Chemistry 112 **Spring 2007** **Prof. Metz** **Exam 1 KEY**

1. Ammonia, NH_3, has a much higher boiling point than phosphine, PH_3. This is because:

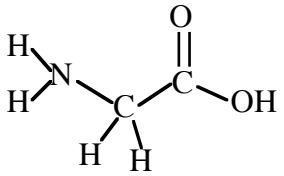
(A) NH_3 has a lower molecular weight than PH_3.
(B) NH_3 is not planar.
(C) NH_3 is extensively hydrogen bonded.
(D) PH_3 is a strong acid.
(E) PH_3 is extensively hydrogen bonded.

NH_3 can hydrogen bond, PH_3 cannot.

2. The predominant intermolecular attractive force in solid sodium is:

(A) covalent
(B) metallic
(C) ionic
(D) dipole-dipole
(E) induced dipole-induced dipole

Sodium is a metal. It also has induced dipole-induced dipole forces, but these are much smaller than the metallic forces.



3. Glycine (shown above) would be predicted to be most soluble in which solvent:

(A) CH_4 (B) CCl_4 (C) CCl_3H (D) H_2O (E) C_3H_8

Glycine is polar and can hydrogen bond (the N-H and O-H), so it would be most soluble in a polar, hydrogen bonding solvent, and the only one listed is water.

4. A solute is most likely to be highly soluble in a solvent if the solute is _____ and the solvent is _____.

	SOLUTE	SOLVENT
(A)	ionic or polar,	polar
(B)	ionic or polar,	non-polar
(C)	non-polar,	polar
(D)	non-polar,	ionic
(E)	oil,	water

Again, like dissolves like, so polar solute in polar solvent.

5. The heat of vaporization of water is 40.7 kJ/mol. It boils at 100 °C at 1 atm. At what temperature does water boil at the top of Mt. Everest, where the atmospheric pressure is 0.35 atm?

(A) 72°C (B) 94 °C (C) 98 °C (D) 100 °C (E) 106 °C

$$\ln\left(\frac{P_2}{P_1}\right) = \left(\frac{\Delta H^0_{vap}}{R}\right)\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$$

Use T_1=100+273=373 K, P_1=1 atm, P_2=0.35 atm, ΔH_{vap}=40.7 kJ/mol and R=8.314x10^{-3} kJ/(mol K)

$$\ln\left(\frac{0.35}{1.0}\right) = \left(\frac{40.7\ kJ/mol}{8.314x10^{-3}\ kJ/(mol\ K)}\right)\left[\frac{1}{373K} - \frac{1}{T_2}\right]$$

$$-1.0498 = (4895.4\ K)\left[0.00268097\frac{1}{K} - \frac{1}{T_2}\right]$$

$$-0.00021445\ \frac{1}{K} = \left[0.00268097\frac{1}{K} - \frac{1}{T_2}\right]$$

$$-0.0028954\ \frac{1}{K} = -\frac{1}{T_2}$$

$$T_2 = 345.4\ K = 72.4\ ^0C$$

Use the following information about acetone, CH_3COCH_3, for the next problem.

MW = 58.1 g/mole.
Normal Boiling point 56°C
Normal Melting poing -95°C
Heat of fusion = 5.7 kJ/mole.
Heat of vaporization = 32 kJ/mole.

6. Compute ΔH for the conversion of 73 grams of liquid acetone to gas, all at 56°C.

(A) 4.5 kJ (C) 7.2 kJ (E) 40 kJ
(B) 5.7 kJ (D) 32 kJ

73 grams * (1 mole/58.1 grams) = 1.256 moles acetone
liquid to gas, so use heat of vaporization:
ΔH = 32 kJ/mol * 1.256 moles = 40.2 kJ

7. The decomposition of N_2O_4 is a first-order reaction:

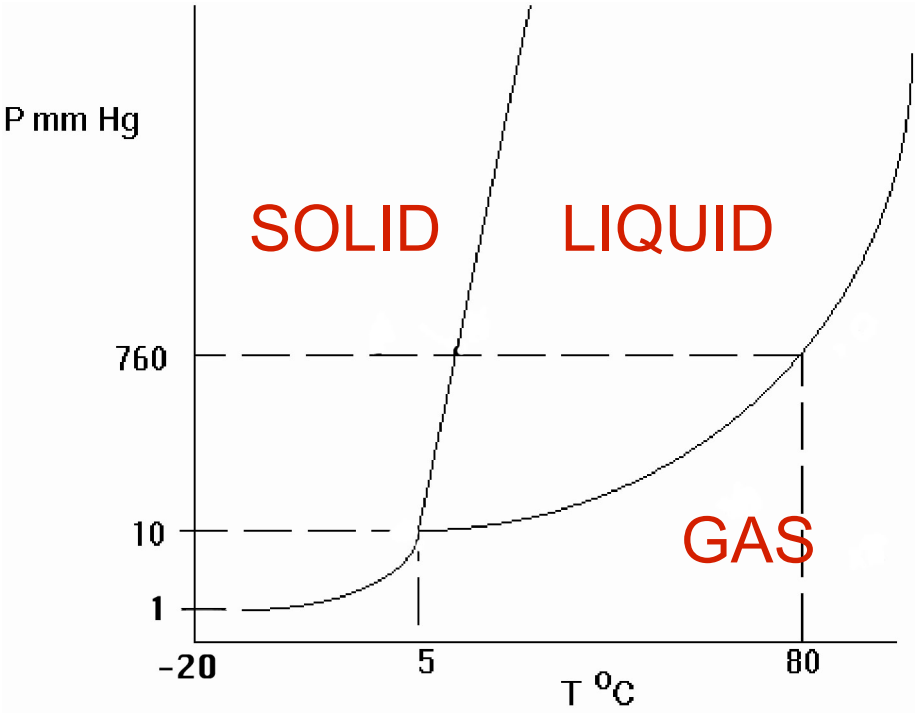
$N_2O_{4(g)} \rightarrow N_{2(g)} + 2\ O_{2(g)}$

The rate constant is 0.31 1/sec. What is the rate of the reaction at an initial concentration $[N_2O_4]$ of 1.2 x 10^{-3} mol/L ? The rate is in units of mol/(L sec).

(A) 4.5 x 10^{-7} (B) 3.7 x 10^{-4} (C) 2.1 x 10^{-5} (D) 3.9 x 10^{-3} (E) 1.2 x 10^{-3}

Rate = k[N_2O_4] = (0.31 1/sec) * (1.2 x 10^{-3} mol/L) = 3.72 x 10^{-4} mol/(L sec)

Use the following phase diagram for a substance to answer questions 8 and 9.



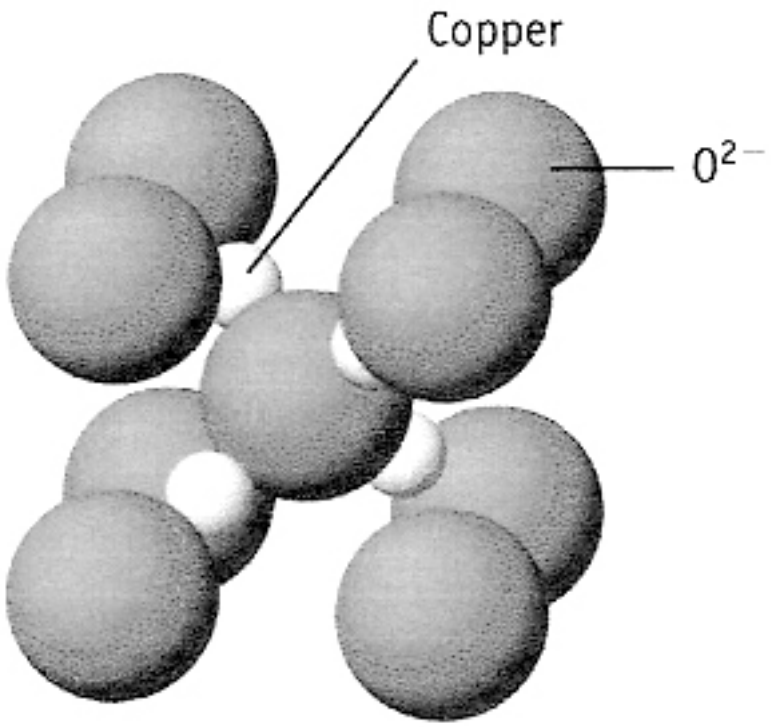
8. A sample of the substance is placed in a container at a temperature of 45°C and the pressure is fixed at 760 mm Hg. Under these conditions what phase(s) exist?

(A) solid only
(B) liquid only
(C) gas only
(D) liquid and gas
(E) solid and liquid

9. A sample of the substance is placed in a container at a temperature of 0°C and a pressure of 500 mm Hg. The pressure is then gradually lowered to 0.5 mm Hg, at constant temperature. What phase changes does the sample go through?

(A) liquid only
(B) liquid to gas only
(C) solid to gas only
(D) solid to liquid only
(E) solid to liquid to gas

Start at 0°C and 500 mm Hg, so it's a solid. Drop the pressure (at constant T), so draw a vertical line down on the phase diagram, end up in the gas region (at 0.5 mm Hg and 0°C), but the substance goes directly from solid to gas (it was never a liquid – it sublimes)



10. The unit cell of the mineral cuprite is shown above. The formula of cuprite is _____.
    (A) CuO
    (B) Cu_2O
    (C) CuO_2
    (D) Cu_2O_3
    (E) Cu_4O_9

Have 8 oxygens at the corners, each counts 1/8, for a total of 1
Have 1 oxygen at the center, which counts 1
Total oxygens in unit cell: 2
Have 4 coppers, they are inside the unit cell (each counts 1)
Total coppers in unit cell: 4
This is Cu_4O_2, reducing terms gives Cu_2O.

11. The unit cell described by the O^{2-} ions in cuprite is _____.
    (A) simple cubic
    (B) face centered cubic
    (C) body centered cubic
    (D) hexagonal close packing
    (E) tetrahedral

The oxygens are at the corners, and there is also one in the center.

12. The chemical formula for water is
    (A) NaCl
    (B) H_2O
    (C) NaOH
    (D) HCl
    (E) H_2SO_4

Worth 2 pts (the rest are 5 pts each), and determined the exam version.

13.

The initial rate of the reaction of nitrogen monoxide and oxygen

$$2\ NO(g) + O_2(g) \longrightarrow 2\ NO_2(g)$$

was measured at 25 °C for various initial concentrations of NO and O_2. Data are collected in the table. Determine the rate equation from these data.

Experiment	Initial Concentrations (mol/L) [NO]	[O_2]	Initial Rate (mol/L ·s)
1	0.020	0.010	0.028
2	0.020	0.020	0.057
3	0.020	0.040	0.114
4	0.040	0.020	0.227
5	0.010	0.020	0.014

(A) $R = k[NO][O_2]$ (D) $R = k[NO]^2$
(B) $R = k[NO][O_2]^2$ (E) $R = k[NO][O_2]^{-1}$
(C) $R = k[NO]^2[O_2]$

Expt 2 vs 1: [NO] unchanged; [O_2] doubles -> rate doubles, so first order in [O_2]
Expt 4 vs 2: [O_2] unchanged; [NO] doubles and-> rate quadruples, so second order in [NO]
$R = k[NO]^2[O_2]$

14. The reaction $2\ I^-(aq) + Br_2(aq) \rightarrow I_2(aq) + 2\ Br^-(aq)$
is first-order in [I^-] and second order in [Br_2].
If the rate of the reaction is 0.0126 Ms^{-1} when [I^-] = 0.08 M and [Br_2] = 0.04 M, what is the rate constant in $M^{-2}s^{-1}$?

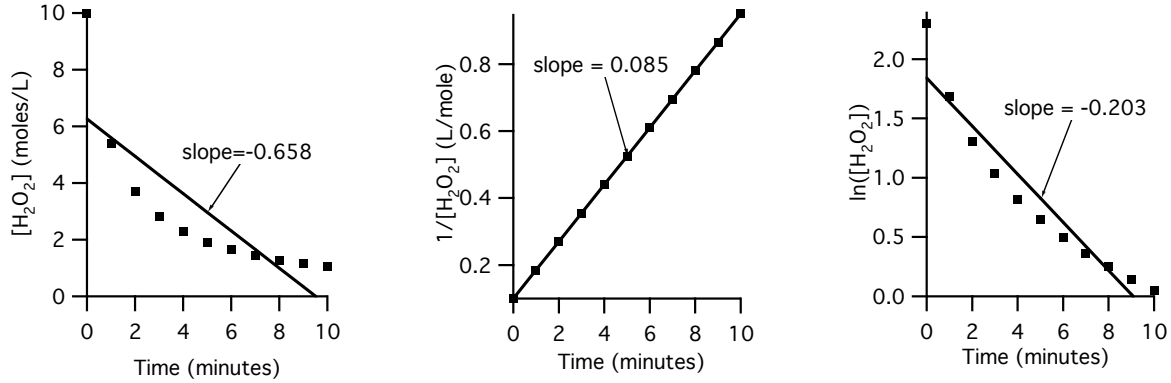
(A) 98 (B) 49 (C) 3.9 (D) 4.0×10^{-5} (E) 1.6×10^{-6}

Rate = $k\ [I^-][Br_2]^2$, so
$0.0126\ Ms^{-1} = k\ (0.08\ M)\ (0.04\ M)^2$
$0.0126\ Ms^{-1} = (1.28 \times 10^{-4}\ M^3)\ k$
$k = 98\ M^{-2}s^{-1}$

15. Iodine-131 is a radioactive isotope that is used to study the thyroid gland. It has a half life of 8.1 days. What is the first order rate constant for the decay of Iodine-131?

(A) 0.086 day^{-1} (D) 8.1 day^{-1}
(B) 0.123 day^{-1} (E) not enough information
(C) 11.7 day^{-1}

$t_{1/2} = 0.693/k$, so
$k = 0.693/(t_{1/2}) = 0.693/(8.1\ day) = 0.086\ day^{-1}$



16. In a study of the gas phase decomposition of hydrogen peroxide (H_2O_2), the concentration of H_2O_2 was followed as a function of time. The data (and best straight line fits) are shown above, plotted as (from left to right) $[H_2O_2]$ vs time, $1/[H_2O_2]$ vs time and $\ln([H_2O_2])$ vs time. Based on these plots, the reaction is _____ order in H_2O_2 and the rate constant for the reaction is _____.

(A) zero, 0.658 mol/(L min)
(B) first, 0.203 1/min
(C) first, 0.085 1/min
(D) second, 0.203 L/(mol min)
(E) second, 0.085 L/(mol min)

Only the plot of $1/[H_2O_2]$ vs time is a good fit to a line, so it's a second order reaction, and the rate constant k is the slope of the line.

17. The first-order rate constant for the radioactive decay of ^{14}C is 1.21×10^{-4} year^{-1}. An archaelogical sample is being dated and it is found to have 21% of the original concentration of ^{14}C. How old is the sample?

(A) 39,400 years
(B) 12,900 years
(C) 8,260 years
(D) 5,730 years
(E) 1,735 years

For a first order reaction, $\ln[R] = \ln[R]_0 - kt$, so
$\ln(0.21) = \ln(1.00) - (1.21 \times 10^{-4}\ \text{year}^{-1})\ t$
$-1.5606 = 0 - (1.21 \times 10^{-4}\ \text{year}^{-1})\ t$ and $t = 12898$ years

Name	*Formula*	*Boiling Point (°C)*
methane	CH_4	-164
ethane	C_2H_6	-89
propane	C_3H_8	-42
butane	C_4H_{10}	-0.5
pentane	C_5H_{12}	36

18. The boiling points of hydrocarbons C_nH_{2n+2} increases with n as shown in the table above. This is because:

(A) The smaller molecules have more hydrogen bonding.
(B) Pentane is a liquid at room temperature.
(C) Induced dipole effects increase with molecular weight.
(D) The larger molecules are more polar.
(E) both A and D above.

These molecules aren't polar, and no H-bonding. B is true, but doesn't explain why.

19. The oxidation of methanol on a platinum surface at 200 ^{o}C

$$2\ CH_3OH + 3\ O_2 \rightarrow 2\ CO_2 + 4\ H_2O$$

is zero order in CH_3OH with a rate constant of $1.30 \times 10^{-6}\ Ms^{-1}$.

If the initial concentration of CH_3OH is 0.0020 M, the concentration of CH_3OH will be 0.0005 M after _____ seconds have passed.

(A) 1.15×10^{9}
(B) 4.78×10^{6}
(C) 9.38×10^{5}
(D) 1330
(E) 1150

Zero order, so

$[R] = [R]_0 - kt$

$0.0005\ M = 0.0020\ M - (1.30 \times 10^{-6}\ Ms^{-1})\ t$

$-0.0015\ M = -(1.30 \times 10^{-6}\ Ms^{-1})\ t$

$t = 1154$ sec

20. The gas phase decomposition of nitrosyl chloride at 500 K

$$2\ NOCl \rightarrow 2\ NO + Cl_2$$

is second order in NOCl with a rate constant of $5.90 \times 10^{-2}\ M^{-1}s^{-1}$.

If the initial concentration of NOCl is 0.030 M, what is the concentration of NOCl after 500 seconds have passed?

(A) 4.6×10^{-15} M
(B) 6.4×10^{-14} M
(C) 0.0087 M
(D) 0.016 M
(E) 0.034 M

Second order, so

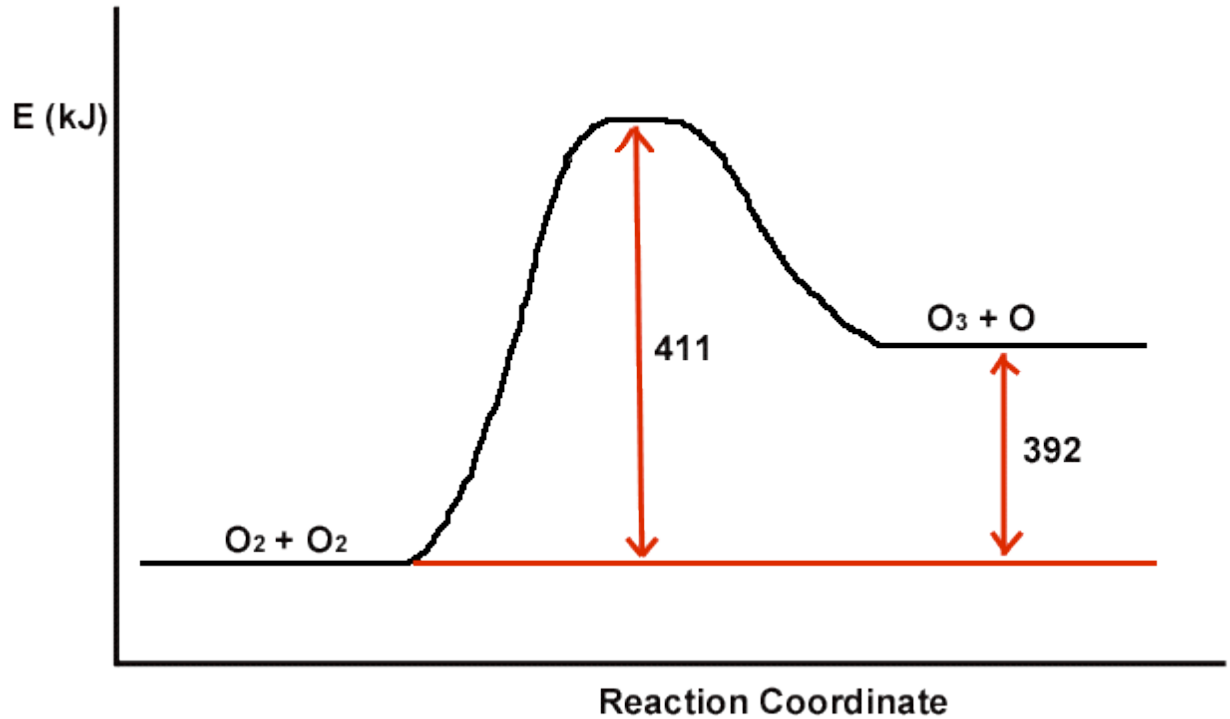
$1/[R] = 1/[R]_0 + kt$

$1/[R] = 1/(0.030\ M) + (5.90 \times 10^{-2}\ M^{-1}s^{-1})(500\ sec)$

$1/[R] = 33.33\ M^{-1} + 29.5\ M^{-1}$

$1/[R] = 62.83\ M^{-1}$

$[R] = 0.0159$ M



21. A reaction profile for the reaction 2 $O_2 \rightarrow O_3 + O$ is shown above. Which of the following is true (choose only one)
(A) This reaction is endothermic, the activation energy is 392 kJ, and ΔE is +411 kJ.
(B) This reaction is endothermic, the activation energy is 803 kJ, and ΔE is +392 kJ.
(C) This reaction is endothermic, the activation energy is 411 kJ, and ΔE is +392 kJ.
(D) This reaction is exothermic, the activation energy is 411 kJ, and ΔE is -392 kJ.
(E) This reaction is exothermic, the activation energy is 392 kJ, and ΔE is -411 kJ.

22. Extra credit (5 pts.)
The normal boiling point of methanol is 338 K.
What is the vapor pressure of methanol at 350 K?
Assume that the enthalpy of vaporization is 36.6 kJ/mol.
(A) 1854 mm Hg (D) 760 mm Hg
(B) 1188 mm Hg (E) 486 mm Hg
(C) 952 mm Hg

$$\ln\left(\frac{P_2}{P_1}\right) = \left(\frac{\Delta H^0_{vap}}{R}\right)\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$$

Use T_1=338 K, P_1=1 atm, T_2=350 K, ΔH_{vap}=36.6 kJ/mol and R=8.314x10^{-3} kJ/(mol K)

$$\ln\left(\frac{P_2}{1.0\ atm}\right) = \left(\frac{36.6\ kJ/mol}{8.314x10^{-3}\ kJ/(mol\ K)}\right)\left[\frac{1}{338K} - \frac{1}{350K}\right]$$

$$\ln\left(\frac{P_2}{1\ atm}\right) = (4402.2\ K)\left[0.00295858\frac{1}{K} - 0.00285714\frac{1}{K}\right]$$

$$\ln\left(\frac{P_2}{1\ atm}\right) = (4402.2\ K)\left[0.00010144\frac{1}{K}\right]$$

$$\ln\left(\frac{P_2}{1\ atm}\right) = 0.44655$$

$$\frac{P_2}{1\ atm} = e^{0.44655}$$

$$P_2 = 1.563\ atm\left(\frac{760\ mm\ Hg}{1\ atm}\right) = 1188\ mm\ Hg$$