



AP[®] Chemistry 2005 Sample Student Responses Form B

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1A,

CHEMISTRY

Section II

(Total time—90 minutes)

Part A

Time—40 minutes

YOU MAY USE YOUR CALCULATOR FOR PART A.

CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

Be sure to write all your answers to the questions on the lined pages following each question in this booklet. Do NOT write your answers on the lavender insert.

Answer Question 1 below. The Section II score weighting for this question is 20 percent.

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{OCl}^-]}{[\text{HOCl}]} = 3.2 \times 10^{-8}$$

1. Hypochlorous acid, HOCl, is a weak acid in water. The K_a expression for HOCl is shown above.
 - (a) Write a chemical equation showing how HOCl behaves as an acid in water.
 - (b) Calculate the pH of a 0.175 M solution of HOCl.
 - (c) Write the net ionic equation for the reaction between the weak acid HOCl(aq) and the strong base NaOH(aq).
 - (d) In an experiment, 20.00 mL of 0.175 M HOCl(aq) is placed in a flask and titrated with 6.55 mL of 0.435 M NaOH(aq).
 - (i) Calculate the number of moles of NaOH(aq) added.
 - (ii) Calculate $[\text{H}_3\text{O}^+]$ in the flask after the NaOH(aq) has been added.
 - (iii) Calculate $[\text{OH}^-]$ in the flask after the NaOH(aq) has been added.



initial 0.175 M 0 0

Δ -x +x +x

final 0.175-x x x

$$3.2 \times 10^{-8} = \frac{[\text{H}^+][\text{OCl}^-]}{[\text{HOCl}]} = \frac{x \cdot x}{0.175 - x}$$

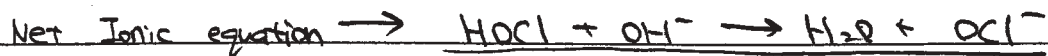
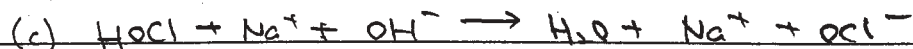
$$x = 7.5 \times 10^{-5} = [\text{H}^+]$$

$$\text{pH} = -\log [\text{H}^+] = \underline{\underline{4.12}}$$

GO ON TO THE NEXT PAGE.

1A₂

ADDITIONAL PAGE FOR ANSWERING QUESTION 1.



(d) (i) $0.435 \text{ M} \times 6.55 \text{ mL}$

$= \frac{0.435 \text{ mol}}{1 \text{ L}} \times 0.00655 \text{ L} = 0.00285 \text{ mol}$



$3.5 \text{ mmol} \quad 2.85 \text{ mmol}$

$-2.85 \quad -2.85 \quad +2.85$

$0.65 \text{ mmol} \quad 0 \quad 2.85 \text{ mmol}$

$[\text{HOCl}] = \frac{0.65 \text{ mmol}}{20 + 6.55 \text{ mL}} = 0.0245 \text{ M}$

$[\text{OCl}^-] = \frac{2.85 \text{ mmol}}{20 + 6.55 \text{ mL}} = 0.107 \text{ M}$



$0.0245 \quad 0.107$

$-x \quad +x \quad +x$

$0.0245 - x \quad x \quad 0.107 + x$

$K_a = 3.2 \times 10^{-8} = \frac{x(0.107 + x)}{0.0245 - x}$

$x = 7.33 \times 10^{-9}$

$[\text{H}_3\text{O}^+] = x = 7.33 \times 10^{-9} \text{ M}$

(iii) $[\text{OH}^-][\text{H}_3\text{O}^+] = 1 \times 10^{-14} \text{ M}$

$[\text{OH}^-] = \frac{1.36 \times 10^{-4}}{1} \text{ M}$

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1B,

CHEMISTRY

Section II

(Total time—90 minutes)

Part A

Time—40 minutes

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CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

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$$K_a = \frac{[\text{H}_3\text{O}^+][\text{OCl}^-]}{[\text{HOCl}]} = 3.2 \times 10^{-8} \quad 0.5$$

1. Hypochlorous acid, HOCl, is a weak acid in water. The K_a expression for HOCl is shown above.

(a) Write a chemical equation showing how HOCl behaves as an acid in water.

(b) Calculate the pH of a 0.175 M solution of HOCl.

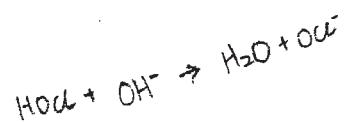
(c) Write the net ionic equation for the reaction between the weak acid HOCl(aq) and the strong base NaOH(aq).

(d) In an experiment, 20.00 mL of 0.175 M HOCl(aq) is placed in a flask and titrated with 6.55 mL of 0.435 M NaOH(aq).

(i) Calculate the number of moles of NaOH(aq) added.

(ii) Calculate $[\text{H}_3\text{O}^+]$ in the flask after the NaOH(aq) has been added.

(iii) Calculate $[\text{OH}^-]$ in the flask after the NaOH(aq) has been added.



0026.55



As the reaction produce H_3O^+ , HOCl acts as an acid in water.

$$(b) \frac{[\text{H}_3\text{O}^+][\text{OCl}^-]}{[\text{HOCl}]} = \frac{[\text{H}_3\text{O}^+][\text{OCl}^-]}{0.175} = 3.2 \times 10^{-8}$$

As we can see from (a), H_3O^+ and OCl^- has same number of mole, thus having same molarity.

Let the molarity be x .

$$\frac{x \times x}{0.175} = \frac{x^2}{0.175} = 3.2 \times 10^{-8}$$

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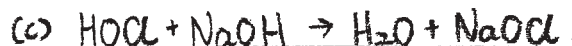
$$\therefore x^2 = 0.175 \times 3.2 \times 10^{-8}$$

$$= 5.6 \times 10^{-9}$$

$$\therefore x = 7.5 \times 10^{-5}$$

$$\therefore \text{pH} = \text{p}(\text{H}_3\text{O}^+) = -\log(7.5 \times 10^{-5})$$

$$= 4.1$$



$$(d) \text{ i) moles of NaOH} = 0.435 \times 0.00655$$

$$= 0.00285 \text{ mole}$$

$$\text{ii) moles of HOCl} = 0.0035 \text{ mole.}$$

When NaOH is titrated with HOCl, $0.0035 - 0.00285$ (mole) of H_3O^+ will remain.

$\therefore 0.00065$ mole remains.

$$[\text{H}_3\text{O}^+] = \frac{0.00065}{0.02655} = 2.45 \times 10^{-2}$$

$$\text{iii) Because } [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14},$$

$$[\text{OH}^-] = \frac{10^{-14}}{2.45 \times 10^{-2}} = 4.08 \times 10^{-13}$$

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1C1

CHEMISTRY
Section II
(Total time—90 minutes)

Part A
Time—40 minutes
YOU MAY USE YOUR CALCULATOR FOR PART A.

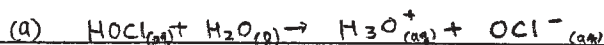
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- (iii) Calculate $[\text{OH}^-]$ in the flask after the NaOH(aq) has been added.



$$(b) K_a = \frac{[\text{H}_3\text{O}^+][\text{OCl}^-]}{[\text{HOCl}]}$$

$$3.2 \times 10^{-8} = \frac{x^2}{0.175}$$

$$x \approx 7.5 \times 10^{-5}$$

$$\therefore [\text{H}^+] = [\text{H}_3\text{O}^+] = 7.5 \times 10^{-5} \text{ M}$$

$$\therefore \text{pH} = -\log(7.5 \times 10^{-5})$$

$$\approx 4.1$$

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1C₂



$$(d) \text{ (i) } n(\text{NaOH}) = cV$$

$$= 0.435 \times 0.00655$$

$$\approx 0.00285 \text{ mol}$$

$$(ii) \frac{n(\text{NaOH})}{n(\text{HOCl})} = \frac{1}{1}$$

is needed.

$$\therefore n(\text{HOCl}) = n(\text{NaOH}) = 0.00285 \text{ mol during the reaction}$$

$$n(\text{HOCl}) \text{ before reaction} = cV$$

$$= 0.175 \times 0.02000$$

$$\approx 0.00350 \text{ mol}$$

$$\therefore n(\text{HOCl}) \text{ remaining} = 0.00065 \text{ mol}$$

$$\frac{n(\text{HOCl})}{n(\text{H}_3\text{O}^+)} = \frac{1}{1}$$

$$\therefore n(\text{H}_3\text{O}^+) = n(\text{HOCl}) = 0.00065 \text{ mol}$$

$$\therefore [\text{H}_3\text{O}^+] = \frac{n}{V}$$

$$= \frac{0.00065}{0.02000 + 0.00655}$$

$$\approx 0.024 \text{ M}$$

$$(iii) n(\text{NaOH}) = 0.00285 \text{ mol}$$

$$\frac{n(\text{NaOH})}{n(\text{OH}^-)} = \frac{1}{2}$$

$$\therefore n(\text{OH}^-) = 2n(\text{NaOH})$$

$$= 2 \times 0.00285$$

$$\approx 0.00570 \text{ mol}$$

$$[\text{OH}^-] = \frac{n}{V}$$

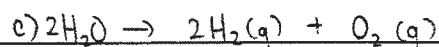
$$= \frac{0.00570}{0.02000 + 0.00655}$$

$$\approx 0.215 \text{ M}$$

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b) $5.61 \text{ min} \left(\frac{60 \text{ s}}{\text{min}} \right) \left(\frac{0.513 \text{ C}}{\text{s}} \right) = 173 \text{ C}$



There are twice as many moles of H_2 produced for each mole of O_2 produced.

d) $173 \text{ C} \left(\frac{\text{mol e}^-}{96500 \text{ C}} \right) \left(\frac{\text{mol O}_2}{4 \text{ mol e}^-} \right) \left(\frac{2 \text{ mol H}_2}{\text{mol O}_2} \right) = 8.95 \times 10^{-4} \text{ mol H}_2$

e) $PV = nRT$

$V = \frac{(8.95 \times 10^{-4} \text{ mol H}_2) R (298 \text{ K})}{1.00 \text{ atm}}$

$= 0.0219 \text{ L H}_2(\text{g})$

f) The total pressure inside the test tube is not composed of H_2 only.

There is also the pressure of water vapor.

$P_{\text{tot}} = P_{\text{H}_2\text{O}} + P_{\text{H}_2}$

thus, the total volume exceeds that of calculations, which is of H_2 only.

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②



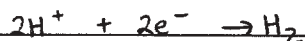
b) $Q = I \cdot t$ $t = 5.61 \text{ minutes} = 5.61 \cdot 60 \text{ seconds} = 336 \text{ seconds}$
 $I = 0.513 \text{ ampere}$

$Q = 0.513 \text{ ampere} \cdot 336 \text{ seconds} = 172 \text{ Coulombs}$



H_2 forms twice as much as O_2 in a given time due to the number of moles in the equation above.

d) $\text{mol e}^- = \frac{172 \text{ C}}{96500 \text{ C}} = 1.78 \times 10^{-3} \text{ moles}$



2 moles of e^- forms one mole of H_2 .

$\frac{1.78 \times 10^{-3}}{2} = 8.9 \times 10^{-4} \text{ mol H}_2$

e) $PV = nRT$

$1.00 \text{ atm} \cdot V = 8.9 \times 10^{-4} \text{ mol} \cdot 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \cdot 298 \cdot \text{K}$

$V = 2.2 \times 10^{-2} \text{ L H}_2 \text{ formed}$

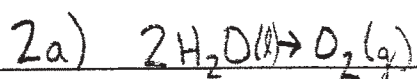
f) By doing the adjustment, the pressure in the tube is decreased. Pressure is inversely proportional to volume, as we can see from the equation below:

$P_1 V_1 = P_2 V_2,$

therefore the volume is greater.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2.



2b) $C = \text{amps} \times \text{sec}$
 $= .513 \times 336.6$

$C = 173 \text{ coulombs}$

2c) the balanced reaction is $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$, therefore there are 2 moles of H_2 for every 1 mole of O_2 , so more H_2 is collected

2d) $173 \text{ C} \left| \frac{1 \text{ mol } e^-}{96500 \text{ C}} \right| \frac{2 \text{ moles } \text{H}_2}{2 \text{ moles } \text{H}_2\text{O}} = 1.79 \times 10^{-3} \text{ moles } \text{H}_2$

2e) $1.79 \times 10^{-3} \text{ moles } \text{H}_2 \left| \frac{22.4 \text{ L}}{1 \text{ mole}} \right| = 4.02 \times 10^{-2} \text{ L } \text{H}_2$

2f) $PV = nRT$; n , R , and T remain constant, so therefore the pressure has decreased, giving it a greater volume.

GO ON TO THE NEXT PAGE.

$$a. \quad .00633 \text{ mol/L} = \frac{n}{5.00 \text{ L}} \quad M = \frac{n}{V}$$

$$.0317 \text{ mols of X}$$

$$b. \quad .00633 - .00427 = .00206 \text{ M}$$

$$.00206 \text{ M} = \frac{n}{5.00 \text{ L}}$$

$$.0103 \text{ mol X after 20 min.} \quad .0206 \text{ mol Y}$$



$$\begin{array}{c|c|c} .0103 \text{ mol X} & 2 \text{ mol Y} & 6.022 \times 10^{23} \text{ molecules} \\ \hline 1 \text{ mol X} & 1 \text{ mol Y} & \end{array}$$

$$= 1.24 \times 10^{22} \text{ molecules Y}$$

c. In respect to X this is a first order reaction because $\ln [X]$ is a straight (linear) line.

$$d. \quad \text{Rate} = k [X]^1$$

$$e. \quad \ln [A]_t - \ln [A]_0 = -kt$$

$$\ln [.00349 \text{ mol/L}] - \ln [.00633 \text{ mol/L}] = -k$$

$$30 \text{ min}$$

$$-.0198 = -k$$

$$.0198 \text{ min}^{-1} = k$$

$$f. \quad \ln [A]_t - \ln [.00633 \text{ mol/L}] = -(.0198 \text{ min}^{-1})(150 \text{ min})$$

$$\ln [A]_t = -2.97 + \ln [.00633 \text{ mol/L}]$$

$$\ln [A]_t = -8.03$$

$$[A]_t = 3.25 \times 10^{-4}$$

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 3.

$$a) n_X = 0.00633 \frac{\text{mol}}{\text{L}} \times 5.00 \text{ L} = 0.03165 \text{ mol}$$

$$b) \text{ molecules Y} = 0.00427 \frac{\text{mol X}}{\text{L}} \times 5.00 \text{ L} \times \frac{2 \text{ mol Y}}{1 \text{ mol X}} \times \frac{6.023 \times 10^{23} \text{ molecules Y}}{1 \text{ mol Y}} \\ = 2.57 \times 10^{22} \text{ molecules Y}$$

c) 1st order w.r.t. $[X]$. Because the plot of the the graph of $\ln [X]$ versus time is a straight line.

$$d) R = k[X] \quad \ln [X] = -kt + \ln [X]_0$$

$$e) k = \frac{-\ln\left(\frac{X}{X_0}\right)}{t} = \frac{+\left(\frac{-5.062}{-5.259}\right)}{10. \text{ min}} = 9.63 \times 10^{-2} \text{ min}^{-1}$$

$$f) \ln [X] = -9.63 \times 10^{-2} \text{ min}^{-1} \times 150 \text{ min} + (-5.062)$$

$$[X] = 3.37 \times 10^{-9} \text{ M}$$

GO ON TO THE NEXT PAGE.

3. d. $\frac{0.00633 \text{ mol X}}{\text{L}} \cdot 5 \text{ L} = 0.0317 \text{ mol X initially}$

b. Initial = 0.0317 mol X

20 minutes = $\frac{0.00427 \text{ mol X}}{\text{L}} \times 5 \text{ L} = 0.0214 \text{ mol X after 20 mins}$

$0.0317 \text{ mol X} - 0.0214 \text{ mol X} = 0.0103 \text{ mol X disappeared}$

= For every 1 mol of X that disappears, 2 mols of Y produced

$0.0103 \text{ mol X} \times 2 = 0.0206 \text{ mol Y produced}$

c. The rate law with respect to X is 1. When X is graphed with time, and the X values are converted to the natural log of X, and the line is straight (slope is constant) then the order with respect to X is 1. When X is plotted normally and it is a straight line, the order is 0. When X is plotted as the inverse and is a straight line, the order is 2.

e. Rate Law = $\frac{\text{mol}}{\text{L min}} = \frac{0.00520 \text{ mol}}{\text{L (10 min)}} = \frac{5.2 \times 10^{-4} \text{ mol}}{\text{L min}}$

$\frac{5.2 \times 10^{-4} \text{ mol}}{\text{L min}} = K \left(\frac{0.00520 \text{ mol}}{\text{L}} \right)$

$K = \frac{5.2 \times 10^{-4} \text{ mol}}{\text{L min}} \cdot \frac{\text{L}}{0.00520 \text{ mol}} = 0.1 \text{ min}^{-1} = K$

f. Rate Law = $K [X]$

$\frac{\text{mol}}{\text{L (150 min)}} = 0.1 \text{ min}^{-1} [X]$

$[X] = \frac{\text{mol}}{\text{L (150 min)}} \cdot \frac{\text{min}}{0.1} = \frac{\text{mol}}{\text{L (150)(0.1)}} = \frac{0.0667 \text{ mol}}{\text{L}}$

$[X] = 0.0667 \text{ M}$

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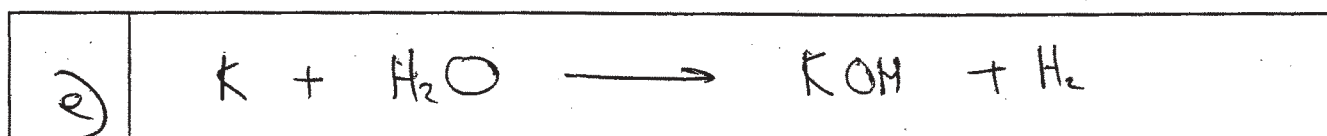
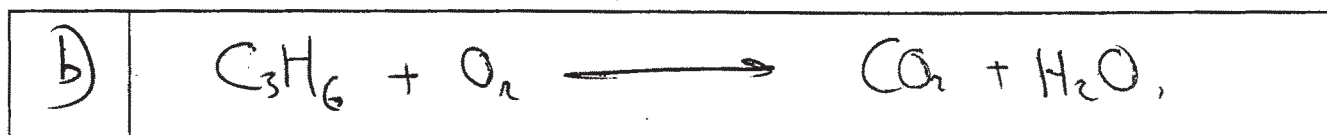
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USE THIS PAGE FOR ANSWERING QUESTION 4.
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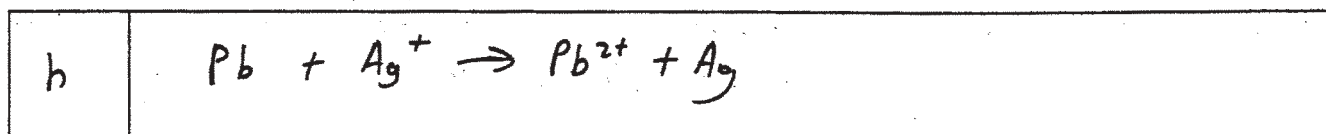
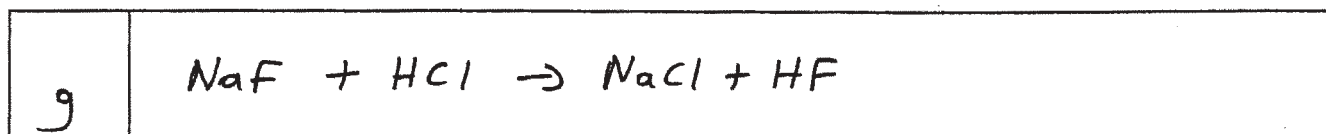
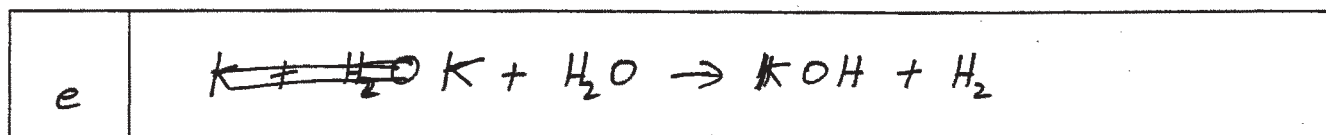
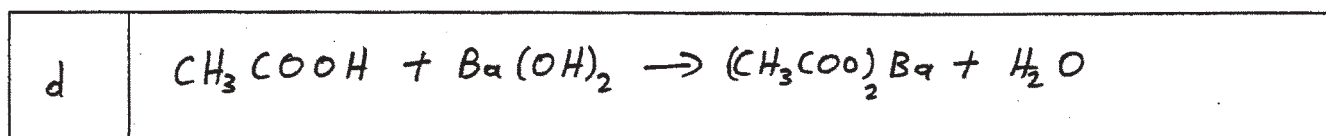
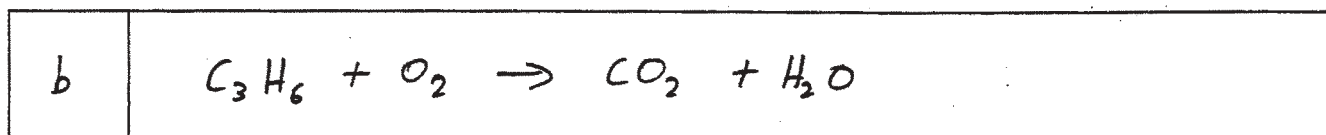
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USE THIS PAGE FOR ANSWERING QUESTION 4.

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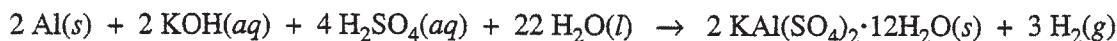
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Your responses to the rest of the questions in this part of the examination will be graded on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

Answer BOTH Question 5 below AND Question 6 printed on page 24. Both of these questions will be graded. The Section II score weighting for these questions is 30 percent (15 percent each).



5. In an experiment, a student synthesizes alum, $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}(s)$, by reacting aluminum metal with potassium hydroxide and sulfuric acid, as represented in the balanced equation above.

- (a) In order to synthesize alum, the student must prepare a 5.0 M solution of sulfuric acid. Describe the procedure for preparing 50.0 mL of 5.0 M H_2SO_4 using any of the chemicals and equipment listed below. Indicate specific amounts and equipment where appropriate.

10.0 M H_2SO_4	50.0 mL volumetric flask
Distilled water	50.0 mL buret
100 mL graduated cylinder	25.0 mL pipet
100 mL beaker	50 mL beaker

- (b) Calculate the minimum volume of 5.0 M H_2SO_4 that the student must use to react completely with 2.7 g of aluminum metal.
- (c) As the reaction solution cools, alum crystals precipitate. The student filters the mixture and dries the crystals, then measures their mass.
- (i) If the student weighs the crystals before they are completely dry, would the calculated percent yield be greater than, less than, or equal to the actual percent yield? Explain.
- (ii) Cooling the reaction solution in an ice bath improves the percent yield obtained. Explain.
- (d) The student heats crystals of pure alum, $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}(s)$, in an open crucible to a constant mass. The mass of the sample after heating is less than the mass before heating. Explain.

a) In order to prepare a 50 ml 5 M H_2SO_4 solution the student should take a 50 ml volumetric flask and initially fill it with 25 ml of 10 M H_2SO_4 that has been measured using the 100 ml graduated cylinder. The student should then use distilled water and fill the volumetric flask until the 50 ml mark has been reached.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

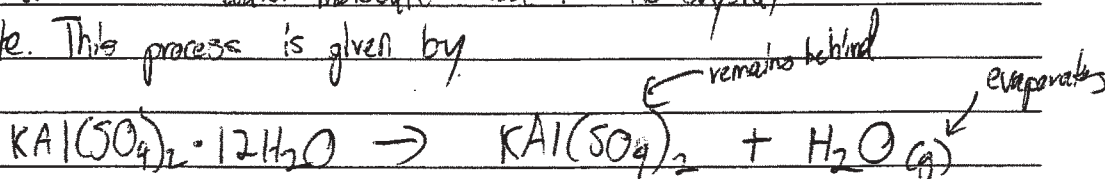
b) $\frac{2.7 \text{ g Al}}{40 \text{ ml of H}_2\text{SO}_4} \times \frac{\frac{\text{mol}}{27 \text{ g Al}}}{\frac{4 \text{ mol H}_2\text{SO}_4}{2 \text{ mol Al}}} \times \frac{1 \text{ L H}_2\text{SO}_4}{5 \text{ mol H}_2\text{SO}_4} = 0.04 \text{ L of H}_2\text{SO}_4 \text{ or}$

c) (i) % yield = $\frac{\text{experimental}}{\text{theoretical}} \times 100\%$

The percent yield would be greater since the experimental mass of the crystals would be greater.

ii) By cooling the reaction solution more of the crystals form thus there is a higher mass of crystals (experimental) and a higher % yield.

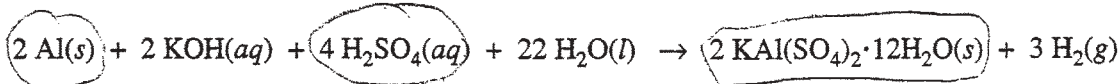
d) The mass of the sample after heating is less than the mass before heating as dehydration occurs, where the water molecule bound to the crystal tends to evaporate. This process is given by



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Answer BOTH Question 5 below AND Question 6 printed on page 24. Both of these questions will be graded. The Section II score weighting for these questions is 30 percent (15 percent each).



5. In an experiment, a student synthesizes alum, $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}(s)$, by reacting aluminum metal with potassium hydroxide and sulfuric acid, as represented in the balanced equation above.

- (a) In order to synthesize alum, the student must prepare a 5.0 M solution of sulfuric acid. Describe the procedure for preparing 50.0 mL of 5.0 M H_2SO_4 using any of the chemicals and equipment listed below. Indicate specific amounts and equipment where appropriate.

10.0 M H_2SO_4

50.0 mL volumetric flask

Distilled water

50.0 mL buret

100 mL graduated cylinder

25.0 mL pipet

100 mL beaker

50 mL beaker

- (b) Calculate the minimum volume of 5.0 M H_2SO_4 that the student must use to react completely with 2.7 g of aluminum metal.
- (c) As the reaction solution cools, alum crystals precipitate. The student filters the mixture and dries the crystals, then measures their mass.
- (i) If the student weighs the crystals before they are completely dry, would the calculated percent yield be greater than, less than, or equal to the actual percent yield? Explain.
 $\%Y = \frac{\text{original mass}}{\text{calculated mass}}$
- (ii) Cooling the reaction solution in an ice bath improves the percent yield obtained. Explain.
- (d) The student heats crystals of pure alum, $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}(s)$, in an open crucible to a constant mass. The mass of the sample after heating is less than the mass before heating. Explain.

a) $\% \text{ of moles before dilution} = \% \text{ of moles after dilution}$

$C_1 = 10.0 \text{ M}$

$C_2 = 5.0 \text{ M}$

$C_1 V_1 = C_2 V_2 \Rightarrow$

$V_1 = ?$

$V_2 = 50.0 \text{ mL}$

$V_1 = \frac{C_2 V_2}{C_1} = \frac{(5.0)(50.0)}{10.0} = 25.0 \text{ mL}$

Using a 25.0 mL pipet, transfer 25.0 mL of 10.0 M H_2SO_4 into a

50.0 mL volumetric flask. Add distilled water to the flask until

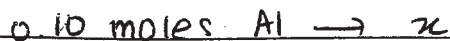
calibration mark. Stopper and mix the flask. The resulting solution is

50.0 mL, 5.0 M H_2SO_4 .

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$$b) n = \frac{m}{M} = \frac{2.7}{26.98} = \frac{2.7}{27} = 0.10 \text{ moles Al}$$



$$C = 5.0M \Rightarrow C = \frac{n}{V} \Rightarrow V = \frac{n}{C} = \frac{0.20}{5.0} = 0.040L$$

$$n = 0.20$$

$$c)(i) \text{ percent yield} = \frac{\text{original mass}}{\text{calculated mass}} \times 100.$$

since the crystals are not completely dry, their mass increases. \Rightarrow denominator increases and percent yield decreases, therefore the calculated percent yield will be less than the actual percent yield.

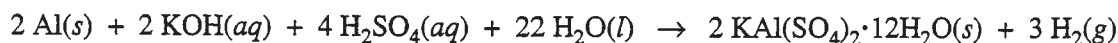
(ii) because calculated mass will cool down and increase its weight which will be closer to the original mass thus improving percent yield

d) after heating, the mass becomes less because all water molecules evaporate from the crystals while before it is heated water molecules are present which increase mass of crystals.

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10.0 M H_2SO_4	50.0 mL volumetric flask
Distilled water	50.0 mL buret
100 mL graduated cylinder	25.0 mL pipet
100 mL beaker	50 mL beaker

- (b) Calculate the minimum volume of 5.0 M H_2SO_4 that the student must use to react completely with 2.7 g of aluminum metal.
- (c) As the reaction solution cools, alum crystals precipitate. The student filters the mixture and dries the crystals, then measures their mass.
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- (ii) Cooling the reaction solution in an ice bath improves the percent yield obtained. Explain.
- (d) The student heats crystals of pure alum, $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}(s)$, in an open crucible to a constant mass. The mass of the sample after heating is less than the mass before heating. Explain.

Ⓐ 25ml of 10.0 M H_2SO_4 in 100ml beaker then pour 25ml distilled H_2O into a graduated cylinder and add to the 100 mL beaker of H_2SO_4

Ⓑ

2.7g	1 mole	2 mole	1L = 1L
	27g	1 mole	5mole 25
1	2	2	
10	5	50	

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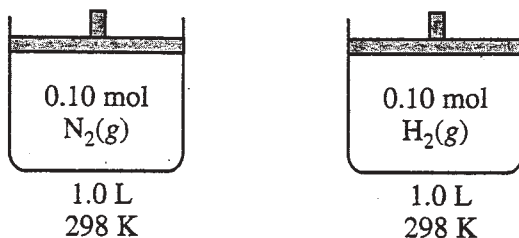
ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

(b)(i) greater than because the water would make the precipitate more massive so your calculations would show you yielded more precipitate.

(ii) This allows the crystals to form and harden

(d) The H₂O molecules have evaporated therefore the mass is less.

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6. Consider two containers of volume 1.0 L at 298 K, as shown above. One container holds 0.10 mol $N_2(g)$ and the other holds 0.10 mol $H_2(g)$. The average kinetic energy of the $N_2(g)$ molecules is 6.2×10^{-21} J. Assume that the $N_2(g)$ and the $H_2(g)$ exhibit ideal behavior.

- Is the pressure in the container holding the $H_2(g)$ less than, greater than, or equal to the pressure in the container holding the $N_2(g)$? Justify your answer.
- What is the average kinetic energy of the $H_2(g)$ molecules?
- The molecules of which gas, N_2 or H_2 , have the greater average speed? Justify your answer.
- What change could be made that would decrease the average kinetic energy of the $N_2(g)$ molecules in the container?
- If the volume of the container holding the $H_2(g)$ was decreased to 0.50 L at 298 K, what would be the change in each of the following variables? In each case, justify your answer.
 - The pressure within the container
 - The average speed of the $H_2(g)$ molecules

(a) $PV = nRT$

$P = \frac{nRT}{V}$

since the number of moles, temperature and volume are equal in both containers,

and because R is a constant,

the pressure in the container holding the H_2 is equal to the pressure in the container holding the N_2 .

(b) Since average kinetic energy is directly proportional to temperature, and the temperatures in both containers are the same, the average kinetic energy of the H_2 molecules would equal 6.2×10^{-21} J.

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(c) speed of a molecule is inversely proportional to its square root of mass. Since N_2 has a larger mass than H_2 , the molecules of H_2 have a greater average speed.

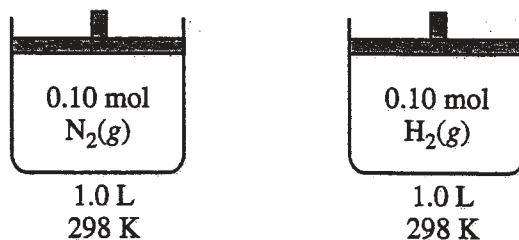
(d) as stated in (b), average kinetic energy is directly proportional to temperature, so in order to decrease average kinetic energy of N_2 molecules, temperature should be decreased.

(e) (i) initial pressure : $P_i = \frac{nRT}{V} = \frac{0.10 \times 0.082 \times 298}{1}$
changed pressure : $P_f = \frac{0.10 \times 0.082 \times 298}{0.5} = \frac{0.10 \times 0.082 \times 298}{\frac{1}{2}} = 2 \times P_i$

the pressure would double in its value.

(ii) the speed would not change since the temperature is kept constant and the mass of the individual molecules does not change.

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6. Consider two containers of volume 1.0 L at 298 K, as shown above. One container holds 0.10 mol $N_2(g)$ and the other holds 0.10 mol $H_2(g)$. The average kinetic energy of the $N_2(g)$ molecules is 6.2×10^{-21} J. Assume that the $N_2(g)$ and the $H_2(g)$ exhibit ideal behavior.
- Is the pressure in the container holding the $H_2(g)$ less than, greater than, or equal to the pressure in the container holding the $N_2(g)$? Justify your answer.
 - What is the average kinetic energy of the $H_2(g)$ molecules?
 - The molecules of which gas, N_2 or H_2 , have the greater average speed? Justify your answer.
 - What change could be made that would decrease the average kinetic energy of the $N_2(g)$ molecules in the container?
 - If the volume of the container holding the $H_2(g)$ was decreased to 0.50 L at 298 K, what would be the change in each of the following variables? In each case, justify your answer.
 - The pressure within the container
 - The average speed of the $H_2(g)$ molecules

6(a) The pressure in the container holding the $H_2(g)$ is equal to the pressure in the container holding the $N_2(g)$. This is supported by the ideal gas law, $PV = nRT$: if the volume, the temperature, and the number of moles is the same, then the pressure must also be equal.

6(b) ~~$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$$= \sqrt{\frac{3(1.38 \times 10^{-23})(298)}{2.0 \times 10^{-3}}}$$~~

The average kinetic energy of the $H_2(g)$ molecules is 6.2×10^{-21} J — the $H_2(g)$ is at the same temperature as

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the $N_2(g)$ so that the average kinetic energy of the molecules must be the same.

(c) $U_{rms} = \sqrt{\frac{3KT}{m}}$ $H_2: 0.10 \left(\frac{2g}{mol} \right) = 0.20g$
 $N_2: 0.10 \left(\frac{28g}{mol} \right) = 2.8g$

The average speed of the $H_2(g)$ molecules is greater, as they have a smaller mass than the molecules of $N_2(g)$.

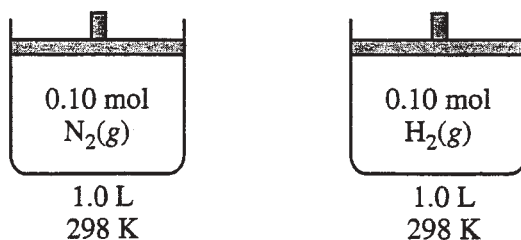
This is supported by the equation: $U_{rms} = \sqrt{\frac{3KT}{\text{mass}}}$

(d) The volume could be decreased, so that according to $KE = \frac{1}{2}mv^2$, the kinetic energy would decrease.

(e) (i) The pressure within the container would increase according to $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$. if the temperature is kept constant, this becomes $P_1 V_1 = P_2 V_2$ so that if the volume is decreased, the pressure must increase.

(ii) The average speed would remain the same because the temperature remains constant.

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6. Consider two containers of volume 1.0 L at 298 K, as shown above. One container holds 0.10 mol $N_2(g)$ and the other holds 0.10 mol $H_2(g)$. The average kinetic energy of the $N_2(g)$ molecules is 6.2×10^{-21} J. Assume that the $N_2(g)$ and the $H_2(g)$ exhibit ideal behavior.

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- What is the average kinetic energy of the $H_2(g)$ molecules?
- The molecules of which gas, N_2 or H_2 , have the greater average speed? Justify your answer.
- What change could be made that would decrease the average kinetic energy of the $N_2(g)$ molecules in the container?
- If the volume of the container holding the $H_2(g)$ was decreased to 0.50 L at 298 K, what would be the change in each of the following variables? In each case, justify your answer.
 - The pressure within the container
 - The average speed of the $H_2(g)$ molecules

6. a. The pressure in the container holding $H_2(g)$ is equal to the pressure in the container holding $N_2(g)$ because $P = \frac{nRT}{V}$ and n , R , T , and V for both $N_2(g)$ and $H_2(g)$ are equal.

b. KE per molecule = $\frac{1}{2} (0.2 \text{ g}) (1)^2$
= 0.1

c. The molecules of H_2 have the greatest average speed because the lighter the molecule (H_2 's molar mass is 2.016 g while N_2 's molar mass is 28 g) the faster its speed.

d. To decrease the average kinetic energy of the $N_2(g)$ molecules in the container, we

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6C₂

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could decrease the volume.

- e. i. Pressure would increase because $P = nRT/V$. Pressure and volume are inversely related, if one goes up the other must come down.
- ii. The average speed of H_2 molecules would increase because when the volume is decreased, the pressure on the gas molecules increases and forces them to move even faster.

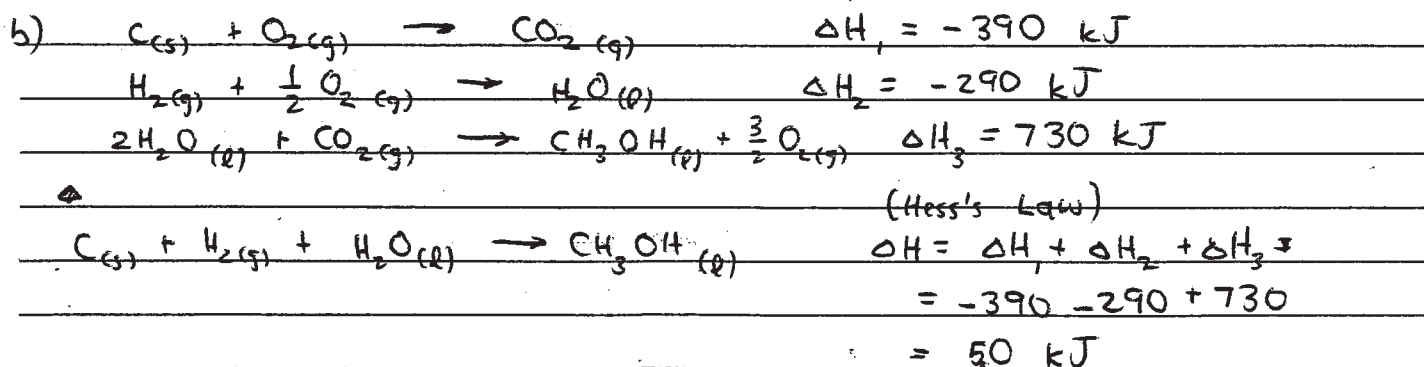
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Answer EITHER Question 7 below OR Question 8 printed on page 28. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 15 percent.

7. Answer the following questions about thermodynamics.

Substance	Combustion Reaction	Enthalpy of Combustion, $\Delta H_{\text{comb}}^\circ$, at 298 K (kJ mol ⁻¹)
H ₂ (g)	$\text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$	-290
C(s)	$\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$	-390
CH ₃ OH(l)	$\text{CH}_3\text{OH}(\text{l}) + \frac{3}{2} \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$	-730

- (a) In the empty box in the table above, write a balanced chemical equation for the complete combustion of one mole of CH₃OH(l). Assume products are in their standard states at 298 K. Coefficients do not need to be whole numbers.
- (b) On the basis of your answer to part (a) and the information in the table, determine the enthalpy change for the reaction $\text{C}(\text{s}) + \text{H}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{CH}_3\text{OH}(\text{l})$.
- (c) Write the balanced chemical equation that shows the reaction that is used to determine the enthalpy of formation for one mole of CH₃OH(l).
- (d) Predict the sign of ΔS° for the combustion of H₂(g). Explain your reasoning.
- (e) On the basis of bond energies, explain why the combustion of H₂(g) is exothermic.



d) It is negative. Initially we have one and a half moles of

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gaseous moles, and then we end up with one mole of liquid water. Gases have more positional entropy than liquids. Since entropy of the system decreases, ΔS° is negative.

e) $\Delta H = \sum E_{\text{bonds broken}} - \sum E_{\text{bonds formed}}$
in the combustion of one mole of H_2 we are breaking one mole of $H-H$ bonds and half a mole of $O-O$ bonds. We are forming two moles of $O-H$ bonds. The energy stored in 2 moles of $O-H$ bonds is greater than that stored in one mole of $H-H$ bonds and half a mole of $O-O$ bonds. $\sum E_{\text{bonds formed}} > \sum E_{\text{bonds broken}}$
consequently $\Delta H < 0$ and the reaction is exothermic

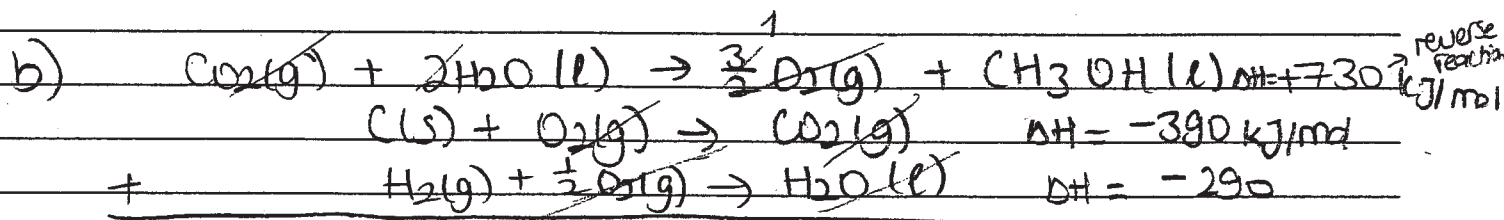
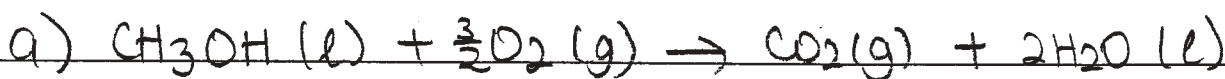
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- (c) Write the balanced chemical equation that shows the reaction that is used to determine the enthalpy of formation for one mole of CH₃OH(l).
- (d) Predict the sign of ΔS° for the combustion of H₂(g). Explain your reasoning.
- (e) On the basis of bond energies, explain why the combustion of H₂(g) is exothermic.



$\text{H}_2(\text{g}) + \text{C}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{CH}_3\text{OH}(\text{l})$ is the reaction we get using Hess' law. According to the same law again, by adding the ΔH values we can calculate the enthalpy change for the overall reaction

$$\Delta H = 730 - 390 - 290$$

$$\Delta H = 50 \text{ kJ/mol}$$

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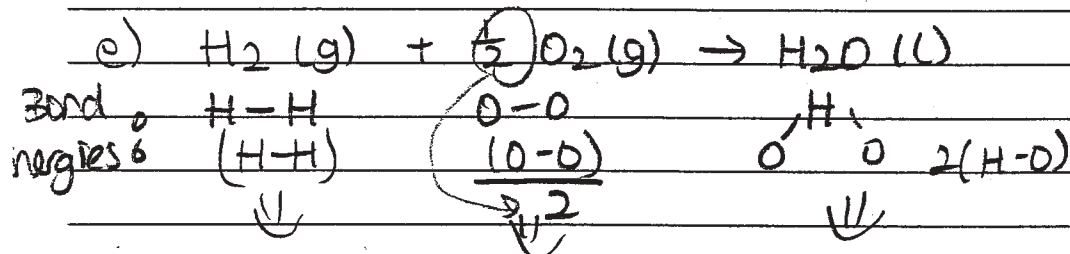
$$\begin{aligned} c) \Delta H_{\text{comb}}^{\circ} \text{CH}_3\text{OH} &= \Delta H^{\circ} \text{f products} - \Delta H^{\circ} \text{f reactants} \\ &= \Delta H^{\circ} \text{f}(\text{CO}_2) + [\Delta H^{\circ} \text{f}(\text{H}_2\text{O})] 2 - \Delta H^{\circ} \text{f} \text{CH}_3\text{OH} \end{aligned}$$

comb: Combustion f: formation

$$\Delta H^{\circ} \text{f} \text{CH}_3\text{OH} = \Delta H^{\circ} \text{f}(\text{CO}_2) + 2[\Delta H^{\circ} \text{f}(\text{H}_2\text{O})] - \Delta H^{\circ} \text{comb. CH}_3\text{OH} + 1$$

d) When we heat $\text{H}_2(\text{g})$, combustion occurs and the reaction results in the formation of H_2O which is liquid. Since the entropy of gases is higher than that of the liquid substances, a decrease in the entropy is seen. Therefore, ΔS° is negative (-).

$$\Delta S^{\circ} = S_{\text{products}} - S_{\text{reactants}} = (-)$$



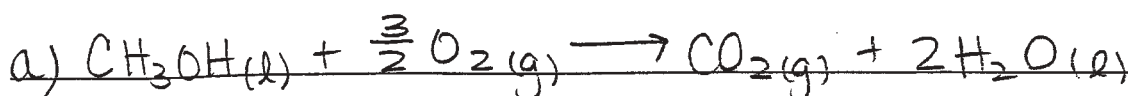
In order to break bonds, energy is needed. In this case, the opposite is present. There are new bonds formed for the formation of H_2O , therefore, energy is released. This means that energy is released as the bonds are formed, which means that the exothermic.

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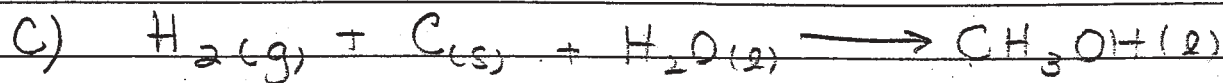
b) $\Delta H^\circ = \Delta H(\text{CH}_3\text{OH}) - (\Delta H(\text{C}) + \Delta H(\text{H}_2) + \Delta H(\text{H}_2\text{O}))$
 $\Delta H^\circ = \sum \text{products } \Delta H - \sum \text{reactants } \Delta H$

Hess' Law:

$\text{H}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{H}_2\text{O}$	$\Delta H = -290 \text{ kJ}$	-290
$\text{C} + \text{O}_2 \rightarrow \text{CO}_2$	$\Delta H = -390 \text{ kJ}$	-390
$\text{CO}_2 + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{OH} + \frac{3}{2}\text{O}_2$	$\Delta H = +730 \text{ kJ}$	$+730$
$\text{H}_2(\text{g}) + \text{C}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{CH}_3\text{OH}(\text{l})$	$\Delta H =$	-680
	$+50 = \Delta H$	-680
	kJ	5

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d) $\Delta H - \Delta S(T) = \Delta G$ ΔG determines spontaneity
 $\Delta H = +$ of Reaction

$(+) - (+)(298\text{K}) = \Delta G$ $+\Delta G$ Spontaneous in
 $+ = \Delta G$ forward direction

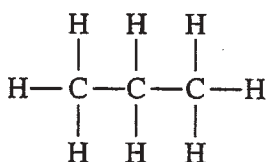
ΔS positive

e) $\text{H}_2(\text{g})$ is exothermic because H_2 is non-polar
 with a London Forces Intermolecular
 attractive force

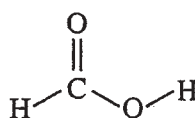
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8. Use principles of atomic structure, bonding, and intermolecular forces to answer the following questions. Your responses must include specific information about all substances referred to in each part.

- (a) Draw a complete Lewis electron-dot structure for the CS_2 molecule. Include all valence electrons in your structure.
- (b) The carbon-to-sulfur bond length in CS_2 is 160 picometers. Is the carbon-to-selenium bond length in CSe_2 expected to be greater than, less than, or equal to this value? Justify your answer.
- (c) The bond energy of the carbon-to-sulfur bond in CS_2 is 577 kJ mol^{-1} . Is the bond energy of the carbon-to-selenium bond in CSe_2 expected to be greater than, less than, or equal to this value? Justify your answer.



Propane

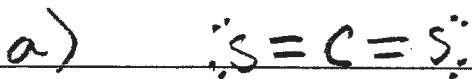


Methanoic Acid

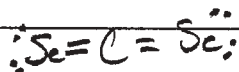
- (d) The complete structural formulas of propane, C_3H_8 , and methanoic acid, HCOOH , are shown above. In the table below, write the type(s) of intermolecular attractive force(s) that occur in each substance.

Substance	Boiling Point	Intermolecular Attractive Force(s)
Propane	229 K	Van der Waals (London dispersion)
Methanoic acid	374 K	Hydrogen bonding, London dispersion

- (e) Use principles of intermolecular attractive forces to explain why methanoic acid has a higher boiling point than propane.



b) The Lewis structure for CSe_2 is:



which is similar to the Lewis structure for CS_2 , however, since the Se atom is slightly bigger in radius than the S atom, its bond length will be slightly longer.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 8.

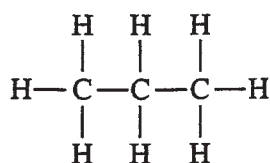
c) The bond energy of CSe_2 should be less, since we determined in (b) that the C-Se bond is slightly longer than the C-S bond, making it slightly weaker, thus requiring less energy to break it (bond energy).

d) ~~is~~ on page

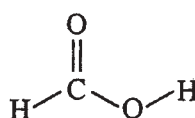
e) Since methanoic acid is bonded by the relatively strong intermolecular attractive force of hydrogen bonding (dipole attraction which is abnormally strong with F, N, O and H), it requires more energy to change its phase by breaking the bonds than propane, which is bonded by the relatively weak London dispersion forces.

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Propane

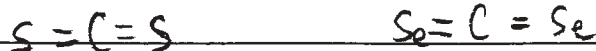
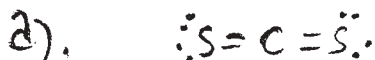


Methanoic Acid

- (d) The complete structural formulas of propane, C_3H_8 , and methanoic acid, HCOOH , are shown above. In the table below, write the type(s) of intermolecular attractive force(s) that occur in each substance.

Substance	Boiling Point	Intermolecular Attractive Force(s)
Propane	229 K	London Dispersion Force (LDF)
Methanoic acid	374 K	H-bonding and LDF.

- (e) Use principles of intermolecular attractive forces to explain why methanoic acid has a higher boiling point than propane.



They should have equal lengths, because they both exhibit ~~linear~~ a linear molecular structure and have ~~the~~ ~~double bonds~~ double bonds between atoms.

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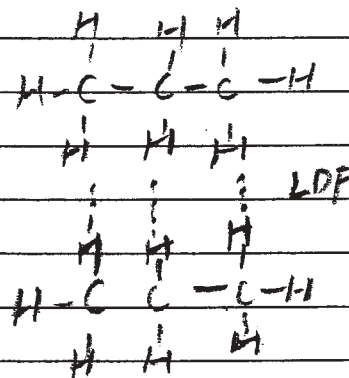
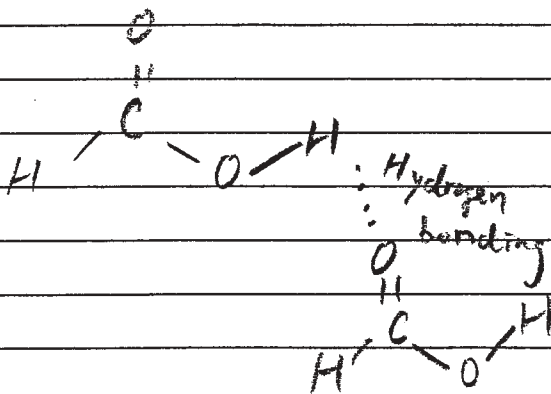
ADDITIONAL PAGE FOR ANSWERING QUESTION 8.

c). The ^{bond energy of} C-Se bond in CSe₂ should be ~~be~~ less than the C-S bond in CS₂.

It's because the Se atom has a bigger size than S atom, refer to the equation $E = \frac{Q_1 Q_2}{d}$, a longer distance between atoms should result in a smaller bond energy.

e). Methanoic Acid

Propane



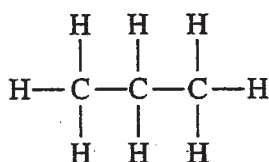
As the intermolecular force of Methanoic acid is H-bonding & LDF (mainly H-bonding) which is a much stronger ~~bonding~~ bonding than the LDF in Propane molecules.

With a ~~str~~ stronger bonding, it takes more energy to break the ~~ba~~ bonds in order to go to gas state.

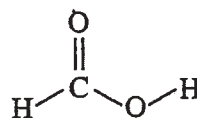
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Propane



Methanoic Acid

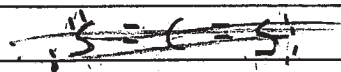
- (d) The complete structural formulas of propane, C_3H_8 , and methanoic acid, HCOOH , are shown above. In the table below, write the type(s) of intermolecular attractive force(s) that occur in each substance.

Substance	Boiling Point	Intermolecular Attractive Force(s)
Propane	229 K	London dispersion
Methanoic acid	374 K	H-bonding, Dipole-Dipole, + London Dispersion

- (e) Use principles of intermolecular attractive forces to explain why methanoic acid has a higher boiling point than propane.

a.

$$4 + 6 + 6 = 16$$



b.



The bond length in CSe_2 should be the same as in CS_2 because they are identical bond structures.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 8.

c. The bond energy in CSe_2 is expected to be greater because Se is a larger atom than S and therefore has more protons + a stronger hold on its electrons.

d. on chemt

e. Methanoic acid has a higher boiling point than propane because Hydrogen bonding is the strongest of all intermolecular forces + is therefore the hardest to break apart. Propane doesn't even have any dipole moments to keep it attracted. Methanoic acid is therefore much harder to break.

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