Chemistry 1A, Fall 2002

Midterm Exam III, Version A
November 12, 2002

(90 min, closed book)

Name:_______________________________ **TA:**___________

SID:_________________________________ **Section:**

Please read this first: Write your name and that of your TA on all 9 pages; On the **Scantron™**, bubble in Form A.

Test-taking Strategy

This test consists of two parts: multiple choice (**answers to be circled and entered on the Scantron™ sheet**) and short answer. In order to maximize your score on the exam:

- Do the questions you know how to do first.
- Then, go back and spend more time on the questions you find more challenging.
- Budget your time carefully -- don't spend too much time on one problem.
- Show all work for which you want credit and don't forget to include units.

Page	**Score**
MC	
7	
8	
9	
Total	

Potentially Useful Information

$PV = nRT$

$$E_{kin} = \frac{3}{2}RT$$

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$\Delta E = q + w$

$w = - P_{ext}\Delta V$

$$\Delta E = \frac{3}{2}nR\Delta T$$

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta H° = \Sigma\ \Delta H°_f$ (products) - $\Sigma\ \Delta H°_f$ (reactants)

R = 8.314 J / (K·mol)
$N_A = 6.022 \times 10^{23}$
1 cal = 4.18 J
101.3 J = 1 L·atm
R = 0.08206 (atm·L) / (mol·K)
= 8.314 J/(mol·K)
$k_B = 1.381 \times 10^{-23}$ J / K
$h = 6.626 \times 10^{-34}$ J s
$c = 3.0 \times 10^{8}$ $m \cdot s^{-1}$
1 nm = 10^{-9} m
1 kJ = 1000 J
1 Torr = 1 mmHg
1 atm = 760 mmHg
J = $(kg \cdot m^2)/s^2$

PbS (s) + $^3/_2$ O_2 (g) $\rightarrow$ PbO (s) + SO_2 (g)	ΔH = - 413.7 kJ
P_4 (s) + 6 Cl_2 (g) $\rightarrow$ 4 PCl_3 (l)	ΔH = + 106.8 kJ
P_4 (s) + 5O2 $\rightarrow$ P_4O_{10} (s)	ΔH = -2984.0 kJ
PbO (s) + C (s) $\rightarrow$ Pb (s) + CO (g)	ΔH = + 106.8 kJ
P_4 (s) $\rightarrow$ 4 P (g)	ΔH = +1258.6 kJ
P_4 (s) + 6 Cl_2 (g) $\rightarrow$ 4 PCl_3 (g)	ΔH= -1148.0 kJ

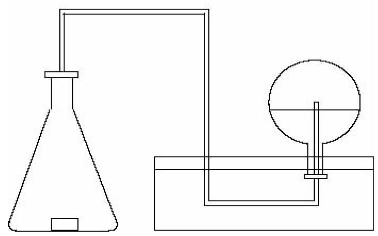
Compound	DH_f^o **(kJ/mol)**
HCl	-92.31
HBr	-36.40
HI	+26.48
H_2O (g)	-241.82
H_2O (l)	-285.83
Br_2 (g)	+30.91
I_2 (g)	+62.44
CO_2	-393.51
methane	-74.81
ethane	-84.68
propane	-103.85
butane	-126.15
pentane	-146.44

Bond Energies, kJ/mol	
H-H	436
C-Cl	338
Cl-Cl	242
C-H	412
H-Cl	431
C-C	348
C-O	360
O-H	463
O=O	498
C=O	743
C=C	612

Part I Multiple Choice (4 pts each, 80 pts total) Bubble in the correct answer on your Scantron™ form AND circle your answer on the exam. There is only one correct answer for each question, so you should circle and fill in one and only one answer for each question. There is no penalty for an incorrect response.

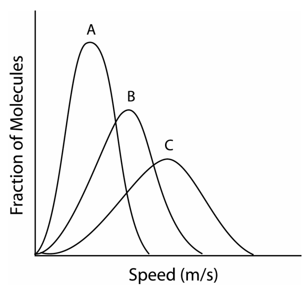
1.) The reaction of magnesium with hydrochloric acid shown is carried out in an Erlenmeyer flask using the apparatus shown. The products are collected in the inverted round bottom flask as they bubble through water in the collection tray. If 456 ml of gas is collected at 742 mmHg and 22.0°C, what is the total number of moles of H_2 produced? (The vapor pressure of water at 22.0°C is 19.8 torr)

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2\ (aq) + H_2\ (aq)$$



A) 0.0184 B) 0.0179 C) 0.0034 D) 0.148 E) 0.040

Consider a flask containing a mixture of neon, argon, krypton, and xenon gases at 300 K and the plot shown below for the next two questions.



2.) In the diagram, if B is the initial Maxwell-Boltzmann distribution for argon, which curve is a possible distribution for argon after an increase in temperature?

A) A B) B C) C D) not shown E) can't tell

3.) In the diagram, if B is the initial Maxwell-Boltzmann distribution for argon, which curve is a possible distribution for xenon?

A) A B) B C) C D) not shown E) can't tell

4.) Which of the following is *not* an assumption of the kinetic model of an ideal gases?

A) The particles are considered point masses.
B) The particles don't influence each other except during collisions.
C) The gas consists of particles in continuous random motions.
D) Reactions between particles result in increased speed.
E) The particles move in a straight line until they collide.

5.) Which is the highest temperature where the mean speed of Br_2 gas is smaller than that of your professor running at a speed of 5 m/s?

A) 50 K B) 10 K C) 5.0 K D) 1.0 K $\boxed{\text{E) 0.1 K}}$

6.) Which of the following is the strongest force of attraction between two helium atoms?

A) Ion-dipole
B) Dipole-dipole
$\boxed{\text{C) London forces}}$
D) Hydrogen bonding
E) Ion-ion

7.) Which of the following pure liquids will most likely form intermolecular hydrogen bonds in the condensed phase?

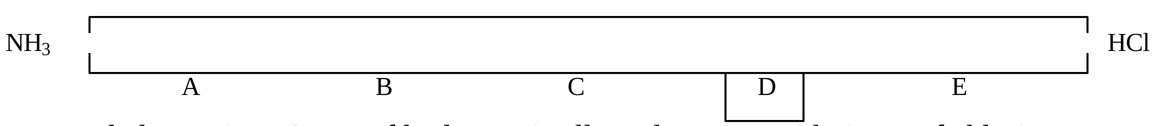
A) $CH_2OCH_2CH_3$
B) CH_3OCH_3
$\boxed{\text{C) } CH_3CH_2OH}$
D) C_6H_6
E) $CH_3CH_2CH_3$

8.) A piston moves against a pressure of 1.0 atm in order to change the volume it encloses from 2.0 L to 4.0 L. Assuming that the temperature is 25 ^{o}C, how much work is done on or by the system?

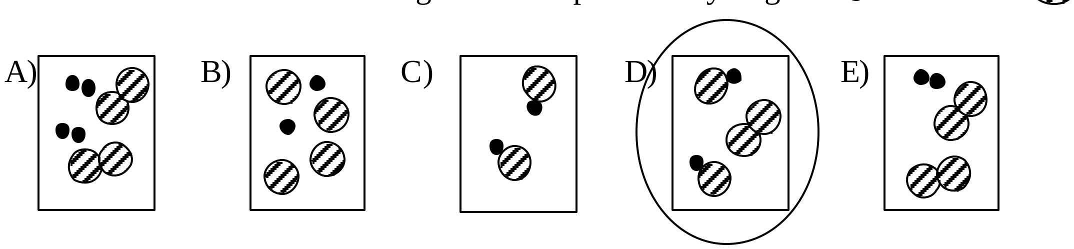
A) 2.0 J B) 200 J C) –20 J $\boxed{\text{D) -200 J}}$ E) 2.0 kJ

9.) NH_3(g) and HCl(g) are allowed to diffuse from opposite ends of a tube toward each other until they meet. At which point does solid NH_4Cl form?

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$



10.) In a sealed container, 2 atm of hydrogen is allowed to react with 4 atm of chlorine to form HCl. Which diagram below best represents a microscopic view of the molecules after the reaction has gone to completion? Hydrogen = ● Chlorine =



11.) Heat is given off when hydrogen burns in air according to the equation

$$2\,H_2 \;+\; O_2 \;\rightarrow\; 2\,H_2O$$

Which of the following is responsible for the heat?

A) breaking H-H and O-O bonds
B) breaking O-H bonds
C) forming H-H and O-O bonds
$\boxed{\text{D) forming O-H bonds}}$
E) boiling of the water

12.) What is the enthalpy of the reaction between lead sulfide (PbS) and carbon?

$$PbS(s) + C(s) + {}^{3}/_{2}O_2 \rightarrow Pb(s) + CO(g) + SO_2$$

A) –520.5 kJ B) +520.5 kJ C) +306.9 kJ $\boxed{\text{D) –306.9 kJ}}$ E) +201.1 kJ

There was an error on version D of the exam. Everyone gets full credit for #12.

13.) Given that $\Delta S°=87.3$ J/(mol•K) and $\Delta H°=30.8$ kJ/mol for benzene(g)→benzene(l), what is the boiling point of benzene in °C?

A) 60
B) 70
$\boxed{\text{C) 80}}$
D) 90
E) 100

Use these options for the following two questions:

I. $w>0$ II. $\Delta T>0$ III. $\Delta S>0$ IV. $\Delta E>0$ V. $q>0$

14.) Which is true for isothermal expansion of an ideal gas against constant non-zero pressure?

A) I and III $\boxed{\text{B) III and V}}$ C) III and IV D) II and IV E) I and V

15.) Which is true for adiabatic expansion of an ideal gas against constant non-zero pressure?

A) I B) II $\boxed{\text{C) III}}$ D) IV E) V

16.) The equilibrium constant for the reaction shown is 6.8×10^8 at 298 K. What is the equilibrium partial pressure (in atm) of NH_3 at 298 K when the partial pressure of N_2 is 0.01 atm and H_2 is 0.02 atm?

$$N_{2(g)} + 3\,H_{2(g)} \qquad 2\,NH_{3(g)}$$

A) 136
B) 1.3
C) 0.23
$\boxed{\text{D) 7.38}}$
E) 0.05

17.) Under which conditions is a reaction spontaneous if it is endothermic and the entropy change is negative?

A) All T
$\boxed{\text{B) No T}}$
C) High T, not low T
D) Low T, not high T
E) Spontaneous only at 0°C

18.) For which of the following processes does the entropy of the system increase?

$\boxed{\text{A) Heating a gas at constant pressure}}$
B) Condensing water vapor
C) Compressing a gas
D) Freezing a liquid
E) The entropy increases for all of these

19.) At the triple point of water, which of the following has the greatest entropy

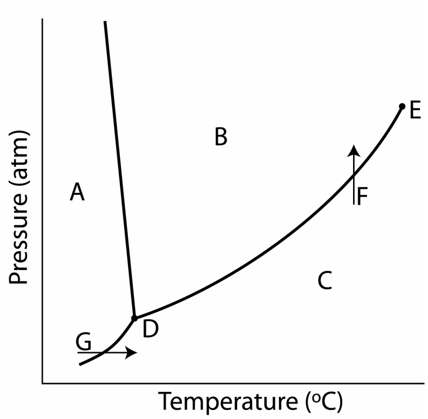
A) 1 mol water vapor
$\boxed{\text{B) 2 mol water vapor}}$
C) 1 mol liquid water
D) 2 mol liquid water
E) 2 mol ice

20.) Which of the following explains why the bond enthalpy of CO (carbon monoxide) is 1074 kJ/mol and the bond enthalpy of each carbon-oxygen bond in CO_2 (carbon dioxide) is 743 kJ/mol?

A) Random differences between different molecules
B) Carbon dioxide is bigger so the bonds are weaker
$\boxed{\text{C) Carbon monoxide has a higher bond order}}$
D) There are two oxygen atoms on CO_2
E) Carbon dioxide has no dipole moment

Part 2: Short Answer Problems (70 pts total)
Instructions: Enter answers in the boxes where provided. Show all work for which you wish to receive credit. Where explanations are required, only the first fifteen words will be considered for your grade.

1.) (15 points total) Use the phase diagram shown to answer the following questions.



a) Label the features of the phase diagram with the following labels (not all labels will be used): solid phase, liquid phase, gas phase, sublimation, freezing, melting, vaporizing, triple point, boiling point, critical temperature, critical point, vaporization point, condensation, and crystallization. (1 point each)

A._____ solid phase __________ E.____ critical point ___

B.______ liquid phase ________ F._____ condensation _

C._____ gas phase ________ G.____ sublimation ___

D._____ triple point ____

b) The phase diagram above most likely represents which of the following molecules? (Circle your answer) (4 points)

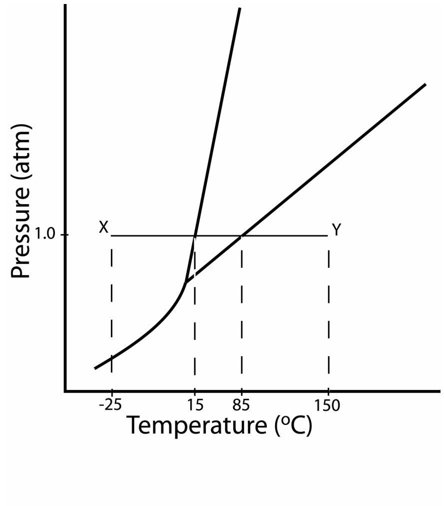
CCl_4 CH_4 H_2O CO_2 CH_3CN

c) What feature of the phase diagram most influenced your choice in part b? (4 points)

-negative slope of the melting curve

2.) (27 points total) Calculate the number of kilojoules of heat that are absorbed by the system (5.0 g, 0.25 mol) in moving from point X to point Y on the phase diagram shown.

Thermochemical Data	
ΔH_{fusion}	9.92 kJ/mol
$\Delta H_{vaporization}$	31.2 kJ/mol



Specific Heats	
Gas	2.10 J/g•°C
Liquid	4.18 J/g•°C
Solid	5.63 J/g•°C

T (-25°C to 15°C, warming the solid) (5 points)

$q = m\,C\,\Delta T$

$= (5.0\text{ g})(5.63\text{ J/g}\bullet{}^{o}\text{C})(15 - {}^{-}25\,{}^{o}\text{C})$

= 1126 J or 1.126 kJ

T (solid to liquid at 15 °C, melting) (5 points)

enthalpy for a phase change = $\Delta H \times$moles

= 9.92 kJ/mol $\times$ 0.25 moles

= 2.48 kJ

T (15°C to 85°C, warming the liquid) (5 points)

$q = m\,C\,\Delta T$

$= (5.0\text{ g})(4.18\text{ J/g}\bullet{}^{o}\text{C})(85\text{-}15\,{}^{o}\text{C})$

= 1463 J or 1.463 kJ

T (liquid to gas at 85°C, vaporization) (5 points)

enthalpy for a phase change = $\Delta H \times$moles

= 31.2 kJ/mol $\times$ 0.25 moles

= 7.8 kJ

T (85°C to 150°C, heating the gas) (5 points)

$q = m\,C\,\Delta T$

$= (5.0\text{ g})(2.10\text{ J/g}\bullet{}^{o}\text{C})(150\text{-}85\,{}^{o}\text{C})$

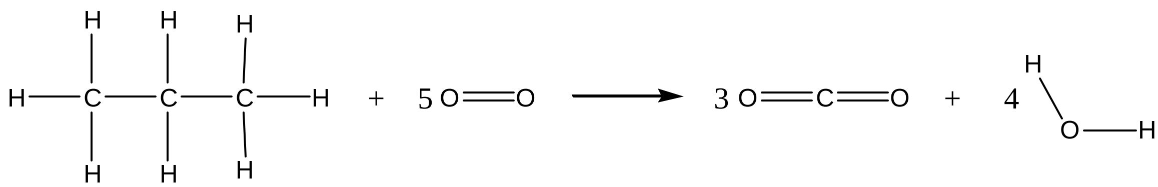
= 682.5 J or 0.6825 kJ

Total energy used = 13.55 kJ (2 points)

3) (28 points total) Use the reaction for the combustion of propane to answer the following questions.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

a) Calculate the enthalpy of the reaction in kilojoules using bond energies. (14 points)



<u>Bonds broken:</u>
(1 × 8 moles)(C-H) + (1 × 2 moles)(C-C) + (5 × 1 moles)(O=O)
= (8 mol × 412 kJ/mol) + (2 mol × 348 kJmol) + (5 × 498 kJ/mol)
= 6482 kJ

<u>Bonds formed:</u>
(3 × 2 moles)(C=O) + (4 × 2 moles)(O-H)
= (6 mol × 743 kJ/mol) + (8 mol × 463 kJ/mol)
= 8162 kJ

$\boxed{\text{Total enthalpy = broken – formed = 6456 – 8530 kJ = -1680 kJ}}$

b) Calculate the enthalpy of the reaction in kilojoules using the relevant heats of formation. (10 points)

$\Sigma\ \Delta H°_f$ (products) = (3 mol)($\Delta H°_{CO2}$) + (4 mol)($\Delta H°_{H2O}$)
= (3 mol)(-393.51 kJ/mol) + (4 mol)(-241.82 kJ/mol)
= -2147.81 kJ

$\Sigma\ \Delta H°_f$ (reactants) = (1 mol)($\Delta H°_{propane}$) + (5 mol)($\Delta H°_{O2}$)
= (1 mol)(-103.85 kJ/mol) + (5 mol)(0 kJ/mol)
= -103.85

$\Delta H° = \Sigma\ \Delta H°_f$ (products) - $\Sigma\ \Delta H°_f$ (reactants)
= -2147.81 kJ - -103.85
$\boxed{\text{=-2043.96 kJ}}$

c) Comment on the differences in the values from parts a and b. Why do you think that this difference exists? (4 points)

bond enthalpies are average values so depending on the reaction, they might not be the most accurate predictor of enthalpy