CHEMISTRY 534
ANSWERS
EXAM #1
JUNE 2009

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2	B
3	B
4	C
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6	D
7	A
8	D
9	D
10	A
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15 **Example of an appropriate and complete solution** /4

Since the volumes, temperatures, and pressures of the two gases are the same, the moles of the two gases must also be the same.

Calculate the mass of nitrogen gas:

Mass in cylinder nº 1: 45.317 kg – 45.205 kg
= 0.112 kg
= 112 g

Calculate the number of moles of nitrogen gas.

Molar mass of nitrogen gas: 2×14.01
= 28.02 g/mol

Moles of nitrogen gas: $\frac{\text{mass of nitrogen gas}}{\text{molar mass of nitrogen gas}}$

$= \frac{112\text{ g}}{28.02\text{ g/mol}}$

= 4.00 mol

Moles of carbon dioxide gas = moles of nitrogen gas
= 4.00 mol

Calculate mass of carbon dioxide gas.

Molar mass of carbon dioxide gas: 12.01 + 2(16.00)
= 44.01 g/mol

Mass of carbon dioxide gas = moles of carbon dioxide $\times$ molar mass of carbon dioxide
= 4.00 mol $\times$ 44.01 g/mol
=176 g or 0.176 kg

Mass of cylinder filled with carbon dioxide gas: 0.176 kg + 48.112 kg
= 48.288 kg

Answer: The mass of the filled cylinder of carbon dioxide gas is **48.288 kg**.

16 **Example of an appropriate and complete solution** /4

Mass of gas sample

$$d = \frac{m}{V}$$
$$m = d \times V$$
$$m = 6.00 \text{ g/L} \times 0.0973 \text{ L}$$
$$m = 0.584 \text{ g of gas}$$

Moles of gas in sample

$$n = \frac{PV}{RT}$$
$$n = \frac{(100.0 \text{ kPa})(0.0973 \text{ L})}{(8.31 \text{ kPa} \bullet \text{L/mol} \bullet \text{K})(293 \text{ K})}$$
$$n = 0.00399 \text{ moles}$$

Molar mass of sample

$$\text{molar mass} = \frac{\text{mass}}{\text{moles}}$$
$$= \frac{0.584 \text{ g}}{0.00399 \text{ moles}}$$
$$= 146 \text{ g/mol}$$

Molar mass of SF_6

Molar mass of S = 32 g/mol

Molar mass of F = 19 g/mol

Molar mass of SF_6 = $(32 + 6 \times 19)$ g/mol

= 146 g/mol

17 **Example of an appropriate and complete solution** /4

Gas A

If the gas is ideal, then $P \times V$ will be constant.

$100 \times 25.0 = 2500$
$125 \times 20.0 = 2500$
$200 \times 12.5 = 2500$

Behaviour of Gas A Ideal ___✓___ Non–ideal _______

Gas B

If the gas is ideal, then $\frac{P}{T}$ will be constant.

$$\frac{100}{(21+273)} = 0.34$$

$$\frac{200}{(42+273)} = 0.63$$

$$\frac{300}{(63+273)} = 0.89$$

Behaviour of Gas B Ideal _______ Non–ideal ___✓___

Gas C

Gas C is an ideal gas if $\frac{V}{T}$ is constant.

$$\frac{2.4}{(27+273)} = 0.008$$

$$\frac{2.6}{(52+273)} = 0.008$$

$$\frac{2.8}{(77+273)} = 0.008$$

Behaviour of Gas C Ideal ___✓___ Non–ideal _______

18 **Example of an appropriate and complete solution** /4

Number of moles of sulphuric acid

$n = c \times V$

$n = 18 \text{ mol/L} \times 5.0 \times 10^2 \text{ L}$

$n = 9.0 \times 10^3$ mol of H_2SO_4

Number of moles of hydrogen gas produced
Since the mole ratio is 1:1 then,
Mol of hydrogen gas = 9.0×10^3 mol
Volume of hydrogen gas produced

$$V = \frac{(n \times R \times T)}{P}$$

$$V = \frac{(9.0 \times 10^3 \text{ mol})(8.31 \text{ kPa} \bullet \text{L/mol} \bullet \text{k})(292 \text{ K})}{100.8 \text{ kPa}}$$

$V = 2.2 \times 10^5$ L

Answer: Jacques Charles would have produced **2.2×10^5 L** of hydrogen gas.

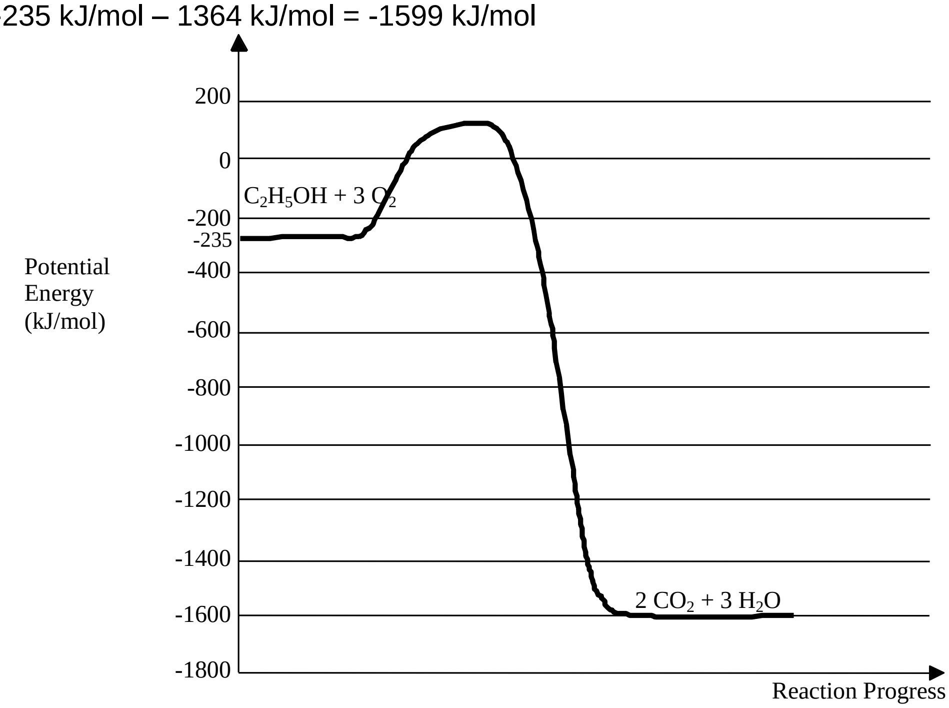
19 **Example of an appropriate and complete solution** /4

Enthalpy of activated complex

-235 kJ/mol + 368 kJ/mol = 133 kJ/mol

Enthalpy of products

-235 kJ/mol – 1364 kJ/mol = -1599 kJ/mol



20 **Example of an appropriate and complete solution** /4

Heat of combustion of propane

$C_3H_{8(g)} \rightarrow \cancel{3C_{(s)}} + \cancel{4 H_{2(g)}}$ $\Delta H = +103.7 \frac{kJ}{mol} \times 1 = +103.7 \frac{kJ}{mol}$

$\cancel{3 C_{(s)}} + 3 O_{2(g)} \rightarrow 3 CO_{2(g)}$ $\Delta H = -393.5 \frac{kJ}{mol} \times 3 = -1180.5 \frac{kJ}{mol}$

$\cancel{4 H_{2(g)}} + 2 O_{2(g)} \rightarrow 4 H_2O_{(g)}$ $\Delta H = -242.0 \frac{kJ}{mol} \times 4 = -968.0 \frac{kJ}{mol}$

$C_3H_{8(g)} + 5 O_{2(g)} \rightarrow 3 CO_{2(g)} + 4 H_2O_{(g)}$ $= -2044.8 \frac{kJ}{mol}$

The heat produced for 1 mole of carbon dioxide produced is $\frac{2044.8 \text{ kJ}}{3} = 681.6 \frac{kJ}{mol}$ of CO_2.

Heat of combustion of gasoline

$C_8H_{18(g)} \rightarrow \cancel{8C_{(s)}} + \cancel{9 H_{2(g)}}$ $\Delta H = +208.4 \frac{kJ}{mol} \times 1 = +208.4 \frac{kJ}{mol}$

$\cancel{8 C_{(s)}} + 8 O_{2(g)} \rightarrow 8 CO_{2(g)}$ $\Delta H = -393.5 \frac{kJ}{mol} \times 8 = -3148.0 \frac{kJ}{mol}$

$\cancel{9 H_{2(g)}} + 4.5 O_{2(g)} \rightarrow 9 H_2O_{(g)}$ $\Delta H = -242.0 \frac{kJ}{mol} \times 9 = -2178.0 \frac{kJ}{mol}$

$C_8H_{18(g)} + 12.5 O_{2(g)} \rightarrow 8 CO_{2(g)} + 9 H_2O_{(g)}$ $= -5117.6 \frac{kJ}{mol}$

The heat produced for 1 mole of carbon dioxide produced is $\frac{5117.6 \text{ kJ}}{8} = 639.7 \frac{kJ}{mol}$ of CO_2.

Difference in heat produced for 1 mole of carbon dioxide
681.6 kJ/mol – 639.7 kJ/mo = 41.9 kJ/mol

Answer: The combustion of propane provides **41.9 kJ/mol** more energy per mole of CO_2 than the combustion of gasoline.

21 **Example of an appropriate and complete solution** /4

Calculate the quantity of heat absorbed by the water in the calorimeter.

$Q = mc\Delta T$
$Q = 500\text{g} \times 4.19\text{J/g/°C} \times 30.0\text{°C}$
$= 62\,850 \text{ J } (62.85 \text{ kJ})$

Calculate the ΔH per mole of ethanol burned.

$$\text{Moles of ethanol} = \frac{\text{mass of ethanol}}{\text{molar mass of ethanol}}$$

$$= \frac{2.30 \text{ g}}{46 \text{ g/mol}}$$

$$= 0.05 \text{ mol}$$

$$\Delta H = -\frac{Q}{n}$$

$$= -\frac{62.85 \text{ kJ}}{0.05 \text{ mol}}$$

$$= -1257 \frac{\text{kJ}}{\text{mol}}$$

If the sample was 100% pure ethanol, then the $\Delta H = -1367 \frac{\text{kJ}}{\text{mol}}$

$$\frac{-1257}{-1367} = 92\%$$

92% of the heat was released, therefore it is 92% pure.

Answer: The sample is an acceptable biofuel.

22 **Example of an appropriate and complete solution** /4

Calculate the heat gained by the water.

$$\begin{aligned} Q_{water} &= m \bullet c \bullet \Delta T \\ &= 250\text{ g} \times 4.19\text{ J/g}\bullet°\text{C} \times (30.7 - 25.0)°\text{C} \\ &= 5970.75\text{ J} \\ &= 5.971\text{ kJ} \end{aligned}$$

Calculate the moles of solid used.

NaCl

Molar mass = $(22.99 + 35.45)\ \text{g/mol}$

Moles NaCl = $\dfrac{\text{mass}}{\text{molar mass}}$

Moles NaCl = $\dfrac{4.67\ \text{g}}{58.44\ \text{g/mol}}$

= 0.0799 mol

Calculate the heat of solution in kJ/mol.

$$\begin{aligned} \Delta H &= -\frac{Q}{n} \\ &= -\frac{5.971\ \text{kJ}}{0.0799\ \text{mol}} \\ &= -74.72\ \frac{\text{kJ}}{\text{mol}} \end{aligned}$$

Answer: The solid is **NaCl**.

23 **Example of an appropriate and complete solution** /4

Volume of nitrogen dioxide produced in 90.0 minutes

$$\frac{25\ \text{mL}}{(1000\ \text{mL/L})} = 0.025\ \text{L}$$

Calculate, using the Ideal Gas Law, the moles consumed

$$n = \frac{P \bullet V}{R \bullet T}$$

$$= \frac{(101.9\ \text{kPa} \bullet 0.025\ \text{L})}{\left(\frac{8.31\ \text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}}\right) \bullet (20.5 + 273°\ \text{K})}$$

$$= 1.0 \times 10^{-3}\ \text{mol}$$

Since this is a 1:2 ratio, the moles of copper consumed = 2 × moles of nitrogen dioxide produced.

$= 2.0 \times 10^{-3}$ mol $Cu_{(s)}$

Molar mass of copper

63.55 g/mol

Mass of copper

(63.55 g/mol) • (2.0×10^{-3} mol)
= 1.3×10^{-1} g

Rate of consumption of copper

$$\frac{1.32 \times 10^{-1}\ \text{g}}{90.0\ \text{min}}$$

$$= \frac{1.4 \times 10^{-3}\ \text{g}}{\text{min}}$$

Answer: The average rate of consumption of copper during the first 90.0 minutes is $\mathbf{\frac{1.4 \times 10^{-3}\ g}{min}}$.

4 marks Appropriate and complete procedure.

24 **Example of appropriate and complete responses** /4

1. Use powdered Magnesium.
   The use of powdered magnesium increases the surface area of the magnesium. A greater surface area results in more collisions between the molecules, which results in a greater reaction rate.

2. Increase the concentration of the HCl.
   A higher concentration of reactants results in more collisions between the molecules, which results in a greater reaction rate.

3. Use HCl that has been heated.
   Raising the temperature of the molecules causes the molecules to move faster, which results in more collisions. It also means that the molecules have more kinetic energy, which makes the collisions more likely to be effective. Therefore increasing the temperature increases the reaction rate.

4. Add a catalyst.
   A catalyst provides a reaction pathway with a lower activation energy, which makes the collisions more likely to be effective. Therefore, the presence of a catalyst increases the reaction rate.

25 **Example of an appropriate and complete solution** /4

Example 1

$[NH_3]$ at 30 seconds

H_2 consumed = 10.0 mol/L – 7.0 mol/L
= 3.0 mol/L

H_2 consumed: NH_3 produced = 3:2

Therefore, NH_3 produced = 2 mol/L

$[NH_3]$ at 120 seconds

H_2 consumed = 10.0 mol/L – 3.4 mol/L
= 6.6 mol/L

H_2 consumed: NH_3 produced = 3:2

Therefore, NH_3 produced = 4.4 mol/L

Rate of production of ammonia

$$= \frac{\text{change in concentration of } NH_3}{\text{change in time}}$$

$$= \frac{(4.4\text{ mol/L} - 2.0\text{ mol/L})}{(120\text{ s} - 30\text{ s})}$$

$$= \frac{2.4\text{ mol/L}}{90\text{ s}}$$

$$= \frac{0.027\text{ mol/L}}{\text{s}}$$

Example 2

Change in H_2 concentration between 30 s and 120 s:

3.4 mol/L − 7.0 mol/L = -3.6 mol/L

NH_3: H_2 = 2 : 3

Change in concentration of NH_3 between 30 s and 120 s:

$$3.6\text{ mol/L} \times \frac{2}{3} = 2.4\text{ mol/L}$$

Average rate of production of NH_3:

$$= \frac{\text{change in conentration of } NH_3}{\text{change in time}}$$

$$= \frac{2.4\text{ mol/L}}{90\text{ s}}$$

$$= \frac{0.027\text{ mol/L}}{\text{s}}$$

Answer: The average rate of production of ammonia between 30 seconds and 120 seconds is **0.027 mol/L/s**.

26 **Example of an appropriate and complete solution** /4

	SO_2	O_2	SO_3
Initial Concentration	**0.875 mol/L**	**0.625 mol/L**	**0**
Change in concentration	-0.8 mol/L	-0.4 mol/L	+0.8 mol/L
Equilibrium Concentration	0.075	0.225 mol/L	**0.8 mol/L**

The change in concentration of SO_3 was 0.8 mol/L.
Using the mole ratio of O_2: SO_3 as 1:2, the change in concentration of O_2 is 0.4 mol/L.
Using the mole ratio of O_2: SO_2 as 1:1, the change in concentration of O_2 is 0.8 mol/L.

$$K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

$$K_{eq} = \frac{[0.8]^2}{[0.075]^2[0.225]}$$

Answer: The equilibrium constant, K_{eq}, is $\mathbf{5.1 \times 10^2}$.

27 **Example of an appropriate and complete solution** /4

Molar mass of hydrogen fluoride

1.01 g/mol + 19.00 g/mol
= 20.01 g/mol

Moles of hydrogen fluoride

$$\frac{40.0 \text{ g}}{20.01 \text{ g/mol}}$$

= 2.00 mol

Initial concentration of the acid

$$\frac{2.0 \text{ mol}}{4.0 \text{ L}}$$

= 0.500 mol/L

Since this is a weak acid, we can state the following:

$$\text{Ka} = \frac{x^2}{[\text{HF}]}$$

where x is the molar concentration of H^+ and F^- at equilibrium

[HF] is the initial molar concentration of the acid

$$7.2 \times 10^4 = \frac{x^2}{0.500 \text{ mol/L}}$$

$$x = 1.897 \times 10^{-2}$$

pH = - log $[H^+]$
= - log (1.897×10^{-2})
= 1.72

Answer: The pH of the hydrofluoric acid solution is **1.72**.

28 **Example of an appropriate and complete solution** /4

$HA_{(aq)}$	$\leftrightarrow$	$H^+_{(aq)}$	+	$A^-_{(aq)}$
0.10 mol/L		0 mol/L		0 mol/L
-0.0020 mol/L		+0.0020 mol/L		+ 0.0020 mol/L
0.098 mol/L		0.0020 mol/L		0.0020 mol/L

$$K_a = \frac{(0.0020 \text{ mol/L})^2}{0.098 \text{ mol/L}}$$

$K_a = 4.1 \times 10^{-5}$

Acid HB

$$K_a = \frac{(1.3 \times 10^{-4} \text{ mol/L})^2}{0.074 \text{ mol/L}}$$

$K_a = 2.3 \times 10^{-7}$

Acid HC

$K_a = 4.9 \times 10^{-7}$

Answer: In order of increasing strength, the acids are **HB, HC, HA**.

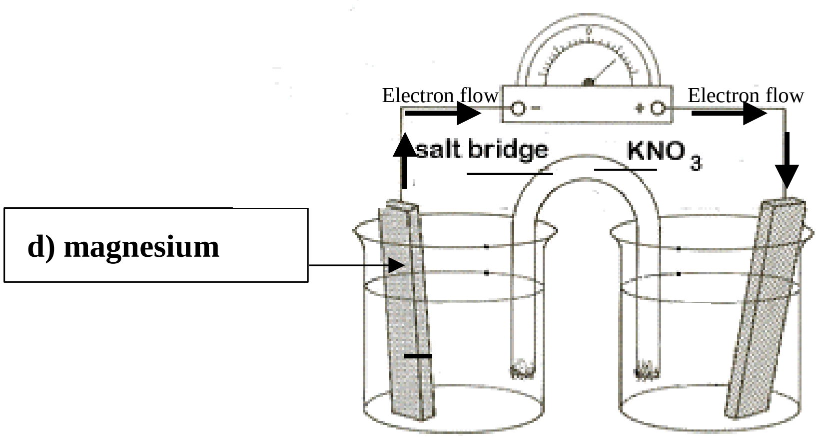
29 **Example of an appropriate and complete solution** /4

a) $2\ Ag^+_{(aq)} + Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + 2\ Ag_{(s)}$ 1 mark

b) The E^o value is: +3.17 V 1 mark

c) The reducing agent is magnesium. 1 mark

Electrochemical Cell



1 mark

EXAM #2
JUNE 2008

1 B

2 C

3 B

4 D

5 A

6 A

7 B

8 C

9 D

10 A

11 D

12 A

13 B

14 C

15 **Example of an appropriate and complete solution** /4

Determine the molar mass of Cl_2

2×35.45 g/mol = **70.90 g/mol**

Determine the molar mass of NH_3

14.01 g/mol + 3×1.01 g/mol = **17.04 g/mol**

Answer: The students at the high school will smell the ammonia gas first because its lower molar mass permits it to diffuse at a faster rate.

16 /4

Number of moles of N_2

$= 84.0 \div 28.02$ g/mol
= 3.00 moles

Volume of the tire

$$= \frac{nRT}{P}$$
$$= \frac{3.00\text{ mol} \times 8.31\text{ kPa} \bullet \text{L/mol} \bullet \text{K} \times 296\text{ K}}{315\text{ kPa}}$$
= 23.4 L

After leaking: number of moles

$$= \frac{PV}{RT}$$
$$= \frac{235\text{ kPa} \times 23.4\text{ L}}{8.31\text{ kPa} \bullet \text{L/mol} \bullet \text{K} \times 288\text{ K}}$$
= 2.30 moles

Mass present

2.30 moles $\times$ 28.02 g/mol = 64.4 g

Answer: The mass of nitrogen gas that remained in the tire is 64.4 g.

17 /4

Molar mass of $NaClO_3$

22.99 + 35.45 + 3 (16.00) = 106.44 g/mol

Number of moles of $NaClO_3$

$$\frac{3.42\text{ g}}{106.44\text{ g/mol}} = 0.0321\text{ mol}$$

Number of moles of O_2 produced

$$(0.0\ 321\text{ mol}) \times \frac{3}{2} = 0.0482\text{ mol}$$

$$R = \frac{PV}{nT}$$
$$= \frac{102.5\text{ kPa} \times 1.24\text{ L}}{0.0482\text{ mol} \times 347\text{ K}}$$
$$= 7.60\ \frac{\text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}}$$

Answer: The experimental value of the universal gas constant is $\mathbf{7.60}\ \dfrac{\mathbf{kPa \bullet L}}{\mathbf{mol \bullet K}}$.

18 **Example of an appropriate and complete solution** /4

Number of moles of NH_3

$$PV = nRT$$
$$(101.3\text{ kPa})(85\,000\text{ L}) = n(8.31\text{ kPa}\bullet\text{L/mol}\bullet\text{K})(273\text{ K})$$
$$n = 3\,800\text{ mol }NH_3$$

Number of moles of $(NH_4)_2SO_4$

$$2\text{ mol }NH_3 = 1\text{ mol }(NH_4)_2SO_4$$
$$3\,800\text{ mol }NH_3 = 1\,900\text{ mol }(NH_4)_2SO_4$$

Convert to mass

$$1\,900\text{ mol }(NH_4)_2SO_4 = \frac{x}{132.17\text{ g/mol}}$$
$$x = 251\,000\text{ g or }251\text{ kg}$$

Answer: The mass of ammonium sulfate that can be produced from 85.0 kL of ammonia gas at STP is **251 000 g or 251 kg**.

19 **Example of an appropriate and complete solution** /4

Application of Hess' law

$NaOH_{(aq)} \rightarrow NaOH_{(s)}$ $\Delta H = +\,44.2\text{ kJ}$

$NaOH_{(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$ $\Delta H = -100.1\text{ kJ}$

$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$ $\Delta H = -55.9\text{ kJ}$

Determining the heat generated by the heat of neutralization

$$-Q_{neutralization} = +Q_{water}$$
$$Q_{neutralization} = -(m_{water})(c_{water})(\Delta T_{water})$$
$$= -(300.0\text{ g})(4.19\text{ J/g°C})(38.0\text{°C} - 25.0\text{°C})$$
$$= -16341\text{ J}$$
$$= -16.3\text{ kJ}$$

Determining the number of moles

$$\frac{-55.9\text{ kJ}}{1\text{ mol}} = \frac{-16.3\text{ kJ}}{x}$$
$$x = 0.292\text{ mol}$$

Answer: The number of moles of NaOH used in the third experiment is **0.292**.

20 /4

$$\Delta H = \frac{mc\Delta T}{n}$$

$$n = \frac{3.84\text{ g}}{138.17\text{ g/mol}}$$

$$= 0.0278\text{ mol}$$

$$3.02 \times 10^3\text{ J/mol} = \frac{(100\text{ g})(4.19\text{ J/g°C})(\Delta T)}{0.0278\text{ mol}}$$

$$\Delta T = 2.01 \times 10^{-1}\text{ °C}$$

Answer: The change in the temperature (ΔT) of the water is **2.01×10^{-1} °C** or **0.201°C**.

21 /4

Heat lost by water = Heat gained by stones

$-Q_{\text{water}} = +Q_{\text{stones}}$

$-mc\Delta T = +mc\Delta T$

$-m\text{ (4.19 J/g°C) (63°C} - \text{100.0°C)} = +(3.0 \times 10^3\text{ g) (0.84 J/g°C) (63°C} - \text{21.0°C)}$

$m\text{ (155.03 J/g)} = 105840\text{ J}$

$$m = \frac{105\,840\text{ J}}{155.03\text{ J/g}}$$

$$= 6.8 \times 10^2\text{ g}$$

Since the density of water is 1.0 g/mL, the volume is 6.8×10^2 mL = 0.68 L

Answer: The volume of boiling water that must be prepared is
0.68 L or 6.8×10^2 mL or 680 mL.

22 **Example of an appropriate and complete solution** /4

$C_{(s)} + O_{2\,(g)} \rightarrow CO_{2(g)}$	ΔH = -394.1 kJ/mol	multiply × 6
$6\ C_{(s)} + 6\ O_{2\,(g)} \rightarrow 6\ CO_{2(g)}$	**ΔH = -2364.6 kJ/mol**	
$H_2O_{(l)} \rightarrow H_{2(g)} + \frac{1}{2}\ O_{2(g)}$	ΔH = + 286.2 kJ/mol	reverse × 6
$6\ H_{2(g)} + 3\ O_{2(g)} \rightarrow 6\ H_2O_{(l)}$	**ΔH = -1717.2 kJ/mol**	
$6\ C_{(s)} + 6\ H_{2(g)} + 3\ O_{2(g)} \rightarrow C_6H_{12}O_{6(s)}$	ΔH = - 1274.5 kJ/mol	reverse
$C_6H_{12}O_{6(s)} \rightarrow 6\ C_{(s)} + 6\ H_{2(g)} + 3\ O_{2(g)}$	**ΔH = + 1274.5 kJ/mol**	

Add

$6\ C_{(s)} + 6\ O_{2(g)} \rightarrow 6\ CO_{2(g)}$	ΔH = -2364.6 kJ/mol
$6\ H_{2(g)} + 3\ O_{2(g)} \rightarrow 6\ H_2O_{(l)}$	ΔH = -1717.2 kJ/mol
$C_6H_{12}O_{6(s)} \rightarrow 6\ C_{(s)} + 6\ H_{2(g)} + 3\ O_{2(g)}$	ΔH = + 1274.5 kJ/mol
$C_6H_{12}O_{6(s)} + 6\ O_{2(g)} \rightarrow 6\ CO_{2(g)} + 6\ H_2O_{(l)}$	ΔH = -2807.3 kJ/mol

Number of moles $C_6H_{12}O_{6(s)}$ = 90.0 g/180 g/mol
= 0.500 mol
2807.3 kJ/mol × 0.500 mol = **1403.7 kJ**

Answer: The amount of heat produced by the combustion of 90.0 g of glucose is **1403.7 kJ**.

23 **Example of an appropriate and complete solution** /4

1. Increase the concentration of the HCl.

   Explanation: A greater concentration of HCl will result in more collisions with the oxygen gas, resulting in a greater rate of reaction.

2. Increase the concentration of oxygen gas. (Increase the pressure on the system by adding oxygen or decrease the volume of the container.)

   Explanation: A greater concentration of oxygen gas will result in more collisions with the HCl, resulting in a greater rate of reaction.

Answer continued on next page…

3. Add a catalyst.

   Explanation: Adding a catalyst will lower the activation energy allowing a greater percentage of the collisions to be effective and lead to the formation of the products.

   OR

   Adding a catalyst provides an alternative pathway for the reaction and so effective collisions occur more readily and therefore more quickly.

4. Increase the temperature.

   Explanation: Increasing the temperature increases the speed of the molecules, which results in more collisions per second. It also means that the reacting molecules have greater kinetic energy and will be able to reach the activation energy needed more often resulting in a greater rate of reaction.

24 **Mass of hydrogen at 5 s** /4

0.08 g

Mass of hydrogen at 25 s

0.12 g

Mass of hydrogen produced between 5 s and 25 s

0.12 – 0.08 = 0.04 g

Mass of silver consumed

$$\frac{0.04 \text{ g of } H_2}{2.02 \text{ g/mol}} \times \frac{2 \text{ Ag}}{1 \, H_2} \times 107.87 \text{ g/mol} = 4 \text{ g}$$

Average rate of consumption of Ag

$$\frac{4 \text{ g}}{20 \text{ s}} = 0.2 \text{ g/s}$$

Answer: The average rate of consumption of silver between 5 s and 25 s is **0.2 g/s**.

25 **Example of an appropriate and complete solution** /4

Initially, [HCl]

$10^{-1.00}$ mol/L = 0.100 mol/L

Number of moles of HCl

0.100 mol

At 25 s, [HCl]

$10^{-2.00}$ mol/L = 0.0100 mol/L

Number of moles of HCl

0.0100 mol

Number of moles of HCl used in 25 s

0.100 – 0.0100 = 0.090 mol

Moles of CO_2 produced

$$0.090 \text{ mol} \times \frac{1\,CO_2}{2\,HCl} = 0.045 \text{ mol } CO_2$$

Rate of formation of CO_2

$$\frac{0.045 \text{ mol}}{25 \text{ s}} = 0.0018 \text{ mol/s}$$

Answer: The average rate of formation of carbon dioxide gas was **0.0018 mol/s**.

Note: Accept the answer 0.079 g/s also.

26 **Example of an appropriate and complete solution** /4

1. Cool the system. Because the system is exothermic, decreasing the temperature will shift the equilibrium to produce more heat and therefore favour the products.

2. Decrease the pressure or increase the volume of the system. The reaction will shift to the side with the more gas molecules (products).

3. Remove oxygen from the system. This will cause the system to shift towards the products to replace the oxygen that has been removed.

4. Increase the concentration of hydrogen peroxide. This will shift the system to the products to use up the added reactant.

Allot 1 mark for each correct response and appropriate explanation.

27 /4

	$[SO_2]$	$[O_2]$	$[SO_3]$
Initial	1.20 mol ÷ 4.0 L = 0.30 mol/L	1.00 mol ÷ 4.0 L = 0.25 mol/L	0 mol/L
Change	0.10 – 0.30 = - 0.20 mol/L	- 0.20 × 1/2 = - 0.10 mol/L	+0.20 mol/L
Equilibrium	0.40 mol ÷ 4.0 L = 0.10 mol/L	0.25 – 0.10 = 0.15 mol/L	0.20 mol/L

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$
$$= \frac{0.20^2}{0.10^2 \times 0.15}$$
$$= 27$$

Answer: The value of the equilibrium constant, K_c, for this reaction is **27**.

28 /4

RICE table

	Reaction: $CH_3COOH_{(aq)}$	$H^+_{(aq)}$	$CH_3COO^-_{(aq)}$
Initial:	0.30	0	0
Change:	$-x$	$+x$	$+x$
Equilibrium	0.30	x	x

Put into equilibrium expression:

$$1.8 \times 10^{-5} = \frac{(x)(x)}{0.30}$$

$x = 2.3 \times 10^{-3}$ mol/L
$= [H^+]$

Find pH
$-\log [H^+] = 2.6$

Answer: The pH of the solution of acetic acid is **2.6**.

29 /4

1. The balanced net equation for this cell is

$$2\,Fe^{3+}_{(aq)} + 2\,e^- \rightarrow 2\,Fe^{2+}_{(aq)}$$
$$Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$$
$$2\,Fe^{3+}_{(aq)} + Zn_{(s)} \rightarrow 2\,Fe^{2+}_{(aq)} + Zn^{2+}_{(aq)}$$

2. The E^o value is: 0.77 V + 0.76 V = 1.53 V

3. The oxidizing agent is $Fe^{3+}_{(aq)}$

4. No

   Increasing the concentration of Zn^{2+} will shift the reaction towards the left, which would lower the E^o value, and would decrease the reduction of iron(III) ions.

CHEMISTRY 534
ANSWERS
EXAM #3
JUNE 2007

1 B

2 C

3 D

4 B

5 B

6 C

7 A

8 C

9 D

10 A

11 D

12 A

13 C

14 A

15 **Example of an appropriate and complete solution** /4

P = 12 books
k = 90.0 books • mL
V = ?

Find V

$$PV = \frac{k}{P}$$
$$= \frac{90.0 \text{ books} \bullet \text{mL}}{12 \text{ books}}$$
$$= 7.50 \text{ mL}$$

Answer: When 12 books are placed on the syringe, the volume will be **7.50 mL**.

16 **Example of an appropriate and complete solution** /4

$$T = 20.0 + 273$$
$$= 293\ \text{K}$$

$$V = 468\ \text{mL} \times \frac{1\ \text{L}}{1000\ \text{mL}}$$
$$= 0.468\ \text{L}$$

$$(1.27\ \text{g KClO}_3) \times \left(\frac{1\ \text{mol}}{122.45\ \text{g}}\right) = 0.01\ \text{mol KClO}_3$$

$$(0.01\ \text{mol KClO}_3) \times \left(\frac{3\ \text{mol O}_2}{2\ \text{mol KClO}_3}\right) = 0.016\ \text{mol O}_2$$

$$PV = nRT$$
$$R = \frac{PV}{nT}$$
$$= \frac{(94.7)(0.468)}{(0.016)(293)}$$
$$= 9.45\ \frac{\text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}}$$

Answer: The gas **cannot** be considered an ideal gas.

17 **Example of an appropriate and complete solution** /4

P = 98.0 kPa
V = 334 mL
n = ?
$$R = 8.31\ \frac{\text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}}$$
T = 20.0 °C

334 mL = 0.334 L

20.0 + 273 = 293 K

Continued on next page…

Gas	Molar mass g/mol
CH_4	16.01
CO_2	44.01
O_3	48
CHF_3	70.02
CF_4	88.01

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$= \frac{(98.0\ \text{kPa})(0.334\ \text{L})}{\left(8.31\ \frac{\text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}}\right)(293\ \text{K})}$$

$$= 0.0134\ \text{mol}$$

$$m_{(\text{gas})} = m_{(\text{flask + gas})} - m_{(\text{flask})}$$

$$= 51.96\ \text{g} - 51.02\ \text{g}$$

$$= 0.94\ \text{g}$$

$$mm = \frac{m_{(\text{gas})}}{n_{(\text{gas})}}$$

$$= \frac{0.94\ g}{0.0134\ \text{mol}}$$

$$= 70.2\ \text{g/mol}$$

Answer: The unknown gas is most likely **CHF_3** because its molar mass is closest to 70.2 g/mol.

18 **Example of an appropriate and complete solution** /4

Using

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$n = \frac{(100\ \text{kPa} \times 0.1741\ \text{L})}{[8.31\ (\text{kPa L/mol K}) \times (273 + 30.0\ °\text{C})]}$$

$$n = 0.00691\ \text{moles of hydrogen}$$

Since the number of moles of hydrogen and magnesium are equivalent,

then

$$(0.00691\ \text{mol Mg})\left(\frac{24.31\ \text{g}}{1\ \text{mol Mg}}\right) = 0.1679\ \text{g}$$

$$= 0.168\ \text{g of Mg used}$$

19 **Example of an appropriate and complete solution** /4

$$\begin{aligned} Q &= mc\Delta T \\ &= (225\text{ g} + 375\text{ g})(4.19\text{ J/g °C})(30.0\text{ °C}) \\ &= 75\ 420\text{ J} \end{aligned}$$

$$C = \frac{n}{V}$$

$$1 = \frac{n}{0.225}$$

$$n = 0.225\text{ mol}$$

Molar heat

$$\frac{75.42\text{ kJ}}{0.225\text{ mol}} = 335.2\text{ kJ/mol}$$

Answer: The molar heat of nitric acid, HNO_3 is **–335** kJ/mol.

20 **Example of an appropriate and complete solution** /4

Reverse equation (3) and change sign for ΔH:

$$C_2H_5OH_{(l)} \rightarrow 2\,C_{(s)} + 3\,H_{2(g)} + \frac{1}{2}O_{2(g)} \qquad \Delta H = +278\text{ kJ}$$

Select equation (2) and not (4) since the former contains the needed liquid H_2O. Multiply by 3.

$$3\,H_{2(g)} + \frac{3}{2}O_{2(g)} \rightarrow 3\,H_2O_{(l)} \qquad \Delta H = 3(-285) = -855\text{ kJ}$$

Double equation (1)

$$2\,C_{(s)} + 2\,O_{2(g)} \rightarrow 2\,CO_{2(g)} \qquad \Delta H = -2(394)\text{ kJ} = -788\text{ kJ}$$

Sum:

$$C_2H_5OH_{(l)} + 3\,O_{2(g)} \rightarrow 2\,CO_{2(g)} + 3\,H_2O_{(l)} \qquad \Delta H = -1365\text{ kJ}$$

This is for 1 mole of C_2H_5OH.

We want -5509 kJ $\left(\frac{\text{mole}}{-1365\text{ kJ}}\right)$ = 4.0 moles $C_2H_5OH_{(\ell)}$

4.0 moles $C_2H_5OH_{(\ell)} \times \frac{46\text{ g}}{\text{mole}}$ = 184 g of ethanol

Answer: **184 g** of ethanol is required to produce the same amount of energy as 1 mole of octane.

21 **Example of an appropriate and complete solution** /4

Experiment 1

$$Q = mc\Delta T$$
$$= (50.0 \text{ g})(4.19 \text{ J/g °C})(2.7 \text{ °C})$$
$$= 566 \text{ J } (0.566 \text{ kJ})$$

$$n = \frac{m}{mm}$$
$$= \frac{0.200 \text{ g}}{65.39 \text{ g/mol}}$$
$$= 0.00306 \text{ mol}$$

$$\Delta H = \frac{-Q}{n}$$
$$= \frac{-0.566 \text{ kJ}}{0.00306 \text{ mol}}$$
$$= -185 \text{ kJ/mol}$$

Experiment 2

$$Q = mc\Delta T$$
$$= (50.0 \text{ g})(4.19 \text{ J/g °C})(2.1 \text{ °C})$$
$$= 440 \text{ J } (0.440 \text{ kJ})$$

$$n = \frac{m}{mm}$$
$$= \frac{0.390 \text{ g}}{81.4 \text{ g/mol}}$$
$$= 0.00479 \text{ mol}$$

$$\Delta H = \frac{-Q}{n}$$
$$= \frac{-0.440 \text{ kJ}}{0.00479 \text{ mol}}$$
$$= -91.9 \text{ kJ/mol}$$

Hess' Law

$Zn_{(s)} + 2\ HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$	ΔH = -185 kJ/mol
$ZnO_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_2O_{(\ell)}$	ΔH = 91.9 kJ/mol (reverse)
$H_{2(g)} + \frac{1}{2}\ O_{2(g)} \rightarrow H_2O_{(\ell)}$	ΔH = -286 kJ/mol
$Zn_{(s)} + \frac{1}{2}\ O_{2(g)} \rightarrow ZnO_{(s)}$	ΔH = -379 kJ/mol

22 **Example of an appropriate and complete solution** /4

Using $\text{heat lost } (Q \text{ lost}) = \text{heat gained } (Q \text{ gained})$

$$-(80.5\text{ g})(\text{c})(23.8°\text{C} - 95.7°\text{C}) = (105\text{ g})(4.19\text{ J/g °C})(23.8°\text{C} - 15.6°\text{C})$$
$$-(80.5\text{ g})(\text{c})(-71.9°\text{C}) = (105\text{ g})(4.19\text{ J/g °C})(8.2°\text{C})$$
$$\text{c} = \frac{(105\text{ g})(4.19\text{ J/g °C})(8.2°\text{C})}{(80.5\text{ g})(71.9°\text{C})}$$
$$\text{c} = 0.623\text{ J/g°C}$$

Answer: The specific heat capacity of the piece of brass is **0.623 J/g °C**.

23 **Example of an appropriate and complete solution** /4

Group A
CH_4 because it has the fewest bonds to break

Group B
$CH_3OH_{(g)}$ because substances in their gaseous states react faster.

24 **Example of an appropriate and complete solution** /4

Ratio

$2\ \text{HCl} : 1\ \text{CO}_2$

At time 0

$0.249\ \text{mol HCl} : 0.125\ \text{mol CO}_2$

Ratio

$2\ \text{HCl} : 1\ \text{CO}_2$

At 7 minutes

$0.244\ \text{mol HCl} : 0.122\ \text{mol CO}_2$

$$\frac{\Delta \text{mol HCl}}{\Delta t} = \frac{0.125 - 0.122}{7\ \text{min}} = \frac{0.00300\ \text{mol}}{7\ \text{min}} = 4.29 \times 10^{-4}\ \text{mol/ min}$$

.

25 **Example of an appropriate and complete solution** /4

Question A

Curve 1 represents the reaction without a catalyst. Since the volume is not increasing as quickly as in curve 2, the rate of reaction is slower for curve 1.

Question B

Diagram 2 represents the reaction with a catalyst. Since the activation energy is lower in diagram 2, this one represents the reaction with a catalyst.

26 **Example of an appropriate and complete solution** /4

	$2\ H_2$	$2\ NO \leftrightarrow N_2$	$H_2O_{(\ell)}$ is ignored
Initial	$\frac{4.0}{2.0}$ = 2.0 M	2.0 M	0
Change	0.40 × 2 = 0.80 M	0.40 × 2 = 0.80 M	0.40 M
Equilibrium	(2.0 – 0.80) M = 1.2 M	(2 – 0.80) M = 1.2 M	$\frac{0.80}{2.0}$ = 0.40 M

$$K_c = \frac{[N_2]}{[H_2]^2\,[NO]^2} = \frac{0.40}{(1.2)^2\,(1.2)^2} = 0.19$$

Answer: The value for K_c is **0.19**.

27 **Example of an appropriate and complete solution** /4

	$HCOOH$	+	H_2O	$\rightarrow$	H_3O^+	+	$HCOO^-$
I	0.1 mol		–		0		0
C	$-x$		–		$+x$		$+x$
E	$0.1 - x$		–		x		x

$$K_a = \frac{[H_3O^+][HCOO^-]}{[HCOOH]}$$

$$K_a = \frac{(x)(x)}{(0.1-x)} \approx \frac{x^2}{0.1}$$

$$1.77\times10^{-4} = \frac{x^2}{0.1}$$

$$0.1(1.77\times10^{-4}) = x^2$$

$$1.77\times10^{-5} = x^2$$

$$\sqrt{1.77\times10^{-5}} = x$$

$$4.21\times10^{-3} = x$$

$$x = [H_3O^+] = 4.21\times10^{-3}$$

$$pH = -\log[H^+]$$

$$pH = -\log 4.21\times10^{-3}$$

$$pH = 2.38$$

Answer: The pH of the solution is **2.38**.

Note: Accept 2.37 and 2.39 also.

28 **Example of an appropriate and complete solution** /4

A) The **aluminum** electrode is oxidized.

B)

$3\ Cu^{2+}_{(aq)} + 6\ e^- \rightarrow 3\ Cu_{(s)}$	E° = +0.34 V
$2\ Al_{(s)} \rightarrow 2\ Al^{3+}_{(aq)} + 6\ e^-$	E° = +1.66 V
$\mathbf{3\ Cu^{2+}_{(aq)} + 2\ Al_{(s)} \rightarrow 3\ Cu_{(s)} + 2\ Al^{3+}_{(aq)}}$	E° = +2.00 V

C) The standard cell potential is **+2.00 V**.

D) $Cu^{2+}_{(aq)} + 2\ e^- \rightarrow Cu_{(s)}$ is the reduction half-cell.

Assign **one mark** for each correct answer.

29 **Example of an appropriate and complete solution** /4

A) The complete cell reaction is:

$2\ Ag^{+}_{(aq)} + 2\ e^{-} \rightarrow 2\ Ag_{(s)}$	$E° = +0.80$ V
$Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2\ e^{-}$	$E° = -0.34$ V
$\mathbf{2\ Ag^{+}_{(aq)} + Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2\ Ag_{(s)}}$	$E° = +0.46$ V

B) The net cell voltage is **+0.46 V**.

C) A method to increase the net cell voltage is **to increase the concentration of $AgNO_3$**.

D) By adding NaCl to the system, the net cell voltage would **decrease** because **the concentration of Ag^{+} would decrease**.

ANSWERS
EXAM #4
JUNE 2006

1 A

2 C

3 D

4 D

5 A

6 C

7 B

8 D

9 B

10 D

11 B

12 A

13 B

14 C

15 **Example of an appropriate and complete solution**

$$\frac{P_1 \bullet V_1}{T_1} = \frac{P_2 \bullet V_2}{T_2}$$

$$\frac{101.8\ \text{kPa} \bullet 1.5\ \text{L}}{295\ \text{K}} = \frac{102.3\ \text{kPa} \bullet \text{V}_2}{306\ \text{K}}$$

V_2 = 1.55 L OR V_2 = 1550 mL

Answer: The volume of the balloon when it is outside is **1.55 L or 1550 mL.**

16 **Example of an appropriate and complete solution**

Answer: The balloon that will deflate the fastest is **A**.

Justification: Helium diffuses faster than carbon dioxide because helium has a smaller molar mass.
Rate of diffusion increases when temperature increases because the gas molecules move faster.

17 **Example of an appropriate and complete solution**

Mass of NH_3 in the tank
8421 g – 8275 g = 146 g

Number of moles of NH_3
146 g ÷ 17.0 g/mol = 8.59 mol

Number of moles of CO_2 = Number of moles of NH_3
= 8.59 mol

Mass of CO_2
8.59 mol × 44.0 g/mol = 378 g

Total mass of the cylinder and CO_2
8275 g + 378 g = 8653 g

Answer: The total mass of the tank and carbon dioxide is **8653 g**.

18 **Example of an appropriate and complete solution**

Moles of S

$$\frac{6.40\text{ g}}{32.0\text{ g/mol}}$$

= 0.200 mol

Moles of H_2S

$$\frac{2\text{ mol }H_2S}{x\text{ mol}} = \frac{3\text{ mol S}}{0.200\text{ mol}}$$

mol H_2S = 0.133 mol

T = 294 K

P = 67.5 kPa

R = 8.31 kPa•L/mol•K

$PV = nRT$
(67.5 kPa)(L) = (0.133 mol)(8.31 kPa•L/mol•K)(294 K)
= 4.81 L H_2S

Answer: The volume of the container is **4.81 L**.

19 **Example of an appropriate and complete solution**

$$\Delta H = \frac{-mc\Delta T}{\text{mol HCl}}$$

m = 70.0 g

c = 4.19 J/g°C

ΔT = 29.8°C – 22.4°C
= 7.4°C

mol HCl = 3.00 mol/L × 0.0200 L
= 0.0600 mol

$$\Delta H = \frac{-(70.0\text{ g})(4.19\text{ J/g°C})(7.4\text{ °C})}{0.0600\text{ mol}}$$

= - 36 000 J/mol or - 36 kJ/mol

Answer: The molar heat of neutralization of $HCl_{(aq)}$ is **- 36 000 J/mol or - 36 kJ/mol.**

20 Mass of water in each cup

125 mL × 1.00 g/mL = 125 g

Heat lost by metal cube = Heat gained by water

$-Q_{(metal)} = +Q_{(water)}$

Cube A: -[(115 g) (c) (32°C – 98°C)] = (125 g) (4.19 J/g°C) (32°C – 21°C)
c = 0.76 J/g°C

Cube B: -[(132 g) (c) (35°C – 98°C)] = (125 g) (4.19 J/g°C) (35°C – 21°C)
c = 0.88 J/g°C

Cube C: -[(175 g) (c) (37°C – 98°C)] = (125 g) (4.19 J/g°C) (37°C – 21°C)
c = 0.79 J/g°C

Answer: The metal cube with the largest heat capacity is **Cube B**.

21 Example of an appropriate and complete solution

Heat absorbed by the water

$Q = mc\Delta T$

275 g × 4.19 J/g°C × (94.7 – 16.4)°C = 90 221 J

Molar mass of methanol

12.0 + 4(1.0) + 16.0 = 32.0 g/mol

Mass of methanol burned

642.53 g – 635.68 g = 6.85 g

Number of moles of methanol burned

6.85 g ÷ 32.0 g/mol = 0.214 mol

ΔH

-90 221 J ÷ 0.214 mol = -422 000 J/mol or -422 kJ/mol

Answer: The molar heat of combustion (ΔH) of methanol is -422 000 J/mol or -422 kJ/mol.

22 **Examples of an appropriate and complete solution**

$N_2O_{5(g)} \rightarrow N_{2(g)} + \frac{5}{2} O_{2(g)}$	ΔH = -14 kJ
$N_{2(g)} + 3\ O_{2(g)} + H_{2(g)} \rightarrow 2\ HNO_{3(aq)}$	ΔH = -348 kJ
$H_2O_{(l)} \rightarrow H_{2(g)} + \frac{1}{2} O_{2(g)}$	ΔH = +286 kJ
$N_2O_{5(g)} + H_2O_{(l)} \rightarrow 2\ HNO_{3(aq)}$	ΔH = -76 kJ

Answer: **The heat of reaction (ΔH) for this reaction is** -76 kJ**.**

23 **Example of an appropriate and complete solution**

Rate of reaction

$$\frac{\Delta m}{\Delta t}$$

$$= \frac{1\ \text{mol}}{4\ \text{s}}$$

$$= 0.25 \frac{\text{mol}}{\text{s}}$$ for Petroleum

Rate of oxygen consumption

$$0.25\ \text{mol/s} \times \frac{25}{2}$$

$$= 3.1 \frac{\text{mol}}{\text{s}}$$

Answer: The average rate of consumption of oxygen gas is 3.1 mol/s.

24 **Example of an appropriate and complete answer**

For 0-10 s

moles $Fe_{(s)}$ used = 1.10 mol – 0.75 mol
= 0.35 mol

moles $CO_{(g)}$ present

$Fe(s) : Co_{(g)}$ = 3:2

moles $CO_{(g)}$ = 0.35 mol × $\frac{3}{2}$

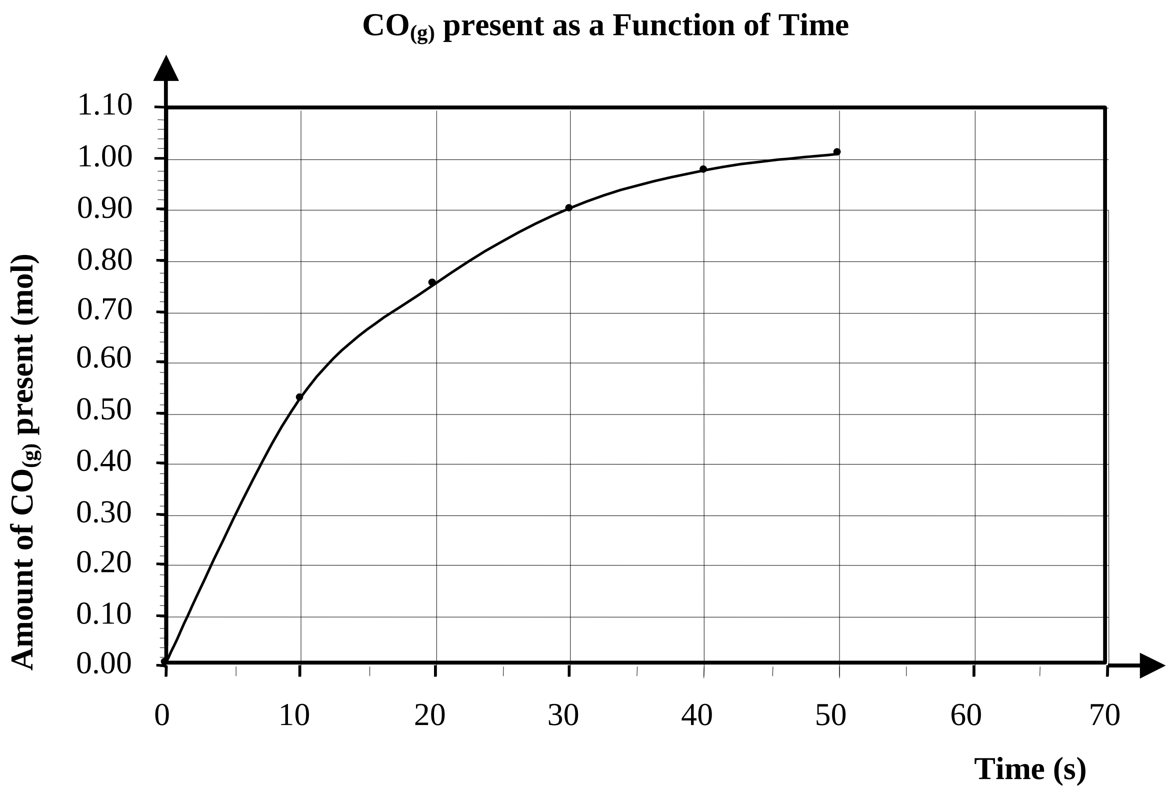
= 0.553 mol

At 10 s, 0.53 moles of $CO_{(g)}$ is present.

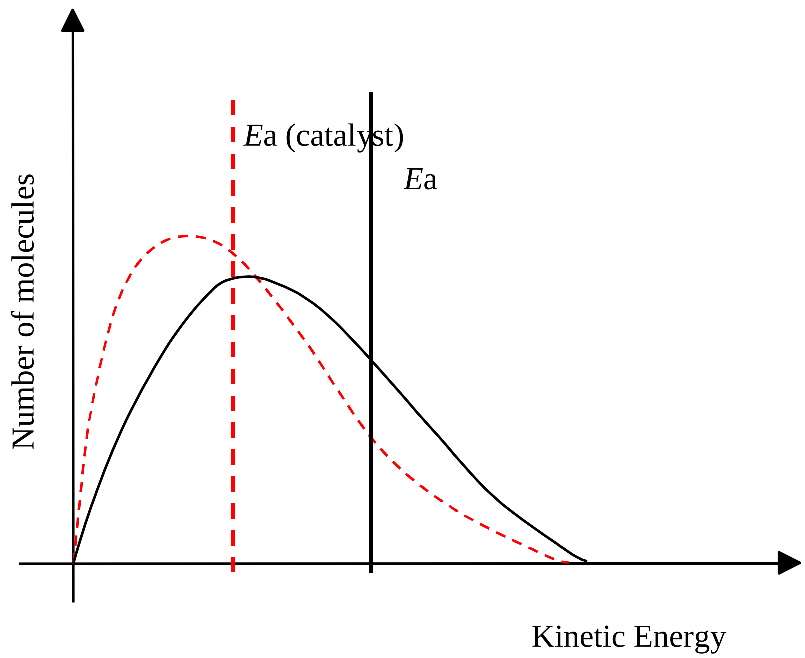
Repeat calculations for subsequent intervals.

The following table summarizes the results.

Time (s)	$Fe_{(s)}$ present (mol)	$Fe_{(s)}$ used (mol)	$CO_{(g)}$ present (mol)
0	1.10	0	0
10	0.75	0.35	0.53
20	0.60	0.50	0.75
30	0.50	0.60	0.90
40	0.45	0.65	0.98
50	0.42	0.68	1.02


CO(g) present as a Function of Time
Amount of CO(g) present (mol)
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
10
20
30
40
50
60
70
Time (s)

25 Example of an appropriate and complete solution



Justification: Decreasing the temperature increases the probability of finding molecules with lower energy levels; hence, the curve shifts to the left.

When a catalyst is added, the reaction follows an alternate pathway that has a lower activation energy. This results in the activation energy (E_a) shifting to the left.

26 **Example of an appropriate explanation**

1. Yes ❑ No ☑
   Raising the temperature will favour the endothermic reaction, which in this case will favour the reactants, and this is undesirable.

2. Yes ☑ No ❑
   According to Le Chatelier's principle, increasing the pressure will cause the system to shift in favour of the reaction that has the fewest moles of gas molecules. Since there are two moles of gas molecules on the left side of the equation, and one mole of gas molecules on the right side of the equation, the system will shift to favour the production of ethanol.

3. Yes ❑ No ☑
   Adding more catalyst will have no effect on the position of equilibrium. A catalyst only affects the rate at which equilibrium is established.

4. Yes ☑ No ❑
   According to Le Chatelier's principle, adding a reactant causes the equilibrium to shift towards the product, consuming the reactant and producing more ethanol.

27

	$NH_{3(g)}$	$O_{2(g)}$	$NO_{(g)}$	$H_2O_{(g)}$
Initial Concentration (mol/L)	1.5	2.0	0	0
Change in concentration (mol/L)	-0.80	-1.0	0.80	1.2
Equilibrium concentration (mol/L)	0.7	1.0	0.80	1.2

$$K_c = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$$

$$= \frac{[0.80]^4[1.2]^6}{[0.7]^4[1.0]^5}$$

$$= \mathbf{5.09}$$

Answer: The equilibrium constant, K_c, for this reaction is **5**.

28

$[H_3O^+] = 10^{-pH}$
$= 10^{-4.6}$
$= 2.5 \times 10^{-5}$ mol/L

$[OBr^-] = [H_3O^+]$
$= 2.5 \times 10^{-5}$ mol/L

Since the pH is relatively large, the acid is quite weak and the ionization will not create an appreciable change in the concentration of the hypobromous acid.

Therefore,

[HOBr] = 0.085 mol/L

K_a

$$\frac{[H_3O^+] \times [OBr^-]}{[HOBr]} = \frac{(2.5\times10^{-5})(2.5\times10^{-5})}{(0.085)}$$

$= 7.4 \times 10^{-9}$

Answer: The acid ionization constant, K_a, for this acid is $\mathbf{7.4 \times 10^{-9}}$.

29

Example of an appropriate and complete answer

a) The $E°$: 1.56 V

b) From Zinc to Silver

c) $2\ Ag^+_{(aq)} + Zn_{(s)} \rightarrow 2\ Ag_{(s)} + Zn^{2+}_{(aq)}$

d) Zinc is the anode.

ANSWERS
EXAM #5
JUNE 2005

1 D

2 D

3 C

4 A

5 C

6 D

7 C

8 A

9 A

10 D

11 B

12 C

13 C

14 B

15 **Example of an appropriate and complete solution**

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

$$\frac{P_1\,(2\text{ L})}{n\,(293\text{ K})} = \frac{P_2\,(0.5\text{ L})}{0.5\,n\,(253\text{ K})}$$

$$\frac{P_1\,(2\text{ L})}{n\,(293\text{ K})} = \frac{P_2\,(0.5\text{ L})}{0.5\,n\,(253\text{ K})}$$

$$\frac{2\text{ L}}{n\,(293\text{ K})} \times \frac{253\text{ K}\,(0.5\,n)}{(0.5\text{ L})}\,P_1 = P_2$$

$$1.73\,P_1 = P_2$$

Answer: The ratio is **1.73 : 1**.

16 Step 1: Find mass of nitroglycerine.

$d = \frac{1.59\text{ g}}{\text{mL}}$

$\frac{1.59\text{ g}}{\text{mL}} = \frac{\text{mass}}{100\text{ mL}}$

159 g of nitroglycerine present in 100 mL.

Step 2: Find moles of H_2O gas

M for nitro glycerine = $\frac{227\text{ g}}{\text{mol}}$

$\frac{159\ g}{\frac{227\text{ g}}{\text{mol}}}$ = 0.70 mol of nitro glycerine

$$\frac{4\text{ mol }C_3H_5(ONO_2)_{3(l)}}{0.70\text{ mol }C_3H_5(ONO_2)_{3(l)}} = \frac{10\text{ mol }H_2O_{(g)}}{x\text{ mol }H_2O_{(g)}}$$

x = 1.75 mol $H_2O_{(g)}$

Step 3: Find volume $H_20_{(g)}$

Use either:

A. Ideal gas Law, $PV = nRT$

or

B. Avogadro, at STP 1 mol gas = 22.4 L

Answer: The volume of water vapour produced is **39 L**.

17 Mass of unknown gas

47.61 g – 46.02 g = **0.69 g**

$PV = nRT$

$n = \frac{PV}{RT}$

$= \frac{46.9\text{ kPa} \times 0.296\text{ L}}{8.31\frac{\text{kPa L}}{\text{mol K}} \times (18 + 273)}$

= **0.00574** mols unknown gas

Molar mass of unknown gas

$\frac{0.69\text{ g}}{0.00574\text{ mols}}$

= 120.2 g/mol

Therefore, the unknown gas is CF_2Cl_2

Answer: The unknown gas is most likely **CF_2Cl_2** because its molar mass is 121 g/mol.

18 a) Temperature **has a direct effect on the average kinetic energy** of a molecule. Colder temperatures imply that the **molecules will move at a slower rate**. Since the molecules are moving at a slower rate they will diffuse (spread out) at a slower pace.

b) The molecular mass of helium is less than the molar mass of oxygen. Because both gases have the same kinetic energy, the velocity of the helium molecules must be greater than the velocity of the helium molecules must be greater than the velocity of the oxygen molecules. Therefore helium will diffuse more rapidly.

19

$\Delta T_{water} = 26\ °C - 14\ °C = 12\ °C$

$\Delta T_x = 95\ °C - 26\ °C = 69\ °C$

$M_w C_w \Delta T_w = M_x C_x \Delta T_x$

$$C_x = \frac{M_w C_w\ \Delta T_w}{M_x\ \Delta T_x}$$

$$= \frac{(65\ g)(12\ °C)(4.19\ J/g°C)}{(150\ g)(69\ °C)}$$

= 0.32 J/g °C

Answer: The specific heat capacity of the unknown metal is **0.32 J/g °C**.

20 1. Moles of $NaOH_{(aq)}$ used

$M = \frac{n}{V}$ or $n = MV$

(1.0 mol/L)(50.0 mL/1000mL) = 0.050 moles

2. Heat absorbed

$Q = mc\Delta T$

(70.0 g)(4.19 J/(g°C)(29.8-22.3 °C) = 2200 J

3. Since Q for the surroundings is positive, Q for the system must be negative (or -2200 J)

4. Molar heat of neutralization

$\Delta H = \frac{Q}{n}$

$\frac{-2200\ J}{0.050\ moles}$ NaOH

-44000 J or -44 kJ/mol NaOH

Answer: ΔH is **-44 kJ/mol NaOH**.

21 Moles of diamond used

$$\frac{1.00\text{ g}}{12.01\text{ g/mol}} = 8.33 \times 10^{-2}\text{ mol C}$$

$Q = mc_{\text{water}}\,\Delta T$
$= (150.0\text{ g})(4.19\text{ J/(g°C)})(74.5 - 22.0\text{ °C})$
$= 3.30 \times 10^{4}\text{ J}$

Q for diamonds is -3.30×10^{4} J or -3.30×10^{1} kJ

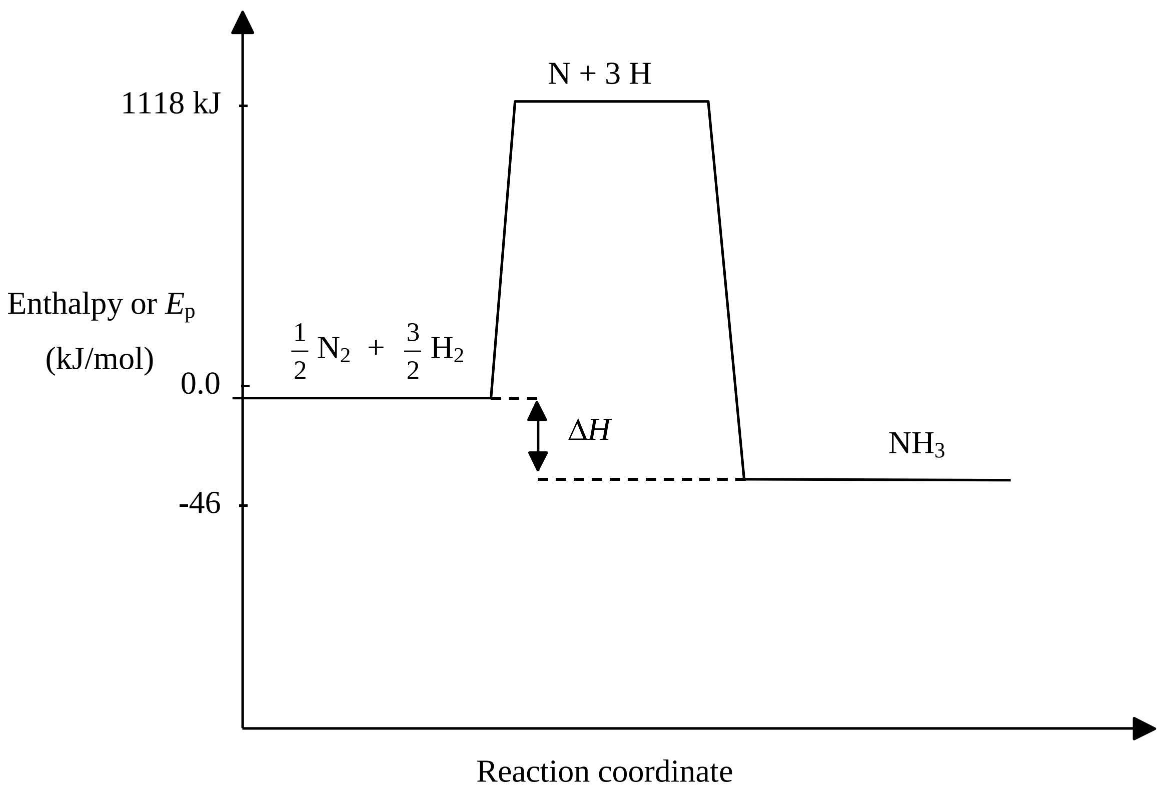
Molar Heat of Combustion

$$\frac{Q}{n} = \frac{(-3.30 \times 10^{1}\text{ kJ})}{(8.33 \times 10^{-2}\text{ moles})}$$

$= -396$ kJ/mol

Answer: **ΔH is** -396 kJ/mol or -396 000 J/mol**.**

22



Criteria:

1. *y* axis is labelled correctly, including units and values.
2. Correct ΔH.
3. Activation energy values are correctly indicated.
4. Reactants, activated complex, and products are correctly labelled.

23 Rate of N_2 consumption

$$\frac{(0.60 - 4.00)\,\text{mol/L}}{50\text{ min}} = -0.068 \text{ or } -6.8 \times 10^{-2} \text{ mol/L/min}$$

Rate of NH_3 production

$$\frac{-6.8 \times 10^{-2}\text{ mol/L}}{\text{min}} \times \frac{2\text{ mol }NH_3}{1\text{ mol }N_2} = 1.4 \times 10^{-1} \text{ mol/L/min}$$

Answer: **The average rate of ammonia production is** 1.4×10^{-1} mol/L/min**.**

24 (I) NO
(II) OH^-
(III) OH^- and NO

25 Example of an appropriate and complete solution

a) **Data Table**

Time (min)	$[I^-]$ (mol/L)	$[I_2]$ (mol/L)
0.0	0.0800	**0**
0.2	0.0400	**0.02**
0.4	0.0200	**0.03**
0.6	0.0100	**0.035**
0.8	0.0050	**0.0375**
1.0	0.0025	**0.0387**

b) **Calculate the rate**

$$\text{Rate} = \frac{(0.03875 - 0)\,\text{mol/L}}{1.0 - 0.0\text{ min}}$$

$$= \frac{0.03875\text{ mol/L}}{1.0\text{ min}}$$

= 0.03875 mol/L/min
= 3.88×10^{-2}
= 3.9×10^{-2} mol/L/min

Answer: The average rate of reaction for the production of $I_{2(aq)}$ is **3.9×10^{-2} mol/L/min**.

26 **Example of an appropriate and complete answer**

	$4\ NH_{3(g)}$	+ $3\ O_{2(g)}$	$\leftrightarrow$	$2\ N_{2(g)}$	+ $6\ H_2O_{(g)}$
I	0.0150	0.0150		0	0
C	-3.92×10^{-3}	-2.94×10^{-3}		$+1.96 \times 10^{-3}$	$+5.88 \times 10^{-3}$
E	1.11×10^{-2}	1.21×10^{-2}		$+1.96 \times 10^{-3}$	$+5.88 \times 10^{-3}$

$$K_c = \frac{[N_2]^2\,[H_2O]^6}{[NH_3]^4\,[O_2]^3}$$

$$= \frac{[1.96 \times 10^{-3}\ \text{mol/L}]^2\,[5.88 \times 10^{-3}\ \text{mol/L}]^6}{[1.11 \times 10^{-2}\ \text{mol/L}_3]^4\,[1.21 \times 10^{-2}\ \text{mol/L}]^3}$$

$$= 6.01 \times 10^{-6}$$

Answer: The K_c for the reaction at this temperature is $\mathbf{6.01 \times 10^{-6}}$.

27 Example of an appropriate and complete solution

Butanoic Acid

	HA	$\leftrightarrow$	H^+	+	A^-
I	0.15		0		0
C	-1.51×10^{-3}		1.51×10^{-3}	+	1.51×10^{-3}
E	0.148		1.51×10^{-3}		1.51×10^{-3}

$$K_a = \frac{[1.51 \times 10^{-3}\ \text{mol/L}]^2}{0.148\ \text{mol/L}}$$

$$= \mathbf{1.54 \times 10^{-5}}$$

Hydrofluoric Acid

First find $[H^+]$

$$\frac{K_W}{7.59 \times 10^{-10}} = 1.32 \times 10^{-5}$$

	HA	$\leftrightarrow$	H^+	+	A^-
I	0.035		0		0
C	-1.32×10^{-5}		1.32×10^{-5}	+	1.32×10^{-5}
E	0.035		1.32×10^{-5}		1.32×10^{-5}

$$K_a = \frac{[1.32 \times 10^{-5}\ \text{mol/L}]^2}{0.0350\ \text{mol/L}}$$

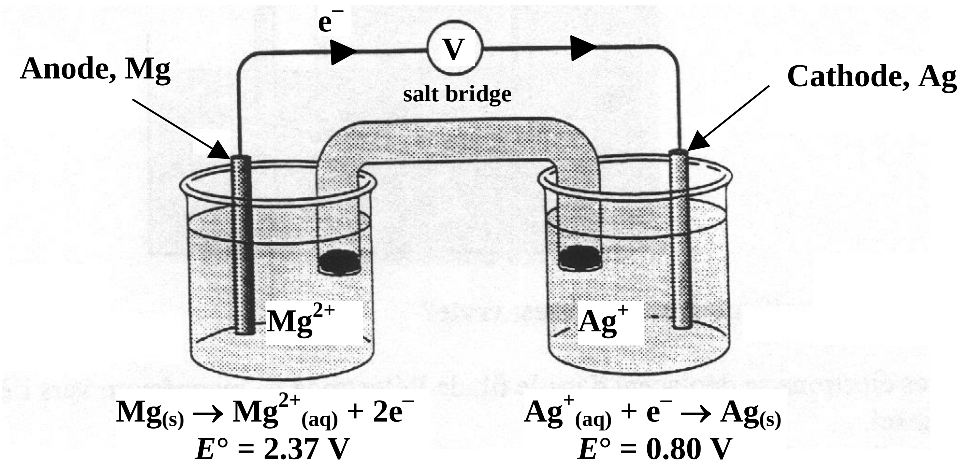
$$= \mathbf{4.98 \times 10^{-9}}$$

Answer: **Butanoic acid** is the stronger of the two.

Note: Comparing percent ionization is an acceptable justification.

28 **Example of an appropriate and complete answer**

a)



b) $E°_{cell}$: 2.37 V + 0.80 V = 3.17 V

c) To increase the cell potential, the concentration of $AgNO_3$ should be increased or the concentration of $Mg(NO_3)_2$ should be decreased.

29 **Example of an appropriate and complete answer**

1. $Fe^{2+} + 2e^- \rightarrow Fe$ -0.44 V
   $Cu \rightarrow Cu^{2+} + 2e^-$ -0.34 V Maintains integrity of pipes (1 mark)
   -0.78 V

2. $Pb^{2+} + 2e^- \rightarrow Pb$ -0.13 V
   $Cu \rightarrow Cu^{2+} + 2e^-$ -0.34 V Maintains integrity of pipes
   -0.47 V

3. $2\,Ag^{+} + 2e^- \rightarrow 2\,Ag$ $+0.80$ V Copper pipe corrodes
   $Cu \rightarrow Cu^{2+} + 2e^-$ -0.34 V
   $+0.46$ V

Answer: The technician did cause chemical reaction to occur in the pipes because silver nitrate corrodes copper pipes.

ANSWERS
EXAM #6
JUNE 2004

1 C

2 B

3 D

4 B

5 A

6 B

7 D

8 B

9 A

10 D

11 D

12 B

13 C

14 D

Part B

15 **Example of an appropriate and complete solution**

1. $\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$ $\therefore T_2 = \frac{P_2V_2n_1T_1}{P_1V_1n_2}$

2. Set P_1, V_1, n_1 and $T_1 = 1$

$$T_2 = \frac{(2\cancel{P_1})\left(\frac{1}{2}\cancel{V_1}\right)(\cancel{n_1})(T_1)}{(\cancel{P_1})(\cancel{V_1})(3\cancel{n_1})} = \frac{1}{3}T_1$$

Answer: The temperature must change by a factor of $\mathbf{\frac{1}{3}}$.

16 **Example of an appropriate and complete solution**

$PV = nRT$
P = 407 inches H_2O
V = 22.4 L
n = 1 mol
$R = x$
T = 273 K

(407 inches H_2O) (22.4 L) = (1.00 mol) (x) (273 K)

$$x = \frac{33.4 \text{ inches } H_2O \bullet L}{mol \bullet K}$$

Answer: The ideal gas constant is $\mathbf{\frac{33.4 \text{ inches } H_2O \bullet L}{mol \bullet K}}$.

17 **Example of an appropriate and complete solution**

Mass of O_2 = 79.078 g – 76.411 g = **2.667 g** of O_2

Mass of other gas = 97.578 g – 76.411 g = **21.167 g** of other gas
Since these masses represent equal volume and therefore equal moles of gases:

$$\frac{\text{molar mass of } O_2}{\text{molar mass of unknown gas}} = \frac{32 \text{ g}}{x} = \frac{2.667 \text{ g}}{21.167 \text{ g}}$$

x = molar mass of unknown gas = 254 g

Since the molar mass of S_2F_{10} is 254 g, the unknown gas is S_2F_{10}.

Answer: The unknown gas is $\mathbf{S_2F_{10}}$.

18 **Example of an appropriate and complete solution**

1. $PV = nRT$
   $(101.3)(3.00 \times 10^3) = n(8.31)(298)$
   123 = n

2. $$\frac{1(C_{17}H_{33}COO)_3C_3H_5}{x} = \frac{3\,H_2}{123}$$
   x = 41.0 mols

3. $n = \frac{m}{mm}$ mm = 884 g/mol
   $41.0 = \frac{m}{884}$
   m = 36 200 g or 36.2 kg

Answer: The mass of hydrogenated Olein is **36 200 g or 36.2 kg**.

Part C

19 **Example of an appropriate and complete solution**

$Q_{oil} = -Q_{water}$

$m_{oil} \times c_{oil} \times \Delta T_{oil} = m_{water} \times c_{water} \times \Delta T_{water}$

$20.0\text{ g} \times c_{oil} \times 20.5°\text{C} = 100\text{ mL} \times 4.19\text{ J/g°C} \times 2.40°\text{C}$

$c_{oil} = 2.45\text{ J/g°C}$

Answer: The unknown liquid is **glycerine**.

20 **Example of an appropriate and complete solution**

Mass

120.0 mL × 1.0 g/mL = 120.0 g

Specific heat

4.19 J/g°C

$\Delta q = m \times c \times \Delta T$
$= (120)(4.19)(2.2)$
$= 1100\text{ J}$
$= -1100\text{ J (or -1.1 kJ)}$

$0.02\text{ L HCl} \times 1.0\ \frac{\text{mol}}{\text{L}}\text{ HCl} = 0.02\text{ moles HCl}$

$$\Delta H = \frac{\Delta q}{n} = \frac{-1.1\text{ kJ}}{0.02\text{ mols}} = -55\text{ kJ/mol}$$

Answer: The ΔH for the reaction is **-55 kJ/mol**.

21 Example of an appropriate and complete solution

$Q = mc\Delta T$ for the oil

$$0.92\ \frac{\text{g}}{\cancel{\text{cm}}^3} \times 500.0\ \cancel{\text{mL}} = 460\ \text{g}$$

$$Q = 460\ \text{g} \times 2.01\ \frac{\text{J}}{\text{g°C}} \times (300.0\text{°C} - 25.0\text{°C})$$

$= 250\ 000$ J or 2.5×10^2 kJ of heat energy to increase the temperature of the oil

$$\frac{1\ \text{mol ethanol}}{-278\ \text{kJ}} \times 2.5 \times 10^2\ \text{kJ} \times \frac{46.0\ \text{g}}{1\ \text{mol ethanol}}$$

= 42 g ethanol required

Answer: 42 g **of ethanol was burned to heat the oil.**

22 **Examples of an appropriate and complete solution**

Approach #1

$$
\begin{array}{lll}
S_\beta + \cancel{O}_{2(g)} \rightarrow \cancel{SO}_{2(g)} & & \Delta H = -299\ \text{kJ} \\
\underline{\cancel{SO}_{2(g)} \rightarrow S_\sigma + \cancel{O}_{2(g)}} & & \underline{\Delta H = +294\ \text{kJ}} \\
S_\beta \rightarrow S_\sigma & & \Delta H = -5\ \text{kJ}
\end{array}
$$

Because the net reaction above is exothermic, the energy released must have been stored as potential energy in S_β. Therefore S_β has 5 kJ more enthalpy than S_σ.

Approach #2

$$
\begin{array}{lll}
S_\sigma + \cancel{O}_{2(g)} \rightarrow \cancel{SO}_{2(g)} & & \Delta H = -294\ \text{kJ} \\
\underline{\cancel{SO}_{2(g)} \rightarrow S_\beta + \cancel{O}_{2(g)}} & & \underline{\Delta H = +299\ \text{kJ}} \\
S_\sigma \rightarrow S_\beta & & \Delta H = +5\ \text{kJ}
\end{array}
$$

Because the net reaction above is endothermic, the energy absorbed is being stored in the product (S_β) as a potential energy. Therefore S_β has 5 kJ more enthalpy than S_σ.

Approach #3

Burning S_β produces 5 kJ more energy than burning S_σ. Since the burning reactions are identical except for the sulphur, the "extra" 5 kJ in the second reaction must have been stored in the S_β. Therefore the S_β has 5 kJ more energy than the S_σ.

Answer: S_β has the higher enthalpy.

Part D

23 **Example of an appropriate and complete answer**

1. At 20 s, $[AlCl_3]$ = 0.28 mol
   At 10 s, $[AlCl_3]$ = 0.37 mol **(moles $AlCl_3$ ±0.02 mol)**

   0.37 mol – 0.28 mol = 0.09 mol $AlCl_3$

2. 0.09 mol $AlCl_3$ × $\frac{3\text{ mol }Cl_2}{2\text{ mol }AlCl_3}$ = 0.14 mol Cl_2

3. $\frac{0.14\text{ mol }Cl_2}{20\text{ s} - 10\text{ s}}$ = 0.014 $\frac{\text{mol}}{\text{s}}$ $Cl_{2(g)}$

Answer: The average rate of formation of $Cl_{2(g)}$ between 10 s and 20 s was **0.014** $\mathbf{\frac{mol}{s}}$.

24 The surface area of the flour has been greatly increased and is mixing with the oxygen in the air.

By increasing the surface area, more effective collisions will occur between the flour and the oxygen, thereby increasing the rate of the reaction.

25 In the second experiment, the marble slab is sliced into two parts. As a consequence, the surface area of the marble will be doubled and the rate will double.

Since this is experimental data, some variation (± 1 sec) in the data and in the answers must be allowed. The final time must be close to 23 sec (≈ $\frac{45}{2}$).

Answer:

Volume of gas	5 mL	10 mL	15 mL	20 mL	25 mL	30 mL
Elapsed time	**4 s**	**8 s**	**11 s**	**15 s**	**19 s**	**22 s**

The surface area of the four edges of the slab is not doubled when the slab is cut but this will be a very minor factor given that the slab of marble is said to be "very thin".

Calculate the rate:

$$\text{Average rate} = \frac{30\text{ mL of }CO_2}{22\text{ s}}$$

$$= \frac{1.4\text{ mL of }CO_2}{\text{s}}$$

Answer: The average rate of reaction in the second experiment is $\frac{\mathbf{1.4\ mL\ of\ CO_2}}{\mathbf{s}}$.

Part E

26 **Example of an appropriate and complete answer**

R	$SO_{2(g)}$	$\longleftrightarrow$	$S_{(s)}$	$+\ O_{2(g)}$
I	$\frac{0.5\ \text{mol}}{10\ \text{L}}$		—	—
C	$-x$		—	$+x$
E	$0.05 - x$		—	x

$$K_{eq} = \frac{[O_2]}{[SO_2]} = 2.4 \times 10^{-2}$$

$$\frac{x}{0.05\ \frac{\text{mol}}{\text{L}} - x} = 2.4 \times 10^{-2}$$

$$x = 1.2 \times 10^{-3} - 2.4 \times 10^{-2}\,x$$

$$x = 1.2 \times 10^{-3}$$

$[O_2]$ = 0.0012 mol/L $[SO_2]$ = 0.049 mol/L

If student states that the change in concentration is negligible, we calculate by:

$$[SO_2] = \frac{0.5\ \text{mol}}{10\ \text{L}} = 0.05\ \text{mol/L}$$

$$K_{eq} = \frac{[O_2]}{[SO_2]} = 2.4 \times 10^{-2}$$

$$\frac{[O_2]}{0.05\ \frac{\text{mol}}{\text{L}}} = 2.4 \times 10^{-2}$$

O_2 at equilibrium = 1.2×10^{-3} mol/L

R	$SO_{2(g)}$	$\longleftrightarrow$	$S_{(s)}$	$+\ O_{2(g)}$
I	0.05 mol/L		—	—
C	-0.0012 mol/L		—	+ 0.0012 mol/L
E	0.045 mol/L		—	0.0012 mol/L

$[O_2]$ = 0.0012 mol/L $[SO_2]$ = 0.049 mol/L

Answer: The equilibrium concentration of **SO_2 is 0.049 mol/L and of O_2 is 0.0012 mol/L**.
Note: If student states *x* is negligible, accept procedure as correct.

27 Example of an appropriate and complete solution

Approach #1

Find the pH of good quality vinegar

Molarity of Acetic Acid

$$\frac{60\text{ g }CH_3COOH}{1\text{ litre of solution}} = 1.0\text{ M } CH_3COOH \text{ solution}$$

$$\frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = \frac{x \bullet x}{1.0\text{ M}}$$

$$x^2 = 1.8 \times 10^{-5}$$

$$x = 4.24 \times 10^{-3}\text{ M}$$

$$\text{pH} = 2.37 = 2.4$$

This pH matches that of the sample, therefore this vinegar is good.

Approach #2

Find the "K_a" of the acid in the sample assuming the solution is 1.0 M CH_3COOH.

Since the pH is 2.4, the $[H^+] = 4.24 \times 10^{-3}$ M

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$$

$$= \frac{(4.24 \times 10^{-3}\text{ M})^2}{1.0\text{ M}}$$

$$= \mathbf{1.8 \times 10^{-5}}$$

This K_a matches that of acetic acid so clearly the solution of the sample was 1.0 M in CH_3COOH (i.e. Good quality).

Answer: The vinegar **has not** been watered down.

28 **Example of an appropriate and complete answer**

1.

$2\,Ag^{+}$	+	$\cancel{2e^-}$	$\rightarrow$	$2\,Ag_{(s)}$			+0.80 V
$Mg_{(s)}$			$\rightarrow$	Mg^{2+}	+	$\cancel{2e^-}$	+2.37 V
$2\,Ag^{+}$	+	$Mg_{(s)}$	$\rightarrow$	$2\,Ag_{(s)}$	+	Mg^{2+}	

2 marks

2. $E°$ = **3.17 V**

1 mark

3. **Mg** is the reducing agent.

1 mark

29 **Example of an appropriate and complete answer**

1. $Zn_{(s)} + Cu^{2+}{}_{(aq)} \rightarrow Zn^{2+}{}_{(aq)} + Cu_{(s)}$

Note: Accept ↔ in the equation also.

2. Adding Zn ions to the system causes a stress on the system. The higher the concentration of zinc ions the more the system will shift to rid this stress by shifting to the reactants. The result is an increase in copper ions. The highest concentration (1.5 M) of $Zn(NO_3)_2$ will be the most favourable to increase the rate of the reverse reaction.

ANSWERS
EXAM #7
JUNE 2003

1	B
2	D
3	A
4	B
5	B
6	C
7	A
8	C
9	C
10	C
11	B
12	A
13	A
14	D
15	B
16	D
17	D
18	C

Part B

19 **Example of an appropriate and complete answer**

Molar mass of HgO = 216.6 g/mol

Mol HgO $= \dfrac{\text{mass HgO}}{\text{molar mass HgO}} = \dfrac{54.0\ \text{g}}{216.6\ \text{g/mol}}$

= 0.25 mol HgO

From the balanced equation: 2 mol HgO produces 1 mol O_2

Therefore 0.25 mol HgO will produce 0.125 mol O_2

Solution A

$PV = nRT$

P = 101.3 kPa

V = x L

n = 0.125 mol

$R = 8.31 \dfrac{\text{kPa L}}{\text{mol K}}$

T = 273 K

$(101.3\ \text{kPa})\ (x\ \text{L}) = (0.125\ \text{mol})\ (8.31 \dfrac{\text{kPa L}}{\text{mol K}})\ (273\ \text{K})$

V = 2.80 L O_2

OR

Solution B

1 mol of a gas at STP occupies a volume of 22.4 L, therefore:

$$\frac{1\ \text{mol} = 22.4\ \text{L}}{0.125\ \text{mol}\ O_2 = x\ \text{L}}$$

V = 2.80 L O_2

Answer: The volume of oxygen required is **2.80 L**.

20 1. Determine the molar mass of CCl_4

1 mol C + 4 mol Cl

(12.01 g/mol) + (4 mol × 35.45 g/mol)

153.81 g/mol

2. Find the volume of 1 mole of the sample under these conditions

125°C = 125°C + 273

= 398 K

PV = *nRT*

(95.2 kPa) (V) = (1 mol) (8.31 kPa L/mol K) (398 K)

***V* = 34.7 L**

3. Find density

Δ = m/v

= 153.81 g/34.7 L

Δ = 4.43 g/L

Answer: The density of the sample of CCl_4 is **4.43 g/L**.

21 1. Mass of unknown gas

6.00 g – 4.40 g = 1.60 g

2.

P	•	*V*	=	*n*	•	*R*	•	*T*
102 kPa	•	1.21 L	=	*n*	•	8.31 kPa L/mol K	•	273 + 18°C
		0.051	=	*n*				

3. $n = \frac{m}{mm}$

$0.051 \text{ mol} = \frac{1.60 \text{ g}}{mm}$

$31.4 \frac{g}{mol} = mm$

4. Molar mass of O_2 = 32 g/mol

Answer: **The unknown gas is O_2.**

22 **Example of an appropriate and complete answer**

Heat lost by the metal = Heat gained by the water

$$Q_1 = mc\Delta T$$
$$= (52.8 \text{ g})(c)(26.0°\text{C} - 100.0°\text{C})$$
$$Q_1 = -1770 \text{ J}$$
$$c = 0.453 \text{ J/g°C}$$

$$Q_2 = mc\Delta T$$
$$= (90.0 \text{ g})(4.19 \text{ J/g°C})(26.0°\text{C} - 21.3°\text{C})$$
$$Q_2 = +1770 \text{ J}$$

Answer: **The unknown metal is** Iron**.**

23

$Q = mc\Delta T$
$m = 100$ g
$c = 4.19$ J/g°C
$\Delta T = 6.7$°C

$Q = 2.81$ kJ

mol NaOH = 1.0 mol/1000 mL
= 0.05 mol in 50 mL

$\Delta H = -Q/n$

$$\Delta H = \frac{-2.81 \text{ kJ}}{0.05 \text{ mol NaOH}}$$

$\Delta H = -56.1$ kJ/mol

Answer: The heat of neutralization is **-56.1 kJ/mol**.

24

1. 1 mol of water has a mass of 18.0 g

2. Heating 1 mol of water from 25.0°C to 100.0°C
$Q = mc\Delta T$
= (18.0 g)(4.19 J/g°C)(100.0°C – 25.0°C)
= 5660 J or 5.66 kJ

3. Evaporation of the water

$H_2O_{(l)} \rightarrow H_{2(g)} + 1/2\ O_{2(g)}$	$\Delta H = +285.9$ kJ/mol
$H_{2(g)} + 1/2\ O_{2(g)} \rightarrow H_2O_{(g)}$	$\Delta H = -241.8$ kJ/mol
$H_2O_{(l)} \rightarrow H_2O_{(g)}$	$\Delta H = +44.1$ kJ/mol

4. Total heat required
Q_{total} = 5.66 kJ + 44.1 kJ = 49.8 kJ

Answer: The total amount of heat required to evaporate the water is **49.8 kJ.**

25 1. Amount of H_2O_2 consumed after 60 s

0.925 mol/L × (2 mol H_2O_2/1mol O_2) = 0.185 mol/L

2. Amount of H_2O_2 consumed after 300 s

0.292 mol O_2 × (2 mol H_2O_2/1mol O_2) = 0.584 mol/L

3. Average rate of H_2O_2 consumed from 60 s to 300 s

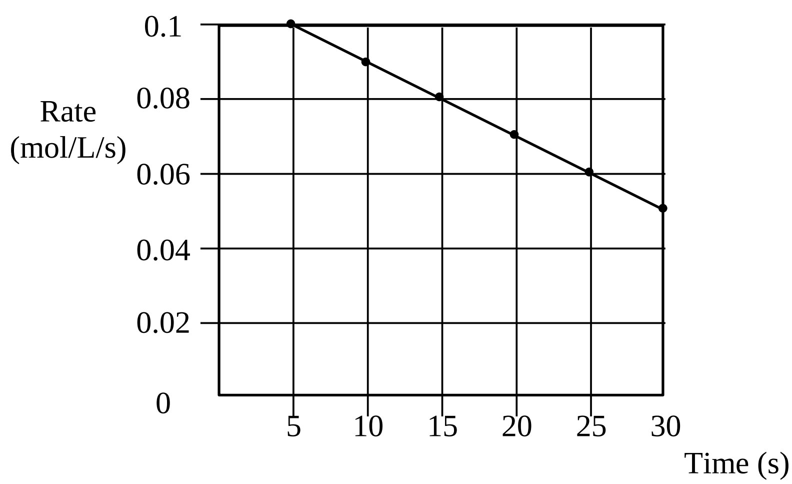
$$\text{Average rate} = \frac{(0.584 - 0.185)\ \text{mol/L}}{(300 - 60)\ \text{s}}$$

$$= \mathbf{0.00166\ mol/L/s\ or\ 1.66 \times 10^{-3}\ mol/L/s}$$

Answer: The rate of decomposition is **1.66×10^{-3} mol/L/s.**

26 **Example of an appropriate and complete answer**

Average Rate of formation of B_2



Time (seconds)	Concentration of BC (mol/L)	Concentration of B_2 (mol/L)	Rate of B_2 (mol/L/s)
0	4.0	0	0
5	3.0	**0.50**	**0.10**
10	2.3	**0.85**	**0.09**
15	1.7	**1.15**	**0.08**
20	1.4	**1.30**	**0.07**
25	1.2	**1.40**	**0.06**
30	1.1	**1.45**	**0.05**

27 Example of an appropriate and complete answer

1.

CO: 4 moles per 4 L = 1 mol/L
H_2: 9 moles per 4 L = 2.25 mol/L
CH_3OH: 2 moles per 4 L = 0.5 mol/L

2.

	$CO_{(g)}$	+ $2\ H_{2(g)}$	$\rightarrow$ $CH_3OH_{(g)}$
I	1.0 mol/L	2.25 mol/L	0
C	-0.5	-1.0	+0.5 mol/L
E	0.5	1.25	0.5

3.

$$K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$$
$$= \frac{(0.5)}{(0.5)(1.25)^2}$$
$$= 0.64$$

Answer: The equilibrium constant is **0.64**.

28 **Example of an appropriate and complete answer**

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$
$$[CH_3COOH] = 0.50 \text{ mol in } 2.00 \text{ L}$$
$$= 0.25 \text{ mol/L}$$
$$[CH_3COOH] = [H^+] = x$$
$$1.8 \times 10^{-5} = \frac{x^2}{0.25 \text{ mol/L}}$$
$$x = 2.1 \times 10^{-3} = [H^+]$$
$$-\log \text{ of } 2.1 \times 10^{-3} = 2.7$$

Answer: The pH of the solution is **2.7**.

29 **Example of an appropriate and complete answer**

A. $3\ Ni^{2+} + 2\ Al_{(s)} \rightarrow 3\ Ni_{(s)} + 2\ Al^{3+}$

B. 1.40 V

C. $Ni^{2+}_{(aq)}$

D. From Al to Ni