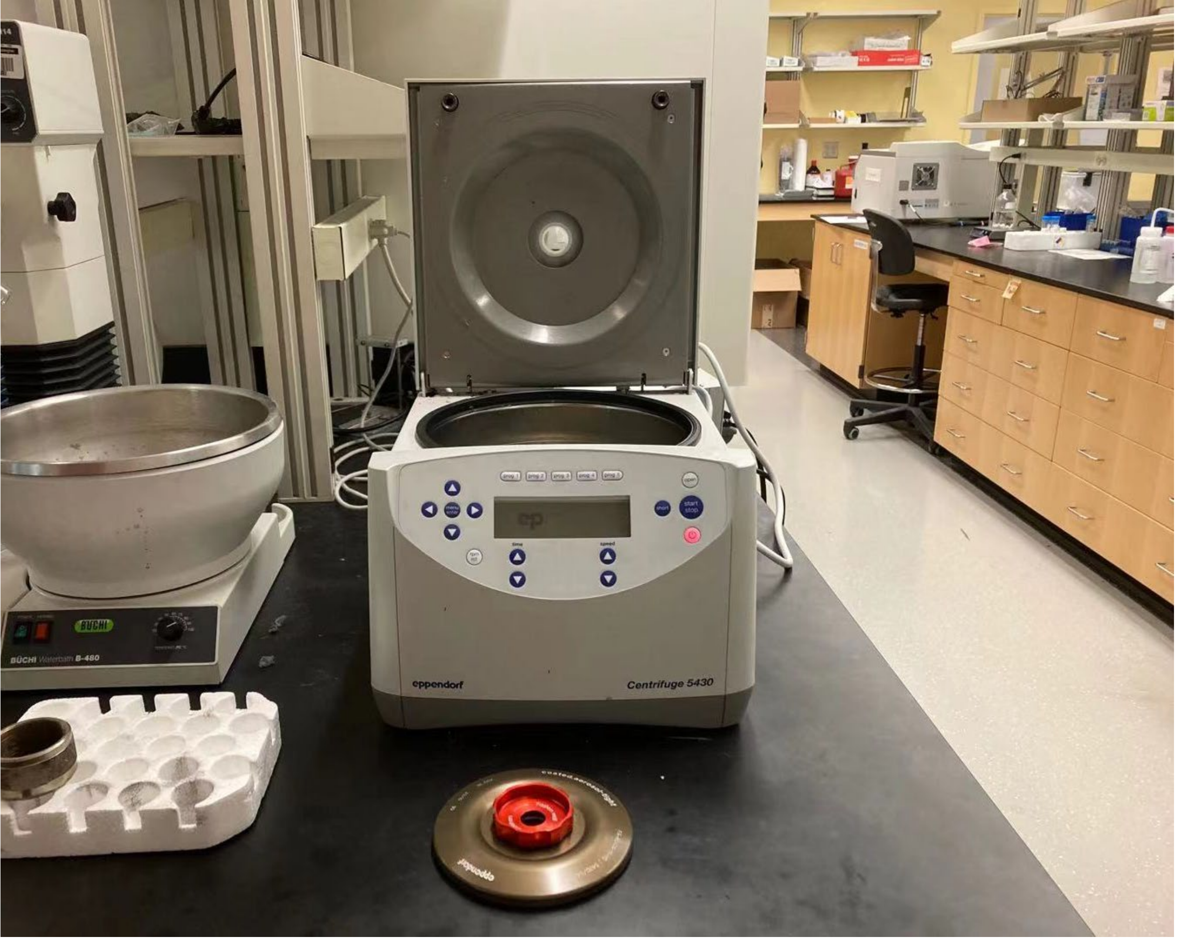
When defining the rotational speed in revolutions per minute (rpm) and the rotational radius is given in centimeters (cm), the above formula becomes

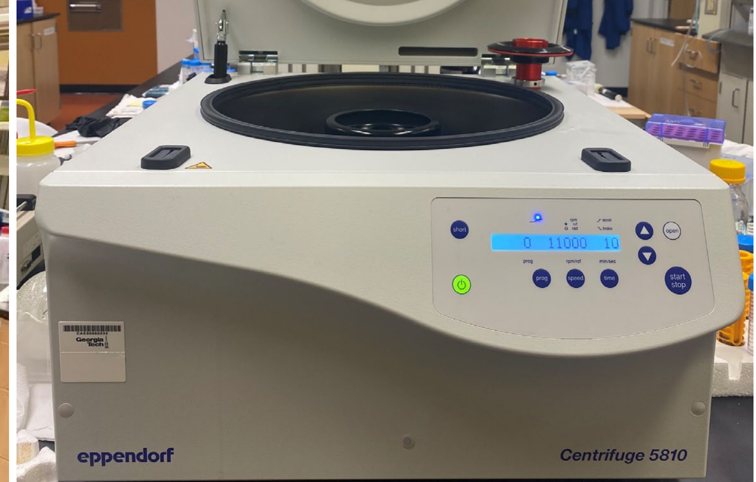
$$\begin{aligned} rcf &= (4 \times \pi^2 \times r \times n^2)/g \\ &= (39.48 \times r \times n^2)/9.81\ m/s^2 \\ &= (4.02\ s^2/m) \times r \times n^2 \\ &= (0.000011175\ min^2/cm) \times r \times n^2 \end{aligned}$$

and finally

$$rcf = 1.118 \times 10^{-5} \times r_{cm} \times n^2_{rpm}$$

where
„rcm" is the rotational radius measured in centimeters (cm)
„nrpm" is the rotating speed measured in revolutions per minute (rpm).


eppendorf
Centrifuge 5430
BÜCHI Waterbath B-480

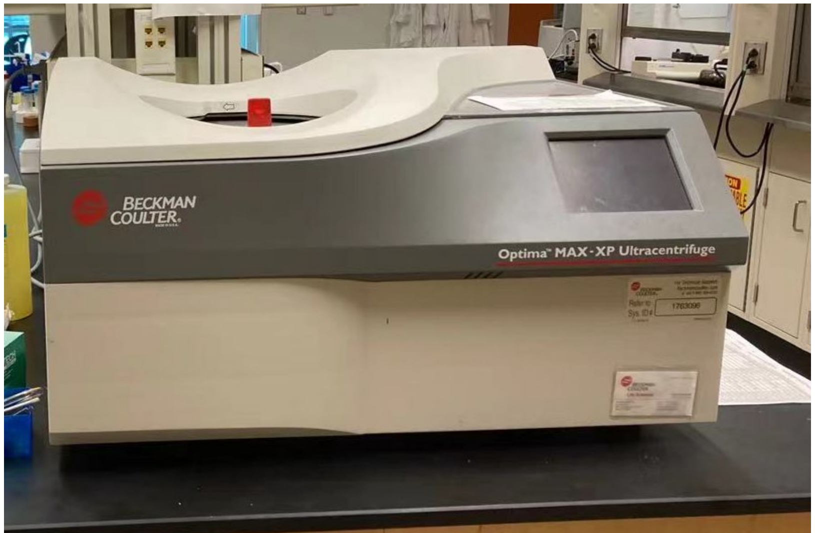

eppendorf
Centrifuge 5810
short
open
start stop
prog
speed
time

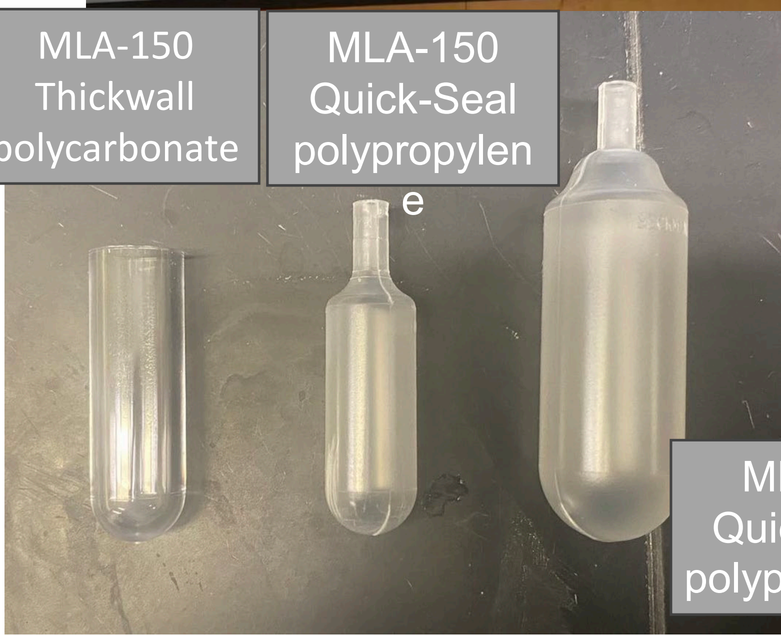

eppendorf
Centrifuge 5418
eppendorf
Centrifuge 5417 C


Spectrafuge
eppendorf
Centrifuge 5415 D


HERMLE Z206A
Labnet
BECKMAN COULTER
Optima MAX-XP Ultracentrifuge
KIMTECH

Ultracentrifuge

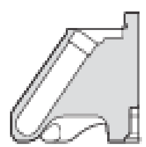


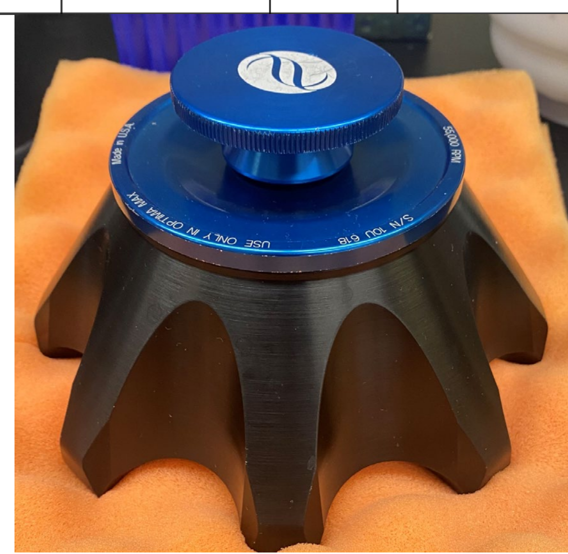


MLA-150 Thickwall polycarbonate

MLA-150 Quick-Seal polypropylene

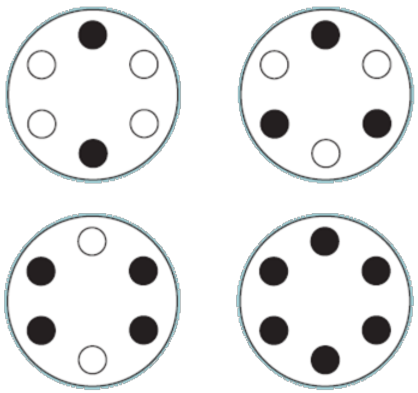
MLA-55 Quick-Seal polypropylene

Rotor Profile	Description	Max RPM/ k factor[a]	Max RCF[b] ($\times g$) at r_{max}	Number of Tubes × Nominal Capacity
	MLA-150 Fixed Angle 30° Angle	150,000 10.4	1,003,000	8 × 2.0 mL
	MLA-55 Fixed Angle 35° Angle	55,000 53	287,000	8 × 13.5 mL

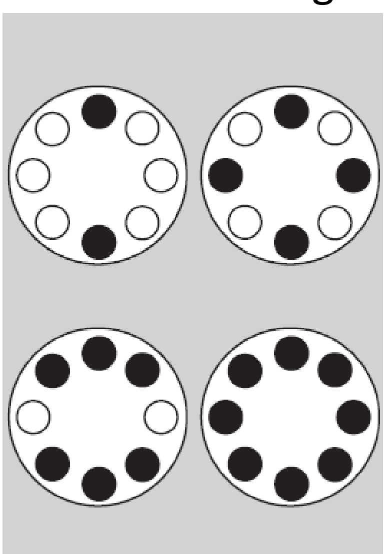


Find Your Balance

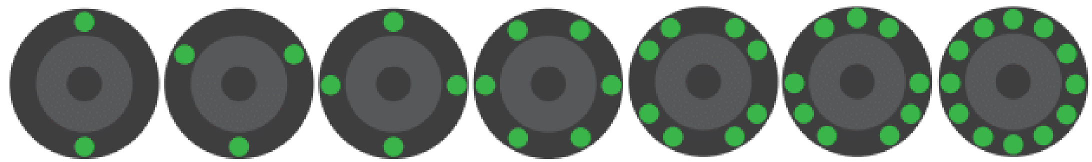
6 Tube Centrifuge



8 Tube Centrifuge

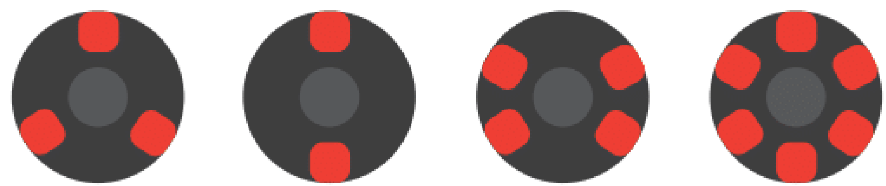


12 Tube Centrifuges

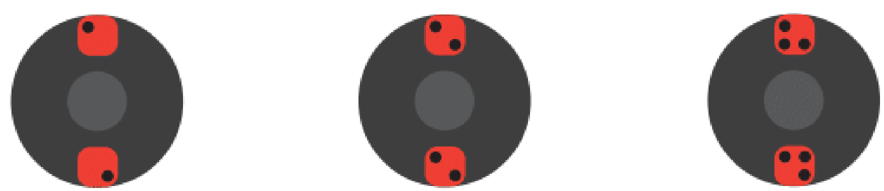


24 Tube Centrifuges

Balanced Rotor Loading



Proper Bucket Loading

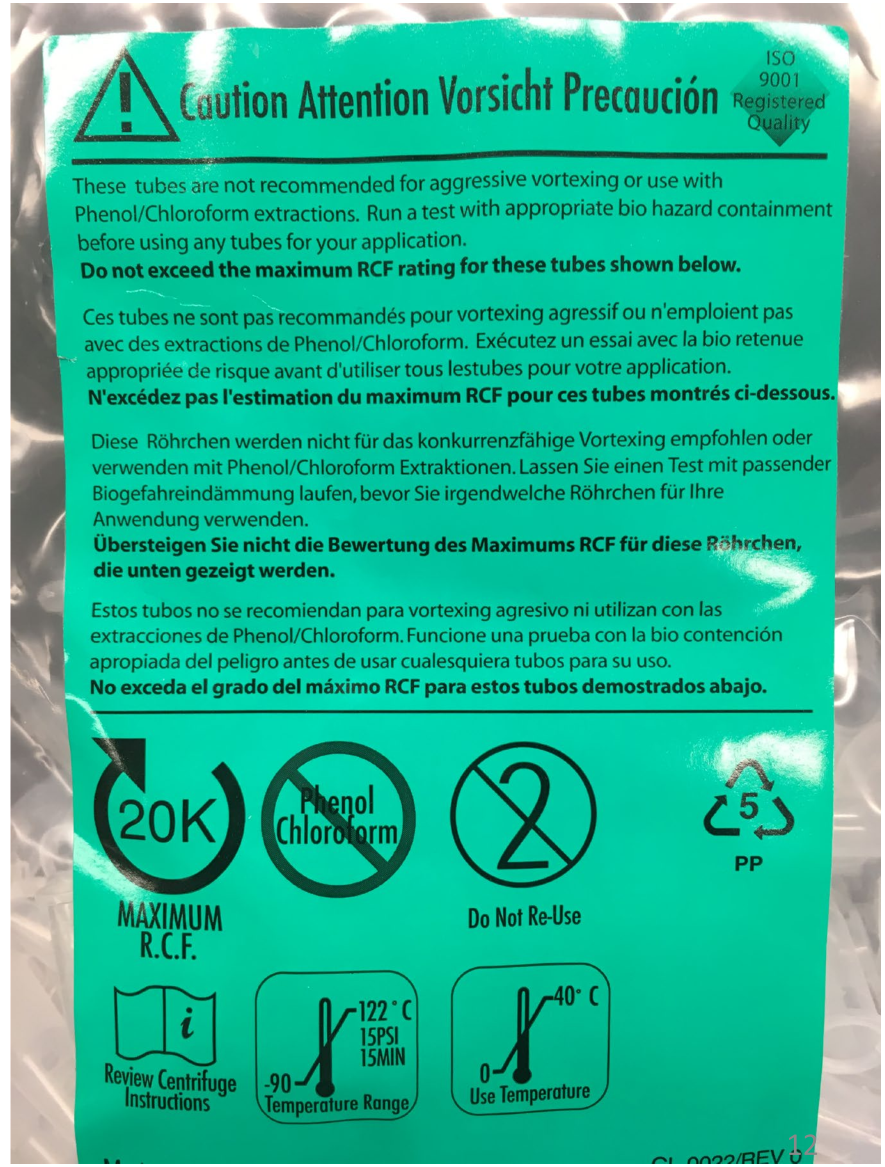


https://druckerdiagnostics.com/knowledge/a-guide-to-balanced-centrifuge-loads/

Pay Attention to Your Solvent

Organic solvent/Acid/Base

Read instructions



Pay Attention to Your Solvent

Chemicals / IUPAC Name	acetal copolymer (celcon)	acrylic	Aluminum	[illegible]	anodic coating[7]	Buna N	copolymer (polyallomer)	Delrin (acetal homopolymer)	EPDM	epoxy resin	epoxy resin/carbon composite	Mylar	neoprene	Noryl (PPO)	nylon (6, 6/6)	paint, water-based	PET	polycarbonate
SOLVENTS																		
acetone 2-propanone	M	U	S	M	S	U	S	S	S	U	U	M	U	U	S	U	M	U
acetonitrile ethanenitrile	S	U	S	S	S	U	S	S	U	M	M	S	S	U	S	U	S	U
benzene	M	U	S	S	S	U	U	M	U	U	U	S	U	U	S	U	S	U
carbon tetrachloride tetrachloromethane	S	U					U	S	U	U	U	S	U	U	S	S	S	U
chloroform trichloromethane	S	U	3				M	S	U	S	S	S	U	U	U	S	S	U
[illegible]	S	U					M	S	U	U	U	S	U	U	U	U	S	U
cyclohexane	S	U	S	S	S	S	U	S	U	S	S	S	U	U	S	S	S	U
diethyl ether ethoxyethane	S	U	S	S	S	U	U	S	U	S	S[2]	S	U	U	S	S	S	U
diethyl ketone 3-pentanone	S	U	S	S	X	U	M	S	M	M	M	X	U	U	S	U	X	U
N,N-dimethylformamide N,N-dimethylmethanamide	S	U	S	S	S	M	S	S	M	M	M	S	U	U	S	S	S	U
dimethyl sulfoxide sulfinylbis[methane]	S	M	S	S	S	U	S	S	S	S	S	S	U	S	S	S	S	U
dioxane 1,4-dioxacyclohexane	S	U	S	M	S	U	M	M	M	S	S	S	U	U	S	U	S	U

Chemicals / IUPAC Name	polyethylene (HDPE)	polyethelene (LDPE)	polypropylene (homopolymer)	polystyrene	polysulfone	polyurethane liner	polyurethane paint	polyvinyl chloride (PVC)	Radel (PPS)	Rulon A (Teflon)	Silastic (RTV)	silicone rubber	stainless steel	titanium	Tygon (flexible PVC)	Ultem	Ultra-Clear™	Viton
SOLVENTS																		
acetone 2-propanone	S	S	S	U	U	U	M	U	M	S	U	M	M	S	U	S	U	U
acetonitrile ethanenitrile	S	S	S	U	U	U	U	M	M	S	S	S	S	S	U	X	U	U
benzene	U	U	U	U	U	U	S	U	M	S	U	U	M	S	U	X	U	S
carbon tetrachloride tetrachloromethane	U	U	U	U	S	U	S	U	S	M	U	U	U	3	U	S	U	S
chloroform trichloromethane	U	U	U	U	U	U	M	U	U	S	U	U	U	3	U	U	U	U
[illegible]	U	U	U	U	U	U	U	U	X	S	S	U	S	S	U	X	U	S
cyclohexane	U	U	U	U	M	U	S	U	S	S	U	U	M	M	U	S	U	S
diethyl ether ethoxyethane	U	U	U	U	U	U	S	U	S	S	U	S	U	S	U	S	U	U
diethyl ketone 3-pentanone	U	U	M	U	U	U	S	U	M	S	X	U	M	S	U	S	U	U
N,N-dimethylformamide N,N-dimethylmethanamide	S	S	S	U	U	U	S	U	X	S	S	M	S	S	U	X	U	U
dimethyl sulfoxide sulfinylbis[methane]	S	S	S	S	U	U	S	U	X	S	U	S	S	S	U	X	U	U
dioxane 1,4-dioxacyclohexane	U	U	S	U	U	U	S	U	X	S	S	U	S	S	U	X	U	U

S = satisfactory resistance
M = marginal resistance
U = unsatisfactory resistance

[1] discloloration
[2] below 26°C only
3 explosion hazard due to possible material/chemical reaction under rotor failure conditions

3 explosion hazard due to possible material/chemical reaction under rotor failure conditions

electrical contacts. Depending on the centrifuge type, such exposure could occur either during normal centrifugation or under failure conditions.

[7] most aluminum components have anodic coating finishes
[8] avoid high temperatures at high concentrations
[9] nickel acetate unsatisfactory
[10] vegetable oils may be marginal or unsatisfactory

Fix minor issue on your own: fuse replacement

Thank you !
Any questions?

Sedimentation of particles

- Reason why larger particles sediment faster

$$v = \frac{d^2 (p - L) \times g}{18\, n}$$

v = sedimentation rate or velocity of the sphere
d = diameter of the sphere
p = particle density
L = medium density
n = viscosity of medium
g = gravitational force