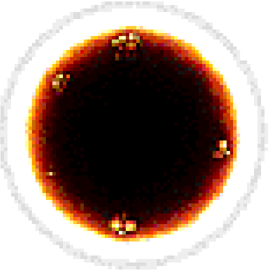
Introduction to Petroleum

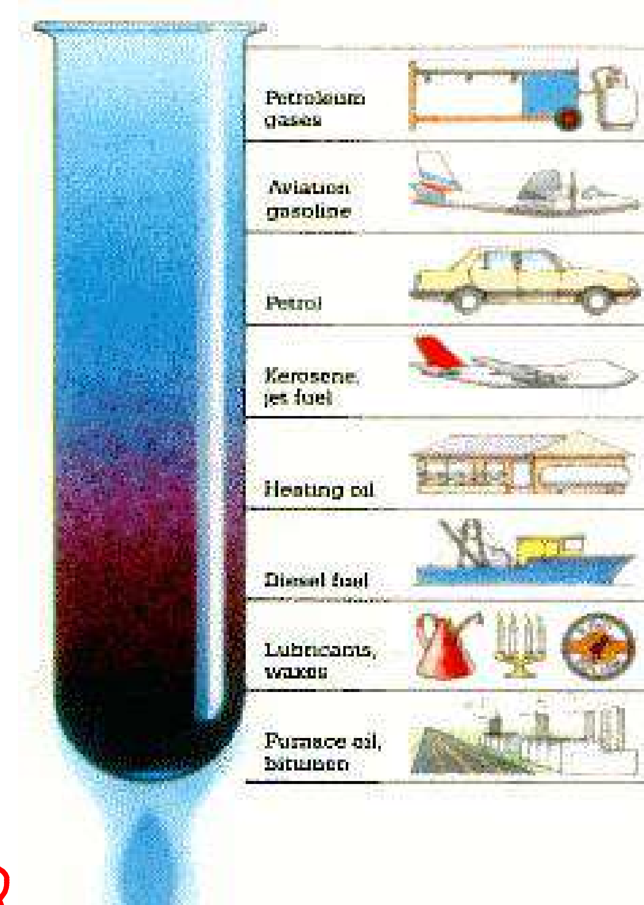
What is  crude OIL?

What is it?

Petroleum - a liquid mixture of hydrocarbons that is present in rock layers

- It can be extracted and refined to produce fuels including gasoline, kerosene, and diesel oil
- Also used for chemicals, plastics, and synthetic materials
- Also known as crude oil, or black gold, or Texas Tea

- Petroleum (crude oil) is a mixture of hundreds to thousands of different compounds which
- a) are very rich in energy when burned
- b) can be transformed into many different compounds



Petroleum
a) is burned for energy
b) is transformed into many compounds

Other uses of Petroleum

- Look around! Find something that DOESN'T come from petroluem
- - cd's, sports equipment, clothing, auto parts, carpeting, artificial limbs, medication. Etc.
- Eighty-four percent of petroleum us used outright as fuel
- Seven percent is used for medications and plastics
- The remaining 9% used for:
- - lubricants, paving materials, miscellaneous products
- For every gallon of petroleum used to make useful products, more than five gallons are burned to release energy

What is it like?

- Color?? Varies from pale yellow to dark black

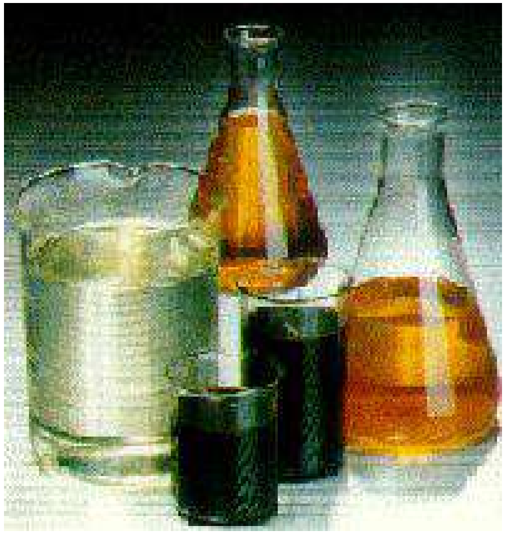
Color: Wide Range

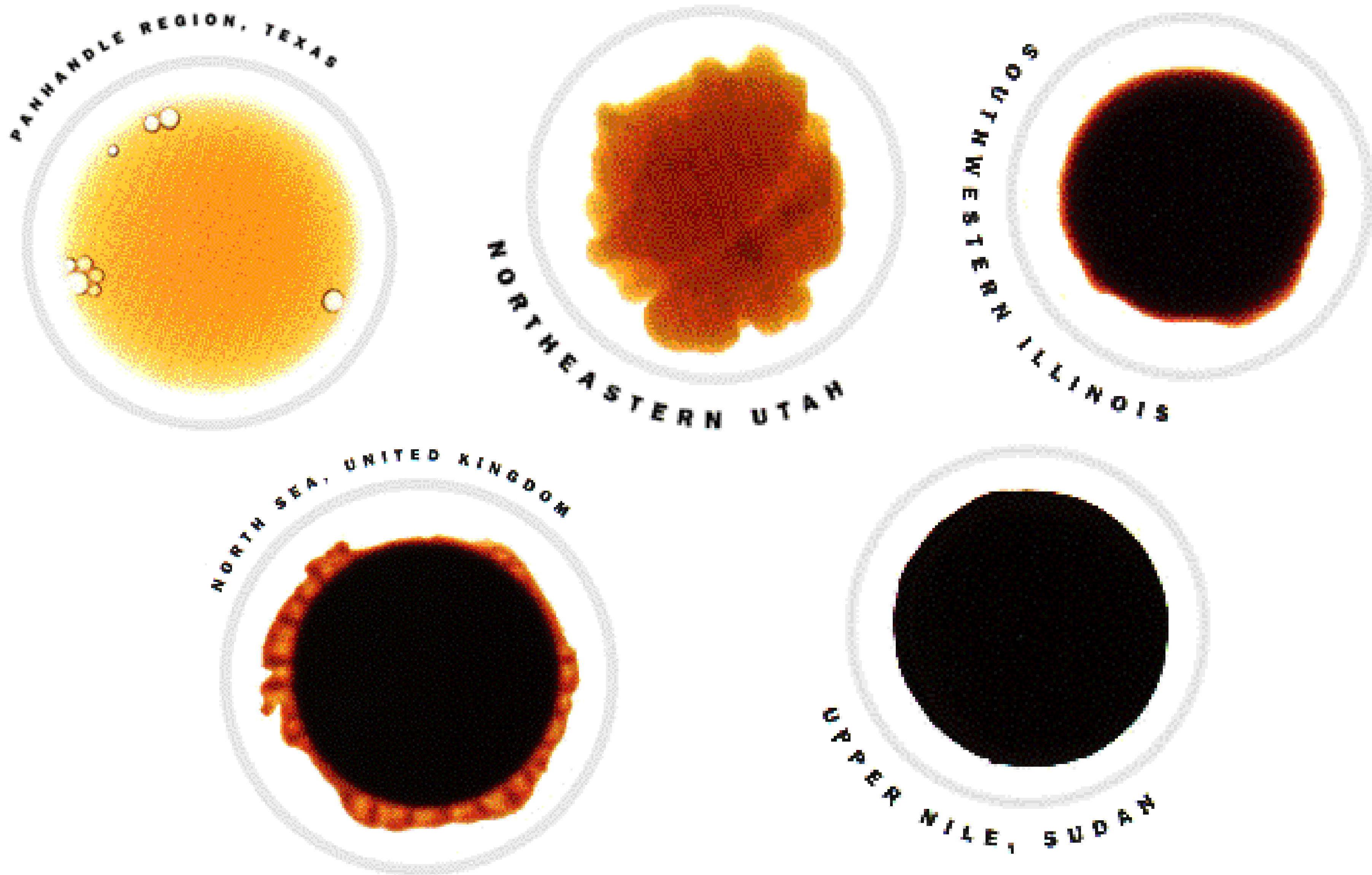
- Texture?? Varies from very runny to a sludge-like texture (viscous)

Texture: very runny to highly viscous

- Viscosity - resistance to flow; slow flowing liquids are very viscous

Viscosity - resistance to flow

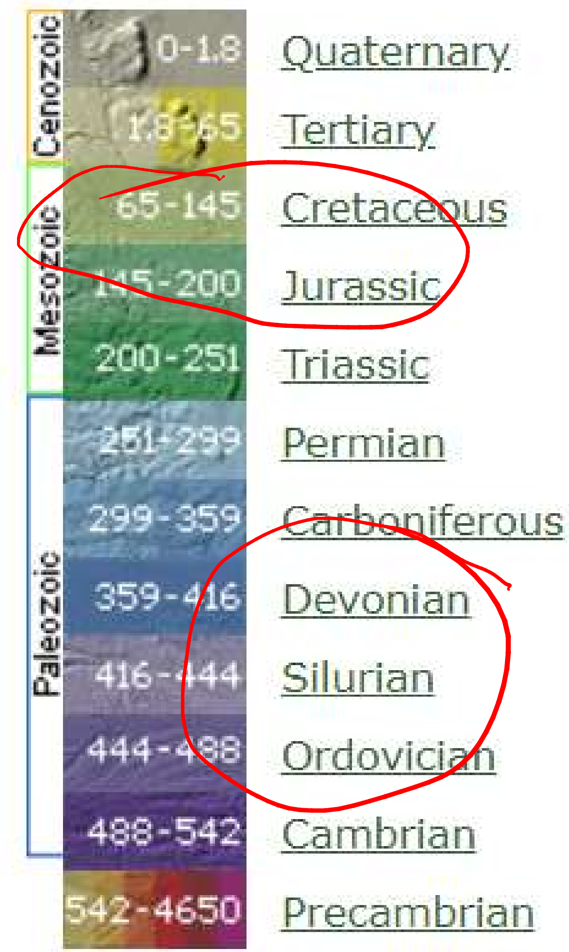




Petroleum From Around the World

When did most petroleum form?

- *252 to 66 million years ago*
  - ***70% of oil deposits existing today were formed in the Mesozoic age (252 to 66 million years ago),***
  - ***20% were formed in the Cenozoic age (65 million years ago), and only***
  - ***10% were formed in the Paleozoic age (541 to 252 million years ago).***

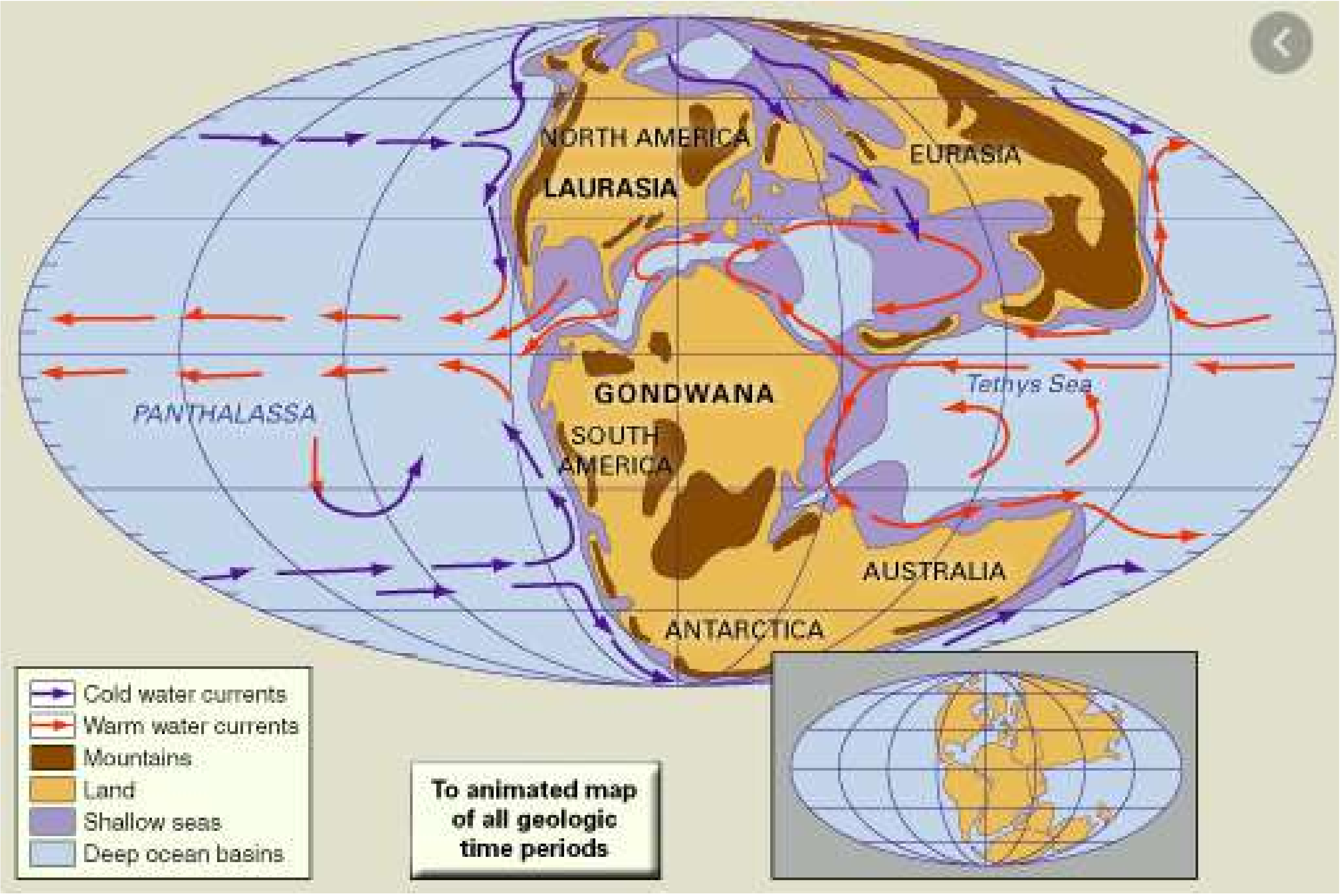


Summary

- Most petroleum on the planet formed around 200 million years ago for three reasons:

1. It was significantly warmer than it is now
2. The ocean level was much higher, which resulted in MANY shallow seas
3. The shallow seas were TEEMING with life.

Note: there have been other geological episodes similar to this in which abundant petroleum formed.


NORTH AMERICA
LAURASIA
EURASIA
GONDWANA
SOUTH AMERICA
PANTHALASSA
Tethys Sea
AUSTRALIA
ANTARCTICA
Cold water currents
Warm water currents
Mountains
Land
Shallow seas
Deep ocean basins
To animated map of all geologic time periods

The Greenhouse Era 100 Myr Ago
The Cretaceous Period of the Mesozoic Era

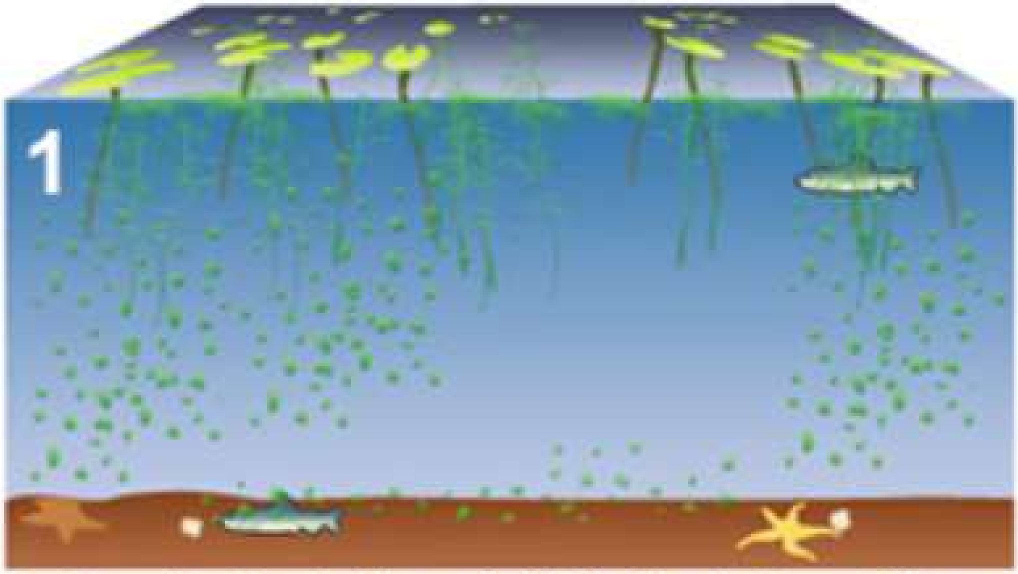
- Global Sea Level – 200 m higher than today
- Shallow seas flooded continental interiors
- Cretaceous is from the Latin word *creta* which means chalk

So, how did it form?

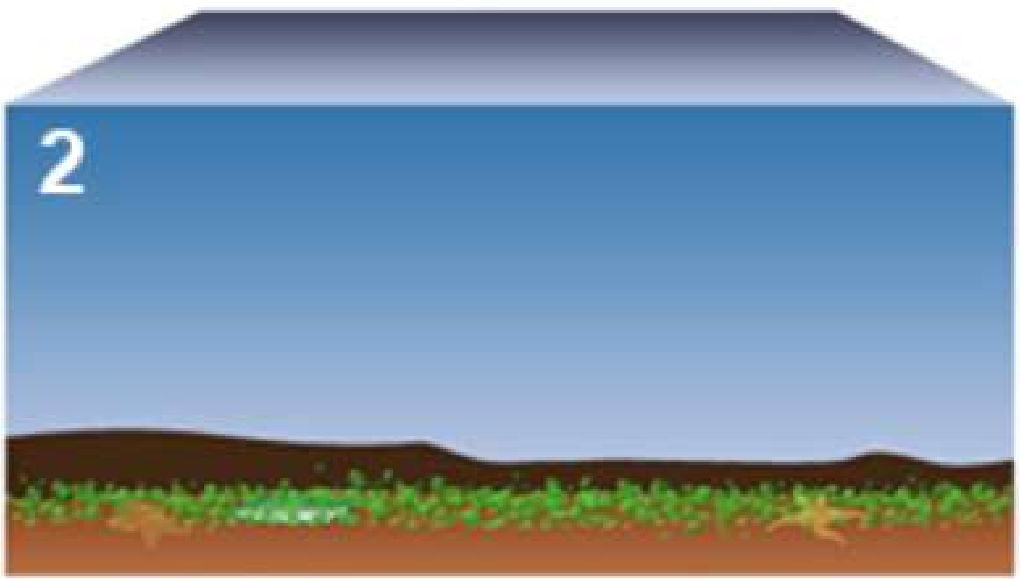
- *200 m.y.a – many continents were covered by warm, shallow seas*
- *marine life was abundant!! (mostly itty bitty stuff)*
- *it died, fell and built up on the ocean floor*
- *it rotted, got compressed from overlying material, and was heated from inside the earth*
- *this resulted in a mixture of gooey petroleum molecules!!!*

What Happens Next??

- *After petroleum molecules form….*
- *they heat up and become less dense than the rocks around them*
- *they begin to rise up through the rocks*
- *petroleum can either escape into the atmosphere (where it is of no use to us) or….*
- *It can get trapped in a geologic structure*



Plants and animals die and sink to the bottom of the sea.



The plant and animal layer gets covered with mud.

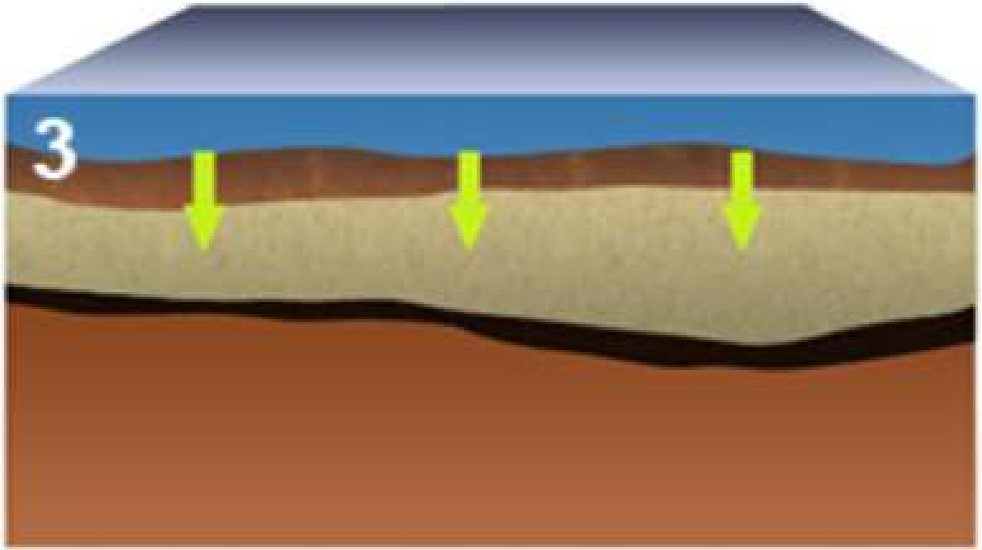
Petroleum Formation

→ marine life, which is abundant in warm shallow seas, dies and sinks to the bottom of the sea.

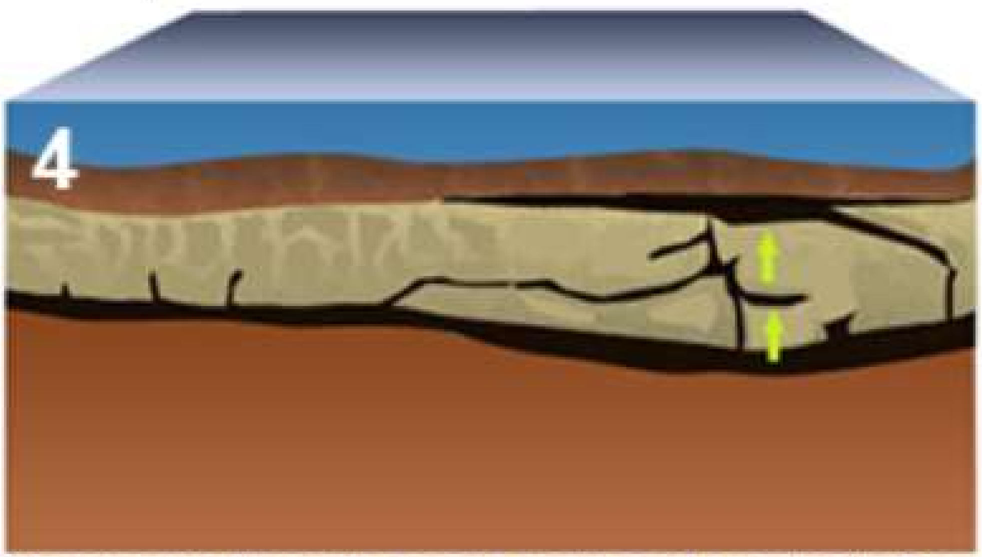
→ layers begin to form with the dead organisms and mud.

→ rotting organic matter becomes compressed from overlying layers

→ compression and heat from the earth rearrange the molecules into a wide variety of hydrocarbons (petroleum)



Over time, more sediment creates pressure, compressing the dead plants and animals into oil.

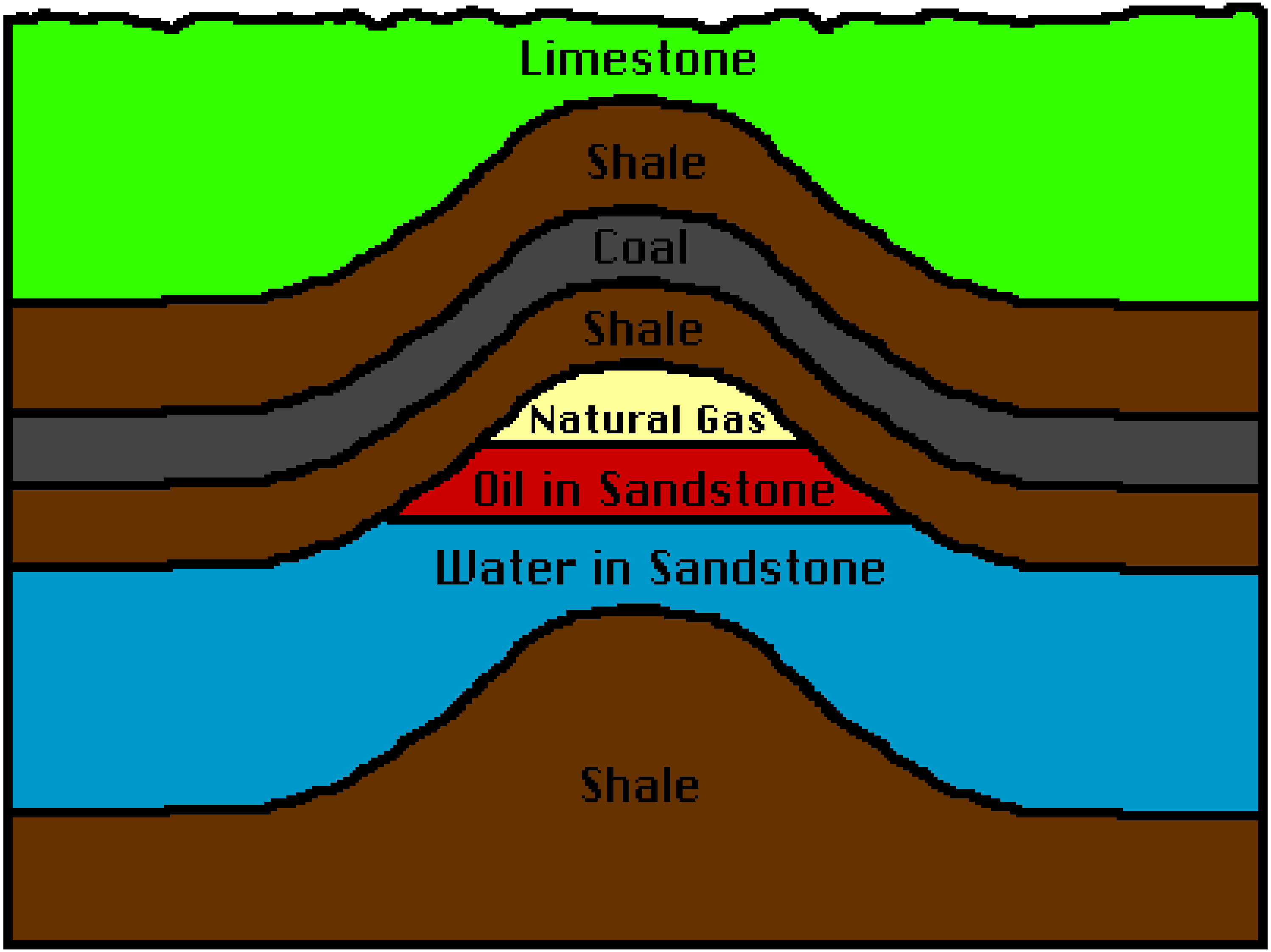


Oil moves up through porous rocks and eventually forms a reservoir.

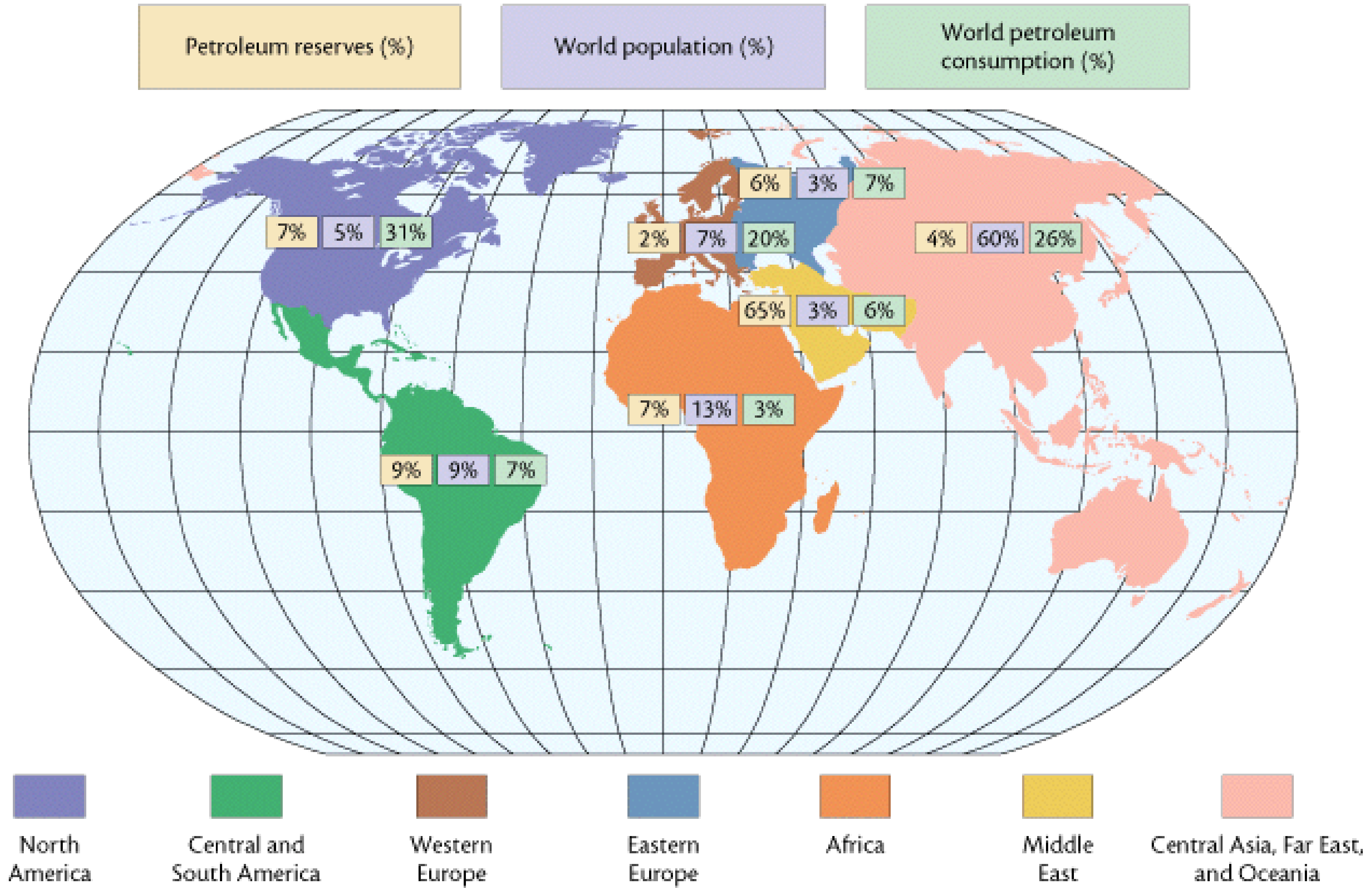
→ New petroleum molecules heat up, become less dense, and begin to rise through the surrounding materials

→ it may continue rising all the way to the surface OR get trapped and accumulate as a reservoir in a geologic structure.


Paige Gill - Florida Keys NMS


Limestone
Shale
Coal
Shale
Natural Gas
Oil in Sandstone
Water in Sandstone
Shale

World Distribution, Population, and Usage



Petroleum Distribution and Usage

- Petroleum is not uniformly distributed
- Approximately 57% of out world's known reserves are located in just five Middle Eastern nations, which include: Iran, Iraq, Saudi Arabia, Kuwait, and United Arab Emirates
- North America accounts for just 7% of the world's known reserves

Petroleum Distribution and Usage

→ Petroleum is not uniformly distributed or used.

→ We use the most (and have a relatively low population).

→ Most reserves are in the Middle East

Refining Petroleum

- Crude oil cannot be used in its natural state, and must be shipped to oil refineries where it is separated into simpler compounds
- The refining process doesn't separate each compound, but rather several mixtures called fractions

- Fractional Distillation – separating parts of a mixture by differences in boiling points

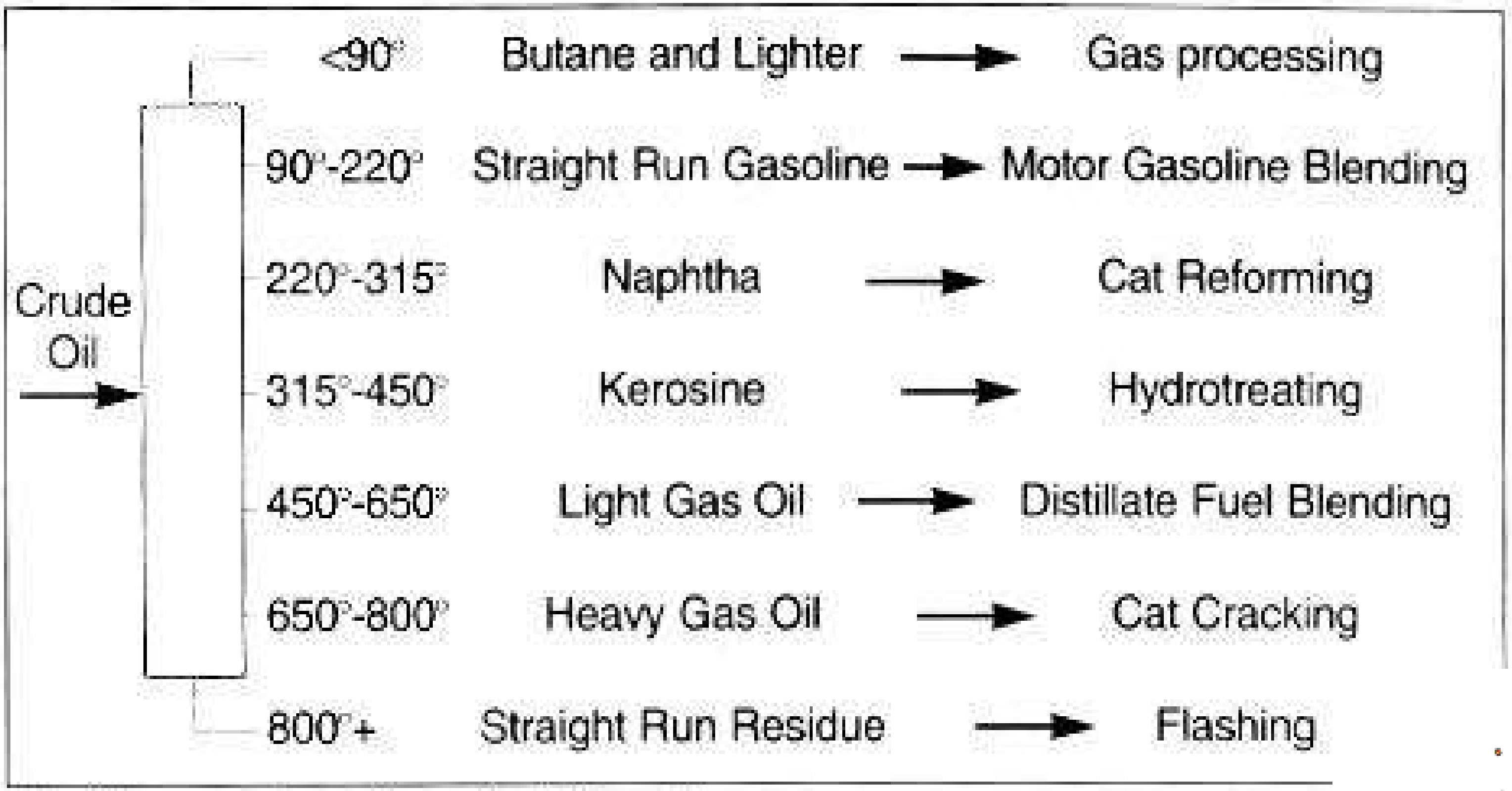
Refining Petroleum

→ crude oil cannot be used in its natural state.

Fractional Distillation - separating parts of a mixture by differences in boiling points.

→ the separated parts are called fractions.

Petroleum Refining



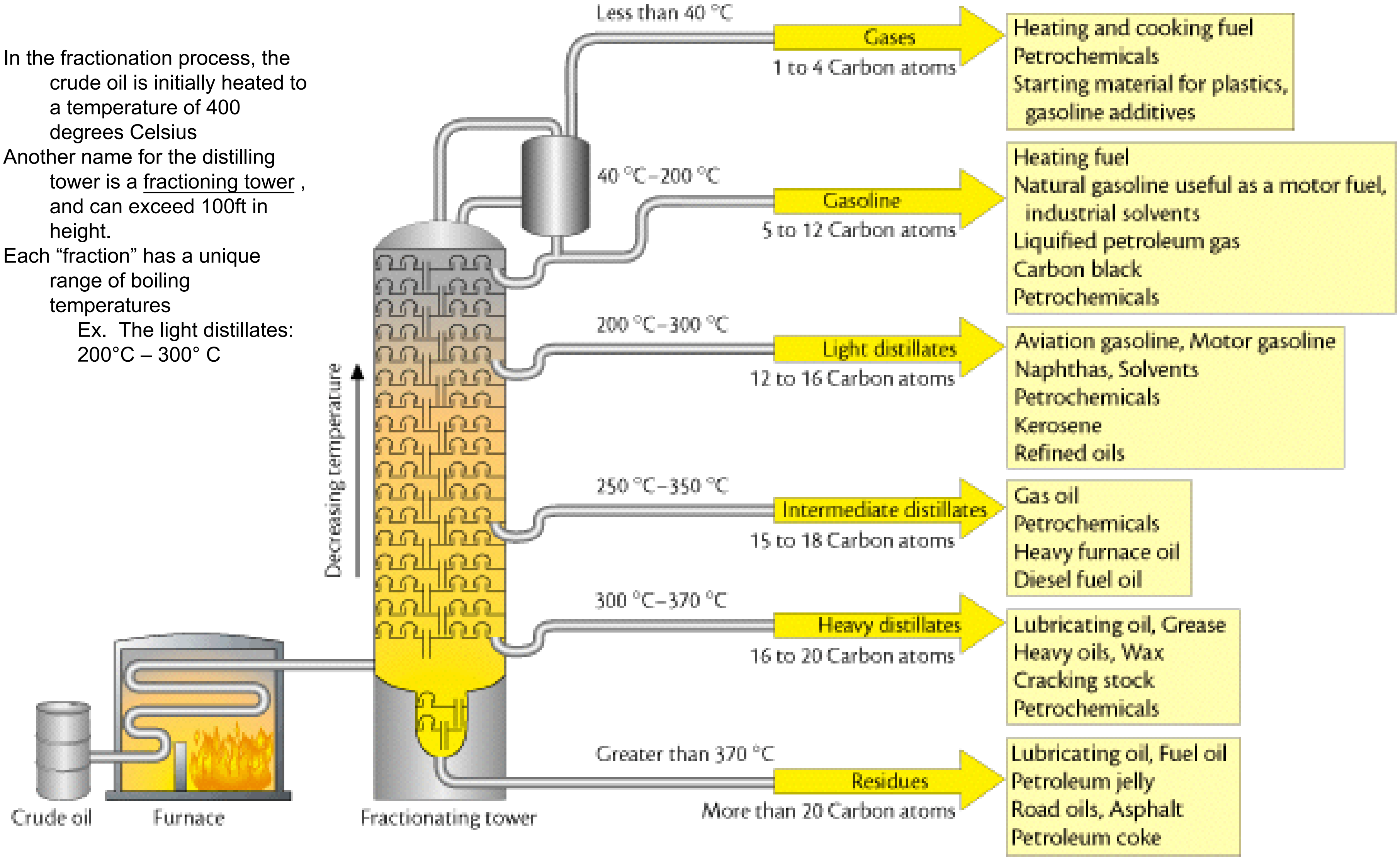
Distilling crude and product disposition

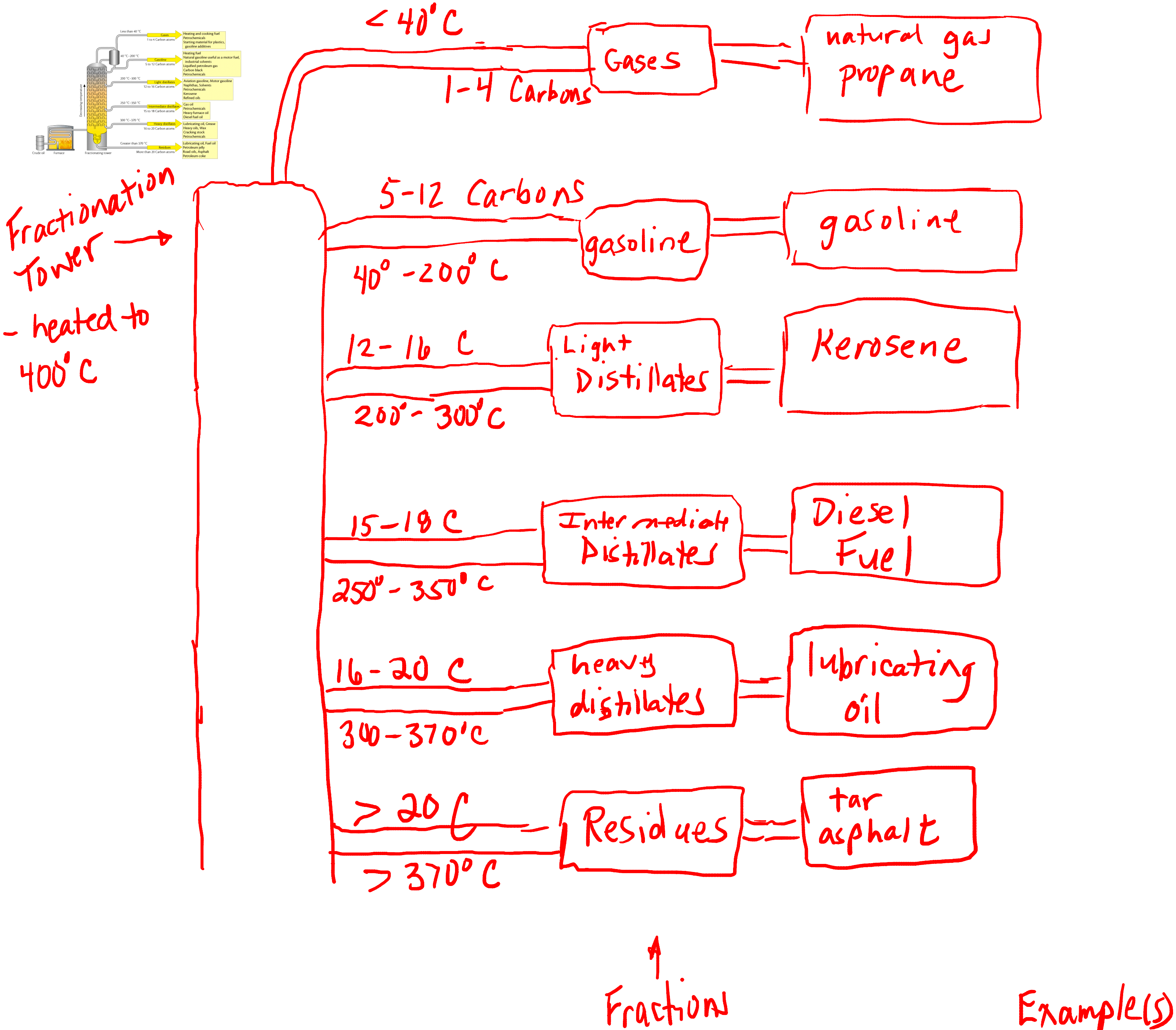
In the fractionation process, the crude oil is initially heated to a temperature of 400 degrees Celsius

Another name for the distilling tower is a fractioning tower , and can exceed 100ft in height.

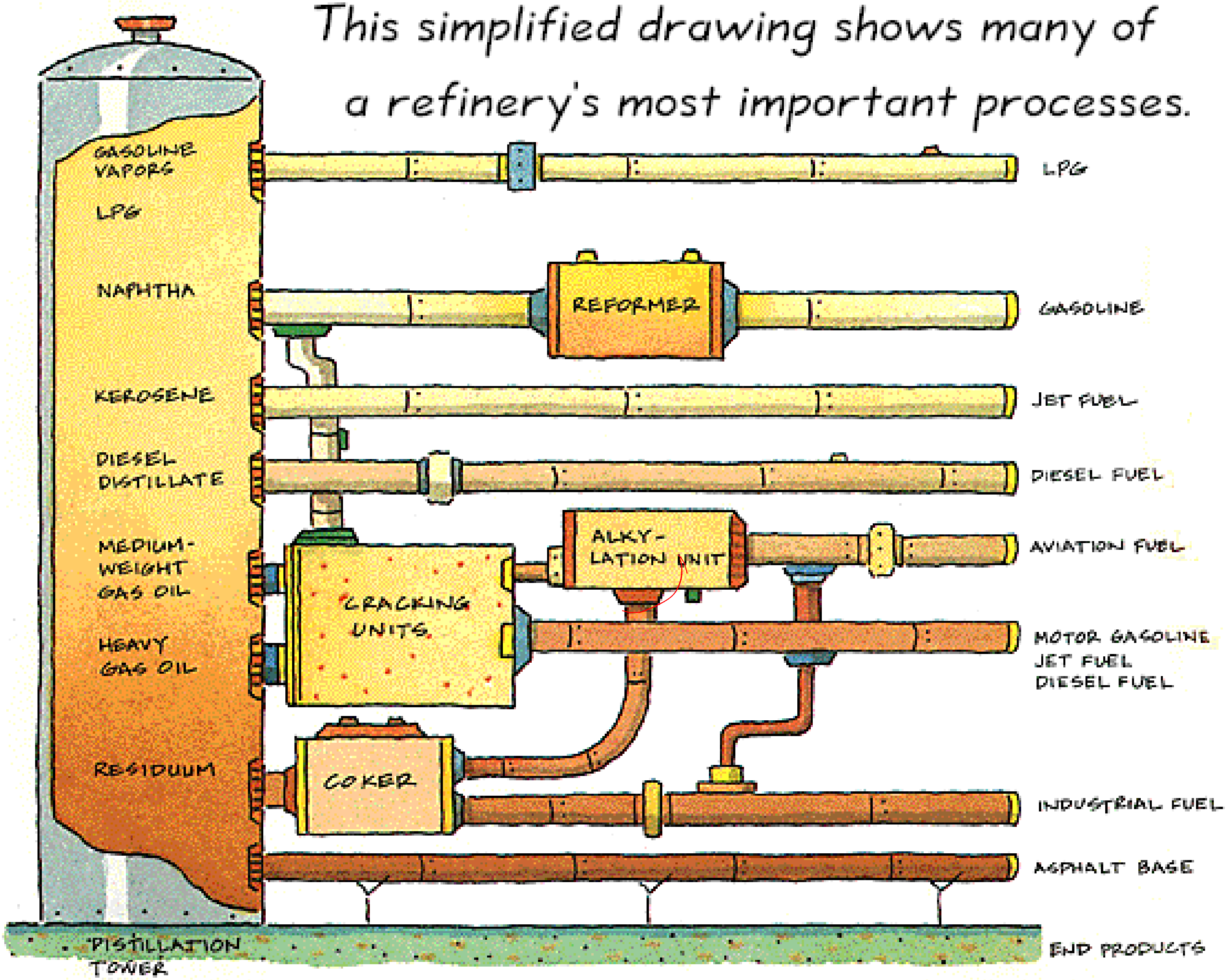
Each “fraction” has a unique range of boiling temperatures

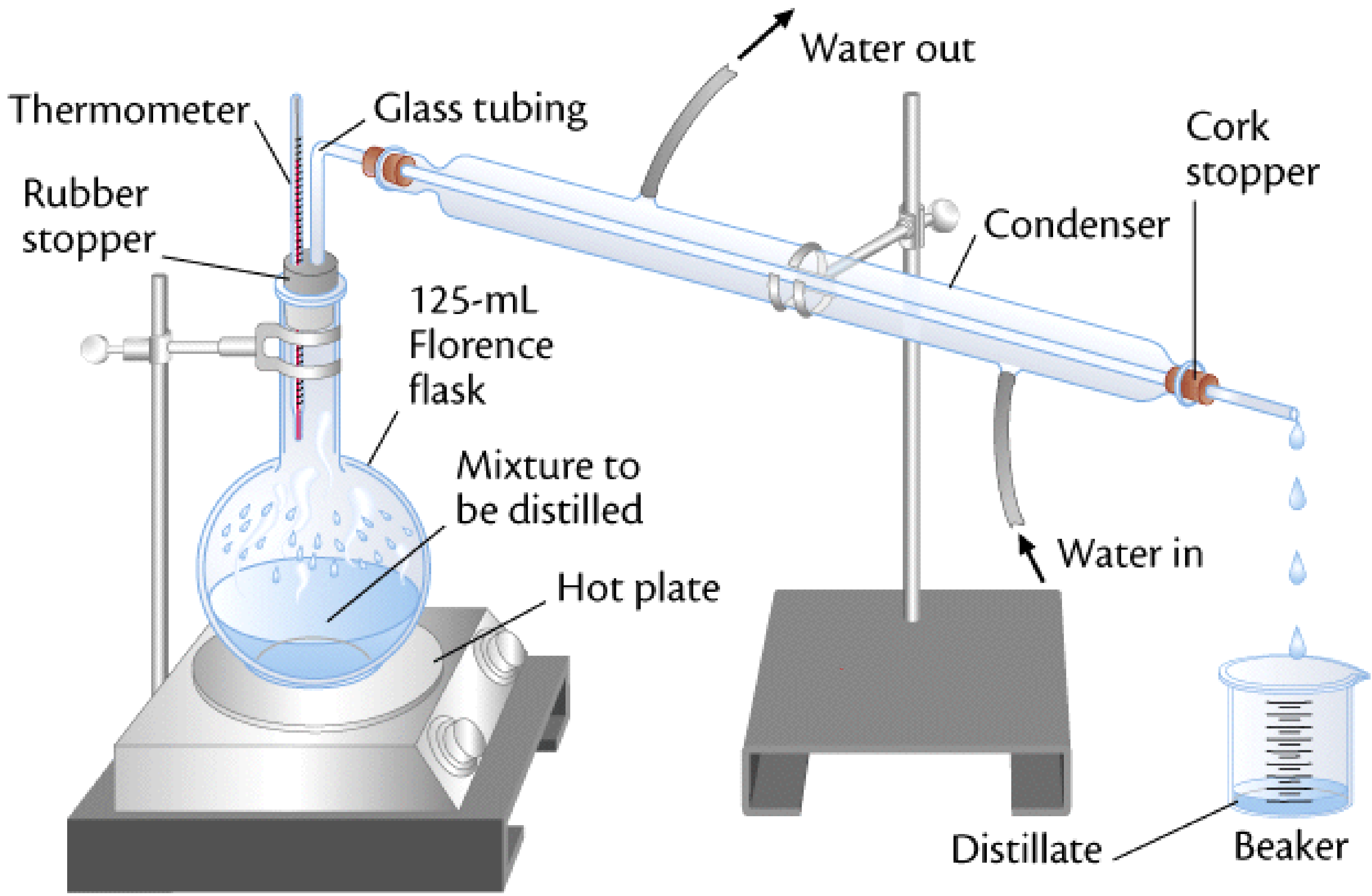
Ex. The light distillates: 200°C – 300° C




Fractionation Tower
- heated to 400° C
< 40° C
1-4 Carbons
Gases
natural gas
propane
5-12 Carbons
40° - 200° C
gasoline
gasoline
12-16 C
200° - 300° C
Light Distillates
Kerosene
15-18 C
250° - 350° C
Intermediate Distillates
Diesel Fuel
16-20 C
300-370° C
heavy distillates
lubricating oil
> 20 C
> 370° C
Residues
tar
asphalt
Fractions
Example(s)

This simplified drawing shows many of a refinery's most important processes.





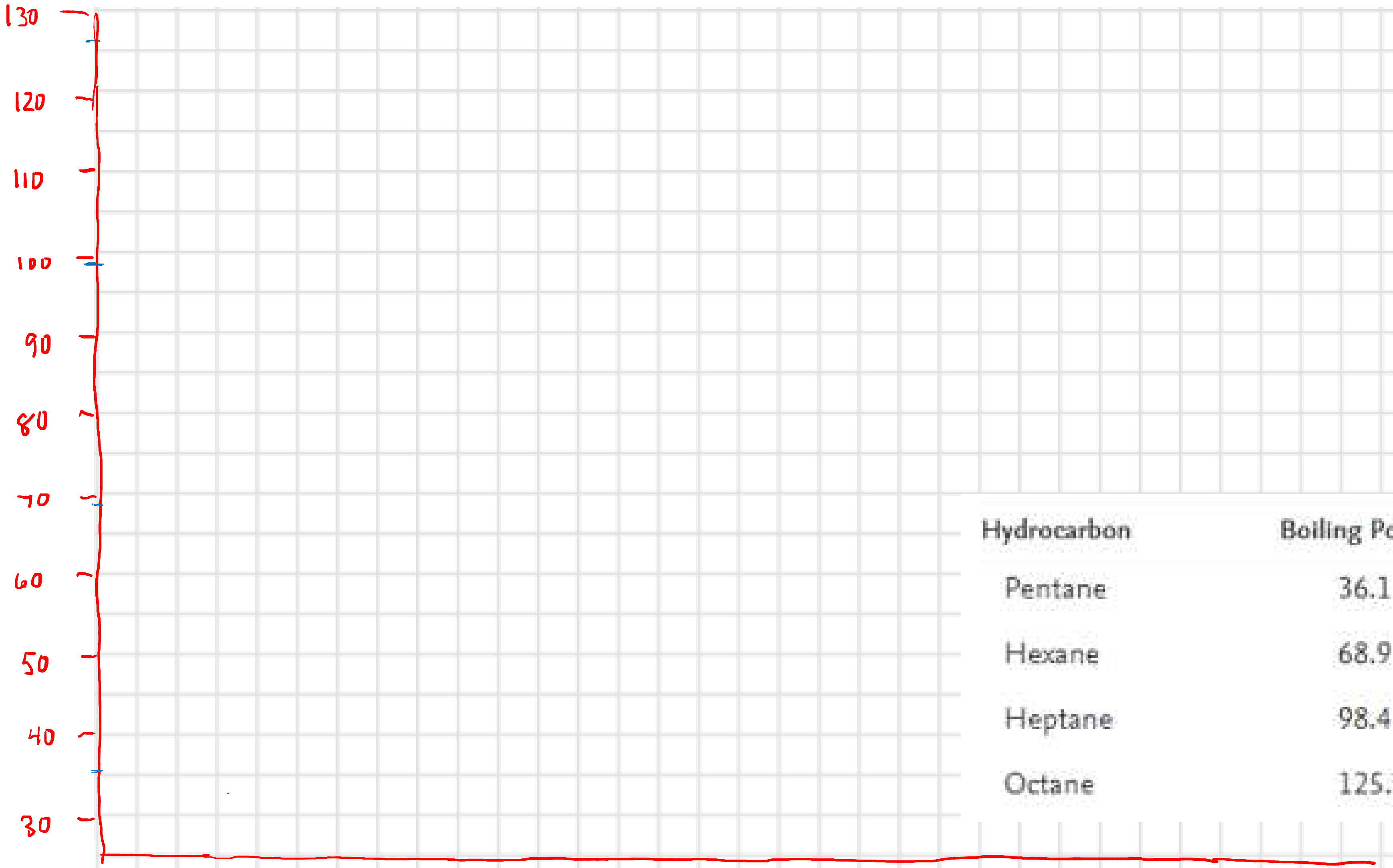
Distillation - a way to separate substances from one another according to boiling points.

- compounds with lower boiling points will evaporate first and leave the distillation flask

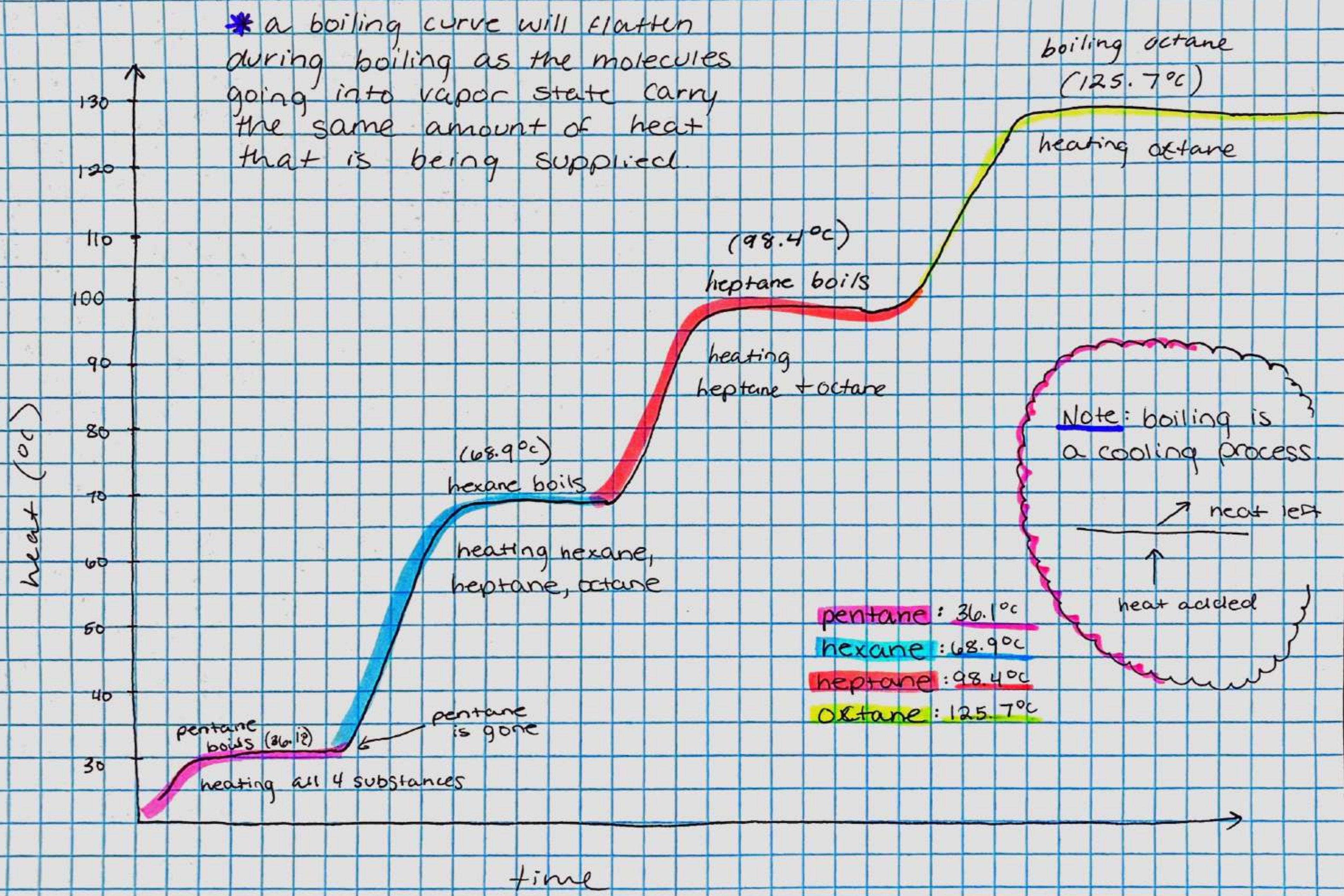
It is then converted back to liquid as it passes through the condenser, all before the second substance begins to boil and distill

- can then condense vapors to form distillates

Distillation Curve for a Mixture of Hydrocarbons

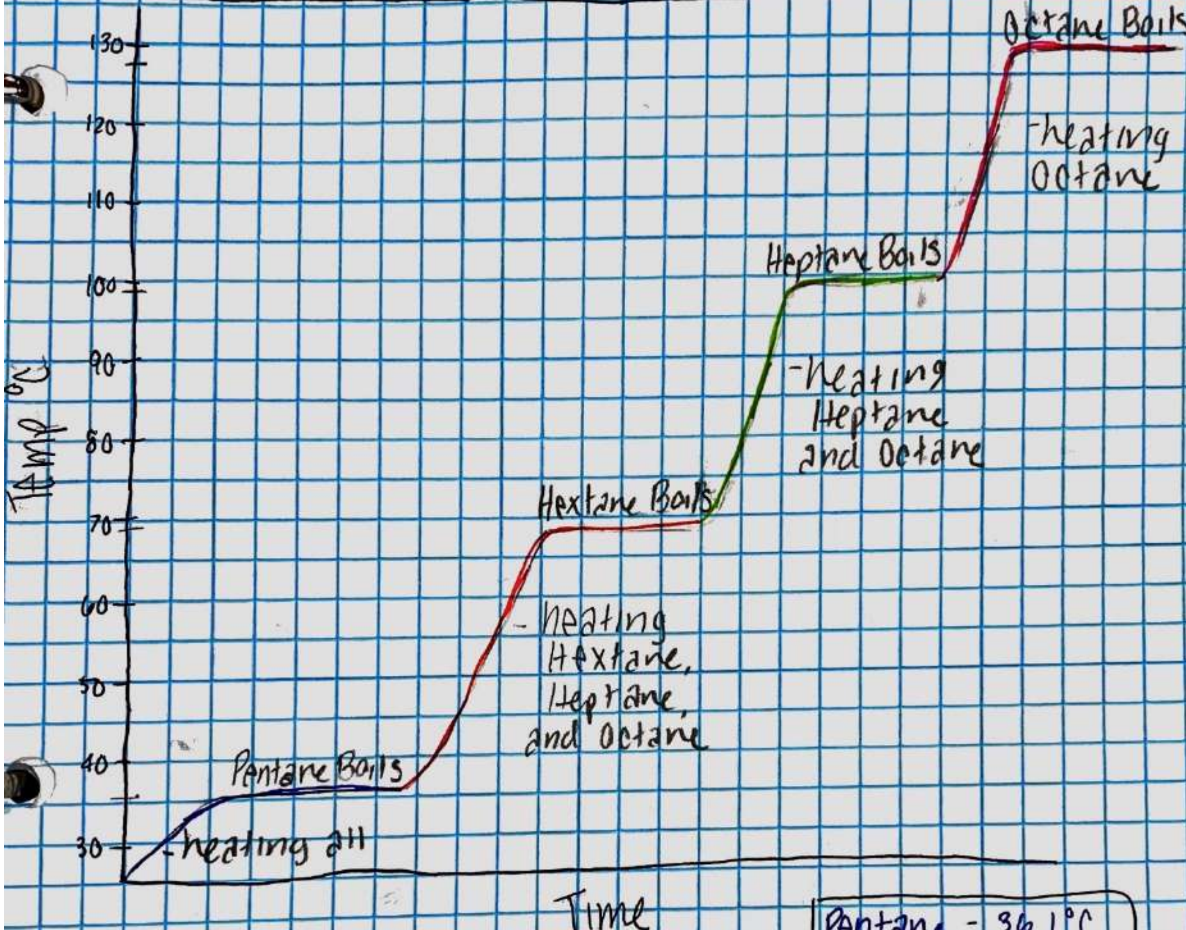


Hydrocarbon	Boiling Point (°C)
Pentane	36.1
Hexane	68.9
Heptane	98.4
Octane	125.7



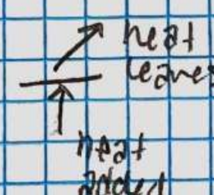
* a boiling curve will flatten during boiling as the molecules going into vapor state carry the same amount of heat that is being supplied.
boiling octane (125.7°c)
heating octane
(98.4°c)
heptane boils
heating heptane + octane
(68.9°c)
hexane boils
heating hexane, heptane, octane
pentane boils (36.1°)
pentane is gone
heating all 4 substances
Note: boiling is a cooling process
heat left
heat added
pentane : 36.1°c
hexane : 68.9°c
heptane : 98.4°c
octane : 125.7°c
heat (°c)
130
120
110
100
90
80
70
60
50
40
30
time

Distillation Curve for a mixture of Hydrocarbons



Pentane - 36.1°C
Hextane - 68.9°C
Heptane - 98.4°C
Octane - 125.7°C

* A boiling curve will flatten during boiling as the molecules going into vapor state carry the same amount of heat that is being supplied.



* NOTE: Boiling is a cooling process!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201
197

Energy and Petroleum

- Petroleum is liquid sunshine
- All energy from fossil fuels originates from the sun!!!!
- Plants capture that energy during photosynthesis
- Plants die
- Animals eat plants…and die
- Plants use sunlight to make sugar (glucose)
- Sunlight + $6CO_2$ + $6\ H_2O \rightarrow$ $C_6H_{12}O_6$ + $6O_2$
- Endothermic Reaction – requires energy

Energy and Petroleum

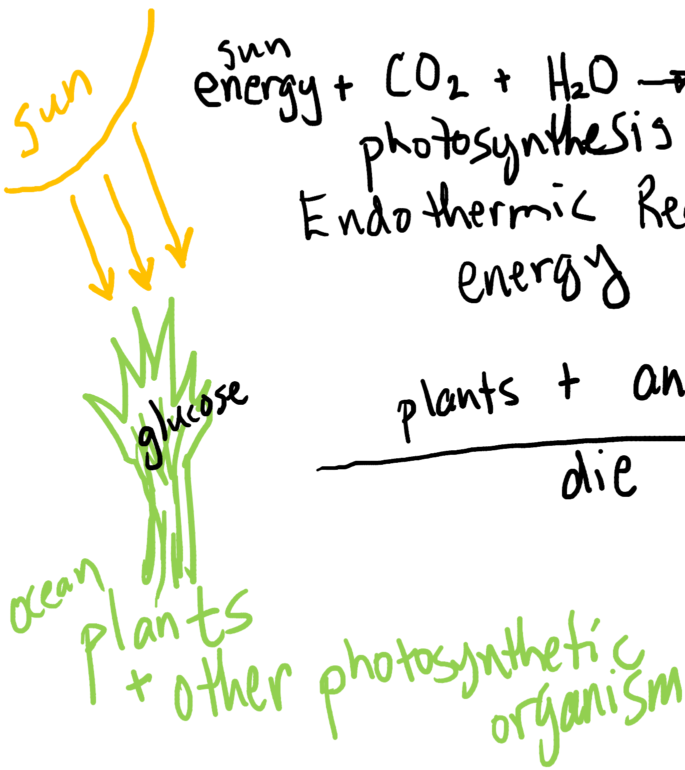
* Petroleum is liquid sunshine

→ all energy stored in the bonds originates from the sun.

sun energy + CO_2 + $H_2O \rightarrow$ $C_6H_{12}O_6$ + O_2

photosynthesis

Endothermic Reaction – requires energy



plants + animals die →

Energy remains stored in the newly created petroleum molecules. (hydrocarbons)

Fossil Fuel Energy

* Combustion of fossil fuels releases the energy stored in hydrocarbon bonds.
  → Exothermic Reaction – heat/energy released.

Simplest:

$$CH_{4(g)} + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{energy}$$

methane

$$C_{25}H_{52} + 38O_2 \longrightarrow 25CO_2 + 26H_2O + \text{energy}$$

wax

Health and Environmental Concerns of Petroleum Combustion

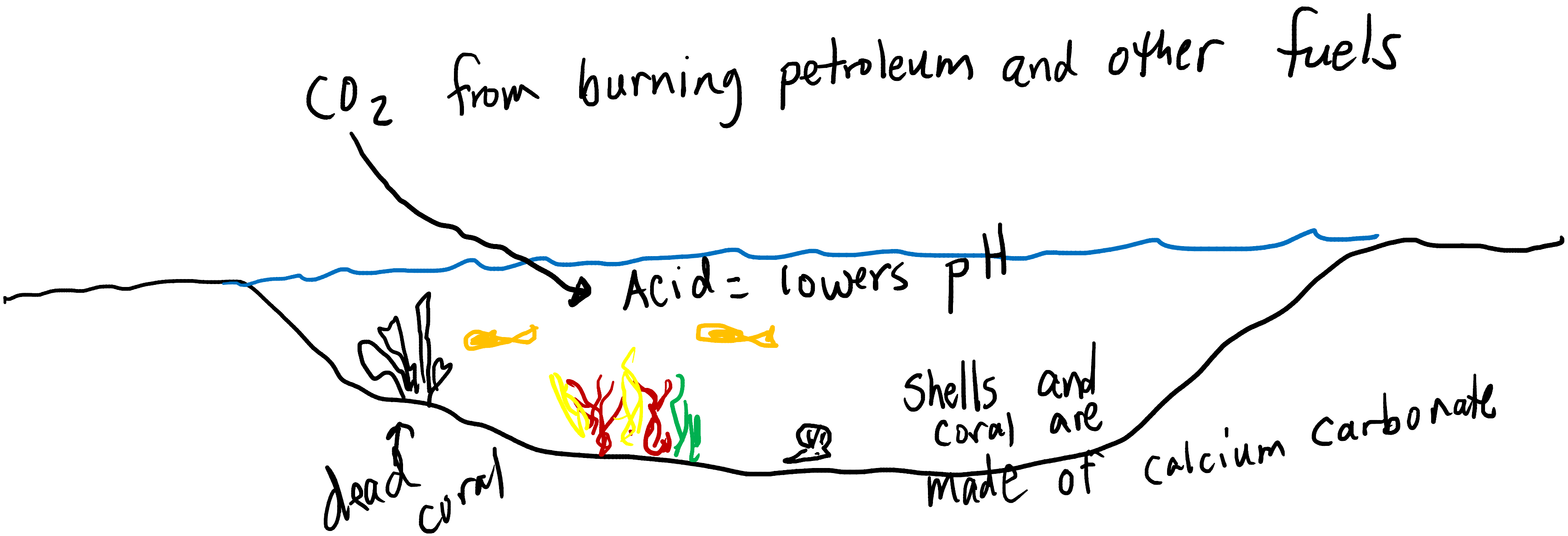
Carbon Monoxide Poisoning

- → Burning any petroleum product in a combustion reaction produces carbon monoxide
- → Faulty appliances produce even higher levels
- → Poor ventilation can trap and concentrate carbon monoxide
- → Binds to oxygen receptors 200x more readily than O_2 to produce sickness and even death.

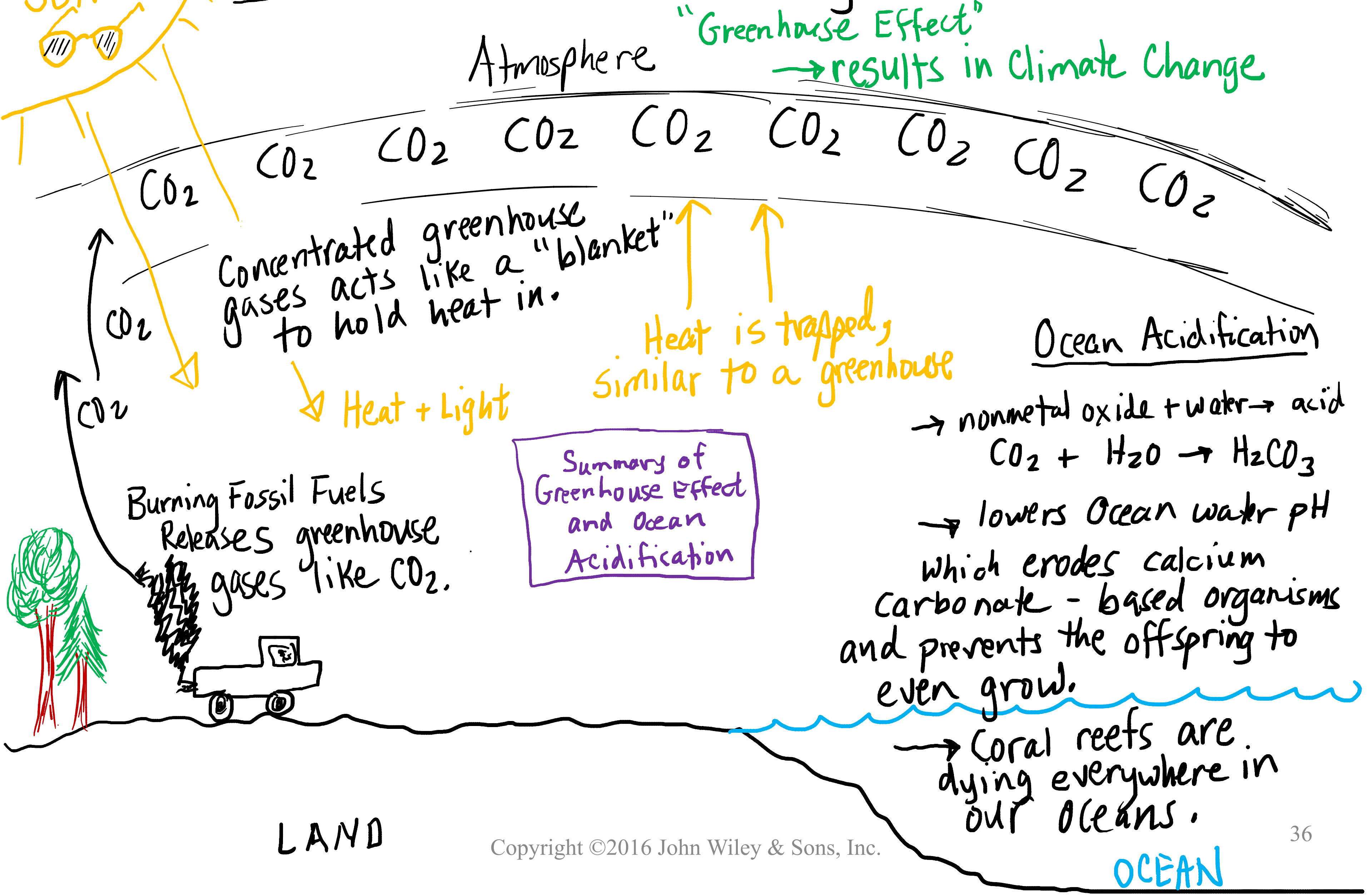
Ocean Acidification

→ CO_2 released by burning petroleum reacts with water produce an acid, which lowers ocean water pH.

→ acid ocean water is currently eroding reef organisms and other calcium carbonate organisms at a rapid rate.



Environmental Concerns Resulting From Combustion Reactions



Isomerism

Isomers are molecules that have the same molecular formula but different structural formula

2 types:

1. Structural Isomers – atoms bonded in different orders

Isomerism – molecules with the same formula and different structures

2 Types

1) Structural Isomers

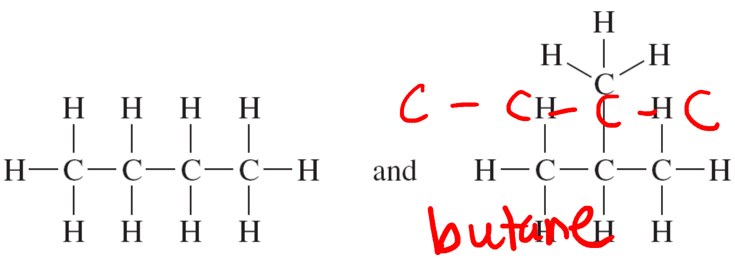
→ atoms bonded in different orders.

→ we will focus on alkanes (saturated hydrocarbons)

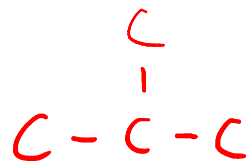
Structural Isomerism

Ex. C_4H_{10}

C_4H_{10}



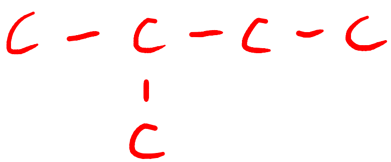
butane isobutane



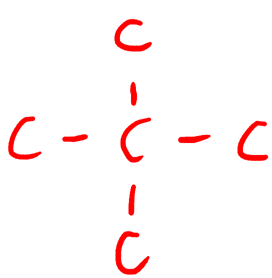
methylpropane

How many structural isomers for C_5H_{12}

pentane



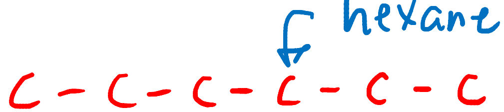
2-methylbutane



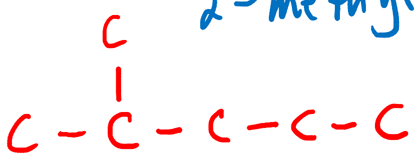
2,2-dimethylpropane

How many structural isomers for C_5H_{12}

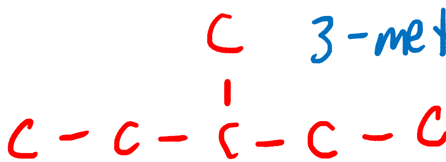
hexane



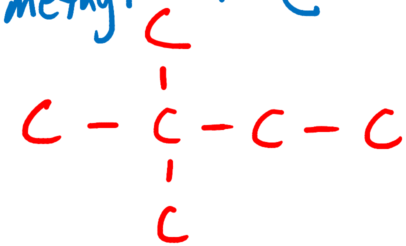
2-methylpentane

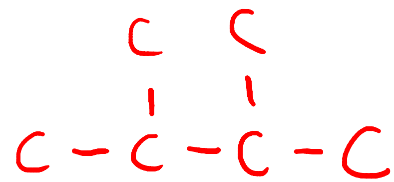


3-methylpentane



2,2-dimethylbutane





2,3-dimethylbutane

Geometric Isomerism

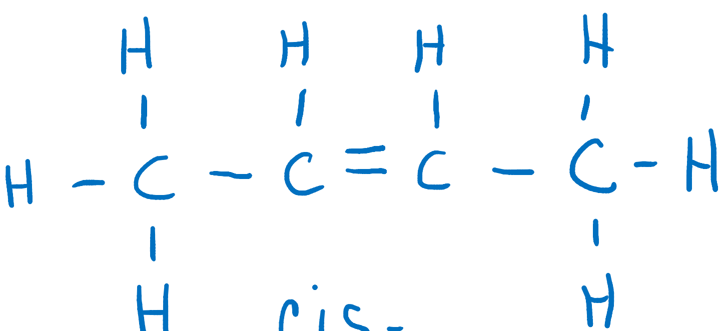
- 2. Geometric Isomers - atoms bonded in same order with different arrangement of atoms relative **to double bonded carbons**

2) Geometric Isomers

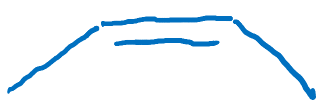
→ are found with alkenes

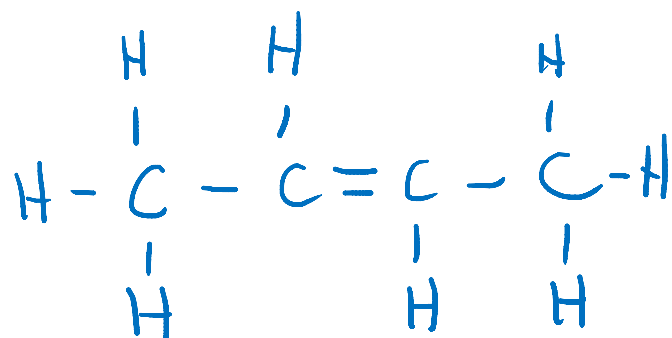
inside (not on an end)

→ arrangement of atoms attached to double-bonded carbons.

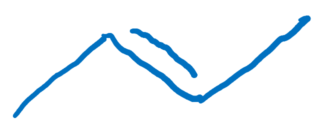


cis-

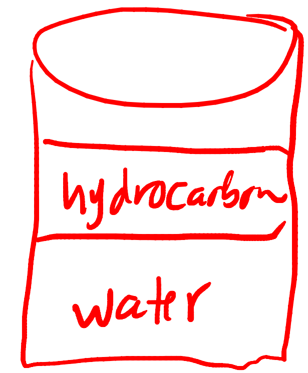




trans -



Properties of Hydrocarbons



1) Non-polar substances
2) Insoluble in water
3) Less dense than water
4) Very weak intermolecular forces
   → Van der Waals only (no polar bonds!)
5) Low melting points and low boiling points
6) Boiling points increase as carbons are added.
7) Undergo combustion reactions.

Combustion Reactions

hydrocarbon + O_2 $\longrightarrow$ CO_2 + H_2O

C_5H_{12} + O_2 $\longrightarrow$ CO_2 + H_2O

C_6H_{14} + O_2 $\longrightarrow$ CO_2 + H_2O

C_7H_{16} + O_2 $\longrightarrow$ CO_2 + H_2O

Balancing Tips -

balance C first

H second

O ALWAYS LAST.

$C_5H_{12} + 8O_2 \longrightarrow 5CO_2 + 6H_2O$

C - 5
H - 12
O - ~~2~~ 16

C - ~~1~~ 5
H - ~~2~~ 12
O - ~~3~~ ~~11~~ 16

$2C_6H_{14} + 19O_2 \longrightarrow 12CO_2 + 14H_2O$ (~~6~~ CO_2, ~~7~~ H_2O)

24
14
38

C - 6
H - 14
O - ~~2~~ 38

C - ~~1~~ 6
H - ~~2~~ 14
O - ~~3~~ ~~13~~ ~~19~~ 38

uneven - double ALL

$C_7H_{16} + 11O_2 \longrightarrow 7CO_2 + 8H_2O$

14
8

C - 7
H - 16
O - ~~2~~ 22

C - ~~1~~ 7
H - ~~2~~ 16
O - ~~3~~ ~~15~~ 22

Saturated Hydrocarbons: Alkanes

Alkanes: Saturated – no double or triple bonds

General formula C_nH_{2n+2}

TABLE 19.3 | Names, Formulas, and Physical Properties of Straight-Chain Alkanes

Name	Molecular formula C_nH_{2n+2}	Condensed structural formula	Boiling point (°C)	Melting point (°C)
Methane	CH_4	CH_4	−161	−183
Ethane	C_2H_6	CH_3CH_3	−89	−172
Propane	C_3H_8	$CH_3CH_2CH_3$	−42	−187
Butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$	−0.6	−135
Pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$	36	−130
Hexane	C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$	69	−95
Heptane	C_7H_{16}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	98	−90
Octane	C_8H_{18}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	125	−57
Nonane	C_9H_{20}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	151	−54
Decane	$C_{10}H_{22}$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	174	−30