Hemodialysis Machines
Testing Your Understanding

NANT – Dialysis Boot Camp

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Las Vegas, Nevada

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History – First Proportioning Machine

In the early days of dialysis, the initial dialysis apparatus were one of a kind devices created by the doctor primarily to study and begin to understand how to treat ESRD. With the development of cannula to allow long term care, the need for mass production of equipment became a reality. Which company produced the first single patient fixed proportioning hemodialysis machine in the United States?

- A) Drake Willock
- B) Gambro
- C) Milton Roy
- D) Travenol Laboratories
- E) Baxter

History – First Proportioning Machine

- C) Milton Roy Company – The Model A in 1964
- It featured:
  - Hot water disinfection at 85 ^{o}C
  - Diode logic (Automated start-up and shut-down)
  - Variable Sodium
  - Alarm testing prior to treatment
  - Stainless steel plumbing
  - Patient remote control
  - Wood veneer for that “furniture” look
  - Price - $7,200.00

Milton Roy Model A

Company History

There are a variety of companies making hemodialysis machines. Almost all of them started as pharmacies and evolved from there. Do you know your company's history? Try this matching game:

- 1) Baxter
- 2) B. Braun
- 3) Fresenius
- 4) Gambro
- 5) Hospal

- A) Oldest company
- B) 1st balance chambers
- C) 1st synthetic membrane
- D) 1st production dialyzer
- E) 1st dry bicarb proportioning

Oldest Company (2-A)

Company	Year	Founder
Baxter Healthcare	October 19th, 1931	Don Baxter/Ralph Falk
B. Braun Medical	June 23rd, 1839	Julius Wilhelm Braun*
Fresenius Medical; Care	October 1st, 1912	Dr. Eduard Fresenius
Gambro	1964	Nils Alwall/Holger Crafoord

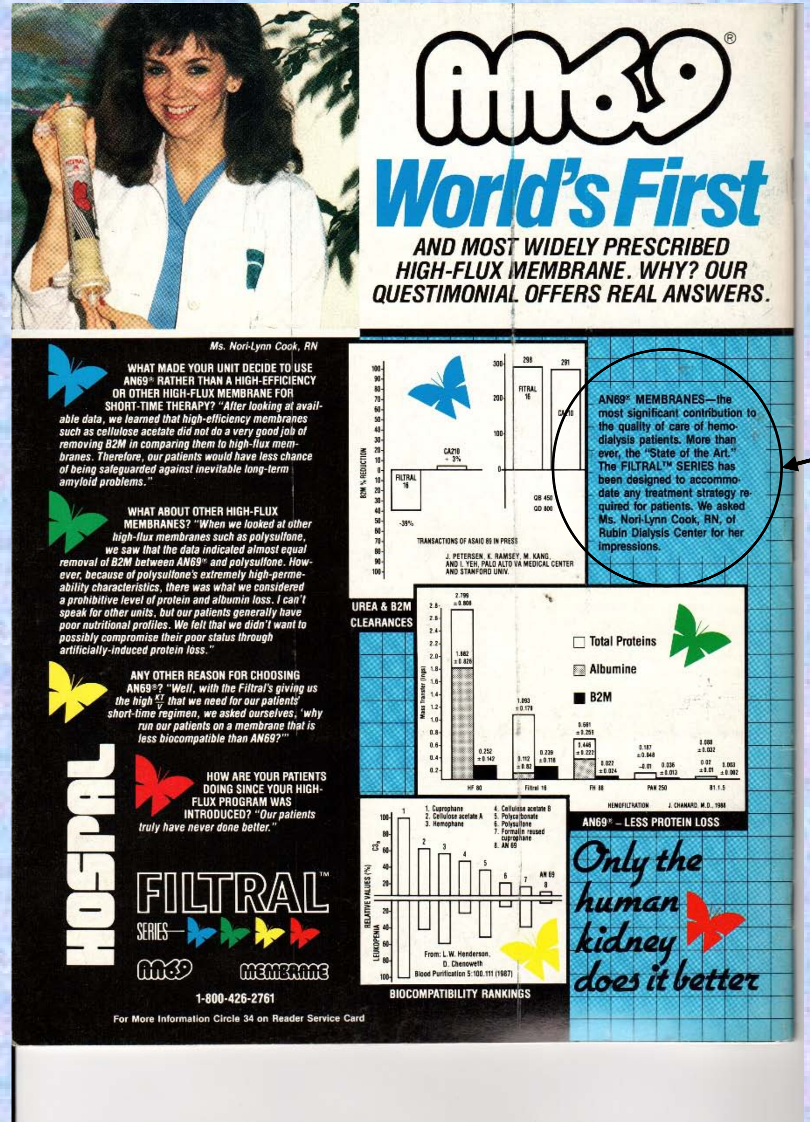
Other company’s founding dates include Cobe Laboratories – 1964, Drake Willock – 1964, Hospal - 1977

* The “B” in B. Braun comes from Braun’s son, Bernhard

A Series of Firsts

- 1st balance chambers (3 – B)
  - Fresenius – A 2008 C - 1979
- 1st synthetic membrane (5 – C)
  - Hospal – AN69 - 1971
- 1st production dialyzer (1 – D)
  - Baxter (Travenol Labs) – U 200 – 1956
- 1st dry bicarb proportioning (4 – E)
  - Gambro – BiCart - 1987

Hospal – HF Membrane – AN69



AN69® Membranes – the most significant contribution to the quality of care of hemodialysis patients. More than ever, the "State of the Art". The FILTRAL™ SERIES has been designed to accommodate any treatment strategy required of patients.

Heat Disinfection

- Dialysis machines using chemical disinfectants have not been fully successful in preventing the buildup of precipitation and bio-slime in their fluid pathways. Heat disinfection has proven to be more successful. Which of the following combinations of time and temperature will result in adequate disinfection?
- A) 80^{o}C for 60 minutes
- B) 85^{o}C for 45 minutes
- C) 90^{o}C for 30 minutes
- D) 95^{o}C for 20 minutes

Killing Bacteria = Time x Temperature

- The formula to ensure bacteria are killed is:

$$A_o = 10^{\left(\frac{T - 80^0 C}{Z}\right)} \text{ x } \Delta T$$

Where: A_o = kill factor = 3000 for bacteria in water

Z = value varies by bacteria type. Use 10 if unknown

T = water temperature (^{o}C)

ΔT = Time at fixed temperature (seconds)

- The kill factor needs to be 5 t0 10 times greater than 3000 to kill bacteria on system surfaces

Killing Times vs. Temperature

Green = no kill, Red = water kill, Blue = min biofilm kill, Black = max. biofilm kill

(80^{o}C for 60 minutes = 3600)

Temp (^{o}C)	5 min	10 min	20 min	30 min	45 min	60 min
85	949	1897	3795	5692	8538	11384
86	1194	2389	4777	7166	10749	14332
87	1504	3007	6014	9021	13532	18043
88	1893	3786	7571	11357	17036	22714
89	2383	4766	9532	14298	21447	28596
90	3000	6000	12000	18000	27000	36000
91	3777	7554	15107	22661	33991	45321
92	4755	9509	19019	28528	42792	57056
93	5986	11972	23943	35915	53872	71829
94	7536	15071	30143	45214	67821	90428
95	9487	18974	37947	56921	85381	113842

The Answer is D – 95^{o}C @ 20 minutes

Dialysate Conductivity

- The standard way that a machine checks to ensure the proper mixture of concentrate and water is to measure the dialysate’s ability to conduct electricity. Dialysate consists of a variety of individual ions that contribute to the final total conductivity. If a dialysate prescription is changed to yield a higher bicarbonate level while keeping the Sodium constant the conductivity displayed by the machine should:

  A) remain unchanged since the Sodium is still the same

  B) increase because there is more bicarbonate

  C) decrease because there is less chloride

  D) Depends on how the machine is calibrated

Conductivity Calculation

Electrolyte	(#1) Conductance Factor	(#2) Charge mEq/L	(#3) Multiply #1 x #2	Divide #3 by 1000 Conductivity mS/cm
NaCl	104.178	100.00	10,418	10.418
KCl	126.185	2.00	252.4	0.252
$CaCl_2$	102.810	2.50	257.0	0.257
$MgCl_2$	105.973	0.75	79.5	0.080
$NaC_2H_3O_2$	69.829	4.00	279.3	0.279
$NaHCO_3$	73.464	33.00	2,424.3	2.424
Total positive charges = Total negative charges				13.710

The Case of the Increasing Bicarbonate

Bath fixed components: Ca^{++} (1.5 mmol/L), K^{+} (2 mmol/L), Mg^{++} (0.5 mmol/L), CH_3COO^- (3.0 mmol/L), $C_6H_{12}O_6$ (8.33 mmol/L)

Conductance factors: NaCl = 104.17, $NaHCO_3$ = 73.46

Bicarb (mEq/L)	30.0	31.0	32.0	33.0	34.0	35.0	36.0
Chloride (mEq/L)	110.0	109.0	108.0	107.0	106.0	105.0	104.0
Conductivity (mS/cm)	13.87	13.84	13.81	13.78	13.74	13.71	13.68

Correct Answer: C) decrease because there is less chloride

Thinking Cost of Use

- Nothing comes cheap these days. The average cost of a kilowatt-hour of electricity in the United States is $ 0.13. With that in mind, about how much does it cost to operate a dialysis machine 16 hours a day, six days a week for an entire year?
- A) $100.00
- B) $250.00
- C) $500.00
- D) $1000.00

Energy Basics

- Watt is the unit of energy in the metric system
- 1 watt (w) = 1 volt x 1 ampere
- 1 kilowatt (kW)= 120 volts x 8.33 ampere
- 1 kilowatt – hour (kWh) = 860,420.7 calories
- 1 calorie = energy to raise 1 mL of water 1^{o}C
- A 100 watt light bulb burning for 10 hours = 1 kWh = $0.13
- The average household in the US used 10,837 kWh in 2012
- That's 903 kWh/month x $0.13 = $117.39

Figuring the Cost

- Assume:
  - Water temperature to the machine is 25 ºC (77ºF)
  - Daily treatment time is 12 hours
  - Disinfect time is 4 hours
  - Disinfect = 300 mL/min @ 85ºC
  - Two scenarios:
    - Dialysate flow = 500 mL/min @ 37ºC
    - Dialysate flow = 800 mL/min @ 37ºC

Heating dialysate

- 500 mL/min @ 37ºC =   30,000 mL/h
- Temperature change = 12 ºC
- Calories = 30,000 x 12 = 360k/h
- 360k calories = 0.418 kWh/h
- 0.418 kWh x $0.13 = $0.054/h
- 312 days x 12 h/day x $0.054/h = $203.30

- 800 mL/min @ 37ºC = 48,000 mL/h
- Temperature change = 12 ºC
- Calories = 48,000 x 12 = 516k/h
- 516k calories = 0.600 kWh/h
- 0.600 kWh x $0.13 = $0.078/h
- 312 days x 12 h/day x $0.078/h = $292.03

Final Figures

- Yearly cost to disinfect 300 mL/min @ 85 ºC for 312 days at 4 hours/day = $202.18 (based on 1,255 W)
- Actual Disinfect Wattage
  - Gambro Phoenix = 1,840 W ($296.42)
  - Gambro AK200 = 1,650 W ($265.81)
  - Fresenius 2008T = 1,500 W ($241.65)
- Add 0.250 kWh/h for pumps, electronics, monitor, etc. for 312 days at 16 hours/day = $162.24
- Final Cost:
  - 500 mL/min: $203.30 + $ 202.18 + $162.24 = $567.72
  - 800 mL/min: $292.03 + $ 202.18 + $162.24 = $656.45
- The correct answer is C) $500.00

Urea Monitoring

- If the urea clearing the dialyzer could be measured during a treatment, the true Kt/V could be known instead of being approximated. In recent years, methods have been developed and incorporated into the latest dialysis machines improving our ability to provide a better treatment for the patient. What are these technologies and their benefits?

On-line Urea Monitoring during Hemodialysis: A Review S. Stiller, A. Al-Bashir, Helmut Mann;
Saudi J Kidney Dis Transplant 2001;12(3):364-374 © 2001 Saudi Center for Organ Transplantation

Urea Monitoring via Conductivity –
Fresenius Medical Care - OCM®, Gambro - DIASCAN®

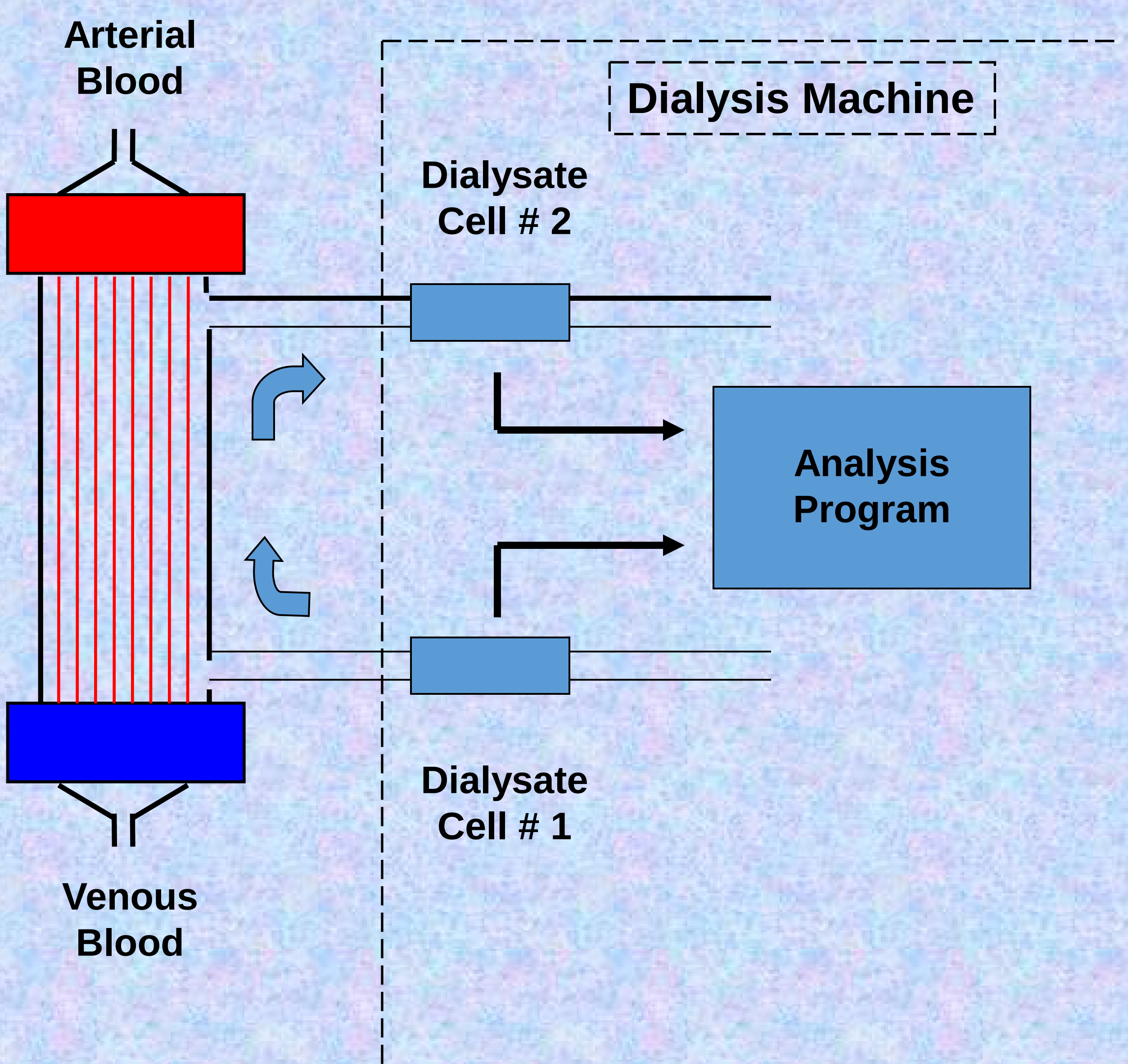
- Utilizes the fact that diffusion rates for urea and Sodium Chloride are similar. (Sodium Chloride = 58.5, Urea = 60.0)
- Monitors dialysate conductivity pre and post dialyzer for differences due to blood interaction.
- Temporarily increases dialysate Sodium slightly at 20 minute intervals during treatment.
- Compares dialysate conductivity difference following the change with prior readings.
- The conductivity change will be in proportion to the urea clearance.

On-Line Clearance Method

Conductivity cell #1 measures dialysate conductance.

Conductivity cell #2 measures effluent conductance.

The conductivity difference is directly proportional to urea clearance.



On-Line Na^+ Clearance Results

- Provides information on ***effective*** clearance.
  - Vs. dialyzer manufacturer's claims
  - New vs. reused dialyzer actual performance
  - Detection of technical problems *(but not identification of specific problem)*
    - ex. High pre-pump arterial pressure, inaccurate blood pump setting, error in pump calibration, inadequate Q_D, dialyzer clotting, etc.
- With multiple sampling during dialysis, can predict treatment outcome.
  - Enables adjustment of treatment parameters, prn
  - Dialysis efficiency can be documented every run

On-Line Na^+ Clearance

- Advantages[1]
  - Accuracy equivalent to Daugirdas-Schneditz urea method
  - No blood or dialysate sampling
  - No lab costs
  - No staff time, effort
  - Real time results enable intervention

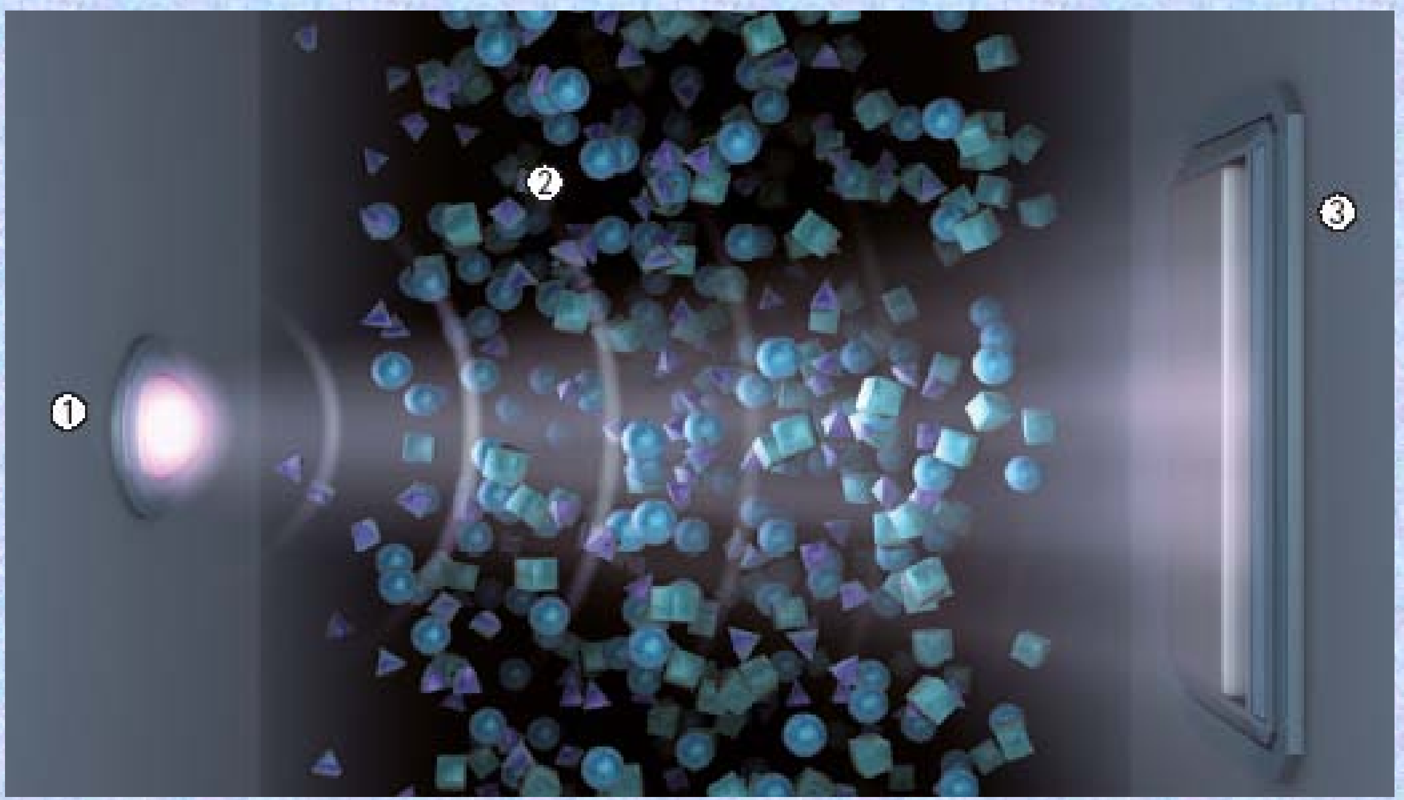
- Disadvantages
  - Does not measure urea, thus no:
    - **PCR**
    - **Total urea removal**
    - **True treatment time**
  - Small risk of excess sodium exposure
  - Small additional equipment cost

[1] Di Filippo s, Manzoni C, Locatelli F: Kt/V or solute removal index. *Neph Dial Transplant*, 1998, 13:2199-2202.

Urea Monitoring using UV Absorption -
B. Braun - Adimea® Urea Monitor

- Measures dialysis efficiency by determining the reduction in molar concentration of urinary excreted substances in the spent dialysate.
- A UV light source shines light through the effluent coming from the dialyzer
- Particles in the effluent absorb the UV light reducing the amount that reaches the UV sensor diametrically across from the light source.
- The reduction in light is in direct proportion to the amount of excreted substances from the patient.
- Urea is the key ingredient

Urea Monitoring using UV Absorption



1 – Ultraviolet light source
2 – Waste products from the patient
3 – Ultraviolet light detector

Urea Monitoring using UV Absorption

- Adimea® provides an accurate measurement process for reliable and continuous control of the dialysis dose (Kt/V) throughout the entire treatment. Treatment parameters can be adjusted by doctors and nursing staff for the benefit of patients even during treatment. This allows the equipment to optimally support the execution of the treatment objectives.
- The UV absorption measurements can be used for determining the dialysis dose as there is a very close linear correlation between the measured UV absorption signal and the urea in the dialysate.

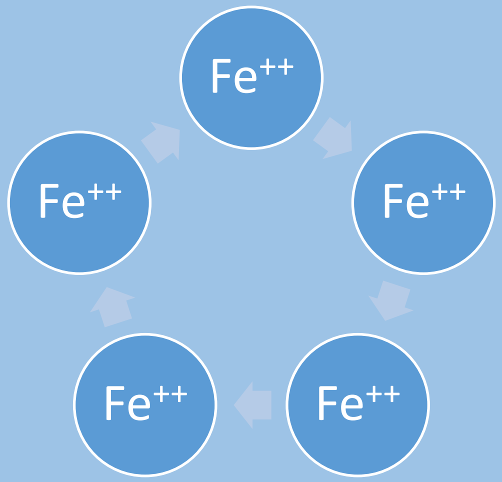
Uhlin F, Fridolin I, Magnusson M, Linberg L-G. Dialysis dose (Kt/V) and clearance variation sensitivity using measurement of ultraviolet absorbance (on-line), blood urea, dialysate urea and ionic dialysance. Nephrol Dial Transplant (2006) 21: 2225-2231

Urea Monitoring using UV Absorption - Benefits

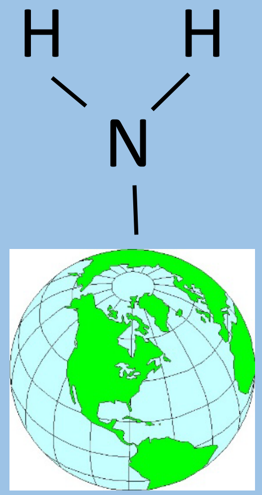
- Monitoring of the effluent for substances coming from the patient is continuous
- No determination of V – merely requires the pre-dialysis weight
- Configurable and clear display of URR, spKt/V, eKt/V as well as result prognosis
- Changes to treatment parameters possible at any time
- Notification if expected URR will not be reached

Final Question!

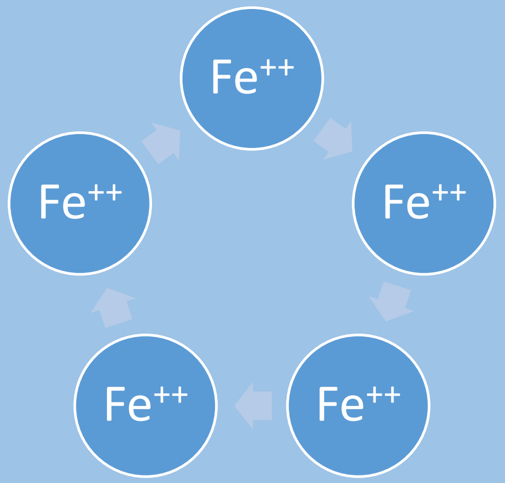
- This question relates to chemistry. Identify the following chemical formulas. Hint: Two of them are jokes and the third is a real substance.



$(C_{27}H_{22}O_4S)_n$



Final Answers!



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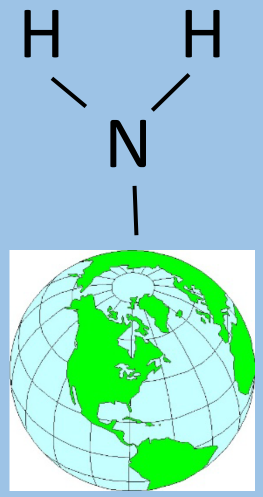

Ferrous Wheel

Polysulpone

Amino World