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ETHANOL INGESTION STUDIES

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BLOOD ALCOHOL TESTS/BREATH TESTS/TEST EQUIPMENT

ostract

A set of ethanol ingestion studies was designed to test the feasibility of collecting frequent blood samples to construct an ethanol tolerance curve. Three methods of analysis were tested - gas chromatography, an enzyme method and the breathalyser.

There was poor correlation between the weight of the individual, and the blood alcohol concentration on a fixed intake of ethanol. The effect of food on the blood alcohol concentration gave conflicting results.

The enzyme method used to estimate the blood alcohol concentration was unreliable but good correlation existed between the methods of gas chromatography and breathalyser.

The studies indicated that only a small loading dose of ethanol can be regarded as safe in order to remain below the level of .05 grams per 100 mls blood.

ACKNOWLEDGEMENTS

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ETHANOL INGESTION STUDIES

TABLE OF CONTENTS

INTRODUCTION

The present investigations followed a series of drinking experiments conducted in 1973 in the hope of obtaining some information about the relationship of the blood alcohol concentration (BAC) to various levels of alcohol consumption. Different social settings were examined; the beverages used were beer, wine and spirits. The BAC was estimated using only the Breathalyser (Model 900); certain disadvantages inherent in this method became manifest:

(i) no readings could be obtained during the period of active drinking, and for about ten minutes after drinking had ceased. Thus there was uncertainty about the shape of the rising limb of the ethanol tolerance curve and of the actual peak BAC values;

(ii) where more than twenty subjects were tested, the use of Breathalysers precluded frequent readings on all subjects, and even the taking of readings at precise regular intervals;

(iii) use of the Breathalyser alone did not afford any opportunity to test the validity of the readings against other methods of blood alcohol analysis.

Because we could not be sure of peak BAC values, some results were inconclusive. However, certain impressions were gained, based on mean values and several individual curves which could be drawn with some precision because readings were more frequent:

(i) in the range of average weights (65-75 kg), there was a poor correlation between the BAC reading and the weight of the subject for a given alcohol intake. Significant differences did appear when comparisons were made between results obtained in individuals at both ends of the weight scale, e.g. 55 and 85 kg;

(ii) when alcohol was drunk with a meal, the peak BAC value seemed to occur earlier than when the same amount of alcohol was taken in the fasting state. Food also apparently lowered BAC readings on the same intake of alcohol, although this was not an invariable finding;

(iii) values for the peak BAC ranged from 1.0-2.0mg per 100 ml. blood per gram of alcohol consumed. The mean value was 1.3mg per 100ml. blood per gram of alcohol, with S.D. $\pm$ 0.2;

(iv) the rate of elimination of alcohol from the circulation ranged from 7-17mg. per 100ml blood per hour. The median value was 13mg per 100ml blood per hour.

The present experiments set out to clarify these impressions, and to develop a methodology which would permit accurate construction of ethanol tolerance curves.

AIMS

1. To plot the blood alcohol concentration (BAC) versus time to determine the shape of the ethanol tolerance curve, especially the rising limb during the phase of drinking.

2. To determine and compare the BAC vs time curves in male subjects under fasting and non-fasting conditions.

3. To determine the ethanol tolerance curve in fasting female subjects.

4. To attempt to correlate the peak BAC with the size and sex of the subject.

5. To determine the rate of elimination of ethanol from the circulation.

6. To compare three different methods of analysis for blood alcohol concentration. These three methods were:

   (A) Gas chromatography

   (B) Breathalyser - Model 900

   (C) Cal-Biochem Statpak (Enzyme method)

METHODOLOGY

Beverages Used

(1) Carlton Draught Beer containing 3.8% w/v ethanol (7.6g/200ml).

(2) Shenley's Dry Gin containing 29.3% w/v ethanol (8.7 grams/30ml). This was administered diluted in orange juice; the total volume of each drink was 120ml.

Analysis of Samples

(1) Blood Samples: Split samples of blood were obtained for blood analyses. An indwelling needle was inserted into a vein in the cubital fossa, and the lumen was kept patent by a solution of heparin-saline. Samples were collected into fluoride oxalate tubes. Additional samples were collected into lithium heparin tubes for separation of plasma to be stored in a deep freeze. Early samples were drawn at five minute intervals, and after two to three hours, samples were drawn at ten minute intervals. Gas chromatographic tests on blood samples were conducted by the Forensic Science Laboratory of the Victoria Police.

(2) Breath Samples: Two Breathalysers (Model 900) were provided and operated by the Victoria Police. These were standardised by the breathanalysis section of the Victoria Police and operated by trained field officers of the squad. In most cases, breathanalysis was carried out every 10 to 20 minutes, commencing about 20 minutes after drinking had ceased.

(3) Enzyme Method: The "Cal-Biochem. Statpak" was used to estimate the BAC.

Experiments

A total of four experiments was conducted. Each was carried out on a separate day, and utilised the services of the matabolic ward of St. Vincent's Hospital, Melbourne. In all experiments, both breathanalysis and blood tests were carried out on each subject.

Experiment 1: Five 200ml glasses of beer (equivalent to 38 grams of ethanol) were administered at 12 minute intervals to four fasting male subjects. The final drink was consumed within the total time of 60 minutes. In this and subsequent experiments in which fasting subjects were used, a minimum period of 8 hours without food or drink was demanded.

Experiment 2: Alcohol was administered as in Experiment 1 for the first hour. In the second hour, two further 200ml glasses of beer were consumed at 24 minute intervals. Thus a total dose of 53.2 grams of ethanol was consumed over a two hour period.

Experiment 3: Alcohol was administered as in Experiment 1, except that the subjects were not fasted. The meal consumed is set out in Appendix A and was taken immediately before drinking commenced.

Experiment 4: 40.6 grams of ethanol, as diluted gin, was administered to three fasting female subjects. It was given as four 120ml drinks (each containing 8.7 grams ethanol) and one 120ml drink containing 5.8 grams ethanol.

Subjects

The subjects in Experiments 1, 2 and 3 were male medical students (subjects A,B,C and D). The subjects in Experiment 4 were female members of the Victoria Police (subjects E,F and G). The following characteristics of the subjects were measured:

(1) Height

(2) Weight

(3) Fat thickness

(4) Packed cell volume and a full blood examination

(5) Occurrence of nystagmus

(6) Blood pressure - before and during the experiments

(7) Gross behavioural change, especially disinhibition.

Some of these measurements are given in Table 1. Values for the remainder of the above parameters are not shown, since there were not used in the course of the experiments or in interpreting results.

Table 1

Subject	Weight (kg)	Height (cm)	Surface Area (m^2)	Packed Cell Volume %
A	79.5	175	1.95	43
B	69.6	176	1.85	46
C	87.2	182	2.08	48
D	69.5	173	1.83	47
E	74.0	170	1.85	32
F	52.8	165	1.56	40
G	65.0	169	1.75	37

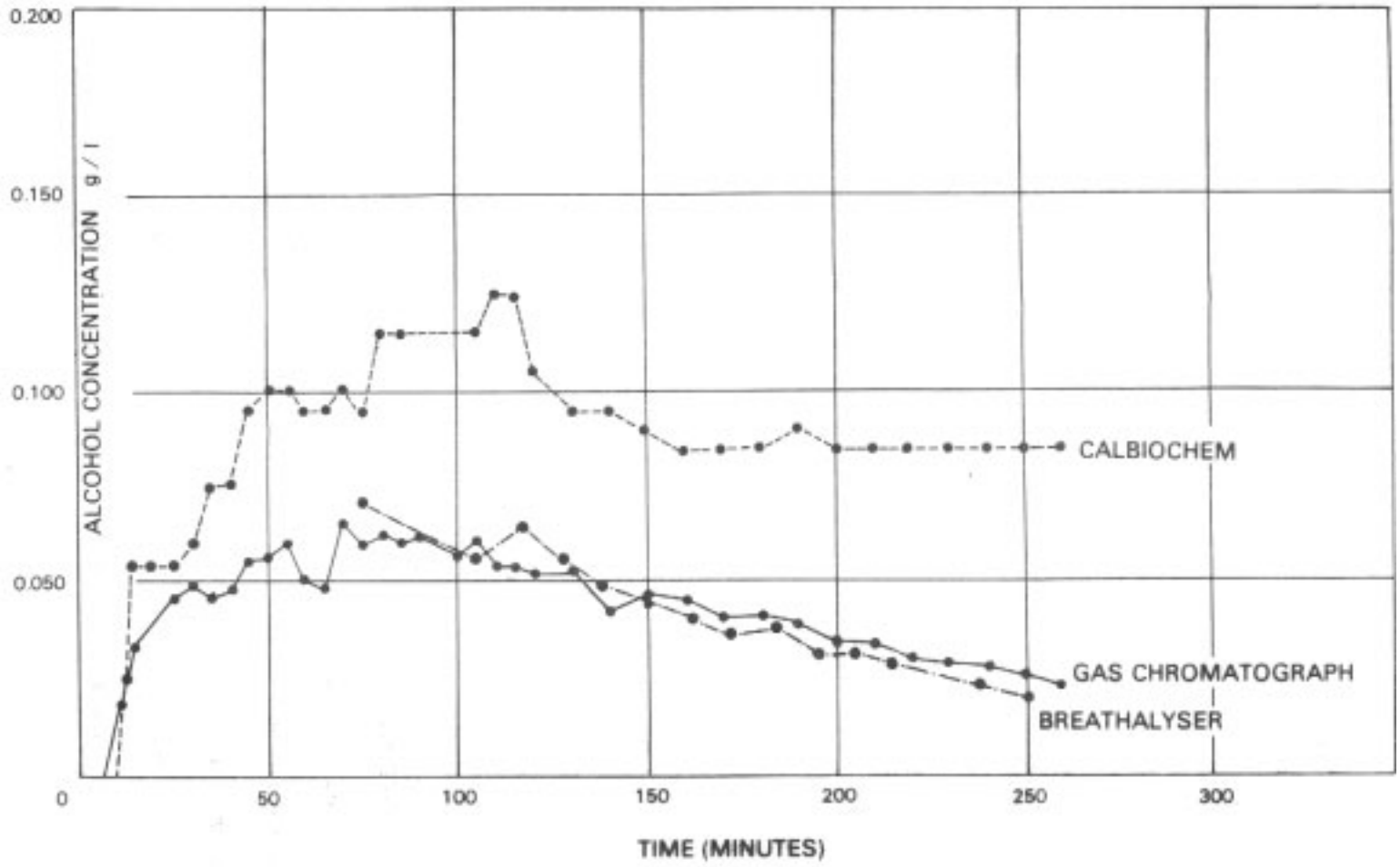
0.200
0.150
0.100
0.050
0
ALCOHOL CONCENTRATION g / l
50
100
150
200
250
300
TIME (MINUTES)
CALBIOCHEM
GAS CHROMATOGRAPH
BREATHALYSER

Figure 1

RESULTS

Comparison between Three Different Methods of Analysis for BAC

Figure 1 shows the BAC vs time curves obtained for subject A in Experiment 1, using the three different analytical methods specified. The enzyme method proved to be unreliable in all experiments. In general, gas chromatography and the breathalyser gave results that matched closely and predictably. Because of the good agreement obtained between the two methods, the results displayed in the tables for each of the four experiments are those for analysis of blood only.

Results of Experiments 1,2,3 and 4

Tables 2,3,4 and 5 show the results of the four experiments. The values given are peak BAC and the time after the last drink at which the peak BAC occurred. Graphs of BAC versus time for Experiments 1,2,3 and 4 are shown in Appendix B.

Experiment 1: Table 2

Subject	Peak BAC (mg/100ml blood)	Time of Peak BAC (mins)
A	65	10
B	77	20
C	55	8
D	64	20

Experiment 2: Table 3

Subject	Peak BAC (mg/100ml blood)	Time of Peak BAC (mins)
A	94	5
B	117	10
C	91	10
D	101	15

Experiment 3: Table 4

Subject	Peak BAC (mg/100ml blood)	Time of Peak BAC (mins)
A	50	18
B	60	15
C	56	10
D	68	5

Experiment 4: Table 5

Subject	Peak BAC (mg/100mls blood)	Time of Peak BAC (mins)
E	72	30
F	77	15
G	85	10

Table 6 shows the weight and sex of each subject, and the corresponding peak BAC per gram of ethanol consumed.

Subject	Sex	Weight (kg)	Peak BAC per gram Ethanol (mg/100ml blood/gm ethanol)
F	Female	52.8	1.9
G	Female	65.0	2.1
D	Male	69.5	1.7
B	Male	69.6	2.0
E	Female	74.0	1.9
A	Male	79.5	1.7
C	Male	87.2	1.4

Table 7 shows the rates of elimination of ethanol from the blood for each subject, for each of the four experiments. These values were calculated from the rate of fall of the BAC over the interval from the time of the peak BAC, to the time of termination of the experiment.

Subject	Experiment	Rate of Elimination (mg/100mls blood/hour)
A	1	13.2
B	1	19.8
C	1	10.2
D	1	10.2
A	2	17.4
B	2	20.4
C	2	14.4
D	2	16.2
A	3	14.4
B	3	18.0
C	3	16.8
D	3	15.6
E	4	11.4
F	4	13.8
G	4	15.0

Table 8 compares results from experiments 1 and 2. BAC values at 80 minutes, 105 minutes and 130 minutes after commencement of drinking, are given for the four subjects in each of these experiments.

Subject	BAC mg/100ml					
	Expt 1			Expt 2		
	80 min	105 min	130 min	80 min	105 min	130 min
A	62	61	52	68	79	91
B	74	61	49	73	90	117
C	54	45	41	60	74	91
D	64	47	48	52	76	101

DISCUSSION

These experiments were essentially a pilot study to test the feasibility of frequent blood tests and the reliability of the methods of blood alcohol analysis. The experiments revealed that the methodology was practicable, but labour intensive. The method was valuable in that it permitted an accurate drawing of the ethanol tolerance curve, which is not possible with breathanalysis.

The results of the experiment are for the most part inconclusive, and the small number of subjects precludes statistical analysis.

However, it would appear that consumption of five standard glasses of beer (200 ml, standard beer) at an even rate over a one hour drinking period, will almost certainly lead to a maximum blood alcohol level which is above the legal limit for driving, (0.05) this is so even when alcohol is ingested with a meal. This result is in general agreement with previous experiments (Santamaria, 1974).

Starmer and Teo (1978) showed that consumption of food with alcohol yields lower BAC's than occur in the fasting state. The work of Bayly and McCallum indicated a similar result. However, according to these workers, the effect of food on the time of occurrence of the peak BAC is not clear. The present experiments do not conclusively demonstrate the effect of food on the BAC versus time curve. The use of a large sample of subjects is probably necessary to show such an effect.

Table 6 indicates no apparent relationship between peak BAC per gram of ethanol and body weight of subjects. This is in accord with the results of our previous experiments (1974), and those of McCallum and Scroggie (1963). The value of the correlation coefficient r was -0.7, which was not significant. The value of r^2 was 0.49, which means that 40% of the observed variation in peak BAC is explained by differences in body weight, and 51% is due to other factors. Starmer (1978) did observe a closer negative correlation, using a larger sample; on purely physiochemical grounds such a correlation would be expected.

The effect of the sex of the subject on the peak BAC cannot be ascertained at this stage because of lack of data.

Rates of elimination show much variability, but are generally within the range reported by Schumate et al (1976). The range of values of 10-20 mg/100mls blood/hour corresponds to about 5-10 grams per hour. (A 200 ml glass of standard Australian beer contains about 8 grams of alcohol).

This relatively low rate of elimination is reflected in Table 8, which compares results from Experiments 1 and 2. These show that once a BAC of about 0.05% has been attained, the consumption of even a small amount of alcohol in the succeeding hour can be expected to cause a further steep rise in the BAC. This finding has serious implications for patterns of drinking in our community. The tendency to drink a loading dose in the fasting state means that very little can be ingested in succeeding hours if subjects are involved in a long drinking session and wish to avoid a continuing rise in BAC.

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R.P. Schumate et al — "The Metabolism Rates of Alcohol in the Human Body" J. Foren.Med. (1967) 14:3, 83-100

J.N. Santamaria — Proc. 6th International Conf. on Alcohol, Drugs and Traffic Safety (1974)

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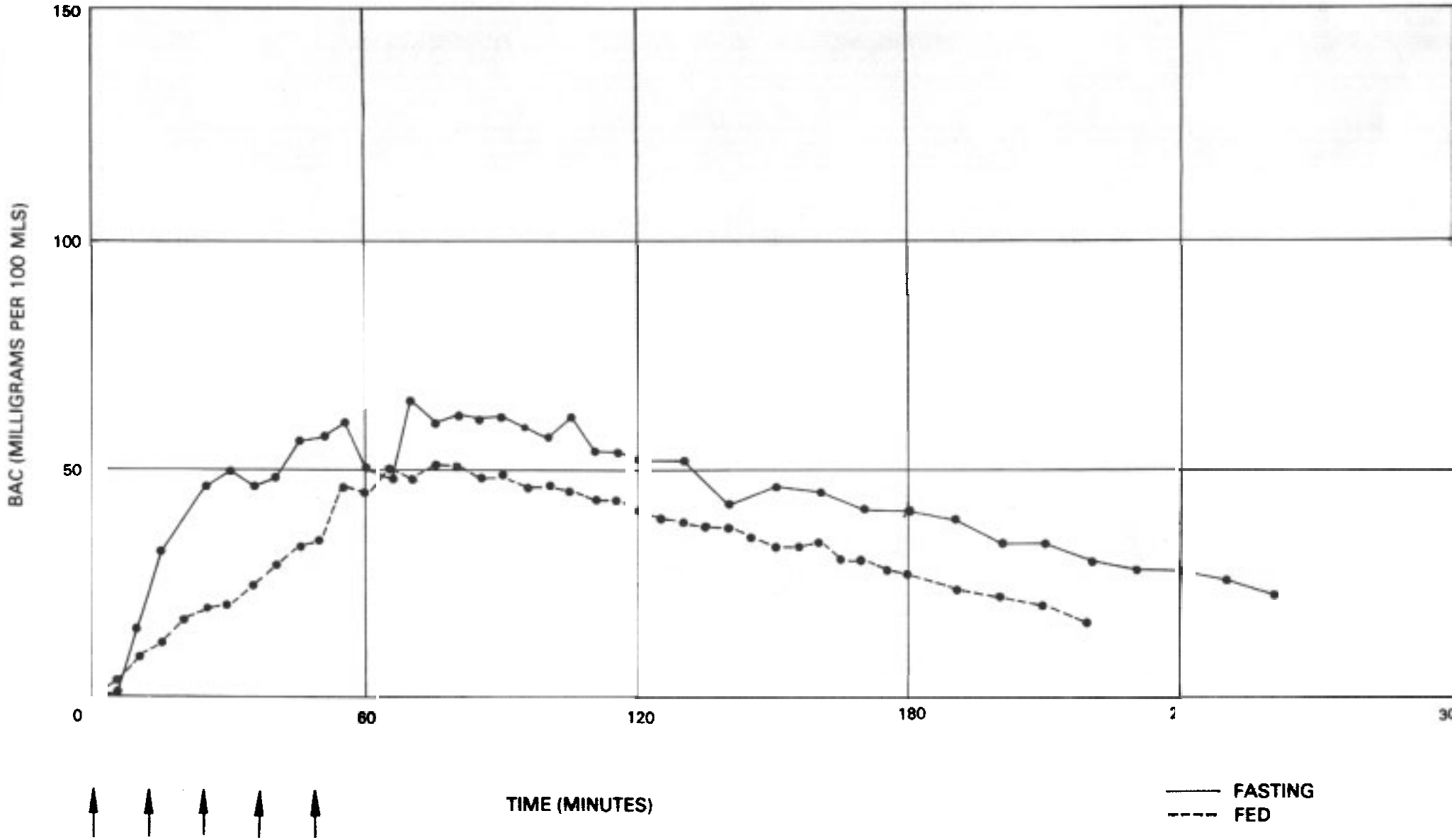
APPENDIX A: STANDARD MEAL FOR ALCOHOL STUDY

Porterhouse steak, medium fat (fried medium)	8 oz (cooked)
French fried chips	6 oz (cooked)
Tossed salad	2 oz lettuce 2 oz tomato 1 oz cucumber 1 oz beetroot
French dressing (oil and vinegar)	Served separately, as desired
White bread (sandwich loaf)	2 slices
Butter	As desired
Tea or coffee	Black, as desired
Milk	2 oz
Sugar	As desired

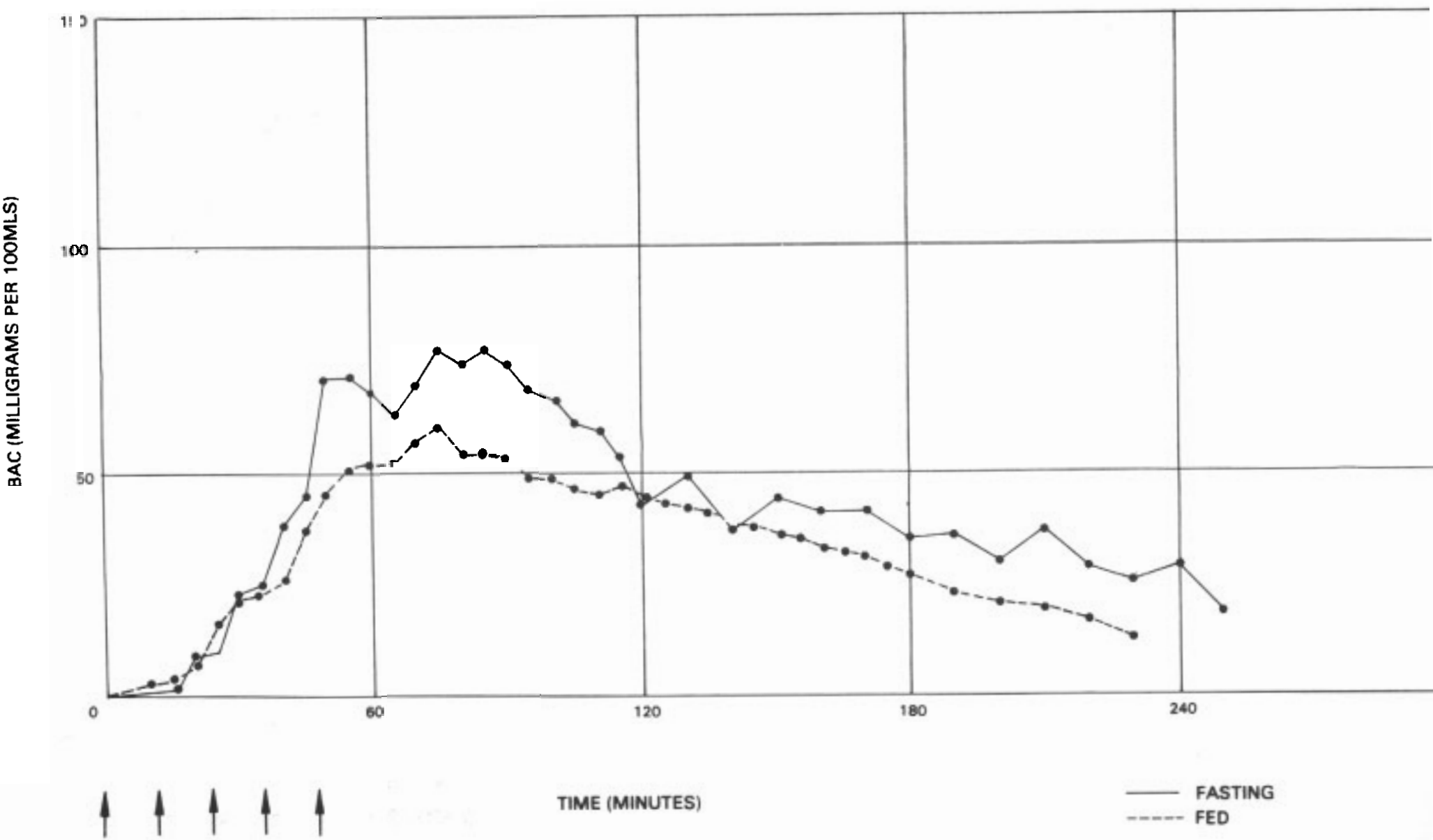
APPENDIX B: GRAPHS OF BAC VERSUS TIME FOR EXPERIMENTS 1, 2, 3 AND 4

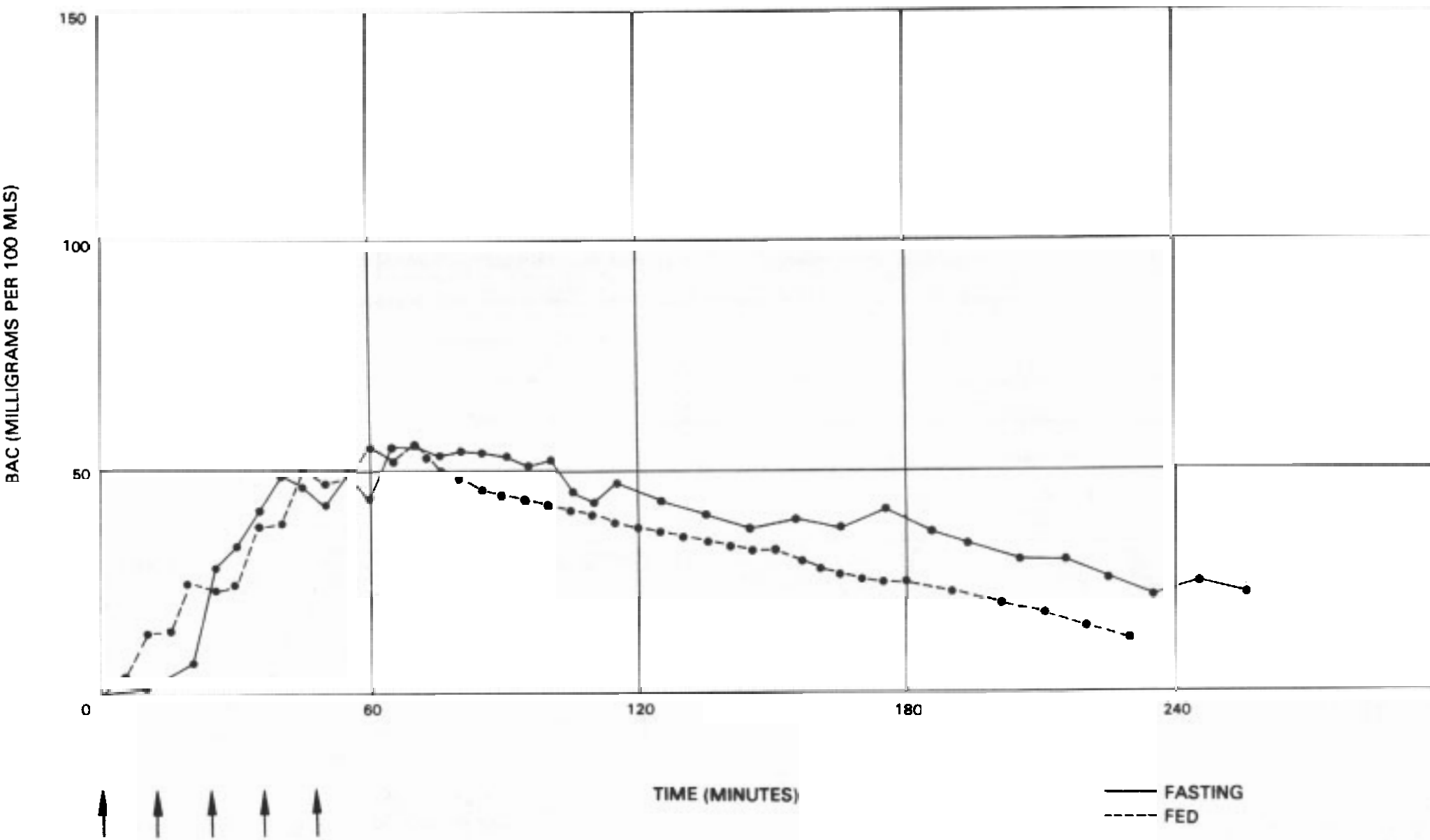
EXPERIMENTS 1 & 3 **SUBJECT A**

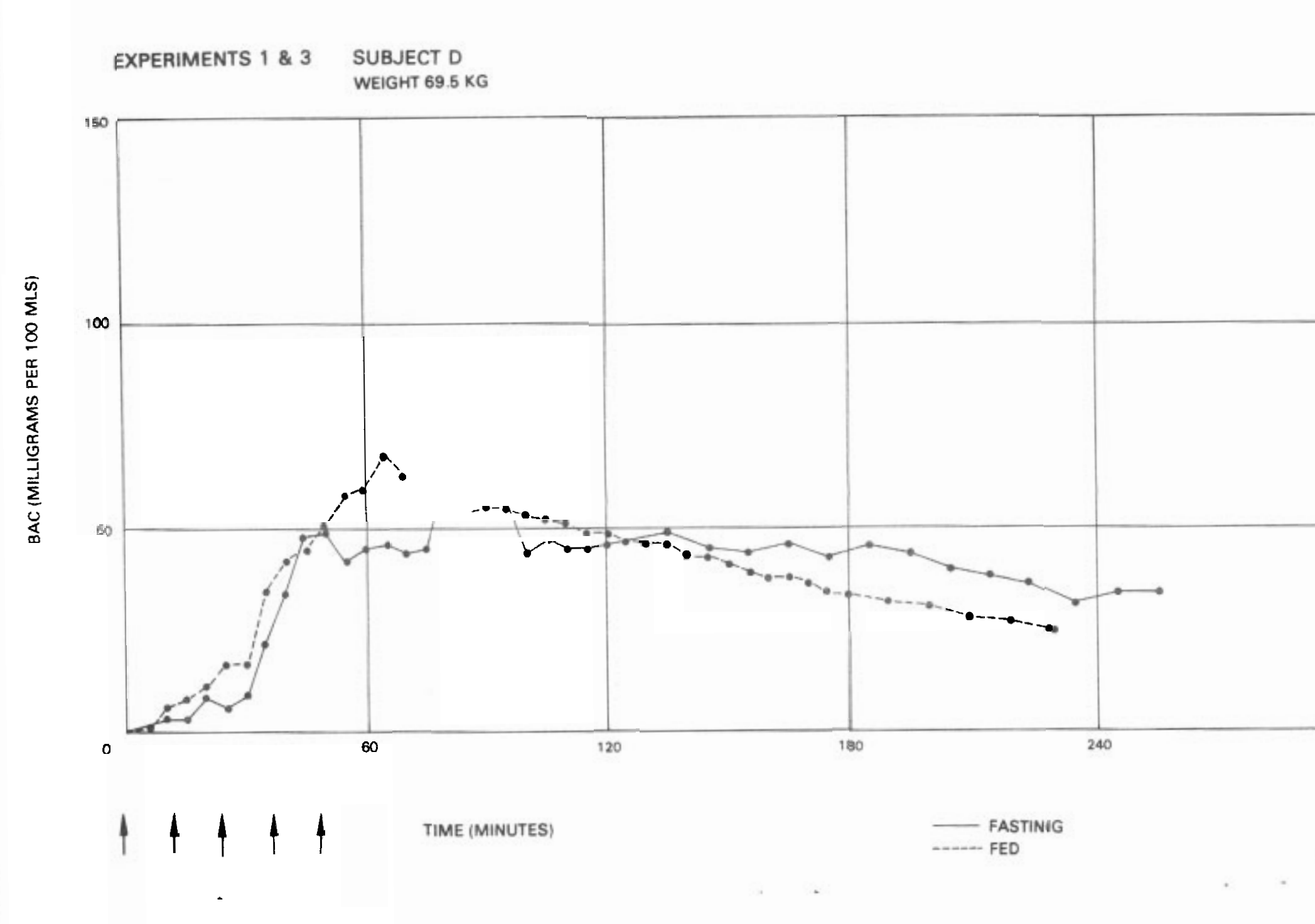
WEIGHT 79.5 KG



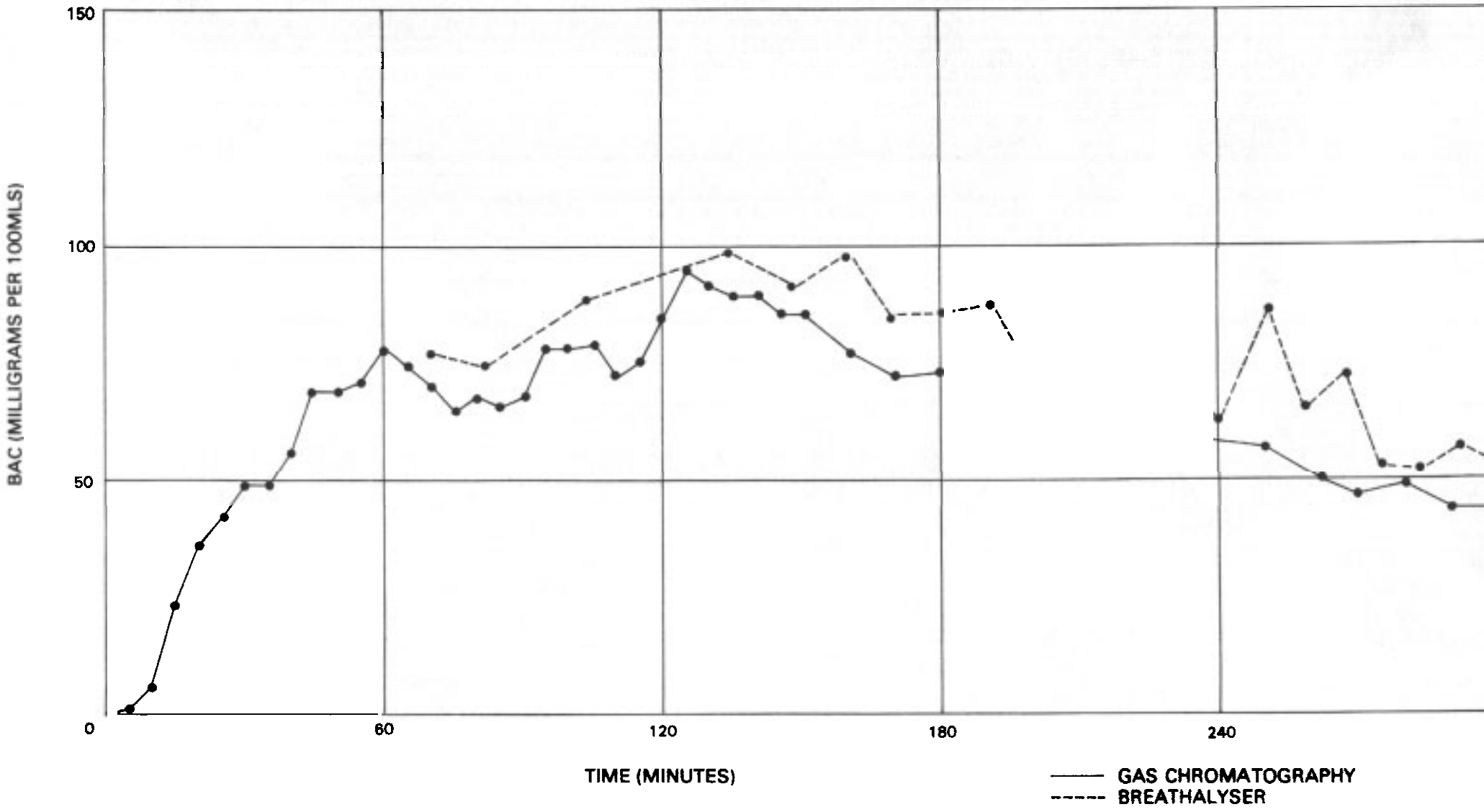
EXPERIMENTS 1 & 3 SUBJECT B
WEIGHT 69.4 KG



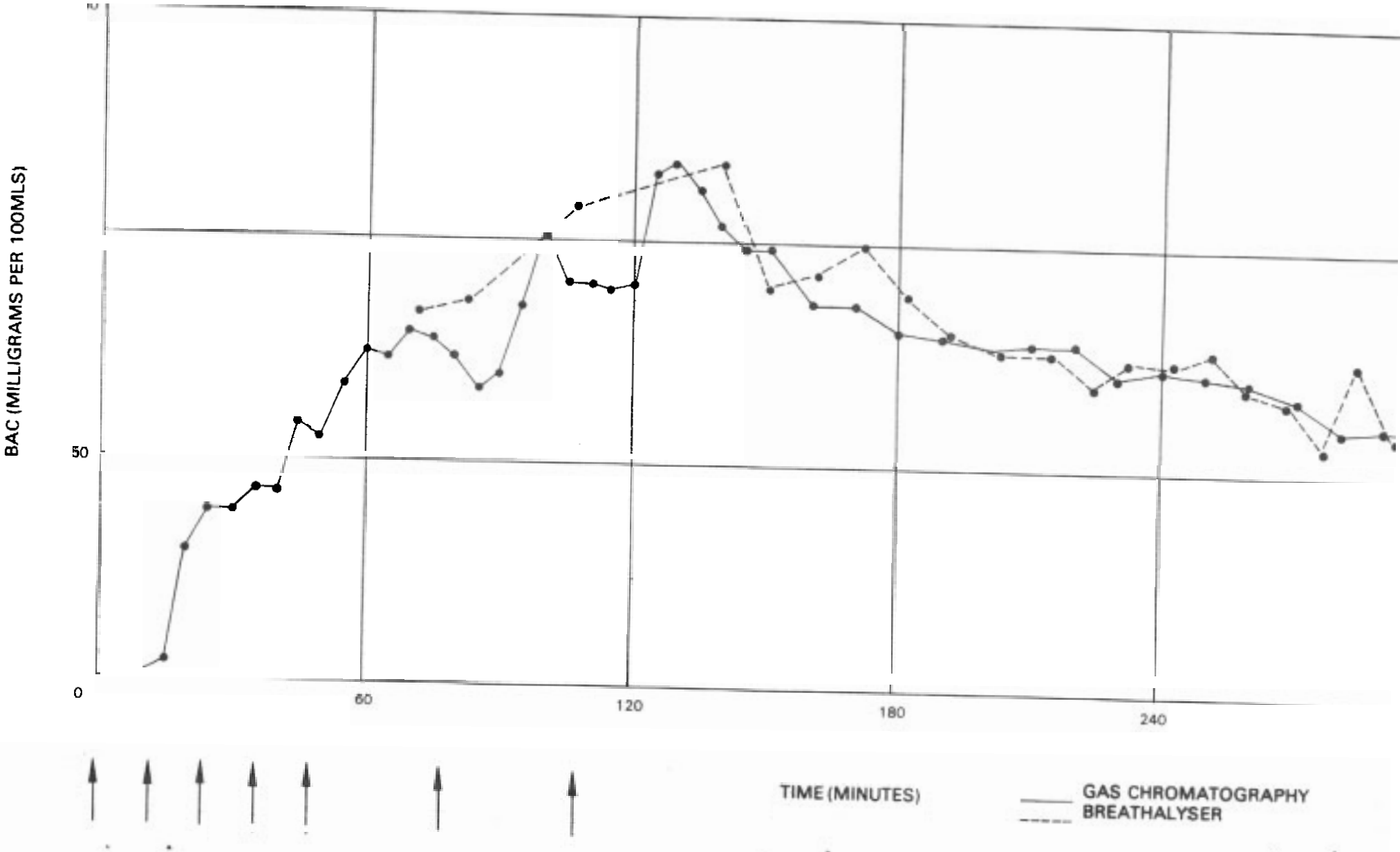

EXPERIMENTS 1 & 3
SUBJECT C
WEIGHT 87.2 KG
150
100
50
0
60
120
180
240
BAC (MILLIGRAMS PER 100 MLS)
TIME (MINUTES)
FASTING
FED


EXPERIMENTS 1 & 3
SUBJECT D
WEIGHT 69.5 KG
150
100
50
0
BAC (MILLIGRAMS PER 100 MLS)
60
120
180
240
TIME (MINUTES)
FASTINIG
FED

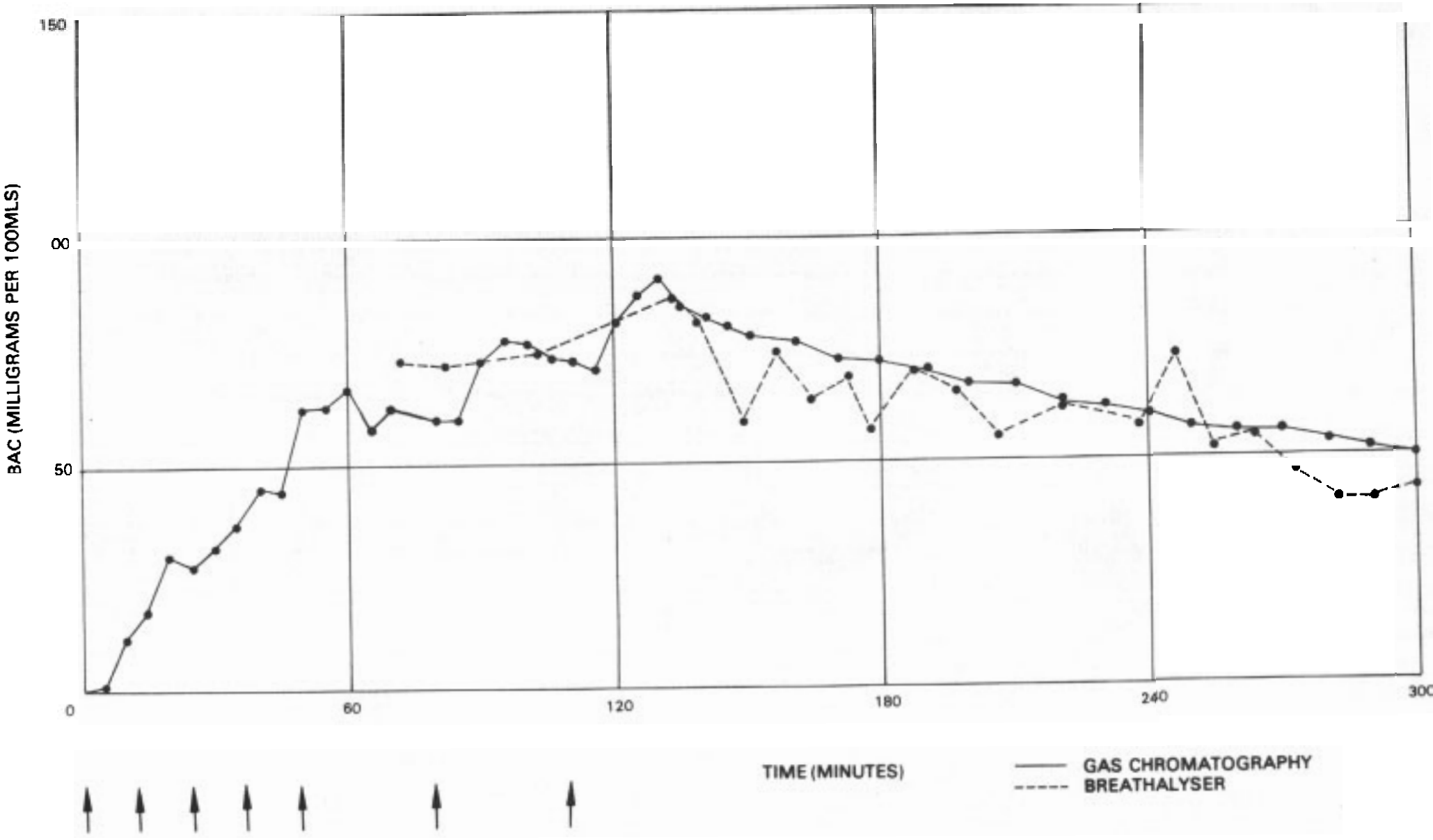
EXPERIMENT 2 SUBJECT A



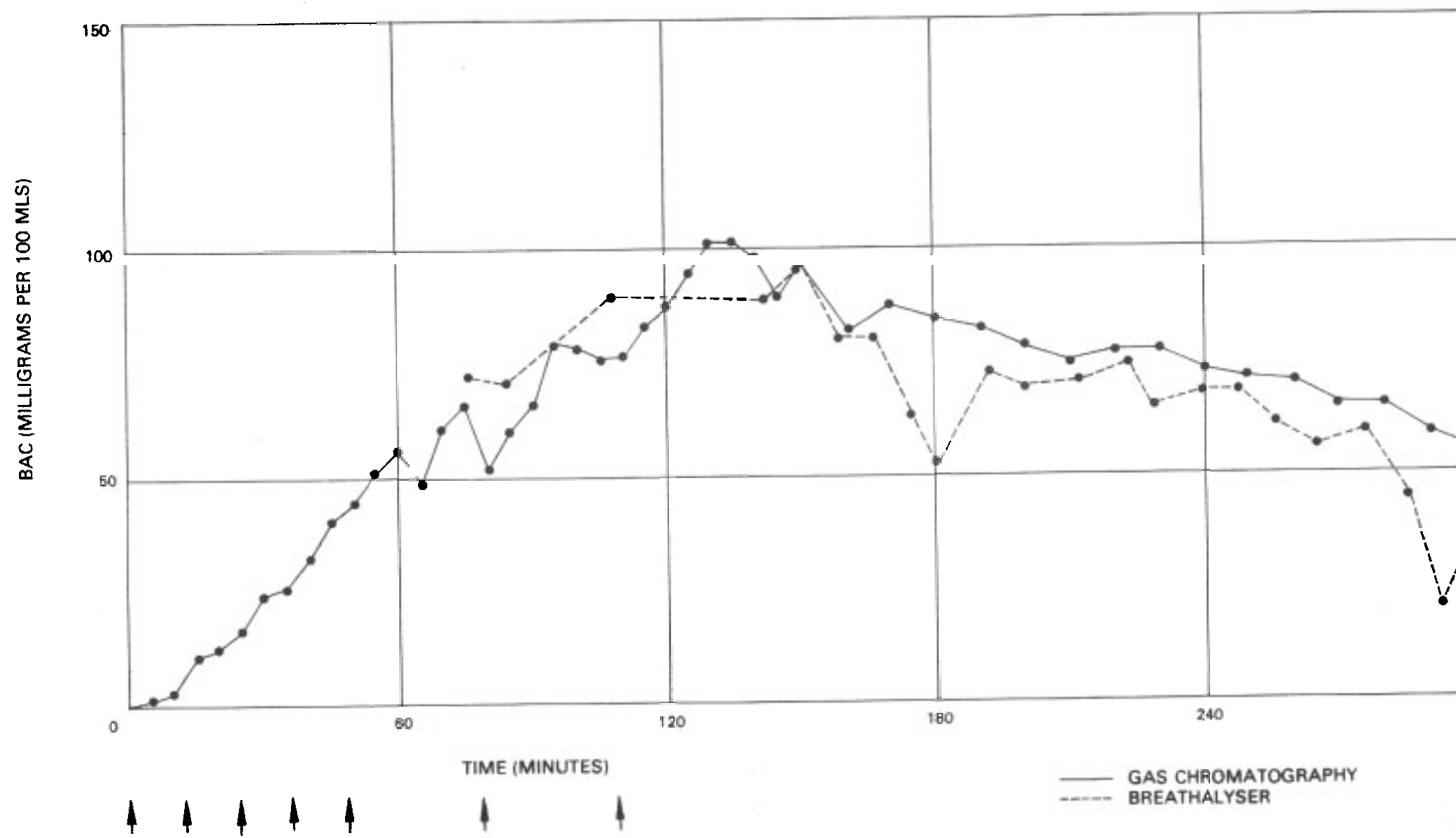
EXPERIMENT 2 SUBJECT B

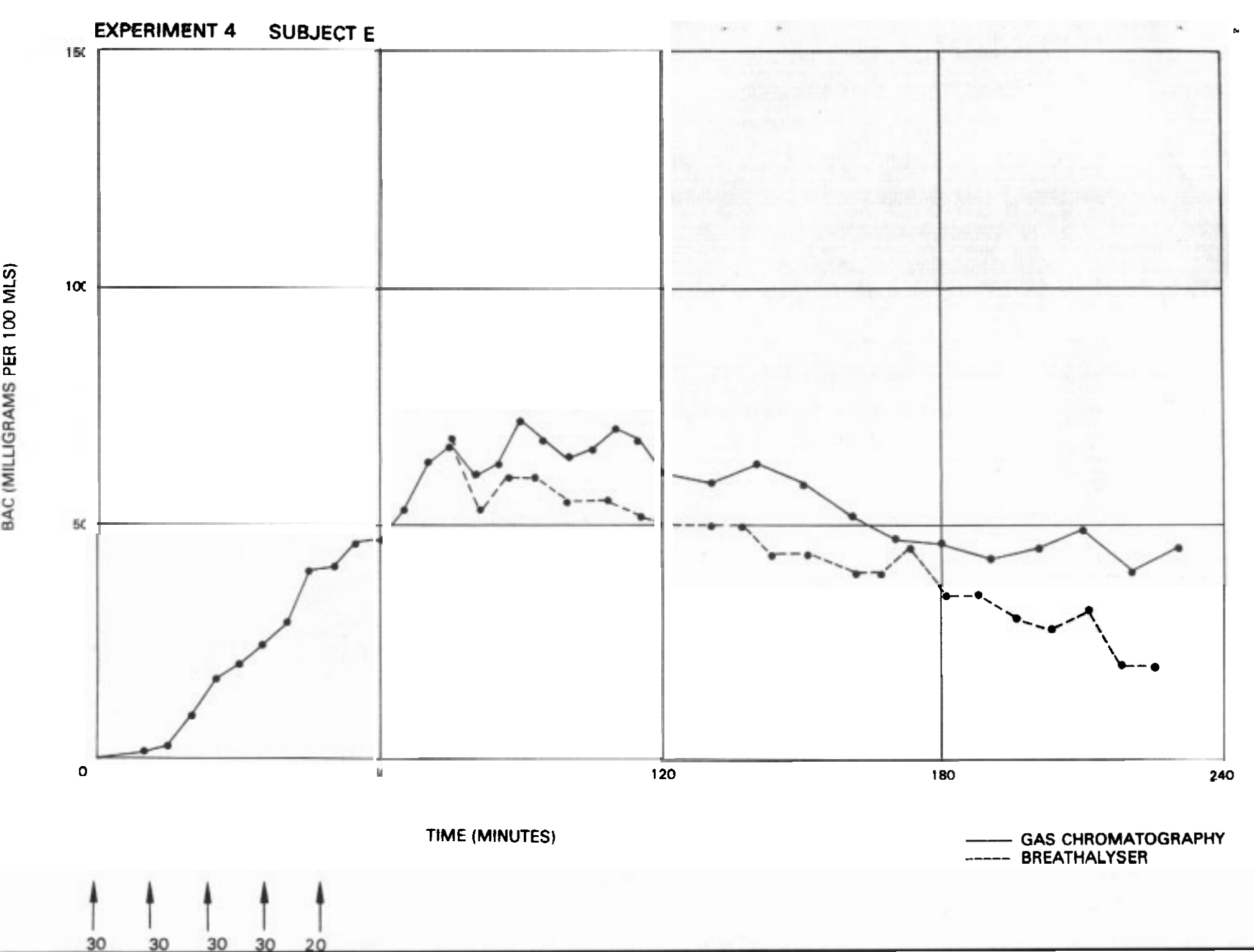


EXPERIMENT 2 SUBJECT C

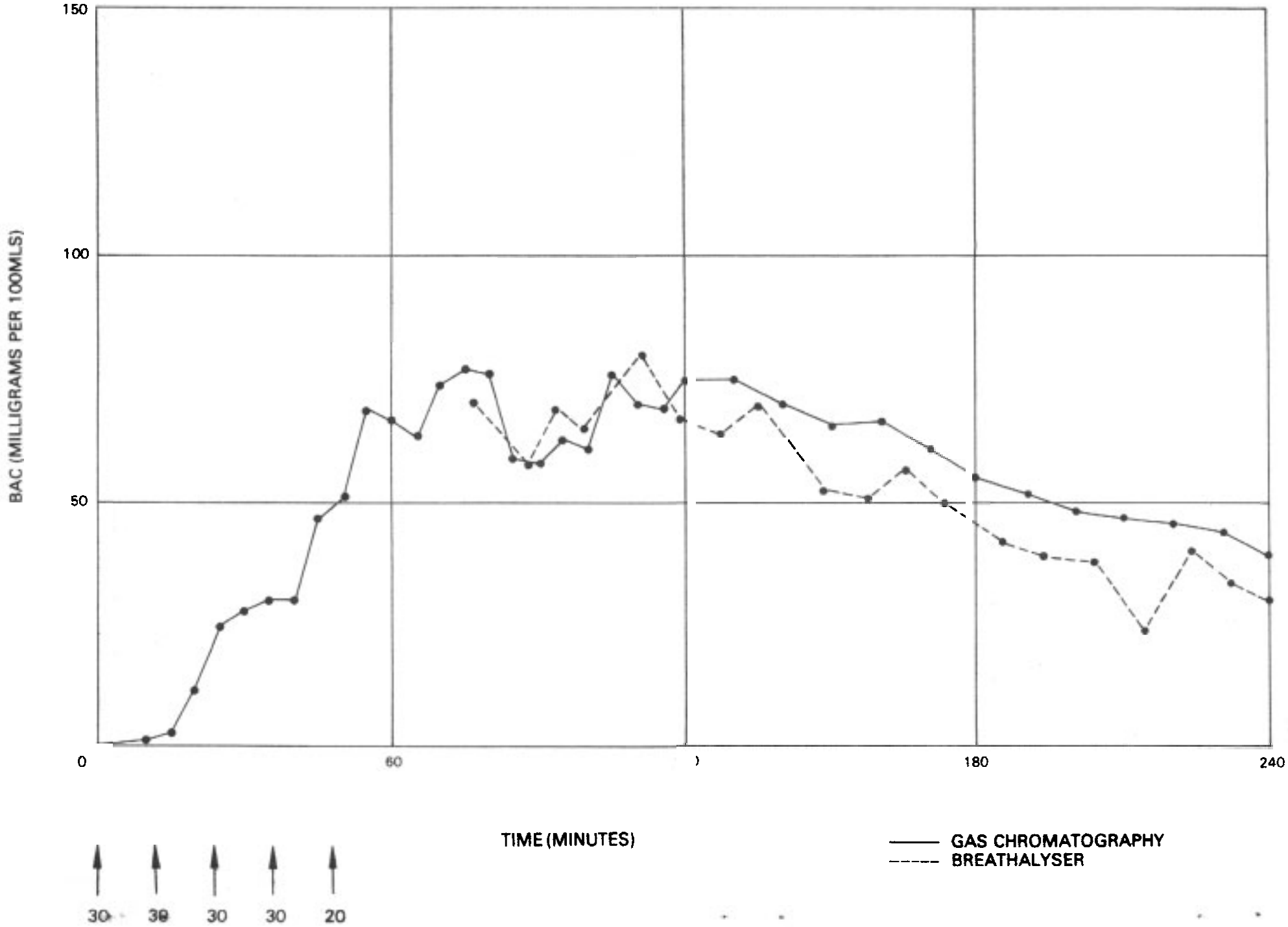


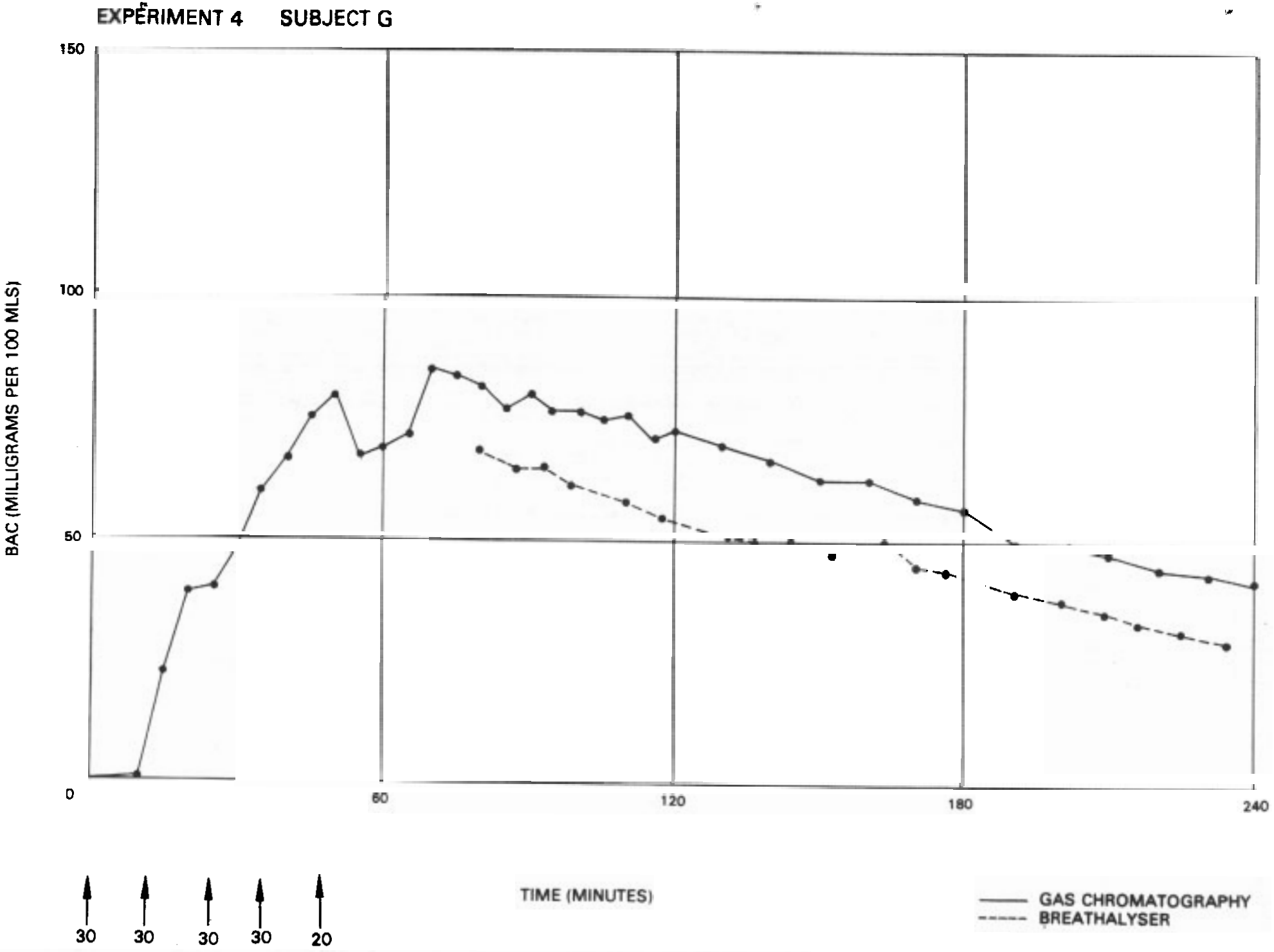
EXPERIMENT 2 SUBJECT D




EXPERIMENT 4 SUBJECT E
BAC (MILLIGRAMS PER 100 MLS)
0
50
100
150
120
180
240
TIME (MINUTES)
GAS CHROMATOGRAPHY
BREATHALYSER
30
30
30
30
20

EXPERIMENT 4 SUBJECT F




EXPERIMENT 4 SUBJECT G
150
100
50
0
BAC (MILLIGRAMS PER 100 MLS)
60
120
180
240
TIME (MINUTES)
30
30
30
30
20
GAS CHROMATOGRAPHY
BREATHALYSER