Chemistry 1A, Fall 2010

Midterm Exam #1
September 15, 2010
(90 min, closed book)

Name:_____**KEY**_____

SID:_____

GSI Name:_____

- The test consists of 5 short answer questions and 18 multiple choice questions.
- Put your written answers in the boxes provided. Answers outside the boxes may not be considered in grading.
- Write your name on every page of the exam.

Question	Page	Points	Score
Multiple Choice (1-18)	2-6	54	
Anesthetics Short Answer	4	7	
Mohs Short Answer	6	4	
Nail Polish Short Answer	6	10	
Total		75	

Useful Equations and Constants:

$PV = nRT$

$$\left(P + a\frac{n^2}{V^2} \right)(V - nb) = nRT$$
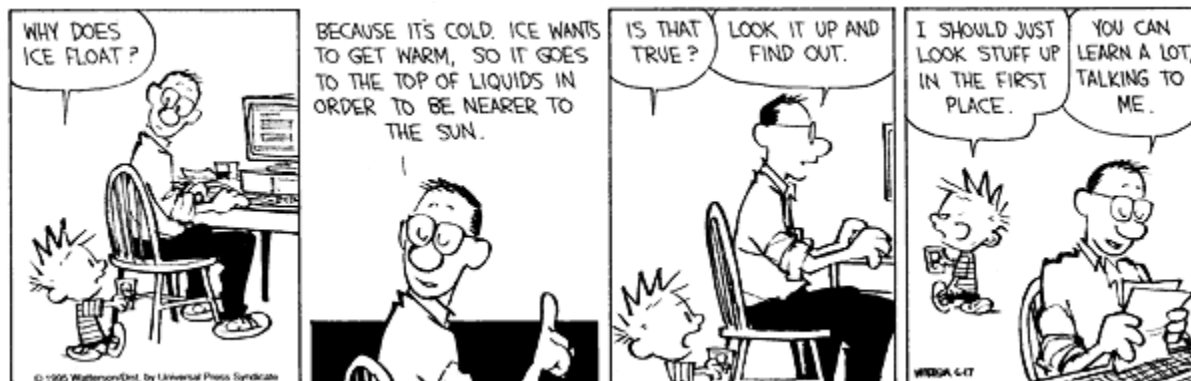
$$KE = \frac{1}{2}mv^2$$

$P_{total} = P_A + P_B = X_A P_{total} + X_B P_{total}$

$N_0 = 6.02214 \times 10^{23}$ mol^{-1}

T (K) = T (°C) + 273.15

$R = 0.0821$ L atm K^{-1} mol^{-1}

1 atm = 760 mm Hg = 760 torr $\approx$ 1 bar

Airbags Experiment

In the airbag lab, you were challenged to generate the largest gas volume in a plastic bag by reacting baking soda, $NaHCO_3$, with acetic acid, CH_3COOH.

$$NaHCO_3 \text{ (s)} + CH_3COOH \text{ (aq)} \rightarrow CH_3COONa \text{ (aq)} + H_2O \text{ (l)} + CO_2 \text{ (g)}$$

A pair of students performed the following trials in building their airbags.

Trial	Moles of sodium bicarbonate, $NaHCO_3$	Moles of acetic acid, CH_3COOH	Moles of carbon dioxide, CO_2
A	0.012 mol	0.017 moles	
B	0.018 mol	0.017 moles	
C	0.018 mol	0.025 moles	
D	0.012 mol	0.025 moles	

1. Which of the trials shown in the table produced the optimal "GREEN" airbag (minimal unreacted starting material)?
         A (3)   B (4)   C   D

2. CO_2 (g) produced in the reaction of baking soda and acetic acid is collected in a 100 mL metal container. What amount of CO_2 (g) will fill the container to 5 atm at 300 K?
   A)   0.020 moles (2)
   B)   100 mL
   C)   0.020 grams
   D)   20 moles

3. A sample of CO_2 is sealed in a metal container at 300 K. The pressure inside the container is 6 atm. What is an estimate of the pressure inside the container if you cool the gas to 100 K? At this temperature, CO_2 is a solid.
   A)   2.0 atm (2)   B)   1.8 atm   C)   1.0 atm (3)   D)   0.01 atm (4)

4. Helium, He, and carbon dioxide, CO_2, gases are confined in identical containers. The graph of P vs T for the gases is shown. Why is the slope for the He larger than that for CO_2?
   A)   The volume of He atoms is smaller.
   B)   The temperature of He is larger.
   C)   The volume of the container with the CO_2 sample is smaller.
   D)   There are fewer number of moles of CO_2. (4)

5. Compare two samples of a gas.
   Sample A: A plastic baggie filled with 0.060 moles of N_2 at 400 K.
   Sample B: A sealed container at 6 atm with 0.020 moles of CO_2 at 300 K.
   How do the average speeds of the gas molecules in Samples A and B compare?
   A)   The average speed in Sample A is higher because the temperature is higher. (3)
   B)   The average speed in Sample B is higher because the pressure is higher.
   C)   The average speed in Sample A is higher because the number of moles of gas is greater.
   D)   The average speed in Sample B is higher because the mass of the gas is higher.
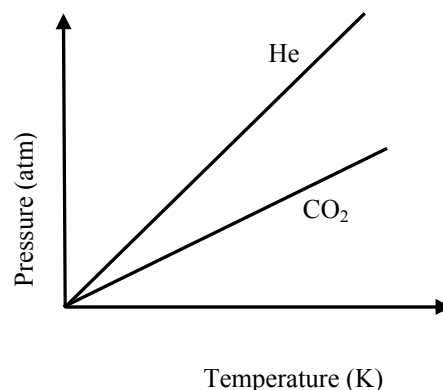
General Anesthesia

The molecules below all function as anesthetics to producing a state of unconsciousness that allows humans to tolerate surgery. It is difficult to imagine surgery without these compounds.

Name	Formula	Structure	Molar mass	Boiling point
xenon	Xe	Xe	131 g/mol	-108°C
nitrous oxide	N_2O	---------	44 g/mol	-88.5°C
chloroform	$CHCl_3$		119 g/mol	61°C
halothane	$CF_3CHBrCl$		197 g/mol	50°C
dimethyl ether	CH_3OCH_3		46 g/mol	-23.6°C
diethyl ether	$CH_3CH_2OCH_2CH_3$		74 g/mol	34.6°C
isoflurane	$CF_3CHClOCHF_2$		185 g/mol	48.5°C

6. How many molecules with distinct properties have the overall chemical formula $CHCl_3$?
   A)   1 (2)   B)   2   C)   3   D)   4 or more

7. Are the C-O-C atoms in dimethyl ether, CH_3OCH_3, arranged in a straight line?
   A)   Yes, because there are two carbon atoms connected to oxygen
   B)   Yes, because the molecule is symmetrical
   C)   Yes, because the molecule satisfies the HONC1234 rule.
   D)   No, because the electronic shape around oxygen is tetrahedral. (3)

8. Which compound would you expect to have the largest value of "a" in the van der Waals' equation?
   A) $CHCl_3$ (4)
   B) $CF_3CHBrCl$ (3)
   C) CH_3OCH_3
   D) N_2O

9. "Smelling salts" are volatile chemical compounds containing nitrogen for reviving a person who is unconscious. Which of the compounds listed below can you buy from a chemical company to make a "smelling salt"?
   A) CH_4N B) CH_5N (3)   C) CH_6N D) CH_7N

10. Why does xenon, Xe, have the lowest boiling point?
    A)   Because there are large London forces between Xe atoms
    B)   Because it has a large mass
    C)   Because it is spherical and small (3)
    D)   Because it has the largest number of electrons

11. Dimethyl ether is soluble in water, but isoflurane is not. Explain why.
    A)   Isoflurane molecules bond to each other with strong hydrogen bonds.
    B)   The dipole moment of isoflurane is pointing away from the lone pairs. (4)
    C)   Isoflurane molecules have a smaller C-O-C bond angle.
    D)   Isoflurane molecules have a larger dipole moment.

12. Three resonance structures are shown for nitrous oxide, N_2O. Which structure is the least likely to contribute to the overall structure?
    A) $:N≡N—\ddot{O}:$ B) $:\ddot{N}=N=\ddot{O}:$ C) $:\ddot{N}—N≡O:$ (2)

    Explain your reasoning

    > **Formal charge is a model that tracks the electron distribution when atoms form molecules. Formal charges different from zero indicate a the level of rearrangement of electrons. Structure C has the highest formal charge (-2, +1, +1). The negative formal charge should be on the most electronegative element, oxygen, not on nitrogen. (4 points)**

13. Isoflurane is one of the most potent general anesthetics. If you inhale this compound, you will be unconscious almost immediately. However, isoflurane is not soluble in blood. Low solubility in blood indicates that the molecule is not very polar. This is important as it allows isoflurane to cross the blood brain barrier to act in the brain. Given this information, do you think a single isoflurane molecule has a large effect or a small effect. Explain your thinking.
    A)   Small effect (2)   B)   Large effect (2)
    Explain your reasoning

    > **If a small amount of anesthetic dissolves in the blood, then that same small amount will get into the brain. So a few molecules must have a large effect on the body if you become unconscious after inhalation. (3 points)**
    >
    > **We also accepted that one molecule would not make much of a difference to something as large as the brain which is composed of so many more molecules.**

Hardness of solids

The Mohs hardness scale is used to rank solids from 1 (very soft) to 10 (very hard). Use the data in the table to answer the questions below.

Substance	Formula	Hardness
Diamond	C	10
Aluminum oxide	Al_2O_3	9
Steel	Fe/C	7
Silicon	Si	6.5
Germanium	Ge	6
Iron	Fe	4
Arsenic	As	3.5
Copper	Cu	3
Gold	Au	2.5
Sodium oxide	Na_2O	2.5
Sulfur	S	2
Selenium	Se	2
Ice	H_2O	1.5
Lithium	Li	0.5
Wax	$C_{20}H_{42}$	0.2

14. Estimate the hardness of the high density polyethylene, $[CH_2]_n$, used in plastic water bottles.
    A)   0.5 (2)   B)   2 (2)   C)   5   D)   8

15. Estimate the hardness of the magnesium oxide, MgO.
    A)   0.5   B)   2 (1)   C)   6 (2)   D)   10

16. Which explanation best accounts for the observation that ice, H_2O, is harder than wax, $C_{20}H_{42}$?
    A)   Ice is less dense than wax.
    B)   The water molecules are more strongly attracted to one another. (3)
    C)   The molar mass of water is smaller than the molar mass of wax.
    D)   The molecules in wax are linear whereas the water molecules are bent.

17. Titanium nitride, TiN, looks like gold, Au. How can you test if a piece of metal that you want to use for jewelry is real gold or not?
    A)   Find a substance with a hardness of 6. This will scratch the Au, but not TiN. (3)
    B)   Find a substance with a hardness of 1. This will scratch the Au, but not TiN.
    C)   Find a substance with a hardness of 9. This will scratch the TiN, but not Au.
   D)   Find a substance with a hardness of 9. This will scratch both TiN and Au.

18. Which statement below explains why silicon, Si, is softer than diamond, C.
    A)   Si is less dense than C, so it is softer. (3)
    B)   The effective nuclear charge is larger for Si, so the bonds are stronger.
    C)   The effective nuclear charges are the same, but the bonds for Si are longer and weaker. (4)
    D)   The effective nuclear charge for Si is smaller, and the bonds are longer and weaker.

19. Explain why arsenic, As, is softer than germanium, Ge. Be specific about differences in structure.

As atoms in the solid can only bond to three other atoms because of the lone pair. The As solid could at best form sheets of molecules. Ge atoms can bond to four other atoms. The greater number of attachments will lead to a stronger overall structure in the solid because the whole thing is linked in 3 dimensions.

(4 points)
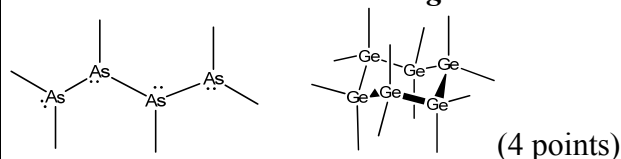
Nail polish remover and a poisonous gas

20. Acetone, $(CH_3)_2CO$, is a sweet-smelling liquid found in nail polish remover. Phosgene, Cl_2CO, is a gas that has a faint odor of cut grass; it is a deadly poison that causes suffocation.

    a) Draw Lewis structures to show how the molecules are similar. Be specific about the shape and any formal charges

Acetone, $(CH_3)_2CO$	Phosgene, Cl_2CO
(3)	(3)
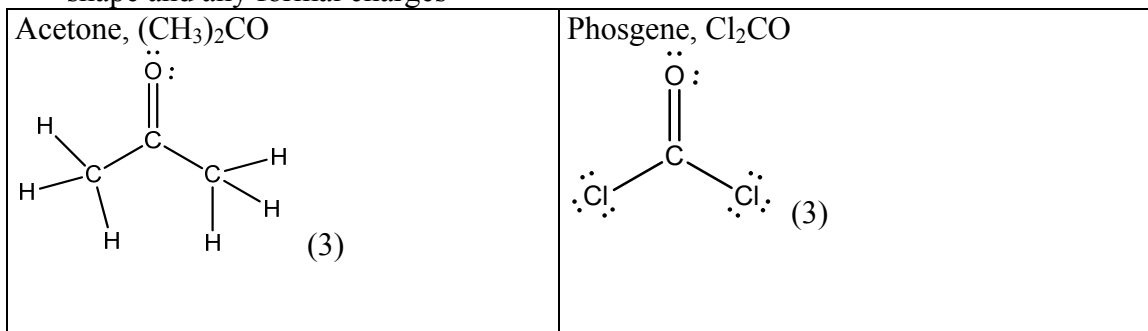
    b) Explain why acetone, $(CH_3)_2CO$, is a liquid at room temperature, but phosgene, Cl_2CO, is a gas. Does this make sense based on mass?

Whether a molecule is a liquid or gas at room temperature depends on the strength of the intermolecular forces. By mass, it would seem that phosgene would have stronger London forces and boil higher than acetone, but it does not. Both molecules are polar, with a dipole across the C=O bond. In phosgene, the overall dipole moment of the molecule is weakened. The electronegative Cl atoms also cause a dipole across the C-Cl bond. (4 points)