

Chemistry 2710 Spring 2004 Test 1

Total marks: 47

Aids allowed: Calculator. One $8\frac{1}{2} \times 11$ -inch piece of paper containing any information you need. No other printed materials (e.g. periodic tables, calculator manuals) are allowed.

Instructions: Answer all questions in the booklets provided.

Graphs should *either* be sketched in your exam booklet (if you are using a graphing calculator) or drawn on the graph paper provided. If you are hand-drawing graphs, make sure to put your name and the question number on the graph paper. If you decide to use a graphing calculator, provide a clearly labeled and reasonably accurate sketch of any graphs used in answering a question.

Clarity may be considered in evaluating your answers. Make sure to explain your reasoning, and don't give any numbers without giving some indication of how you obtained them.

Useful data:

$$1 \text{ amu} = 1 \text{ g/mol}$$

1. The half-life of ^{102}Tc is 5.3 s.
 - (a) How long would it take for 95% of the ^{102}Tc in a freshly prepared sample to decay? [4 marks]
 - (b) Suppose that 0.0432 g of ^{102}Tc has been prepared. This isotope decays by emitting a single β particle (an electron). What is the initial rate of production of β particles? The isotopic mass of ^{102}Tc is 101.909 213 amu. [5 marks]
2. The accumulation of nitrate from agricultural sources in drinking water is a significant problem in some parts of the world. The catalytic reduction of nitrate, producing nitrogen gas and some ammonium as a byproduct, has been studied as a possible water purification technology by Chen and coworkers.¹ In one set of experiments, the following initial rate data were obtained:

$[\text{NO}_3^-]$ (mg/L)	49.7	80.5	101	151
v ($\text{mg L}^{-1}\text{min}^{-1}$)	2.28	4.23	5.90	9.64

Does the reaction appear to follow a simple rate law? If so, give the order of the reaction with respect to the nitrate concentration. [10 marks]

Note: In questions like this one, you are required to take a position and to hold to it. Ambiguous or inconsistent answers will generally receive reduced credit.

¹Y.-X. Chen, Y. Zhang and H.-Y. Liu, *J. Env. Sci.* **15**, 600–606 (2003).

3. Many reactions involving solids occur at surfaces (crystal growth, dissolution, etc.). In many of these reactions, the rate turns out to be simply proportional to the surface area. The mass is proportional to the volume. The volume is proportional to the cube of the linear dimensions (length, diameter, etc.) of the crystal, and the area is proportional to the square of a length, so a typically observed rate law is

$$\frac{dm}{dt} = \pm km^{2/3}. \quad (1)$$

- Would the sign be positive or negative for the dissolution of a crystal? [2 marks]
 - Using the method of separation of variables, derive an integrated rate law for dissolution starting from equation 1. [7 marks]
 - Explain how, for a reaction which satisfied the rate law, you could calculate the rate constant from experimental data using your integrated rate law. [5 marks]
 - If m is measured in grams and t in seconds, what are the units of k ? [2 marks]
4. Benzylpenicillin (bp) is an antibiotic which is commonly administered to farm animals to increase productivity by preventing the animals from contracting diseases while living in crowded conditions. Unfortunately, many humans are hypersensitive to penicillins. There has therefore been some concern over the presence of residues of this antibiotic in meat products. Bp is not heat stable, so some bp is destroyed when meat is cooked. The following data were obtained from meat fried in oil at 180°C:²

t (min)	2.21	5.16	13.26	22.84	40.52	60.41
% bp remaining	95	83	65	44	23	10

Compounds which are heat sensitive often degrade by a first-order process. Are these data consistent with a first-order reaction? If so, what is the half-life of bp during the frying of meat? [12 marks]

²M. D. Rose et al., *Analyst* **122**, 1095 (1997).