

PHYSICAL CHEMISTRY EXAM

21 September 1988

CONSTANTS: $g=9.81 \text{ ms}^{-2}$ $R=8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
 $N_A = L = 6.022 \times 10^{23} \text{ mol}^{-1}$

(1) 10 points.

By considering momentum changes for an individual molecule inside a rectangular box, derive an expression for PV in terms of the molecular mass, the number of molecules and the mean square speed.

Compare this to the ideal gas equation to show that the mean kinetic energy of a molecule is $1.5 \frac{R}{L} T$.

(2) 10 points.

A balloon contains 1 kg He (molar mass $0.004 \frac{\text{kg}}{\text{mol}}$) at $2 \times 10^5 \text{ Pa}$ and 298 K. Assume ideal gas behavior.

- What is the volume of the gas?
- How many He atoms are there?
- What is the root mean square velocity?
- What is the mean kinetic energy of the He atoms?
- What is the total kinetic energy of the gas?

(3) 2 points.

What is Graham's law of effusion?

(4) 10 points.

- Give 3 postulates or assumptions of the kinetic-molecular model for ideal gases.
- The van der Waals equation $(P + \frac{a n^2}{V^2})(V - n b) = n R T$ better describes the behavior of real gases. Explain the physical significance of a and b in the light of your answer to part (a).
- Sketch a P versus V diagram for a real gas and label the axes. Show i) The 4 areas corresponding to the liquid, gas, liquid + vapor, and supercritical fluid phases.
ii) The critical point.
iii) An isotherm corresponding to gas liquefaction by pressure.

OVER...

(5) 8 points.

a) Barometric pressure varies as $P = P_0 \exp\left(-\frac{M g h}{R T}\right)$. Assume that $P_0 = 10^5$ Pa, T is constant at 298 K and $M = 0.029$ kg mol⁻¹. Estimate P at the height of a space shuttle orbit, $h = 100$ km.

b) The mean free path is given by $\lambda = \frac{V}{\sqrt{2} \pi d^2 N}$.

In a few lines explain the physical significance of λ .

c) Assuming ideal gas behavior, substitute for V to express λ as a function of P and T .

d) Hence calculate λ for the conditions of part (a).

Use $d = 3 \times 10^{-10}$ m.

ANSWERS

Exam of 9-21-88

1) See notes and text book for $PV = \frac{Nm \bar{u}^2}{3}$

m is the molecular mass

2) (a) $V = \frac{nRT}{P}$, $n = \frac{1 \text{ kg}}{0.004 \text{ kg mol}^{-1}} = 250 \text{ mol}$

$\therefore V = 3.10 \text{ m}^3$

(b) $250 \text{ mol} \times 6.022 \times 10^{23} \text{ mol}^{-1} = 1.51 \times 10^{26} \text{ atoms} = N$

(c) $PV = \frac{1}{3} Nm \bar{u}^2 \therefore \bar{u}^2 = \frac{3PV}{Nm}$

m is the molecular mass (see (1)) = $\frac{0.004 \text{ kg mol}^{-1}}{6.022 \times 10^{23} \text{ mol}^{-1}}$

Hence $\bar{u}^2 = 1.85 \times 10^6 \text{ m}^2 \text{ s}^{-2} \therefore \sqrt{\bar{u}^2} = \underline{1360 \text{ m s}^{-1}}$

(d) $KE = \frac{1}{2} m \bar{u}^2 = 6.16 \times 10^{-21} \text{ J}$

(e) N times answer to (d) i.e. $9.30 \times 10^5 \text{ J}$

3) The rate of effusion is inversely proportional to the square root of the molecular mass or the square root of the density.

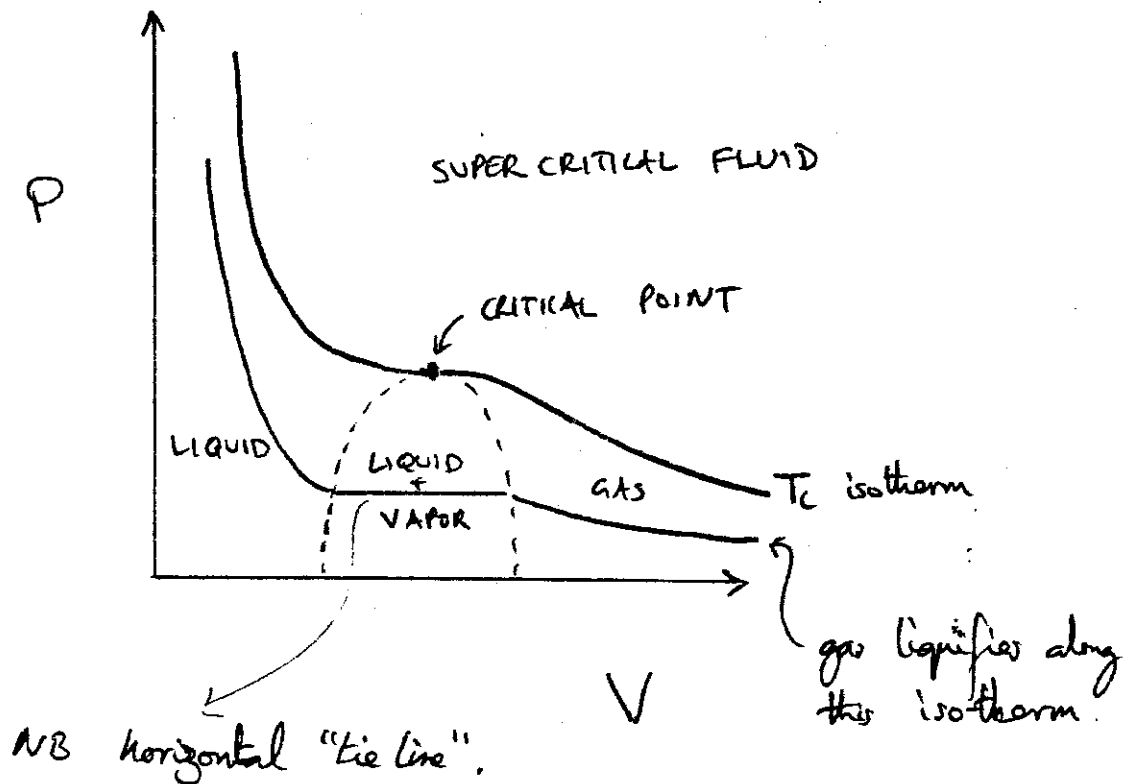
$$\frac{\text{rate}_1}{\text{rate}_2} = \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{\rho_2}{\rho_1}}$$

4) (a) The molecules are in constant motion.
They have negligible volume.
There are no intermolecular forces.

(b) a reflects the influence of intermolecular forces. The attraction between a molecule close to the wall of a vessel and the bulk of the gas slightly reduces the effective pressure below the ideal value.

b is a correction for the non-zero volume of the molecules and accounts for the volume free to be occupied being less than in the ideal case.

(c)



$$\begin{aligned}
 5) (a) \quad P &= 10^5 \text{ Pa} \exp \left\{ - \frac{0.029 \text{ kg mol}^{-1} \cdot 9.81 \text{ m s}^{-1} \cdot 10^5 \text{ m}}{8.314 \text{ J K}^{-1} \text{ mol}^{-1} \cdot 298 \text{ K}} \right\} \\
 &= 10^5 \text{ Pa} \exp \{ -11.48 \} \\
 &= 10^5 \text{ Pa} \times 1.03 \times 10^{-5} \\
 &= \underline{1.03 \text{ Pa}}.
 \end{aligned}$$

(b) The mean free path is the average distance traveled by a molecule between collisions. Graham's Law applies for gas flow through a hole narrower than λ .

$$(c) \quad V = \frac{nRT}{P} \quad \therefore \quad \lambda = \frac{nRT}{\sqrt{2} \pi d^2 NP}$$

$$\text{but } \frac{n}{N} = \frac{1}{L}$$

$$\therefore \quad \lambda = \frac{RT}{\sqrt{2} \pi d^2 LP}$$

(d)

$$\lambda = \frac{8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times 298 \text{ K}}{\sqrt{2} \pi (3 \times 10^{-10} \text{ m})^2 \times 6.022 \times 10^{23} \text{ mol}^{-1} \times 1.03 \text{ Pa}}$$

$$= 0.010 \frac{\text{J}}{\text{m}^2 \text{ Pa}} = \underline{\underline{0.010 \text{ m}}}$$

PHYSICAL CHEMISTRY EXAM 2

7 October 1988

DATA: $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$. $C_p - C_v = R$. $C_p/C_v = \gamma$.

(1) 10 Points.

Consider the reversible adiabatic expansion of 1 mol of an ideal gas, from V_1 at T_1 to V_2 at T_2 . Show, using the 1st Law of Thermodynamics, that $C_v \ln(T_2/T_1) + R \ln(V_2/V_1) = 0$. Hence find the relation between P , V and γ for an adiabat. On a P - V diagram sketch and label the isotherm and the adiabat which both pass through the point V_1, P_1 at temperature T_1 .

(2) 10 Points.

- What is the difference between a process that is carried out reversibly or irreversibly?
- What is an exact differential and what is special about it?
- What is the distinction between C_p and C_v ?
- What is the standard heat of formation of a substance?
- What are endothermic reactions? Are they permitted by the 1st Law of Thermodynamics?

(3) 10 Points.

$\Delta_f H^\circ(298 \text{ K}) \text{ C}_2\text{H}_4(\text{g}) = 52.3 \text{ kJ mol}^{-1}$. $\Delta_f H^\circ(298 \text{ K}) \text{ CO}_2(\text{g}) = -393.5 \text{ kJ mol}^{-1}$.
 $\Delta_f H^\circ(298 \text{ K}) \text{ H}_2\text{O}(\text{l}) = -237.2 \text{ kJ mol}^{-1}$. $C_p \text{ C}_2\text{H}_4(\text{g}) = 43.6$, $C_p \text{ O}_2(\text{g}) = 29.4$,
 $C_p \text{ H}_2\text{O}(\text{l}) = 75.5$ and $C_p \text{ CO}_2(\text{g}) = 37.1 \text{ J K}^{-1} \text{ mol}^{-1}$.

- What is $\Delta H^\circ(298 \text{ K})$ for the combustion of C_2H_4 ?
- What is $\Delta H^\circ(370 \text{ K})$ for this combustion?
- If $0.01 \text{ mol C}_2\text{H}_4$ is burnt in the open, at 298 K and 10^5 Pa pressure, what is the work done against the atmosphere?
- What is ΔU for the situation in (iii)?
- If the combustion of 0.01 mol occurred in a sealed rigid vessel at 298 K , what would be the work done in this case?

(4) 8 Points.

$\Delta_f H^\circ(\text{H}_2\text{O}(\text{g})) = -241.8 \text{ kJ mol}^{-1}$. $\Delta_f H^\circ(\text{OH}(\text{g})) = 249.2 \text{ kJ mol}^{-1}$. $\Delta_f H^\circ(\text{O}(\text{g})) = 246.8 \text{ kJ mol}^{-1}$. $\Delta_f H^\circ(\text{H}(\text{g})) = 218.0 \text{ kJ mol}^{-1}$. Calculate

- The heat of atomization of $\text{H}_2\text{O}(\text{g})$.
- The average bond dissociation energy of $\text{H}_2\text{O}(\text{g})$.
- The H-OH bond strength.
- Would you expect your answers to (ii) and (iii) to be equal? Why?

(5) 12 Points.

Helium may be treated as an ideal gas. $C_p = 20.79 \text{ J mol}^{-1}$.

A. 1 mol, initially at 298 K and $1.013 \times 10^5 \text{ Pa}$, is heated by 10 K within a sealed rigid vessel.

- How much heat is required?
- How much work is done?
- What is the change in internal energy of the gas?

B. 1 mol, initially at 298 K and $1.013 \times 10^5 \text{ Pa}$, is heated by 10 K within a vessel with a movable piston, at a constant pressure of $1.013 \times 10^5 \text{ Pa}$.

- How much heat is required?
- How much work is done?
- What is the change in internal energy of the gas?

PHYSICAL CHEMISTRY EXAM 3

28 October 1988

Data: $R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$

(1) 10 Points.

Illustrate the Carnot cycle on a P-V diagram and label each of the four parts. Derive an expression for the efficiency of a reversible Carnot engine in terms of the temperatures between which it works, T_h and T_c . You may assume these results for changes from 1 to 2: $q = RT \ln(V_2/V_1)$ and $w = -q$ for the reversible isothermal expansion of an ideal gas, and $w = C_v(T_2 - T_1)$ for the reversible adiabatic expansion of an ideal gas.

Suppose $T_h = 800 \text{ K}$, $T_c = 200 \text{ K}$ and $q_h = 150 \text{ J}$.

- What is the thermodynamic efficiency of the engine?
- How much heat is rejected at the lower temperature?
- What is the entropy increase of the working fluid during the isothermal expansion at 800 K?

(2) 10 Points.

1 mol of an ideal gas is expanded isothermally from 2 to 20 dm³ at 400 K. Calculate (a) ΔU (b) ΔH (c) ΔS (d) ΔA (e) ΔG .

(3) 12 Points.

Initially at 500 K and 10^5 Pa pressure, 1 mol of an ideal gas undergoes an irreversible isothermal expansion in which its volume is doubled, and the work it performs is 500 J. What are the values of q , ΔU , ΔH , ΔS and ΔG ? What would be the work performed if the expansion had been carried out reversibly?

(4) 8 Points.

Prove that for 1 mol of a van der Waals gas, $(\partial U/\partial V)_T = a/V^2$, where V is the molar volume. The equation of state for 1 mol of a van der Waals gas is $(P + a/V^2)(V - b) = RT$. Show your reasoning and any results you assume.

(5) 1 Point. Bonus question: part of an arithmetic survey!

Suppose a car sells for \$10,000 when tax at 7% is included in the price. What is the price of the car before tax is added?

ANSWERS for EXAM 3 1988, Fall

1 a)
$$\epsilon = \frac{T_h - T_c}{T_h} = \frac{800 - 200}{800} = 75\%$$

b) 25% of the heat is therefore rejected = 37.5 J.

c)
$$\Delta S = \int \frac{dq_{rev}}{T} = \frac{150 \text{ J}}{800 \text{ K}} = 0.1875 \text{ JK}^{-1}$$

2 a) b) $\Delta U = \Delta H = 0$ because U and H are functions of T only.

c)
$$\Delta S = R \ln \frac{20}{2} = 19.14 \text{ JK}^{-1}$$

d)
$$\Delta A = \Delta U - T\Delta S = -7657 \text{ J}$$

e)
$$\Delta G = \Delta H - T\Delta S = -7657 \text{ J}$$

3) $w = -500 \text{ J} \therefore q = 500 \text{ J}$ because $\Delta U = 0$ (see 2a).

$\Delta H = 0$ for same reason.

$$\Delta S = R \ln 2 = 5.763 \text{ JK}^{-1}$$

$$\Delta G = \Delta H - T\Delta S = -2881 \text{ J}$$

Remember $\Delta G = \max_{\text{possible}} \text{work}$, the reversible work \therefore

max. work that could be done is 2881 J.

4) $U = A + TS \therefore \left(\frac{\partial U}{\partial V}\right)_T = \left(\frac{\partial A}{\partial V}\right)_T + T \left(\frac{\partial S}{\partial V}\right)_T$

$= -P + T \left(\frac{\partial P}{\partial T}\right)_V$ by Maxwell relations.

It would also be acceptable to write down this equation of state without proof.

$$\left(P + \frac{a}{V^2}\right)(V-b) = RT \therefore P = \frac{RT}{V-b} - \frac{a}{V^2}$$

$$\therefore \left(\frac{\partial A}{\partial T}\right)_V = \frac{R}{V-b} \Rightarrow \left(\frac{\partial U}{\partial V}\right)_T = -P + \frac{RT}{V-b} = -P + \left(P + \frac{a}{V^2}\right) = \underline{\underline{\frac{a}{V^2}}}$$

5) Price is x . $x + 7\% = \$10,000 = 1.07x \therefore$

$$x = \frac{\$10,000}{1.07} = \$9345.79 \neq \$9300$$

EXAM 4
14 November 1988

Data: $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$

1 atm = 101325 Pa

IMPORTANT: Write clearly and neatly. Make sure that you give some reasoning or working for each answer. Full marks will NOT be awarded for the final answer by itself, UNLESS it is supported by a few words of explanation.

(1) 10 points.

A gas reaction $A = B + C$ is exothermic and has $K_p = 1$ atm at 298 K. With reference to a standard state of 1 atm,

- What is ΔG° at 298 K?
- What is the sign of ΔS° ? Why?
- Will K_p at 310 K be greater or less than 1 atm? Why?
- What will be the sign of ΔG° at 310 K? Why?
- Calculate K_c (standard state 1 mol dm^{-3}) at 298 K.

(2) 10 points.

In the gas phase, n-pentane ("A") can isomerize to neopentane ("B"). Thermodynamic data for A and B, for 298 K and a standard state of 1 atm, are:

A	$\Delta_f H^\circ = -146.44 \text{ kJ mol}^{-1}$	$S^\circ = 349.0 \text{ J K}^{-1} \text{ mol}^{-1}$
B	$\Delta_f H^\circ = -165.98 \text{ kJ mol}^{-1}$	$S^\circ = 306.4 \text{ J K}^{-1} \text{ mol}^{-1}$

For the reaction $A = B$ at 298 K,

- Calculate ΔH° and ΔS° .
- Calculate ΔG° and K_p . If the temperature is raised, does the shift in equilibrium favor A or B? Why?
- Pure A is in a vessel at 1 atm and 298 K, and the reaction to form B is allowed to proceed to equilibrium. Calculate the final partial pressures of A and B.
- If the reaction had been written as $2A = 2B$ instead, how would your calculated ΔG° , K_p and final partial pressures have changed, if at all?

(3) 12 points.

The temperature dependence of K_p is given by $d(\ln K_p)/d(1/T) = -\Delta H^\circ/R$.

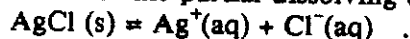
- Assuming ΔH° is independent of T, derive an expression for $\ln(K_{p,1}/K_{p,2})$, the natural logarithm of the ratio of K_p at two temperatures T_1 and T_2 .
- Consider the process $N_2O_4 = 2 NO_2$. The following experimental data were obtained for an equilibrium mixture:

T	$p(N_2O_4)$	$p(NO_2)$
298 K	0.0605 atm	0.0303 atm
305 K	0.0895 atm	0.0395 atm.

Calculate K_p at each temperature.
- Calculate ΔH° for the interval 298 to 305 K, standard state 1 atm, assuming it to be independent of T.
- Calculate ΔG° at 298 K and hence ΔS° (standard state 1 atm).
- What is the degree of dissociation α of N_2O_4 at 298 K?
- Calculate K_c at 298 K (standard state 1 mol dm^{-3}).

(4) 8 points.

Consider the partial dissolving of a slightly soluble salt AgCl in water:



- The conventional equilibrium constant for this reaction is called the solubility product K_s . What is K_s in terms of the concentrations of the species involved?
- The molar mass of Ag is 0.108 kg; that of Cl is 0.035 kg. A saturated aqueous solution of AgCl contains $1.9 \times 10^{-6} \text{ kg dm}^{-3}$. What is K_s ?
- To 1 dm^3 of the above solution Cl^- is added until $[\text{Cl}^-(\text{aq})] = 1 \text{ mol dm}^{-3}$. What is the new equilibrium $[\text{Ag}^+(\text{aq})]$?
- Is this new $[\text{Ag}^+(\text{aq})]$ greater or less than the $[\text{Ag}^+(\text{aq})]$ in part (b)? How did the system change physically as Cl^- was added to adjust to the new $[\text{Ag}^+(\text{aq})]$?

Answers to EXAM 4.

- 1 a) $\Delta G^\circ = 0$
 b) $\Delta S < 0$.
 c) K_p decreases.
 d) $\Delta G > 0$.
 e) $K_c = 0.0409 \text{ mol dm}^{-3}$.

- 2 a) $\Delta H^\circ = -19.54 \text{ kJ mol}^{-1}$ $\Delta S^\circ = -42.6 \text{ J K}^{-1} \text{ mol}^{-1}$
 b) $\Delta G = -6845 \text{ J mol}^{-1} = -RT \ln K_p$
 $\therefore K_p = 15.85 \text{ atm}$.
 Exothermic \therefore highest favours A.

- c)

	$A \rightleftharpoons B$	
Init.	1 0	$K_p = \frac{x}{1-x}$, $x = 0.9406$ = p_B
Eq.	$1-x$ x	

 $\therefore p_A = 0.0594$.

- 3 a) $\ln(K_1/K_2) = \frac{\Delta H}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$.
 b) $K_p(298\text{K}) = 0.0152 \text{ atm}$, $K_p(305\text{K}) = 0.0174 \text{ atm}$.
 c) $\Delta H = 14.80 \text{ kJ mol}^{-1}$ by (a).
 d) $\Delta G^\circ(298) = 10372 \text{ J mol}^{-1} \therefore \Delta S = \frac{\Delta H - \Delta G}{T} = 14.86 \text{ J K}^{-1} \text{ mol}^{-1}$.
 e) Initial $p(\text{N}_2\text{O}_4) = 0.0605 + \frac{0.0303}{2} \text{ atm} \therefore 20\% \text{ dissociated}$.
 f) $K_c = K_p/RT = 6.22 \times 10^{-4} \text{ mol dm}^{-3}$.

- 4 a) $K_s = [\text{Ag}^+][\text{Cl}^-]$.
 b) Molar mass $\text{AgCl} = 0.1434 \text{ kg} \therefore [\text{Ag}^+] = [\text{Cl}^-] = 1.33 \times 10^{-5} \text{ mol dm}^{-3}$
 $\therefore K_s = 1.77 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$.
 c) $[\text{Ag}^+] = 1.77 \times 10^{-10} \text{ mol dm}^{-3}$.
 d) Lower. More $\text{AgCl}(s)$ precipitates out of solution.

TAKE HOME QUESTIONS
Due on Monday 21 November, 10 am

Data:

$$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$1 \text{ atm} = 101325 \text{ Pa}$$

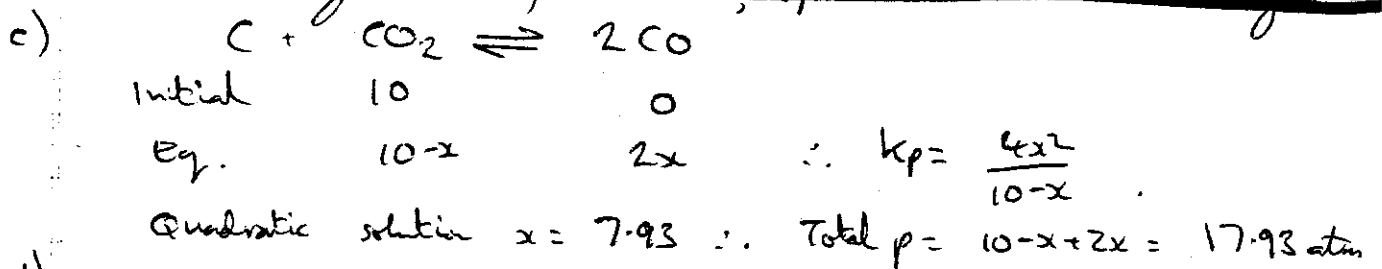
IT IS ESSENTIAL that you show working or give brief explanations. You will not get full credit otherwise.

- (1) At 1000°C, K_p for $\text{CO}_2(\text{g}) + \text{C}(\text{graphite}) \rightleftharpoons 2 \text{CO}(\text{g})$ is 121.5 atm.
- (a) Calculate ΔG° (standard state 1 atm).
- ~~_____~~
- (c) If a vessel at 1000°C initially contains solid carbon and 10 atm of CO_2 , what will be the total pressure in the vessel at equilibrium?
- (d) Calculate K_c (standard state 1 mol dm^{-3}) at 1000°C. What is ΔG° (standard state 1 mol dm^{-3})?
- (2) K_p for the reaction $\text{COCl}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{Cl}_2(\text{g})$ is measured to be 0.0195 atm at 636 K and 0.5183 atm at 760 K.
- (a) Calculate ΔH° and ΔS° (standard state 1 atm), on the assumption that they are independent of temperature.
- (b) What is ΔG° at 298 K?
- (c) What is the degree of dissociation of 1 atm of pure COCl_2 at 760 K?
- (d) If 1 atm of COCl_2 and 9 atm of Cl_2 are allowed to come to equilibrium at 760 K, what then is the degree of dissociation of the COCl_2 ?

ANSWERS TO TAKE-HOME QUESTIONS

1 a) $\Delta G^\circ = -R \times 1273 \text{ K} \times \ln 121.5 = -50.8 \text{ kJ mol}^{-1}$.

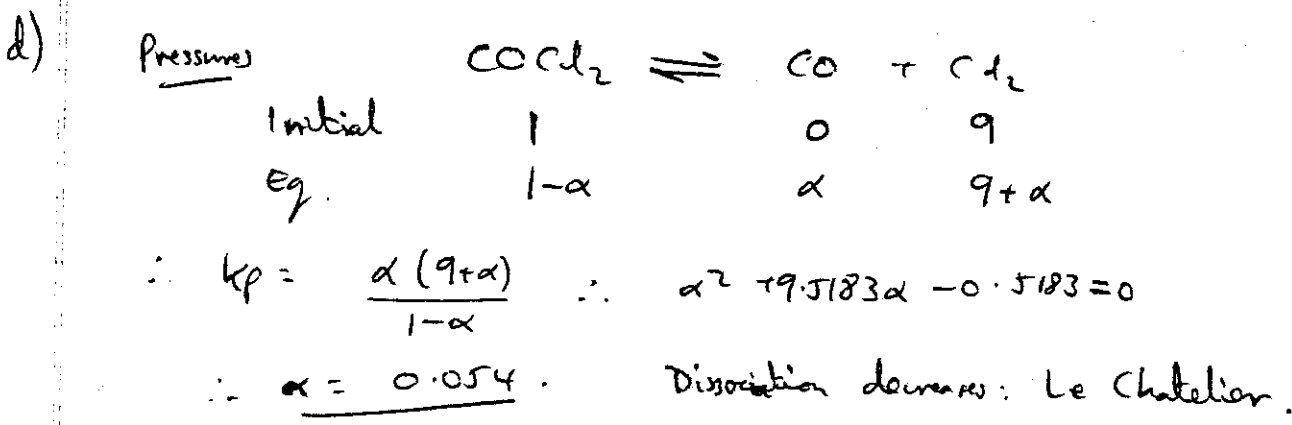
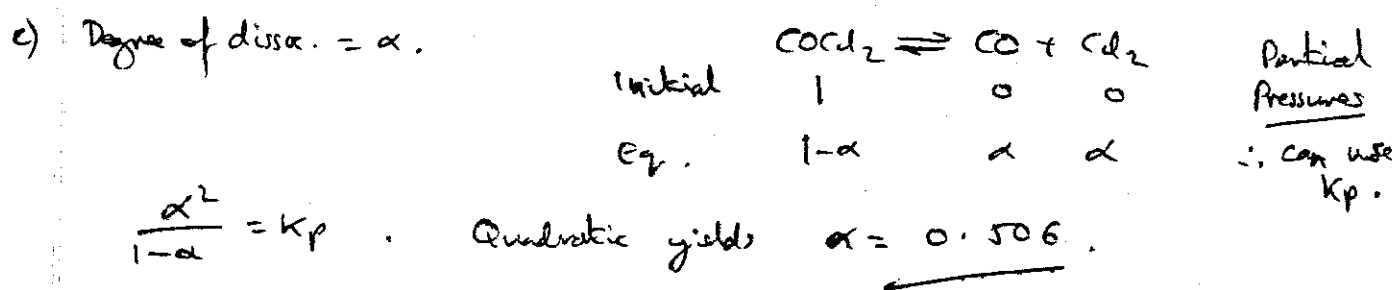
b) ~~_____~~
~~_____~~
~~_____~~



d) $K_c = \frac{K_p}{RT} = \frac{121.5 \times 101325}{8.314 \times 1273 \times 1000} = 1.163 \text{ mol dm}^{-3}$. $\Delta G^\circ = -RT \ln K_c = -1600 \text{ J mol}^{-1}$
Count only gaseous species in $\Sigma \nu_i$.

2 a) $\ln \left(\frac{K_1}{K_2} \right) = \frac{\Delta H^\circ}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$ gives $\Delta H^\circ = 106300 \text{ J mol}^{-1}$. ΔG at $636 \text{ K} = 20819 \text{ J mol}^{-1} = \Delta H - T\Delta S \therefore \Delta S = 134.4 \text{ J K}^{-1} \text{ mol}^{-1}$.

b) $\Delta G = \Delta H - 798 + \Delta S = 66249 \text{ J mol}^{-1}$.



Approx. soln. if you knew α was small: $9+\alpha \approx 9$, $1-\alpha \approx 1$
 $\therefore K_p \approx 9\alpha \therefore \alpha \approx 0.058$.

EXAM 5
Take-home questions on Chapter 9
Due on Wednesday 30 November 1988 at 10 am

Data: $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$

(1) 9 points.

Some results for the rate of a reaction between A and B are:

[A]/mol dm ⁻³	[B]/mol dm ⁻³	rate/mol dm ⁻³ s ⁻¹
2	1	5
2	2	10
4	4	80

Deduce the order of the reaction with respect to A and B. What is the overall order of the reaction? What is the rate constant? What are its units?

(2) 15 points.

The composition of a solution initially containing pure A was measured as a function of time. A reacted with stoichiometry $A \rightarrow B$ in a reaction that was first-order with respect to A and which did not depend on [B]. The following data were obtained:

t/min	0	10	20	30	40	∞
[B]/mol dm ⁻³	0	0.089	0.153	0.200	0.230	0.312

What is a_0 , the initial value of [A]? Find the rate constant by plotting a graph of $\ln \{a_0/(a_0 - [B])\}$ against t as discussed in the notes. Fit a straight line to the points by eye: least-squares fitting is not required. Give the units of the rate constant.

ATTENTION: 5 of the points are for graphing style i.e. adherence to the following five essential rules for ANY scientific graph:

- i) Use only graph or squared paper.*
- ii) Use a ruler for all straight lines: no freehand sketching.*
- iii) Label both axes, and show the units.*
- iv) Each axis must be at least 4" (10 cm) long: no micro drawings.*
- v) No silly scales like 17.3 squares per unit.*

PENCIL IS PERFECTLY ACCEPTABLE AND LETS YOU CORRECT MISTAKES: I recommend it.

(3) 15 points.

The rate constant k of a second-order reaction has been measured as a function of temperature:

T/K	200	250	300	350	400
$k/\text{mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$	9.4	25	64	100	150

Plot a graph of $\ln k$ against $1/T$. Fit a straight line to the scattered points by eye: a regression analysis is not required. Find the two Arrhenius parameters. Give their units. Again, there are 5 easy points for following the graph rules of Q.2.

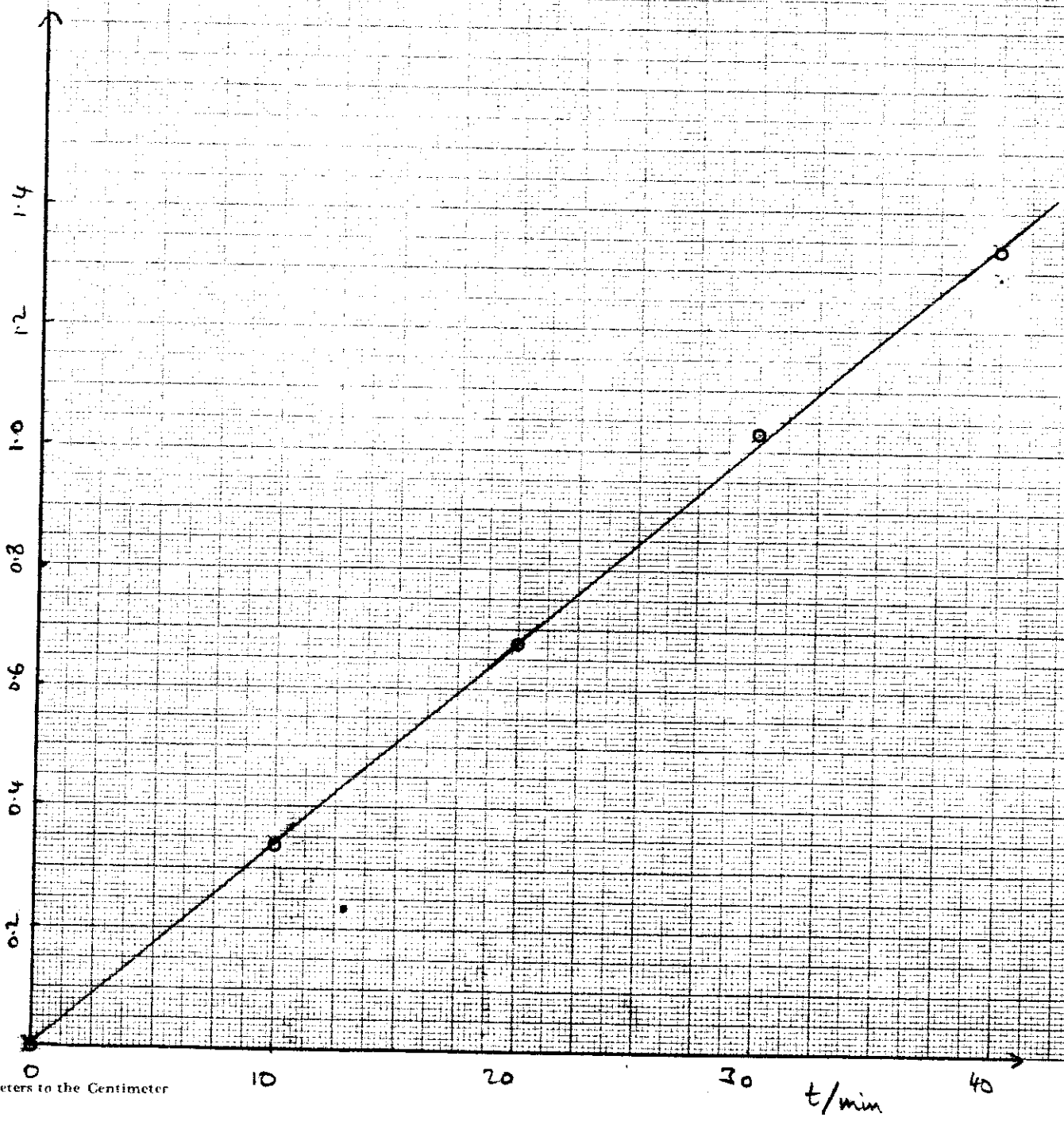
1) $v \propto [A]^2[B] \therefore 3^{\text{rd}}$ order overall,

$$k = \frac{5 \text{ mol dm}^{-3} \text{ s}^{-1}}{(2 \text{ mol dm}^{-3})^2 \cdot 1 \text{ mol dm}^{-3}} = 1.25 \text{ mol}^{-2} \text{ dm}^6 \text{ s}^{-1}$$

2) $a_0 = [B]_{t=0} = 0.312 \text{ mol dm}^{-3}$.

$$k = \text{slope} = \frac{1.35}{40 \text{ min}} = 0.034 \text{ min}^{-1}$$

$\ln \left(\frac{a_0}{a_0 - [B]} \right)$

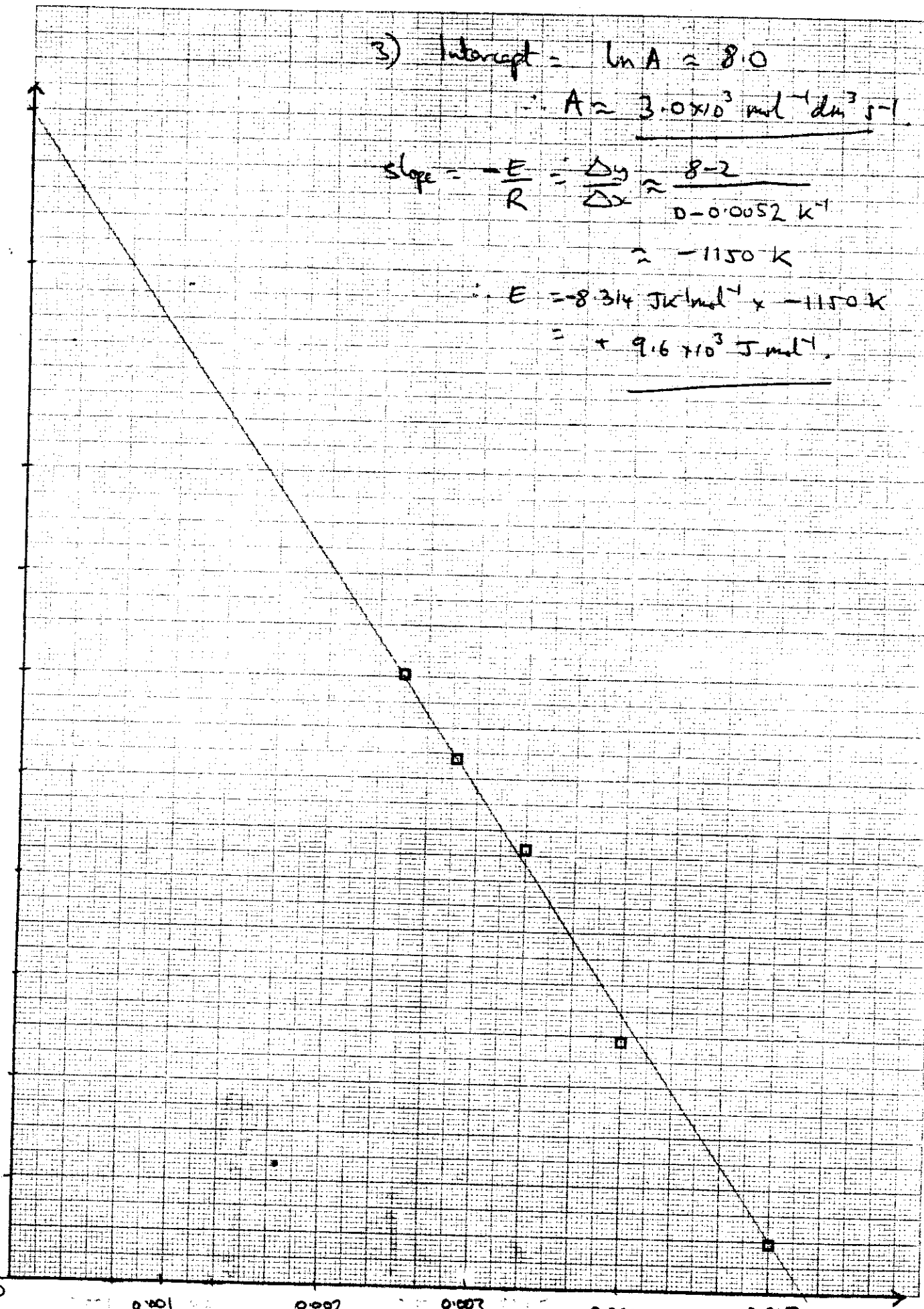


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ln (k / mol⁻¹ dm³ s⁻¹)

3) Intercept = ln A = 8.0
 $\therefore A \approx 3.0 \times 10^3 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$
 slope = $-\frac{E}{R} = \frac{\Delta y}{\Delta x} \approx \frac{8-2}{0-0.0052 \text{ K}^{-1}}$
 $\approx -1150 \text{ K}$
 $\therefore E = -8.314 \text{ J mol}^{-1} \times -1150 \text{ K}$
 $= + 9.6 \times 10^3 \text{ J mol}^{-1}$

10 Millimeters to the Centimeter



1/T / K⁻¹