# Welcome to Chemistry 154!

Please make sure to sync your iClicker Cloud
to Chem154 Section 113

# Reminders

- **Worksheet: Unit 4**
- Due Oct. 9th at 11:59pm

- **Achieve Assignment #4**
- Due Oct. 9th at 11:59pm

- Watch Chapter 4 helpful videos on All Lectures site

**Instructor Office Hours**
Monday and Friday 7-8pm via Zoom (All Lectures Site)

# Unit 4
# Intermolecular Interactions
# &
# Phases of Matter

# Summary

| Force type | Strength | Exhibited by | Examples |
|---|---|---|---|
| London Dispersion forces | Weak | Present in all atoms and molecules. Strength increases as the number of electrons in the molecule increases (more polarizable) | $I_2$, Kr, $PCl_5$ |
| Dipole-dipole interactions | Strong | Molecules with a permanent dipole. | $PCl_3$, ICl, $CH_3Cl$ |
| Hydrogen bonds | Strong | Molecules with H bonded to F, O, or N. The large electronegativity difference and resulting permanent dipole are responsible for the strength of these forces. | HF, $H_2O$ |
| Charge-charge or Ion-ion interactions | Very Strong | Ionic solids or ionic liquids. | NaCl, $K_3PO_4$ |

# Worksheet Question #2

Which type of intermolecular interactions need to be overcome to convert each of the following liquids to gases?

a) $CH_4$

b) $CH_3F$

c) $CH_3OH$

# Worksheet Question #2 - Clicker Question

Which of the molecules from WS Q2 ($CH_4$, $CH_3F$, and $CH_3OH$) will experience **London dispersion forces**?

A. $CH_4$

B. $CH_3F$

C. $CH_3OH$

D. $CH_4$ and $CH_3F$

E. All of the above

# Worksheet Question #2 - Clicker Question

Which of the molecules from WS Q2 ($CH_4$, $CH_3F$, and $CH_3OH$) will experience **dipole-dipole** interactions?

A. $CH_4$

B. $CH_3F$

C. $CH_3OH$

D. $CH_3F$ and $CH_3OH$

E. All of the above

# Worksheet Question #2 - Clicker Question

Which of the molecules from WS Q2 ($CH_4$, $CH_3F$, and $CH_3OH$) will experience **hydrogen bonding** interactions?

A. $CH_4$

B. $CH_3F$

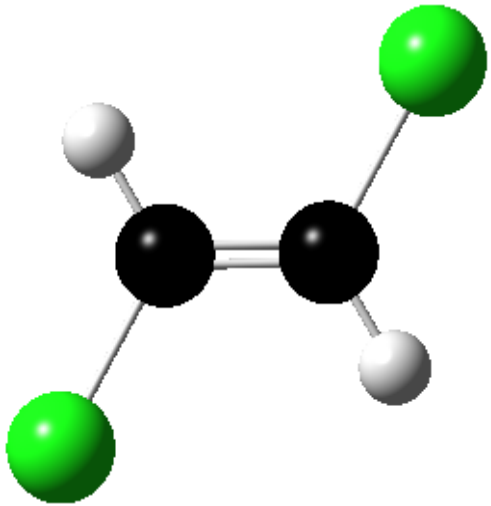
C. $CH_3OH$

D. $CH_3F$ and $CH_3OH$

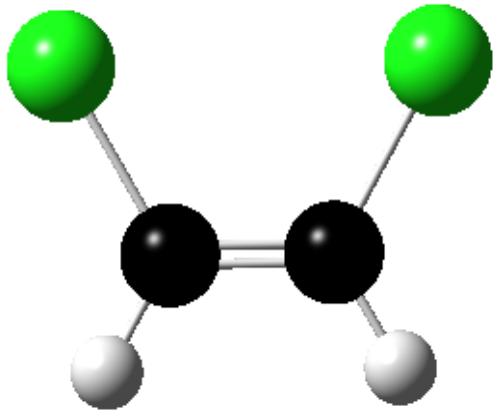
E. All of the above

# Clicker Question

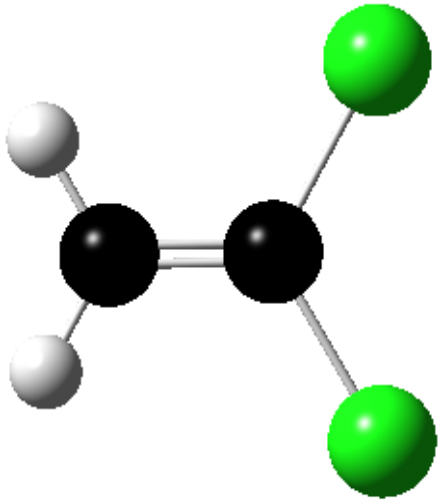
There are three isomers of $C_2H_2Cl_2$, shown as ball-and-stick models below. Which isomer experiences London Dispersion forces only?



a.



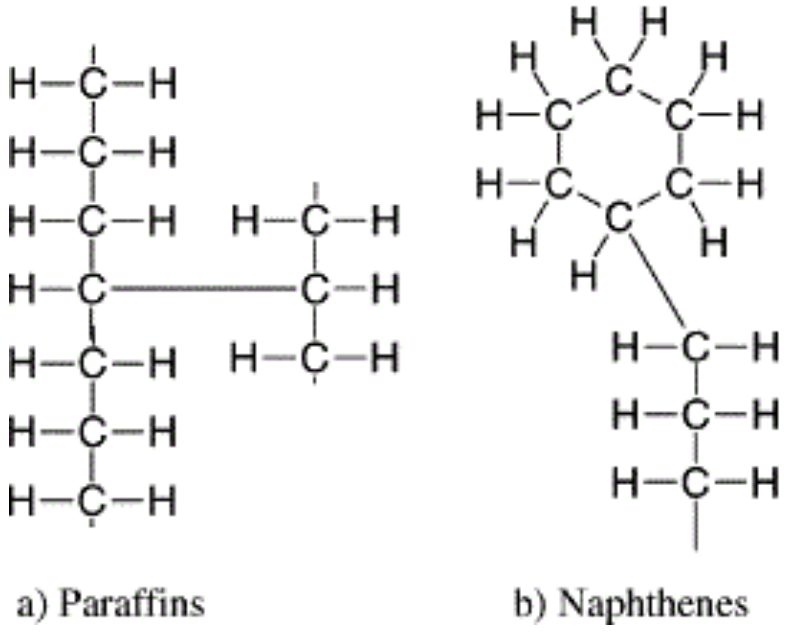
b.



c.

# How do detergents and dispersants work?

## Hydrocarbons from petroleum

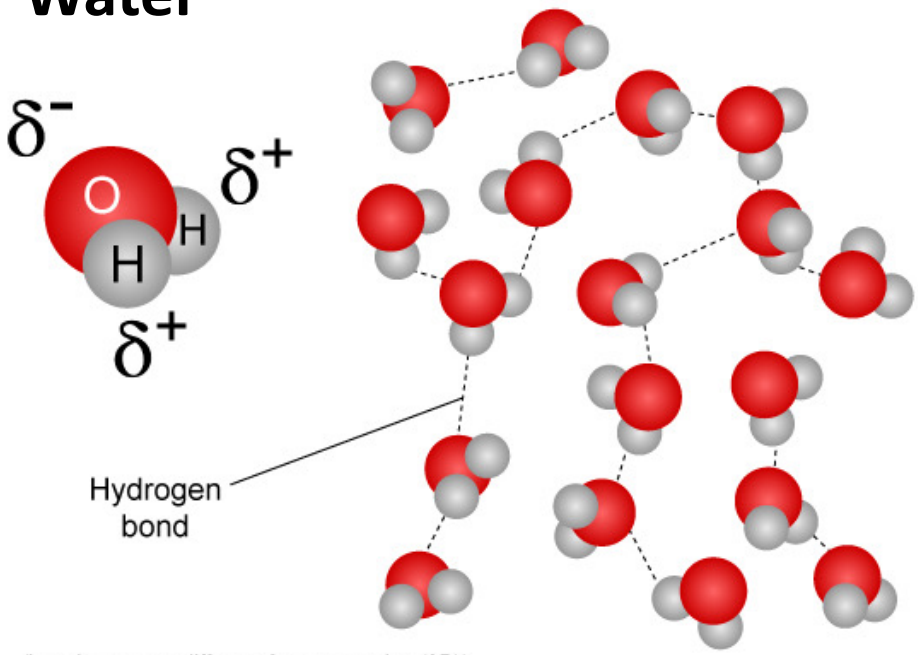


a) Paraffins



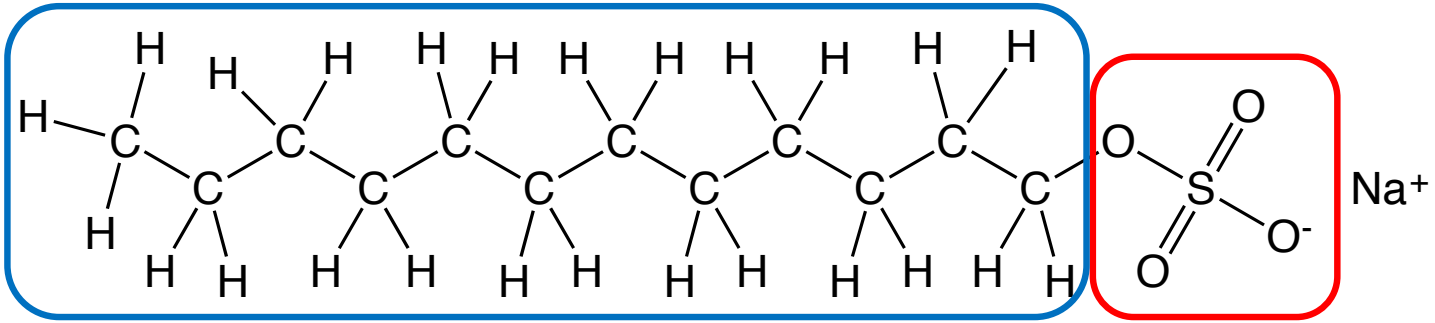
b) Naphthenes

## Water

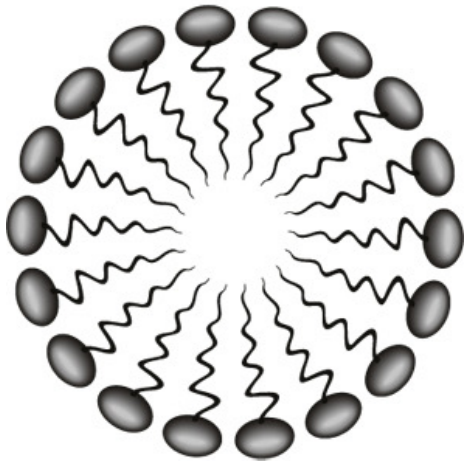



(length appears different for perspective (3D))



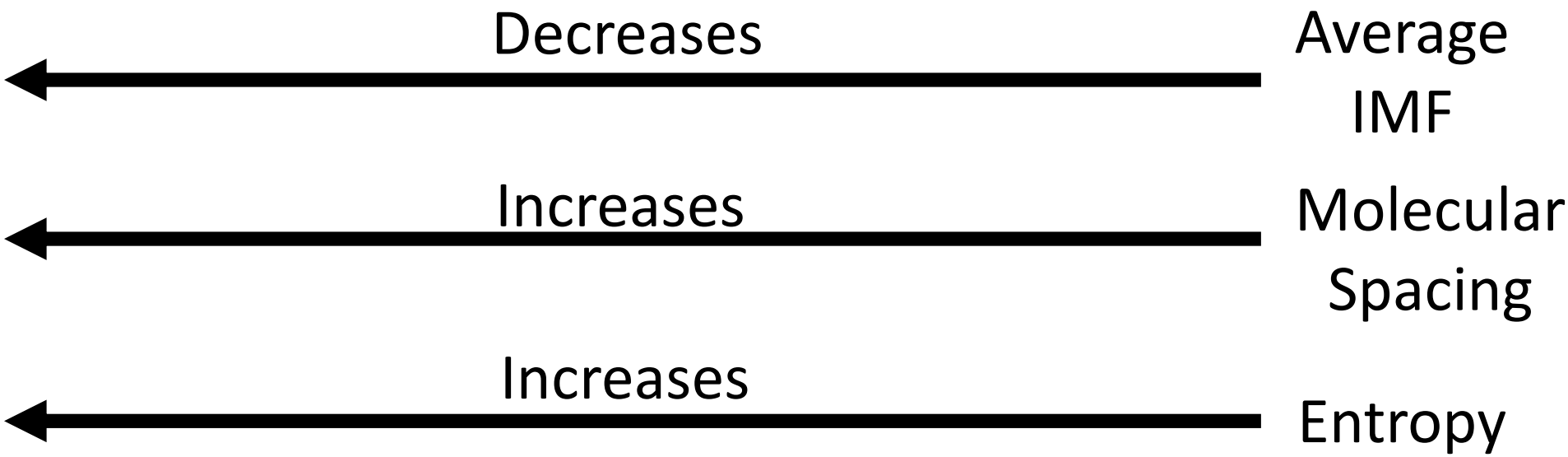



sodium dodecyl sulfate



## Detergent or dispersant

# Phases of matter

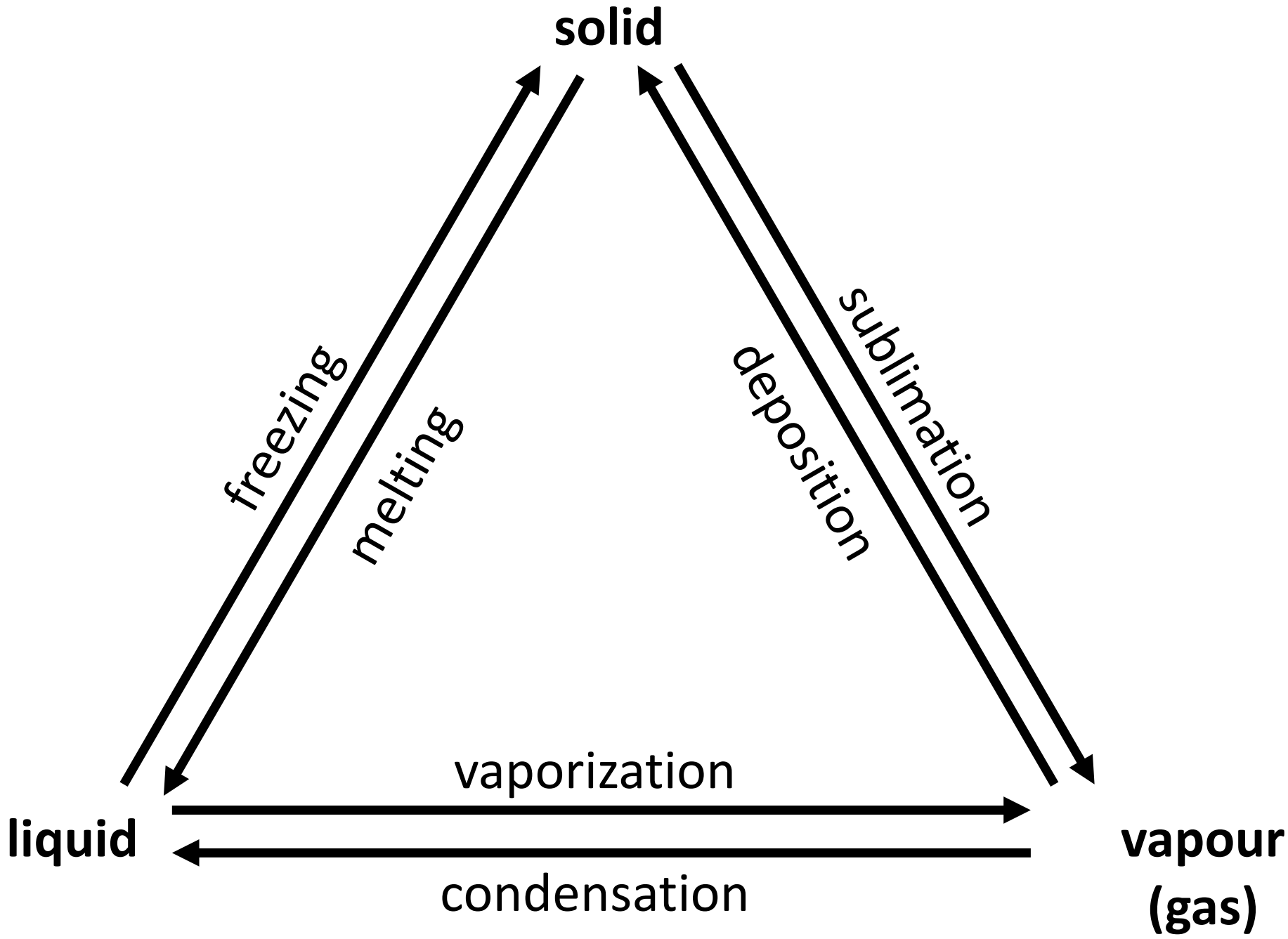
# Phases - definitions

A substance is in a distinct phase when all physical properties, such as density or chemical composition, are uniform throughout. Examples: solid, liquid, gas, plasma, supercritical fluid.

A phase change occurs when a substance changes from one phase to another.

A one-component system is characterized by a single, pure chemical substance. E.g. $H_2O$: ice, water and steam.

# Phases of matter, phase changes



# Thermodynamic Equilibrium

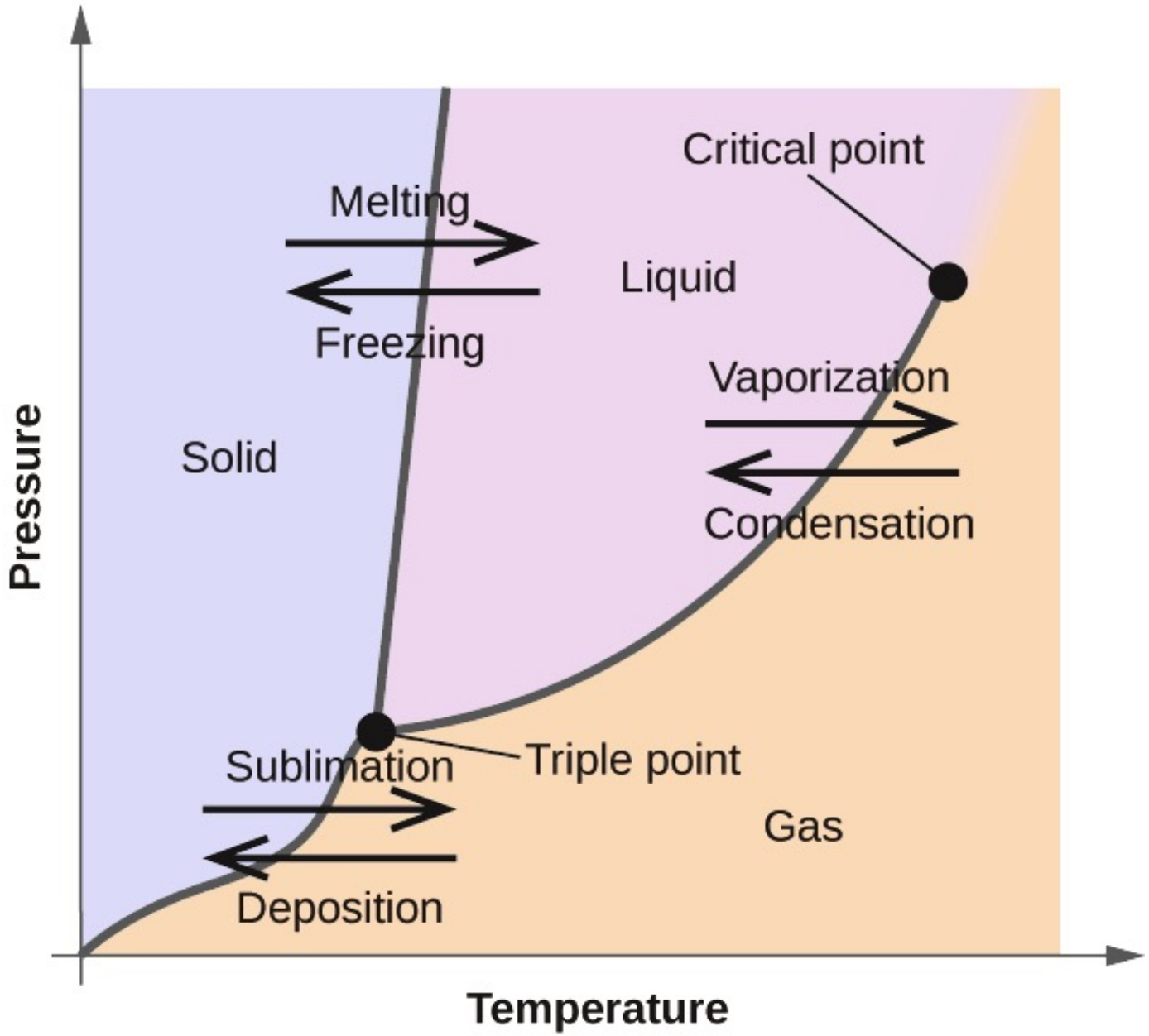
→ When there are no **net macroscopic** flows of matter or energy within a system or between the system and surroundings.

→ The macroscopic properties of the system remain constant with time **and** the system is robust when subjected to minor perturbations.

| Type of Equilibrium | Thermodynamic Variable |
|---|---|
| Thermal | Temperature, T |
| Mechanical | Pressure, P |
| Chemical or Material | Concentration or Chemical potential, μ |

→ All these equilibria must be satisfied for a system to be in thermodynamic equilibrium.

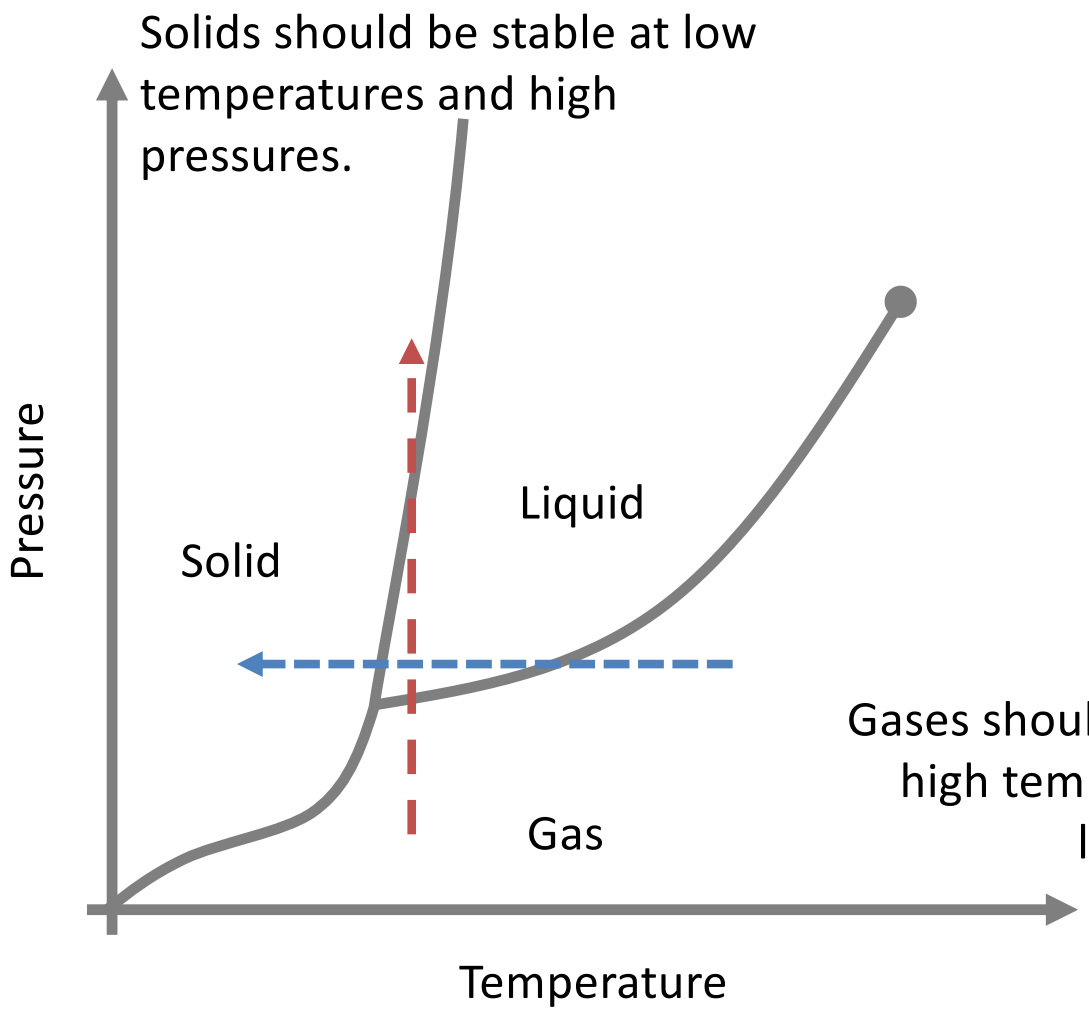
# Generic One-Component P-T Phase Diagram




Taken from https://opentextbc.ca/chemistry/chapter/10-4-phase-diagrams/

# Density and pressure

Increasing **pressure** ↑ or decreasing temperature ← changes stable phase from a less dense to a more dense form.



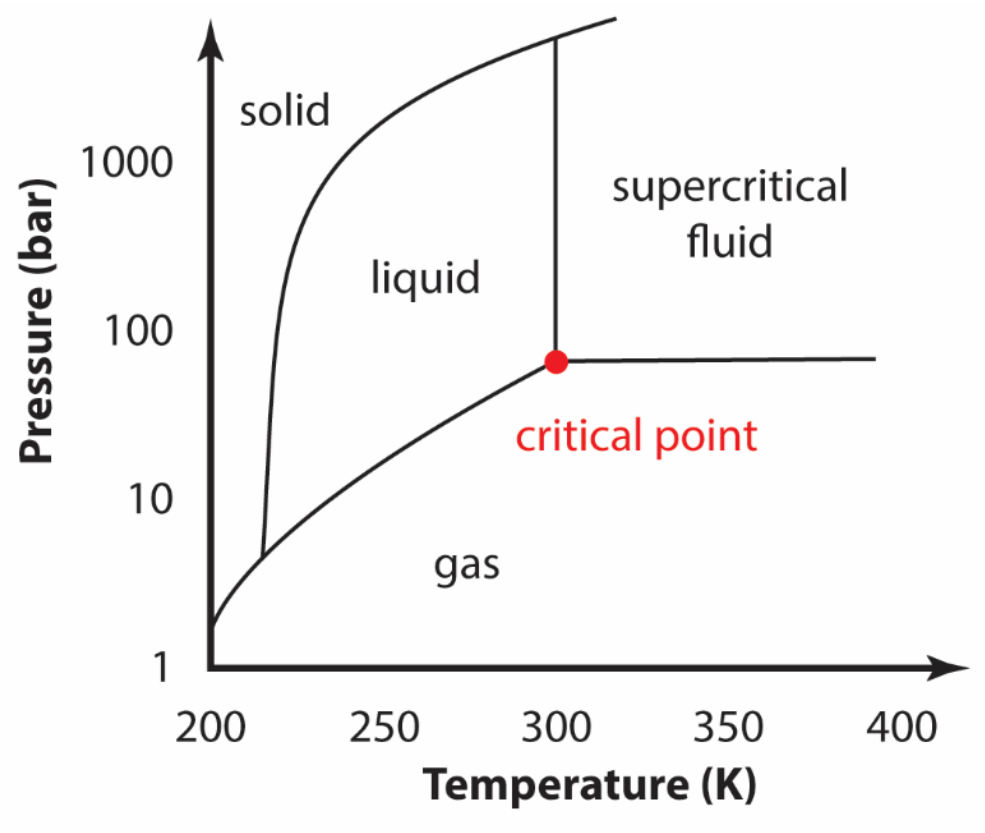

Both dashed arrows show phase changes: gas → liquid → solid

Adding/removing heat moves one towards higher or lower temperatures, respectively.

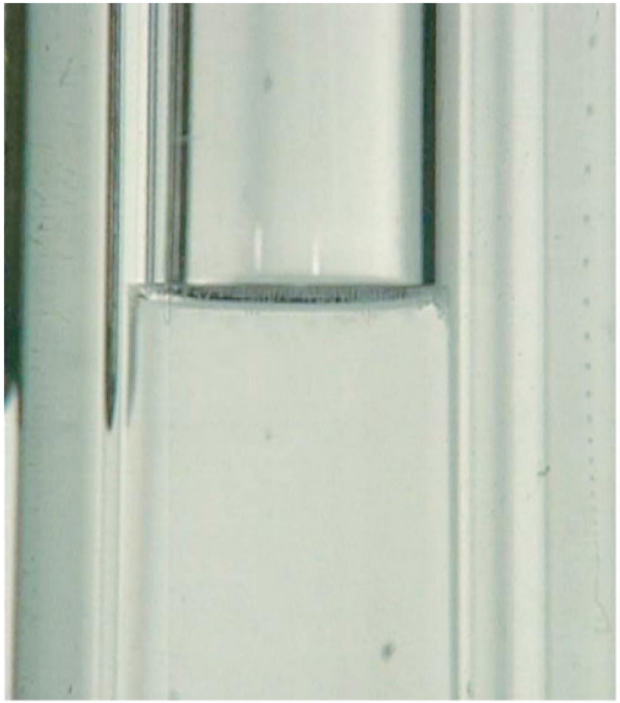
Gases should be stable at high temperatures and low pressures.

# Supercritical Fluids

A substance behaves as a supercritical fluid at temperatures and pressures beyond the critical point. A supercritical fluid exhibits properties of a liquid and a gas.



# Critical Point



About 10 °C
below $T_c$

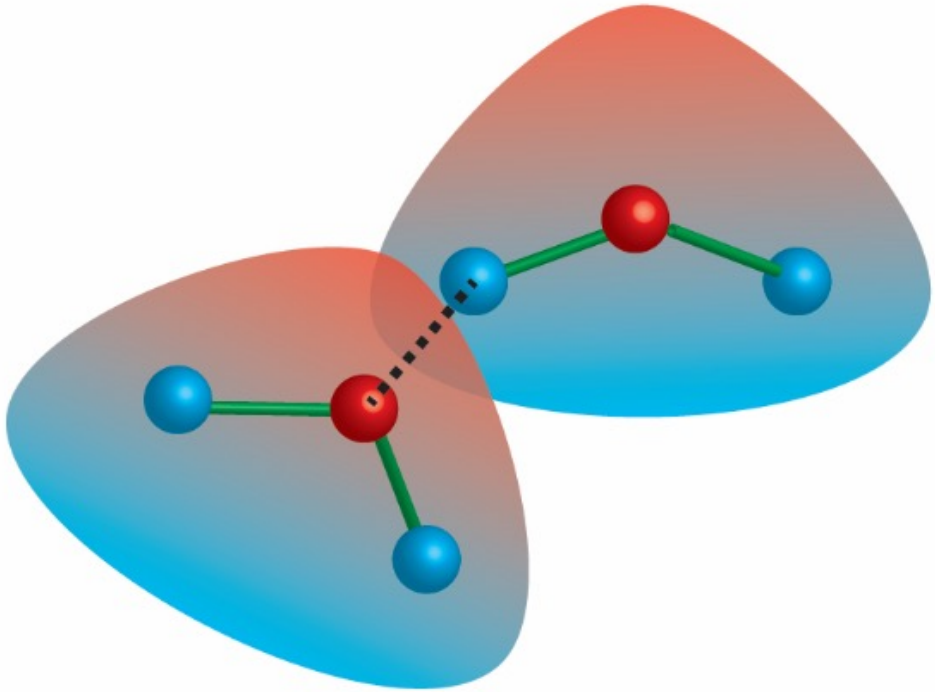
About 1 °C
below $T_c$

Critical
temp. $T_c$

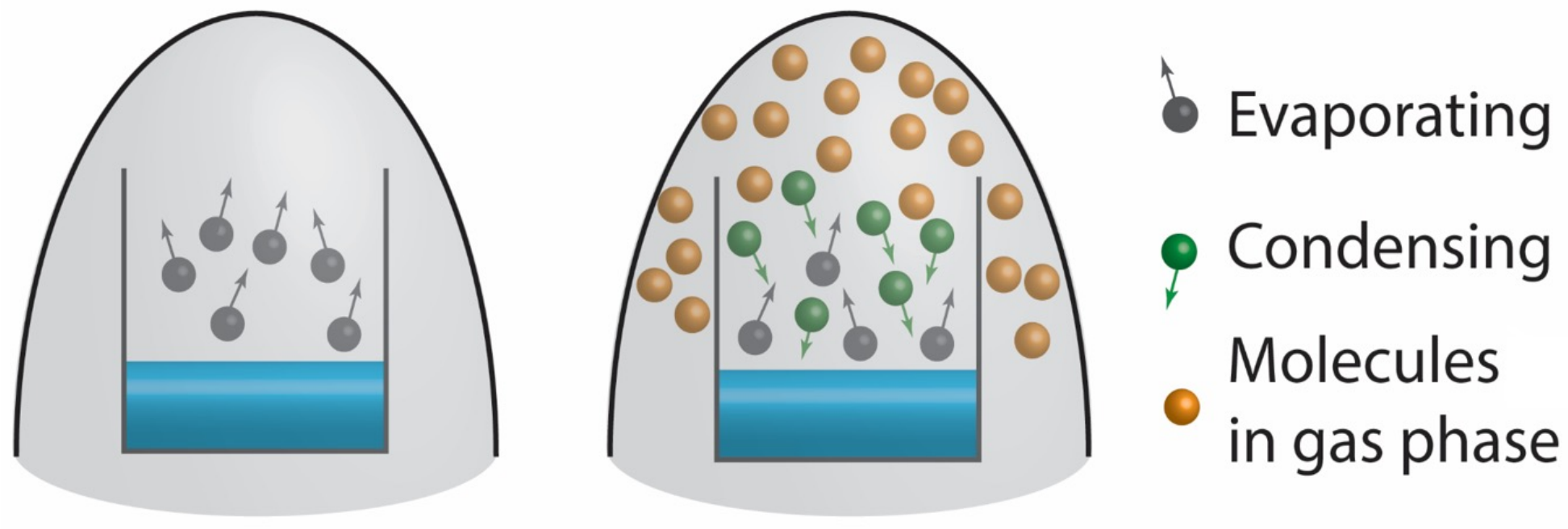
– Critical Point = Liquid and gas phase become indistinguishable.

# Hydrogen Bonding in Water

In water, oxygen has a higher electron density due to its higher electronegativity compared to hydrogen. Oxygen atoms in one molecule are attracted to hydrogen atoms in a neighbouring water molecule to maximize electrostatic interactions.



# Vapour pressure

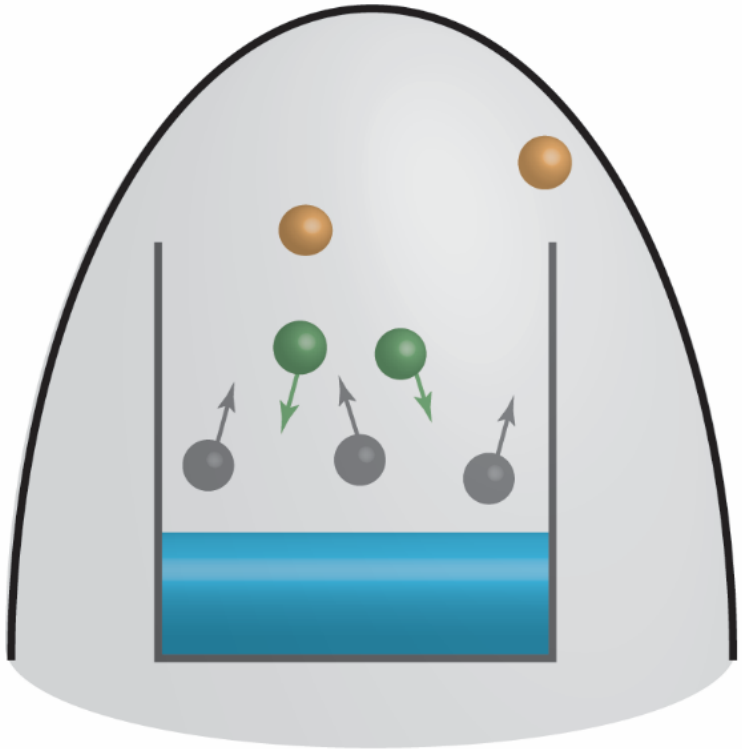



Two processes occurring: Vapourization and condensation

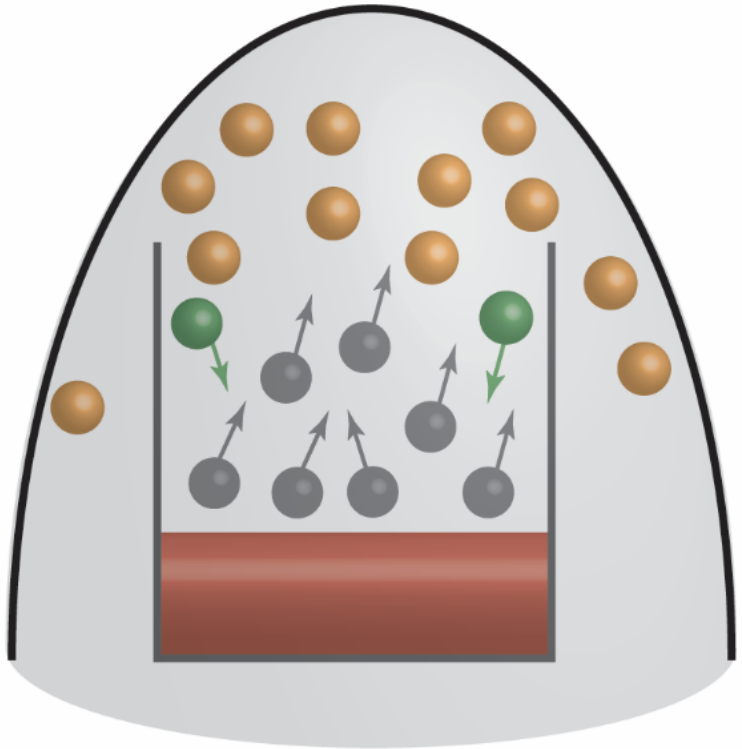
Liquid ⇌ Gas

Vapour pressure is the **pressure** exerted by a **vapour** in thermodynamic equilibrium with its condensed phases (solid or liquid) at a given temperature in a closed system.

# Volatility and Vapour Pressure

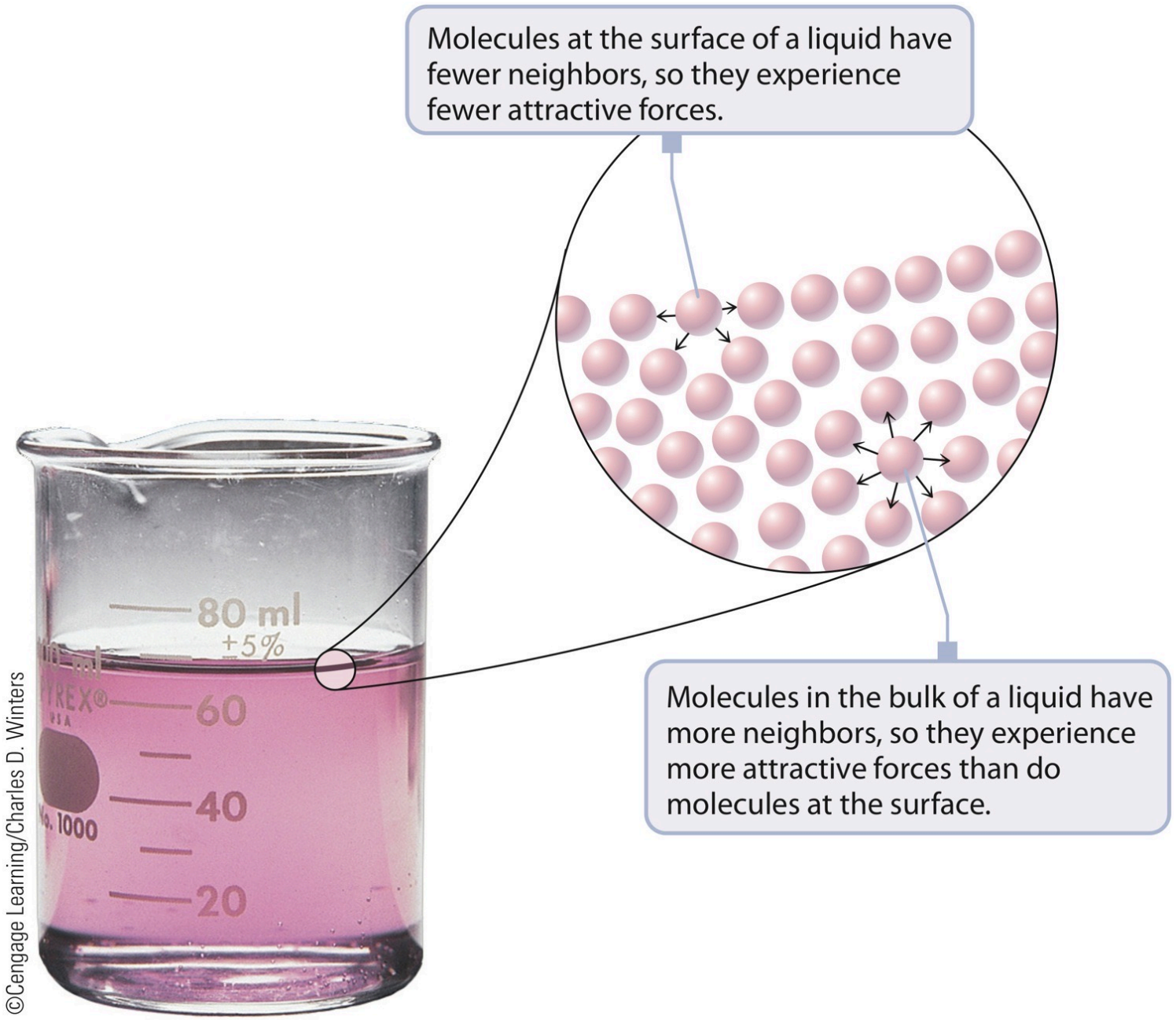


Less volatile liquid,
lower vapor pressure



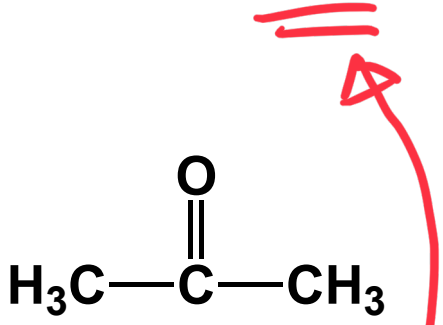
More volatile liquid,
higher vapor pressure

# Why does a liquid evaporate?

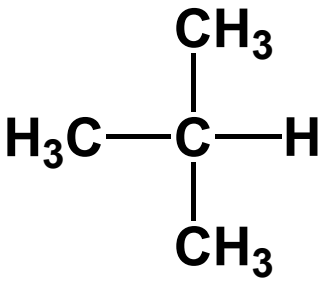


# Clicker Question

Acetone boils at a significantly higher temperature than 2-methylpropane (isobutane) because…




Acetone




2-Methylpropane

Stronger Intermolecular forces

a) The London dispersion forces in 2-methylpropane are weaker than the dipole-dipole forces in acetone

b) Dipole-dipole forces are always greater than dispersion forces

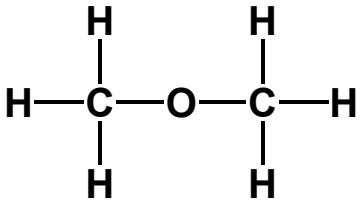
c) The molecular mass of acetone is slightly less than that of 2-methylpropane

d) The hydrogen bonding interactions in acetone are stronger than the London dispersion forces in isobutane.

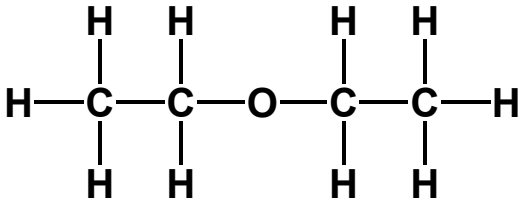
e) The London dispersion forces in 2-methylpropane are weaker than those in acetone

# Clicker Question * Revisit on Tuesday (Oct. 10th)

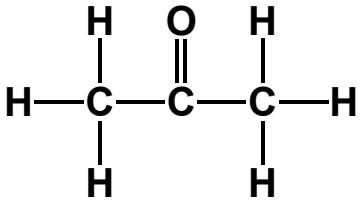
Arrange the following molecules in order of increasing vapour pressure at room temperature.



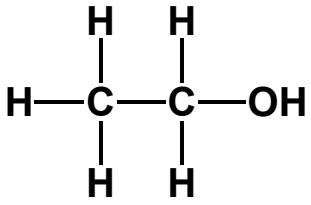
1



2



3



4

a) 2 < 3 < 1 < 4

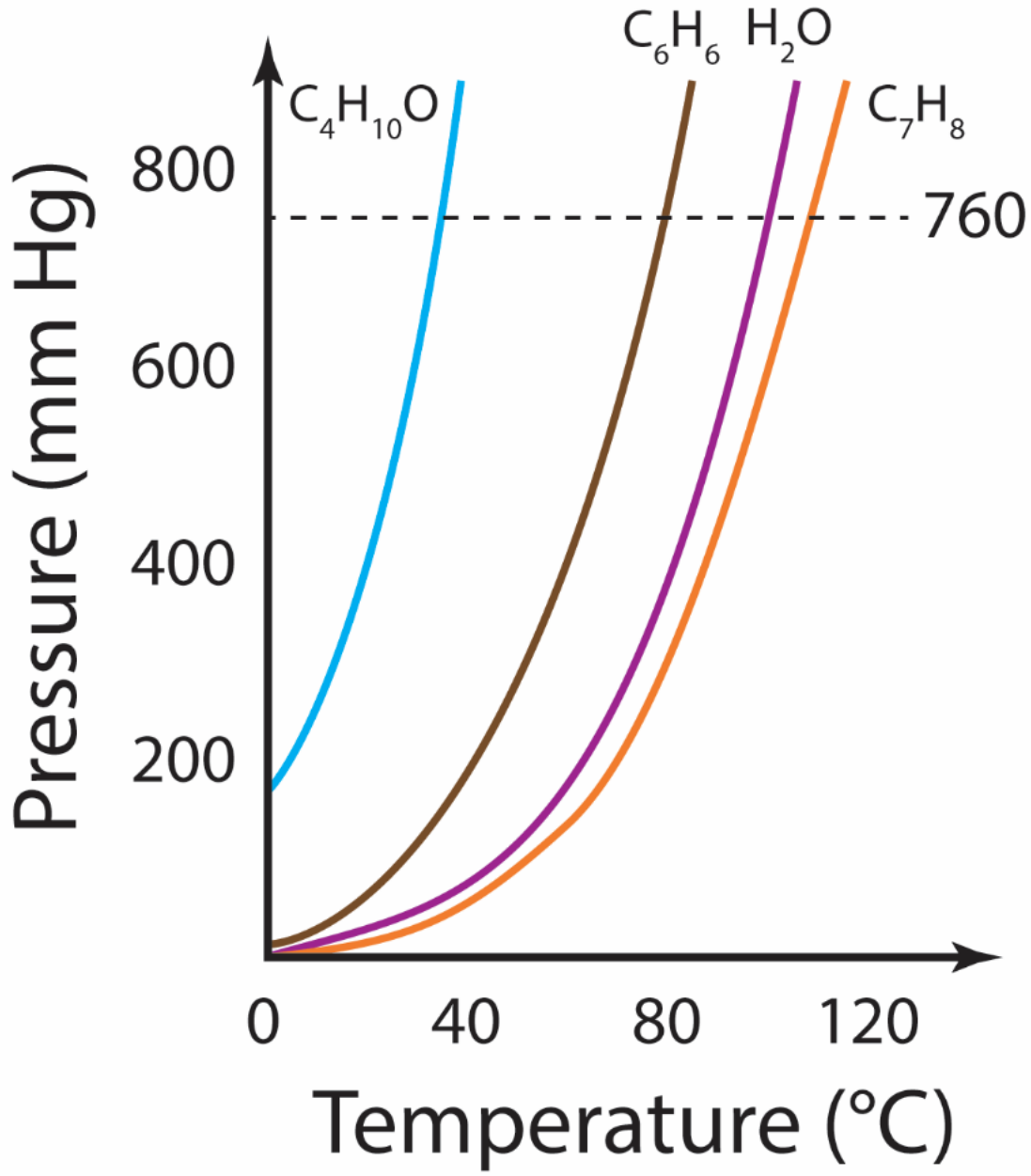
b) 1 < 4 < 3 < 2

c) 4 < 3 < 2 < 1

d) 3 < 4 < 1 < 2

e) 4 < 1 < 2 < 3

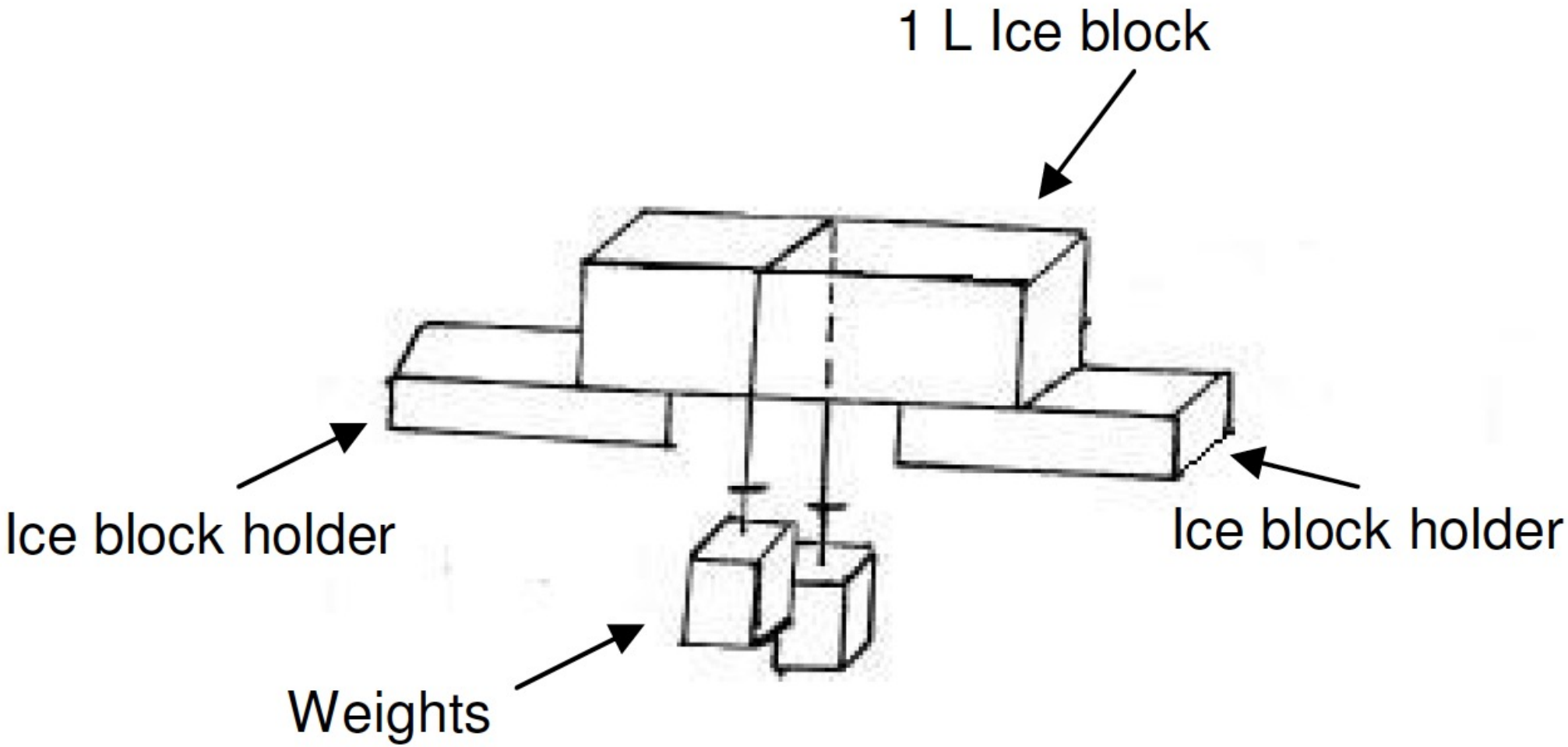
# Vapor pressure




1. VP increases with increasing T
2. More molecules escaping to gas phase

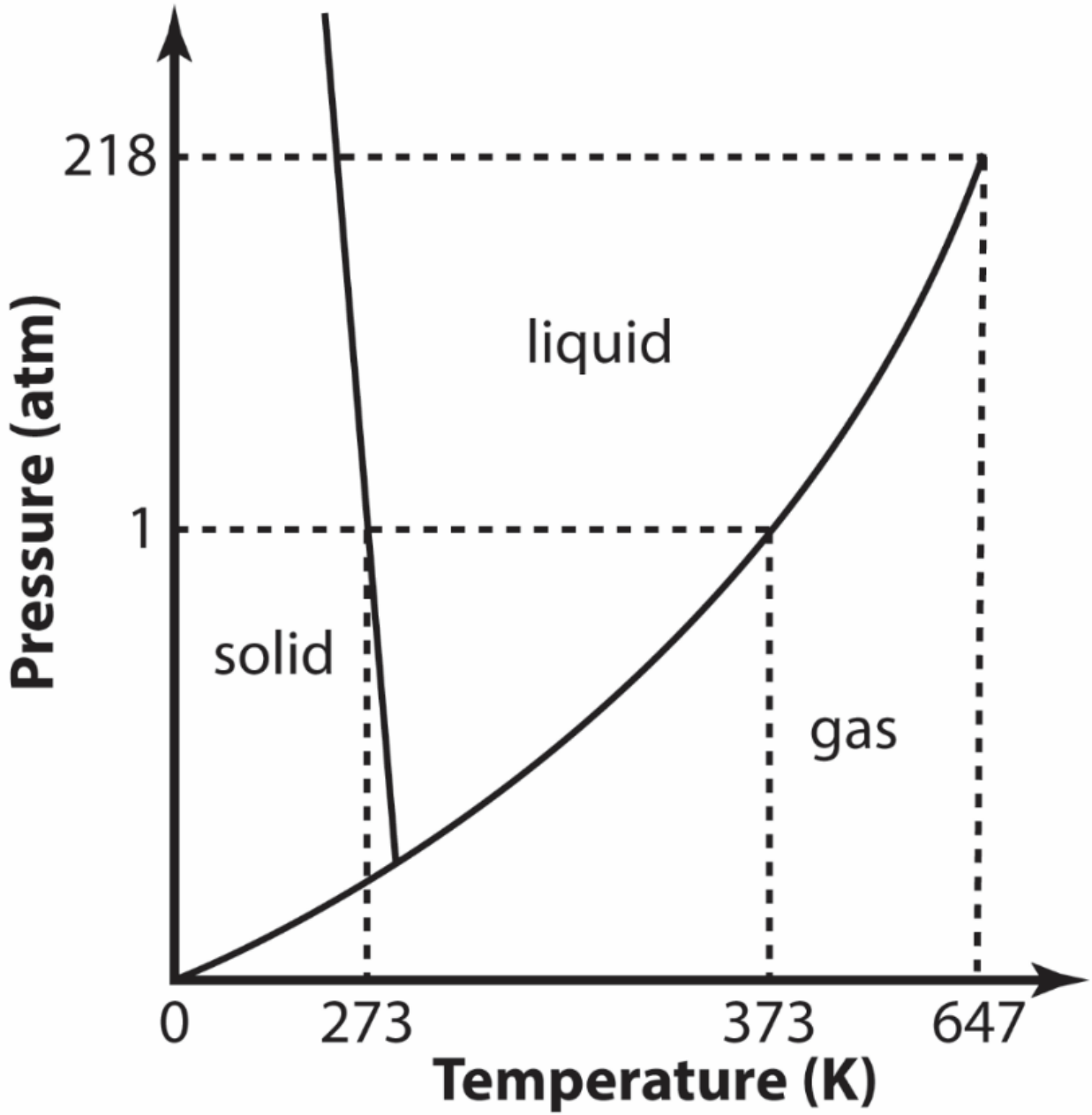
**Liquids boil when VP = atmospheric pressure**

# Demonstration for Today



# Worksheet Question #9

…Use the phase diagram for water (right) to explain the results of the experiment.



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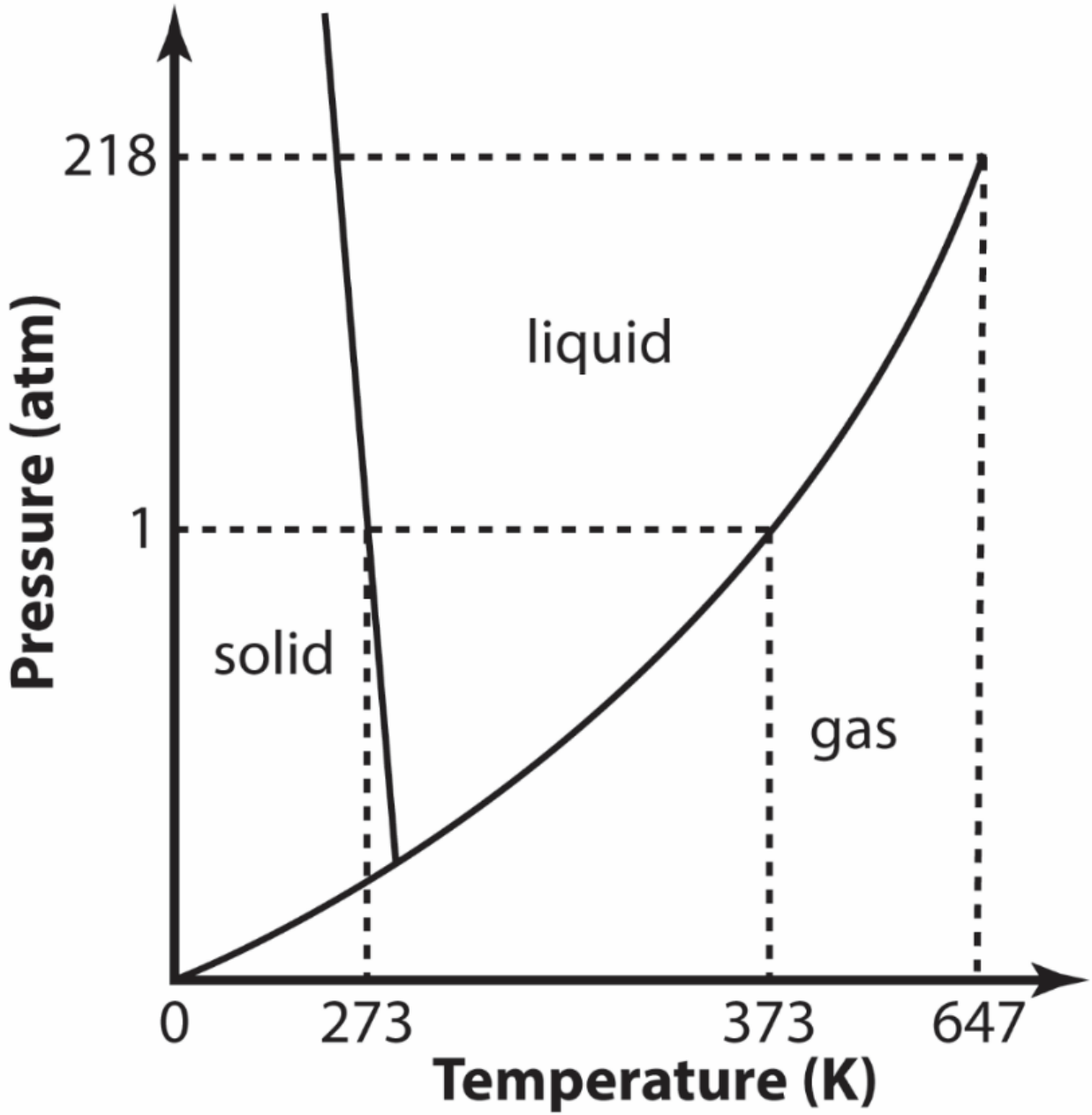
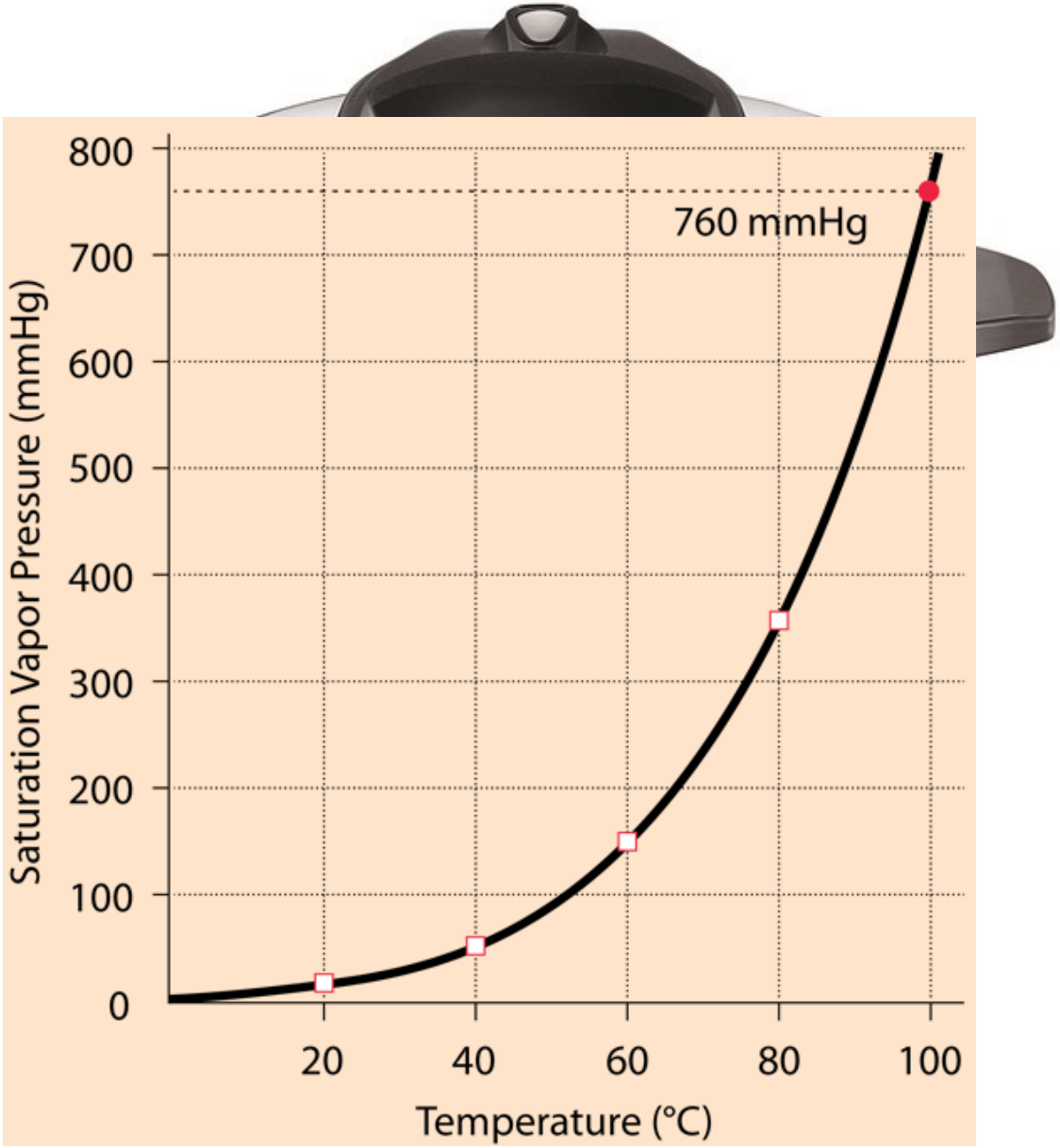


# Cooking food, faster (Pressure cooker)




Pressure cookers operate at 15 psi (1 bar = 1 atm) ABOVE atmospheric pressure. ($P_{int}$ = 2 bar = 2 atm)

Water boils at 120 °C at 2 bar pressure.

Higher boiling point = faster cooking!

# Clicker Question

Which of the following processes is endothermic?

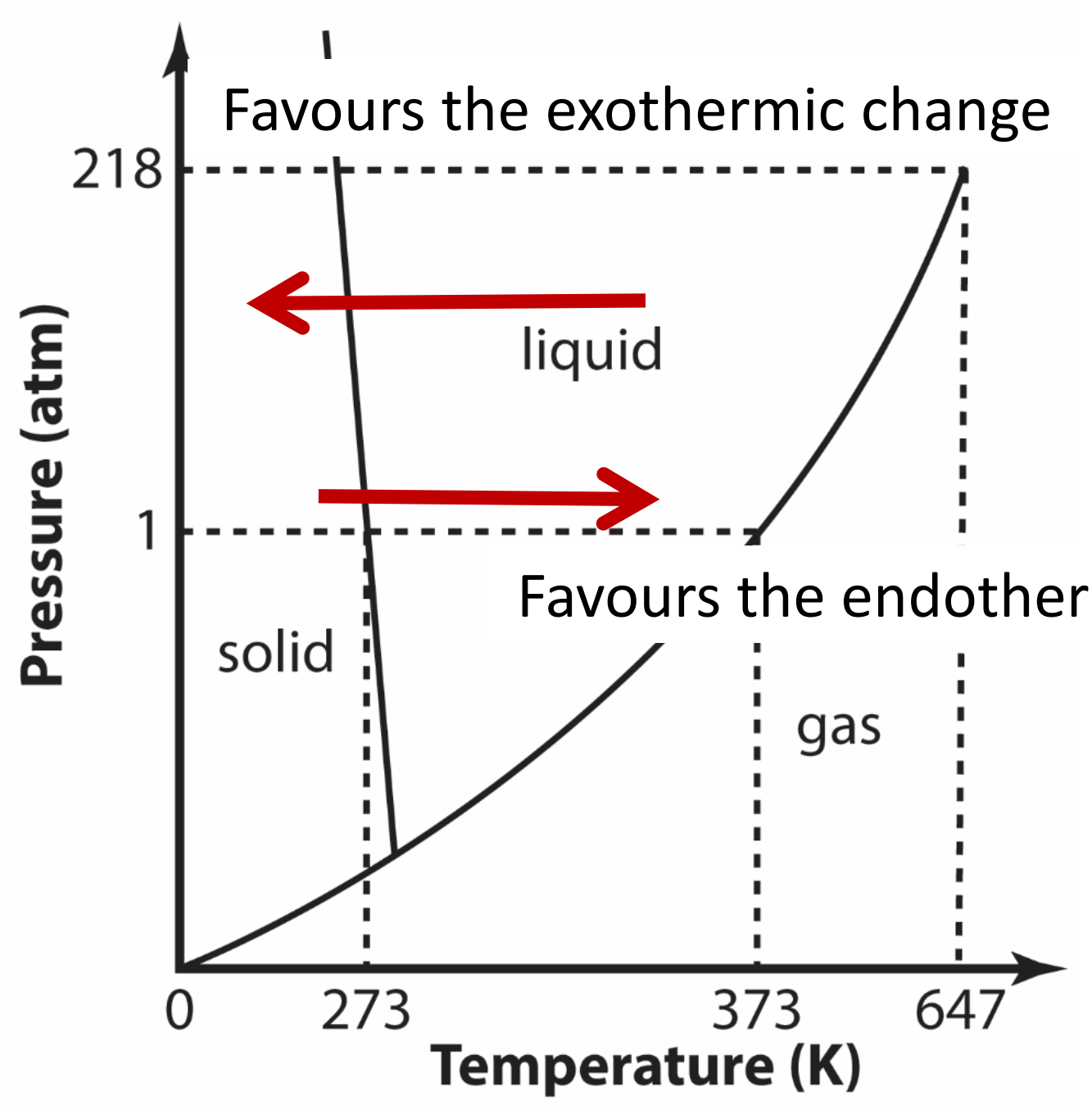
a) Vaporization

b) Condensation

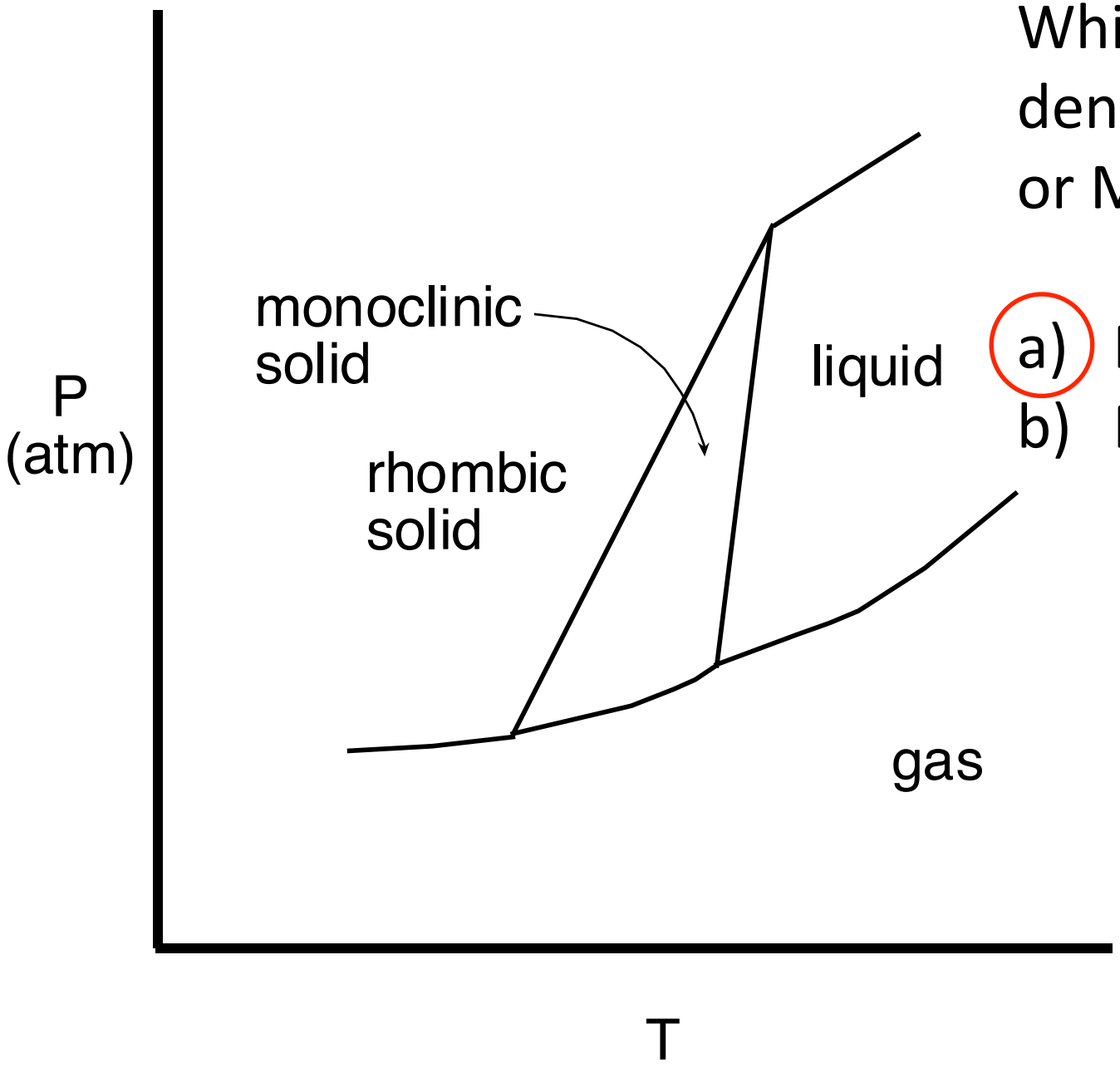
c) Deposition

d) Freezing

# Temperature and phase diagrams



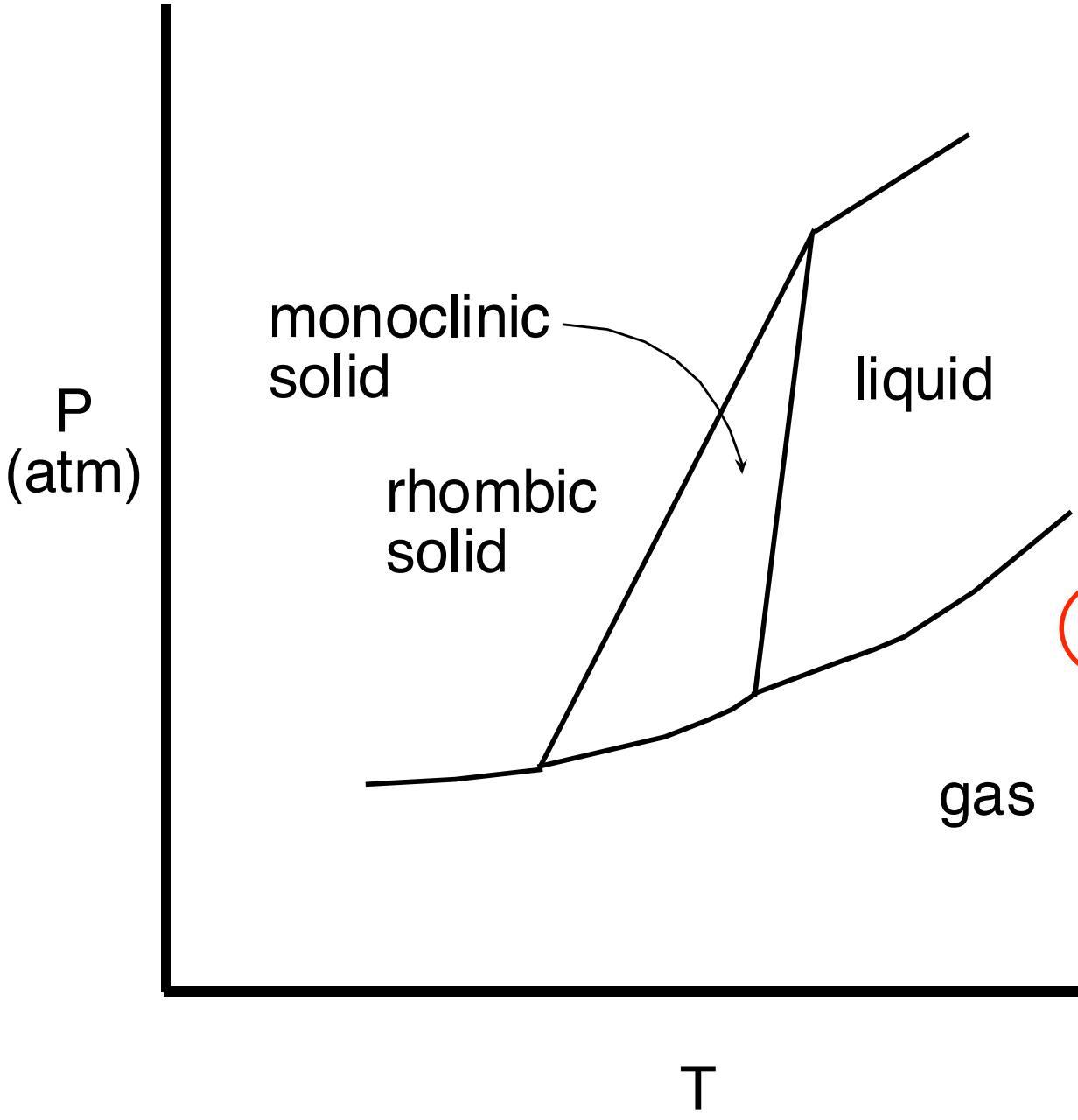
# Clicker Question




Which phase is more dense - Rhombic solid or Monoclinic solid?

a) Rhombic solid
b) Monoclinic solid

# Clicker Question




Which best describes the monoclinic solid -> rhombic solid transition?

a) Fusion
b) Endothermic
c) Exothermic
d) Crystallization
e) None of the above