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A Review of Commercial Radionuclide Calibrators

M Baker, K Chari, S M Judge, T D MacMahon and A Stroak

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A Review of Commercial Radionuclide Calibrators

M. Baker, K. Chari, S M Judge, T D MacMahon, and A Stroak
Division of Quality of Life

ABSTRACT

Radionuclide Calibrators are used in nuclear medicine departments to assay the radioactive content of radiopharmaceuticals prior to administration to the patient. The aim of the measurement is to ensure that the patient receives the lowest practicable radiation dose compatible with obtaining a good quality image for diagnostic purposes or with delivering the required dose to the tumour in therapeutic use.

It is a condition of the license to use radiopharmaceuticals (ARSAC certificate) that the activity administered is within 10% of the prescribed activity. This implies that the Radionuclide Calibrators should have an accuracy better than this – perhaps around 5%. This report summarises the results from tests of commercial Radionuclide Calibrators to verify the accuracy of such measurements if the instrument is used 'as is' from the manufacturer. Nine commercial Radionuclide Calibrators were obtained from the manufacturers for testing. Each chamber was tested using samples of typical radionuclides used in nuclear medicine (^{18}F, ^{00}Cr, ^{67}Ga, ^{99m}Tc, ^{111}In, ^{123}I, ^{125}I, ^{131}I, ^{201}Tl). Each nuclide was dispensed into common formats (2ml BS ampoule, 10R Schott vial, 2 ml BD syringe, 5 ml BD syringe and P6 vial).

The results show that some instruments do meet the 5% specification on accuracy for a range of radionuclides and sample formats. However, some instruments give readings that are significantly in error (up to 90% wrong), others show systematic discrepancies for all the radionuclides tested.

The conclusion is that experimental verification of the accuracy of commercial Radionuclide Calibrators is essential when used in the clinical setting.

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Approved on behalf of the Managing Director, NPL
by Dr. T.D. MacMahon, authorised by the Director, Quality of Life Division

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1 Introduction

Radionuclide Calibrators are instruments used in hospital radiopharmacies to assay the total activity in doses of radiopharmaceutical products, prior to administration to patients. The aim of the measurement is to ensure that the patient receives the lowest practicable radiation dose compatible with obtaining a good quality image for diagnostic purposes or with delivering the required dose to the tumour in therapeutic use.

A wide range of models of Radionuclide Calibrator are in common use in the UK but there has been no published information available comparing the performance of available models, in particular, investigating whether the instruments could attain the accuracy of measurement needed to meet regulatory requirements. The aim of this study was to address this shortfall in the information available.

Nine commercial Radionuclide Calibrators were obtained from the manufacturers for testing. Each chamber was tested using samples of typical radionuclides used in nuclear medicine (^{18}F, ^{00}Cr, ^{67}Ga, ^{99m}Tc, ^{111}In, ^{123}I, ^{125}I, ^{131}I, ^{201}Tl). Each nuclide was dispensed into common formats (2ml BS ampoule, 10R Schott vial, 2 ml BD syringe, 5 ml BD syringe and P6 vial). Each sample was assayed in each chamber in accordance with the manufacturer's instructions, and the results were compared to the known activities in the samples.

This reports summarises how the samples were prepared for measurement, how the measurements on the radionuclide calibrators were performed and presents the results from the study. The identities of the models are not disclosed as the purpose is to give general guidance on the use of such instruments and not to act as a selection guide.

First, a brief summary of the regulatory requirements for Radionuclide Calibrators is given.

2 Regulatory requirements

The main regulatory issue for most radiopharmacies is compliance with the conditions of the ARSAC Certificate, and the professional body for Medical Physicists (IPEM) has produced guidance on how this may be achieved. Some radiopharmacies (particularly those involved in production of FDG for PET) may also require compliance with GMP.

Further details of these three issues are given below, with the aim of establishing the accuracy needed in practice for measurements using Radionuclide Calibrators.

a ARSAC Certification

Regulation 2 of the Medicines (Administration of Radioactive Substances) Regulations 1978 requires that any doctor or dentist who wishes to administer a radiopharmaceutical to a patient must hold a certificate issued by Health Ministers.
The Administration of Radioactive Substances Advisory Committee (ARSAC) was set up to advise ministers on applications for certificates. The National Radiological Protection Board published "Notes for Guidance on the Clinical Administration of Radiopharmaceuticals and Use of Sealed Sources" in 1988 on behalf of ARSAC. Under this guidance, practitioners are expected to collaborate with physicists to assist the practitioner with procedures including the calibration of equipment and estimating tissue dose (paragraph 2.24). One principle of the guidance is that the activity administered to the patient must be the minimum consistent with acquiring adequate information (paragraph 3.2). The guidance goes on to specify 'Diagnostic Reference Levels' – the activity level of a radiopharmaceutical that is not expected to be exceeded when good and normal practice regarding diagnostic technical performance is applied. The Medical Exposure Directive 97/43/Euratom requires Member States to promote the establishment and use of these Diagnostic Reference Values.

During inspections for compliance with the terms of the ARSAC Certificate, it is normally expected that all administered activities are within 10% of the Diagnostic Reference Level (DRL). If activities are consistently greater than the DRL, further investigation and action may be taken even if the activities are within 10% of the DRL, as this could not considered as optimisation [1].

b IPSM (IPEM) Report No 65: Protocol for establishing and maintaining the calibration of medical radionuclide calibrators and their quality control

The IPSM Protocol was written in order to give clear recommendations on how to perform the quality control of Radionuclide Calibrators. The main recommendations were:

- The calibration of the instrument should be traceable to a national primary standard
- The activity administered to the patient should be within 10% of the prescribed activity
- An accurate 'Reference Instrument' may be used to calibrate 'Field Instruments' – the 'Field Instrument' being intended for routine daily use, the 'Reference Instrument' being a Radionuclide Calibrator that has been calibrated using secondary standard sources directly traceable to a national standards laboratory.

- The recommended acceptable tolerances for these instruments are:

Parameter	Reference Instrument	Field Instrument
Agreement with secondary standard	2%	Not applicable
Agreement with tertiary standard (obtained using the reference instrument)	Not applicable	5%

- Subsidiary calibrations should be performed to establish the response of the instrument to radiopharmaceuticals in containers (for example, syringes) or volumes which are different from the containers or volumes used to calibrate the instrument.

c Regulations for the manufacture of radiopharmaceuticals (GMP)

The Medicines for Human Use (Marketing Authorisations etc.) Regulations 1994 SI 3144 require that medicinal products are licensed before they can be marketed in the UK. These regulations include compliance with a quality standard (Good Manufacturing Practice (GMP)). The principles and guidelines of GMP are stated in an EC Directive (91/356/EEC).

One issue under GMP is that the activity content of a dose of the radiopharmaceutical has to be within the range of activities stated on the Marketing Authorisation or the product specification. For some radiopharmaceuticals, the specification that the product is expected to meet is stated in the British Pharmacopoeia (BP) or in the equivalent European (Ph Eur) or US (USP) publications. This authoritative publication is the responsibility of the British Pharmacopoeia Commission (BPC).

The BP includes monographs covering a number of radiopharmaceuticals. For example, for Fludeoxyglucose [^{18}F] Injection, the Ph Eur states in Monograph 1325:

The injection contains not less than 90.0 per cent and not more than 110.0 per cent of the declared fluorine-18 radioactivity at the date and time stated on the label.

A tolerance of 10% is also stated for other radiopharmaceuticals (for example, ^{111}In, ^{67}Ga).

All the above regulations and guidance indicate that the activity to be administered to the patient must be within 10% of the prescribed activity. This implies that the activity must be assayed with an accuracy better than 10%. Given that a Radionuclide Calibrator can be used to assay activity to an accuracy of 1-2% in a laboratory setting, a reasonable accuracy to aim for would be 5% for a 'field' instrument.

3 Experimental study

The National Physical Laboratory holds the UK primary standards of radioactivity. These primary standards have been used to calibrate a stable transfer instrument (an ionisation chamber) that has been shown to be stable to better than 0.1% over a period of 30 years.

For each radionuclide studied, a bulk solution containing the radionuclide was obtained. An accurately weighed aliquot of the solution was dispensed into a 2ml BS ampoule and measured on the NPL transfer instrument to determine the radioactivity concentration. Corrections were applied where necessary for any gamma-emitting impurities present as measured by high resolution gamma spectrometry.

The bulk solution was then dispensed gravimetrically to the different containers (2ml BS ampoule, 10R Schott vial, 2 ml BD syringe, 5 ml BD syringe and P6 vial). The activity in each container was then calculated from the mass of the solution dispensed and known radioactivity concentration.

The following types of sample were prepared:

Container	**Nominal volume of solution (ml)**
2 ml BS ampoule	1 ml
10R Schott vial	4 ml
2 ml BD syringe	1 ml
5 ml BD syringe	2.5 ml
P6 vial	4 ml

The uncertainty in the activity was less than 2%.

4 Measurement of samples on the commercial chambers

The samples were measured on the Radionuclide Calibrators using the following protocol:

1) The calibration factor was set according to the manufacturer's instructions
2) Corrections were applied where indicated in the equipment manual for syringes, Schott vial or P6 vial, or the appropriate preset dial factor was selected. These radionuclide dependent correction factors ranged from zero to 25%.
3) If no corrections were indicated in the manual, none were made
4) No corrections were applied for gamma emitting impurities
5) Samples were loaded into the chambers for measurement following manufacturer's instructions

Corrections were included for background and for radioactive decay.

5 Results

The recorded activity was compared to the known activity; the results are given in Appendix 1. No uncertainties have been assigned to the measured results as the aim of this exercise is to investigate the variability of the results.

6 Discussion

The results may be analysed in terms of dependence on radionuclide or dependence on instrument. Assuming an accuracy of 5% is a reasonable figure given the regulatory requirements, a comparison of the results is given in Table 1 (dependence on radionuclide) and Table 2 (dependence on calibrator), overleaf.

It should be noted that these results indicate only the accuracy of the factory-set calibration factors for the Radionuclide Calibrators. The instruments may still provide reliable, reproducible, results if the calibration factors are reset experimentally using traceable reference sources.

Nuclide	Schott vial	P6 vial	2ml syringe	5ml syringe	2ml ampoule	Largest discrepancy
F-18	8	8	5	6	8	13%
Cr-51	4	4	6	4	6	30%
Ga-67	6	6	7	8	7	15%
Tc-99m	7	7	7	7	7	19%
In-111	5	4	2	4	3	20%
I-123	6	5	1	4	2	25%
I-125	1	2	0	3	4	88%
I-131	8	8	3	2	6	13%
Tl-201	8	8	3	2	6	11%

Table 1: Number of Calibrators that read within 5% of the true value
The table shows the number of commercial calibrators (out of a total of 9 calibrators tested) that read within 5% of the known activity for a particular radionuclide and container format.

Comments on Table 1

- Many of the chambers assayed common radionuclides (^{99m}Tc, ^{131}I etc) accurately in vial formats
- The accuracy was less consistent in other formats (syringes)
- A number of large discrepancies were observed (up to 88% wrong for ^{125}I)
- The accuracy in assaying ^{125}I was poor for many Calibrators – this could be expected for this low energy radionuclide
- Some radionuclides (^{111}In, ^{125}I) appear more difficult to assay than others

Calibrator	10R Schott vial	P6 vial	2ml syringe	5ml syringe	2ml ampoule	Maximum error (excluding I-125)
A	8	6	3	4	7	21%
B	6	7	4	5	6	20%
C	6	7	4	4	6	20%
D	7	9	7	7	9	6%
E	2	2	0	1	2	11%
F	4	4	5	6	4	12%
G	3	4	6	7	4	13%
H	8	8	9	9	9	8%
I	8	8	8	9	9	8%

Table 2: Number of radionuclides assayed within 5% by Calibrator

The table shows the number of radionuclides (out of a total of 9 tested) that each Calibrator (labelled A-I) assayed within 5% of the true value, for each type of container format tested. The last column shows the maximum error observed, excluding ^{125}I for which large discrepancies were observed.

Comments

- There is a marked difference between the performance of the chambers, with some instruments assaying nearly all the radionuclides with an accuracy of better than 5%, whereas some chambers assay very few radionuclides accurately
- At least one chamber shows a systematic discrepancy of –10% for all measurements
- Some chambers assay many radionuclides accurately but have large discrepancies for particular cases; for example, a chamber that assays ^{99m}Tc accurately is not necessarily accurate for ^{111}In

7 Conclusions

This report has summarised the results from an extensive experimental study of the accuracy of commercial Radionuclide Calibrators. The instruments were operated in accordance with manufacturer's instructions, using factory-set calibration factors.

The results from this study show that the variability in the measurements is greater than the 5% accuracy needed to meet the 10% tolerance for compliance with regulatory and other guidance. Although some of the instruments performed extremely well, meeting the 5% specification, some instruments did not assay a number of radionuclides within this band. Of particular concern are the few large errors (up to 90% wrong) that were observed; these errors might not be detected unless the instrument is subjected to a systematic quality assurance programme.

This demonstrates the continuing need for calibration and testing of the instruments using reference standards that are traceable to national primary standards.

8 References

[1] Ebdon-Jackson, S., Private Communication 2004

9 Acknowledgements

The authors would like to express their thanks to the manufacturers and suppliers of Radionuclide Calibrators who kindly loaned the instruments for testing, and to Mike Woods (IRMC Ltd) for advice and guidance.

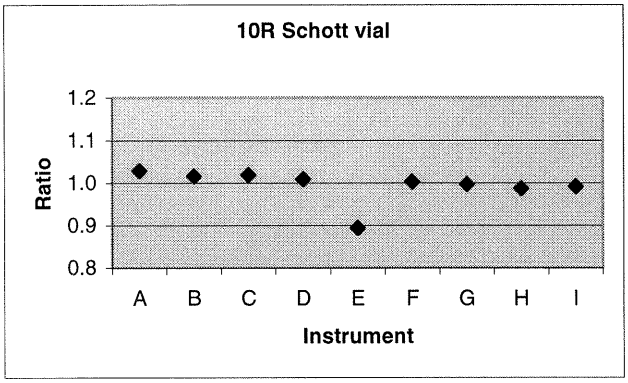
We gratefully acknowledge the financial support of the UK Department of Trade & Industry (National Measurement System Directorate).

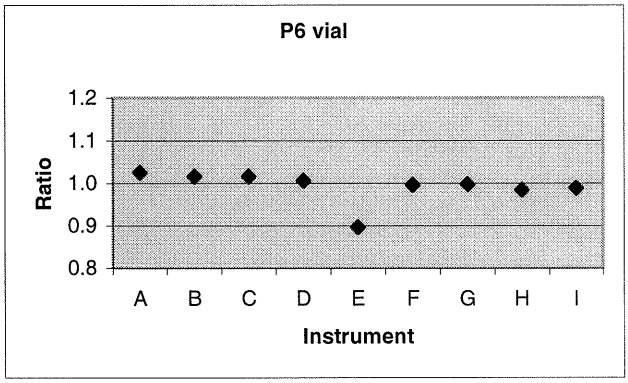
Appendix 1: Results from experimental study

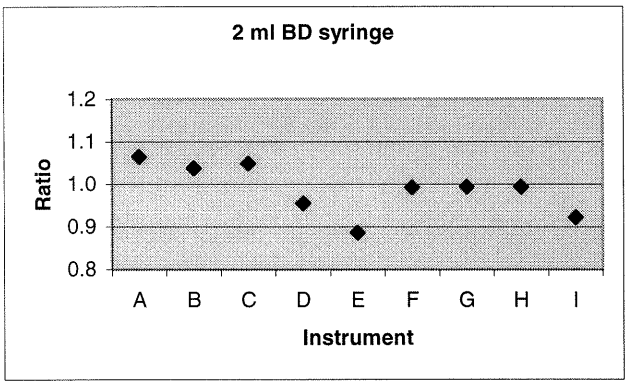
F-18 results

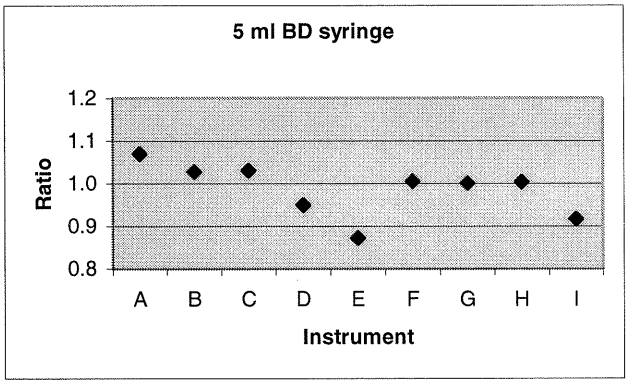
Shown by Instrument

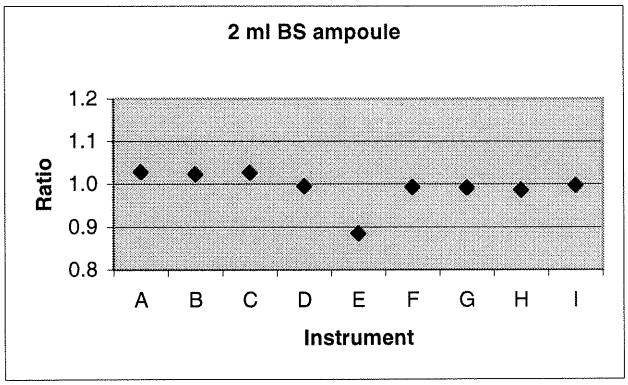
Container	A	B	C	D	E	F	G	H	I
2 ml BS	1.028	1.023	1.027	0.995	0.885	0.993	0.991	0.986	0.997
10R Schott	1.029	1.016	1.019	1.009	0.894	1.003	0.997	0.987	0.992
2 ml BD (syr)	1.065	1.038	1.049	0.955	0.886	0.993	0.994	0.994	0.922
5 ml BD (syr)	1.07	1.028	1.031	0.95	0.872	1.006	1.001	1.004	0.917
P6 vial	1.025	1.016	1.016	1.006	0.896	0.996	0.998	0.984	0.989





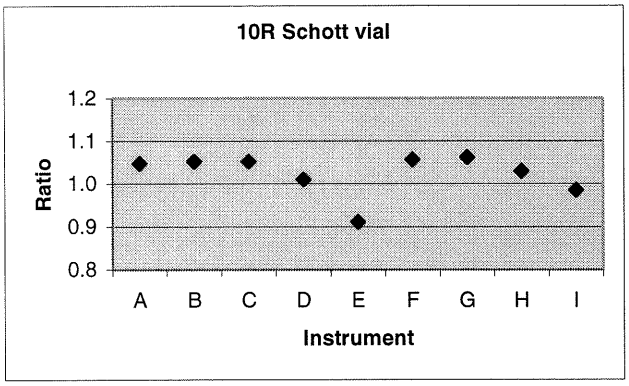


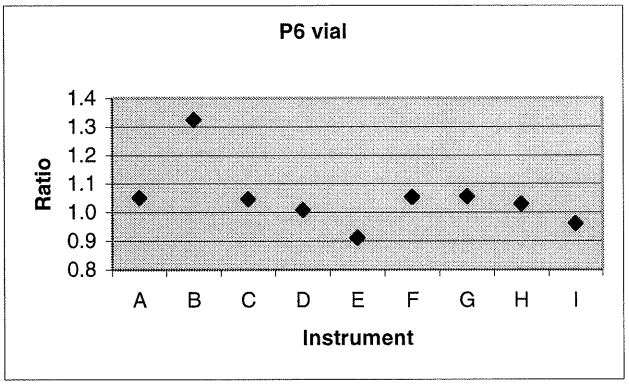


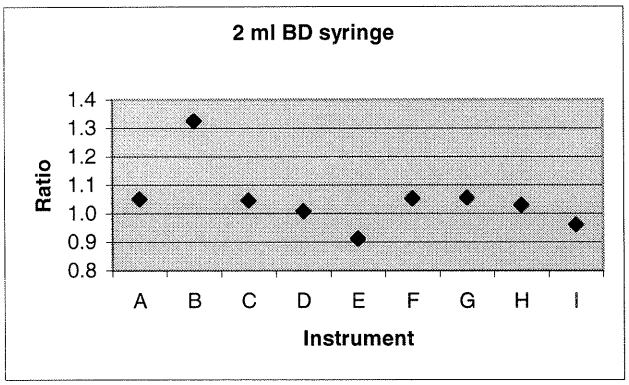


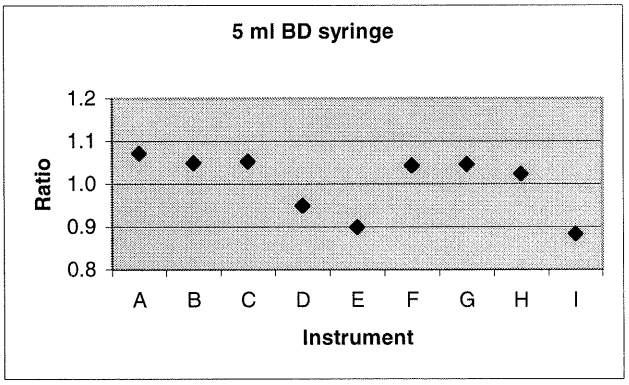
Cr-51 results
Shown by Instrument

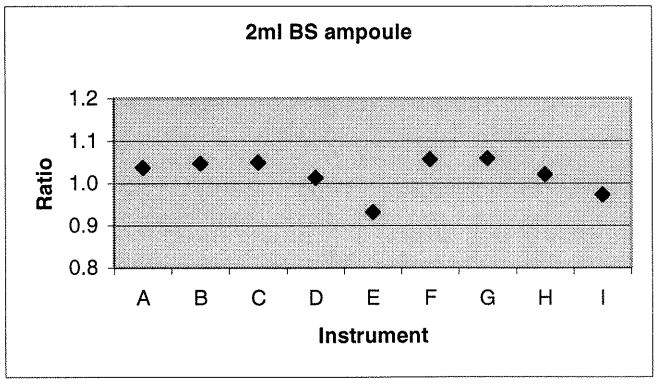
Container	A	B	C	D	E	F	G	H	I
2 ml BS	1.037	1.047	1.049	1.013	0.932	1.057	1.059	1.021	0.973
10R Schott	1.048	1.052	1.052	1.010	0.911	1.057	1.062	1.030	0.985
2 ml BD (syr)	1.056	1.043	1.043	0.954	0.909	1.039	1.049	1.007	0.895
5 ml BD (syr)	1.072	1.049	1.053	0.949	0.899	1.043	1.046	1.024	0.883
P6 vial	1.051	1.325	1.047	1.008	0.911	1.053	1.056	1.030	0.961





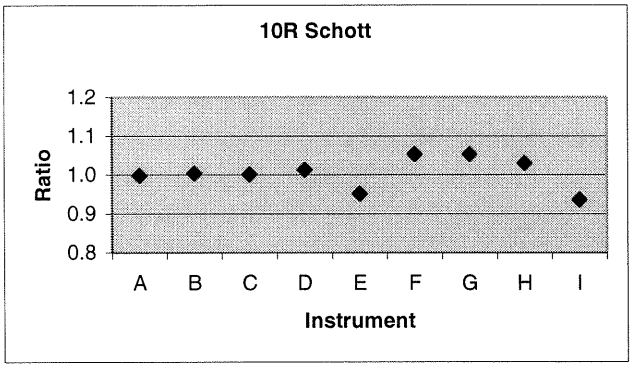


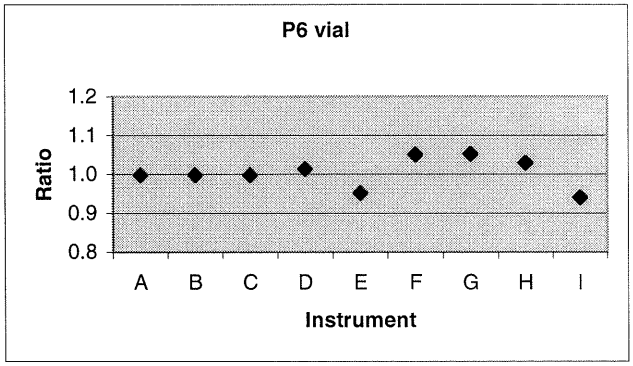


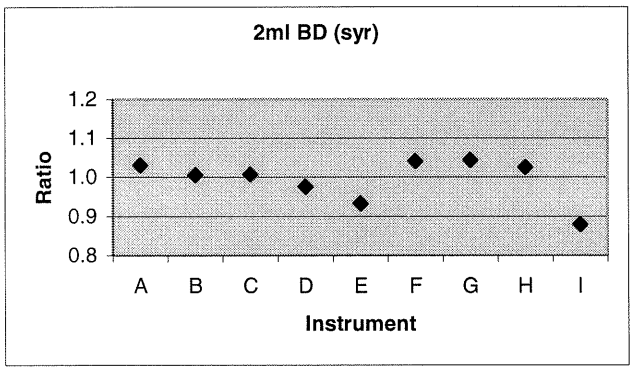


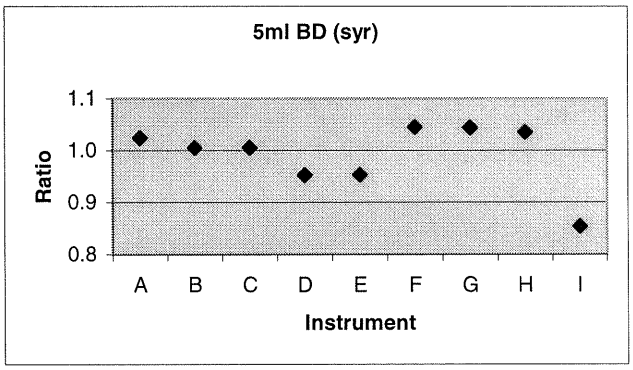
Ga-67 results
Shown by Instrument

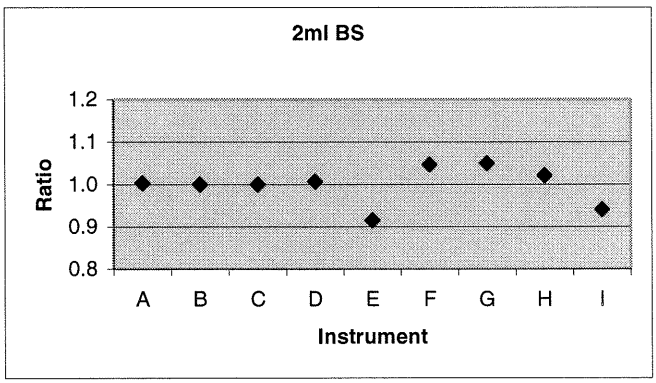
Container	A	B	C	D	E	F	G	H	I
2 ml BS	1.003	1.000	1.000	1.007	0.915	1.047	1.050	1.021	0.940
10R Schott	0.998	1.004	1.001	1.013	0.951	1.053	1.053	1.030	0.936
2 ml BD (syr)	1.030	1.005	1.007	0.976	0.933	1.041	1.043	1.025	0.879
5 ml BD (syr)	1.024	1.005	1.005	0.952	0.953	1.045	1.044	1.035	0.854
P6 vial	0.998	0.998	0.998	1.014	0.952	1.051	1.052	1.029	0.940





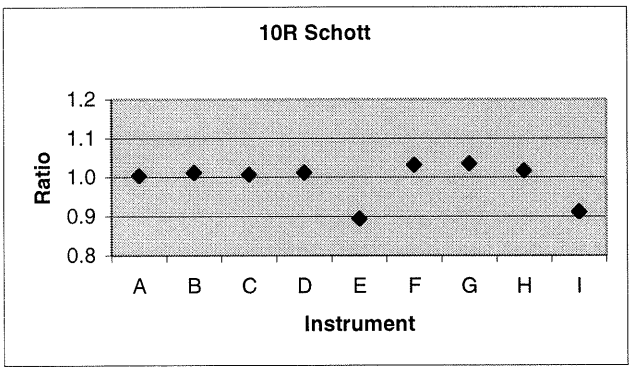


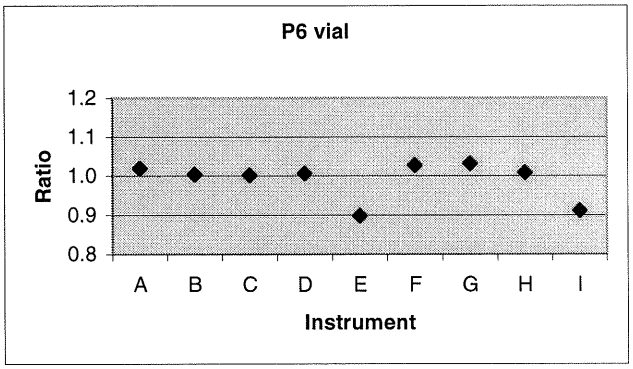


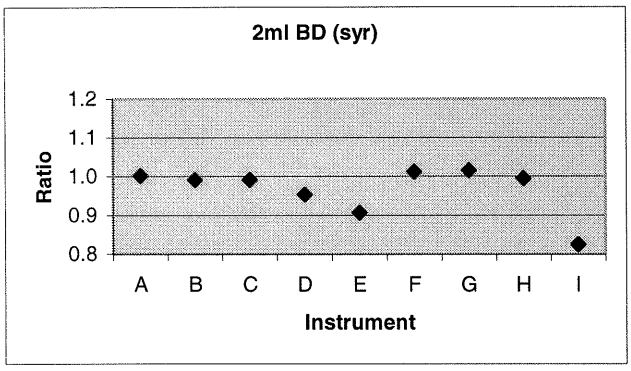


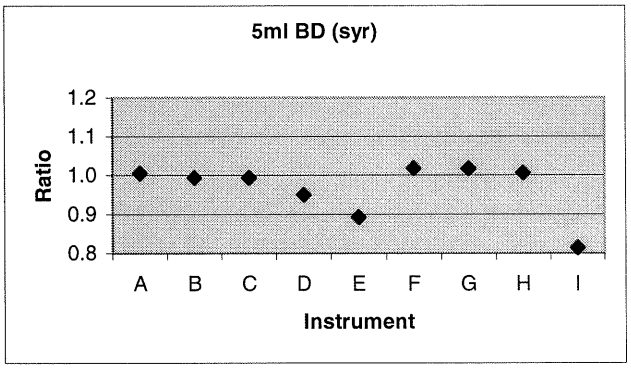
Tc-99m results
Shown by Instrument

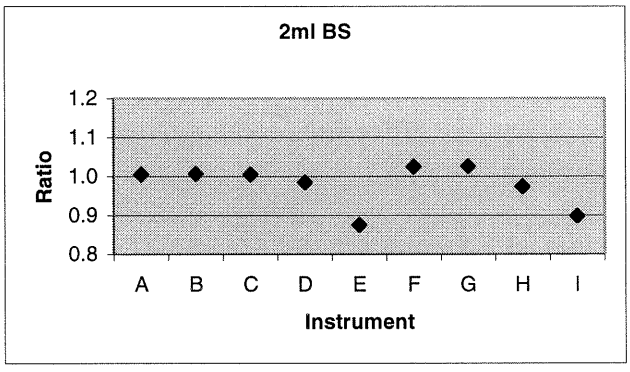
Container	A	B	C	D	E	F	G	H	I
2 ml BS	1.005	1.007	1.005	0.985	0.875	1.025	1.026	0.974	0.898
10R Schott	1.004	1.012	1.007	1.012	0.894	1.032	1.035	1.017	0.911
2 ml BD (syr)	1.002	0.991	0.991	0.953	0.906	1.012	1.015	0.995	0.825
5 ml BD (syr)	1.005	0.994	0.994	0.950	0.892	1.018	1.017	1.006	0.814
P6 vial	1.019	1.004	1.002	1.006	0.898	1.028	1.032	1.009	0.911





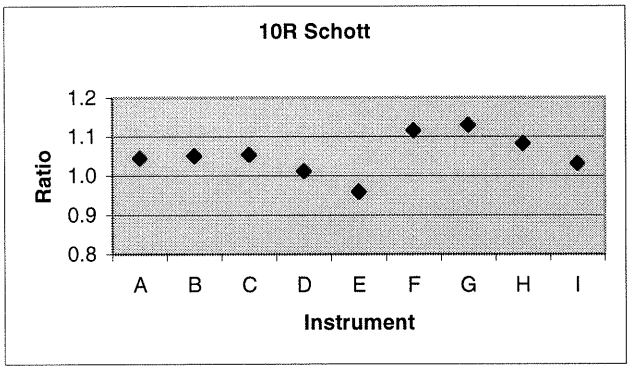


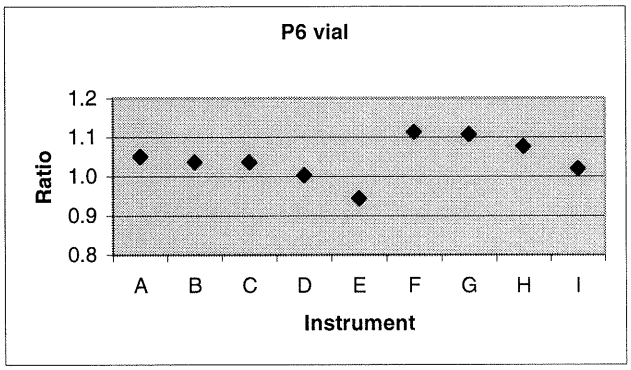


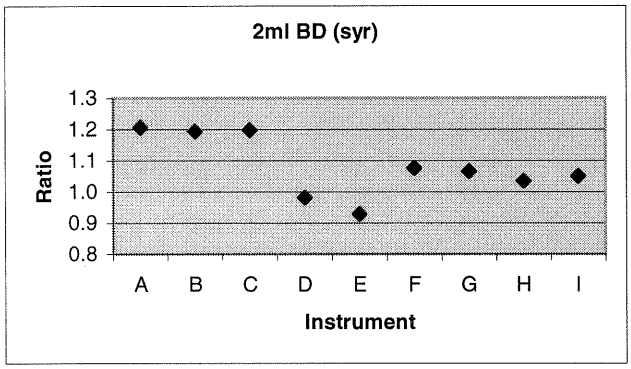


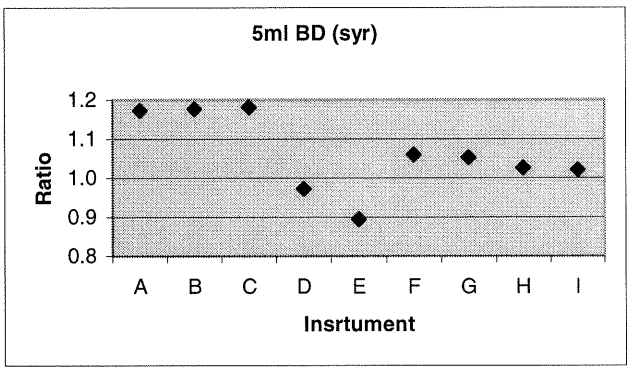
In-111 results
Shown by Instrument

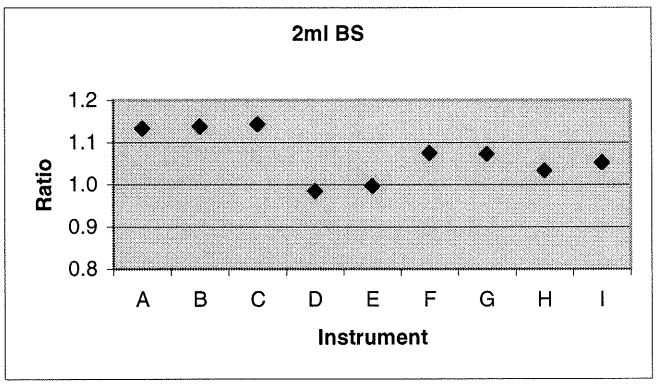
Container	A	B	C	D	E	F	G	H	I
2 ml BS	1.133	1.138	1.143	0.985	0.997	1.075	1.073	1.033	1.052
10R Schott	1.045	1.051	1.054	1.012	0.959	1.116	1.130	1.083	1.032
2 ml BD (syr)	1.206	1.194	1.198	0.981	0.929	1.076	1.066	1.035	1.051
5 ml BD (syr)	1.173	1.177	1.181	0.972	0.895	1.060	1.052	1.026	1.021
P6 vial	1.051	1.037	1.037	1.004	0.944	1.113	1.108	1.077	1.020





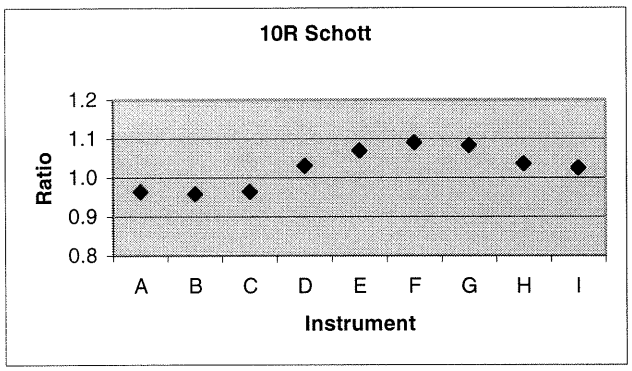


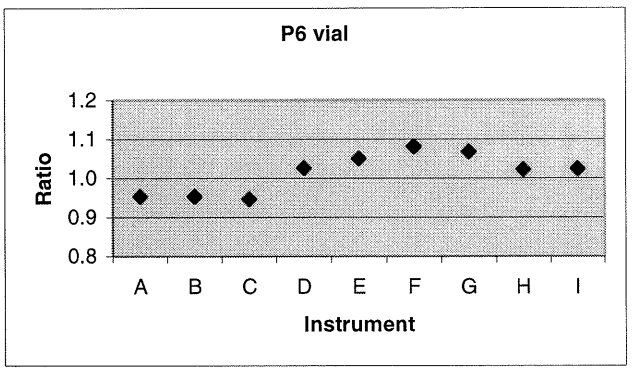


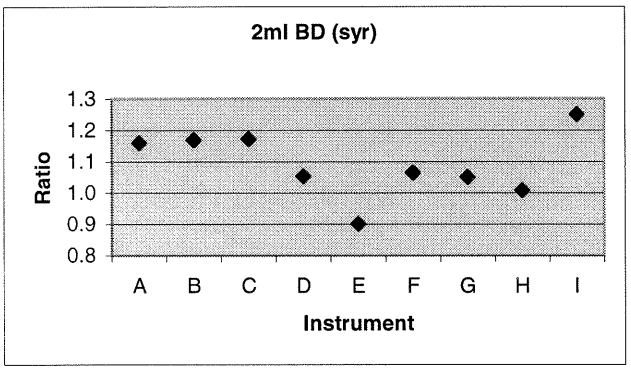


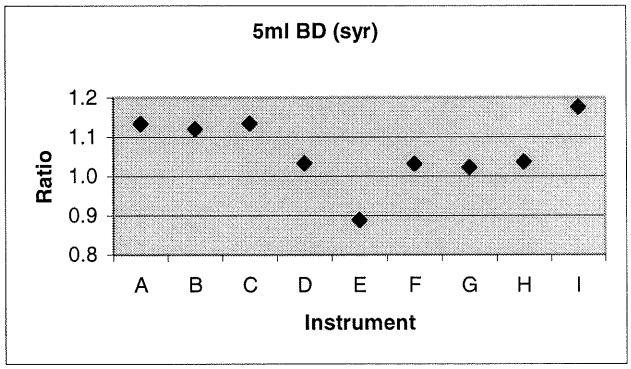
I-123 results
Shown by Instrument

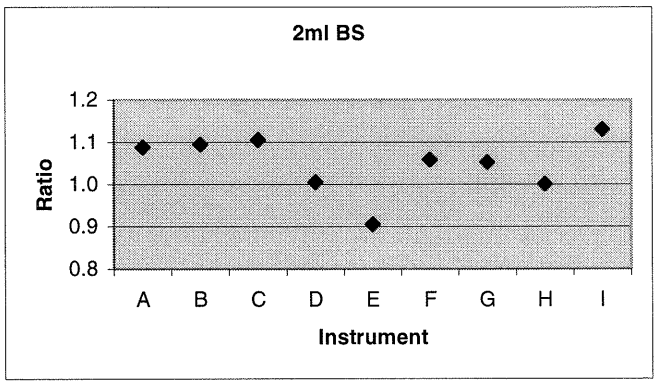
Container	A	B	C	D	E	F	G	H	I
2 ml BS	1.088	1.095	1.105	1.005	0.905	1.058	1.052	1.001	1.130
10R Schott	0.964	0.958	0.964	1.031	1.070	1.090	1.083	1.036	1.025
2 ml BD (syr)	1.160	1.169	1.172	1.054	0.901	1.065	1.051	1.008	1.251
5 ml BD (syr)	1.134	1.121	1.135	1.033	0.888	1.032	1.023	1.037	1.176
P6 vial	0.953	0.953	0.947	1.026	1.051	1.081	1.068	1.023	1.024





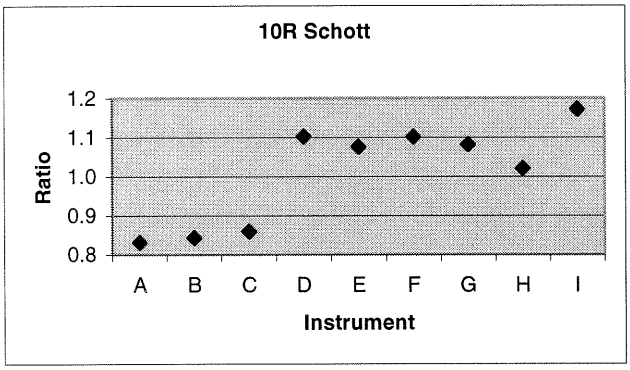


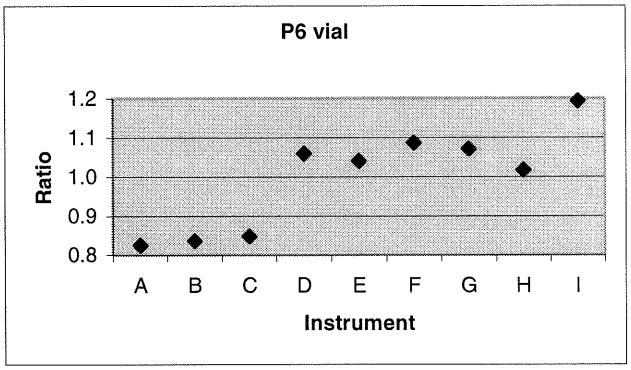


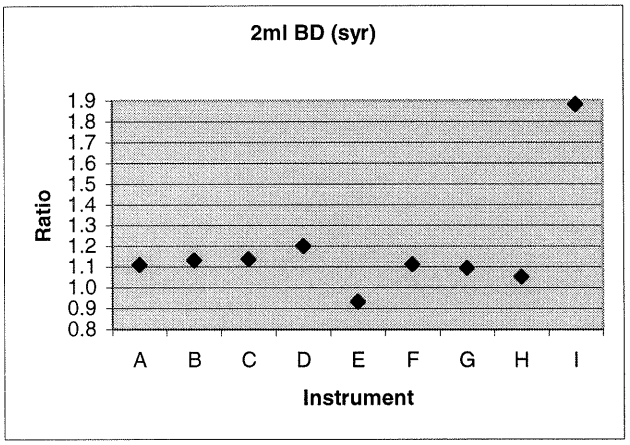


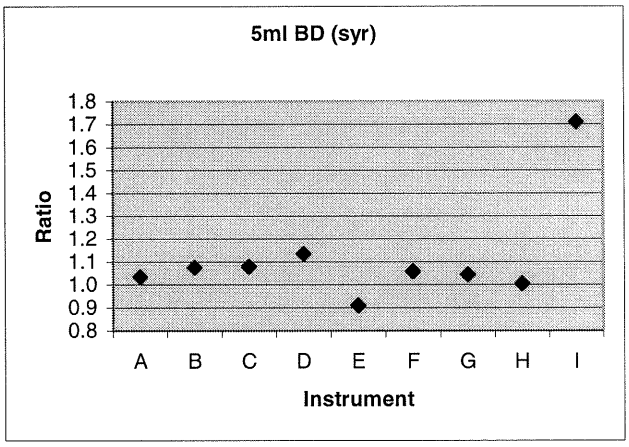
I-125 results
Shown by Instrument

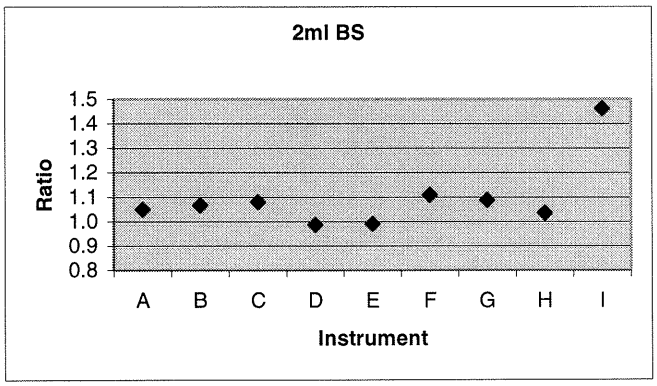
Container	A	B	C	D	E	F	G	H	I
2 ml BS	1.049	1.066	1.080	0.986	0.991	1.109	1.087	1.035	1.462
10R Schott	0.831	0.843	0.859	1.103	1.076	1.102	1.082	1.021	1.172
2 ml BD (syr)	1.109	1.131	1.137	1.201	0.933	1.113	1.094	1.053	1.882
5 ml BD (syr)	1.034	1.074	1.079	1.135	0.909	1.058	1.043	1.005	1.711
P6 vial	0.825	0.836	0.848	1.060	1.041	1.087	1.071	1.018	1.193





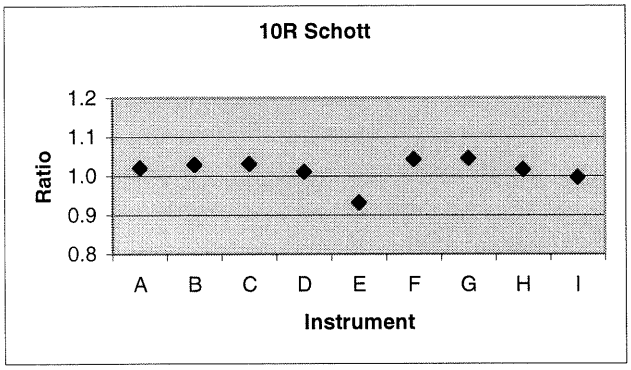


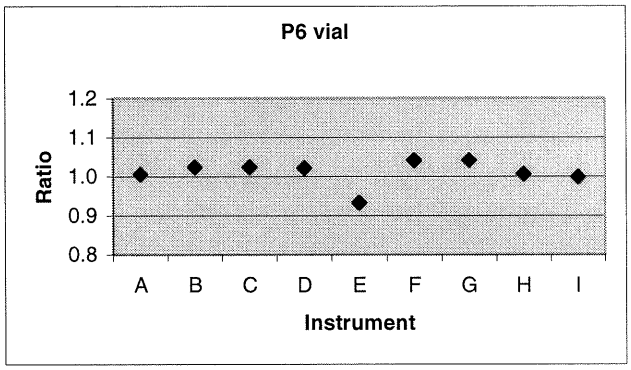


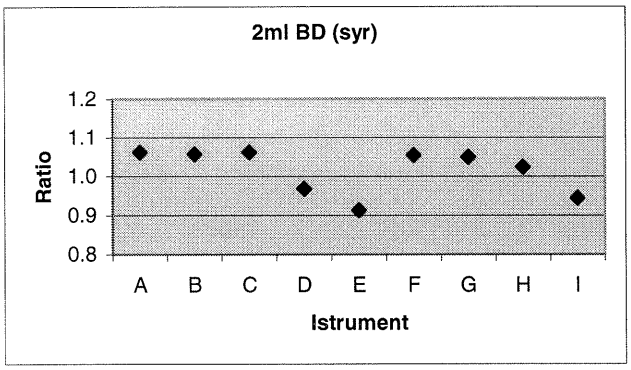


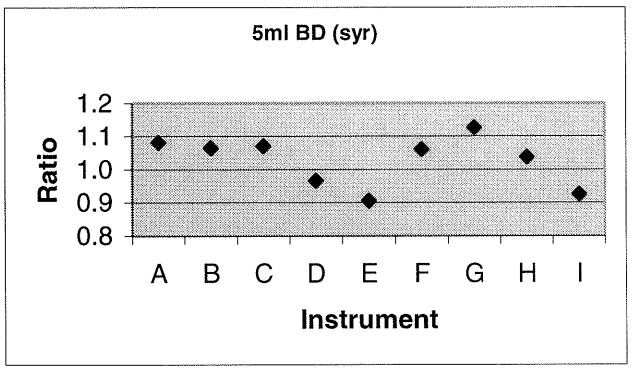
I-131 results
Shown by Instrument

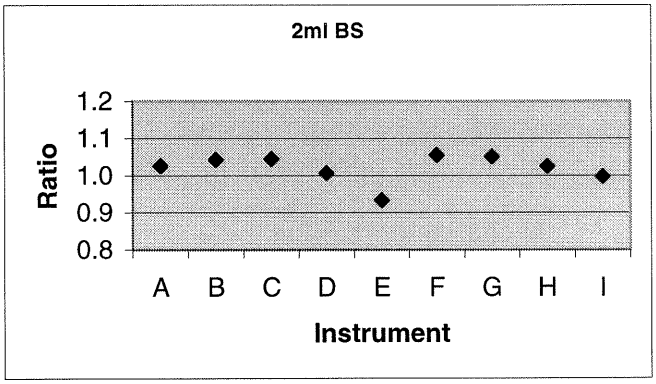
Container	A	B	C	D	E	F	G	H	I
2 ml BS	1.026	1.042	1.045	1.007	0.933	1.055	1.051	1.025	0.997
10R Schott	1.021	1.029	1.032	1.011	0.932	1.043	1.046	1.017	0.997
2 ml BD (syr)	1.062	1.057	1.062	0.968	0.913	1.055	1.050	1.024	0.944
5 ml BD (syr)	1.081	1.065	1.071	0.966	0.905	1.061	1.127	1.038	0.926
P6 vial	1.006	1.024	1.024	1.022	0.933	1.042	1.042	1.006	0.999





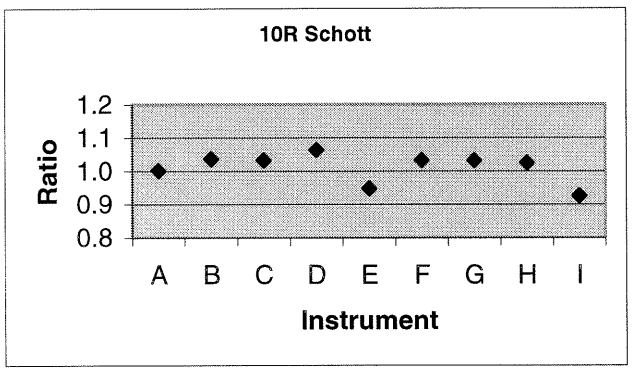


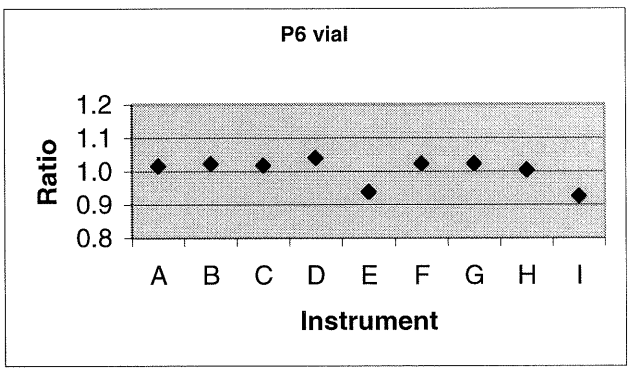


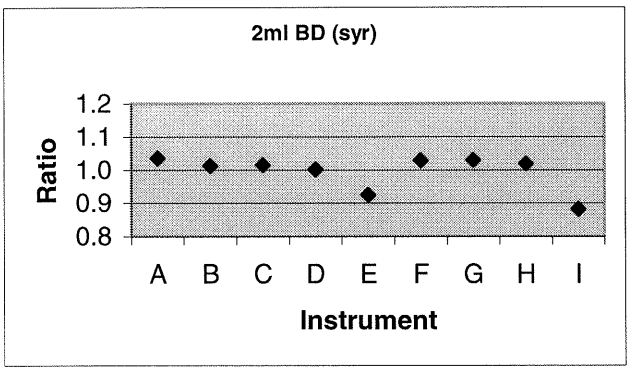


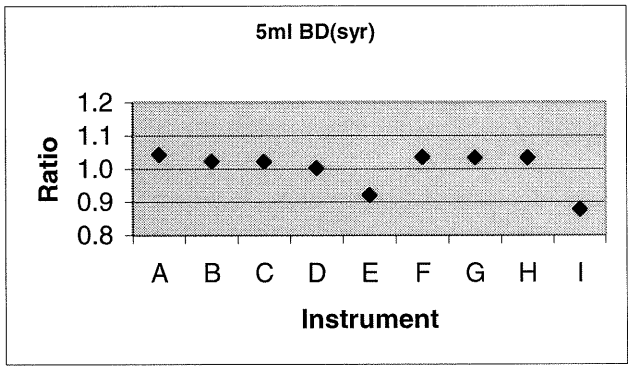
Tl-201 results
Shown by Instrument

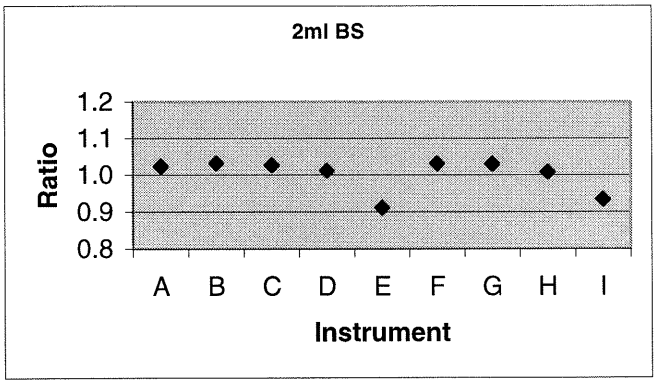
Container	A	B	C	D	E	F	G	H	I
2 ml BS	1.026	1.042	1.045	1.007	0.933	1.055	1.051	1.025	0.997
10R Schott	1.021	1.029	1.032	1.011	0.932	1.043	1.046	1.017	0.997
2 ml BD (syr)	1.062	1.057	1.062	0.968	0.913	1.055	1.050	1.024	0.944
5 ml BD (syr)	1.081	1.065	1.071	0.966	0.905	1.061	1.127	1.038	0.926
P6 vial	1.006	1.024	1.024	1.022	0.933	1.042	1.042	1.006	0.999





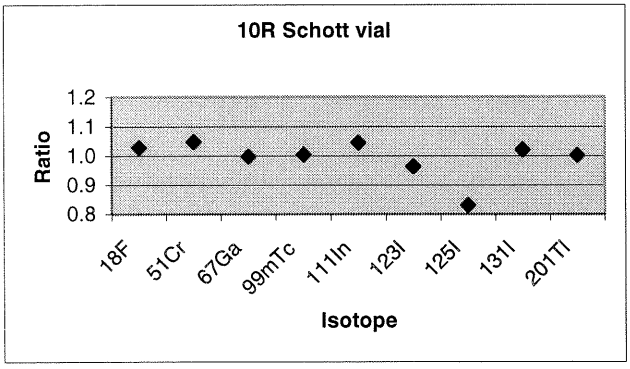


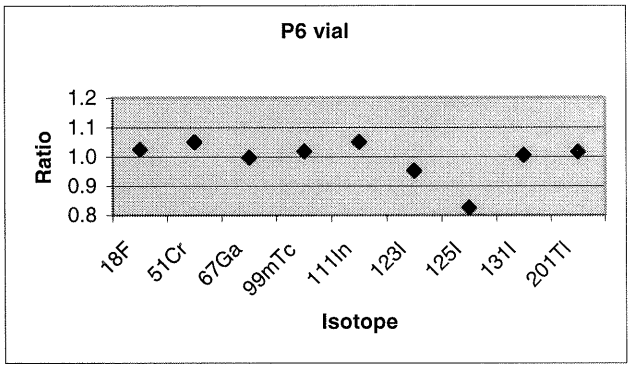


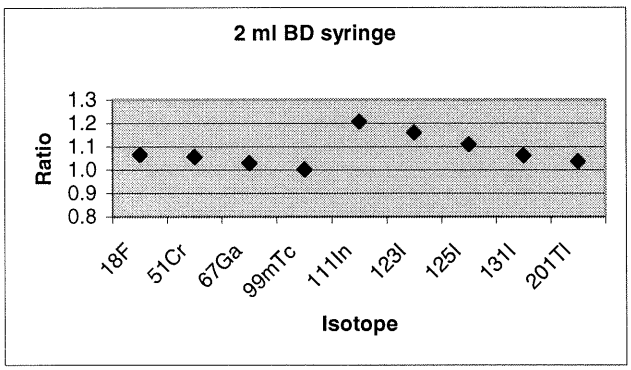


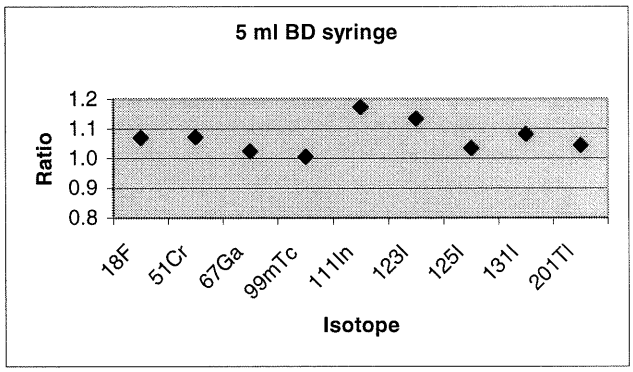
Instrument A results
Shown by Nuclide

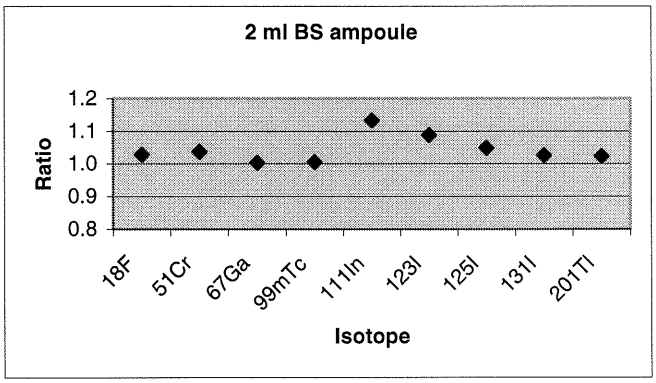
Container	^{18}F	^{51}Cr	^{67}Ga	^{99m}Tc	^{111}In	^{123}I	^{125}I	^{131}I	^{201}Tl
2 ml BS	1.028	1.037	1.003	1.005	1.133	1.088	1.049	1.026	1.023
10R Schott	1.029	1.048	0.998	1.004	1.045	0.964	0.831	1.021	1.002
2 ml BD (syr)	1.065	1.056	1.030	1.002	1.206	1.160	1.109	1.062	1.036
5 ml BD (syr)	1.07	1.072	1.024	1.005	1.173	1.134	1.034	1.081	1.043
P6 vial	1.025	1.051	0.998	1.019	1.051	0.953	0.825	1.006	1.016





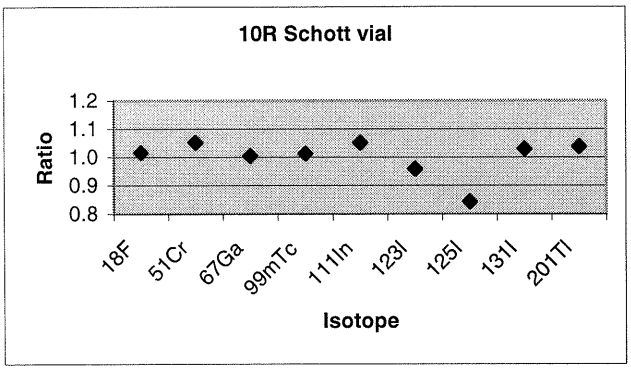


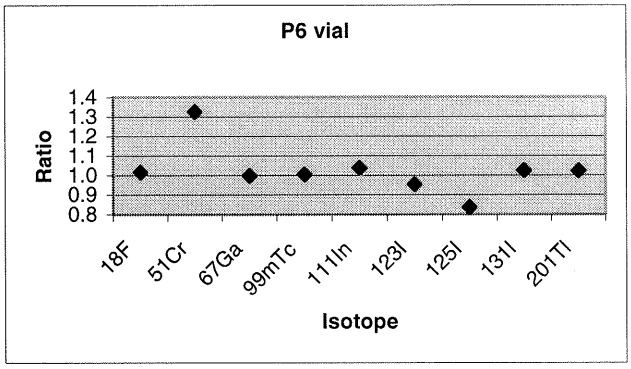


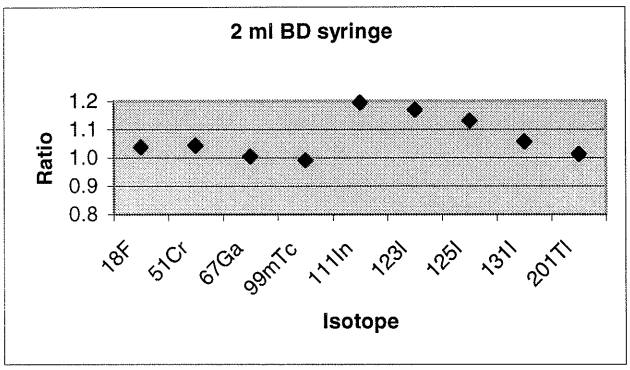


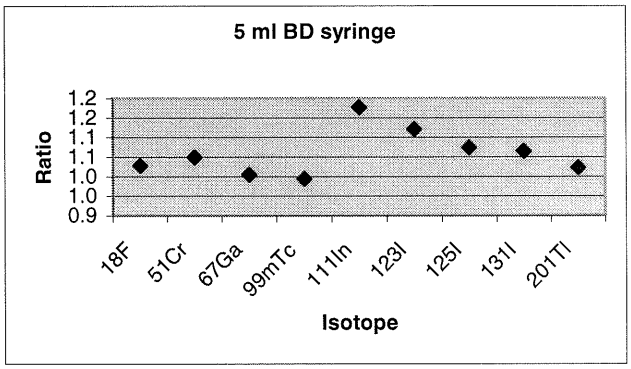
Instrument B results
Shown by Nuclide

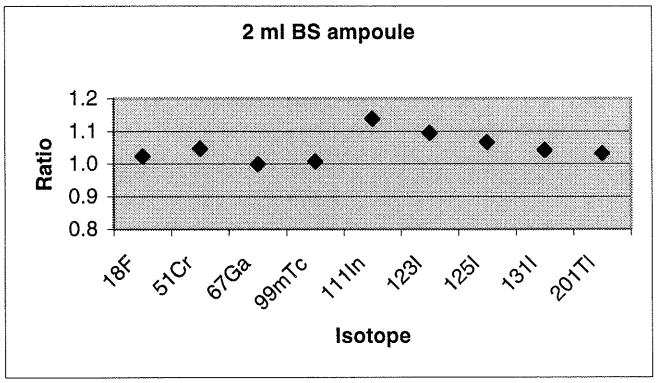
Container	^{18}F	^{51}Cr	^{67}Ga	^{99m}Tc	^{111}In	^{123}I	^{125}I	^{131}I	^{201}Tl
2 ml BS	1.023	1.047	1.000	1.007	1.138	1.095	1.066	1.042	1.032
10R Schott	1.016	1.052	1.004	1.012	1.051	0.958	0.843	1.029	1.037
2 ml BD (syr)	1.038	1.043	1.005	0.991	1.194	1.169	1.131	1.057	1.013
5 ml BD (syr)	1.028	1.049	1.005	0.994	1.177	1.121	1.074	1.065	1.023
P6 vial	1.016	1.325	0.998	1.004	1.037	0.953	0.836	1.024	1.023





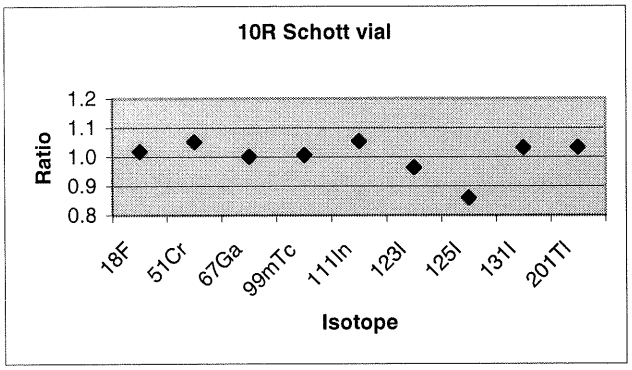


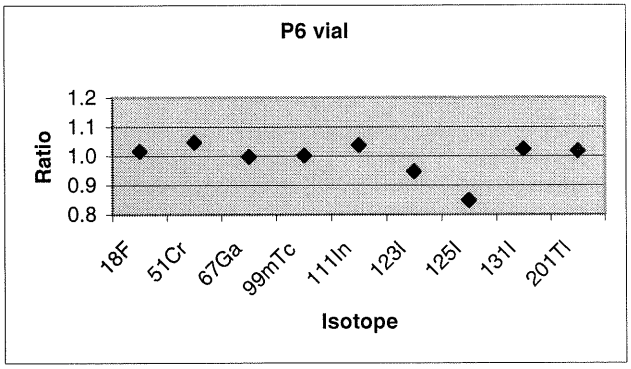


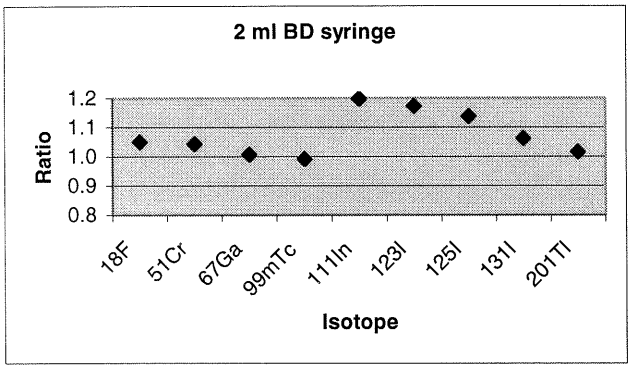


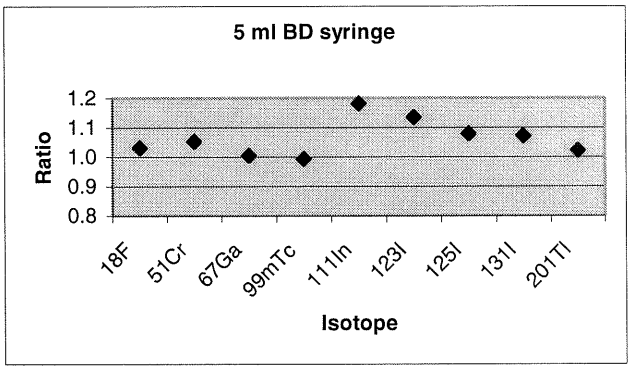
Instrument C results
Shown by Nuclide

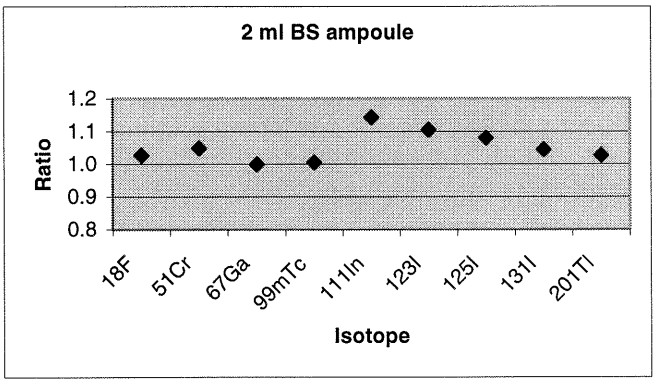
Container	^{18}F	^{51}Cr	^{67}Ga	^{99m}Tc	^{111}In	^{123}I	^{125}I	^{131}I	^{201}Tl
2 ml BS	1.027	1.049	1.000	1.005	1.143	1.105	1.080	1.045	1.027
10R Schott	1.019	1.052	1.001	1.007	1.054	0.964	0.859	1.032	1.033
2 ml BD (syr)	1.049	1.043	1.007	0.991	1.198	1.172	1.137	1.062	1.015
5 ml BD (syr)	1.031	1.053	1.005	0.994	1.181	1.135	1.079	1.071	1.022
P6 vial	1.016	1.047	0.998	1.002	1.037	0.947	0.848	1.024	1.018





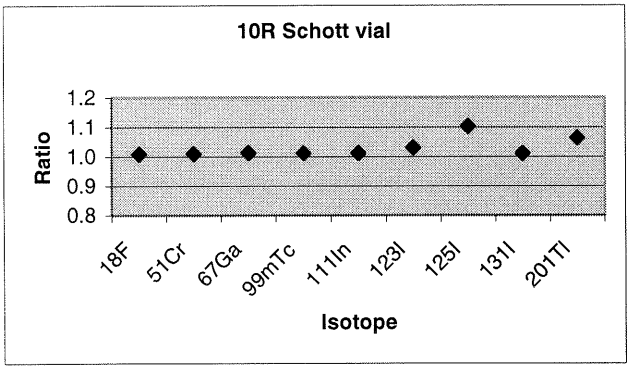


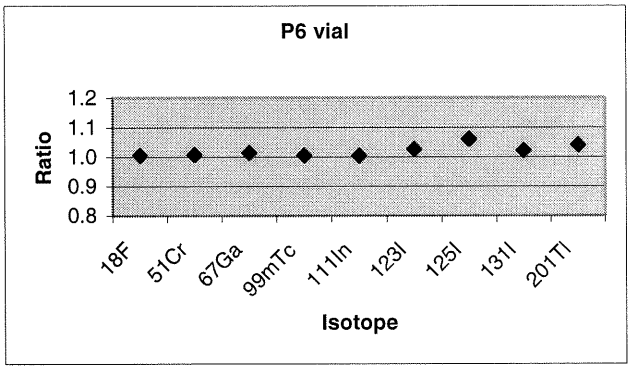


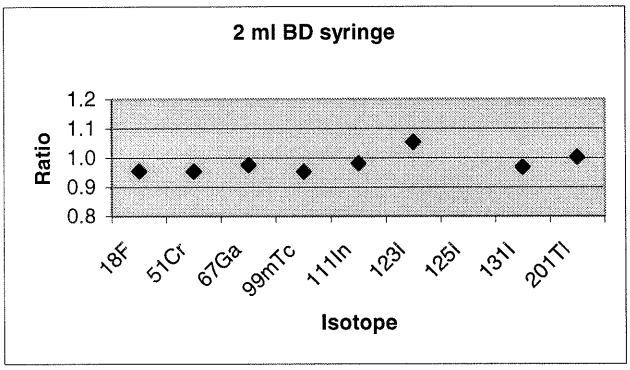


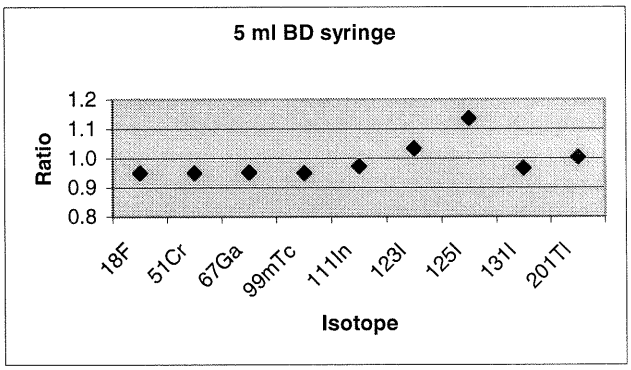
Instrument D results
Shown by Nuclide

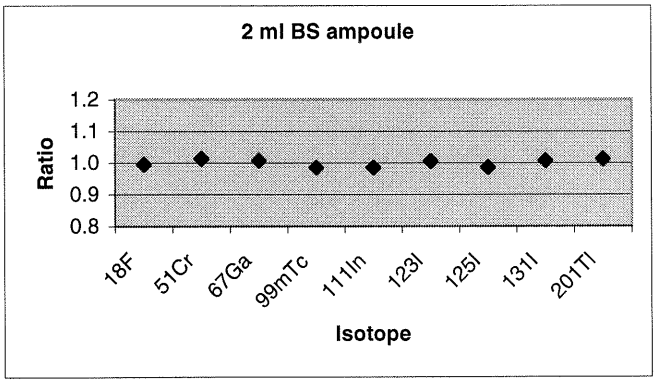
Container	^{18}F	^{51}Cr	^{67}Ga	^{99m}Tc	^{111}In	^{123}I	^{125}I	^{131}I	^{201}Tl
2 ml BS	0.995	1.013	1.007	0.985	0.985	1.005	0.986	1.007	1.012
10R Schott	1.009	1.010	1.013	1.012	1.012	1.031	1.103	1.011	1.064
2 ml BD (syr)	0.955	0.954	0.976	0.953	0.981	1.054	1.201	0.968	1.002
5 ml BD (syr)	0.95	0.949	0.952	0.950	0.972	1.033	1.135	0.966	1.003
P6 vial	1.006	1.008	1.014	1.006	1.004	1.026	1.060	1.022	1.041





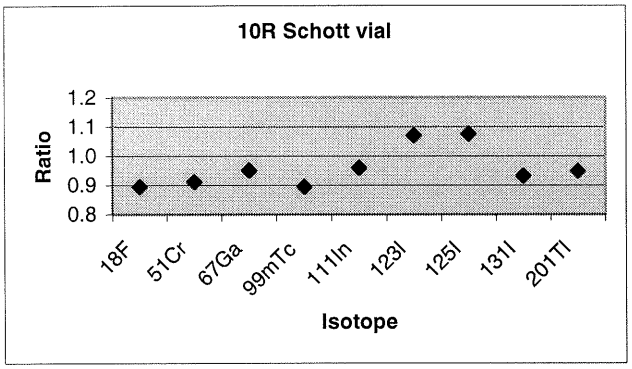


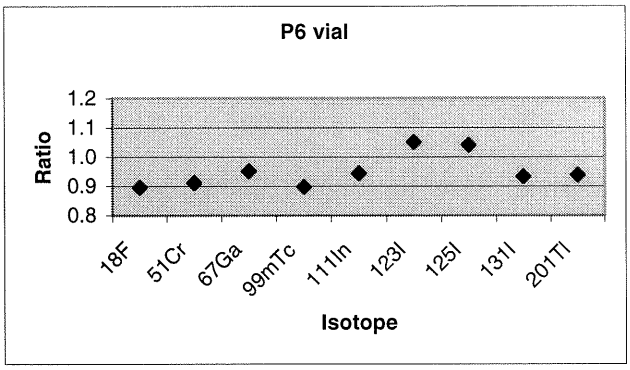


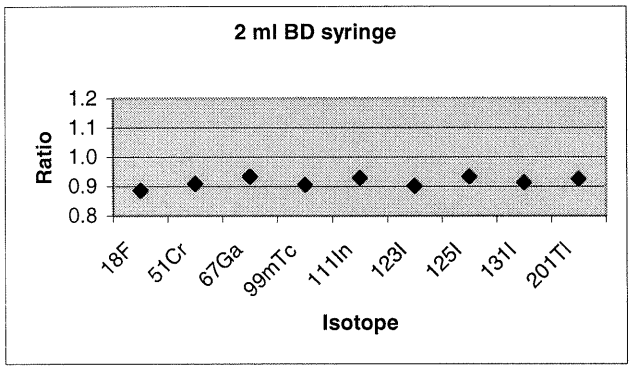


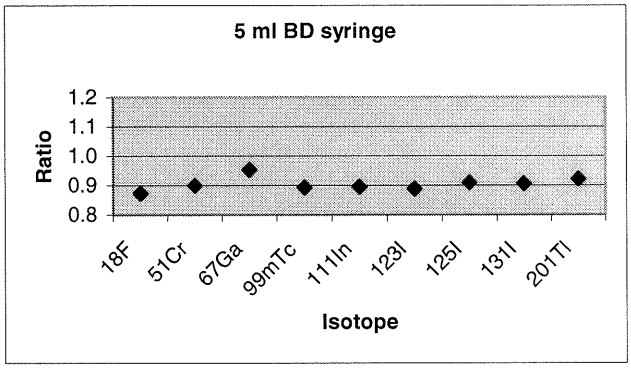
Instrument E results
Shown by Nuclide

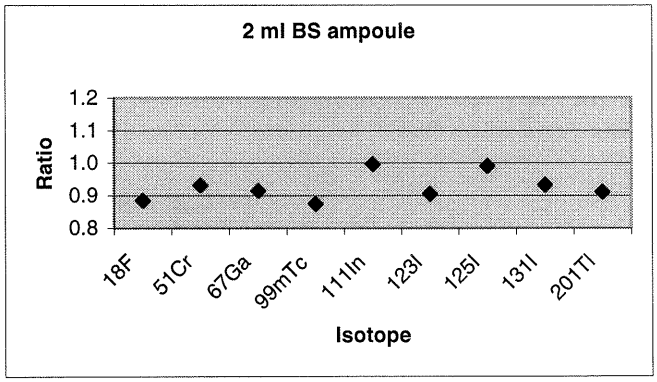
Container	^{18}F	^{51}Cr	^{67}Ga	^{99m}Tc	^{111}In	^{123}I	^{125}I	^{131}I	^{201}Tl
2 ml BS	0.885	0.932	0.915	0.875	0.997	0.905	0.991	0.933	0.911
10R Schott	0.894	0.911	0.951	0.894	0.959	1.070	1.076	0.932	0.948
2 ml BD (syr)	0.886	0.909	0.933	0.906	0.929	0.901	0.933	0.913	0.925
5 ml BD (syr)	0.872	0.899	0.953	0.892	0.895	0.888	0.909	0.905	0.921
P6 vial	0.896	0.911	0.952	0.898	0.944	1.051	1.041	0.933	0.938





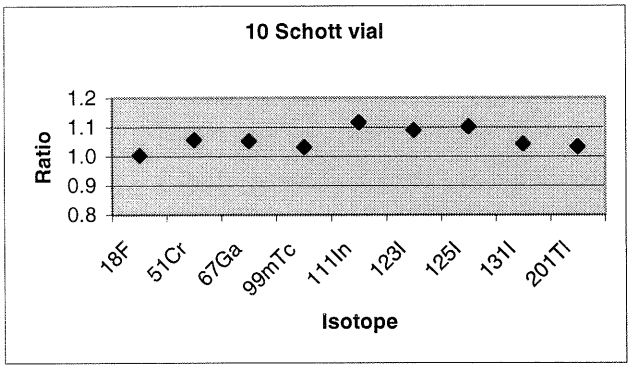


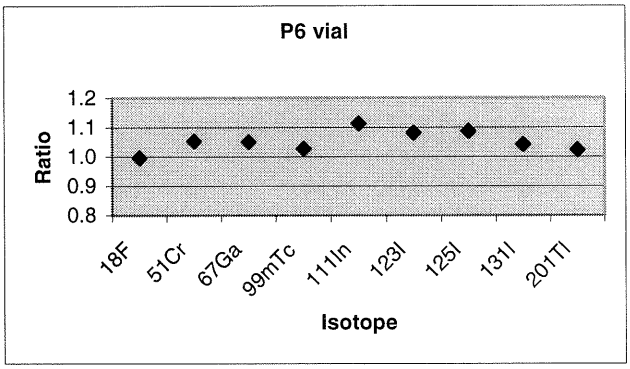


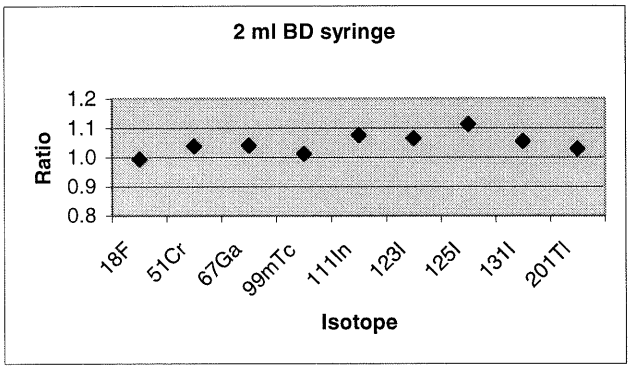


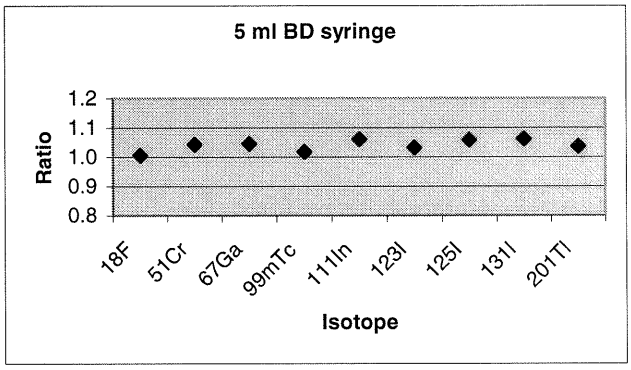
Instrument F results
Shown by Nuclide

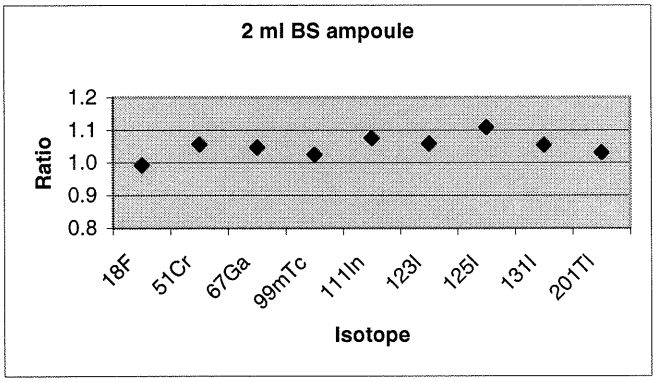
Container	^{18}F	^{51}Cr	^{67}Ga	^{99m}Tc	^{111}In	^{123}I	^{125}I	^{131}I	^{201}Tl
2 ml BS	0.993	1.057	1.047	1.025	1.075	1.058	1.109	1.055	1.031
10R Schott	1.003	1.057	1.053	1.032	1.116	1.090	1.102	1.043	1.033
2 ml BD (syr)	0.993	1.039	1.041	1.012	1.076	1.065	1.113	1.055	1.029
5 ml BD (syr)	1.006	1.043	1.045	1.018	1.060	1.032	1.058	1.061	1.036
P6 vial	0.996	1.053	1.051	1.028	1.113	1.081	1.087	1.042	1.023





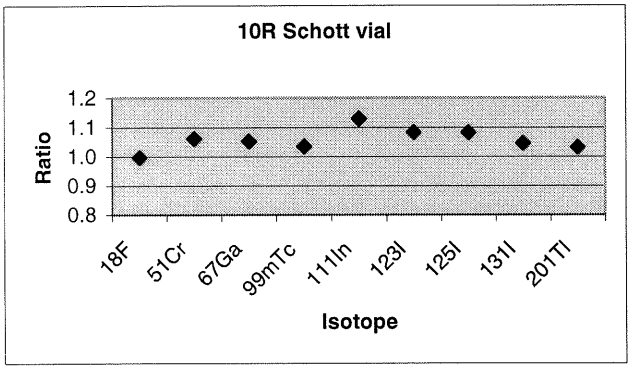


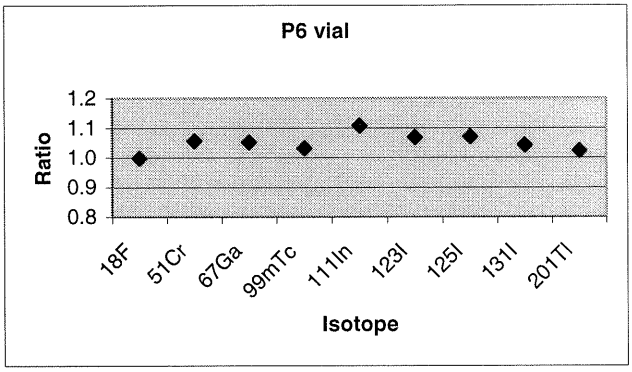


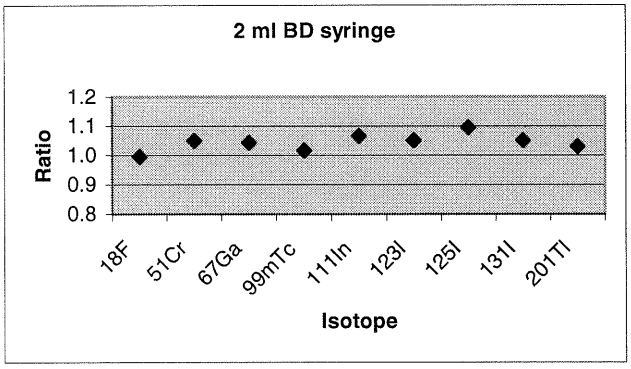


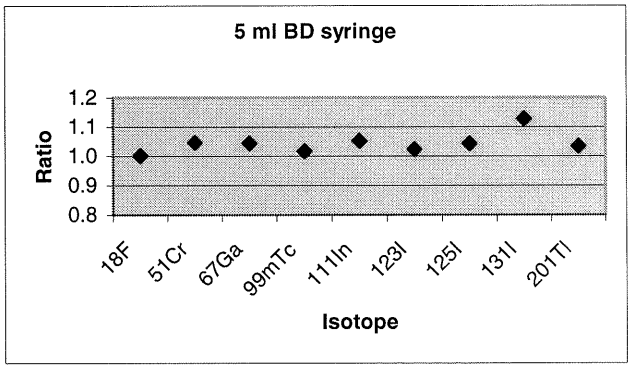
Instrument G results
Shown by Nuclide

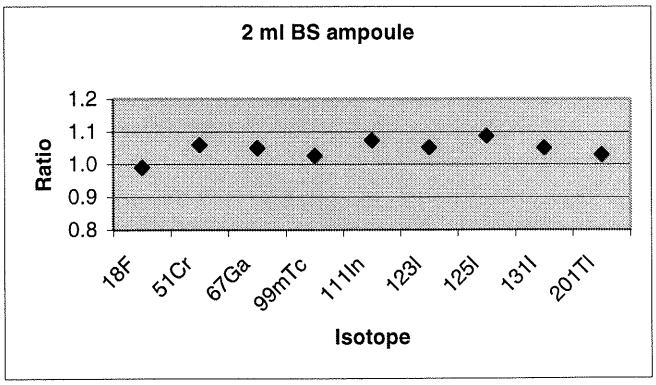
Container	^{18}F	^{51}Cr	^{67}Ga	^{99m}Tc	^{111}In	^{123}I	^{125}I	^{131}I	^{201}Tl
2 ml BS	0.991	1.059	1.050	1.026	1.073	1.052	1.087	1.051	1.03
10R Schott	0.997	1.062	1.053	1.035	1.130	1.083	1.082	1.046	1.032
2 ml BD (syr)	0.994	1.049	1.043	1.015	1.066	1.051	1.094	1.050	1.03
5 ml BD (syr)	1.001	1.046	1.044	1.017	1.052	1.023	1.043	1.127	1.034
P6 vial	0.998	1.056	1.052	1.032	1.108	1.068	1.071	1.042	1.023





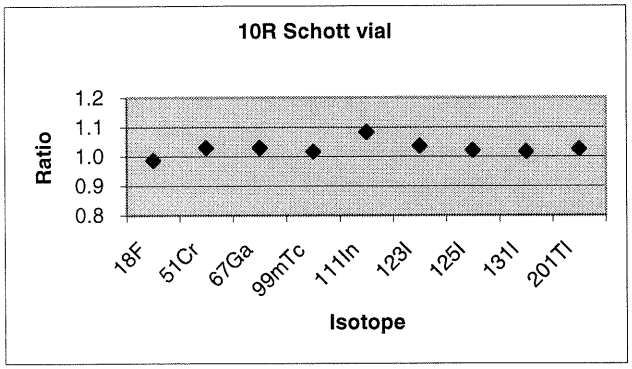


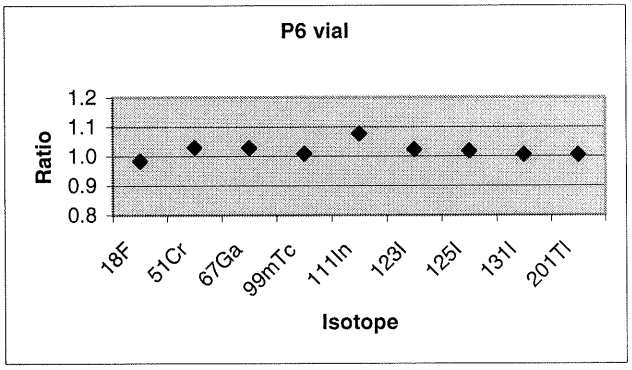


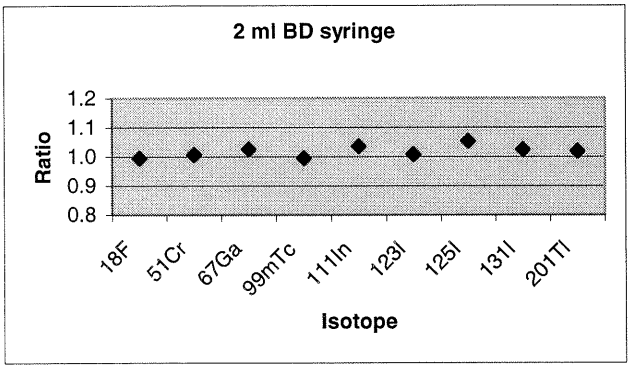


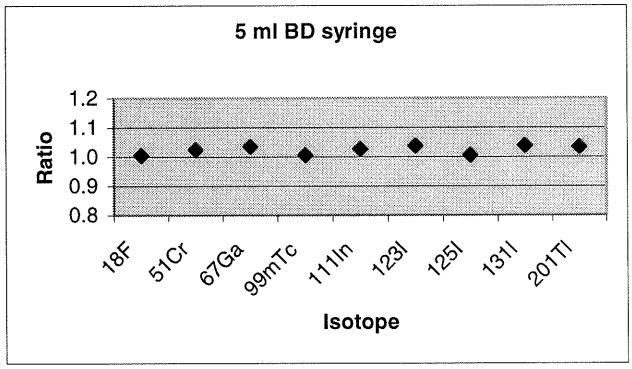
Instrument H results
Shown by Nuclide

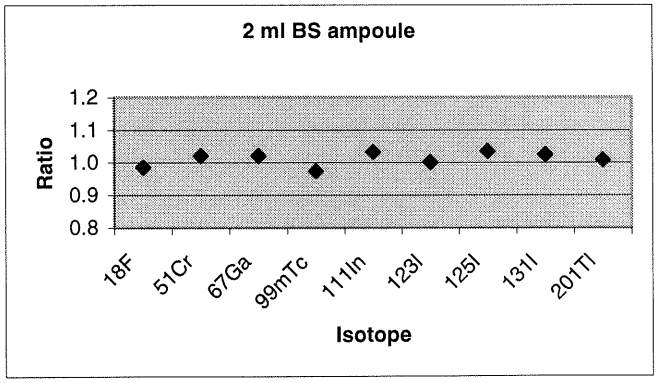
Container	^{18}F	^{51}Cr	^{67}Ga	^{99m}Tc	^{111}In	^{123}I	^{125}I	^{131}I	^{201}Tl
2 ml BS	0.986	1.021	1.021	0.974	1.033	1.001	1.035	1.025	1.008
10R Schott	0.987	1.030	1.030	1.017	1.083	1.036	1.021	1.017	1.025
2 ml BD (syr)	0.994	1.007	1.025	0.995	1.035	1.008	1.053	1.024	1.019
5 ml BD (syr)	1.004	1.024	1.035	1.006	1.026	1.037	1.005	1.038	1.034
P6 vial	0.984	1.030	1.029	1.009	1.077	1.023	1.018	1.006	1.004

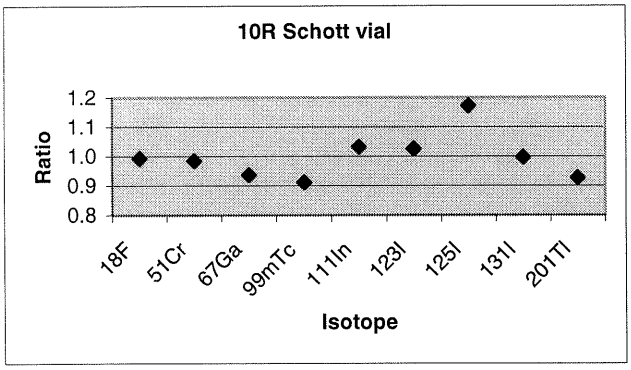
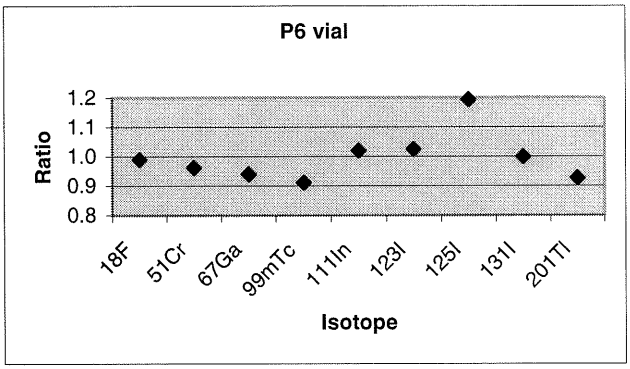
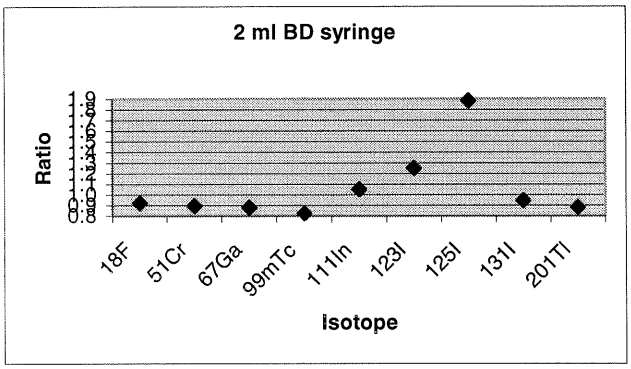
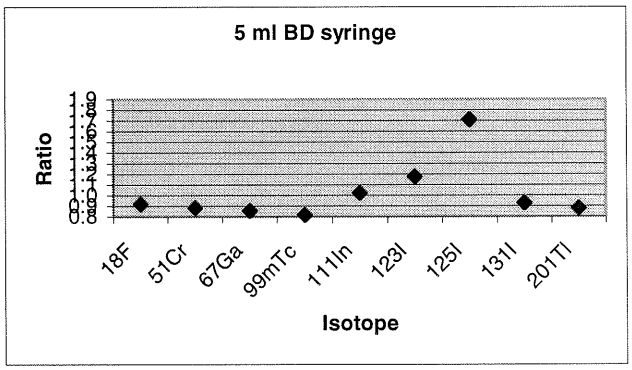
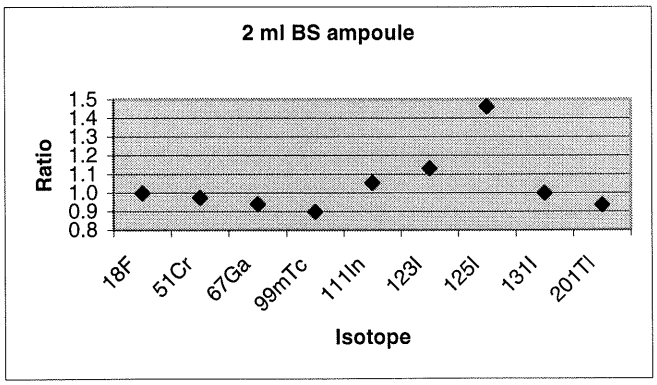










Instrument I results
Shown by Nuclide

Container	^{18}F	^{51}Cr	^{67}Ga	^{99m}Tc	^{111}In	^{123}I	^{125}I	^{131}I	^{201}Tl
2 ml BS	0.997	0.973	0.940	0.898	1.052	1.130	1.462	0.997	0.934
10R Schott	0.992	0.985	0.936	0.911	1.032	1.025	1.172	0.997	0.926
2 ml BD (syr)	0.922	0.895	0.879	0.825	1.051	1.251	1.882	0.944	0.882
5 ml BD (syr)	0.917	0.883	0.854	0.814	1.021	1.176	1.711	0.926	0.878
P6 vial	0.989	0.961	0.940	0.911	1.020	1.024	1.193	0.999	0.926