What is claimed is:

1. A process for producing a high purity product thiol from hydrogen sulfide and an olefin comprising:

feeding the hydrogen sulfide and the olefin to a reactor system, wherein the reactor system is configured to:

form a reactor effluent stream comprising the product thiol, unreacted hydrogen sulfide, unreacted olefin and other components;

separating said reactor effluent stream into a first portion and a second portion;

recycling ~~a~~ said first portion of the reactor effluent stream to the reactor system;

feeding ~~a~~ said second portion of the reactor effluent stream to a flash vaporizer, wherein the flash vaporizer is configured to:

produce a hydrogen sulfide recycle stream comprising at least a portion of the unreacted hydrogen sulfide, and a crude thiol stream comprising the product thiol, the unreacted olefin and the other components;

feeding the hydrogen sulfide recycle stream to the reactor system;

feeding the crude thiol stream to a crude thiol separation system, wherein the crude thiol separation system is configured to:

separate at least a portion of the unreacted olefin from the crude thiol stream to:

produce an olefin recycle stream comprising the unreacted olefin, a first by-product stream comprising a first portion of the other components, and a crude thiol product stream comprising the product thiol and a second portion of the other components;

feeding the olefin recycle stream to the reactor system;

feeding the crude thiol product stream to a product thiol purification unit, wherein the product thiol purification unit is configured to:

produce a thiol product stream comprising purified product thiol comprising at least 90 weight percent of the product thiol and a second by-product stream comprising the second portion of the other components.

2. The process according to claim 1, wherein the olefin comprises a C4-C18 linear alpha olefinic straight-chain hydrocarbon.

3. The process according to claim 1 or 2, wherein the olefin comprises C12 linear alpha olefinic straight-chain hydrocarbon, the product thiol comprises n-dodecylmercaptan, and less than 1000 ppm weight tetradecylmercaptan and less than 1000 ppm sulfides.

4. The process according to any one of claims 1 to 3, wherein an amount of the first portion of the reactor effluent stream recycled to the reactor system maintains an amount of 20% to 60% by weight of the product thiol in the reactor system.

5. The process according to any one of claims 1 to 4,

wherein the crude thiol separation system comprises an olefin separation unit and a secondary separation unit, and

wherein the crude thiol stream is fed to the olefin separation unit,

wherein the olefin separation unit is configured to:

produce the olefin recycle stream and a secondary stream; and to

feed the secondary stream to the secondary separation unit, and

wherein the secondary separation unit is configured to:

separate the secondary stream to produce the first by-product stream and the crude thiol product stream.

6. The process according to any one of claims 1 to 5, wherein the second by-product stream comprising the second portion of the other components comprises sulfides and wherein the second by-product stream is fed to a sulfide cracking and stripping unit, wherein the sulfide cracking and stripping unit is configured to:

convert the sulfides into olefins and thiols;

produce a third by-product stream comprising the sulfides; and

feed the olefins and thiols to the crude thiol separation system.

7. The process according to any one of claims 1 to 4, wherein the crude thiol separation system comprises an olefin separation unit and a crude thiol separation unit, and wherein:

the crude thiol stream is fed to the crude thiol separation unit, wherein the crude thiol separation unit is configured to:

produce the crude thiol product stream and a olefin stream; and to

feed the olefin stream to the olefin separation unit; and wherein:

the olefin separation unit is configured to:

separate the olefin stream to produce the first by-product stream and the olefin recycle stream.

8. The process according to any one of claims 1 to 7, wherein the reactor system comprises an absorption unit in communication with a reactor bank, and wherein the absorption unit is configured to:

receive the hydrogen sulfide and the olefin and the recycled first portion of the reactor effluent stream,

form a liquid reactor bank feed stream comprising at least a portion of the hydrogen sulfide dissolved in the olefin and the recycled first portion of the reactor effluent stream, and

feed the liquid reactor bank feed stream into the reactor bank;

and wherein the reactor bank is configured to:

receive the recycled first portion of the reactor effluent stream and the liquid reactor bank feed stream, and

form the reactor effluent stream comprising the product thiol, unreacted hydrogen sulfide, unreacted olefin and other components.

9. The process according to any one of claims 1 to 8, wherein the reactor effluent stream comprises from 20% to 70% by weight of the product thiol.

10. The process according to any one of claims 1 to 9, wherein the first portion of the reactor effluent stream comprises at least 70 weight percent of a total reactor effluent stream.

11. The process according to any one of claims 1 to 10, wherein a conversion of linear alpha olefin to the product thiol in the reactor system is 50 weight percent or less and wherein the amount of sulfide in the reactor is less than 10 weight percent.

12. The process according to any one of claims 1 to 11, wherein the reactor system is further configured to:

form the product thiol from the hydrogen sulfide and the olefin using electromagnetic radiation, of a wavelength is from 100nm to 600 nm, and the reactor effluent stream comprises less than 5 weight percent of a promotor compound selected from the group consisting of alkyl boranes, phosphites, azobisisobutyronitrile, benzophenones and derivatives thereof, thiobenzophenones, xanthenic compounds, and mixtures thereof and/or less than 5 weight percent of an initiator compound.

13. The process according to any one of claims 1 to 12, wherein the purified product thiol comprises less than 5 ppm weight of phosphorous.

14. The process according to any one of claims 1 to 13, wherein the product thiol purification unit includes at least one distillation column containing structured packing.

15. An apparatus for producing a high purity product thiol from hydrogen sulfide and an olefin comprising:

a reactor system configured to receive the hydrogen sulfide and the olefin and to produce a reactor effluent stream comprising the product thiol, unreacted hydrogen sulfide, unreacted olefin and other components, and wherein the reactor system is further configured to separate said reactor effluent stream into a first portion and a second portion and recycle ~~a~~ said first portion of the reactor effluent stream back to the reactor system;

a flash vaporizer in communication with the reactor system, wherein the flash vaporizer is configured to receive ~~a~~ said second portion of the reactor effluent stream and to produce:

a hydrogen sulfide recycle stream comprising at least a portion of the unreacted hydrogen sulfide, and a crude thiol stream comprising the product thiol, the unreacted olefin and the other components and wherein the flash vaporizer is configured to feed the hydrogen sulfide recycle stream to the reactor system;

a crude thiol separation system comprising an olefin separation unit in communication with a secondary separation unit, and wherein:

the olefin separation unit is in communication with the flash vaporizer and the reactor system, and is configured to:

~~wherein the crude thiol separation system is configured to~~ receive the crude thiol stream~~,~~ ; ~~wherein the crude thiol separation system is configured to:~~

~~separate at least a portion of the unreacted olefin from the crude thiol stream to~~ produce an olefin recycle stream and a secondary stream;~~comprising the unreacted olefin, a first by-product stream comprising a first portion of the other components, and a crude thiol product stream comprising the product thiol and a second portion of the other components; and~~

feed the olefin recycle stream to the reactor system;

feed the secondary stream to the secondary separation unit; and

wherein the secondary separation unit is in communication with the product thiol purification unit and is configured to:

receive the secondary stream; and

separate the secondary stream to produce the first by-product stream and the crude thiol product stream;

a product thiol purification unit in communication with the crude thiol separation system, wherein the product thiol purification unit is configured to:

receive the crude thiol product stream;

produce a product thiol stream comprising purified product thiol comprising at least 98.5 weight percent of the product thiol and a second by-product stream comprising the second portion of the other components.

~~16. The apparatus according to claim 15, wherein the crude thiol separation system comprises an olefin separation unit in communication with a secondary separation unit, and wherein:~~

~~the olefin separation unit is in communication with the flash vaporizer and is configured to:~~

~~receive the crude thiol stream;~~

~~produce the olefin recycle stream and a secondary stream;~~

~~feed the secondary stream to the secondary separation unit; and~~

~~wherein the secondary separation unit is in communication with the product thiol purification unit and is configured to:~~

receive the secondary stream; and

separate the secondary stream to produce the first by-product stream and the crude thiol product stream.

17. The apparatus according to claim 15, further comprising a sulfide cracking and stripping unit in communication with the thiol product purification unit and the crude thiol separation unit, wherein the sulfide cracking and stripping unit is configured to:

receive the second by-product stream comprising the second portion of the other components comprising sulfides;

convert the sulfides into olefins and thiols;

produce a third by-product stream comprising the sulfides; and

feed the olefins and thiols to the crude thiol separation system.

18. The apparatus according to claim 15, wherein the crude thiol separation system comprises an olefin separation unit in communication with a crude thiol separation unit, and wherein the crude thiol separation unit is in communication with the flash vaporizer and the product thiol purification unit, and wherein:

the crude thiol separation unit is configured to:

receive the crude stream;

produce the crude product thiol stream and an olefin stream; and

feed the olefin stream to the olefin separation unit; and

the olefin separation unit is configured to:

separate the olefin stream;

produce the first by-product stream and the olefin recycle stream.

19. The apparatus according to claim 15, wherein the reactor system comprises an absorption unit in communication with a reactor bank, and wherein the absorption unit is configured to:

receive the hydrogen sulfide and the olefin ,

form a liquid reactor bank feed stream comprising at least a portion of the hydrogen sulfide dissolved in the olefin and the recycled first portion of the reactor effluent stream, and

~~feed the liquid reactor bank feed stream into the reactor bank;~~

~~and wherein the reactor bank is configured to:~~

~~receive the recycled first portion of the reactor effluent stream and the liquid reactor bank feed stream, and~~

~~form the reactor effluent stream comprising the product thiol, unreacted hydrogen sulfide, unreacted olefin and other components.~~

~~20~~16. The apparatus according to claim 15, wherein the product thiol purification unit includes at least one distillation column containing structured packing.

~~21~~17. A process for producing a high purity product sulfide from hydrogen sulfide or R^1SH, and an olefin of formula $C_xH_{(2x)}$ comprising:

feeding the hydrogen sulfide or the R^1SH, and the olefin of formula $C_xH_{(2x)}$ to a reactor system, wherein the reactor system is configured to:

form a reactor effluent stream comprising the product sulfide, unreacted hydrogen sulfide or unreacted olefin of formula $C_xH_{(2x)}$, unreacted R^1SH, and other components;

separating said reactor effluent stream into a first portion and a second portion;

recycling ~~a~~ said first portion of the reactor effluent stream to the reactor system;

feeding ~~a~~ said second portion of the reactor effluent stream to a sulfide separation system, wherein the sulfide separation system is configured to:

produce at least one recycle stream comprising at least a portion of the unreacted hydrogen sulfide, the unreacted olefin of formula $C_xH_{(2x)}$, the unreacted R^1SH, and other components, and a product stream comprising the high purity product sulfide.

~~22~~18. The process according to claim ~~21~~17, wherein the sulfide separation system comprises a first separation unit in communication with the reactor system and a product sulfide purification system in communication with the first separation unit, and wherein:

the first separation unit is configured to:

receive the reactor effluent stream from the reactor system;

produce a first portion of the at least one recycle stream comprising the at least a portion of the unreacted hydrogen sulfide or the unreacted R^1SH or the unreacted olefin of formula $C_xH_{(2x)}$, and the other components, and a crude sulfide stream comprising the product sulfide; and

feed the crude sulfide stream comprising the product sulfide to the product sulfide purification system, wherein the product sulfide purification system is configured to:

produce a second portion of the at least one recycle stream comprising at least a portion of the other of the unreacted olefin of formula $C_xH_{(2x)}$ or the unreacted R^1SH, and a sulfide product stream comprising the purified product sulfide.

~~23~~19. The process according to claim ~~21~~17 or 18, comprising a flash vaporizer in communication with the reactor system and the sulfide separation system, and wherein the flash vaporizer is configured to:

receive the second portion of the reactor effluent;

produce a lights recycle stream comprising at least a portion of the unreacted hydrogen sulfide or unreacted R^1SH or unreacted olefin of formula $C_xH_{(2x)}$, and a crude sulfide stream comprising the product sulfide, the other of the unreacted R^1SH or unreacted olefin of formula $C_xH_{(2x)}$, and the other components; and

feed the crude sulfide stream to the sulfide separation system.

~~24~~20. The process according to any one of claims ~~21~~17 to 19, wherein hydrogen sulfide is fed to the reactor system and the high purity sulfide comprises $S(C_xH_{(2x+1)})_2$.

~~25~~21. The process according to any one of claims ~~21~~17 to 19, wherein R^1SH is fed to the reactor system and the high purity sulfide comprises $S(C_xH_{(2x+1)})(R^1)$.

~~26~~22. The process according to any one of claims ~~21~~17 to 19, ~~-~~wherein ~~-~~R^1 of the R^1-SH thiol is methyl, ethyl, propyl, n-butyl, n-pentyl, n-hexyl, n-octyl, n-nonyl, n-decyl, n-undecyl, n-dodecyl, n-tridecyl, n-tetradecyl, n-pentadecyl, n-hexyldecyl, n-heptadecyl or n-octadecyl.

~~27~~23. The process according to any one of claims ~~21~~17 to 22, wherein for the olefin of formula $C_xH_{(2x)}$, x is an integer from 2 to 18.

24. An apparatus for producing a high purity product thiol from hydrogen sulfide and an olefin comprising:

a reactor system comprising an absorption unit in communication with a reactor bank, wherein the absorption unit is configured to:

receive the hydrogen sulfide and the olefin,

form a liquid reactor bank feed stream comprising at least a portion of the hydrogen sulfide dissolved in the olefin and a recycled first portion of a reactor effluent stream, and

feed a liquid reactor bank feed stream into the reactor bank;

and wherein the reactor bank is configured to:

receive the recycled first portion of the reactor effluent stream and the liquid reactor bank feed stream, and

form the reactor effluent stream comprising the product thiol, unreacted hydrogen sulfide, unreacted olefin and other components;

means to separate said reactor effluent stream into a first portion and a second portion and recycle said first portion of the reactor effluent stream back to the reactor system;

a flash vaporizer in communication with the reactor system, wherein the flash vaporizer is configured to receive said second portion of the reactor effluent stream and to produce:

a hydrogen sulfide recycle stream comprising at least a portion of the unreacted hydrogen sulfide, and a crude thiol stream comprising the product thiol, the unreacted olefin and the other components and wherein the flash vaporizer is configured to feed the hydrogen sulfide recycle stream to the reactor system;

a crude thiol separation system in communication with the flash vaporizer and the reactor system, wherein the crude thiol separation system is configured to receive the crude thiol stream, wherein the crude thiol separation system is configured to:

separate at least a portion of the unreacted olefin from the crude thiol stream to produce an olefin recycle stream comprising the unreacted olefin, a first by-product stream comprising a first portion of the other components, and a crude thiol product stream comprising the product thiol and a second portion of the other components; and

feed the olefin recycle stream to the reactor system;

a product thiol purification unit in communication with the crude thiol separation system, wherein the product thiol purification unit is configured to:

receive the crude thiol product stream;

produce a product thiol stream comprising purified product thiol comprising at least 98.5 weight percent of the product thiol and a second by-product stream comprising the second portion of the other components.

~~28. An apparatus for producing a high purity product sulfide from hydrogen sulfide or R^1SH, and an olefin of formula $C_xH_{(2x)}$ comprising:~~

~~a reactor system, wherein the reactor system is configured to:~~

~~receive the hydrogen sulfide or the R^1SH, and the olefin of formula $C_xH_{(2x)}$ to form a reactor effluent stream comprising the product sulfide, unreacted hydrogen sulfide or unreacted olefin of formula $C_xH_{(2x)}$, unreacted R^1SH, and other components;~~

~~recycle a first portion of the reactor effluent stream to the reactor system;~~

~~a sulfide separation system, wherein the sulfide separation system is in communication with the reactor system and is configured to:~~

~~receive a second portion of the reactor effluent stream from the reactor system;~~

~~produce at least one recycle stream comprising at least a portion of the unreacted hydrogen sulfide, the unreacted olefin of formula $C_xH_{(2x)}$, the unreacted R^1SH, and other components, and a product stream comprising the high purity product sulfide.~~

~~29. The apparatus according to claim 28, wherein the sulfide separation system comprises a first separation unit in communication with the reactor system and a product sulfide purification system in communication with the first separation unit, and~~

~~wherein the first separation unit is configured to:~~

~~receive the reactor effluent stream from the reactor system;~~

~~produce a first portion of the at least one recycle stream comprising the at least a portion of the unreacted hydrogen sulfide, the unreacted R^1SH or the unreacted olefin of formula $C_xH_{(2x)}$, and the other components, and a crude sulfide stream comprising the product sulfide and the other of the unreacted R^1SH or the unreacted olefin of formula $C_xH_{(2x)}$;~~

~~and~~

feed the crude sulfide stream comprising the product sulfide to the product sulfide purification system;

and wherein the product sulfide purification system is configured to:

produce a second portion of the at least one recycle stream comprising at least a portion of the other of the unreacted R^1SH or the unreacted olefin of formula $C_xH_{(2x)}$, and a sulfide product stream comprising the purified product sulfide.

30. The apparatus according to claim 28, comprising a flash vaporizer in communication with the reactor system and the sulfide separation system, and wherein the flash vaporizer is configured to:

receive the second portion of the reactor effluent;

produce a lights recycle stream comprising at least a portion of the unreacted hydrogen sulfide or the unreacted R^1SH or the unreacted olefin of formula $C_xH_{(2x)}$, and a crude sulfide stream comprising the product sulfide, the other of the unreacted R^1SH or the unreacted olefin of formula $C_xH_{(2x)}$, and the other components; and

feed the crude sulfide stream to the sulfide separation system.