STLE Annual Meeting
Commercial Marketing Forum
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Chevron Phillips Chemical Company's Synfluid® Polyalphaolefins (PAOs): Opportunistic Blends

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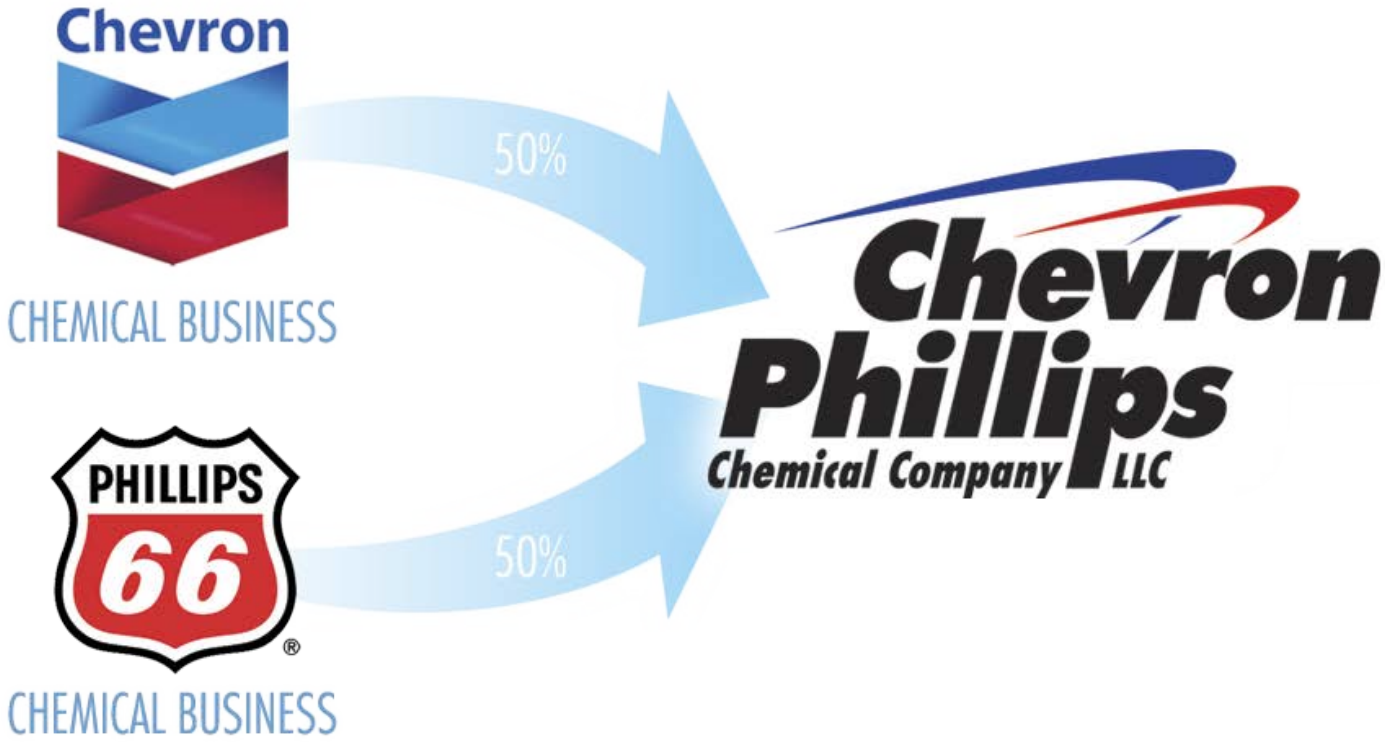
SYNFLUID® POLYALPHAOLEFINS

Topics

- **Low Viscosity PAOs**
  - Historic view
  - Typical properties
- **Special Blend Opportunities**
  - Plurality of permutations!
  - Interesting examples:
    - 6 cSt from PAO 4 and PAO 7
    - 8 cSt from PAO 7 and mPAO 150
    - 4.5 cSt from PAO 2 and 5 or PAO 4 & 6 HVI
- **Summary & Conclusions**

Company Founded in 2000



About Us

- Manufacturer of petrochemicals that are essential to manufacturing over 70,000 consumer and industrial products
- Currently $15.5 billion in assets and more than $8.5 billion in annual revenues
- Trusted supplier to customers in nearly 140 countries
- A highly educated and diverse workforce of approximately 5,000 employees working on four continents across the globe

Chevron Phillips Chemical's History of PAOs

1980: Gulf Oil first to commercialize PAO

1985: Chevron Gulf merger

1995: Chevron first to produce dodecene based PAOs

2000: Chevron Phillips formed and 10kMta expansion

Members of the joint-venture management team watch as Chief Executive Officer Jim Gallogly flips a coin to decide the name of the new company. From left to right: Tim Taylor, Scott Meyer, Greg Garland, Mike Parker, Gallogly, Kent Potter and Bob Hunt.

2011: Chevron Phillips acquires Neste PAO assets

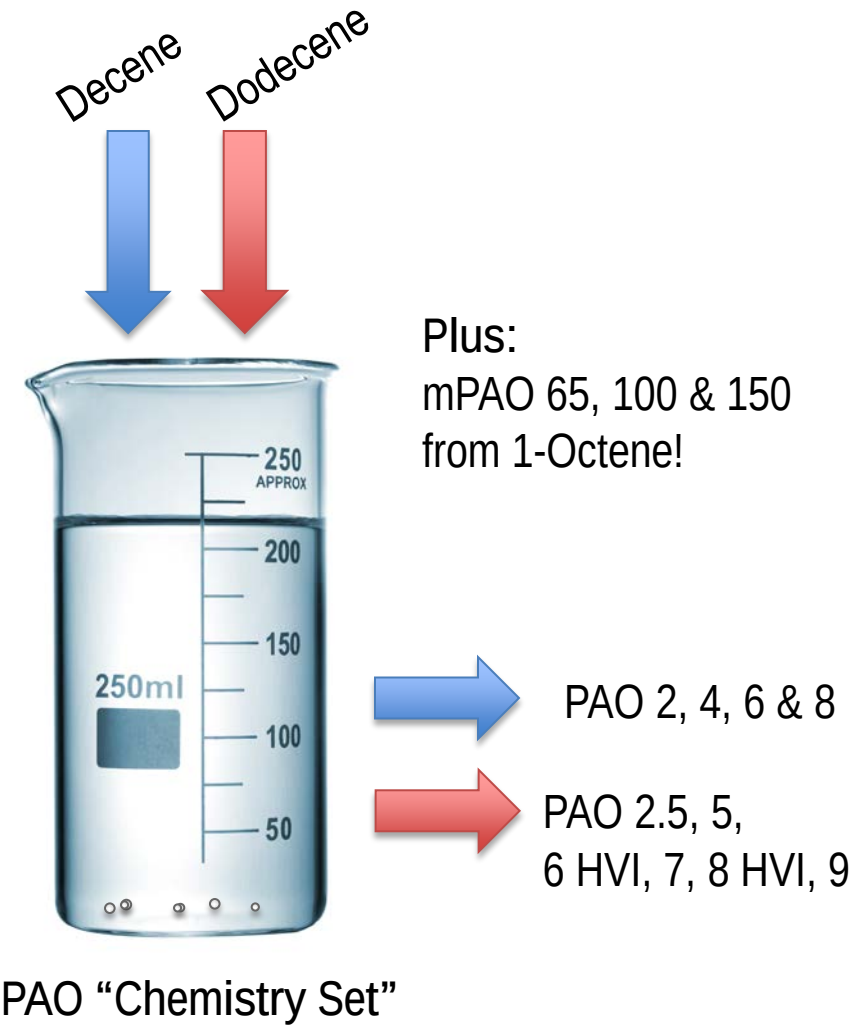
2011: Chevron Phillips begins Synfluid® mPAO production

2017: Chevron Phillips 10kMta expansion

2017: Chevron Phillips 1500kMta ethylene unit

Feedstock / Monomer

- PAOs were originally designed from 1-Decene
- 1-Dodecene was introduced in 1995 to expand supply and provide interesting alternatives to decene
- Some have used a variety of alpha olefins to produce PAO
- This has led to a much wider variety of PAOs than the original 2, 4, 6 & 8 cSt PAOs.
- What can be done with the myriad of combinations possible?



Blend Permutations: 6 cSt

- Lower and higher viscosity PAOs can be blended to an intermediate viscosity (i.e. PAO 4 and PAO 7 to 6 cSt at 100°C)
- Some blends are blacked out if it is impossible (i.e. PAO 2 and PAO 5 to 6 cSt)
- A variety of properties can be calculated for these permutations (Noack Volatility, -40°C viscosity, Pour Point, VI etc.)

5.85 cSt at 100°C Blends

Noack Volatility (wt.%)	PAO 2	PAO 2.5	PAO 4	PAO 5	PAO 6	PAO 6 HVI	PAO 7	PAO 8	PAO 8 HVI	PAO 9	mPAO 65	mPAO 100	mPAO 150
PAO 2	100				7.4	5.3	16.4	21.9	22.4	26.3	66.7	70.2	72.9
PAO 2.5		80			7.5	5.3	16.9	22.4	22.8	26.4	58.9	61.4	63.1
PAO 4			13.6		6.9	5.0	6.7	7.8	7.6	7.9	11.9	12.1	12.3
PAO 5				5.9	6.7	4.9	5.0	5.2	5.1	5.0	5.7	5.7	5.7

Pour Point (°C)	PAO 2	PAO 2.5	PAO 4	PAO 5	PAO 6	PAO 6 HVI	PAO 7	PAO 8	PAO 8 HVI	PAO 9	mPAO 65	mPAO 100	mPAO 150
PAO 2	-73				-62	-44	-46	-58	-48	-43	-59	-60	-58
PAO 2.5		-52			-52	-44	-45	-53	-46	-42	-50	-50	-50
PAO 4			-69		-62	-44	-48	-60	-51	-49	-63	-64	-63
PAO 5				-46	-46	-44	-46	-53	-46	-45	-48	-48	-48

Synfluid® PAO 4/7 Blend vs. PAO 6 & PAO 6 HVI

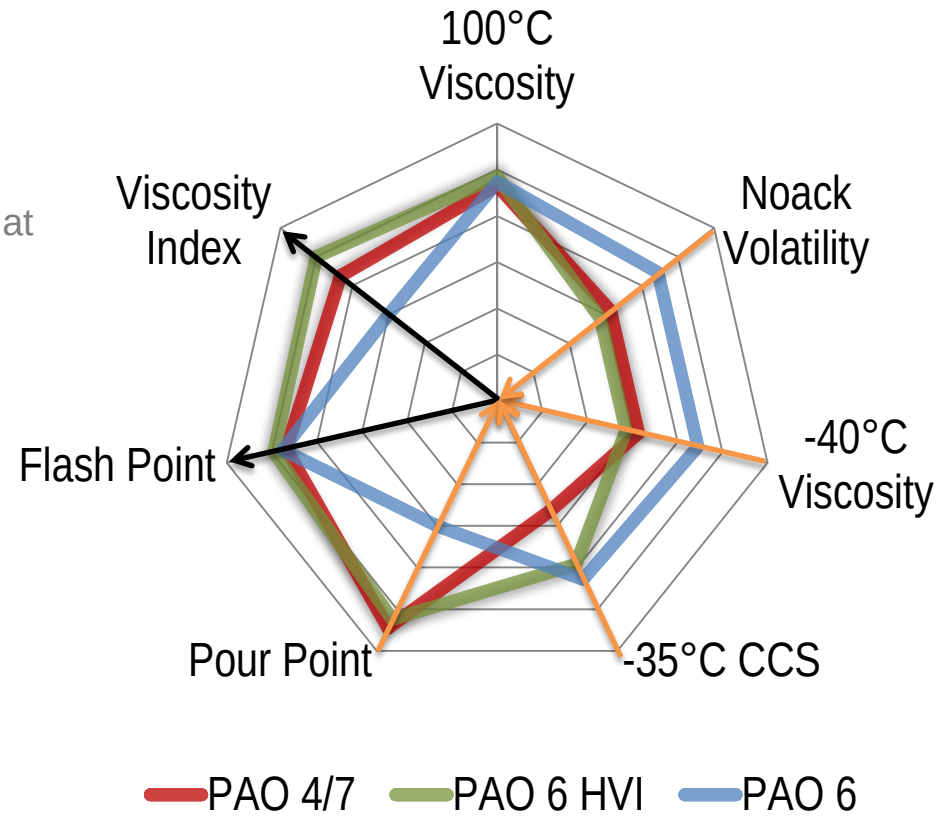
Property	PAO 4 / 7	Synfluid® PAO 6 HVI	Synfluid® PAO 6
Kinematic Viscosity, cSt @ 100°C	5.80	5.91	5.84
Kinematic Viscosity, cSt @ 40°C	29.4	29.1	30.89
Kinematic Viscosity, cSt @ -40°C	6669	6443	7750
CCS, cP @-35°C	3055	3571	3715
Viscosity Index	144	146	137
Pour Point, °C	-49	-50	-64
Flash Point (COC), °C	242	249	244
Fire Point (COC), °C	278	291	274
Volatility, Noack, wt %	6.9	4.9	7.1
Specific Gravity, 15.6°/15.6°C	0.8263	0.8256	0.8277
Total Acid Number	<0.03	<0.03	<0.03
Bromine Index	<200	<200	<200
Odor	No Foreign Odor	No Foreign Odor	No foreign Odor
Appearance	Clear and Bright	Clear and Bright	Clear and Bright
Color, Pt-Co	0	0	0

Comparison of PAO 4/7 Blend with PAO 6 and PAO 6 HVI

- Arrows indicate direction of improved performance
- PAOs are compared at equivalent viscosity at 100°C

Observations:

- The Viscosity Index and -40°C viscosity are better for 6 HVI and 4/7 Blend
- -35°C CCS is best for 4/7 Blend (-571 cP improved from 6 HVI and -715 cP from PAO 6)
- Flash points are close to equivalent
- Pour Point is favored for PAO 6 by 14°C
- Noack Volatility is better for 6 HVI by 2%



Blend Permutations: 8 cSt

- Lower and higher viscosity PAOs can be blended to an intermediate viscosity (i.e. PAO 4 and mPAOs to 8 cSt at 100°C)
- Some blends are blacked out if it is impossible (i.e. PAO 2 and PAO 7 to 8 cSt)

7.8 cSt at 100°C Blends

Noack Volatility (wt.%)	PAO 2	PAO 2.5	PAO 4	PAO 5	PAO 6	PAO 6 HVI	PAO 7	PAO 8	PAO 8 HVI	mPAO 65	mPAO 100	mPAO 150
PAO 2	100							3.9	4.5	59.0	63.4	66.6
PAO 2.5		80						3.9	4.5	52.1	55.4	57.7
PAO 4			13.6					3.8	3.6	10.7	11.1	11.4
PAO 5				5.9				3.8	3.4	5.3	5.4	5.4
PAO 6					6.8			3.8	3.5	6.2	6.3	6.4
PAO 6 HVI						4.9		3.8	3.4	4.6	4.6	4.7
PAO 7							3.7	3.8	3.4	3.6	3.6	3.6

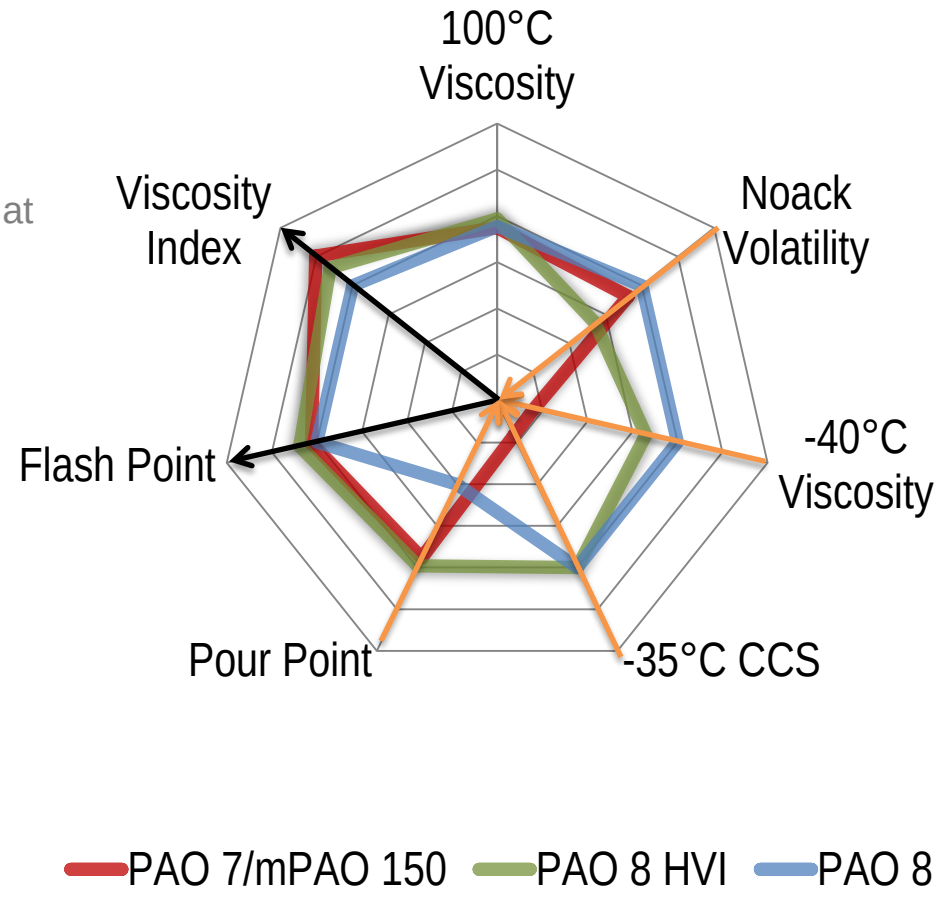
-40°C Viscosity (cSt)	PAO 2	PAO 2.5	PAO 4	PAO 5	PAO 6	PAO 6 HVI	PAO 7	PAO 8	PAO 8 HVI	mPAO 65	mPAO 100	mPAO 150
PAO 2	243							18196	16164	7419	5940	5137
PAO 2.5		1939						18236	16454	17083	14954	13795
PAO 4			2376					18196	16176	10326	9214	8600
PAO 5				4852				18182	16113	11192	10432	10013
PAO 6					7637			18189	16179	13180	12581	12250
PAO 6 HVI						6443		18167	16016	11413	10856	10547
PAO 7							10557	18091	15760	12817	12591	12466
PAO 8	18196	18236	18196	18182	18189	18167	18091	18314				

Comparison of PAO 7/mPAO 150 Blend with PAO 8 and PAO 8 HVI

- Arrows indicate direction of improved performance
- PAOs are compared at equivalent viscosity at 100°C

Observations:

- The Viscosity index (+15 units), -40°C and CCS viscosities are better for the blend
- Pour Point is favored for PAO 8 by 11 degrees
- Noack volatility is better for 8 HVI by 2%



Blend Permutations: 4.5 cSt

- Lower viscosity options to reduce Noack volatility and improve VI while maintaining excellent Pour Points

4.50 cSt at 100°C Blends

Noack Volatility (wt.%)	PAO 2	PAO 2.5	PAO 4	PAO 5	PAO 6	PAO 6 HVI	PAO 7	PAO 8	PAO 8 HVI	PAO 9	mPAO 65	mPAO 100	mPAO 150
PAO 2	100			17.5	26.9	25.2	34.0	38.3	38.7	41.8	76.5	78.6	73.7
PAO 2.5		80		19.1	28.6	27.1	35.3	39.2	39.5	42.1	66.8	68.1	65.0
PAO 4			13.6	9.4	11.0	10.3	11.0	11.4	11.3	11.4	13.0	13.1	12.9
PAO 5	17	19	9.4	5.9									

Pour Point (°C)	PAO 2	PAO 2.5	PAO 4	PAO 5	PAO 6	PAO 6 HVI	PAO 7	PAO 8	PAO 8 HVI	PAO 9	mPAO 65	mPAO 100	mPAO 150
PAO 2	-73			-48	-63	-47	-49	-60	-51	-47	-61	-62	-61
PAO 2.5		-52		-47	-54	-46	-47	-54	-48	-44	-52	-51	-51
PAO 4			-69	-53	-66	-56	-59	-66	-61	-59	-66	-66	-66
PAO 5	-48	-47	-53	-46									

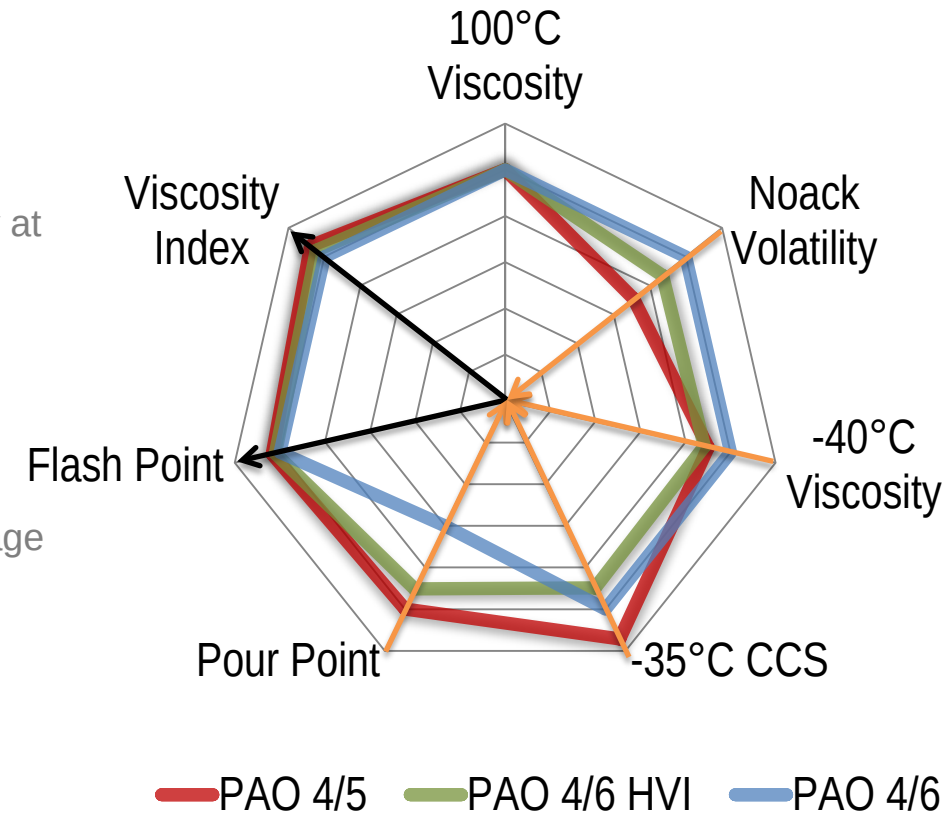
Viscosity Index	PAO 2	PAO 2.5	PAO 4	PAO 5	PAO 6	PAO 6 HVI	PAO 7	PAO 8	PAO 8 HVI	PAO 9	mPAO 65	mPAO 100	mPAO 150
PAO 2	----			142	134	141	144	134	142	141	177	177	171
PAO 2.5		----		142	136	142	145	137	144	143	169	170	166
PAO 4			124	137	132	135	135	131	133	133	138	138	137
PAO 5	142	142	137	145									

Overview: Comparison of PAO 4/5 Blend and PAO 4/6 HVI to 4.5 cSt

- Arrows indicate direction of improved performance
- PAOs are compared at equivalent viscosity at 100°C

Observations:

- Noack Volatility is better for PAO 4/5 blend (9.4%)
- Pour Point is favored for PAO 4/6 by 12°C
- The Viscosity Index shows a slight advantage for the 4/5 and 4/6 HVI blends
- Flash points are close to equivalent



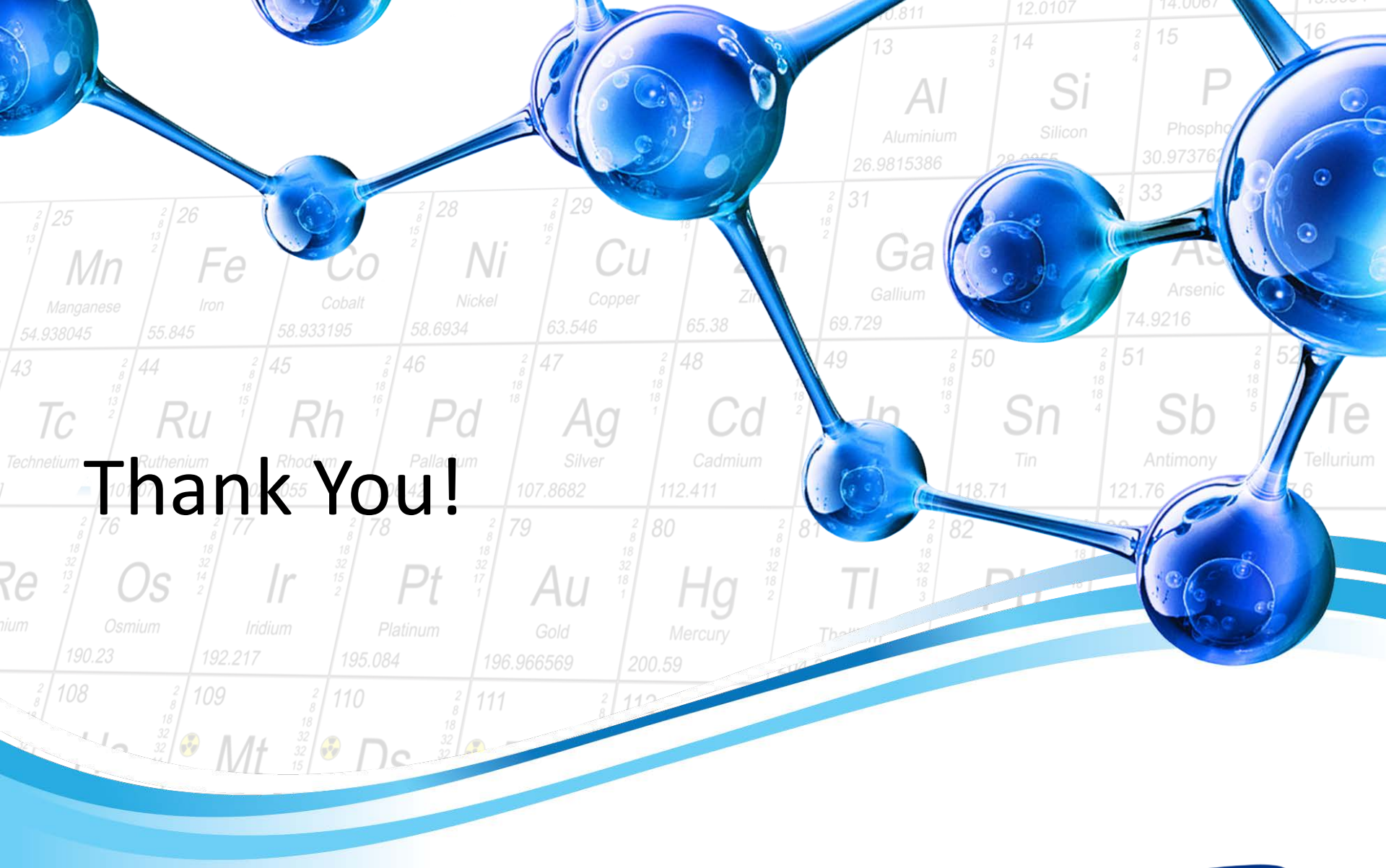
Summary & Conclusions

Summary

- There are many possibilities for blends with different PAO base oils
- PAOs are used in a wide variety of lubricant applications for specific physical properties
- Certain blends can emphasize these specific properties to provide potential improvements

Conclusions

- These example blends show:
  - Noack Volatility can be decreased to below 10% for a 4.5 cSt PAO
  - VI can be elevated for an 8 cSt PAO to 153 and a 30% reduction in the -40°C viscosity
  - A PAO 4/7 blend can be very close to PAO 6 or PAO 6 HVI performance in many aspects
- Many other blend opportunities exist with PAOs in addition to:
  - Ternary component blends (which haven't been explored here)
  - Blends with Group I, II, III, III+



Thank You!

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