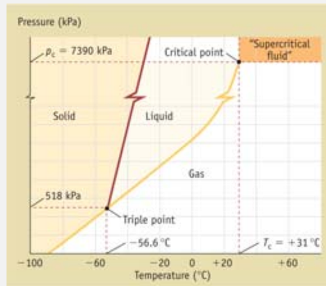
[TP] CO_2 gas at 1 atm, 0 °C
is heated to 1 atm, 60 °C;
then compressed to 75 atm, 60 °C;
then cooled to 75 atm, 0 °C;
then expanded to 73 atm, 0 °C.
At this point, the CO_2 will be a …

25% 1. gas
25% 2. supercritical fluid
25% 3. liquid
25% 4. solid



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Lecture 10 CH102 A2 (MWF 11:15 am)

Friday, February 9, 2018

- Real gases: Effect of molecular size
- Gas law for real gases: van der Waals equation
- Phase diagrams

Next: Begin ch12: Solutions and their behavior (no class on Monday)

Triple point YouTube video: http://goo.gl/4K1SR
Supercritical fluid YouTube video: http://goo.gl/xo2jU

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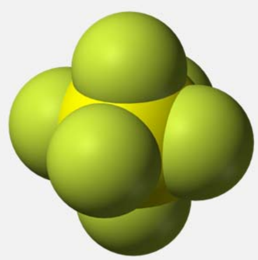
Effect of molecular size

While gas particles are tiny compared to the volume of their container, they do take up some space.

The graphic illustrates the electron cloud of SF_6.



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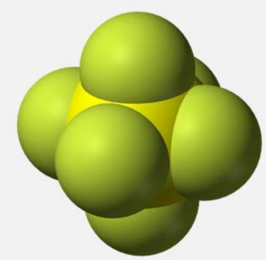
Effect of molecular size

Gas particles have a volume: van der Waals b

$V_{container} = V_{empty} + bn$



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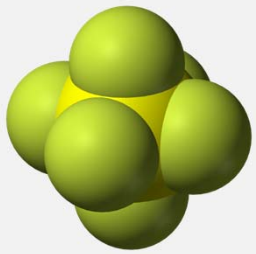
[TP] Gas particles have a volume measured by van der Waals b.
For SF_6, $b = 88$ mL/mol. The percent of gas container volume taken up by the SF_6 molecules themselves is ...

17% 1. 0.01%
17% 2. 0.05%
17% 3. 0.1%
17% 4. 0.5%
17% 5. 1%
17% 6. 5%



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Response Counter 10

Effect of molecular size

Gas particles have a volume: van der Waals b

$$V = V_{\text{container}} = V_{\text{empty}} + bn$$

For SF_6, $b = 88$ mL/mol

% of molar gas volume ...

$\approx$ (0.088 / 22) × 100% = 0.40%

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A gas law for “real” gases: van der Waals equation

We know the ideal gas law $pV = nRT$ where p does not account for inter-particle attractions ...

$$p = p_{\text{empty}} = p_{\text{observed}} + a\left(\frac{n}{V_{\text{container}}}\right)^2$$

and V does not account for particle volume ...

$$V = V_{\text{empty}} = V_{\text{container}} - bn$$

Combine these two expressions into an equation relating p_{observed}, $V_{\text{container}}$, and T.

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A gas law for “real” gases: van der Waals equation

We know the ideal gas law $pV = nRT$ where p does not account for inter-particle attractions and V does not account for particle volume ...

$$p = p_{\text{empty}} = p_{\text{observed}} + a\left(\frac{n}{V_{\text{container}}}\right)^2$$

$$V = V_{\text{empty}} = V_{\text{container}} - bn$$

$$p_{\text{empty}}V_{\text{empty}} = \left\{p_{\text{observed}} + a\left(\frac{n}{V_{\text{container}}}\right)^2\right\}(V_{\text{container}} - bn) = nRT$$

This is known as the van der Waals equation

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When is van der Waals equation is not needed?

$$\left\{p + a\left(\frac{n}{V}\right)^2\right\}(V - bn) = \left\{p + a\left(\frac{n}{V}\right)^2\right\}V\left(1 - b\frac{n}{V}\right) = nRT$$

If gas density, n/V, is very small, then effect of a is negligible.

If gas density, n/V, is very small, compared to molar volume, $1/b$, then effect of b is negligible.

So, a and b are important at high pressure, low volume, and low temperature, that is, near condensation (the boiling point).

Far from condensation, a and b have negligible effect, and so the ideal gas law, $PV = nRT$, can be used.

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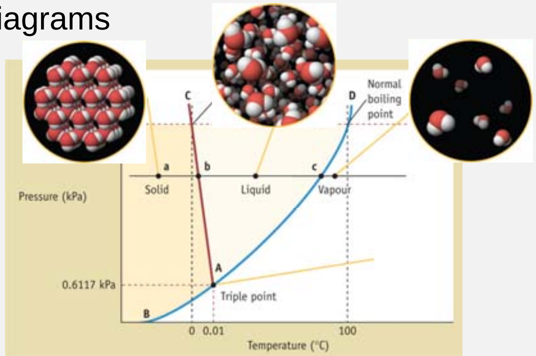
Phase diagrams



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Phase diagrams

Lines of p versus T for which different phases are present at the same time.

That is, values of p and T for which different phases are in equilibrium.

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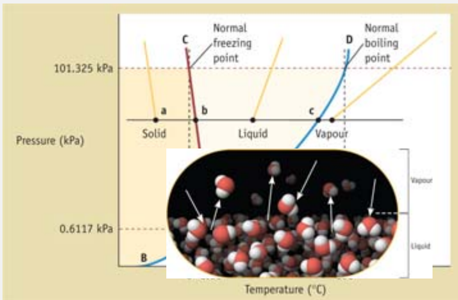
How about on blue line at 45 ºC, point c?



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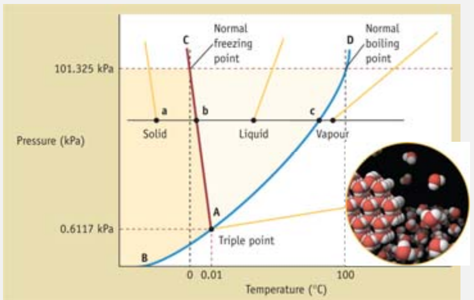
What about the intersection marked “A”



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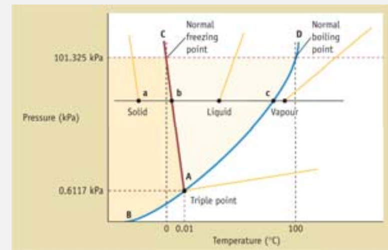
Triple point

Liquid tert-butyl alcohol, $C(CH_3)_3OH$, can boil and freeze at the same time… http://goo.gl/4K1SR



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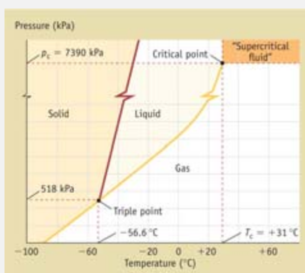
Supercritical fluid

Supercritical transition of liquid Cl_2 … http://goo.gl/xo2jU



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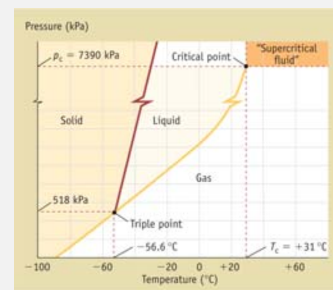
Changes of phase

CO_2 gas at 1 atm, 0 °C
is heated to 1 atm, 60 °C;
then compressed to 75 atm, 60 °C;
then cooled to 75 atm, 0 °C;
then expanded to 73 atm, 0 °C.
At this point, the CO_2 will be a …



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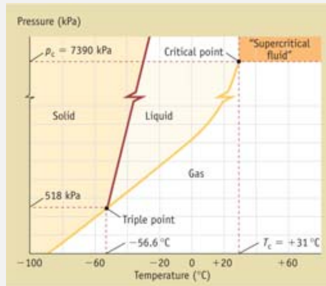

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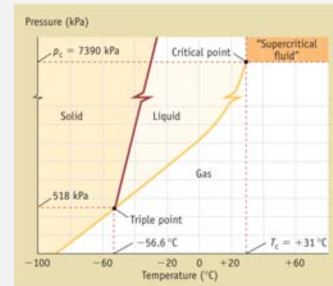
[Group quiz] CO_2 at 1 atm, 0 °C
is heated to 1 atm, 60 °C;
then compressed to 75 atm, 60 °C;
then cooled to 75 atm, 0 °C;
then expanded to 73 atm, 0 °C.
At this point, the CO_2 will have undergone a phase transition …

25% 1. once
25% 2. twice
25% 3. three times
25% 4. None of the above



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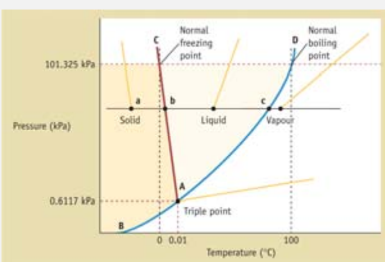
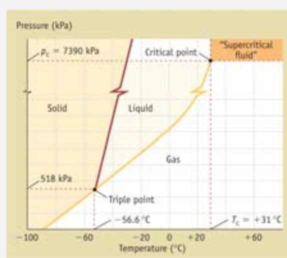
Phase diagrams are specific to each substance

Water



CO_2



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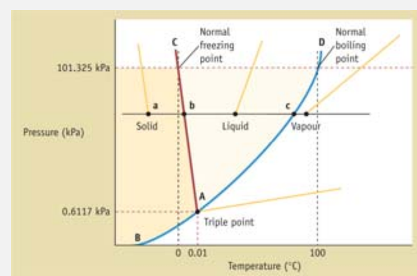
H_2O phase diagram

Is density of liquid H_2O greater than that of solid H_2O?

How can we tell?



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